WIPO
Technology Trends 2021

Assistive Technology

WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

WIPO
Technology Trends 2021

Assistive Technology

WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

Printed in Switzerland

First published 2021

World Intellectual Property Organization
34, chemin des Colombettes, P.O. Box 18
CH-1211 Geneva 20, Switzerland

ISBN: 978-92-805-3257-9
doi.org/10.34667/tind.42582

This report uses patent and other data to provide solid, factual evidence on innovation in the global assistive tech landscape, creating a knowledge base to inform and support business leaders, researchers and policymakers in their decision-making.

WIPO Director General, Daren Tang

Many of these innovations will be adapted for use in a wider array of consumer products in the coming years. This means increased commercialization of assistive tech applications for a wider consumer base.

WIPO Director General, Daren Tang

Foreword

People living with impairments have long relied on new technologies for increased independence and fuller interaction with their world. From the invention of the crutch in ancient Egypt through the simple prosthetics of the Middle Ages to our latter-day Braille tablets, we are now on the cusp of a future where autonomous wheelchairs, mind-controlled hearing aids and wearables monitoring health and emotion alleviate the impact of human limitations.

Innovators the world over have designed assistive technologies for people with specific needs. Many of these innovations will be adapted for use in a wider array of consumer products in the coming years. This means increased commercialization of assistive tech applications for a wider consumer base.

This evolution toward mass use of assistive tech is among the key findings in this report, the second publication in our flagship *Technology Trends* series. With this important inflection point upon us, it is critical to understand the state of play. What are the most-popular assistive technologies right now? What new technologies are under development? What are the commercialization rates of different assistive technologies? Who is leading the race to market – and where?

This report uses patent and other data to provide solid, factual evidence on innovation in the global assistive tech landscape, creating a knowledge base to inform and support business leaders, researchers and policy-makers in their decision-making. This is part of WIPO's dedication to creating knowledge products that support a global economic environment where individuals and enterprises of all sizes can more easily bring exciting new products to market.

For the world of assistive tech, the market is set to expand. Currently, more than 1 billion people globally need at least one assistive product, a figure that is expected to double in the next 10 years as populations age. Even more people will benefit from assistive technology – such as wearables, customized solutions and connected and smart devices – as these technologies spread to the wider population through new consumer goods.

As with all innovations, access to assistive technology needs to become widespread and ensure no one is left behind. Globally, only 1 in 10 people currently have access to the assistive products they need. With this publication, we aim to support the global discussions and efforts towards increased access to assistive technology. These include implementation of the UN Convention on Rights for People with Disabilities (CRPD) and the work of the World Health Organization (WHO) work to promote greater access to assistive technology through its Global Cooperation on Assistive Technology (GATE).

We are grateful for the invaluable support and input received from WHO's GATE, participating United Nations agencies, assistive technology partnerships and user associations, along with the 72 experts in assistive technology from around the world who enriched this report with their valuable comments and insights.

I am pleased that this report is able to contribute to the wider conversation around the prioritization and funding of research on assistive technology, the identification of ways that start-ups, spin-offs and small and medium-sized enterprises can be supported in commercializing their inventions and how these promising innovations can be made available to as many end-users as possible.

Daren Tang
Director General, WIPO

About the contributors

This report includes contributions from experts in assistive technology, intellectual property, policy and innovation. Their viewpoints and comments complement and add context to the information revealed in patent data, addressing issues such as legal and regulatory questions, data protection, ethical concerns and the future of assistive technology.

Martine Abel-Williamson is a consultant for the Convention on the Rights of Persons with Disabilities and treasurer at the World Blind Union, New Zealand

Barbar Akle is Associate Professor of Mechanical Engineering at Lebanese American University, Lebanon

Michael Allen is USAID Senior Advisor for Assistive Health Technologies and Advisor to ATscale, U.S.

Victor de Andrade is an audiologist and lecturer in the department of Speech Pathology and Audiology, School of Human and Community Development, University of the Witwatersrand, South Africa

James Rwampigi Aniyamuzaala is a user of assistive technology and a PhD student on Inclusive Design and Creative Technology Innovation at University College Dublin, Ireland

David Banes is director at David Banes Access and Inclusion, U.K.

Keith Barton is an ophthalmologist at Moorfields Eye Hospital, U.K.

Oded Ben-Dov is the founder and CTO of Sesame Enable, Israel

Doreen Bogdan-Martin is Director of the ITU Telecommunication Development Bureau, Switzerland

Helene Boland is an associate at Hogan Lovells Brussels Office, Belgium

Mohamed Bouri is Group Leader for the Rehabilitation and Assistive Robotics Group (REHAssist), EPFL, Switzerland

Maria Fernanda Cabrera-Umpierrez is Associate Professor of Biomedical Engineering and Innovation director of Life Supporting Technologies (LifeSTech) at Polytechnic University of Madrid, Spain

Ricardo Chavarriaga is Head of the Swiss office of CLAIRE (Confederation of Laboratories for AI Research in Europe), Chair of the IEEE Standards Association, Industry Connections group on Neurotechnologies for BMI, and Senior Scientist at the Zürich University of Applied Sciences, Switzerland

Irene Cheong is Director of the Industry Liaison Office, National University of Singapore, Singapore

Greg Cosendai is Device Operations Manager at Verily, U.S.

Alan Cottenden is Emeritus Professor of Incontinence Technology at the Department of Medical Physics and Biomedical Engineering at UCL, U.K.

Jonathan Darrow is Assistant Professor at Harvard Medical School Program on Regulation, Therapeutic and Law (PORTAL), U.S.

Mandy Fader is Professor of Continence Technology and Head of the School of Health Sciences at the University of Southampton, U.K.

Joakim Falk is a project manager at the Swedish Institute for Standards and Committee Manager of ISO/TC 173 Assistive products, Sweden

Giuseppe Fico is Assistant Professor of Biomedical Engineering, Head of Health Area at Life Supporting Technologies (LifeSTech) at Polytechnic University of Madrid, Spain

Alain Franco is an honorary professor at Nice-Sophia Antipolis University Hospital, France

Kristoffer Gandrup-Marino is Chief of Innovation at UNICEF Supply Division and UNICEF representative on the ATscale board, Denmark

Kate Gaudry is a partner at the Washington, D.C. office of Kilpatrick Townsend & Stockton LLP, U.S.

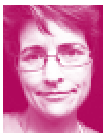
Tom Griffiths, Clinical Scientist (Clinical Engineering Innovation) at Cambridge University Hospitals NHS Foundation Trust, U.K.

Mayank Gurnani is Associate Director, Industry Liaison Office, National University of Singapore, Singapore

Michael Haddad is UNDP Regional Goodwill Ambassador for Climate Action, a world record holder and a social entrepreneur, Lebanon

Lise Henningsten is Head of Audiology at Widex, Denmark

Phyllis Heydt is Director at the Office of the WHO Ambassador for Global Strategy and an independent member of the ATscale board, U.S.



Catherine Holloway is Professor of Interaction Design & Innovation, UCLIC, and Academic Director, Global Disability Innovation Hub, U.K.

Pete Horsley is the founder of Remarkable – Accelerating Disability Tech, Cerebral Palsy Alliance, Australia

Grégoire Huot is PRP Production Transition Manager at the International Committee of the Red Cross (ICRC), Switzerland

Auke Ijspeert is a professor at EPFL and Head of the Biorobotics Laboratory (BioRob), Switzerland

Jonathan P. Jarow is Chief Executive Officer, FDA Solutions Group, U.S.

Arnav Kapur is a graduate student at MIT Media Lab, U.S.

Yuichi Kawamura is Vice President of Business Development at RXM Corporation, U.S.

Chapal Khasnabis is Head (AI) of the Access to Assistive Technology and Medical Devices Unit at the World Health Organization, Switzerland

Brian Kemler is Product Manager for Android Accessibility at Google, U.S.

Lina Kontos is a partner at Hogan Lovells (Washington Office), Medical Device and Technology Group, U.S.

Konstantinos Kourkoutas is Coordinator CORE Smart & Sustainable Cities, Urban Innovation & Living Labs at Universitat Autònoma de Barcelona, Spain

Tatjana Latinovic is Vice-President of Intellectual Property at Össur, Iceland

Alistair McEwan is Professor and Ainsworth Chair of Technology and Innovation at the School of Biomedical Engineering; and Chief Investigator at the ARC Training Centre for Innovative BioEngineering at the University of Sydney, Australia

Iain McKinnon is Director of Operations & Inclusive Design at the Global Disability Innovation Hub

Bradley McPherson is Honorary Professor in Human Communication, Development & Information Sciences at the University of Hong Kong, Hong Kong, China

Pattie Maes is a professor at MIT Media Lab and leads the Fluid Interfaces group, U.S.

Maria João Maia is a researcher at the Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT), Germany

Vinaya Manchaiah is a professor at Lamar University, Texas, U.S.

Mark P. Mathison is a partner at the California office of Kilpatrick Townsend & Stockton LLP, U.S.

Stefan Menzl is Chief R&D Officer, WS Audiology, Denmark

Silvestro Micera is Professor and Bertarelli Foundation Chair in Translational Neuroengineering at the Center for Neuroprosthetics and Institute of Bioengineering at EPFL, Switzerland; and the BioRobotics Institute and in the Department of Excellence in Robotics and AI at Sant'Anna School of Advanced Studies, Italy

Alejandro Moledo is Policy Coordinator at the European Disability Forum, Belgium

Patricia Castellanos de Muñoz is the founder and medical director of CEDAF Hearing Centre, Guatemala

Suranga Nanayakkara is Associate Professor and Director of Augmented Human Lab at the Auckland Bioengineering Institute, University of Auckland, New Zealand

Daniel Paccioretti is an audiologist at CEWA, U.S.

Jamie Paik is a professor at EPFL and Director of the Reconfigurable Robotics Lab, Switzerland

Ioannis Pallikaris is Professor of Ophthalmology at the University of Crete, Greece

Mikaela Patrick is Inclusive Design Researcher at the Global Disability Innovation Hub, U.K.

Jon Pearlman is Associate Professor and Chair in the Department of Rehabilitation Sciences and Technology at the University of Pittsburgh, and director of the International Society of Wheelchair Professionals, U.S.

Fabien Roy is a partner at Hogan Lovells, Brussels Office, Belgium

Bernhard Sendhoff is Professor, President, CEO and Head of Global Operations of the Honda Research Institute, Japan

Seyed Shahrestani is Senior Lecturer in Computer and ICT at West Sydney University, Australia

Matthew Smuck is Professor of Orthopaedic Surgery and Director of the Wearable Health Lab at Stanford University, U.S.

Arezoo Talebzadeh is an architect and PhD student at Ghent University, Belgium

Jutta Treviranus is Director and Professor, Inclusive Design Research Centre, OCAD University, Canada

Stefan Tromel is Senior Disability Specialist at ILO, Switzerland

Maria Teresa Arredondo Waldmeyer is Professor of Biomedical Engineering, founder and director of Life Supporting

Technologies (LifeSTech), director of Vodafone Chair at Polytechnic University of Madrid, Spain

Peter Walter is Professor of Ophthalmology at the University Clinic Aachen, Germany

Luc de Witte is Professor of Health Services Research, Centre for Assistive Technology and Connected Healthcare, University of Sheffield, UK, and President of Global Alliance of Assistive Technology Organizations (GAATO), U.K./Netherlands

Gregor Wolbring is Associate Professor at the Community Rehabilitation and Disability Studies Cumming School of Medicine, University of Calgary, Canada

Masaru Yamaoka is General Manager of Smart-Aging Project at Panasonic Corporation, Japan

Hongliu Yu is Professor and Director of the Institute of Rehabilitation Engineering and Technology at the University of Shanghai for Science and Technology (USST); Director of the Shanghai Engineering Research Center of Assistive Devices; President-mentor, Coalition of Rehabilitation Engineering and Assistive Technology of Asia (CREATe Asia); and President of the Rehabilitation Robot Alliance of the Chinese Association of Rehabilitation Medicine (CARM), China

Wei Zhang is Technical Officer at Access to Assistive Technology and Medical Devices Unit, World Health Organization (WHO), Switzerland

Leonidas Zografos is an honorary professor at the University of Lausanne (UNIL), Switzerland

Acknowledgments

This second edition of WIPO *Technology Trends* was made possible with the leadership and support of Daren Tang, Director General, whose vision of the importance of patent analytics as an evidence-based tool for informed decision-making and policy formulation underpins the series. This publication is the result of the invaluable collective efforts of a team of external contributors and WIPO colleagues. It was prepared under the direction of Alejandro Roca Campañá (Senior Director, IP for Innovators Department) and Andrew Czajkowski (Director, Technology and Innovation Support Division, TISD), and led by Irene Kitsara (IP Information Officer, TISD).

The report is based on a methodology developed by the core analytics team at WIPO, led by Irene Kitsara, including Rafaela di Sabato Guerrante, Matt Luby and Patrice Lopez; and a Clarivate Analytics team, the key members of which were Jack Hopwood, Shamsher Singh, Ed White, Gaurav Agnihotri, Pardeep Singh Bhandari, Atul Dhaka and Prateesh Shukla. The technology readiness level (TRL) and impact assessment methodology and platform were developed by Michell Zappa, Fabio Andrade and Thomaz Rezende (Envisioning.io) and Irene Kitsara, with inputs from Chapal Khasnabis and Wei Zhang (WHO), Luc de Witte (University of Sheffield/GAATO), Alejandro Moledo (EDF) and Cathy Holloway (UCL/GDI Hub), with assessments by 32 subject matter experts. The industrial designs search and analysis were carried out by Puyuan Zhang.

The report was edited by Catriona Vernal, and the lead reviewer was Luc de Witte. Interviews were conducted by Irene Kitsara and Nancy Pignataro, who also carried out background research and provided drafts for Chapters 4 and 5. Case studies and comments were kindly provided by Laura Sheridan and Kurtis MacFerrin (Google); Christopher Sciacca and Yves Veulliet (IBM); Andrew Arnold (WS Audiology); Kamata Kenji and Masato Murayama (Panasonic); Nancy Pignataro and Grégory Huot (ICRC); Peter Willimott (WIPO Singapore Office), Michael Haddad and Barbar Akle (Michael Haddad/Lebanese American University); Silvestro Micera, Jón Gunnarsson (Icelandic IP Office) and Tatjana Latinovic (Össur); Suranga Nanayakkara and Arnav Kapur (Alter Ego); Tamara Sznaidleder (Permanent Mission of Israel to the UN and International Organizations; Sesame Enable and OrCam); and Michele de Souza (Cycor).

Gratitude is due to the 72 leading experts in assistive technology and contributors who provided advice, peer reviewed the draft content, and shared their perspectives contextualize the findings. The report also draws on valuable input received from Chapal Khasnabis and Wei Zhang (WHO), Luc de Witte, Alain Franco (Nice-Sophia Antipolis University Hospital), and from Rich Corken, Chris Harrison and a group of patent examiners (UK IPO).

The report benefited greatly from inputs and reviews by a number of WIPO colleagues, including Hans Georg Bartels, Amy Dietterich, Carsten Fink, Nicolas Hoibian, Mosahid Khan, Allison Mages, Tomoko Miyamoto, Julio Raffo, Mona Remlawi, Charles Rudolph, Ning Xu and Alison Züger.

Thanks also go to WIPO colleagues Rafael Ferraz, Monica Halil Lövblad and Michele Woods for providing text on the Marrakesh Treaty and the ABC Consortium; Dalila Hamou for providing resources; and Bruno Pouliquen and Akshat Dewan for providing speech-to-text software. Figures were prepared by Vipin Saroha, with data visualization and accessibility-related inputs from Lisa Cornish, and infographics and maps and overall design by Edwin Hassink. Thanks also go to Charlotte Beauchamp for her invaluable support and advice; Edwin Hassink and Sheyda Navab for their design expertise; and staff in the Printing Plant.

Executive summary

Over 1 billion users currently need assistive technology. This figure is expected to reach 2 billion by 2050 as the population ages and consumer electronics and assistive products converge. The market is shaped not only by demographics and the demand for consumer electronics, and the investment this attracts, but by legislation and policies. The Convention on the Rights of Persons with Disabilities (CRPD) recognizes access to assistive technology as a human right, bringing with it state obligations and expected market influence.

This study is the first to systematically look into patenting and technology trends across assistive technology at scale, analyzing data on patent filings from 1998 to 2019. Its unique taxonomy separates conventional assistive technology from emerging assistive technology, and identifies nine "enabling" technologies which allow for the development of emerging assistive products.[1] It also explores the technology readiness level (TRL) of the identified emerging assistive products filed for patent protection, to see how close they are to commercialization.[2]

Overall trends

Our findings show that patenting activity in the area of conventional technology is nearly eight times bigger than that of emerging assistive technology, with 117,209 patent filings compared to 15,592. However, filings in emerging technology are growing three times faster than conventional, with a 17% average annual growth rate (AAGR) compared to 6%. Most patent filings in conventional assistive technology relate to mobility, followed by the built environment, hearing and vision. Yearly filings in mobility are more than those of all six other domains combined.

In the emerging assistive technology space, the most active domain over the period is hearing, followed by mobility, vision and communication. However, since 2014 mobility has taken the lead among emerging technology filings too. Indeed, the fastest growing areas for patent filings relate to mobility and environment both in conventional (9% and 7% AAGR respectively in 2013-2017), and emerging assistive technology (24% and 42% AAGR respectively).

Data shows that emerging products are usually not replacing conventional assistive products, but complementing them.

Convergence of assistive technology with other technologies, disciplines and markets

Assistive technology has traditionally been considered external to the human body and non-invasive. The field is now converging with medical technologies. Several emerging assistive products include implants and other products that would qualify as medical devices, with many of those moving beyond assistance towards augmentation or recovery of missing human functions.

Our analysis reveals that all identified emerging assistive products use one or a combination of several enabling technologies, such as artificial intelligence (AI), the Internet of Things, brain–computer/machine interface (BCI/BMI) and advanced sensors. These allow for smarter and connected assistive products which learn from the user's behavior and environment, optimize and customize their functions and support independent living and navigation, telemedicine and smart nursing.

The primary crossover disciplines in emerging assistive technologies are information technology, data science, materials science and neuroscience, while the overlaps with the consumer electronic goods market are mainly in the areas of communication, navigation and gaming. The convergence between disciplines, domains and markets increases the breadth of functionality of products for different user profiles and boosts the pace of innovation in emerging assistive technology.

The data shows that emerging products are usually not replacing conventional assistive products, but complementing them. As a result there are parallel product markets serving different user needs, preferences and settings.

Geographical trends in innovation in assistive technology

Patent protection for assistive technology is sought primarily in five markets: China, the U.S., Europe (as reflected by European Patent applications), Japan and the Republic of Korea. The previous dominance of the U.S. and Japan has declined in recent years as filings increase in China and the Republic of Korea. The widest patent protection being sought is for mobility assistive technologies. Protection for other domains, whether conventional or emerging assistive technologies, is largely focused in the five main target markets.

The same five territories also house the top origins of invention. Similar to the evolution in the markets for protection, the geographical profile of top players in assistive technology is also changing: traditional European, Japanese and U.S. players now face increasing competition from Chinese and Korean players.

Applicant profiles and patent portfolios

We find that big corporate players are leading the development of assistive technology (48% of conventional and 60% of emerging assistive technology), dominating in hearing and vision, and to some extent communication. Other domains are fragmented, with a big number of patent applicants and top patent applicants with small patent portfolios. The leading players are pursuing holistic strategies to protect their innovations, using not only patents and utility models but also industrial designs to protect the ornamental aspects of assistive products.

Corporate applicants are either specialized assistive technology companies, consumer electronic goods companies or from the car industry. Consumer electronic good companies have a diversified patent portfolio across several domains. This is in contrast to specialized assistive technology companies or car industry companies, which file mainly in the domain of mobility and to a lesser extent in environment. This reflects diverse commercialization interests among this group, as well as the impact and applications of enabling technologies and information and communications technology (ICT) in general in the assistive technology space.

The top corporate applicants are hearing aid and orthoses and prostheses manufacturers, reflecting the size of the hearing and mobility datasets and their dominance by larger companies, and large optics and ophthalmological companies.

Universities and public research organizations are more prominent in the emerging assistive technology dataset (23% of patent applicants versus 11%). Independent inventors, over one-third of whom are based in China, dominate simpler technologies (40% of patent applicants in conventional assistive technology versus 18% in emerging), as often reflected in the number of utility model filings (accounting for 25% of the conventional and 13% of the emerging assistive technology filings).

Trends in specific domains

Within specific domains of assistive technology, trends are not homogeneous. There are particular findings to note in each.

Mobility

The profile of patent applicants in conventional technology is wide-ranging and diverse, led by European mobility specialists, Japanese conglomerates, and U.S. healthcare device companies, with a notable share of contributions by independent inventors. However, in emerging mobility assistive technology and all its functional categories, academic institutions dominate.

Emerging products and devices introduce advanced versions of conventional assistive products, namely advanced walking aids (balancing aids and smart canes), advanced prosthetics (neuroprosthetics, smart and 3D printed prosthetics), advanced wheelchairs (including self-driving wheelchairs and wheelchair control) and exoskeletons (full-body exosuits, lower and upper body exoskeletons and control thereof). Advanced wheelchair filings are growing at a rate of 34%, advanced prosthetics and exoskeletons at 24% AAGR, while 3D printed prosthetics/orthoses have the highest growth rate at 89% AAGR.

Cognition

This is the smallest area of the conventional technology dataset, reflecting the recent recognition of the importance of assistive technology to support cognitive decline. This field includes memory support and medication dispensing devices, as well as timers. The more advanced assistive technology can be found in the emerging assistive technology

Corporate applicants are either specialized assistive technology companies, consumer electronic goods companies or from the car industry.

domains of self-care and environment, including functionalities of assistive robots.

Communication

Technology companies are driving developments in software-based assistive technology in the area of communication. Two-thirds of emerging communication filings relate to smart assistants. Areas of recent development with great potential are brain–computer interface-based control of devices and sensory substitution technology, with growth rates of 71% and 21% AAGR respectively.

Hearing

Technologies in hearing are dominated by companies based in Europe, while the top five players account for one-fourth of filings. Emerging assistive products include environment-controlling and mind-controlled hearing aids, with cochlear implants accounting for nearly half of the emerging filings. The areas of greatest growth in hearing are non-invasive bone conduction (31% AAGR) and gesture to voice and text (24% AAGR).

Environment

Conventional assistive products for the built environment cover a wide range of technologies to facilitate independent living at home and work. These include structural building components, furniture, assistive products for sports and leisure, and alarms. This large, fragmented market is moving toward a smart, connected and robotic future involving smart homes (including smart appliances at homes and smart toilets), smart cities (smart pavements and navigation aids in public spaces) and assistive robots (companion and pet robots), all growing at fast pace with respective growth rates of 40%, 44% and 54% AAGR in 2013-2017.

Self-care

Conventional assistive products in the area of self-care include adaptive clothing, incontinence products and adaptive eating devices. These same technologies form the basis for advanced products, such as smart diapers and feeding assistant robots. Among conventional patent applications, 59% are filed by independent inventors and one-third include utility models, reflective of the simpler technologies involved.

Wearable and non-wearable health- and emotion-monitoring devices (smart bands, clothing, insoles, smart mirrors and carpets) account for over half of emerging self-care filings and have a growth rate of 24% AAGR reflecting an overall trend in digital health and wearables. These products support independent living, active aging and telemedicine or smart nursing. Small and fast growing areas are smart medication dispensing and management and smart diapers (52% and 68% AAGR respectively).

Vision

While most filings in conventional vision are related to spectacles and tactile devices, such as tactile screens, there are small portfolios which are growing fast, such as screen readers or phones with Braille (50% and51% AAGR respectively).

In the emerging vision assistive technology space, most filings relate to intraocular lenses (IOL) with several sensors and functionalities. Filings related to artificial silicon retina (ASR), smart eyewear and augmented reality (AR) devices are growing at rates of 38% and 35% AAGR respectively.

Top players in the field are major U.S. and European optics manufacturers, as well as some players from the Russian Federation and Israel, while electronics companies are starting to enter into the space of vision assistive technology.

Commercialization

A number of factors may influence commercialization, particularly in low- and middle-income countries. Regulation and standards assure quality and safety, but can present delays in or obstacles to commercialization, particularly when devices are classified as medical devices. Manufacturing, training and maintenance have resource implications while presenting significant opportunities, such as 3D printing for the development of prosthetics.

Some of these factors are particularly challenging for smaller companies and individual inventors, featuring prominently across several assistive technology areas. They need a supportive ecosystem, where the many actors in the innovation chain, from developers and academia to investors and venture capitalists, are incentivized to bring assistive technology to market.

The recognition of access to assistive technology as a human right, as set out in the CRPD, contributing to social and economic development objectives for persons with disabilities, could be an additional impetus for policymakers in supporting the availability of assistive technology, while market-shaping approaches by different multi-stakeholder initiatives and partnerships could also contribute to increased availability.

The future of assistive technology

The changing market demographics for assistive technology, including the aging population, present opportunities to inventors and a potential change of paradigm in the market share, with an increased number of end-users and more varied needs for assistive technology.

New technologies bring with them new challenges in terms of data, privacy and intellectual property.

As some emerging products are tested, approved and accepted by end-users, certain types of technologies could become mainstream rather than specialized, particularly if developers of mainstream technology employ inclusive design principles. However, these potential developments need to be discussed alongside ethical considerations around social exclusion, collection of and access to data and privacy, as well as issues related to intellectual property, particularly in relation to fast-paced developments such as artificial intelligence- or brain–computer interface-based products.

Currently, fully commercialized emerging products do not seem to be replacing conventional ones, while many other emerging assistive technologies exist in a stage between prototyping and commercialization. Conventional and emerging assistive products appear to be developing in parallel to serve different user needs. This could change in future, as emerging products are perceived as more acceptable by end-users.

Increased end-user involvement (co-design of assistive products) and supporting policies are needed for the development of assistive technology, while global initiatives are important in ensuring a sensitive approach to innovation that takes into account user needs. Understanding these developments will help support continued investment in and use of assistive technology by identifying new opportunities for industry, providing guidance for developers and stakeholders and giving end-users the confidence to take up new assistive technologies.

New technologies bring with them new challenges in terms of data, privacy and intellectual property (IP). This is the case with assistive technology, as the development of emerging assistive products relies heavily on the use of enabling technologies. AI in particular solicits debate over patentability requirements and inventorship; as other enabling technology, such as brain–computer interface, develops further, similar or new IP-related questions may emerge. The unprecedented collection and use of data and the related insights it provides are essential to enabling technology, but are not without challenges: data and privacy issues are more accentuated in the area of assistive technology, given the more vulnerable groups involved. Trends towards wearables and health diagnostic software may add to the IP-related concerns.

Licensing will need to evolve at the speed of these innovations if it is to encompass fully the implications of enabling technology in the creation of new IP, as will approaches to ownership of datasets and access to and use of data for training purposes. The responsiveness of the IP system to these debates could in turn influence the speed of development of assistive technology and its commercialization.

Notes

1 The categorizations used in the report are illustrated on pp. 28-30.

2 These data can be explored via an online tool: https://www.wipo.int/tech_trends/en/assistive_technology

1 Introduction

From the invention of the crutch in Ancient Egypt, through to the simple prosthetics of the Middle Ages and onwards to the most recent autonomous wheelchairs, mind-controlled hearing aids and health and emotion monitoring wearables, different types of assistive technology have had one goal in common – to improve the quality of life for those experiencing functional impairment.

While persons with disabilities have historically been the target group for the development of assistive technology, the demographic benefiting from innovation in this field is rapidly widening.

The global trend in ageing populations (the number of people in the world aged 60 years and over is projected to grow from 901 million in 2015 to almost 2.1 billion by 2050), coupled with a higher probability of functional limitations in elderly people, is leading to more of society being affected by disabilities.

Moreover, the extensive use of new technologies, primarily screens and earphones, is expected to lead to an earlier onset of hearing and vision impairments. Currently, more than one billion people around the globe might benefit from assistive technology. This figure is expected to surpass two billion by 2030, with many more older people requiring not one, but several assistive technology products (WHO, n.d.).

Concerns over the economic implications of an ageing population are driving an increased global interest in assistive technology. Solutions that contribute to self-sufficiency, independent living and more efficient health monitoring are therefore of particular interest.

Assistive technology is an umbrella term, covering a broad range of technologies and products, ranging from relatively simple devices, such as a walking stick or reading glasses, to complicated, high-tech systems, such as assistive robots or gesture or emotion recognition software.

There is no universally accepted definition. The World Health Organization (WHO) considers assistive technology to be those products

---

This report provides a landscape and a comprehensive analysis of assistive product innovations. It reveals an increasing interest from industry and research in assistive technology and the trends in emerging innovative products that incorporate enabling technologies.

It is anticipated that the active development showcased by this report will refresh the recognition of assistive technology in society, motivate manufacturers and service providers, and encourage investment in the assistive technology market.

Innovation in products and services is essential, but cannot on its own improve access to assistive technology. Policies are required that facilitate the efficient and effective provision of assistive products and services to users in need. These policies need leadership and innovative thinking if they are to achieve the ultimate goal of universal health coverage and to leave no-one behind.

Chapal Khasnabis, WHO Global Cooperation on Assistive Technology (GATE)

whose “primary purpose is to maintain or improve an individual’s functioning and independence to facilitate participation and to enhance overall well-being” (WHO, 2020).

The European Accessibility Act (EU, 2019) similarly defines assistive technology as “any item, piece of equipment, service or product system including software that is used to increase, maintain, substitute or improve functional capabilities of persons with disabilities”.

Although the ISO9999 (2016) standard on assistive products defines an assistive product as “any product (including devices, equipment, instruments and software) ... especially produced or generally available, used by or for persons with disabilities”, consideration is being given to broadening the target group and adopting an approach that takes into account functional need and product purpose (ISO, 2016).

This report aims to give a comprehensive overview of assistive technology as reflected and described in published patent documents, and identify available technologies and related trends in the development of assistive technology, both within established assistive products and in the emerging assistive technology space.

The report focuses on assistive technology intended to support and be used directly by persons facing functional limitations (typically people with disabilities or the elderly) rather than caregivers and medical professionals. While some of the presented technologies and devices may also relate to more mainstream products for a broader range of users, only those patent documents that specifically mention end-users of assistive technology were included in our analysis.

With the help of these technologies, people who experience functional limitations are more able to live independently and participate in different aspects of life, including education, work, sports, leisure and culture.

The importance of access to and the impact made by the use of assistive technology is acknowledged in the 2006 Convention on the Rights of Persons with Disabilities (CRPD) where access to assistive technology is recognized as a human right.

For an individual who receives appropriate assistive technology from childhood their income will increase by an average of USD 100,000 in their lifetime.

Phyllis Heydt, Office of the WHO Ambassador for Global Strategy, and independent member of the ATscale board

However, assistive products are not accessible to the majority of people who require them. In many low- and middle-income countries, only between 5 and 15 percent of the people it would benefit are able to access assistive technology. Even in high-income countries, the most appropriate assistive product may not always be on offer.

Addressing this unmet need for access to assistive products is critical to advancing the UN’s 2030 Agenda for Sustainable Development and its pledge to "leave no one behind" (UN, 2015). In 2014, the WHO established the Global Cooperation on Assistive Technology (GATE), an initiative to ensure efficient and effective access to assistive products. Further, in 2018 a resolution was adopted at the World Health Assembly to improve access to assistive technology as part of universal health coverage. Achieving such a goal will require a multitude of factors to align, one of which is progress in research and technology.

While much assistive technology involves niche products built to support a specific disability (creating, in some cases, accessibility issues for users with additional disabilities), others have functionalities aligned to mainstream devices and products. A good example is tablet computers, a mass-produced product for the general population that can additionally provide live sign language translations for people with hearing impairments.

Conversely, some products that start out as an assistive technology end up serving the broader population. For example, speech-to-text technology was first created to give greater access to people with disabilities, but has now been integrated into a variety of products, ranging from virtual assistants to home entertainment systems, that form part of speech recognition.

The evident overlap between these technologies is not surprising, because, in a broad sense, all technologies can be assistive; a point of view shared by many assistive technology stakeholders.

From a technology point of view, the future for assistive technology looks bright, with major advances being made by the corporate and academic sectors across different functional categories (as shown in Chapters 2 and 3).

The rapid development and availability of enabling technologies, such as artificial intelligence (AI), augmented and virtual reality (AR/VR), robotics, Internet of Things (IoT), and new materials will play a key role in pushing the boundaries of assistive technology, as innovators integrate more and more of these revolutionizing technologies into their products. Enabling technologies hold great promise in supporting people experiencing functional limitations in their day-to-day life.

In the first issue of *Technology Trends* (WIPO, 2019), we concluded that AI is revolutionizing all possible fields of technology and life. In this report, we explore the extent to which *enabling technologies* are applied to assistive technology so as to lead to new or improved assistive products.

The report identifies a list of enabling technologies and provides factual evidence on their use in the development of advanced assistive products. It also explores the opportunities and challenges resulting from the convergence of traditional assistive technology with other disciplines, for example, neuroscience and medical science.

The analysis of associated patents aims to create a better understanding about the trends in innovation in the field; the primary actors behind these developments; and the geographical distribution of such innovation (see p. 24, “Why use patent data?” for more detail on how patents can be used to assess technology trends).

The report groups assistive technology into seven functional categories: cognition, communication, environment, hearing, mobility, self-care and vision.

Chapter 2 is divided into seven sections, one for each functional category. In each section, technology trends within well-established (conventional) assistive technology are explored, followed by an analysis of the emerging assistive technology, including observations about the ways enabling technologies are contributing to their development (Figures 1.1–1.3).

Key findings and technology trends are brought together in Chapter 3. This chapter explores for the first time 'precisely'how close the identified emerging assistive technology is to commercialization throughan assessment of its technology readiness level, and considers how this relates to the patenting activity in this field.

Chapter 4 contextualizes assistive technology by discussing the factors influencing the entry of a product into the market and its accessibility and availability to end-users. This includes the ways in which policy is seeking to tackle the associated challenges and opportunities.

Finally, Chapter 5 discusses the future for assistive technology in terms of technology, opportunities, policy-making and potential IP and other implications. A stakeholder survey identifing the key opportunities and challenges to the assistive technology community informs the analysis of the wider context in Chapters 4 and 5.

Patent analysis is complemented by insights from 72 assistive technology experts and stakeholders, representing a broad spectrum of user associations, academia, industry, UN agencies, international organizations and non-governmental organizations, and standards associations. Some expertsfocus on the technology, or comment on the report's findings and related assistive products, or assess the technology readiness level of emerging assistive technology. Others provide views on policy and the challenges and opportunities for assistive technology – illustrated with examples and case studies – or describe their vision for future assistive technology. Contributions were made through written submission or interview. A list of the contributors can be found on pages 10-14.

The insights offered, together with a trends analysis of the patent data, provide a valuable guide to the assistive technology landscape, including key technological developments, challenges in making assistive technology available to end-users, policy and other responses and opportunities for the future.

A note on methodology

This report employs a unique approach that groups assistive technology into conventional and emerging assistive technology and uses specially developed taxonomies to analyze technical trends. The different assistive technology products are categorized according to the areas of human functioning they support, namely, cognition, communication, hearing, mobility, self-care and vision, as well as in the built environment. The scope for conventional assistive technology includes devices external to the human body, as per the WHO definition of assistive technology, meant for use by persons with functional limitations and not by caregivers. It excluded learning and rehabilitation as being part of physiotherapy. On the other hand, the scope for emerging assistive technology was led by the retrieved data, and as a result it includes implantable products or components thereof.

The starting point for defining the scope of this report and the related search was the existing definitions, descriptions, categorizations and lists of assistive technology products. Therefore, we took into account WHO's Priority Assistive Products List (APL) (WHO, 2016) and its International Classification of Functioning, Disability and Health (ICF) (WHO, 2018); the classification and terminology for assistive products for persons with disabilities included in ISO 9999 (ISO, 2016); the Medical Subject Headings (MeSH); and the International Patent Classification (IPC) and Cooperative Patent Classification (CPC), with consideration given to the specific ways in which technical subject matter is described and classified in patent applications. We created a concordance table for APL, ISO 9999 and the IPC and CPC, and, based on observations, patent and non-patent literature searches, iterations with subject matter experts and searches in the EASTIN database, we created a conventional assistive technology taxonomy (Annex 1). The study was based on patent (Derwent World Patents Index (DWPI)) and scientific literature (Web of Science) searches conducted on the Derwent Innovation platform.

It is a challenge to define what constitutes "emerging technology" and to identify this in patent data. Moreover, there is usually a lag between scientific publication and patenting activity, as well as an 18-month lag between a patent application and its publication, and this creates a "blind spot" in patenting activity. For this report, "emerging technology" is defined as the specific advanced or new developments in assistive technology expressed in specific applications and products, while the underlying technologies that allowed the development of these products are defined as "enabling technologies".

Developing a taxonomy for emerging assistive technology required a slightly different approach to be taken than for conventional assistive technology, beginning with a manual review of search results from the conventional assistive technology categories. Data mining techniques, a review of scientific literature and topics at assistive technology conferences, and iterative patent searches were used to produce a taxonomy, which was then validated through search iterations and discussions with subject matter experts.

Moreover, when developing the search methodology and reviewing the results, we kept seeing a number of enabling technologies being employed, often in combination, in the emerging assistive technology applications, which allowed improvements to be made to conventional assistive solutions, or even the development of new products. To establish the role of enabling technologies in the development of advanced assistive products, and to substantiate and validate their impact across different product categories, we compiled a list of these enabling technologies, developed related search strings and, once the emerging assistive technology taxonomy was finalized, we searched for these technologies within our dataset for emerging assistive technology. Chapter 3 includes a related description, and the background methodology paper provides further detail on the enabling technologies featured in the emerging assistive products.

This report also explores – for the first time – the technology readiness level of the emerging assistive products identified and how close they are to commercialization, along with their expected impact and ease of adoption, and compares the different rating scores with the patenting activity in these areas. In order to do this, the NASA Technology Readiness Level (TRL) model (NASA, 2012) was adapted to the assistive technology requirements, grouping the different areas in four main categories/levels, namely, research concept, proof of concept, minimum viable, and commercial product. The assessment was carried out by 31 subject matter experts who provided related ratings, and related impact questions were developed in consultation with WHO and leading experts. Results were visualized on an interactive platform developed by Envisioning.io, which is available on the report's dedicated website: www.wipo.int/tech_trends/en/assistive_technology. The results of this assessment and a snapshot of the related visualization are included in Chapter 3.

Full details on the methodology used for the patent search and the related search strings can be found in the background paper on methodology available on the report's website, while the full taxonomies can be found in the Annex.

Why use patent data?

Patent data is highly valuable when tracking research and innovation trends as a source of valuable technical, legal and business information. Patent application documents are systematically collected in a structured data format (including application date, name of applicant and inventor, and a thorough technical description of the invention) in publicly available patent databases. They are therefore a good source of data for analysis from which meaningful conclusions can be drawn.

Analyzing patent data allows us to track changes over time and identify where most patents are being filed and by whom. They are also a rich source of technical information. Digging deeper into the substance of applications yields insights into the types of technologies being developed and those that are emerging, how they are applied and the fields they cover. This helps us gain a better understanding of the current profile and the potential future direction of an industry.

Patent documents contain technical information about developments in a certain field that is often unique. This is because patent applicants – first and foremost companies – will often seek patent protection without publishing related scientific articles. Patent data also inherently contains business and commercially relevant information. Not only does an applicant invest in the research and development of their invention, but the cost of patent filing in each patent office (as patent protection is territorial) means that it is only worth doing in those jurisdictions where there is an existing or a potential product market for solutions with commercial potential. This being the case, information about areas of patenting activity and the related trends, patent filing strategy, and the profile of the top patent applicants and identified collaborations can be a rich source of business intelligence facilitating the decision-making of a broad range of stakeholders.

Aggregation of patent information therefore enables us to draw technical and commercial conclusions, such as the geographical trends in innovation or the identification of changes in activity or in technology commercialization strategy, whether industry-wide or from the perspective of a single organization.

Patents are intellectual property (IP) rights. They are territorial, meaning that they provide protection only within the jurisdiction where an application is filed and patent granted. Patents are thus generally granted by national patent offices – or through regional systems, such as the European Patent Convention (EPC) administered by the European Patent Office (EPO). The Patent Cooperation Treaty (PCT) system administered by the World Intellectual Property Organization (WIPO) makes it possible to seek patent protection for an invention simultaneously in a large number of countries by filing a single "international" patent application instead of several national or regional patent applications.

Patent applications are normally published 18 months after filing, and become publicly available documents. If the patent office decides that an application meets all the patentability criteria and other requirements, a patent is granted, though this may take several years. The term of protection is typically 20 years from the filing date in most jurisdictions, though occasionally protection may lapse earlier (e.g., if the renewal fees are not paid) or be extended.

Data collection and preparation

The patent data were prepared using the patent database Derwent Innovation and covered patent applications filed from 1998 to 2019. The related data were last extracted on August 17, 2020. Scientific publication data were searched using Web of Science. The coverage of these databases is available in the background paper to this report (see Background methodology paper, available at www.wipo.int/tech_trends/en/assistive_technology) and like any data source may not be exhaustive. Patent data are extracted from the DWPI collection provided by Derwent Innovation (https://clarivate.com/derwent/solutions/derwent-world-patent-index-dwpi/), which indexes patent applications and granted patents from more than 100 patenting authorities.

In this report, all counts of records and most of the analysis refer to patent families or inventions, unless stated otherwise. Patent families consist of the earliest patent application filed for patent protection, and the subsequent patent applications related to the same invention. Where patents for the same invention are filed in numerous jurisdictions, they are described as patent applications corresponding to the same invention or as members of the same patent family. There are different definitions of patent families; for this report the Derwent World Patents Index (DWPI) patent family approach was followed.

This involved grouping together as patent family members those patent documents with exactly the same priority data and therefore referring to the same invention filed for patent protection in multiple jurisdictions. The analysis refers to patent families (which in some cases may include a single patent family member). In most graphs and analysis, each patent family is represented by one single patent document, that is, the earliest application in the family. This ensures that even where there are several members of a patent family it is only counted once – in this way we refer to invention numbers – giving a more accurate picture of the actual innovative activity. The patent families are broken down into individual patent applications (counting one per jurisdiction) only in the analysis related to the geographical distribution of the patent protection. Here, the numbers refer to patent applications, and the percentages refer to the proportion of patent families that include a patent application in the jurisdiction in question, reflecting the IP strategy of the patent applicants and their choices of jurisdiction and related markets.

Quick guide to interpreting the patent analysis

Growth

Growth rates indicate whether there is a growing interest in a technology. The average annual growth rate (AAGR) in the number of patent filings provides a comparative measure for growth, and in this report the AAGR for 2013–2017 (with 2013 as the base year) is used, as 2017, as earliest priority year, is the last year for which data was fully available at the time the search was carried out. The percentage of patents filed before or after a particular date also indicates whether an area is an established one or more recent (e.g., a large proportion of patents filed after 2013 would suggest a more recent area or product market).

Geographical distribution

Leading patent offices for protection tells us where there is an existing or potential technology or product market. This does not necessarily mean this is where the technology is being developed, something which is more apparent from the origin of filings (inventors' residence and, where that is not available, office of first filing). Patents filed in only one jurisdiction indicate a more localized or single market interest, whereas those filed in a number of jurisdictions indicate a potential for the technology to "go global" or aiming for multiple markets.

The Patent Cooperation Treaty (PCT), administered by WIPO, and the European Patent Convention (EPC), administered by the European Patent Office (EPO), afford applicants the opportunity to apply for patent protection in more than one jurisdiction. Therefore, filings made at these offices can be regarded as indicators of an applicant's intention of entering into several markets. The mention "WIPO" in the analysis refers to PCT applications and "EPO" to EP applications. Patent filings in other regional patent offices were low (related activity is reported in Chapter 3).

Key players

Patent data provides a context for the major actors and players within a space, as well as serving to identify more niche corporations or research institutions with an expertise and interest in the field. The profile of patent filers gives us an indication of how strong the commercial interest is in the technology, foremost when there is a strong presence of corporate players. Moreover, low-tech applications tend to be developed by many more corporate and independent inventors than high-tech ones, which tend to be filed more by academic or corporate players. A strong presence of academic players indicates areas of more recent or niche technological development.

The analysis of its top applicants can also indicate whether a landscape is consolidated (i.e., when the top applicants account for a bigger part of the dataset) or more fragmented (i.e., when there are no dominant players and top applicants have very small patent portfolios). In addition, utility models are easier to protect, so we often see a large proportion of utility models for more low-tech applications.

Industrial designs

Industrial designs can play a particular role in the area of assistive technology, as the design of such products can facilitate their adoption or lead to their abandonment, for example, by younger or elderly users seeking a sleeker and discrete or more modern design in their products. We explored the search of industrial designs data to add to our understanding of the IP strategy of top players.

Industrial design data was retrieved from the WIPO Global Design Database. A keyword search was initially conducted based on the patent conventional and emerging assistive technology taxonomies. The nature of industrial designs did not allow for a precise like-for-like search, due to a lack of uniformity in classification. For example, wheelchairs are grouped together with strollers and rollators, making it difficult to distinguish or exclude the unrelated terms.

The sample searches across different assistive product categories and a related manual review of the results revealed that all the top industrial design holders were top patent applicants in the related area. In view of this observation and the abovementioned limitation, the names of the top 30 patent applicants for conventional assistive technology, and the top 30 patent applicants (and their subsidiaries) for the emerging assistive technology were used, combined with some assistive product keywords, to look for related industrial design filings. The results were then manually reviewed and validated for their grouping across the different functional categories and related categories and sub-categories.

Figure 1.1 Taxonomy of conventional assistive technology

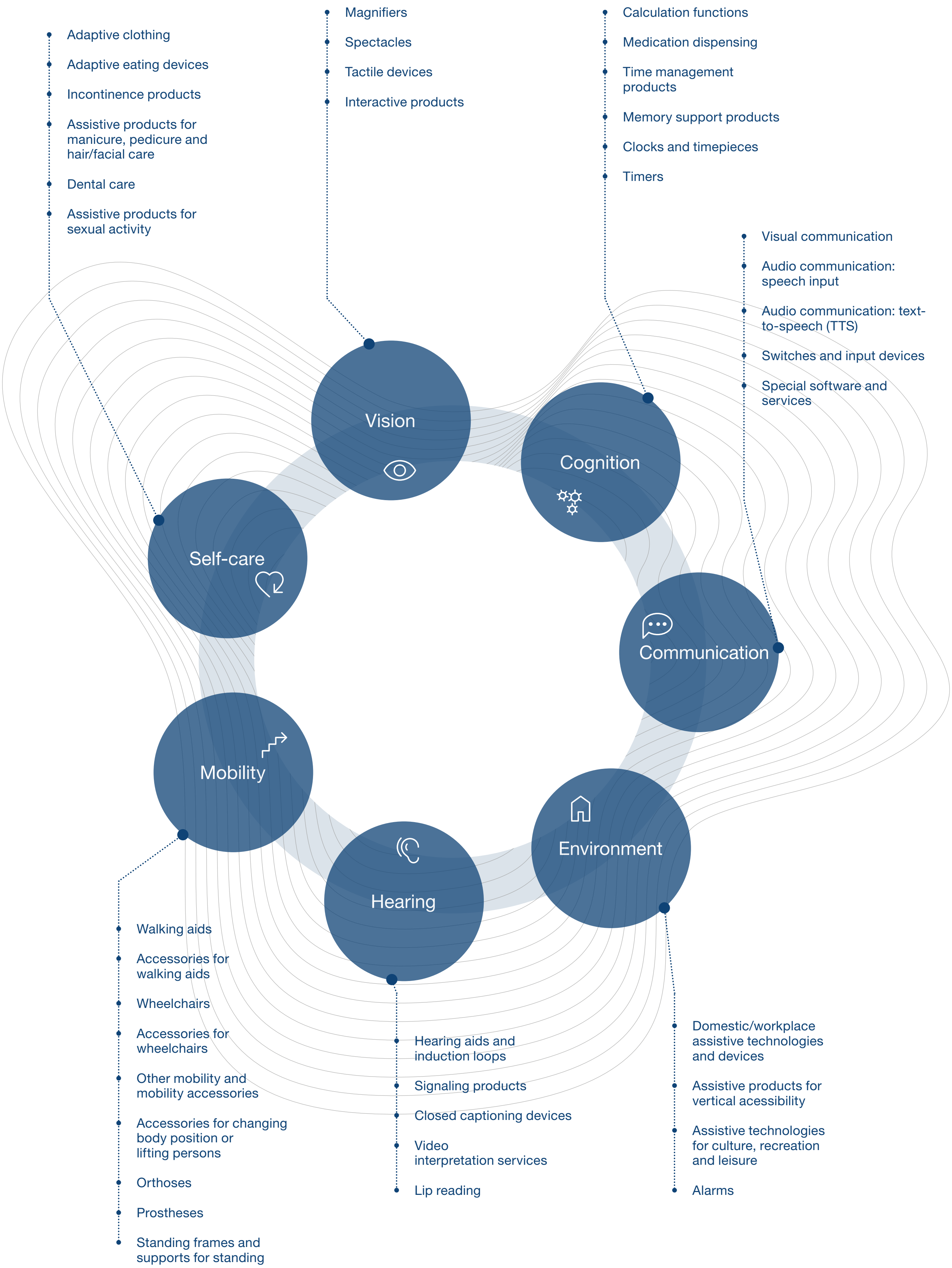


Figure 1.2 Taxonomy of emerging assistive technology

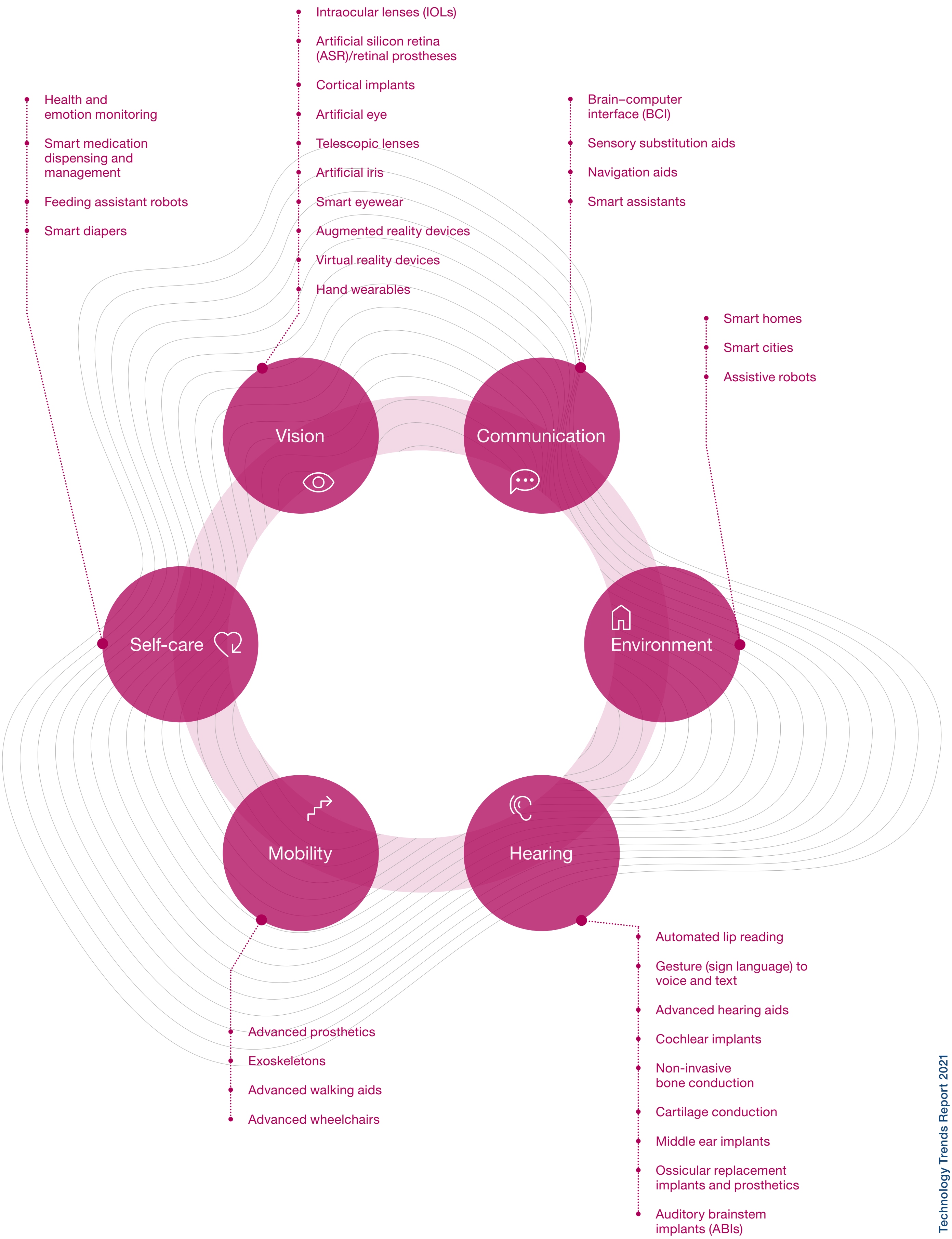
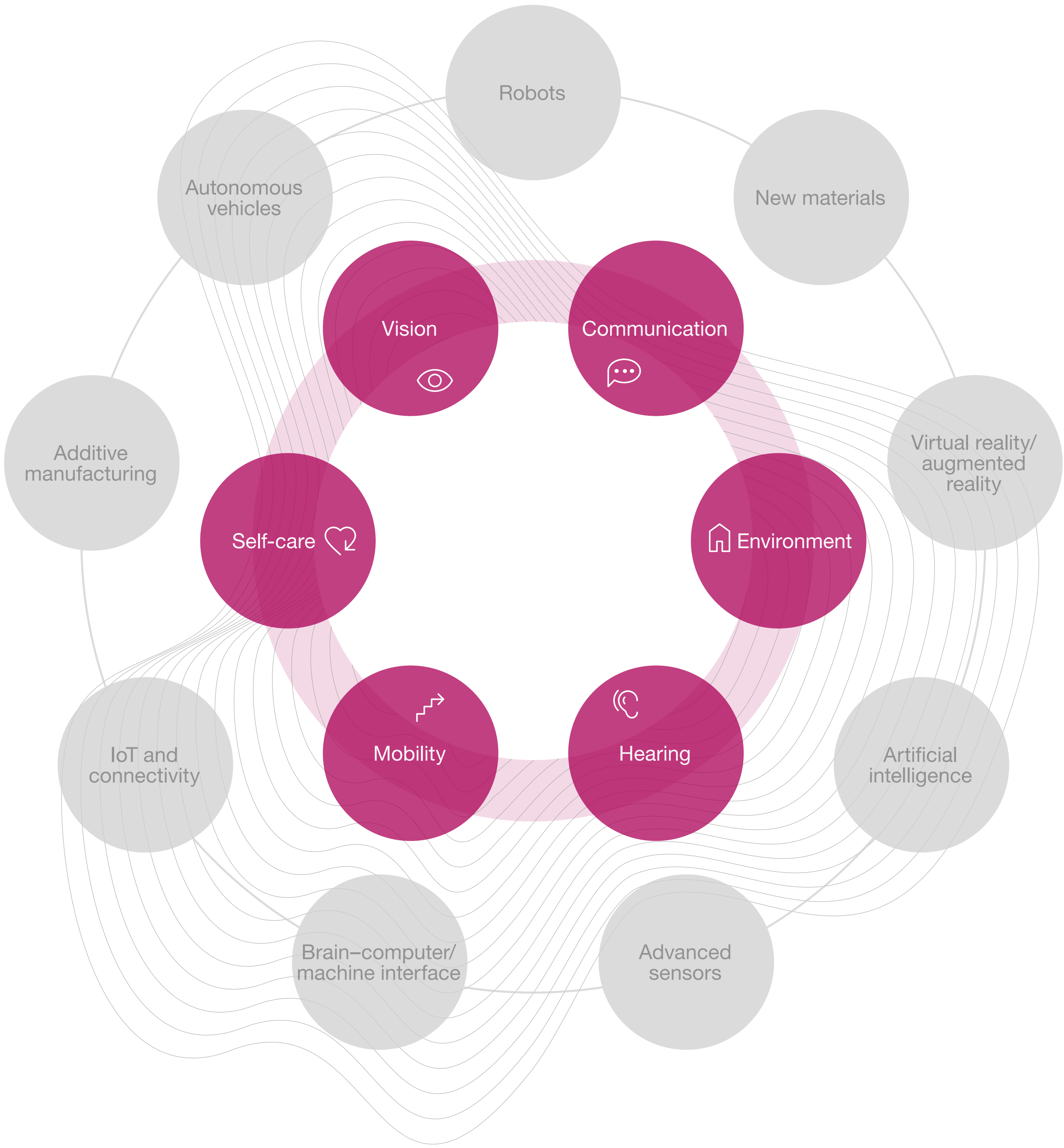


Figure 1.3 Enabling technologies



References

European Union (EU) (2019). Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services, Chapter 1, Article 3, Definition 37. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.151.01.0070.01.ENG&toc=OJ:L:2019:151:TOC (accessed September 14, 2020).

ISO (2016). ISO 9999:2016: Assistive products for persons with disability – Classification and terminology. https://www.iso.org/standard/60547.html (accessed September 14, 2020).

National Aeronautics and Space Administration (NASA) (2012) Technology Readiness Level. https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html (accessed September 14, 2020).

United Nations (UN) (2015). Transforming our World: The 2030 Agenda for Sustainable Development. UN General Assembly, 70th session, Agenda items 15 and 115, Resolution adopted by the General Assembly on 25 September 2015. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed September 14, 2020).

— (n.d.). Ageing and disability. https://www.un.org/development/desa/disabilities/disability-and-ageing.html (accessed September 14, 2020).

World Health Organization (WHO) (n.d.). *Assistive technology: Making Universal Health Coverage inclusive*. https://www.who.int/phi/implementation/assistive_technology/gate-fact_sheet.pdf?ua=1 (accessed September 14, 2020).

— (2016). *Priority assistive products list*. Geneva: WHO. https://www.who.int/phi/implementation/assistive_technology/EMP_PHI_2016.01/en (accessed September 14, 2020).

— (2018). International Classification of Functioning, Disability and Health (ICF). https://www.who.int/classifications/icf/en (accessed September 14, 2020).

— (2020). *Assistive devices and technologies*. https://www.who.int/disabilities/technology (accessed September 14, 2020).

World Intellectual Property Organization (WIPO) (2019). *WIPO Technology Trends 2019: Artificial intelligence*. Geneva: WIPO. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_1055.pdf (accessed September 14, 2020).

2 Assistive technology patent landscape

The appropriateness of an assistive device depends on the type of functional limitation involved and the user's specific needs, requirements and preferences, along with the way assistive technologies ties in with and is supported by the whole innovation ecosystem. Age-related impairments in cognition, hearing, mobility and vision develop over time, so the adjustment strategies for each will be different from those in response to sudden or lifelong impairments. Older individuals are more likely to have multiple impairments, affecting the suitability of assistive technology that relies upon other sensory modalities or capabilities. Moreover, they may be less prone to learn and adopt new communication languages, such as Braille or sign language, that persons with lifelong impairments invested in learning at an earlier age. Additional support may be required for learning, employment, social inclusion, and there may be further barriers to overcome related to stigma, prejudice or the relationship with new technologies. The underlying needs of these different groups are fundamentally the same though: they all require the artificial compensation of bodily functions in order to live more self-sufficient and independent lives.

Through patent analysis, this chapter explores technology and patenting trends within assistive technology across seven functional categories – cognition, communication, environment, hearing, mobility, self-care and vision – to provide a picture of the global assistive technology patent landscape.

2.1 Cognition

Cognitive impairment affects a person's functional skills and ability to reason, understand and learn, making it difficult to process information and make decisions. It can be found in varying degrees of severity among individuals with learning disabilities, autism, multiple disabilities, brain injuries or with progressive conditions, such as multiple sclerosis. The ageing of the population is increasing the prevalence of cognitive disabilities through dementia and diseases such as Alzheimer's. It is estimated that 35.6 million people are living with dementia worldwide, and that this number will double every 20 years (WHO, 2012). Until recently, cognitive disabilities have been stigmatized and are often misdiagnosed or go under reported. This has been a neglected area of research and practice for assistive technology (Boot et al., 2017); an observation confirmed by the smaller number of inventions identified by this study that specifically address cognitive impairment.

Assistive technology for cognitive impairment covers a range of tools, from ubiquitous, low-tech and mainstream devices to specialized, complex technology, such as brain–computer interfaces (explored further in emerging communication, Section 2.2). The technology can support several functional needs, but this section focuses specifically on those technologies predominantly used to support cognitive function to allow individuals to live more independently by supporting activities involved in daily living.

A total of 1,416 related patent families[1] were filed between 1998 and 2019 across 36 patent offices (Figure 2.1); the smallest dataset within conventional assistive technology. Most filing activity is observed in **medication dispensing and management** products, accounting for 42% of the dataset. This category includes devices to help measure, dispense or modify medication, such as pill crushers and splitters, with products incorporating technologies such as audio output, alarms and sensors (see Figure 2.2).

With the advancement of technology, assistive products supporting people living with difficulties in cognition are emerging on the market. From simple products for time management like a digital calendar to more complex products utilizing GPS and wearable technology for tracking wandering in patients with dementia, these assistive products help people to manage their difficulties in daily activities and assist their caregivers in providing support and care as well.

Wei Zhang,
World Health Organization

Slightly less than a third of the dataset (29%) relates to **clocks and timepieces**. These include devices for measuring, displaying and speaking the time. They can be portable and may include an alarm function.

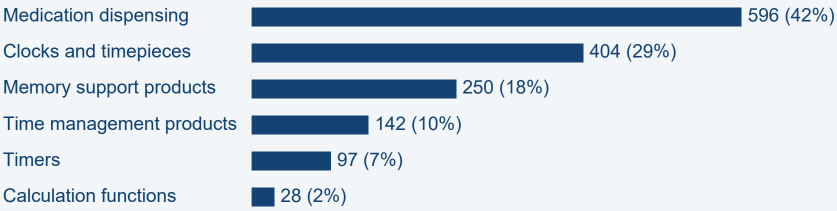
Over half (53%) the patents in the category of **memory support products**[2] (18% of the dataset) apply specifically to elderly people, highlighting a major focus in terms of demographics, while a quarter are dedicated to memory support for taking medication. Other technologies include portable memo pads, memory support notebooks, audio picture books and odor-emitting devices that match smell to certain warnings or reminders; or use object recognition, proximity sensors and a camera to identify certain members of a household and remind them to take their medication. The latter indicates the "smart" and "personalized" direction these systems are starting to take, and devices can be wearable or non-wearable.

Patents for **time management products** (10% of the dataset) are related to devices for storing and organizing data on planned activities. They concentrate on calendars and timetables (Figure 2.3) and include transport scheduling applications.

A variety of technologies are included within the category of **timers** (7% of the dataset), defined as devices to enable the completion of a task on time, such as devices for time-keeping for races and tracking the time a person spends in a bath.

Figure 2.1. Overview of patent families first filed for patent protection from 1998 to 2019 for assistive technology for cognition*

Most patenting activity is observed in medication dispensing and management, followed by clocks and timepieces



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Figure 2.2

An example of medication dispensing and management: a medicine box which incorporates compartments for storage and a notification system (patent document JP2018183351A filed by Sutakku System KK)

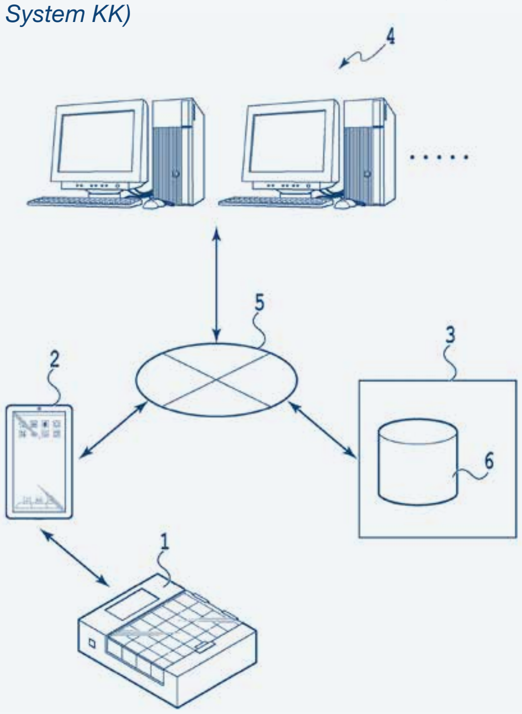


Figure 2.3

An example (patent document US20050179246A1) of a kit that helps with planning, organizing and managing daily activities, including a daily planner used in combination with a color coded reminder system, and components to remind the user of important tasks requiring their immediate attention

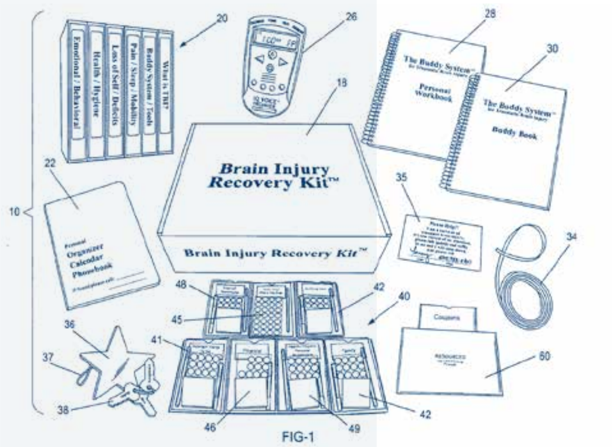


FIG-1

Very few patent filings are observed for **calculation functions** (2% of the dataset) – devices to support the ability to calculate, including abacuses and calculators with large buttons, large digital text, loudspeakers and pocket calculators – indicating a very limited commercial interest in such products.

Growth

The number of patent applications in this domain has grown substantially over the last 20 years, with only slight dips in activity in 2010, 2014 and 2018. The number of patent applications published between 2010 and 2019 grew by 157%, from 49 to 126 documents, highlighting an increasing commercial interest in technologies addressing cognitive impairment. In fact, 68% of the identified patent applications were filed since 2010, indicating a recent field of development. This coincides with the attention given to cognitive impairment in recent assistive technology-related discussions. Medication dispensing and management patents have seen the most recent concentration in activity and the highest growth, with an AAGR for 2013–2017 of 10% and 71% of patent applications filed from 2010.[3] Growth is also observed for clocks and timepieces (an AAGR of 7% between 2013 and 2017) and memory support products (an AAGR of 6% for 2013–2017 with 86% of filings since 2010).

Geographical distribution

Around 90% of patent applications related to assistive technology for cognitive impairment were filed for patent protection in a single jurisdiction, indicating more interest in the local market by applicants. This is the narrowest breadth of patent protection observed in the space of conventional assistive technology, and the functional category with the lowest percentage of patent families that include patent applications in two or more jurisdictions.

China is leading, receiving three times more patent applications than either the United States of America (U.S.) or the Japan patent offices, followed thereafter by PCT filings, the Republic of Korea, the EPO and Germany (Figure 2.4). Only 7% (106) of cognition-related patent filings include a PCT patent application and 4% (63) a European patent (EP) application. This is low when compared with other domains of assistive technology.

The U.S. and Japan are more established patent protection locations. Although the overall number of patent filings puts them among the top patent offices, recent patenting activity is low. Since 2005, the U.S. has received around 12 patent filings a year, while 59% of applications were filed in Japan before 2008. The top patent office in Europe is Germany, followed by the United Kingdom (U.K.) and France, although patent filings in Europe are also relatively low.

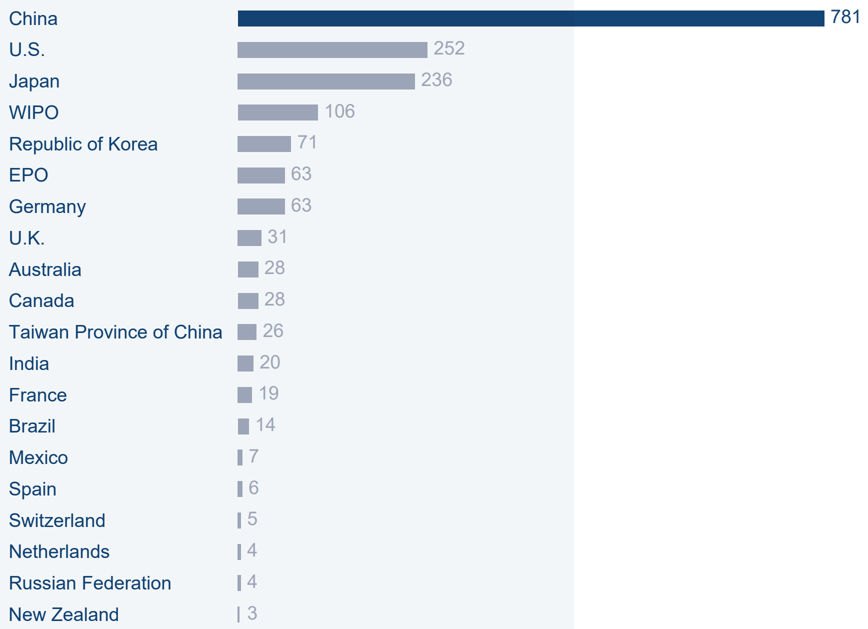
The patent offices of China, the Republic of Korea and Germany only started receiving filings in cognition-related assistive technology in the 2000s and 89%, 63% and 36% of their overall patent applications have been filed since 2010, with an AAGR of 6.2%, 51% and 12.5%, respectively, indicating the recent interest and potential in these markets. One of the foremost drivers behind the growth in filings in the Republic of Korea is Samsung, which accounts for almost a fifth of patent filings in this jurisdiction. China overtook the U.S. in 2007 in number of annual patent filings; 55% of the dataset's patent families include a filing in China, a much higher percentage than for the U.S. (18%), Japan (17%) or the Republic of Korea (5%).

A large proportion (35%) of utility models are filed in the domain of cognition. The majority were filed in China (over half of first filings in China were utility models), and the rapid increase in utility models filed after 2005 has been predominantly driven by China-based independent inventors.

Patent filings by China-based inventors account for 53% of the patent landscape, with 77% of all patent filings from China-based inventors filed from 2013, showing recent research activity in the field. Resident applicants are filing almost all their applications only in China, again indicating a more localized market interest. In Japan, 89% of patent

Figure 2.4. Top 20 patent offices by number of patent applications filed from 1998 to 2019 for cognition assistive technology

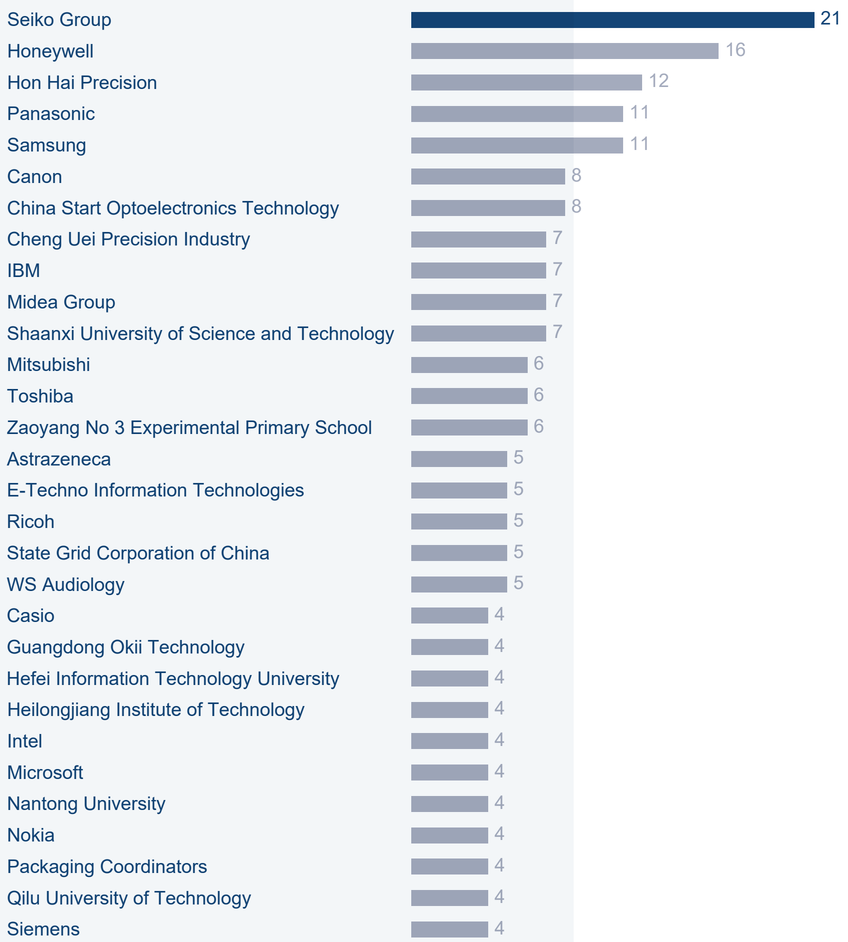
China, the U.S. and Japan are the top three filing offices, with China receiving three times more patent applications than either the U.S. or Japan



Note: EPO is the European Patent Ofiice. WIPO represents PCT applications.

Figure 2.5. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for conventional cognition assistive technology

The top applicants are Seiko Group (Japan), Honeywell (U.S.), Samsung (Republic of Korea), and most top applicants are based in China



applications were from resident applicants, most either independent inventors or from the Seiko Group (Japan). U.S.-based applicants are extending protection for their inventions beyond the local market to include the EPO, China, Australia, Japan and Canada. Honeywell, IBM and Microsoft are the key U.S.-based applicants; interestingly, for Honeywell, 15 out of its 16 patent families have China-based inventors.

Key players

Over half (53%) of patenting activity in the field of cognition assistive technology comes from commercial players. Despite the high level of corporate activity, the market is very fragmented and there are no dominant players – the top 30 applicants (Figure 2.5) account for just 15% of patent filings and all have very small portfolios. The top applicants are Seiko Group (focusing on timers and clocks), Honeywell (focusing on medication dispensing and management), and Samsung. China, with 13 applicants, is by far the most represented location among the top applicants, followed by Japan (7 applicants) and the U.S. (4 applicants), and then Denmark, Finland, Germany, the Republic of Korea and the U.K. (with an applicant each).

Independent inventors account for more than a quarter (30%) of all filings, and are highest (50% of patent filings) for calculation functions and 30% in medication dispensing and management.

Meanwhile, universities and public research organizations account for 17% of filings, 87% of which are based in China. Shaanxi University of Science and Technology is the leading academic institution (with 7 patent filings). A higher level of patenting activity by universities and public research organizations in memory support products (21%), clocks and timepieces (17%) and medication dispensing and management (20%) is potentially an indication of early-stage technologies in the making.

It is noteworthy that the portfolios of the top patent applicants are very small, but also that there are six major consumer electronic goods companies among the top applicants. Smartphones incorporate various types of functionality (e.g., reminders) to support cognitive function, and cognition assistive technology presents an opportunity for these companies to further commercialize existing technology and expand their customer base. The presence of these companies in medication dispensing and management indicates that more high-tech devices and the consolidation of products and markets could be on the horizon.[4] IBM, Intel and Microsoft have a fairly significant presence in the area of time management products. For example, IBM research under *Cognitive Eldercare* is using IoT and sensor technology to help elderly people,[5] while Microsoft has collaboratively introduced a wearable sensor-based technology ARMED for fall prevention, as well as an early detection and prevention solution for elderly people.[6] Another telecommunications company entering the field is Samsung, with four of its six medication dispensing and management patents filed between 2015 and 2018.

Chinese entities were the major growth driver for memory support products, accounting for 65% of patenting activity and responsible for the largest proportion of patent filings in this category. Memory support products are predominantly protected by the corporate sector, but there has been a recent surge in activity from the academic sector in China, which has filed over half of its patents since 2016.

Time management products is the only category where Chinese entities do not lead patent filing, which is instead led by Japan (44 patent applications) and U.S.-based applicants (26 patent applications). Filings are relatively low, however; and, although Japanese and U.S. entities have filed earlier patents, there does not appear to be any recent substantial interest in pursuing this technology.

Given Japan's strong presence in the watch and timekeeping industry, it is no surprise that Japanese entities account for a third of timer-related patent families. These filings were, however, before 2008, indicating a shift away from this technology and possibly related to developments in commercial smartphones and smartwatches. China-based entities are also active in this category (28 patents, 70% of which were filed after 2013), but the patent numbers are too low to suggest that this is an area of future focus.

Summary

This is a recent and a generally growing market. The application of AI to improve and develop assistive products for cognitive impairment has piqued the interest of technology companies such as IBM, Intel, Microsoft and Samsung in a market that is nevertheless fragmented overall. In both the short and long term, this may help consolidate the patenting activity and markets. Medication dispensing and management, clocks and timepieces, and memory support products, in particular, show growth. China is leading as the key market and origin of patenting activity, while the Republic of Korea is also a growing market. Filings tend to have a more localized focus, with the vast majority (90%) filed within a single jurisdiction and the use of the PCT and EP route for this functional category limited in number.

Implications for end-users

Future assistive technology applications for cognitive impairment include the development of companion and pet robots (covered in Environment, Section 2.3). By using a combination of robotics with AI, IoT and sensors, such robots are increasingly addressing various disabilities, including cognitive impairment, and having functionalities similar to those found in conventional cognition assistive technology, such as task/medication reminders, measuring, displaying and telling the time, or managing and delivering medication (such emerging technologies for medication dispensing and management can also be found under self-care applications in Section 2.6). Smart assistants (covered in Communication, Section 2.2, along with navigational aids and brain–computer interface applications) functioning as avatars can also be seen as the future of assistive technology for cognition, encompassing several similar functionalities, such as calculation tasks and storing and organizing data on planned activities. Moreover, persons with cognitive impairment will also benefit from smart environments which facilitate, for example, health and emotion monitoring. The increase in such technologies will effectively support individuals with cognitive impairment, not only by ensuring their safety and well-being, but also by increasing their independence and reducing dependency on caregivers.

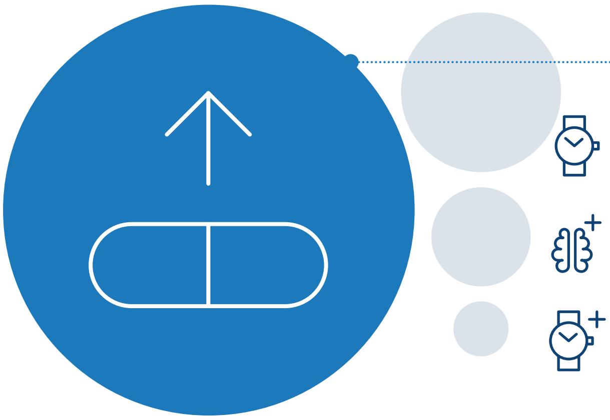
The application of AI to improve and develop assistive products for cognitive impairment has piqued the interest of technology companies.

Conventional cognition assistive technology

1,416

patent families for conventional cognition assistive technology filed across **36 patent offices**

What technologies are involved?



Medication dispensing
596 (42%)

Clocks and timepieces
404 (29%)

Memory support products
250 (18%)

Time management products
142 (10%)

Timers
97 (7%)

Calculation functions
28 (2%)

> Patent applicants focus mainly on local markets with **90%** of the applications filed in **one single jurisdiction**

Which are the fastest growing technologies?

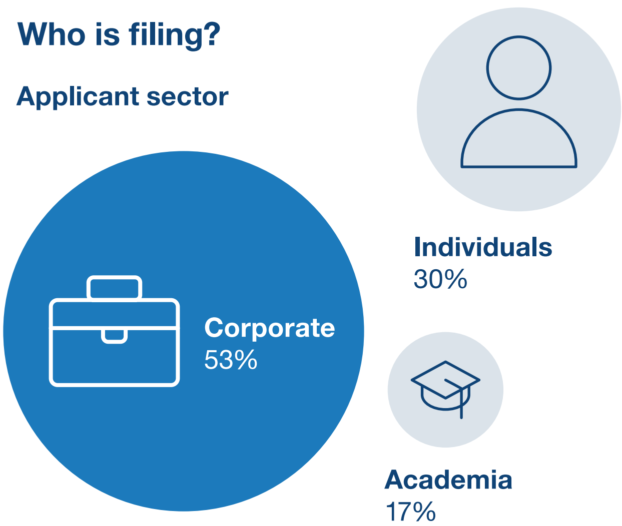
Cognition is the smallest and most recent domain in conventional assistive technology: almost 70% of the dataset was filed after 2010

The number of patent applications published between 2010 and 2019 increased by **157%**, from 49 to 126

10% average growth in filings from 2013 to 2017 for **medication dispensing and management**

Who is filing?

Applicant sector



Top patent applicants

Seiko Group	21
Honeywell	16
Hon Hai Precision	12
Panasonic	11
Samsung	11

Cognition is the domain within conventional assistive technology with most utility model filings (35% of the dataset). Assistive robots, smart assistants and smart environment assistive products in the emerging assistive technology space encompass applications related to cognition

2.2 Communication

Communication involves the use of multiple faculties that include speech, hearing, vision, motor abilities (gestures) and cognition. Technologies for facilitating communication, therefore, can focus on one or more areas of human functioning to assist people experiencing one or several functional limitations.

Conventional technology

Most conventional assistive communication devices and tools focus on substituting an impaired functional ability with another that is more active. For example, a visual tool, such as a symbol-based communication board, may be useful for someone who has difficulty speaking, while an audio-based communication device, such as text-to-speech conversion, may benefit someone with a visual impairment.[7]

Several low-tech devices are included in the dataset, such as printed media communication boards, or head–mouth sticks, oversized trackballs and sip-and-puff switches, with inventions seeking to improve these well-established products. The dataset also includes more hi-tech applications, such as eye-controlled input, software-based visual aids, emulation software and speech recognition and synthesis, which are becoming more prominent with the increasing availability and affordability of computing devices and software-based systems. These are an indication of the developments in the field of communication, which is reflected later in the emerging assistive products (page 88).

A total of 6,899 patent families related to conventional assistive technology for communication were identified (Figure 2.6). The category with the highest number of patent filings is **special software and services** (59% of the dataset). This indicates that industry focus is on software-related solutions for enabling communication. This category includes graphical user interfaces, text editing software and telephony services. Inventions

Will software-based solutions make existing communication assistive technology hardware obsolete?

Limited innovation in printed communication books and boards is not a reflection of their usefulness: they are flexible and versatile, can be used across all contexts and are not prey to the pitfalls of hi-tech solutions such as battery drain and screen glare. They will always have a place. Software- and print-based systems are interdependent and many users and professionals value the use of both in tandem.

“Mid-tech” devices such as static display digital voice output devices have been declining in popularity as software and multi-functional devices increase in availability and reduce in cost. However, these devices still maintain a crucial role for some users.

Tom Griffiths,
Cambridge University Hospitals NHS Foundation Trust

There will be still a market for low-tech products given that ease of use and accessibility may be challenging for some hi-tech solutions. There can be a potential divide on adoption depending on whether techniques rely on specific infrastructure, such as Internet connectivity. Some approaches that leverage functionalities of consumer-oriented technology – in particular, smartphones using local computing capabilities – can be more widely adopted.

Ricardo Chavarriaga,
CLAIRE, IEEE Standards Association, and Zürich University of Applied Sciences

Many people with communication difficulties, particularly those with dysarthria, are unable to use speech input devices (e.g., smart hubs like Google Home) without some modification or a speech-generating device. It is these people for whom hardware communication devices are most useful.

Alistair McEwan,
University of Sydney

Conventional communication assistive technology

6,899

patent families for conventional communication technology filed across **43 patent offices**

What technologies are involved?

Special software and services
4,064 (59%)

Visual communication
1,745 (25%)

Audio communication: speech input
751 (11%)

Switches and input devices
535 (8%)

Audio communication: text-to-speech (TTS)
506 (7%)

> Electronic consumer goods companies, rather than companies specializing in assistive technology, feature as top patent applicants. Chinese and Korean corporate applicants emerged after 2013.

Which are the fastest growing technologies?

Filings in **emulation software** (accounting for over half of **special software and services**) increased almost fourfold between 2011 and 2016

Speech input-related filings have marked an average annual growth rate of 39% from 2013 to 2017

Who is filing?

Applicant sector

Corporate
64%

Individuals
25%

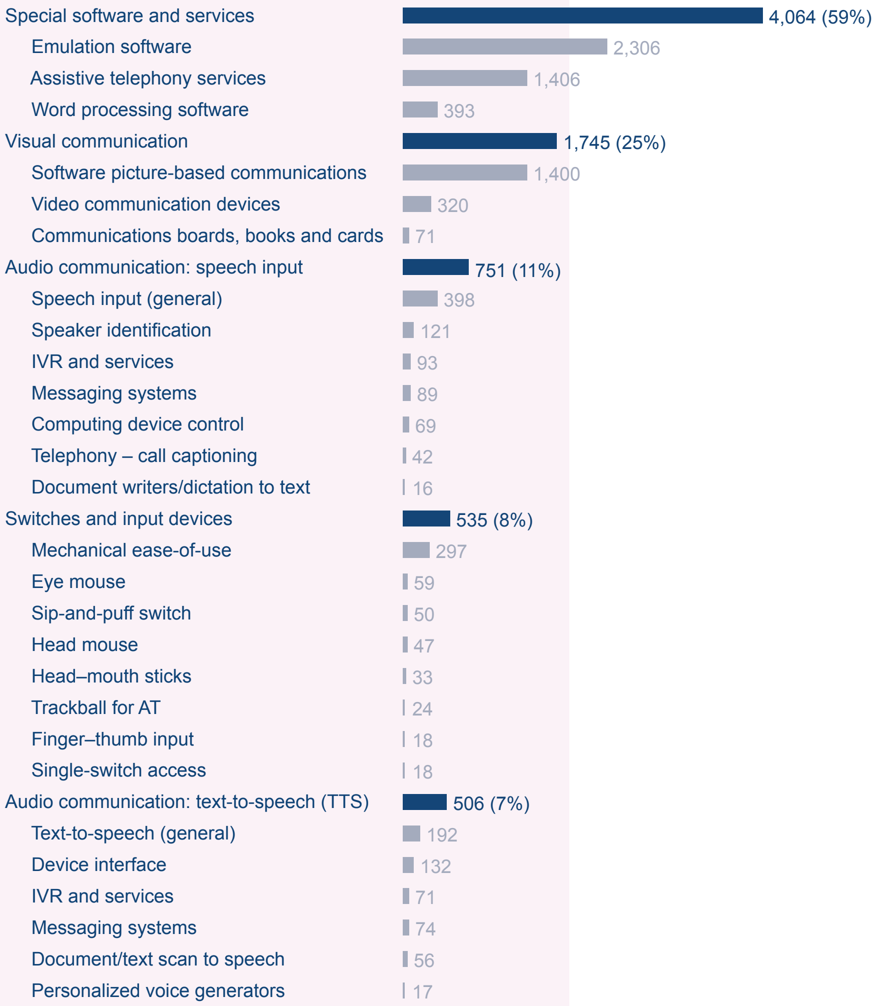
Academia
10%

Top patent applicants

IBM (U.S.)	149
Panasonic (Japan)	115
Samsung (Republic of Korea)	113
NEC (Japan)	82
Microsoft (U.S.)	77

Figure 2.6. Overview of patent families first filed for patent protection from 1998 to 2019 for conventional communication assistive technology*

The majority of patent families (59%) are related to special software and services, and emulation software accounts for over half of patent families within this category



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Figure 2.7. (Top) A keyboard that emulates a smartphone for persons with visual impairment (patent document KR1499904B1); (bottom) a communication card that can adjust the size of its core symbol/icon vocabulary (patent document US20190147757A1)

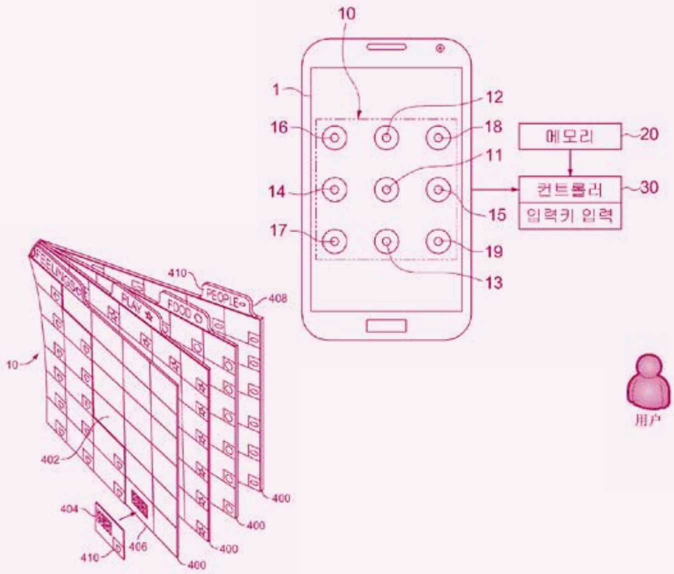
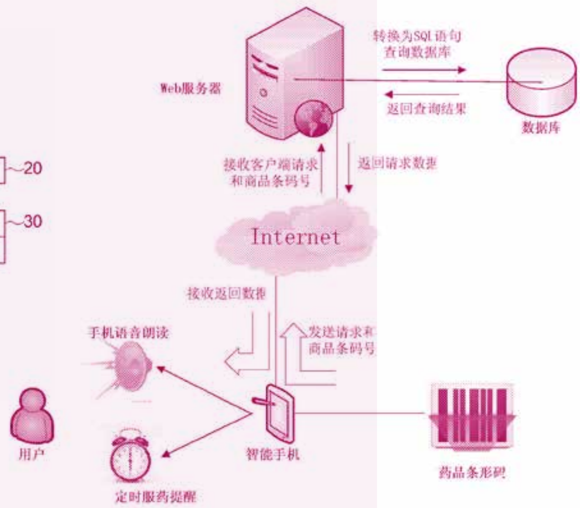


Figure 2.8. A mobile phone is used to scan the contents of a medical label, send them to a server and obtain text output in audio format (patent document CN105380801A filed by Harbin Institute of Technology)



here are aimed at user-friendliness, with more conveniently located buttons and ergonomic keyboards. Over half (2,306 of 4,064) of the patent families within this category relate to **emulation software**. This mainly transforms the user interface of a device (including hardware input devices) into a customized software interface for easier interaction and accessibility for users (Figure 2.7). The second biggest category (25% of the dataset) is **visual communication**, with almost 80% of the related inventions (1,400 of 1,745) referring to **software picture-based communications**, which are more portable and easier to use than the hardware equivalent, as well as special video calling devices. **Speech input audio communications** (11% of the dataset) are an easier way of controlling communication systems or other devices, addressing multiple disabilities and often customized to specific speech impairments. **Text-to-speech** technologies (7% of the dataset) convert digital or scanned text to audio, providing notifications or using cameras on mobile devices to scan and read out text (Figure 2.8). Inventions relating to **switches and input devices** (8% of the dataset) provide accessories that are more ergonomic when using telephone or computing equipment, help compensate for hands that shake, or use eye-tracking techniques to read aloud, save or delete emails and messages. While some of the initial solutions for **eye mouse**-based technologies used desktop cameras to monitor users' eye movements and detect a command (see Figure 2.9), recent inventions focus on improving the accuracy of these solutions by applying more advanced machine vision techniques, such as feature extraction and waveform detection. Eye-input devices based on eye gaze/tracking, even though they have been around for some time, seem to be an emerging concept involving more advanced technologies to develop further applications.

Growth

Filings related to conventional communication assistive technology grew between 2008 and 2014, at nearly 12% AAGR. Patent filings in emulation software, one of the most prominent sub-categories in conventional communication assistive technology, nearly quadrupled, from just 68 patent filings in 2007 to over 273 patent filings a year on average during 2011–2016, and patent filings in software picture-based communications have also been growing significantly since 2011.

Patent applicants appear to have shifted their focus from **text-to-speech** systems (declining since 2008) to **speech input** systems, a small yet fast-growing area. Filings relating to the mechanical ease of use of special switches and input devices have been decreasing significantly since 2013, while filings related to **eye mouse**-based technologies (i.e. using eye tracking as input) have recently been increasing.

Growth in communication technologies

The decline in patent filings for special switches and input devices could be explained by the increase in "accessibility controls" on phones and tablets for those unable to speak, replacing switch devices. Meanwhile, computer vision has become to a great extent open-source. There has also been an increase in webcams on computers and front-facing cameras on phones for video calling. This has accompanied a decrease in privacy concerns and companies like Microsoft have integrated eye-gaze support into their operating system.

Alistair McEwan, University of Sydney

The proliferation of computer vision and camera-equipped devices, such as on mobile phones, webcams, computers and gaming consoles, has contributed to an increase in eye mouse-based technologies. It has provided high-performing hardware ready to support these functionalities at affordable prices.

Ricardo Chavarriaga, CLAIRE, IEEE Standards Association, and Zürich University of Applied Sciences

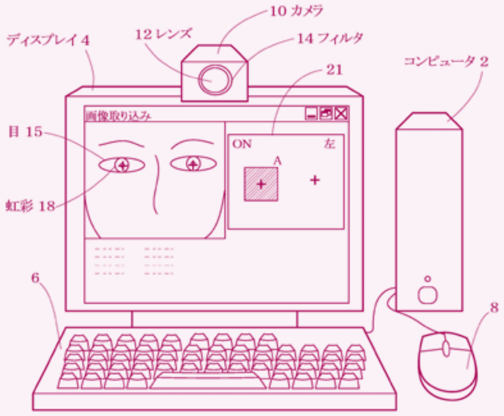
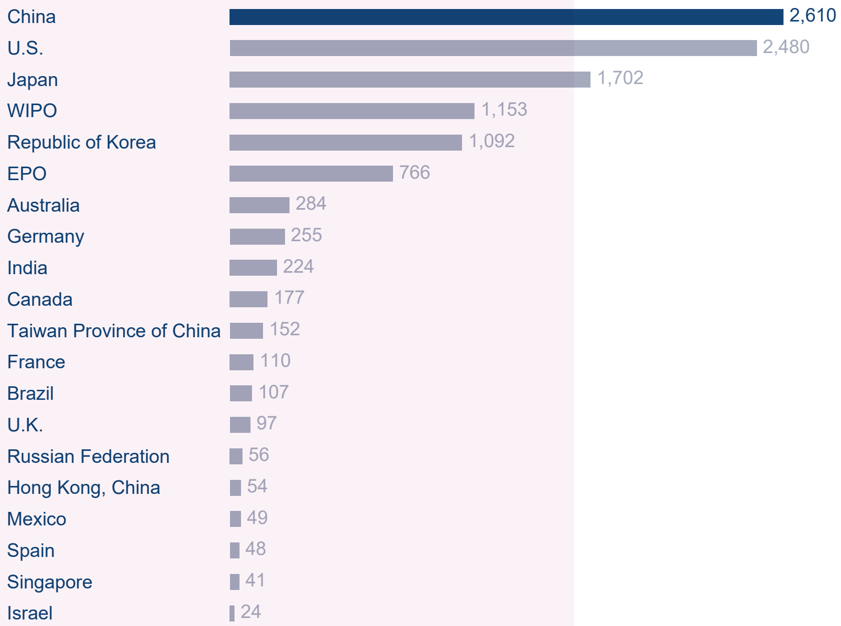


Figure 2.9. A camera is used to monitor eye movements and convert blinking into mouse signals (patent document JP2006059147A)

Figure 2.10. Top 20 patent offices by number of patent applications first filed for patent protection from 1998 to 2019 for conventional communication assistive technology

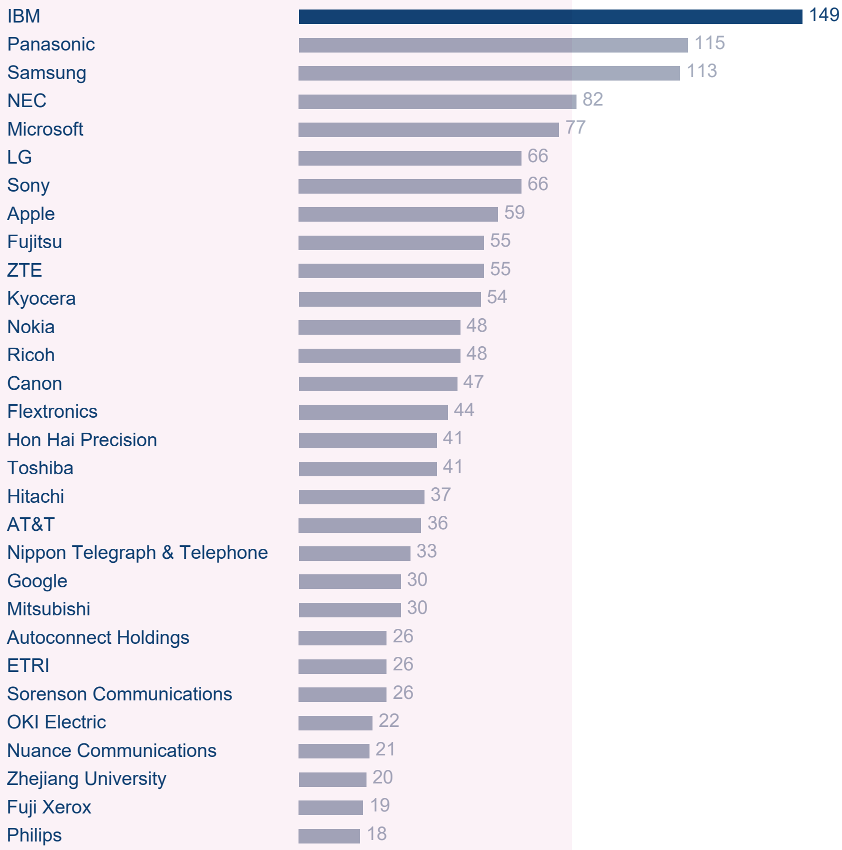
China and the U.S. are the two leading patent offices, with 38% and 36% of patent families, respectively, including a filing with these offices



Note: EPO is the European Patent Ofiice. WIPO represents PCT applications.

Figure 2.11. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 related to conventional communication assistive technology

Consumer electronic goods companies based in Japan, the U.S. and China dominate the top 30 applicants, with IBM (U.S.), Panasonic (Japan) and Samsung (Republic of Korea) the leading applicants



Geographical distribution

Approximately 38% of patent applications were filed for protection in China, followed by the U.S. (36%) and Japan (25%) (Figure 2.10).

Nearly half (46%) of the patent applications filed in China were filed between 2013 and 2017, with an AAGR of 15%. This indicates that China is a recent and growing jurisdiction and a related market. Conversely, almost two-thirds (67%) of the 2,480 patent applications filed in the U.S. were filed before 2013. Japan is similar to the U.S. in this respect: filings in Japan decreased at an AAGR of 16% during 2013–2017, with only 17% of all Japanese documents having been filed during this period.

Overall, 76% of the 6,899 patent families are filed at a single patent office (approximately a third of these in China). Of the 24% remaining, 9.5% are filed for patent protection at two offices, 4.8% at three, and almost 10% at four or more patent offices. This makes conventional communication one of the functional categories with the highest percentage of protection in multiple jurisdictions.

Patent applicants filing in China seem to be mainly focused on the local market, with almost 75% of related patent applications filed only in this jurisdiction, whereas this percentage drops to 47% for patent applications filed in the U.S., indicating an interest in multiple markets.

A PCT patent application is included in 16.6% of the dataset's patent families, and in 11% an EP patent application. The PCT route has consistently received a higher number of patent filings than the EP since 1999, and PCT applications have gradually risen since 2009, whereas EP patent filings have remained consistent.

Key players

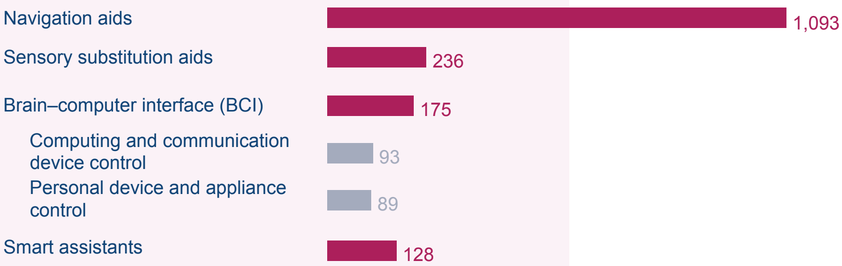
The top 30 patent applicants account for 21% of patent applications, indicating a fragmented patent landscape (Figure 2.11).

The top patent applicants in the field of conventional communication assistive technology are consumer electronic goods companies rather than companiesspecializing in assistive technology. The area was dominated by Japanese players (Panasonic and NEC) until 2008, but the global economic recession led to decreased patenting activity in several countries, including Japan (WIPO, 2010; Kawai and Takagi, 2009). Japanese companies feature as top patent applicants, yet (apart from Sony and Fujitsu) Japanese players filed three-quarters of their applications before 2013 and do not drive recent patent filings. U.S.-based patent applicants (including Apple, Autoconnect Holdings and Google) increased their activity between 2009 and 2013, with a significant presence from Korean-based Samsung, which emerged as top patent applicant during the period 2013–2017, followed by IBM and Microsoft. In the same period China-based applicants emerged, including major mobile phone manufacturers ZTE and Meizu Technologies.

In the overall conventional communication assistive landscape, corporate entities account for almost two-thirds (64%) of patent applicants, with about a quarter based in China, Japan and the U.S. The strong presence of consumer electronic goods applicants from the mobile and computing industry can be explained by the fact that emulation software is used in customizing the interfaces of communication devices, such as mobile phones, personal digital assistants and laptops, and therefore is an area of interest with an impact on these major industries. Apple, IBM, Microsoft, Panasonic and Samsung own more than 10% of patent applications related to emulation software. Similarly, the top patent filers of assistive telephony services are all active providers of telephony services: AT&T, NEC, Nokia, Panasonic, Verizon and ZTE. Sorensen Communications Inc. is the only company with a product portfolio focused on providing services to those with hearing or speech impairments. Some of the top applicants filed patents only during specific periods, such as Flextronics and Autoconnect Holdings (with all their patent applications filed between 2010 and 2013). While Flextronics is a major electronics components provider for automotives, Autoconnect is in the automotive

Figure 2.12. Overview of patent families first filed for patent protection from 1998 to 2019 for emerging communication assistive technology*

Navigation aids is by far the largest category, accounting for 68% of patent families



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families. Seven documents are categorized in both brain–computer interface categories.

Figure 2.13. A walking cane that detects the distance of objects via sound waves (patent document US20090028003A1 filed by IBM)

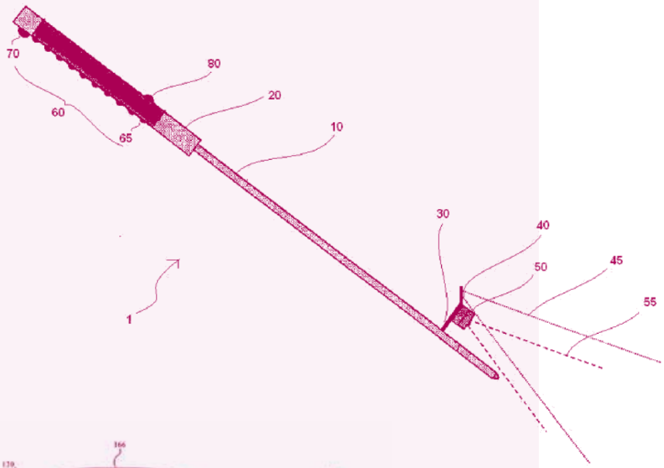
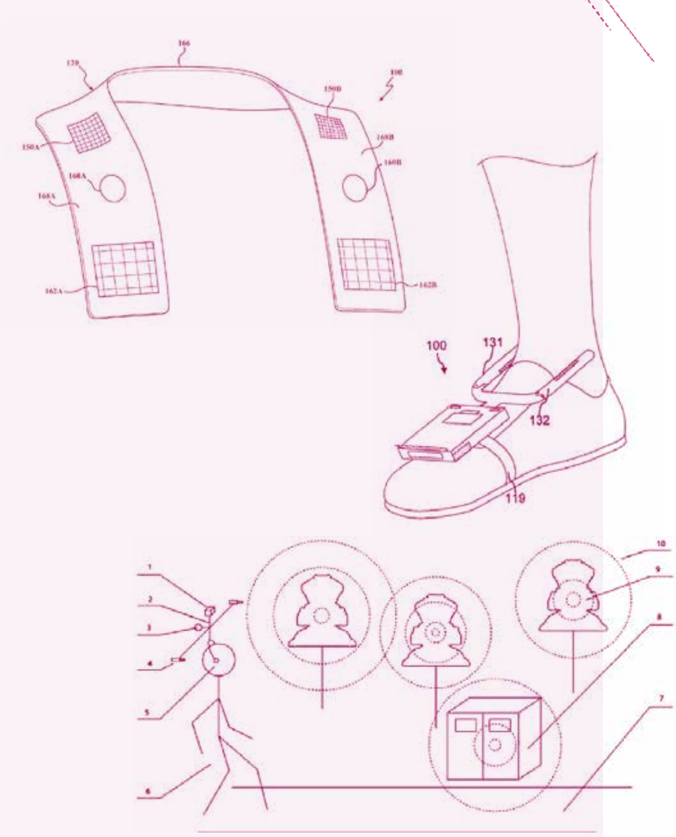


Figure 2.14. Examples of advanced navigation aids

(Top) A smart necklace that provides navigational assistance via audio output (patent document US9993384B1 filed by Toyota). (right) A foot-worn navigation assistive device for a visually-impaired user (patent document US9311827B1). An ultrasonic sensor and GPS tracker provide audible or tactile commands to the user. The robotic arms grip part of the user's leg to alert them to an obstacle. (bottom) A 3D, sound-based augmented reality system for visually-impaired users (patent document CN111121749A filed by Intel) that uses neural network techniques to provide navigation assistance



domain, with no known product on the market (Lee, 2015). Flextronics and Autoconnect Holdings have filed jointly 11 patents focused on providing accessible interfaces for vehicle systems.

As of 2010 and 2015, Philips and Nuance Communications Inc., respectively, stopped filing patents in this domain. Nuance had filed almost half of its applications together with other companies, such as IBM, related to text-to-speech and speech-input technologies.

A quarter of the patent applicants are independent inventors, many based in China, and the majority of the inventions filed for protection relate to software, software picture-based communication systems or emulation software. It is worth noting that communication is the area with the least utility number of models (requiring a lower level of inventive step and often referred to as "minor inventions") among conventional assistive technology, accounting for 10% of the dataset.

Universities and public research organizations account for 10% of overall filings. Almost 60% of these are filed only in China, with just over half filed during 2013–2017, primarily by Chinese universities, including Zhejiang University, South China University of Technology and Tsinghua University.

Emerging technology

Much of the patent activity within conventional communication assistive technology has historically been about allowing a visually- or hearing-impaired person to communicate or interact with basic computing devices such as text-to-speech, older eye-controlled technologies for mouse/keyboard, and speech input for calling and assistive tele-services, linked to the pre-Internet era. By comparison, emerging communication technology for interacting with computing and communication devices use online maps/GPS technology, wireless, online social platforms and gaming, and IoT capabilities to interact and communicate with others and control devices. Of course, the post-Internet age has seen the rise of *smart/virtual assistants*, and such applications are also reflected in the related patent filing activity in emerging communication applications.

The other major differences between conventional and emerging communication areas are in *sensory substitution aids* and *brain–computer interface* patenting activity where only recently have potentially viable commercial possibilities begun to appear. Similarly to other emerging assistive applications, they are aimed at the inclusion, participation and integration of assistive technology users into society.[8]

A total of 1,599 relevant patent families related to emerging communication assistive technology were identified (Figure 2.12).[9]

Navigation aids

Over two-thirds (68%) of the emerging communication dataset relates to navigation aids that provide location information, alert users to approaching obstacles and dangers, and guide them through their surroundings. They are generally enabled by sensors, such as GPS, movement sensors (accelerometers, gyroscopes), proximity sensors (LiDAR, RADAR, infrared or ultrasonic), and cameras and telecommunication signals, possibly also machine vision and scene understanding techniques based on advanced machine learning techniques providing more accurate, reliable information about the surrounding environment. Mobility aids, such as walking sticks, and canes using advanced techniques, such as satellite communication to guide users, are also included in this area.[10] Many of the earlier patent applications in the dataset refer to mobile phone-based or hand-held navigation devices for location guiding, detecting obstacles (Figure 2.13) or helping the user receive information from the environment (e.g., by using electronic product labels that can be read by a user's personal device).

Recent inventions discuss more advanced and customized technologies that learn about a user's specific needs or preferences, such as the assessment of a user's ability to

Emerging communication assistive technology

1,599

patent families for emerging communication assistive technology filed across **39 patent offices**

What technologies are involved?

Navigation aids
1,093 (68%)

Sensory substitution aids
236 (15%)

Brain–computer interface
175 (11%)

Smart assistants
128 (8%)

> Recent growth has been primarily driven by **China-based inventors**, who accounted for 50% of the patent documents filed since 2013.

Which are the fastest growing technologies?

Sensory substitution aids is the fastest growing category with **71%** average annual growth rate between 2013 and 2017

Brain–computer interface applications for controlling computing devices grew on average by **20%** and **navigation aids** by **18%** between 2013 and 2017

Who is filing?

Applicant sector

Corporate
47%

Individuals
27%

Academia
25%

Top patent applicants

IBM (U.S.)	32
Panasonic (Japan)	16
NEC (Japan)	14
Hitachi (Japan)	11
Toshiba (Japan)	10
Mitsubishi Electric (Japan)	10

cross the road, or improve the accuracy and accessibility of navigation aids with the help of ultrasonic sensors, IoT and 5G. The solutions are also becoming more user friendly, with the use of avatars, augmented reality displays and wearable technologies, while others use object recognition and scene understanding techniques to identify pavements or crossing marks on road, or to receive information from online servers to facilitate the navigation of visually-impaired persons. Wearable navigation aids include products such as smart necklaces with positional, movement and vision sensors to help guide users by providing audio or tactile feedback, smart wristbands or foot-worn devices (Figure 2.14) which guide users by providing tactile or audio feedback. Other advanced technologies use machine learning to understand a user's movement patterns and subsequently provide navigation guidance through a smart cane and electronic braille output (Figure 2.15), augmented reality providing 3D sound inputs to facilitate real-time understanding of type and positioning of objects in the surroundings and smoother navigation.

Sensory substitution aids

Sensory substitution aids (15% of the dataset) use advanced technology to convert and convey sensory information about the environment through an alternative sense output, such as audio, haptics, smell or taste feedback, which the recipient of the information is able to perceive and process. They aim to provide solutions that are more satisfactory for users with more than one sensory impairment, who were less well served by conventional technology, such as audio solutions for the visually impaired. While some of the initial inventions in the dataset conveyed information about the shape and size of an object in the user's proximity, more recent inventions can recognize the type and nature of an article and differentiate it from others. Several patent documents disclosed personalized technologies, such as wearable devices with haptic feedback for navigation, or devices installed in shopping malls to help shoppers navigate by following a particular smell (Figure 2.16).

While most of the early patent applications discussed provide a predefined vibratory feedback to the user to alert them to specific events (similar to vibrating a mobile phone to announce the arrival of a message or call), tactile output was also introduced, such as the 1998 patent application filed by the U.S. space agency NASA for a headband using machine vision sensors to detect shapes of objects in the vicinity of a visually-impaired user, and then convert that information into tactile output to be transmitted to the forehead of the user, or a similar application filed by Japanese company Media Grip KK in 2000. These seem to be two of the few initial patents that used machine vision concepts to detect obstacles in front of a visually impaired user and convert it into haptic output.

Patent filings for sensory substitution aids had an AAGR of almost 71% during 2013–2017.

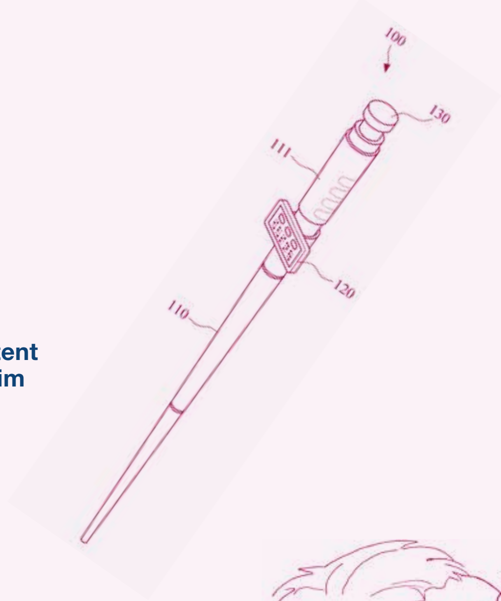
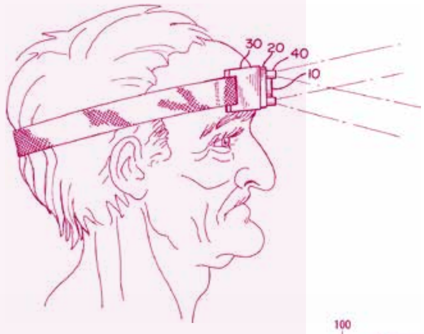


Figure 2.15. A smart cane with electronic braille output. Machine learning is used to understand the user's movement patterns and provide navigational guidance (patent document KR1782059B1 filed by Kim Si Yool)



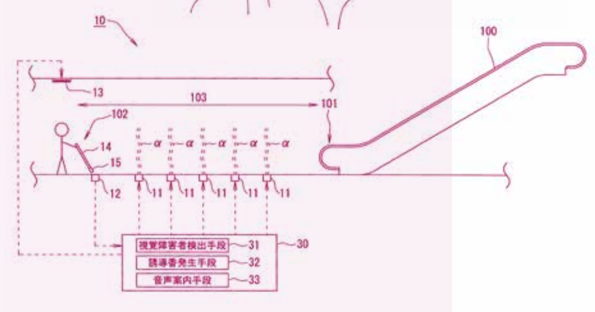


Figure 2.16. Sensory substitution aids convert sensory information into an alternative output

(Top) Optical sensors determine the shape of an object and convey this information to a visually-impaired user in tactile form (patent document US6055048A filed by NASA). (bottom) Smells are used to guide the user, for example in a shopping mall or airport (patent document JP2011121772A filed by Mitsubishi Electric)

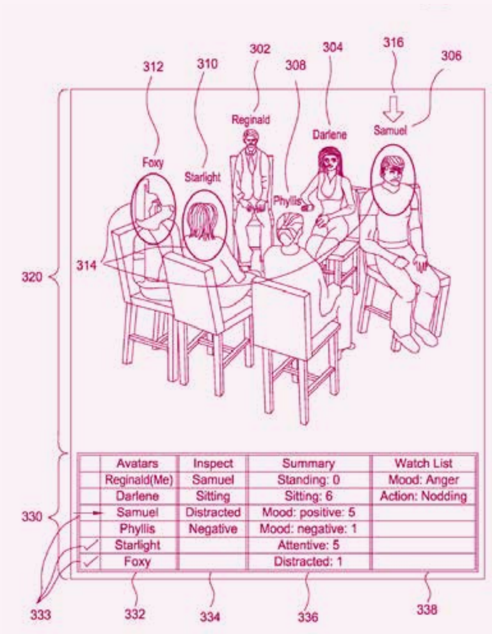


Figure 2.17. A virtual meeting can be held using customized avatars to convey actions based on disability profiles, using visual and audio cues (patent document US8161398B2 filed by IBM)

Brain–computer interface

Brain–computer interface (BCI) or, more generally, brain–machine interface (BMI), are neural interface applications which seek to understand brain activity patterns and map them to specific communication outcomes, linking them to specific commands or actions. BCIs can also be used as sensory substitution mechanisms, whereby the sensory input is translated into direct stimulation of the nervous system. The classic examples are cochlear implants and artificial retinas (see emerging technology for hearing, Section 2.4, and vision, Section 2.7, respectively), while there is also research into conveying tactile information through stimulation of peripheral nerves or cortical areas.

This section considers BCI from the perspective of outward communication. BCIs can be invasive or non-invasive, but most of the inventions captured here refer to non-invasive BCI. Such communication technologies and applications are particularly helpful for users who have different types of impairment and allows for a direct communication pathway between the brain and an external device, closing the gap between the user's thoughts and ability to communicate effectively, as opposed to simply recognizing and communicating individual words. These technologies, which account for 11% of the emerging communication dataset, enable users to interact with others and control appliances, equipment and personal devices using only information derived from brain activity, and are increasingly popular outside of assistive devices, mainly in the gaming industry. They are grouped in two sub-categories: controlling the input and interface of computing and communication equipment (computer, mobile phone, personal digital assistant, etc.); and controlling personal devices and equipment (wheelchair, door locks, home appliances, furniture, etc.). Examples of uses for BCIs are for controlling telephones or smartphones or dialing a specific number or even to note down the thoughts of a user without the need for the user to speak, write or type.

Brain–computer interfaces

Research on BCIs seems more focused on extending the capabilities of the existing approaches (direct control of a prosthetic device or communication assistive technology) by testing them in more realistic conditions. Another area of increased research is the decoding of mental states, such as attention, mental workload and fatigue, as a means of facilitating interaction. More exhaustive assessment and monitoring of their efficiency and efficacy are needed.

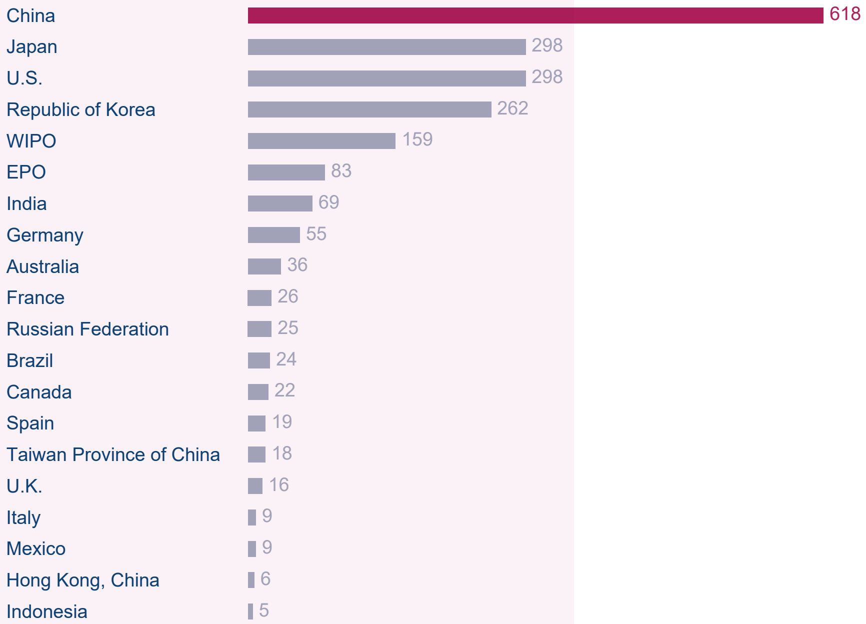
Ricardo Chavarriaga, CLAIRE, IEEE Standards Association, and Zürich University of Applied Sciences

Non-invasive BCI applications are at a lower technology readiness level. Currently, an invasive surgical device is needed for reasonable performance. There are also huge ethical concerns for companies – they do not want to be seen as "reading your thoughts".

Alistair McEwan, University of Sydney

Figure 2.18. Top 20 patent offices by number of patent applications first filed for patent protection from 1998 to 2019 for emerging communication assistive technology*

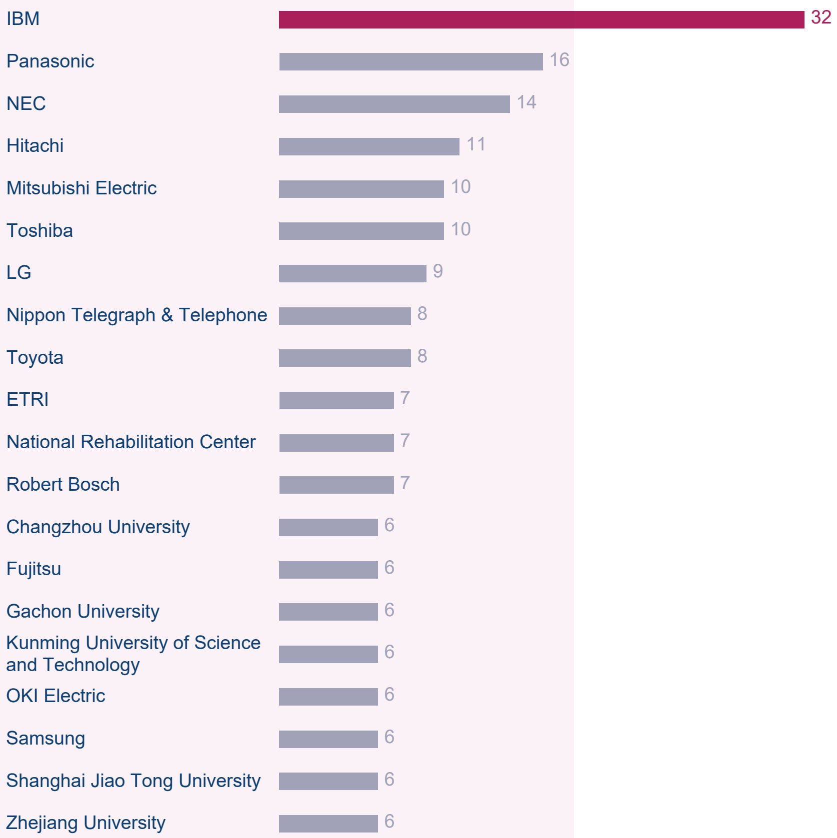
China is the top patent office, followed by the patent offices of Japan, the U.S. and the Republic of Korea. Overall, patent applications for emerging assistive technology for communication were filed across 39 different patent offices



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Figure 2.19. Top 20 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for emerging communication assistive technology

These applicants have small patent portfolios, indicating a fragmented market



* Patent documents can be filed in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of telated patent families.

A majority of the BCI patents in the dataset are focused on communication between the human brain and machines to allow a certain operation. Development of this technology is complex and has many limiting factors (not least the lack of a complete understanding of how the brain works), and the majority of related patent filings come from universities and public research organizations with no dominant patent applicants. This confirms that these technologies are, for the most part, still in the embryonic research phase and that it may take several years for them to reach the market. The majority (74%) of BCI-related patents were filed after 2013; further evidence that this is a recent technology. Research is aiming to move beyond the expression of a specific, direct instruction to an interpretation of the wish of the user, something which is far from becoming a reality.

Smart assistants

Smart assistants (8% of the dataset) use machine learning, pattern recognition and analysis, and other advanced techniques in order to understand a user's requirements by monitoring their activities, routines, interests, likes and reactions, profiling them based on this information and performing specific tasks (such as navigating and participating in online environments) or provide customized recommendations. Avatars that function as virtual smart assistants (see Figure 2.17) are also in this category. Smart assistants can help users with various tasks. Some of the interesting applications discussed in patent documents include assisting in online shopping and delivery of items; food ordering and delivery services; recommending media content, such as games, based on a user's impairment profile; suggestions for independent lifestyle plans; assessment of employability and ability to perform certain tasks; and creating a community for co-assistance and collaboration between users.

Growth

Recently, there has been significant growth in patent filings related to emerging communication assistive technology. Just over half (53%) of patent applications related to emerging communication assistive technology were filed after 2013, indicating a recent area which showed a notable AAGR of 21% during 2013–2017. In particular, a tremendous increase in patent filings for sensory substitution aids has been seen recently, with an AAGR of almost 71% during 2013–2017, driven by patent filings from China and the Republic of Korea; similarly for BCI technologies for controlling computing devices, with an AAGR of 20%, again driven by China.

Geographical distribution

Patent applications in emerging communication assistive technology were filed across 39 different patent offices (Figure 2.18), while 94% of the 1,599 patent families include at least one patent application filed at one of the top 10 patent offices.

Thirty-nine percent of identified inventions for emerging communication assistive technology include a filing in China, the top patent office, where patent filings grew at an AAGR of 28% for 2013–2017. Only 7% of filings in China are from foreign inventors. The top applicants in China are Kunming University of Science and Technology, Changzhou University and Shanghai Jiao Tong University. In the U.S., IBM is the top applicant, followed by Toyota, while in Japan the top filers are Panasonic, NEC, Hitachi and Toshiba.

Using the PCT or the EP route typically show an intention to seek patent protection in multiple jurisdictions. Only 10% of the dataset's patent families include a PCT application and 5% an EP application, indicating less interest in wider geographical patent protection. A quarter of PCT filings originated from the U.S., while of the 83 EP applications 24 came from the U.S., 13 from Germany, 10 from France and only 7 from China.

Until 2008, patent filings in navigation aids primarily originated from Japan (38% of the documents filed in this category up until then had Japan-based inventors), followed by the Republic of Korea and the U.S., each accounting for approximately 15% of the patent applications filed in this category for the same period. However, recent growth in this category has been primarily driven by China-based inventors, who account for approximately half (283 of 563) of the documents filed since 2013. China is also a major source of innovation for both BCI technology and sensory substitution aids, with respectively 61% and 49% of related patent applications filed in these categories since 2013 originating from China.

Key players

Nearly half (49%) of patent applications related to emerging communication assistive technology were filed by commercial players, whereas the other half is shared between universities and public research organizations (26%),[11] and independent inventors (27%). This indicates that, while some technologies are still in the research stage with academia, others seem to be closer to commercialization. This can be confirmed by the outcome of the Technology Readiness Level assessment (see Chapter 3 and dedicated online interactive platform, available at www.wipo.int/tech_trends/en/assistive_technology).

Commercial entities account for nearly half (43%) of patent filings in sensory substitution aids, yet with no dominant player (the two top patent applicants – Mitsubishi Electric and Panasonic – have 5 and 4 patent families, respectively).

In the area of navigation aids, IBM, Panasonic and NEC are the top patent filers and patenting activity is distributed among numerous corporate and academic entities (22% of the related patent families and two-thirds based in China) with few filings each, and 28% of the dataset filed by independent inventors (with nearly one in three involving China-based inventors, and more than half (53%) filed since 2013.

Universities and public research organizations lead the filings in BCI applications, both for computing and communication device control and for personal devices and appliance control, accounting for more than half of the patent families in this category. The majority of these institutions are based in China.

Independent inventors' filings mostly relate to low-tech areas tied to implementation in specific products (e.g., adding navigation aids to wheelchairs, body-worn devices). Independent inventors from China also have a strong presence in BCIs for personal devices and appliance control, owning 27% of patent applications in this sub-category that discuss the general components used in developing these technologies. One independent inventor, Qin Yuanyuan, based in China, owns 16 patent applications related to BCI technology discussing nursing systems controlled by brain signals. Independent inventors contribute almost a third (31%) of patent applications for sensory substitution aids, 26% of which are from China-based independent inventors and 20% from Republic of Korea-based inventors.

Smart assistants are highly customer facing applications, and this is reflected in patent filings being majorly driven by commercial players (led by IBM with 14 patent applications, 11 of which were filed before 2011), accounting for 71% of the 128 patent applications in this category. Most of these commercial players are from the U.S. and Japan, together accounting for 46% of the 128 patent applications.

The top 23 patent applicants (Figure 2.19) contribute just 12% of the total dataset and all have very small patent portfolios, indicating a quite fragmented area with no dominant player. The top applicant, IBM, filed applications on navigation aids (17, most of which were filed before 2010) and smart assistants (14).

Most of the top applicants have filed patent applications in one or two categories of emerging communication, yet have over 80% of their filings in navigation aids (e.g., Bosch, Fujitsu, Hitachi, Navteq, NEC, Nippon Telegraph & Telephone, Oki Electric, Toyota, Zhejiang University). Tianjin University files predominently in brain–computer interface for computing and communication device control, and Gachon University in sensory substitution aids.

Ten of the top 23 patent applicants are Japan-based, six are headquartered in China and five in the Republic of Korea. IBM and Navteq are the only two U.S.-based companies among the top applicants. BOE Technology and Changzhou University are the most recent patent filers, with their earliest filings dating from 2013 and 2016, respectively.

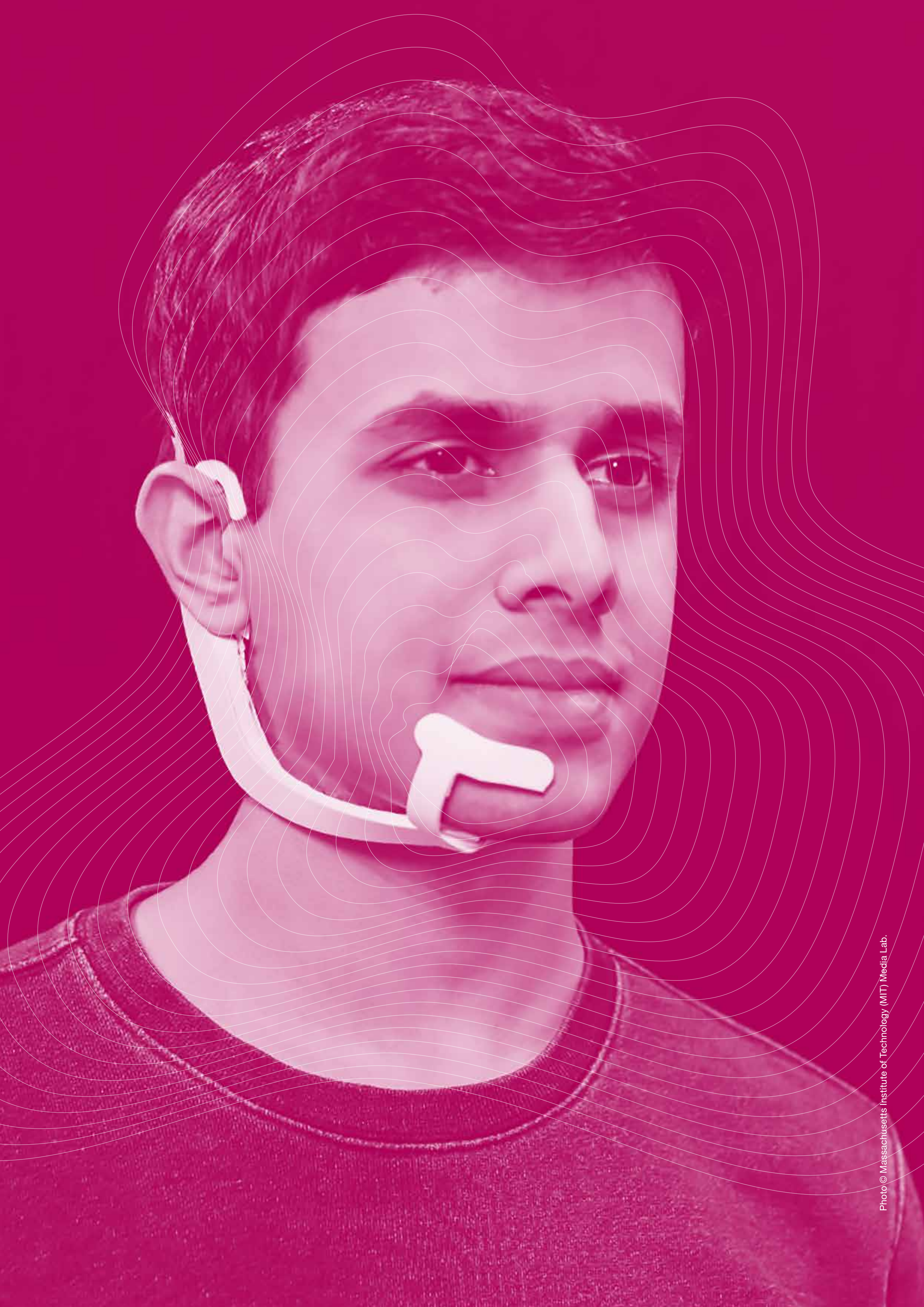
Summary

Patenting activity in conventional communication assistive technology has been stagnating or declining overall in recent years. With the increasing affordability of software-based systems and their scaleability to add more symbol/picture content, the innovation in hardware-based communication boards (books) has become limited to portability and enhancing vocabulary size. Despite that, technologies related to software and services have recorded a positive growth, mainly due to advances and expansion in technologies such as speech input/recognition, machine vision and mobile computing devices. These technologies are driven by commercial players, mainly large manufacturers of smartphones and computing devices, and service providers based in the U.S., Japan and the Republic of Korea. Although China is emerging as a source of innovation, claiming 60% of the patents filed, no major China-based player dominates the patent landscape. The U.S. and Japan are the more traditional markets as top patent offices of filing, but patent filings at these locations have been declining in recent years. However, an increasing focus from major players like IBM, Microsoft, Samsung, ZTE and Google is an indication that software and advanced technologies may be employed in developing new communication assistive technology.

Patenting activity in emerging communication assistive technology on the other hand is growing, particularly in the development of sensory substitution aids, which recorded an impressive AAGR of nearly 71% for 2013–2017. Although almost half of the patents are owned by commercial players, a relatively large proportion (26%) are universities and public research organizations, one of the highest percentages across all functional categories. This demonstrates the strength of the research activity behind many of these technologies, particularly BCI technology. Commercial entities, particularly large electronics companies such as IBM, Panasonic and other large Japanese conglomerates, are leading the development of sensory substitution aids and smart assistants. China is a major source of innovation, particularly for BCI technology and sensory substitution aids.

Implications for end-users

The inventions identified in the field of conventional assistive technology for communication aim to broaden the access to and usability of mainstream communication products; increase user-friendliness and speed of access to different devices and features; facilitate control; move towards greater adaptability and customization to match different user cases and profiles; and improve the accuracy and quality of communications, as well as providing more portable and affordable devices. The move towards customization is also driving the development of emerging assistive technology for communication – learning about the user's specific needs and preferences and ultimately making the world more accessible. These applications are of interest to both the gaming and mobile phone industry, and we could see further convergence of assistive technology with consumer goods. This could evolve into applying, for example, brain wave detection technology to the control of home appliances or posting updates to social media.



Transforming lives for people with speech disorders with human–computer interaction

Conventional technologies for communication, such as printed communication boards, eye-gaze trackers, laser pointers and joysticks, are often slow and strenuous for someone with a speech condition – transmitting close to 10 words per minute, far below the average for human speech of 120 words per minute.

Massachusetts Institute of Technology (MIT) Media Lab is tackling this by focusing on the flow of information from the brain to the nerves that conduct signals to speech muscles. It has developed AlterEgo, a peripheral neural interface that can detect a user's internally articulated speech from the surface of the neck and face and translate it into speech in real time. In other words, the user can "speak" without the need for any discernible action, voice or movement.

Using a combination of distributed sensing, signal processing and machine learning, AlterEgo detects weak electrical signals sourced deep within the mouth cavity from the surface of the skin when even only a fraction of the internal speech muscles are engaged by the brain. Language or speech can therefore be reconstructed from intent of speech even if there has been significant damage to the speech system. The system feeds back via bone conduction, transmitting audio overlaid on the user's natural hearing.

As opposed to head-mounted brain-reading systems, AlterEgo is non-invasive and non-intrusive, physically connected to only a voluntary part of the human body. The system is high bandwidth and users can speak in real time with conversation speeds of up to 100 words per minute. Although still at a research stage, it is currently being tested in clinics and hospitals in patients with Lou Gehrig's disease, multiple sclerosis and autism – in some cases allowing people to "speak" for the first time since their condition rendered them without a voice.

See more at www.media.mit.edu/projects/alterego/overview

Case study by Massachusetts Institute of Technology (MIT) Media Lab

Workplace assistive technology

A lack of assistive technology is a major barrier for persons with disabilities to participate in employment. Some assistive technologies are specific to work and play a key role in ensuring that persons with disabilities have equal opportunities in employment or training. Work-specific assistive technologies differ from more general assistive technologies in that the employer or training provider, rather than the state, is the duty bearer.

Esteban Tromel, ILO

User testing, focus groups and forums in safe environments are vital for incorporating assistive technology into environmental design. Local governments are pivotal in the public transport and physical environment space and are equally responsible for and involved in implementation of the CRPD.

Martine Abel-Williamson, World Blind Union/CRPD

2.3 Environment

Assistive technology for use in domestic, workplace and public environments helps persons experiencing functional limitations to live more independently, and allows caregivers to better manage risk. It can also support cultural, recreational and leisure activities that allow full participation in many aspects of life, thereby fulfilling various of the United Nations Convention on the Rights of Persons with Disabilities (CRPD) goals[12] (see also Chapter 4).

Conventional technology

Conventional environment assistive technology encompasses a very broad range of products and applications, grouped in the following four categories: **domestic and workplace assistive technology and devices**, that is, devices to help users perform routine activities at home and in the workplace to assist with or enhance the ability to live independently and safely; **assistive technology for culture, recreation and leisure**, which include products for play, sports and recreational activities, including for Paralympic sports; **alarms**, that is, personal alarm systems for regular or emergency use, operated by a user or activated automatically; and **general environment – vertical accessibility**, including stairlifts, overhead hoists for wheelchairs and portable ramps.

Exactly 21,326 patent families related to conventional environment assistive products were identified (Figure 2.20). The largest proportion by far (68%) relates to domestic and workplace assistive technology and devices, followed by assistive technology for culture, recreation and leisure (14% of the dataset), **alarms** (12%) and general environment – vertical accessibility (7%).

The largest category, domestic and workplace assistive technology (Figures 2.21–2.24), includes products that facilitate improved access, navigation, movement or safety, such as lighting activated by movement sensors. Most inventions relate to the sub-categories of **bathroom and toilet accessories** and **beds and their accessories**. Such applications refer to innovative structural components of beds that facilitate lying down on or getting up from the bed, movement when on it or getting into a lying position (e.g., raising the upper body to rest it over pillows). Others refer to beds with special sections underneath the mattress that can be hinged to create a back support and, in certain cases, leg support. Some disclose accessories, such as rope ladders, pull straps, hand blocks, or detachable handles affixed either to the bed frame or the legs on the end of the bed, to help a person pull themselves up into a sitting position. Bathrooms and toilet accessories include equipment related to shower units, urinals, toilet seats, bathroom chairs, washbasins, bathtubs (e.g., bathtub grab bars) and modular bathroom units.

Nearly half of the inventions in the category of assistive technology for culture, recreation and

Conventional environment assistive technology

21,326

patent families for conventional environment assistive technology filed across **51 patent offices**

What technologies are involved?

Domestic/workplace assistive technology and devices
14,470 (68%)

Assistive technologies for culture, recreation and leisure
2,985 (14%)

Alarms
2,660 (12%)

Assistive products for vertical accessibility
1,558 (7%)

Which are the fastest growing technologies?

Filings in **assistive products for vertical accessibility** saw an average annual growth rate of **41%** between 2013 and 2017

> Most top filers are Japanese companies. Conventional environment assistive technology encompasses a broad range of technologies and is highly fragmented, with many small patent portfolios.

Who is filing?

Applicant sector

Individuals
45%

Corporate
44%

Academia
10%

Top patent applicants

Panasonic (Japan)	282
Toto (Japan)	158
Sekisui Chemical (Japan)	116
Toagosei (Japan)	97
Stannah Stairlifts (U.K.)	91

Figure 2.20. Overview of patent families first filed for patent protection from 1998 to 2019 for conventional environment assistive technology*

The majority (68%) of patent families relate to domestic/ workplace assistive technologies and devices

*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

leisure relate to **assistive products for play**, followed by **assistive products for sports**. Within the latter sub-category, most inventions refer to *swimming* (153 patent families) and *golf* (139 patent families). The sub-sub-categories of *Paralympics* and *sports wheelchairs* include few documents (44 and 117 patent families, respectively). The category of Paralympics, has, however, seen the highest number of most recent filings, primarily from Japan, and this could be attributed to the Paralympic Games to be held in Tokyo in 2021.

Wandering and locating of persons and items is the largest sub-category within alarms (1,078 patent families) followed by **environment alarms** (926 patent families). Devices in the former sub-category assist with the geolocation of persons – mainly those with cognitive functional limitations who may get lost among their surroundings – with the potential of notifying their caregiver. Environment alarms notify and warn users about certain events in different ways based on their functional limitation profile, for instance, through vibration or multi-sound wrist bracelets, doorbell visual or other indicators, fire and smoke alarm signalers. There is also a sub-category of **fall detectors**, which are widely used by elderly people or other users with mobility limitations. Many of these alarms allow for continued care and observation by others, while at the same time providing greater autonomy and independence for the individual.

Growth

Patent publications increased gradually from approximately 700 patent families in 2000 to approximately 1,800 in 2018. This indicates a growing interest in this area in obtaining patent protection and creating new and incremental inventions, and there is no sign of this slowing down. Assistive products for vertical accessibility within the general environment was the category that had the highest AAGR (41%) during the period 2013–2017, indicating a recent focus on this market. This is followed by the sub-category **light fixtures** (with an AAGR of 17% for 2013–2017), assistive products for play (11% AAGR) and environment alarms (9% AAGR).

Geographical distribution

The identified 21,326 patent families related to conventional environment assistive technology correspond to a total of 26,920 patent applications filed across 51 patent offices (Figure 2.25).[13] China, Japan, the U.S. and the Republic of Korea received most patent applications, with 68% of patent applications including a filing at one of these three offices, and these are also the top countries of origin of the inventors associated with these applications. A total 71% of this area's patent families sought patent protection in a single jurisdiction, with the remainder filed in two or more jurisdictions, and with that a much higher percentage of the dataset seeking patent protection in multiple locations in comparison with other functional categories.

While patent filings in conventional environment assistive technology are growing in general, they are decreasing in the U.S., Europe[14] and Japan, but growing in China and the Republic of Korea, with more than 80% of patent filings being in Asia. This may be indicative of the Asian market and local innovation growing, or/and the general trend of hardware manufacturing moving away from North America and Europe into Asia, particularly China. The top non-resident applicants filing in China are Philips and Panasonic, and most filings in China are in beds and their accessories. The majority (55%) of filings in China are utility models.

In Japan, corporate filings account for 67% and independent inventors account for 31% of patent families. Corporates constitute a majority of the top applicants (19 of the top 30 applicants are Japanese, but they constitute only 6% of the total dataset). Panasonic (282 filings), Toto (158 filings) and Sekisui Chemicals (121 filings) are the top filers in Japan. Japan's filings are mainly related to assistive technology for workplace and domestic safety (74% of filings) and assistive technology for culture, recreation and leisure (15% of filings). In the U.S., corporate filings account for 48% of patent families, compared with 49% from independent inventors. Filings in the U.S. are mainly related to assistive technology for

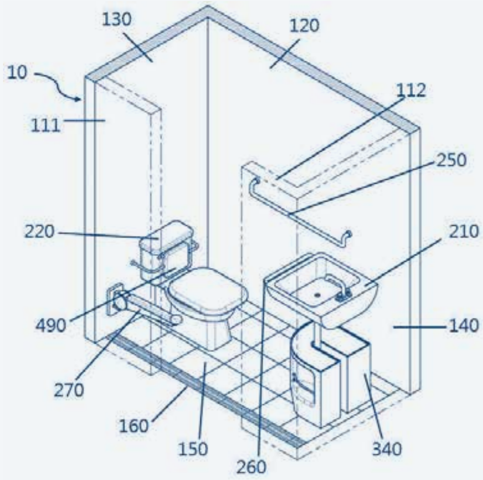


Figure 2.21. Example of domestic assistive technology: a bathroom incorporating safety rails on the toilet and sink, placed closely together for increased safety (patent document KR201703022U filed by Yonsei University)

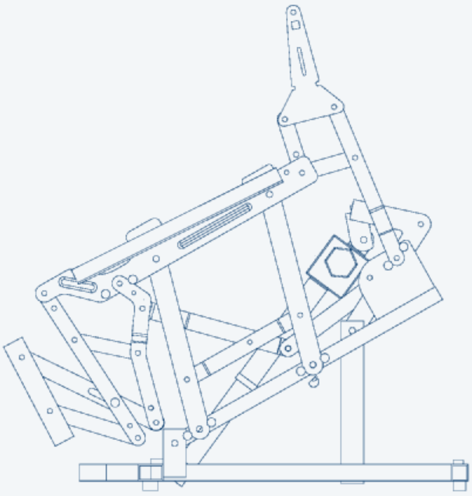


Figure 2.22. A chair that assists elderly and disabled users with moving into a standing position (patent document CN105146944 filed by Zhejiang University of Technology)

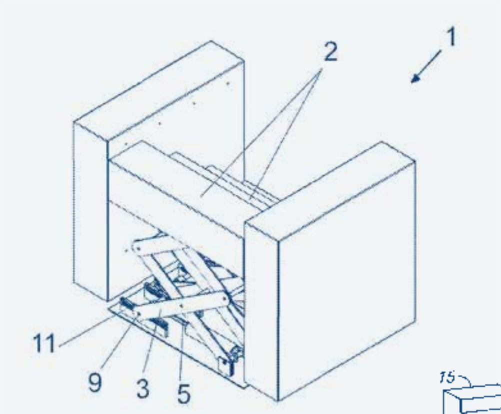


Figure 2.23. Collapsible stairs that can move up or down to create a platform for wheelchair access (patent document GB2474584A filed by independent inventor Manuel Cerda Martinez)

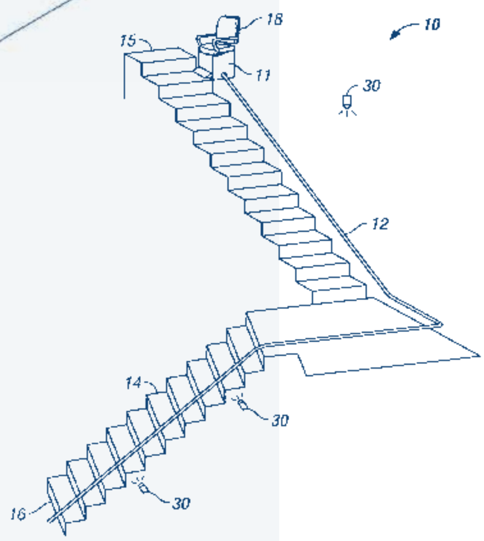


Figure 2.24. A stairlift that uses sensors to detect any obstacles when it moves up or down stairs (patent document WO2009098480A1 filed by Stannah Stairlifts)

workplace and domestic safety (53% of filings) and alarms (23% of filings).

Patent filing in Brazil, India, Mexico, the Russian Federation and South Africa is low (501 patent families in total), accounting for 2.3% of the total patent families. In India (205 filings), most filings are for beds and their accessories and 53% are non-resident filings. The top filers are Philips (related to light fixtures and fall detectors) and Stannah Stairlifts (vertical accessibility). In Brazil (195 filings), most filings are for assistive products for play and 38% are non-resident filings. The top filers are Philips, Inventio AG and 3M Innovation. In Russia (123 filings), most filings relate to products for vertical accessibility, 37% are foreign filings and Philips is the top filer.

Around 7% of the environment assistive technology patent families (1,586 patent families) include a PCT application and 5% (1,089 patent families) an EP application. PCT applications are increasing, whereas EP filings were stable until 2016 after which they began decreasing. The largest proportion of patent families with PCT applications (14%) is observed in all four sub-categories of alarms, indicating an intention to reach multiple markets through the PCT route.

Key players

Looking at the profile of patent applicants, the distribution is almost equal between corporates (44%) and independent inventors (45%).

The categories with the highest number of patent filings from independent inventors generally correspond to low-tech, common household items, such as furniture, kitchenware, bathroom or toilet accessories. The requisite barrier to entry for developing products for these areas is lower and associated historically with craftsmanship rather than intensive, complex R&D. On the other hand, those technologies that require more advanced components, such as electric stairlifts and sensor and communication aspects in alarms, have fewer independent inventors, 36% and 29%, respectively. Finally, niche areas, such as assistive technology for sports, recreation and leisure, have the highest percentage (61%) of independent inventors. Among the top filers in assistive products for sports are the National Rehabilitation Center of the Republic of Korea, Cosmo Sports & Taipei Shoko (joint filings) and Hitech Enterprise Venture Service.

> Japan's population is ageing, on average, at a faster pace than most other countries. In Japan it is recognized that keeping people in work and independent is critical to economic stability and this could explain the numerous Japanese top patent applicants in the area.

Jonathan Pearlman, University of Pittsburgh

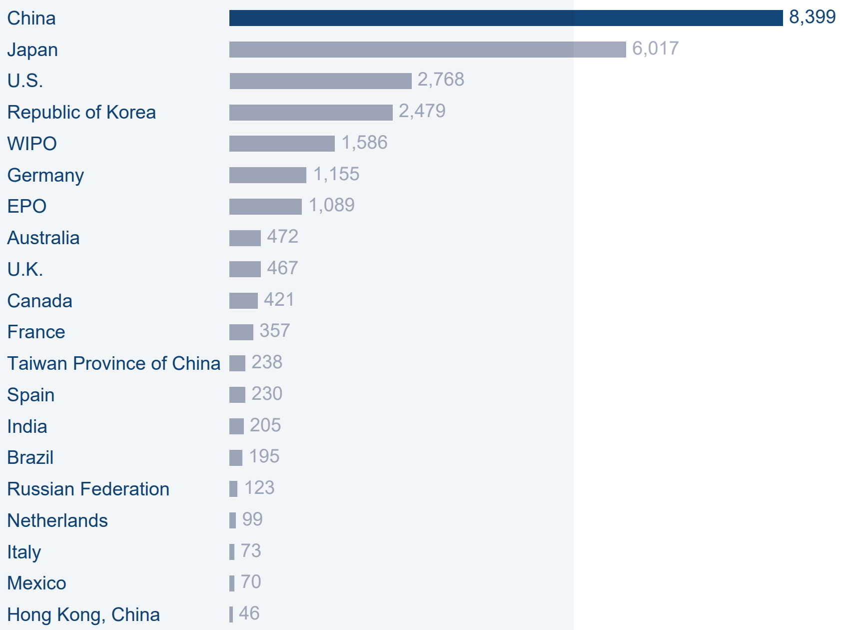
The top 30 applicants constitute only 8% and the top 10 constitute 5% of the total dataset, indicating that there are no big players and the market very fragmented (Figure 2.26). Of the top 30 patent applicants, 26 are corporate entities, 19 of which are based in Japan and account for 6% of total patent families. The presence of Japan-based patent applicants could be attributed to Japan's ageing population, as well as their standards in construction, including accessibility features and related assistive products.

Japan-based multinational Panasonic is the leading corporate filer, yet holds only 1.3% of the overall dataset. Panasonic offers a wide range of products, mainly domestic and workplace safety devices, most of which are filed in Japan, with few of its filings including applications in the U.S. (around 10%) or China (around 8%). Panasonic has also been developing motorized beds for elderly and disabled people (Hornyak, 2009).

Other leading Japanese entities are Toto, Sekisui Chemical, Toagosei and OG Giken, whose filings relate mainly to bathroom and

Figure 2.25. Top 20 patent offices by number of patent applications first filed for patent protection from 1998 to 2019 for conventional environment assistive technology

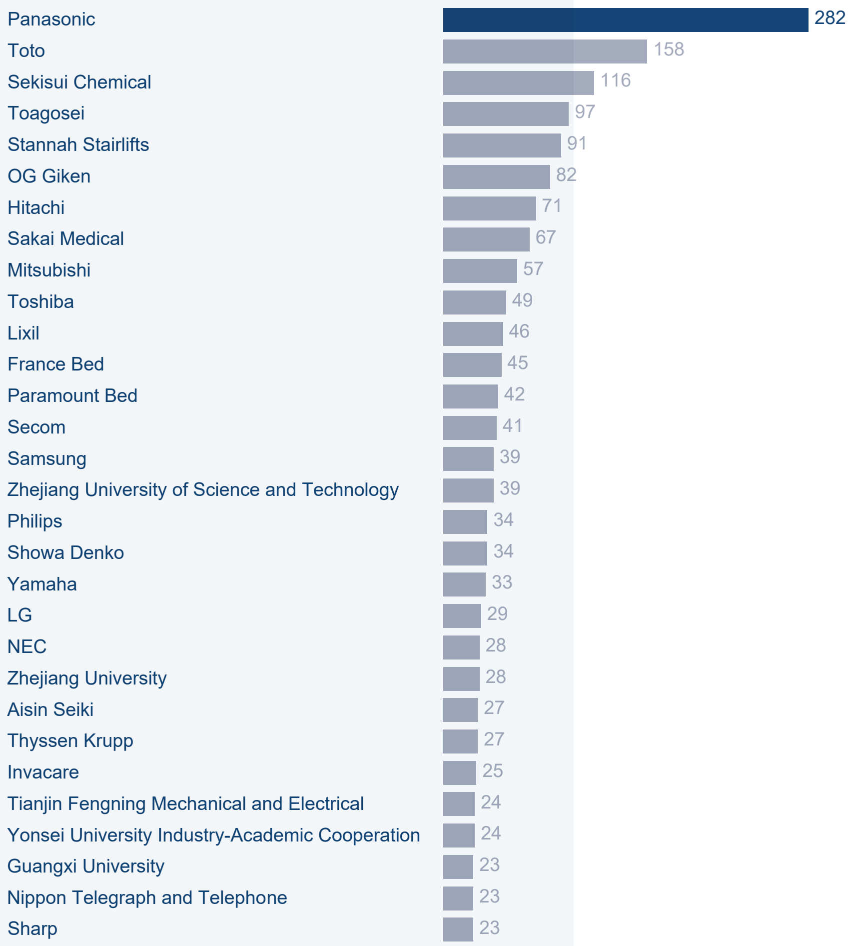
The leading patent offices are China, Japan, the U.S. and the Republic of Korea



Note: EPO is the European Patent Ofiice. WIPO represents PCT applications.

Figure 2.26. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 in conventional environment assistive technology

Nineteen of the top players are Japanese companies, while U.K.-based Stannah Stairlifts features among the top 10



toilet accessories (Toto, the world's largest manufacturer of toilets, leads with 124 patent families in this category). These applicants file only in their local market in Japan. This is the case for two further Japanese companies, Paramount Bed and France Bed, most of whose patents are for beds and their accessories.

The U.K. firm Stannah Lifts features in the top five and provides elevators, escalators and moving walkways, and manufactures stairlifts and platform lifts. It has 91 patent families, all related to vertical accessibility, similar to ThyssenKrupp AG.

Over half (57%) of alarm-related inventions are filed by corporate applicants, with top applicants the Japanese companies Panasonic and Secom, a security systems company. Other consumer electronic goods companies – Philips and NEC Corp. – are also active in this domain. However, this segment is very fragmented and even the top applicants individually have a small patent portfolio.

Universities and public research organizations account for 10% of the dataset, with most filings in the alarms category. The top 30 applicants of the dataset include Chinese universities, for example, Zhejiang University for Sci-Tech (39 patent families) and Zhejiang University of Technology (28 patent families), which are the leading filers in **sitting arrangements and their accessories**. These are also the fastest emerging filers, with the vast majority of their filings made after 2013.

Emerging technology

Emerging environment assistive technology includes inventions that use advanced or enabling technology (robotics, IoT, AI (machine learning, machine vision), BCI/BMI, voice interface systems, advanced sensors, and so on) to assist users at home or in public spaces in living more independently. In total, 1,157 patent families related to emerging environment assistive technology were identified (Figure 2.27). The biggest category is **smart homes**, accounting for 44% of the dataset, followed by **assistive robots** (38%) and **smart cities** (24%), with some documents referring to more than one of these categories. Approximately 15% of the overall dataset are utility models, and 26% of China-based filings are utility models.

There is interest in using technology to identify the location of a toilet seat at night for the elderly and people with cognitive difficulties. Instead of the room lighting up at night (which interrupts circadian rhythms), the seat lights up, while a pressure detector on the mattress triggers a light at the lower level of the bedroom wall to show the path to the washroom.

Arezoo Talebzadeh,
Architect and researcher

The biggest category is smart homes (44%), followed by assistive robots (38%) and smart cities (24%).

Emerging environment assistive technology

1,157

patent families for emerging environment assistive technology filed across **34 patent offices**

What technologies are involved?

Smart homes
504 (44%)

Assistive robots
439 (38%)

Smart cities
273 (24%)

> Recent growth has been primarily driven by **China-based inventors**, who accounted for 50% of the patent documents filed since 2013.

> Emerging environment assistive technology includes inventions that use advanced or enabling technology (including advanced sensors and Internet of Things, artificial intelligence and advanced robotics) to assist users at home or in public spaces. These enabling technologies allow for reliable and efficient solutions in established smart home and city concepts.

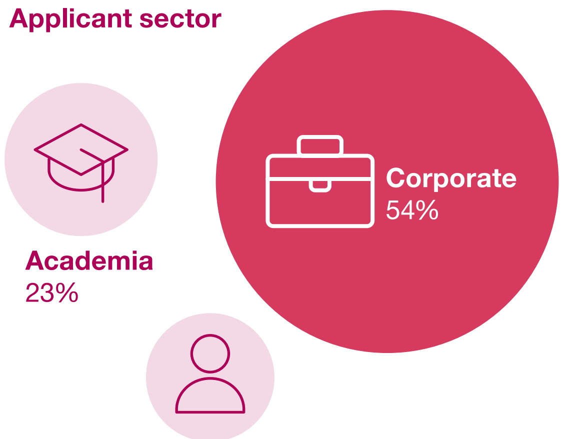
Which are the fastest growing technologies?

Environment is the **fastest growing domain** within the **emerging assistive technology space** with an average annual growth rate (AAGR) of **42%** between 2013 and 2017

Strong growth was recorded for **companion robots** with **55% AAGR** and for **vertical movement technologies** with **52% AAGR** between 2013 and 2017

Who is filing?

Applicant sector



Corporate
54%

Academia
23%

Individuals
21%

Top patent applicants

Panasonic (Japan)	19
Toyota (Japan)	15
Chongqing Youbanjia Technology (China)	12
Sony (Japan)	11
Ningbo Jingjie International Logistics (China)	11

The area of smart homes (technology that is embedded in the user's home) covers nearly half of the emerging environment dataset (44%). Although this category includes applications for the whole spectrum of functional limitations, most refer to users with visual impairments (the same can be said for smart cities). **Smart structural components, appliances and accessories** accounts for more than half of the smart homes category and include intelligent home appliances (refrigerators, air conditioners, cooking hobs, microwave ovens) and smart structural components for the home (lighting fixtures, smart doors/locks, garbage bins, etc.). Although the concept of a smart home has been discussed for over 50 years, developments in enabling technologies are starting to allow for more reliable and efficient solutions, and a growing wish to convert ordinary homes into smart homes, or at the least incorporate smart home components into conventional built environments. This can be attributed to technologies such as IoT, cloud computing, smart sensors, as well as smart and digital assistants, such as Amazon Alexa and Google Home.

Inventions in this category facilitate a number of activities and include intelligent home appliances (e.g., refrigerators, smart air conditioners and heating which can be controlled by a head movement; smart cooking hobs that detect food temperature and provide feedback to the user on the progress of the cooking; and smart cutlery that senses temperature and provides tactile or audio feedback to the user) and smart structural components for the home (lighting fixtures, smart doors/locks, voice-operated and autonomous garbage bins that can locate and move towards the user). Other technologies help control smart appliances through a braille-based remote controller, or use AI to detect and predict the behavior of a user in a home environment.

By integrating enabling technologies, such as robotics and machine learning, **lateral and vertical movement** technologies within smart homes go beyond the mobile hoists (Section 2.5) and the vertical accessibility devices, such as stairways and elevators, that feature in conventional environment technology. Assistive technology for *lateral* movement covers robotic systems (Figure 2.28) or smart hoists. Assistive technology for *vertical* movement includes advanced stairways lifts and elevators equipped with enabling technologies. For example, one smart stairlift for the disabled and the elderly is an IoT-connected smart stairlift that the user can control through an Android-based application (Navya et al., 2018). Various sensors (positioning, force, pressure) play a vital role in the overall functioning of the system. Toyota has filed three patent applications in collaboration with the Illinois Institute of Technology for a robotic device that acts as an advanced alternative to lifting hoists.

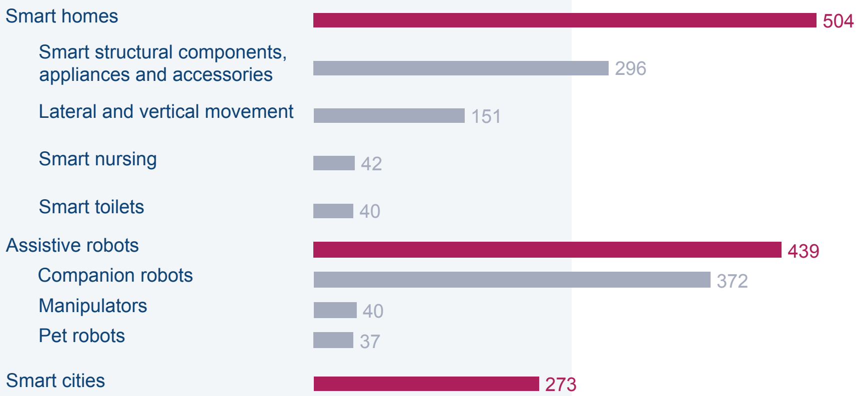
Advanced elevators or stairs are equipped with enabling technologies that not only sense the user, but are also able to distinguish between users so as to provide a priority service. Mitsubishi, Hitachi and Otis Elevators have patents specifically for such smart elevator systems: an emergency communication system for an elevator that allows someone with a speech or hearing impairment to communicate with a control room using characters on their mobile phone; and an IoT-based, staircase-mounted manipulator to aid an elderly user in climbing the stairs, with the seat movement controlled through a central module using the IoT and a wireless network.

From an architectural perspective, these technologies need to be considered from very early in the design and planning stage. Items like hoists require a certain structural integrity that cannot be added at a later stage and may also require building services (e.g., electrical infrastructure) to be planned differently.

Mikaela Patrick,
Global Disability Innovation Hub

Figure 2.27. Overview of patent families first filed for patent protection from 1998 to 2019 for emerging environment assistive technology*

Patent families are relatively evenly distributed across categories, with 44%, 38% and 24% of patent families related to smart homes, robots and smart cities, respectively



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Figure 2.28. Physical assistive robotic system (patent document US20120023661A1)

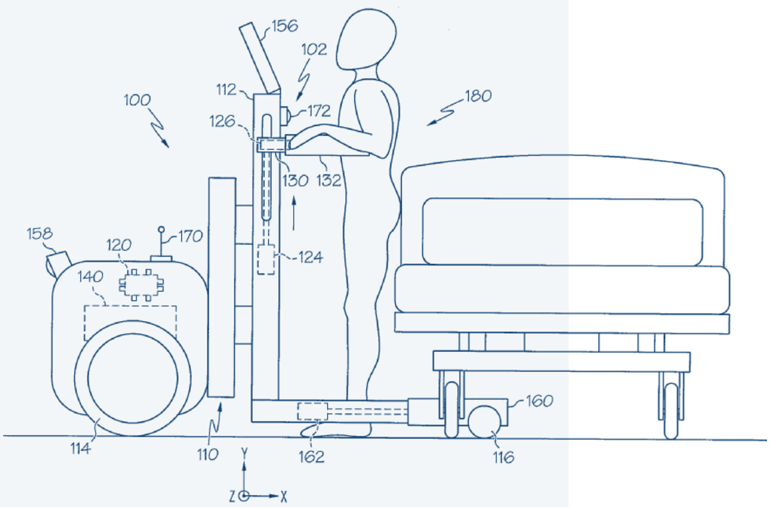


Figure 2.29. A fully automated smart bathing system for people with disabilities (patent document CN109330445A filed by Liuzhou Funeng Robot Development Company)

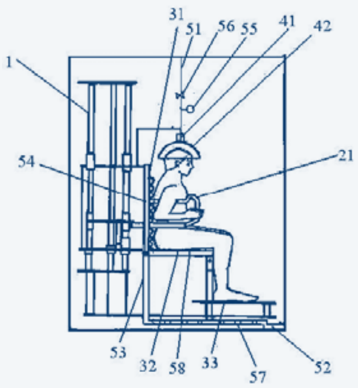
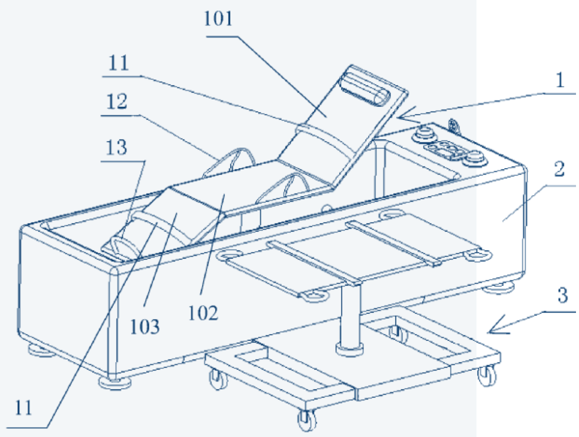


Figure 2.30. Monitoring systems in smart baths to detect falling, drowning or tumbling (patent document CN201958723U)



Smart nursing and **smart toilets** (which includes smart bathrooms) are the smallest sub-categories within smart homes, accounting for only 4% and 3%, respectively, of the overall dataset. Smart nursing devices collect vital information from users at regular intervals or during specific events, communicate this information to health care providers and facilitate nursing functions based on it. Sensors (such as ECG sensors to determine the health of the heart) are deployed in domestic nursing platforms or beds to collect this information, which IoT-based cloud services convey to health care personnel and data analysis techniques are then used to assess the condition and suggest treatment. In this way, they provide an alternative to nursing and facilitate telemedicine. Through the analysis of data, treatment efficacy can potentially be improved, as these systems are able to draw upon the knowledge accumulated by numerous systems and experts rather than solely that of a single caregiver.

This category includes systems that use image and voice analysis to monitor the status of the user and determine the fatigue level of the caregiver, with the information collected shared with cloud networks and online platforms. Patents related to smart toilets allow for greater self-sufficiency with full or partially automatic bathing systems (Figure 2.29) or required adjustments for access to and use of the bathroom. Technologies include toilets with sensors for health monitoring, mechanical designs (for assisting user mobility) and connectivity (control and data transfer over smart phones); a smart display and camera for assisting users in their cleaning and personal hygiene; service robots to assist users with limited mobility in lifting/ascending in the bathroom; monitoring systems in smart baths that detect when a person falls, drowns or tumbles (Figure 2.30); and intelligent doors preventing users from becoming trapped inside the bathroom.

Assistive robots (Figures 2.31 and 2.32) include **companion robots**, which use various enabling technologies for different functionalities to help with independent living, for example, monitoring health and emotions, navigating, communicating and lifting. Several companion robots assist users with taking medication, setting reminders and other self-care and cognitive activities.[15] They can lend cognitive, emotional and social support to the user and provide reassurance by reducing the risk of falls, raising awareness of hazards and notifying a caregiver in the event of a fall. For example, Chongqing Youbanjia Technology Co. of China has developed companion robots for medication dispensing and management, medical assistance or nursing and even as an outdoor walking guide, while Beijing Institute of Petrochemical Technology has developed companion robots for assisting with cooking, toilet activities, bathing and feeding. **Manipulators** are robots capable of applying a physical action to objects in the surrounding environment, usually with a gripping arm mechanism, and inventions included in the emerging environment use a BCI or are IoT-based robotic arms. **Pet robots** are similar to companion robots and have the same functional features, apart from lifting and assisting in walking and movement.

Companion robots use various enabling technologies for different functionalities to help with independent living.

Figure 2.31. Examples of assistive robots

(a) A companion robot that can assist users with variety of tasks – the image shows a walking cane being handed to an elderly user (patent document US9463575B2 filed by Sony). (b) A pet robot with sensors and machine vision intelligence that can find objects, such as a television remote control (patent document JP2018030223A filed by Menicon). (c) A pet robot that can identify a user and converse with them on relevant topics (patent document US20190163961A1 filed by Sony)

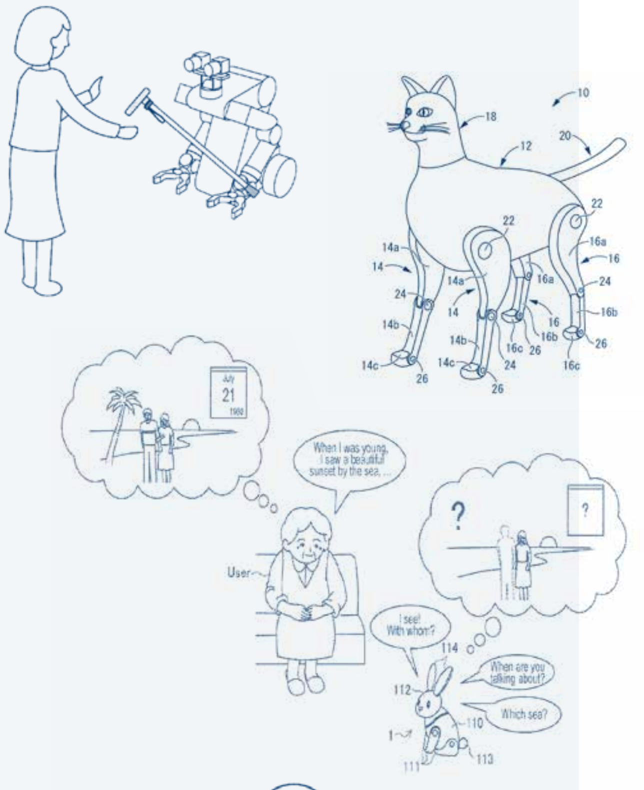


Figure 2.32. Assistive robots

(a) A robot that automatically dispenses medicines based on the user's prescription. It uses identification and authentication mechanisms to select the correct medicine (patent document CN108190483B). (b) A robot that helps elderly people with cooking, with mechanisms for chopping, frying and stirring (patent document CN107510354A). (c) A robot that assists with bathing (patent document CN105054847B)

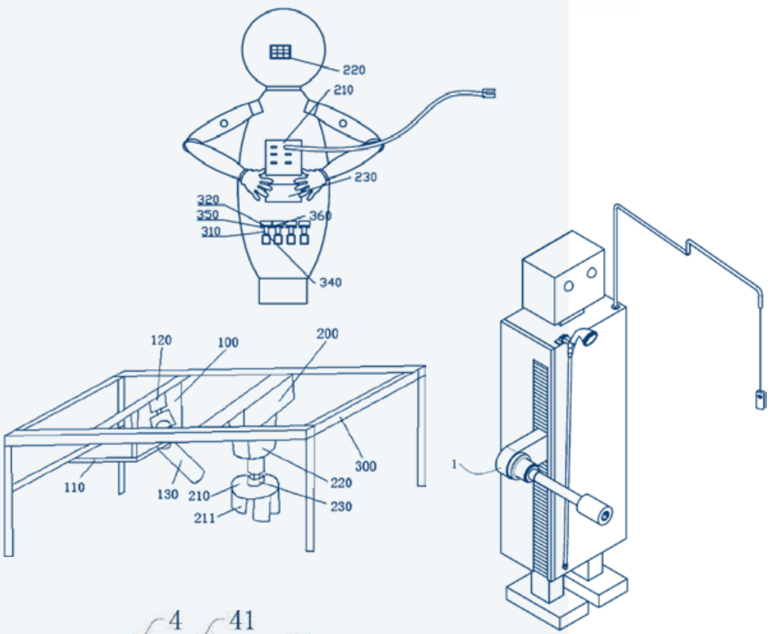
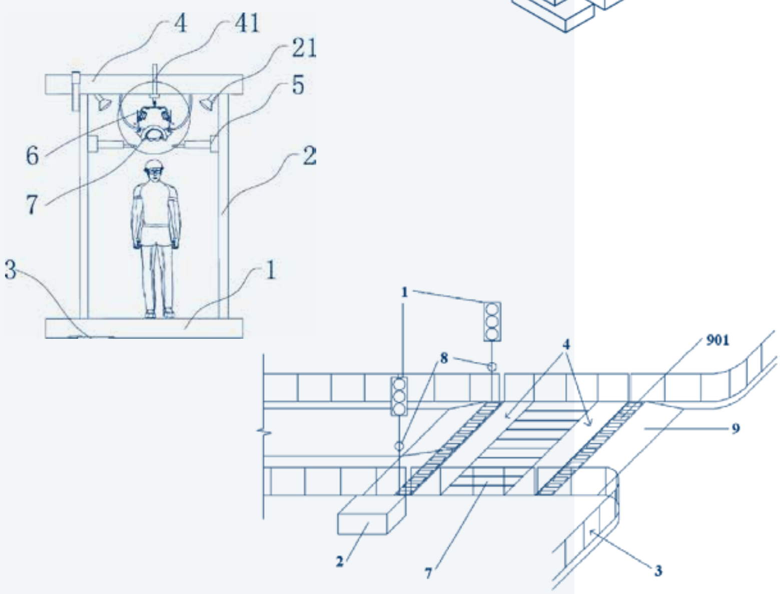


Figure 2.33. Examples of inventions relating to smart cities

(a) An automatic showering system at a swimming pool for users with functional limitations. It also automatically equips the user with a swimming cap and goggles (patent document CN108295440A filed by Ningbo Jingjie International Logistics Company). (b) A smart crosswalk that transfers pedestrians from one side of the road to the other (patent document CN109695186A filed by Changav University)



In the scientific literature there is increasing interest shown in soft robots (Association for Advancing Automation, 2016) which, thanks to highly flexible materials, inspired by those found in living organisms, are characterized by increased hardware and software flexibility and adaptability for accomplishing tasks. Similar discussions exist in the field of mobility with soft exoskeletons. However, these are still in the very early stages of development and there are very few identified patent documents relating to soft robots, only those filed in 2002 and 2006 by Japanese companies Eamax Corporation and Panasonic, respectively.

Smart cities (Figure 2.33) accounts for 24% of the dataset and refers to smart assistive technology installed in sidewalks, transportation systems, malls, offices, stadiums, airports, buildings, swimming pools and other public or community establishments (Ramirez, 2018). They help reassure users about their safety and facilitate access to and navigation in the city environment, along with conveying important information for this purpose. Other technologies facilitate customer experience, for example, in shops, by providing guidance systems and other support mechanisms. Related applications include a vehicle tracker that provides instructions to assist blind passengers with boarding, for example on a bus; an IoT-based parking space guide to help drivers find an appropriate parking space for their vehicle; an emergency response system that monitors risks for people with disabilities (construction sites, potholes, etc.) and for the elderly and notifies the authorities when necessary; a library using a braille keyboard interface to guide blind people; and an intelligent shopping guide system using machine vision, intelligent carts, navigation aids and a mechanical arm to guide blind customers around a shop and pick articles from shelves.

Growth

While patenting activity in the field of emerging assistive technology related to the built environment was relatively low until 2010, it increased after 2014 to an AAGR of 42% for 2013–2017. The highest number of patent filings (204) was in 2018, and, based on the current trend, a similar pace is anticipated to continue into the coming years. It is thought that patenting activity in this particular domain will increase because of advances in enabling technologies and an increased adoption of related products which facilitate self-sufficiency and independent living, along with the increased awareness about the benefits of independent living and the related cost savings from individuals with functional limitations living at home compared with a care facility.

Strong growth is observed, particularly for companion robots (55% AAGR for 2013–2017) and lateral and vertical movement technologies (52% AAGR for 2013–2017).

Geographical distribution

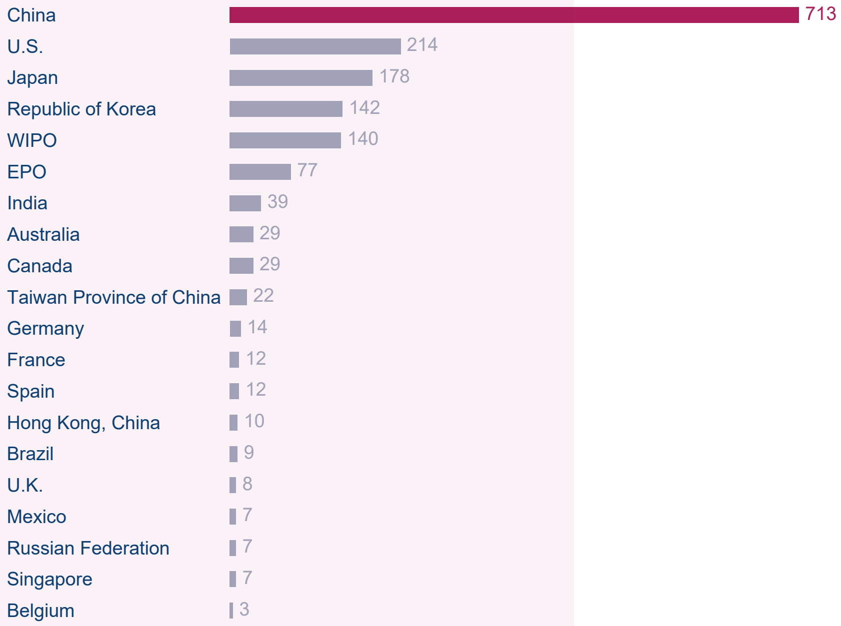
A total of 1,698 patent applications[16] were filed across 34 patent offices (Figure 2.34), with 84% of the dataset filed in only one jurisdiction. The top three patent offices, namely, China, the U.S. and Japan, account for 83% of these 1,698 patent applications filed across all jurisdictions, indicating a high concentration of patenting activity and focus on these markets. Respectively, 12% and 7% of the dataset include a PCT and an EP application. During 2013–2017, PCT applications grew at an AAGR of 31%, compared with 22% for EP applications. Most of the inventions with PCT and EP filings come from commercial players based in China and the U.S.

This growth is clearly driven by applicants based in China. Over half (57%) of patent families come from China, and 62% of all patent families include a patent application in China. This is distantly followed by the U.S. (18% of patent families). Up until 2011, China and the U.S. were receiving filings at almost the same rate, but after 2013 patenting activity in China rose dramatically, with 89% of patent families in China filed from 2013 onwards.

The top three growing markets are China, with an AAGR of 63% for 2013–2017, India (41% AAGR) and the Republic of Korea (39% AAGR). Filings in Japan grew 18% during this period, whereas the U.S. saw no growth.

Figure 2.34. Top 20 patent offices by number of patent applications first filed for patent protection from 1998 to 2019 for emerging environment assistive technology

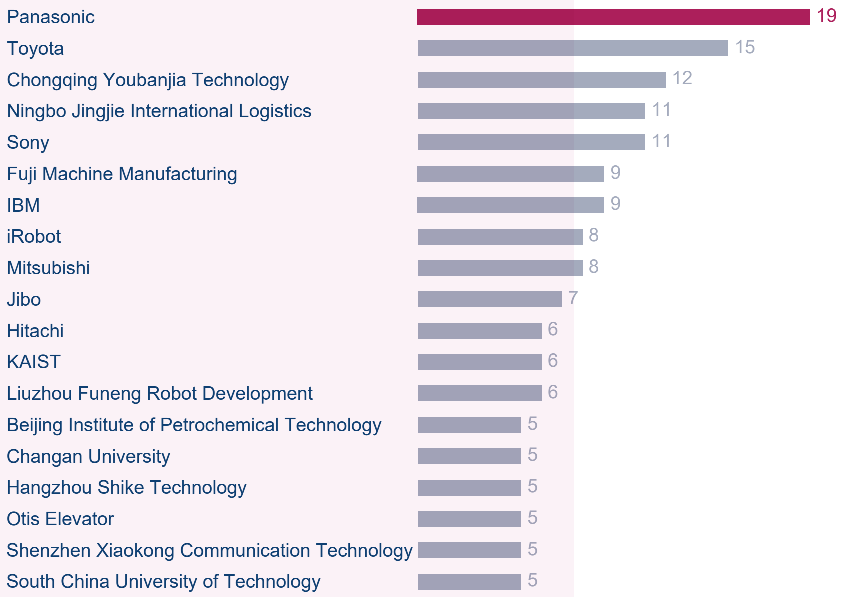
The top three patent offices (China, the U.S. and Japan) account for 83% of the patent applications in this area.



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Figure 2.35. Top 19 patent applicants by number of patent applications in emerging environment assistive technology

The area is fragmented, with top patent applicants having small patent portfolios corresponding to just a small proportion of the dataset



The future in gerontechnology lies in IT platforms – together with IoT and smartphones – being used to signal critical events (e.g., falls) and support independent living while ensuring safety.

Alain Franco,
Nice-Sophia Antipolis University Hospital

Filings in China have also contributed to growth in specific categories: smart structural components, appliances and accessories – since 2013, account for 70% of patent families in this category. Precisely 72% of the smart city-related inventions have China-based inventors. The Republic of Korea is likewise a major source of patent innovation in smart cities, accounting for 16% of related inventions. A total of 89% of patent families in smart structural components, appliances and accessories are protected in a single jurisdiction (primarily China, which coincides with the origin of the inventions). China contributed to a great extent to the datasets of smart toilets (29 of the 32 patent families since 2013), smart nursing (24 of 42 patent families filed during 2018–2019[17]) and companion robots (two-thirds of patent families since 2013).

The top origin locations for manipulator robots are China (11 patent families, all filed after 2016), followed by Japan and the U.S. No patent families have originated from Japan since 2013, indicating that Japanese players (such as Panasonic and Toyota) have recently moved their focus away from manipulator robots. Instead, Japan is the major location of patent innovation for pet robots (25 of 37 patent families, with major companies Sony and Panasonic each owning four patent families).

Key players

The top 28 patent applicants account for 16% of patent families, indicating a fragmented ownership. Twelve of them are from China (split equally between commercial and academic applicants), 8 from Japan (all commercial entities), 6 from the U.S., and 1 each from the Republic of Korea and Switzerland. All the Chinese entities among the top applicants are new entrants, having filed all their patents from 2013 onwards.

Commercial entities account for over half (56%) of the emerging environment dataset, followed by universities and public research organizations (25%). These percentages include the 2% of patent families where collaboration through co-application between commercial entities, universities and public research organizations is observed. The dominance of commercial entities and the significant presence of universities and public research organizations is a consequence of the technology involved. The development of robots requires a substantial research and development setup and requisite funding from commercial entities or public research bodies. Companion robots is by far the leading application, attracting most attention from commercial entities (64%) and an appreciable contribution from universities and public research organizations (25%). Similarly, commercial (49%) and academic applicants (30%) account for the majority of patent families related to smart cities.

Independent inventors (21% of the dataset), however, have found space among less complex technologies. For example, in smart structural components, appliances and accessories, where no major commercial entity

Environment is the fastest growing area in the emerging assistive technology space with 42% AAGR and applications related to smart homes, smart cities and assistive robots.

There is interest in using smart technology to enhance stimuli and improve the quality of life for people with disabilities, using smart lighting to change the color spectrum for people with cognitive difficulties, such as dementia, or people with mental health issues.

Arezoo Talebzadeh, architect

dominates, independent inventors, particularly from China, show the largest growth in activity (146% AAGR for 2013–2017) and account for 27% of patent families. China-based independent inventors have also contributed significantly to companion robots. Before 2013, there were only five patent families in this sub-category filed by independent inventors, four of whom were from the U.S. and one from Israel. Since 2013, 43 patent families have been filed by independent inventors, two-thirds of whom are based in China.

The top commercial entities are Panasonic, Toyota, Chongqing Youbanjia Technology Co, Sony and Ningbo Jingjie International Logistics. Filings by the last named company all relate to smart cities, whereas filings by the other four relate mainly to companion robots. Apart from Sony, with 27% of its filings having been made since 2013, the rest have more recent patent portfolios. Chongqing Youbanjia Technology Co. (China) is active in the robotics field and Ningbo Jingjie International Logistics (China) is active in the logistics sector. In the U.S., the top two applicants are IBM and iRobot; IBM's nine patents are distributed among the companion robots, smart homes and smart city categories, while iRobot has filed all eight of its patents in companion robots.

In China, universities and public research organizations are making an important contribution (30% of patent filings in China) to the development of this domain; for example, all 12 patent families from academia for smart toilets are from institutions in China.

Multiple players from different industries are collaborating to develop smart homes technology; it was observed recently that digital health care companies in collaboration with construction companies are building smart homes to make life easier for people with disabilities (Minion, 2018).

Summary

Conventional environment assistive technology covers a wide range of technologies that facilitate independent living both in the home and at work, including structural building components, furniture, home accessories, assistive products for sports and leisure in general, and alarms, either for different events in the environment or personal alarms identifying a user's caregiver. The broad range of these technologies is reflected in the high number of different applicants with mainly small portfolios, leading to a highly fragmented market. Patent ownership is shared almost equally between independent inventors and corporates, and 10% of patent families come from academia, with activity mainly focused on alarms, with some universities being top filers in sitting arrangements and accessories. Chinese universities are the top academic institutions, appearing among the top 30 applicants, and are also some of the top emerging applicants. Over the past 20 years, filings in Japan, the U.S. and Europe have fallen, whereas filings in China and the Republic of Korea have risen. This could be linked to an increase in local innovation, and/or to a shift in hardware manufacturing from North America and Europe to East Asia, supported also by the fact that the majority of filings in China are utility models. The biggest areas for patent filing are bathroom and toilet accessories, beds and their accessories, light fixtures, sitting arrangements and their accessories, assistive products for play, and wandering and locating of persons or items. The largest growth is observed in vertical accessibility technologies, and we can see the impact of such interest in the development of smart stairs. Other growing areas are light fixtures, assistive products for play and environment alarms, with advances in these technologies to be found in smart homes and cities.

A majority of emerging environment inventions have been filed since 2013 (with the exception of manipulators and pet robots), with significant growth rates, particularly for assistive robots (mainly companion robots), smart cities and smart homes (especially lateral and vertical movement technologies). To a great extent, this growth in patent applications comes from the increasing number of applications originating from and filed in China. The other major locations in terms of patent filings – Japan, the U.S. and the Republic of Korea – have comparatively less activity, while the top three fastest growing markets are China, India and the Republic of Korea. Very few commercial applicants have these particular solutions as their primary focus, perhaps because they are so novel. The significant presence of universities and public research organizations is a consequence of the complex technology involved, particularly for robots. Robotics is the main enabling technology driving the development of environment assistive technology. Innovation in this domain is likely to continue into the coming years, and the commercial availability of these technologies could follow.

Implications for end-users

Environment-related assistive products are one of the major growth drivers in assistive technology. The recent focus on environment assistive technology, whether conventional or emerging, indicates that technologies drawn from different functional categories to assist with activities of daily living, such as cooking, feeding, dressing/undressing, lateral or vertical movements, emotional support, health monitoring, cognition support and communication, are converging on both domestic and public spaces to help users live more independently. Inventions related to environment assistive technology have a great impact on the lives of end-users, helping them perform everyday tasks and carry on activities at home and at work, helping them navigate their homes and other buildings and ensuring safety and security, as well as enabling participation in sports and other leisure activities. These solutions provide a level of freedom and self-sufficiency over an extended period of time which may have been previously considered impossible, particularly for those with cognitive limitations. Smart homes, smart buildings and cities, and robots collectively benefit the elderly and people with disabilities in both indoor and outdoor environments and are becoming popular solutions.

Photo © IBM

Using AI to help people with visual impairment explore urban environments

IBM is developing assistive technologies that use computer vision, embedded sensors and machine learning to help people with visual impairment independently navigate the world around them.

Its AI Suitcase is a suitcase-shaped robot that acts as a companion to guide visually-impaired travellers. This device draws on AI expertise from IBM as well as enabling technologies from four other partners: haptic technology from Alps Alpine, image recognition and sensing techniques from Omron, position navigation system from Shimizu, and automotive technology from Mitsubishi. The suitcase has motorized wheels and is mounted with vision sensors that scan the surroundings. When obstacles are detected the user is alerted by tactile sensations on the haptic handle or the sound of an alarm. Initial development of the AI Suitcase has focused on use in airports and other indoor facilities, but subsequent developments will extend to outdoor use.

CogNav is a smartphone app navigation system originally developed for use on university campuses and in shopping malls. It uses facial and object recognition, scene-captioning technologies and annotated maps to recognize navigation landmarks and offer audio instructions, such as notifying the user if a friend is approaching or if familiar shops are located nearby. A supporting personal object recognition system has also been developed to recognize personal items based on memory, using deep-learning techniques.

Each of these assistive technologies is inspired and driven by the computer engineering expertise of Chieko Asakawa, a researcher at IBM who herself is blind. In order to accelerate research activity in improving accessibility, IBM has open-sourced the fundamentals of these technologies.

Case study by IBM

Hearing aids have become generally smaller and more refined because there has been a big uptake in receiver-in-the-canal aids and slim-tube fittings. People may also be choosing self-care options, such as downloading apps to assist them.

Victor de Andrade, University of the Witwatersrand

2.4 Hearing

Technology to assist people who suffer from hearing loss (estimated at 5% of the world's population (WHO, 2020)) is well established, having developed from 17th-century ear trumpets to today's digital hearing aids.

Conventional technology

Conventional hearing assistive technology primarily comprises non-implantable **hearing aids and induction loops**. Non-implantable hearing aids vary from those that can be **worn (on the body, in or behind the ear)** to those that respond to touch signals or a spectacle-type (offering a combination possible for a person with both hearing loss and visual impairment). These hearing aids can also have telecoils (or T-coils, a precursor of induction loop technology) that work with an audio induction loop system in public places. Hearing loop technology used with implantable hearing devices (such as cochlear implants) is also included in this area.

Conventional assistive technology for hearing also includes interpretation devices (e.g., **video interpretation services**, lip-reading systems and **closed captioning devices**) and other wide-ranging **signalling products** that include visual alarms, haptic (touch) signal devices and wearable devices that incorporate visual and haptic signals (Figures 2.36 and 2.37). Only patent documents that specifically mention lip reading systems for the hearing impaired are included within **lip reading technologies**.

A total of 14,198 relevant patent families filed from 1998 to 2019 were identified (Figure 2.38). The majority are in the field of hearing aids and induction loops (10,381 patent families), followed at a great distance by signalling products (3,771 patent families).[18]

Growth

Patent filings for conventional hearing technology have recently shown a stable patenting activity (2013 onwards) after a moderate growth rate of 3% in the period 2008–2012.

Hearing aids – general and signalling products show a steady growth rate of 2% and 5%, respectively, from 2013 to 2017, whereas **in-the-ear hearing aids** declined by 4% during the same period.

Spectacle hearing aids with induction loops and **induction loops** are relatively new and growing product areas, each with more than 60% of patent filings since 2010 and with an AAGR of at least 10% between 2013 and 2017.

Although video interpretation services and lip reading technologies have fewer patents, these two areas grew at an average rate of 16% between 2013 and 2017. Technological improvement and the broad applications for video interpretation services, hearing loops and lip-reading technologies has piqued the interest of consumer electronic goods companies rather than hearing specialists alone, and show a potential for growth. Sorenson Communications (a U.S.-based company), for example, filed 24 patents in 2013 for video interpretation services and is also active in closed captioning devices.

Similarly, although they are relatively smaller technology areas, patent filings for spectacle hearing aids and **tactile hearing aids** underwent an AAGR of 10% and 20%, respectively, between 2013 and 2017.

Geographical distribution

A total of 28,638 patent applications[19] were filed for patent protection across 47 different patent offices (Figure 2.39). A total of 63% of the 13,198 patent families they belong to were filed for protection in a single jurisdiction,

Conventional hearing assistive technology

14,198

patent families for conventional hearing assistive technology were filed across **47 patent offices**

What technologies are involved?

Hearing aids and induction loops
10,381 (73%)

Signaling products
3,771 (27%)

Closed captioning devices
740 (5%)

Video interpretation services
161 (1%)

Lip reading
28 (0.2%)

> European companies are leading innovation in conventional hearing assistive technology, but there are some emerging Asian players

Which are the fastest growing technologies?

Filings in **spectacle hearing aids** and **tactile hearing aids** saw an average annual growth rate of 10% and 20%, respectively, between 2013 and 2017

Video interpretation services marked an average annual growth rate of 16% since 2000

Who is filing?

Applicant sector

Corporate
75%

Individuals
17%

Academia
8%

Top patent applicants

WS Audiology (Denmark & Singapore)	1,188
Sonova (Switzerland)	846
Demant (Denmark)	527
Cochlear (Australia)	441
GN Group (Denmark)	333

The top 5 patent applicants dominate accounting for 23% of the dataset

Figure 2.36. Signalling products include inventions such as patent document JP2011128671A, which warns a person with hearing loss when a vehicle is approaching

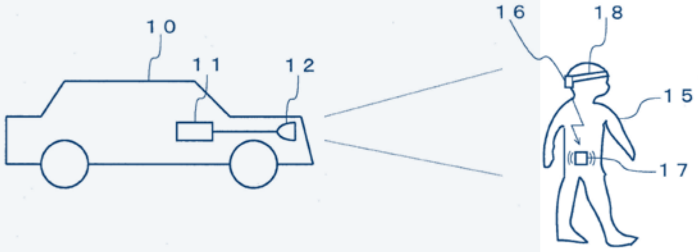


Figure 2.37. A sensor in a bicycle or safety helmet detects obstacles (on the basis of sounds made by the obstacles) and transfers the sounds to a bicycle rider via tactile signals to either hand (patent document KR2012114558A)

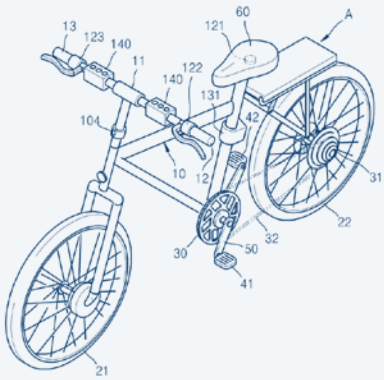
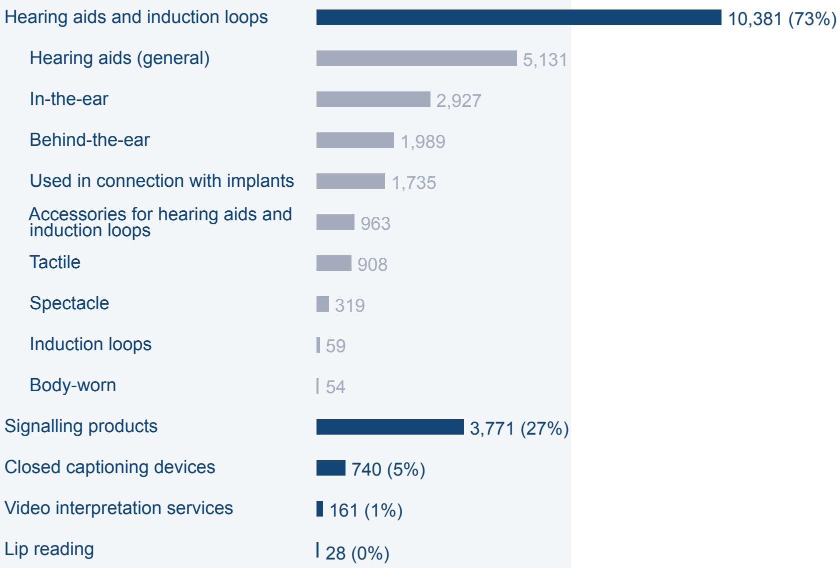


Figure 2.38. Overview of patent families first filed for patent protection from 1998 to 2019 for conventional hearing assistive technology*

Over 70% of patent families are in hearing aids and induction loops



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

about 11% in two and 26% in three or more jurisdictions. Hearing is the only functional category within conventional assistive technology where the U.S. features as the patent office which received most patent applications, followed by China, the European Patent Office (EPO), WIPO, Japan, the Republic of Korea, Germany and Australia. Overall, 99% of all patent applications were published at the top 20 patent offices, and 91% alone at the top eight patent offices. China, the Republic of Korea and India are key growth markets, each with more than half of patent filings since 2010. Denmark, Hong Kong, China and the Russia Federation appear to be further developing markets, while Turkey (11 patent applications) and Argentina (4 patent applications) are new markets, with patent protection sought in these jurisdictions only after 2013.

Nearly 24% (3,398 patent families) of this area's dataset included a PCT application, and 26% (3,751 patent families) an EP application. The U.S., the EPO and Japan are the more established markets, as reflected in their choice as patent protection locations, with a higher number of earlier filings. The patent offices of China and the Republic of Korea, on the other hand, only began receiving filings in the late 1990s and early 2000s, but saw a noticeable growth thereafter. In 2015, China surpassed the U.S. in number of received annual patent applications.

Looking at the origin of innovation in the field of conventional hearing assistive technology, almost a quarter (24%) of patent families have U.S.-based inventors, followed by inventors based in China (23%), Japan (10%), Germany (9%) and the Republic of Korea (8%). China has one of the smallest proportions (61%) of resident filings throughout the entire assistive technology patent landscape, which could be explained by a higher number of European applicants (including WS Audiology (Denmark), Sonova (Switzerland), Demant (Denmark) and GN Group (Denmark)) choosing China for secondary or subsequent filings. Germany, Japan and the Republic of Korea have at least 60% resident filings, whereas these percentages are lower in the U.S. (45%), Canada (17%) and Australia (10%).

An interesting line of research is developing affordable solutions, such as the development of the $1 hearing aid. The hearing aid battery is a big issue in developing countries. So, the idea with low-cost hearing aids should be to use rechargeable batteries. This is gaining a lot of momentum and related patenting may be increasing. ZPower, a US-based company, is leading work in this area.

Vinaya Manchaiah,
Lamar University

Utility models account for 13% of the overall conventional hearing dataset, with 12% corresponding to Chinese utility models, which started being filed in 2005 and account for one-third of all filings in China. Between 2007 and 2012, filings of Chinese utility models grew by 33% a year, on average, while the percentage dropped to 16% in the period 2013 to 2017. Fujian Taier Electronic Tech, Goertek and Huizhou Jinghao Medical Technology are the three top applicants for Chinese utility models.

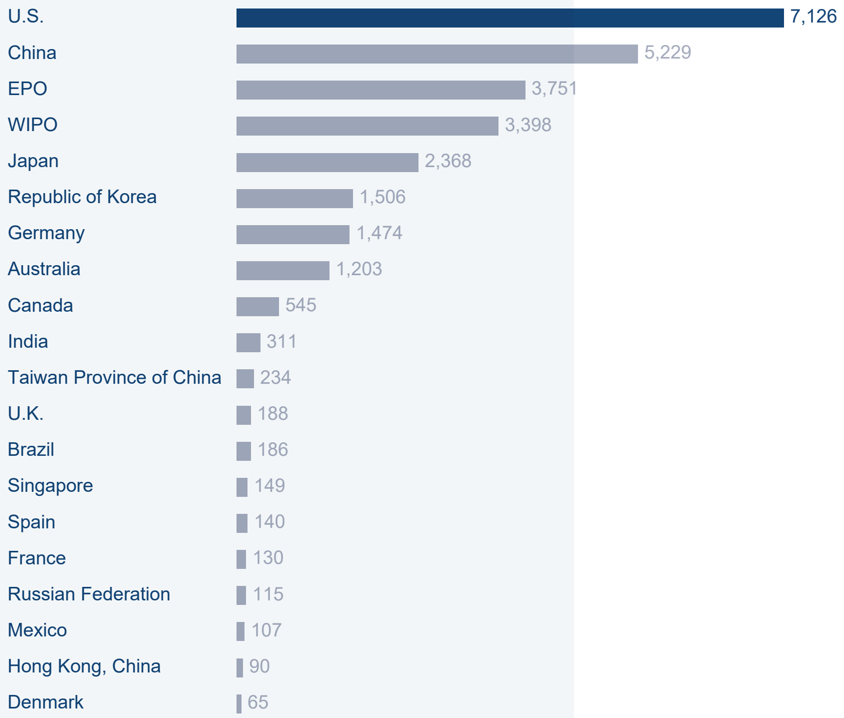
Key players

Hearing is one of the functional categories within conventional assistive technology most dominated by corporate players who account for three-quarters (75%) of the conventional hearing dataset. European companies are clearly in the lead; there are five among the top 10 applicants, led by WS Audiology,[20] followed by Sonova[21] and Demant[22] (Figure 2.40). In fact, 22% of the total patent applications are from the top seven European companies in the dataset (compared with 5% from the top nine U.S. companies). Overall, 37% of total patent filings came from the top 30 applicants.

Universities and public research organizations account for only 8% of filings, but activity from this sector did grow by approximately 12% each year between 2013 and 2017, driven by an increased interest in **induction loops with hearing implants** (such as cochlear implants). The National Institutes of Health (U.S.), Tianjin University (China) and the Fraunhofer Society (Germany) are the three top applicants among universities and public research organizations. Some notable

Figure 2.39. Top 20 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for conventional hearing assistive technology

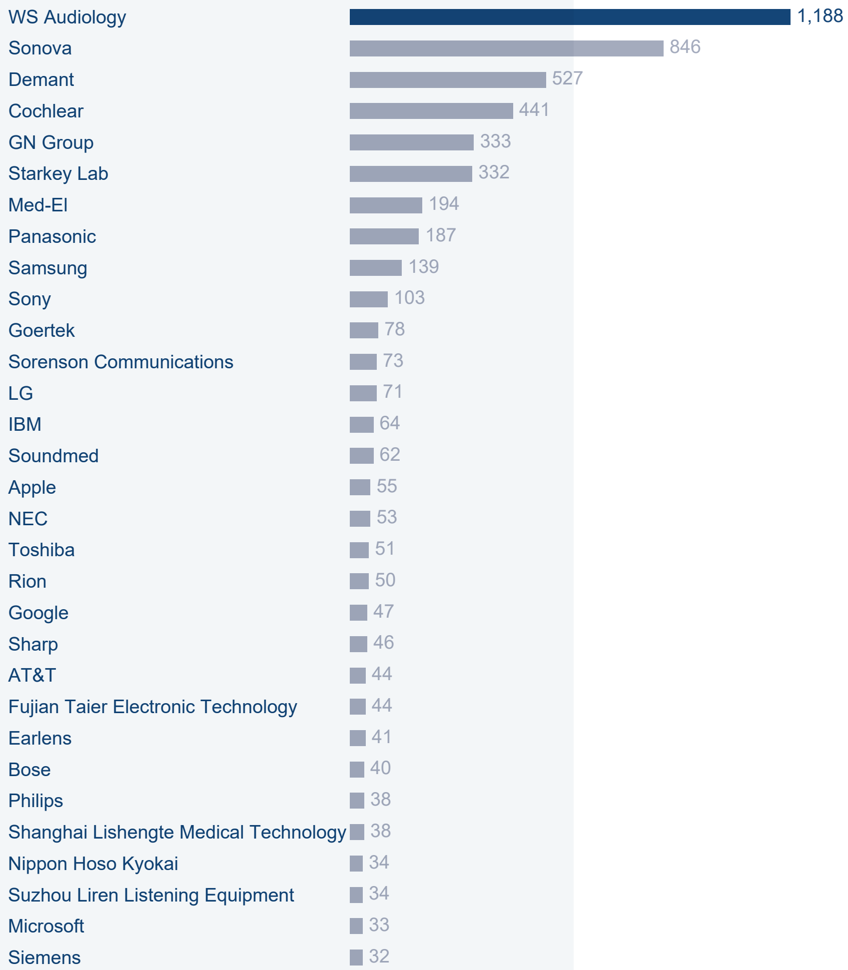
Hearing is the only functional category in conventional assistive technology where the U.S. is the leading patent office, with a quarter of the dataset including a filing in this jurisdiction



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Figure 2.40. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for conventional hearing assistive technology

This space is dominated by large corporates and there are five European companies among the top 10 applicants



corporate–academia partnerships are between Friedrich-Alexander-Universität Erlangen (Nürnberg) and WS Audiology, the University of Illinois and Sonova, the Technical University of Munich and Sonova, and the University of Melbourne and Cochlear (Australia).

Independent inventors – primarily based in China, the U.S. and the Republic of Korea – contributed 17% of the overall patent filings. They account for 29% of filings related to **signalling products**.

The intellectual property (IP) strategy of the top applicants extends beyond filing for IP protection for their own inventions and into licensing, such as Demant, GN Group, Sonova, Starkey Laboratories (U.S.) and WS Audiology, who have licensing agreements with the patent holding company K/S HIMPP (ranked 35th and based in Denmark).

Large companies, specifically Demant, GN Group, Sonova, Starkey Laboratories and WS Audiology, dominate patent filings for hearing aids and related **accessories** (batteries, chargers, and so on). From 2013, however, patent filings in hearing aids has seen significant growth from other players, including Samsung Electronics, Suzhou Liren Listening Equipment (China), Qingdao Beidouxing Cloud Telecommunication (China) and Bragi (Germany), the last two of which only began filings in 2015. Sorenson Communications, Panasonic, SoundMed and Cochlear are filing inventions related to signalling products, closed captioning devices and video interpretation services.

The patent filing and protection strategy of four of the top hearing aid companies – WS Audiology, Demant, GN Group and Med-El – shows that more than 58% of all their inventions are protected in three or more jurisdictions. Although the U.S., Europe and China are the preferred markets for their inventions, these companies are starting to turn to Asian markets, with filings in Japan and Australia. Patent filings in China are dominated by WS Audiology and Demant. In India, Med-El (based in Austria) is the leading applicant, while 3M Innovative Properties (based in the U.S.) is the leading applicant in Brazil, Mexico and South Africa.

Quality versus quantity in patent strategy

Over the last 5–10 years, WS Audiology has developed from a quantitative to more of a qualitative approach, focusing on patents that have the most short-, mid- and long-term value for us.

Similar to what you see in other industries, our IP strategy focuses on where the market is moving, and we try to protect relevant technologies in areas that we believe support such market transition. Customer needs are changing rapidly. Digitization and tele-audiology are the key words.

Our main strategy is to ensure we can maintain our freedom to operate in the market by having a strong and relevant patent position and being an attractive business partner.

A hearing aid is so complicated that it is almost impossible to ensure companies have the rights to do everything in the best possible way. So, the best way forward is to ensure an attractive portfolio of IP rights to bargain with, so that access to rights in specific areas can be negotiated. Of course, the trade-off is that you must give away a bit of what you have done, while you should be willing to enforce your rights. Often, it is to everybody's advantage to find a reasonable business solution in the form of a licensing deal.

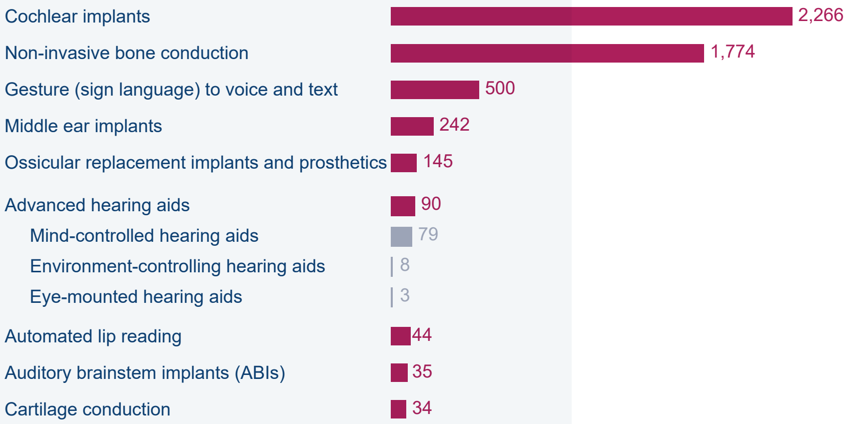
Stefan Menzl, WS Audiology

Beyond the presence of consumer electronic goods companies, there is also the example of SoundMed (part of Sonitus Medical (U.S.)) among the top patent applicants (62 patent families), a patent acquisition and licensing company that is filing across various technical categories.

Shanghai Lishengte Medical Technology (focusing on hearing aid loops in connection with implants) and LG Electronics are the two fastest-growing companies (based on AAGR

Figure 2.41. Overview of patent families first filed for patent protection from 1998 to 2019 for emerging hearing assistive technology by category*

Most filings are found in cochlear implants (46% of dataset) and non-invasive bone conduction hearing aids or devices (36% of dataset)



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Figure 2.42. An ossicular prosthesis, which replaces part of the middle ear (patent document DE202016105874U1)

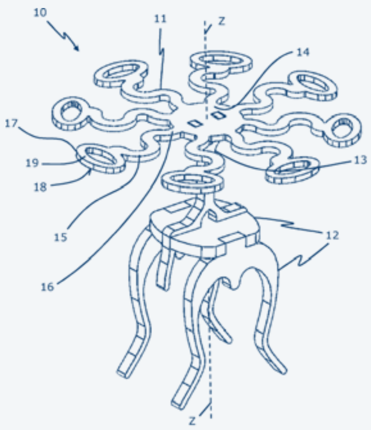


Figure 2.43. An example of a bone conduction speaker system that indirectly transfers audio signals by transmitting vibrations to the inner ear (patent document US20160192048A1 filed by Google)

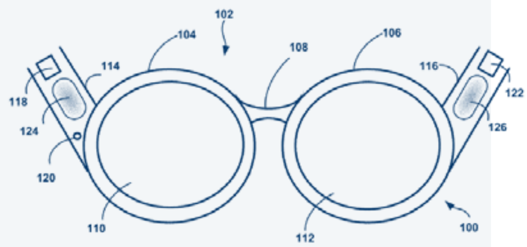
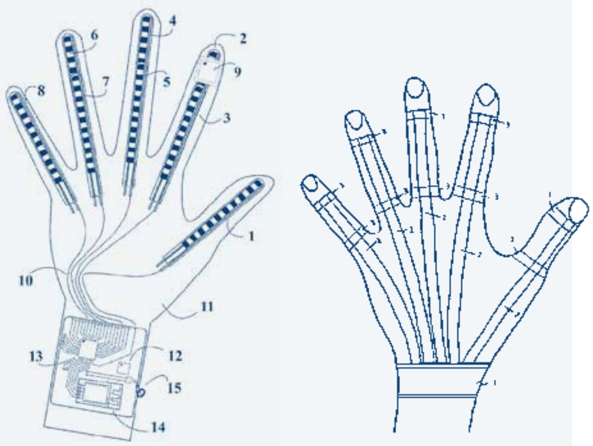


Figure 2.44. Examples of gloves with sensors embedded that measure and detect hand posture, position and gesture in order to translate hand motions into speech and text (patent documents US20180158370A1 (left) and WO2015116008A1 (right))



The role of AI is growing and there are advances in brain-controlled activities. There are combinations of technologies and functions, such as hearing aids, which, beyond amplifying sound for people with hearing loss, can interpret incoming speech into another language and monitor for falls in those at risk.

Victor de Andrade,
University of the Witwatersrand

between 2013 and 2017). By contrast, the leading hearing aid companies, including WS Audiology and Starkey Laboratories, have filed fewer patents for **behind-the-ear hearing aids** since 2014. Although corporate companies have filed 84% of all patents in this category since 2014, the corporate sector as a whole has observed an average drop of 13% between 2013 and 2017. This could be due to the increasing popularity of in-the-ear hearing aids and other options that are smaller, less visible and pick up less noise than behind-the-ear hearing aids (covered below in emerging hearing).

Emerging technology

Emerging assistive technology for hearing includes advanced hearing assistive products to the introduction of corrective products. This area includes in-the-ear implants, non-invasive products such as bone or cartilage conduction, and other advanced technologies, such as **automated lip-reading** and **sign language to voice and text**.

A total of 4,968 patent applications, filed since 1998, were identified (Figure 2.41).

Implantable technology

The implantable products included in the emerging hearing dataset address different causes of hearing impairment with the aim of either correcting or reducing the impediment. **Cochlear implants** (including related accessories) is the category attracting the highest volume of patenting activity. Cochlear implants are used for bilateral or single-sided deafness. They consist of a microphone (placed externally) and a speech processor worn behind the ear or on the skull that converts sound into electrical stimuli, captured by a surgically implanted array of electrodes.

Middle ear implants stimulate and vibrate the bones in the middle ear and include a small prosthesis attached to the bones of the middle ear (ossicles). Rather than amplifying the sound traveling to the eardrum (as with a hearing aid), these prostheses move the bones directly. **Ossicular replacement implants and prosthetics** are specific middle ear implants that act as replacements for damaged or partially damaged ossicles (Figure 2.42).[23]

Auditory brainstem implants (ABIs) are used for severe hearing impairment caused by permanent damage to the cochlea and auditory nerve, with electrodes placed directly on the brainstem.

Non-invasive technology

Non-invasive bone conduction hearing aids or devices (BCHDs) are used to treat conductive hearing loss, single-sided deafness or mixed hearing loss. In conductive hearing loss, sound waves are unable to transmit all the way to the inner ear (usually due to damage to the eardrum). Non-invasive BCHDs use a microphone and a sound processor behind the ear to bypass the damage in the outer ear and transmit sound to the inner ear (Figure 2.43). Normally, non-invasive BCHDs are embodied in soft fabric headbands or adhesive adaptors (in some cases in the arms of spectacles). BCHDs are an effective, non-surgical solution for young children or the elderly. It is worth noting

Cochlear implants are changing – instead of behind the ear, the speech processor can be worn on the skull in a cable-free design.

Victor de Andrade,
University of the Witwatersrand

Emerging hearing assistive technology

4,968

patent families for emerging hearing assistive technology filed across **40 patent offices**

What technologies are involved?

Cochlear implants
2,266 (46%)

Non-invasive bone conduction
1,774 (36%)

Advanced hearing aids
90 (2%)

Gesture to voice and text
500 (10%)

Automated lip reading
44 (1%)

Middle ear implants
242 (5%)

Auditory brainstem implants (ABI)
35 (1%)

Ossicular replacement implants and prosthetics
145 (3%)

Cartilage conduction
34 (1%))

> The domain of emerging hearing assistive technology is dominated by corporate players, whose interest lies mainly in cochlear implants and non-invasive bone conduction

Which are the fastest growing technologies?

Patent filings in **non-invasive bone conduction** saw an average annual growth rate of **31%** between 2013 and 2017

Gesture (sign language) to voice and text marked **24%** growth on average between 2013 and 2017

Who is filing?

Applicant sector

Corporate
72%

Academia
13%

Individuals
13%

Top patent applicants

Cochlear (Australia)	507
Sonova (Switzerland)	494
MED-EL (Austria)	236
Novartis (Switzerland)	79
Zhejiang Nurotron Nerve Electronic Tech (China)	69

that this technology has been explored for mainstream products, such as sports headsets.

In the case of cartilage conduction, sound waves are transmitted through the ear's cartilage into the inner ear. This technology is distinct from the BCHDs that use the mastoid bone to transmit vibrations.

Other advanced technologies

With advances in sensor technologies, image processing technologies, computing and machine learning, gesture (sign language) to voice and text (Figure 2.44) and automated lip reading allow for the participation of persons with hearing impairment in two-way communication.

Advanced hearing aids include **eye-mounted hearing aids** that stimulate the cornea of the eye based on the sound input received by a microphone. In this way, there is a sensory substitution of hearing with an alternative perception of sound through haptic touch on the cornea. The category of advanced hearing aids also includes **environment-controlling hearing aids**, which make adjustments based on the individual's listening situation. **Mind-controlled hearing aids** use artificial intelligence and advanced sensors to support the wearer in focusing on specific voices by singling out and amplifying one voice against background noise or conversation, instead of amplifying all sounds, based on the wearer's brain activity, as their brainwaves indicate which is the sound or voice to which they wish to pay attention (Figure 2.45).

Growth

This is an area of rather recent activity and increasing patenting activity, with nearly two thirds of the dataset first filed from 2010 onwards and an AAGR of 9% for 2013–2017. The technology with the highest volume of patenting activity is cochlear implants, with a market size projected to grow at a 10.5% compound annual growth rate (CAGR) between 2019 and 2026 (Grand View Research, 2020), whereas the market overall for hearing aids is projected to grow at only 7% during the same period (Medgadget, 2019). These market studies support an increased market share for emerging hearing assistive technology (particularly implants) in the near future.

Innovation in hearing technology

The use of bone-conducted headphones by people without a hearing impairment for listening to music is garnering a lot of attention and may go some way toward destigmatizing the use of bone-conducted hearing aids by people with hearing loss. The same applies to hearing aids with the increased use of ear devices, such as earphones and Bluetooth phones, by people without hearing impairment. However, in contexts where the general population doesn't have access to these devices, the potential for destigmatization may be reduced.

Victor de Andrade,
University of the Witwatersrand

There has been quite limited innovation in hearing technology for some years, but that appears to be changing and suggests that the area is ripe for disruption as we see the first hearing-related products embedded into consumer technology emerging.

David Banes,
David Banes Access and Inclusion Services

Non-invasive bone conduction and gesture (sign language) to voice and text are the two categories showing the highest growth, having seen an AAGR of 31% and 24%, respectively, from 2013 to 2017. On the other hand, filings in middle ear implants and ossicular replacement implants and prosthetics declined in the same period, at 15% and 13% per year, respectively.

Geographical distribution

A total of 9,727 patent applications[24] were published across 40 different patent offices

Figure 2.45. An example of a mind-controlled hearing aid that detects neuronal activity in the user's cortex in order to customize the hearing aid (patent document DE102011089661A1 filed by Siemens)

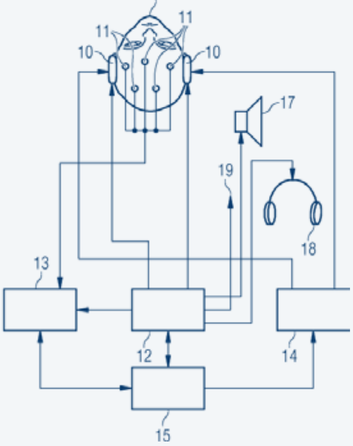
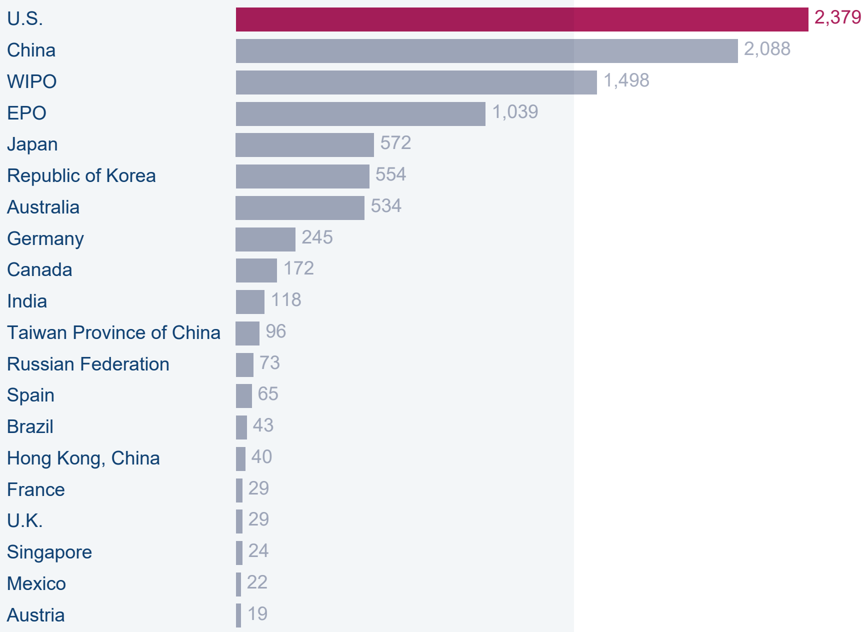


Figure 2.46. Top 20 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for emerging hearing assistive technology

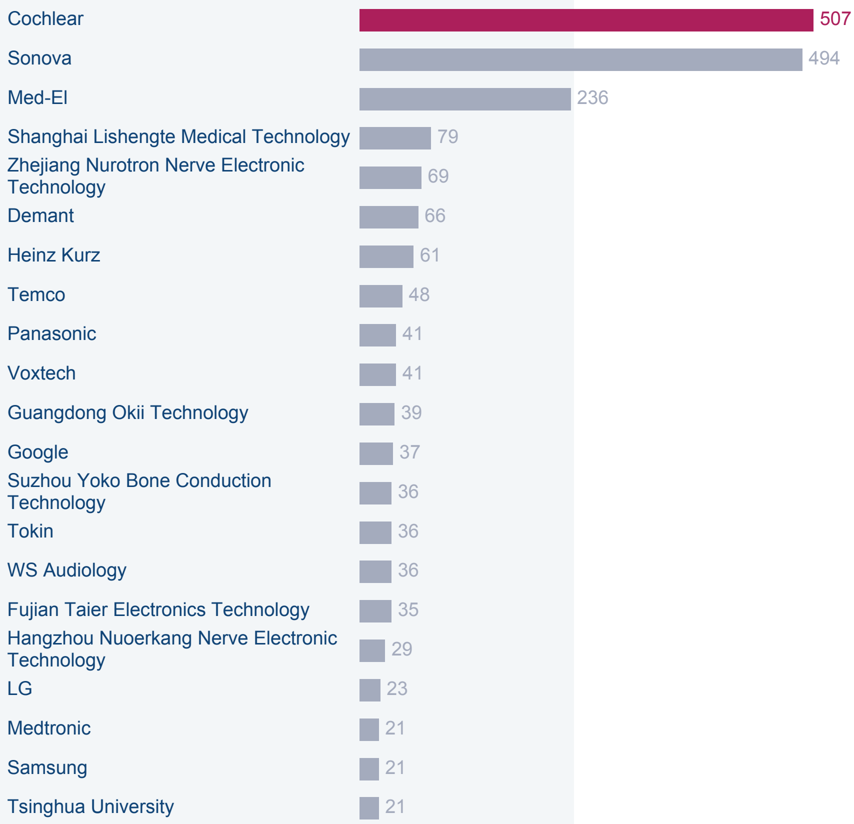
Most filings were received at the U.S. and China patent offices, followed by PCT and EP filings



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Figure 2.47. Top 21 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for emerging hearing assistive technology

Cochlear (Australia) and Sonova (Switzerland) are the leading patent applicants, with 507 and 494 patent applications, respectively, followed by Med-El (Austria) (236 documents)



(Figure 2.46). Overall, 98% were filed at the top 20 patent offices and around 90% of all patent applications were filed at the top seven patent offices alone: the U.S. (24% of patent applications), China (22%), WIPO (15%), the EPO (11%), Japan (6%), the Republic of Korea (6%) and Australia (5%). Only very marginal patent applications were filed at the patent offices of Germany (5% of the dataset), Canada (3%) and India (2%). China, the EPO, the Republic of Korea and India are recent and growing markets.

About 48% of the identified patent families in the field of emerging hearing assistive technology (4,968) include a patent application in the U.S; 42% a filing in China, nearly 30% a PCT application and 21% (1,040) an EP application.

Looking at the origin of the inventors, 31% of the dataset have China-based and 24% U.S.-based inventors. China has 72% of resident filings, and both Japan and the Republic of Korea over 60%. The U.S. (47%) and Australia (17%) have a notably smaller proportion of patent applications with local inventors. The top applicant in China is Med-El (Europe), with 121 patent applications.

Key players

Corporate applicants dominate, owning 74% of patent applications (including 2% co-owned with universities and research organizations). Universities and research organizations account for 15% of the patent families, and independent inventors for 13%.

Patenting activity by universities and public research organizations is relatively recent, with about 75% of patent applications filed after 2010 and a significant AAGR of 22% between 2012 and 2017. This is in contrast to the limited academic activity for conventional hearing assistive technology. Cochlear implants and smart gloves translating gesture (sign language) to voice are growing areas of interest among academic players.

Tsinghua University (China) (21 patent applications), Shandong University of Science and Technology (China) (18 patent applications), China Jiliang University (17 patent applications) and Johns Hopkins University (U.S.) (16 patent applications) are the top university and public research organization players. Corporate and academic partnerships include Cochlear and the University of Melbourne (Australia, since 2000), Sonova and Johns Hopkins University, Demant and University College London, and Cochlear and the University of Zurich (since 2013).

Patent filings by independent inventors are mostly from China-based inventors (245 patent applications, or 5% of all patent filings in this field), followed by inventors based in the Republic of Korea and the U.S. (132 and 97 patent applications, respectively).

The patent filings made by the top 21 applicants (from 1998 until 2019) are shown in Figure 2.47. The top 10 alone filed 33% of the patent applications. Similarly to conventional hearing, large hearing aid companies (including Cochlear, Sonova and Med-El) dominate in a consolidated market, with the top patent applicants being mainly companies based in Europe and China (including Shanghai Listent Medical Technology, the leading applicant from China in the overall emerging assistive technology dataset). There is a stronger presence of Chinese top patent applicant companies in the emerging hearing

The market is dominated by five big players in hearing assistive products which make investments of USD 40–50 million for each product life cycle. Basic research in hearing happens across approximately 10 key labs around the world, currently exploring regrowth of hearing cells for recovery of hearing function.

Bradley McPherson, University of Hong Kong

Developing trends in over-the-counter hearing aids

Innovation in implantable bone conduction devices is mainly incremental, while induction loops are expected to have reduced importance over time with the increased use of Bluetooth and wireless connectivity.

There is a trend towards over-the-counter (OTC) self-fitting hearing aids. BOSE received the first FDA marketing approval, setting minimum standards. This may make affordable hearing aids available to a broader range of users.

There is a trend for using AI in hearing aids, for example, to collect and log data on the user's environment to apply optimized settings when the user returns to the same place. Moreover, beam-forming technologies combined with AI is another trend to optimize the hearing experience, possibly raising privacy issues, while smartphone software is beginning to include hearing aid alternatives, with the potential for audiogram input and related adaptation to the user.

Bradley McPherson, University of Hong Kong

Direct-to-consumer hearing devices (also called personal sound amplification systems (PSAPs) or over-the-counter (OTC) hearing aids) are a new development in the service delivery model to improve accessibility and affordability of hearing devices for end-users. Some PSAPs/OTCs have poor quality sound (e.g., low-frequency emphasis, high distortion, high internal noise) but they are improving each day. Self-fitting hearing aids have a lot of potential and very minimal risk. Output limiting can be set in hearing aids so that they do not produce excessively loud sounds (just like in earphones).

Vinaya Manchaiah, Lamar University

assistive technology than in the conventional area. These large corporate players are mostly filing patents related to cochlear implants and non-invasive bone conduction. German company Heinz Kurz (with 61 patent applications) is filing patents mostly related to ossicular replacement implants and prosthetics, and middle ear implants. Mind-controlled hearing aids are beginning to show a consolidation of patent activity by large companies. The remaining technology categories show very distributed patent filings, with no individual applicant holding more than 10 patent applications.

Despite the relatively large number of China-based leading applicants, only 7% of the overall dataset is from 12 China-based applicants, while 18% is from five European companies. In Europe, Sonova and Med-El account for around 15% of patent filings. Furthermore, applicants from China are recent entrants into this field, with six applicants (out of 12) having started patent filing only after 2010. This indicates a very fragmented market in China, whereas European applicants are moving towards consolidating the market in this area.

Overall, 66% of patent families were filed within a single jurisdiction, 10% in two, 8% in three and 16% in four or more jurisdictions. Top companies Demant, Heinz Kurz, Temco Japan, Panasonic and WS Audiology have sought protection for more than half of their inventions in three or more jurisdictions, and SoundMed and Med-El the same for more than 70% of their inventions. Shanghai Listent Medical Technology and Zhejiang Nurotron Nerve Electronic Technology (China) are the two fastest growing companies, based on their AAGR in new patent filings for 2013–2017.

Similarly to conventional hearing, the U.S. seems to be a key market for leading European and Australian companies in emerging hearing. Interestingly, patent filings in China are dominated by Med-El (Austria) with 121 patent filings.

Summary

Patenting activity for conventional hearing assistive technology shows strong growth in hearing aids and induction loop technologies. The conventional hearing patent landscape is heavily dominated by large corporate players – mainly hearing aid companies from Europe, Japan, the U.S. and Australia – entering new markets in Asia and other developing economies. Patenting activity in signalling products, video interpretation services and closed captioning devices is a relatively newer and slowly growing area. Moreover, these fields are somewhat fragmented and with many new players active, particularly technology companies instead of the traditional hearing aid companies. This suggests that technological advancement and broader applicability is opening doors for newer hearing assistive technology.

Most patenting activity for emerging hearing assistive technology is in the development of cochlear implants and non-invasive bone conduction, which together represent around 81% of filings. Implantable products (cochlear implants, middle ear implants, ABI and ossicular implants) represent around half of all patent filings in the emerging hearing assistive technology. Recent trends show that advanced hearing aids (mind-controlled, environment controlling and eye-mounted hearing aids) along with non-invasive bone conduction and cartilage conduction are areas of potential growth (each with 60% of related patent applications filed after 2010). As is the case with conventional hearing, large corporate applicants dominate (74% of patent applications) in a consolidated market, and appear most interested in cochlear implants and non-invasive bone conduction.

Although there is an increased presence of leading China-based patent applicants in comparison with the conventional hearing technology patent landscape, patenting activity output continues to be led by European companies. Patenting activity by universities and public research institutions is more apparent but relatively recent, particularly in the development of cochlear implants and smart gloves that translate gesture (sign language) to voice output.

> I clearly see a convergence between hearables and hearing aids. For example, Bragi, a German company that makes hearables, is now working with Starkey (U.S.) to develop a product that has both hearable and hearing aid features. Some earphones or headphone companies also started showing interest in developing hearing aids. I see "hearables" and "hearing aids" as parallel markets. However, merging these technologies will open up markets to new users who were not using hearing aids and lifestyle enhancement devices specifically for hearing.

Vinaya Manchaiah,
Lamar University

Implications for end-users

Hearing aids are becoming more discreet and developments include enhancing the perception of speech against background noise and connectivity to smartphones, televisions and other devices. Some interesting examples of advanced hearing aids are ones that include a BCI to enhance the quality of the sound in general and the quality of speech in particular for those with hearing loss, or mind-controlled hearing aids that encompass the ability to monitor health and emotional aspects (crossing over with emerging self-care applications), or address cochlear implants and bone conduction. In the future automated lip reading could find application in assistive robots (included in Environment, Section 2.3).


PAPYRUS
WIDEX
Universal
Universal
PureSound
Music

Using AI to personalize hearing aids

Widex, owned by WS Audiology, is the first hearing aid manufacturer to use AI to create a more natural and personalized sound experience for hearing aid users.

SoundSense Learn uses AI to learn how users best prefer various listening environments and give them greater automated control over their hearing experience.

“Hearing aids can already be adjusted according to the listening environment of the user, but doing so can be unnecessarily ad hoc and manual,” says Lise Henningsen, Head of Audiology at Widex. “By applying AI, integrated with today’s advanced digital hearing aids, a hearing aid can learn from all the users and help a particular user select their personalized settings.”

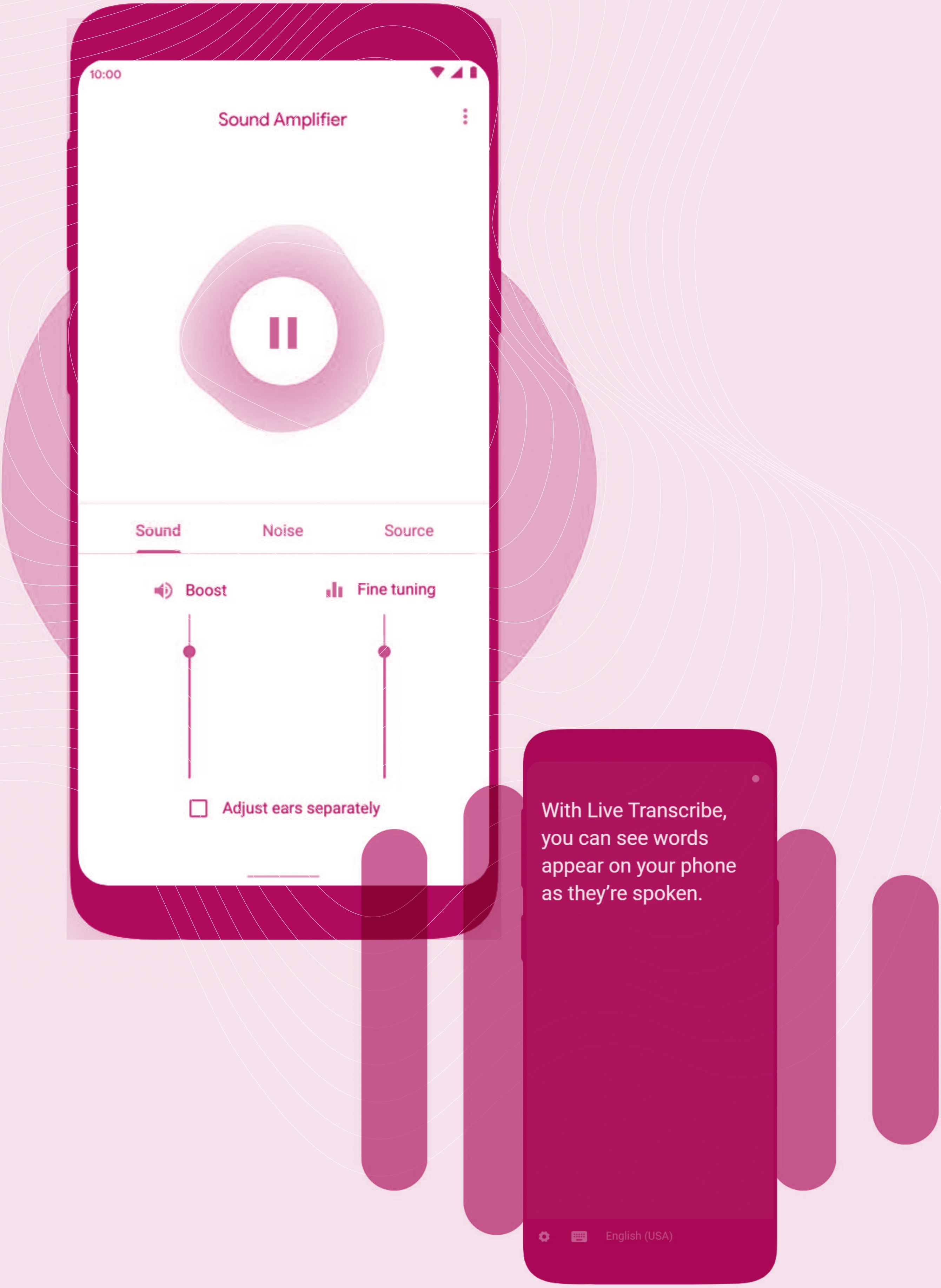
Widex SoundSense Learn processes inputs from connected hearing aids throughout the world and shares anonymized data with a cloud-based AI system. The system then continuously learns from all the users how to further optimize hearing aid settings in different situations for the specific wearer.

For the individual, SoundSense Learn asks users to choose the best of two sounds to initially understand how they prefer sound in an environment. To A–B test each setting would require more than 2 million tests, but by using machine-learning algorithms and data from the individual and other users, only about a dozen comparisons are needed to calculate the optimal settings for each person.

When applied, the settings create a personalized hearing experience based on context, content and intent. Users can store the settings as programs in their smartphones and activate them throughout the day, such as when they are at work or the supermarket or in their kitchen. Anonymized, the programs can also be stored in a secure, cloud-based system and help enhance the hearing experience of other users.

“When you factor in AI technology, hearing aids become something other than medical devices,” stated Henningsen. “They are more like new lifestyle ‘hearables,’ which is a key contribution to making wearing devices to achieve better hearing more acceptable.”

Case study by WS Audiology


10:00
Sound Amplifier
Sound
Noise
Source
Boost
Fine tuning
Adjust ears separately
With Live Transcribe, you can see words appear on your phone as they're spoken.
English (USA)

How software is making audio more accessible

Innovation in sound reduction technology, led by consumer tech companies such as Google, is increasing the accessibility of audio content.

Providing a foundation is the inclusive, holistic approach to accessibility that is inherent to software design. “This is our responsibility as designers – we have an obligation at platform level to make every single app accessible and useful for all users, regardless of their needs,” says Brian Kemler, Product Manager for Android Accessibility at Google.

Fuelled by advances in machine learning and speech recognition, Google has developed three apps for smartphones: Sound Amplifier, Live Transcribe and Live Caption.

Sound Amplifier is used with headphones to minimize everyday background noise and clarify sound, using a computerized stereo equalizer (https://patents.google.com/patent/US10681485B2). It filters, augments and amplifies sounds by increasing quiet sounds, while not over-boosting loud sounds. Sound enhancement settings can be customized and noise reduction applied with a simple interface that uses just two sliders.

Live Transcribe, available in over 70 languages, turns speech in the real world into real-time captions using the smartphone’s microphone, providing the ability to get speech-to-text in real-time conversations. It also enables two-way conversation via a type-back keyboard for users who are unable to speak, and connects with external microphones to improve transcription accuracy. Sound Notifications, a recent new feature, also flags important noises such as baby sounds, water running, smoke and fire alarms, appliance beeping and door knocking.

Much of the user-generated content on social media, as well as most spoken content and apps (media, video or calls), is not captioned – a key way of making content more accessible to many users. Live Caption (https://patents.google.com/patent/WO2020222851A1) provides system-wide live captioning to open up such content and make live content accessible in real time. This uses local machine learning and offline processing, so no data is sent to the cloud and privacy is retained. This also means that an Internet connection is not necessary – key to improving availability in some countries.

However, Google is clear that this technology will not necessarily replace specialist hardware. “These products are intended to be complementary. Sound Amplifier, for example, is not positioned as a hearing aid – but it could act as a backup. There will probably always be a need for hearing aids, as they are dialed in to the individual,” says Brian. “Sound Amplifier is likely to be more useful for those who don’t need to use a hearing aid full time, but these sound reduction technologies do give us opportunities to make the consumption of audio a more pleasant experience for all.”

Case study by Google

2.5 Mobility

Persons with partial or complete loss of physical mobility – estimated at 40.7 million people in the U.S. alone (CDC, 2020) – face challenges in being mobile, accessing and moving in their work, home and outdoor environment in order to participate in everyday activities. Mobility assistive technologies focus on helping these people independently move, manipulate objects, carry out mobility-dependent tasks and travel.

Conventional technology

Conventional assistive technology for mobility primarily encompasses **wheelchairs** and **walking aids**, as well as **orthoses** and **prostheses**. The area of conventional mobility devices is by far the largest of all functional categories, with a wide spectrum of complexity, innovation drivers and types of inventions. A total of 63,245 related patent families were identified and grouped under nine main categories (Figure 2.48). For ease, those that are thematically related are presented together in the analysis.

The underlying motivation for the design of **orthoses and prostheses**[25] is to provide an increased range of mobility or manipulation either through offering supplementary support and stability for an existing limb or motor function or replacing it when missing. Innovation is focused on increasing comfort and control, improving functionality and reducing the potential for long-term side-effects, such as arthritis, skin breakdown and pain. Orthoses (see Figure 2.49) account for 31% of the dataset (19,921 patent families, with more than half referring to lower limb orthoses), and prostheses (see Figure 2.50) for 6% of the dataset (4,024 prostheses-related patent families) (see Figure 2.51 for more detail).

Walking aids and their accessories (see Figure 2.52 for more detail) are at the lower end of the complexity spectrum, with very simple but important innovations, such as tips, grips, seats, lights and shock absorbers for walking sticks and crutches. Walking aids are widely used devices that support a user when walking, and range from simple carried structural supports, such as walking sticks (Figure 2.53) and crutches (Figure 2.54), to rollable or walking frames. They correspond to over a quarter of the conventional mobility dataset (27%), with the highest patenting activity observed in the areas of walking sticks and crutches. Accessories for walking aids aim to improve safety and comfort for users, and related patent families account for 8% of the dataset.

Patenting activity in accessories for wheelchairs

Increased patenting activity related to wheelchair accessories may be due to the most common issues for users. Electric wheelchairs are much more expensive and are not appropriate for some environments. Tyre or wheel changes are needed for different environments. Battery technology is needed to bring down the cost, weight and mileage of electric wheelchairs.

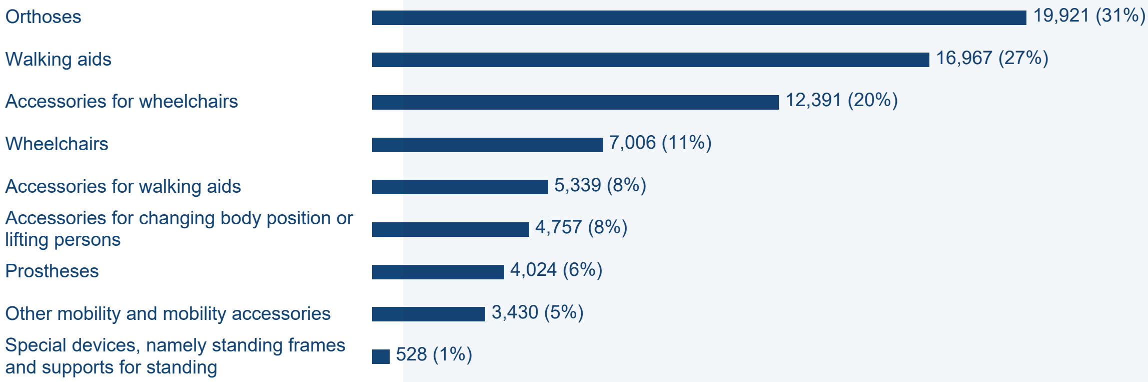
Alistair McEwan, University of Sydney

The concept of a “wheelchair” is not new, neither is related innovation. Innovation is driven more by comfort, greater accessibility to daily tasks, flexibility to the environment and the variability of the terrain. This explains the challenges for innovation for peripherals, accessories and control strategies to give more autonomy and reliability.

Mohamed Bouri, EPFL

Figure 2.48. Overview of patent families first filed for patent protection from 1998 to 2019 for main categories of conventional mobility assistive technology*

The majority of applications are related to orthoses and walking aids, each accounting for almost a third of the dataset, followed by accessories for wheelchairs



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Figure 2.49. Examples of orthoses, which structurally support limbs

(a) Lightweight lower cost hinge for knee orthosis; (b) spinal orthosis with stiffening members (patent document US7316660B1 by DeRoyal Industries)

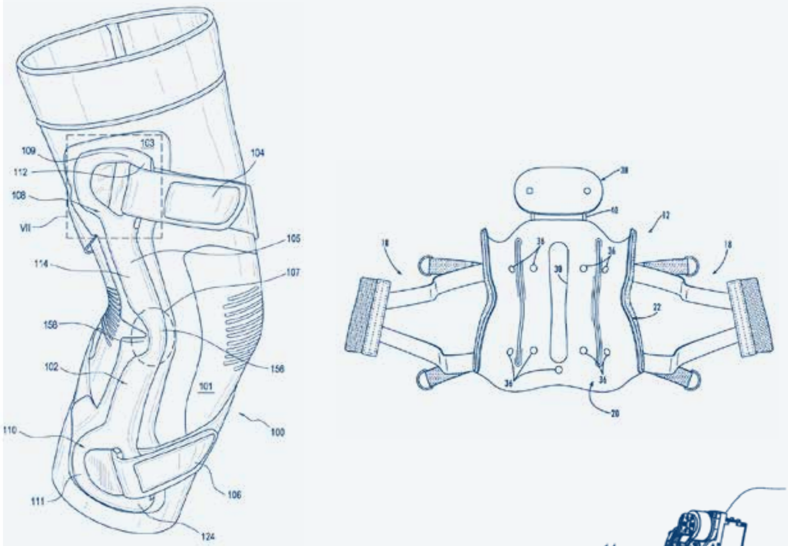


Figure 2.50. Examples of prostheses, also known as artificial limbs

(a) Knee prosthesis (patent document 2014/0142722 A1 filed by Ken Dall). Hand prosthesis (patent document WO 2007/076765 filed by Ottobock). Full prosthetic arm by DEKA with increased degrees of freedom of movement (one of the patents for DEKA Arm SC, albeit without myoelectric control)

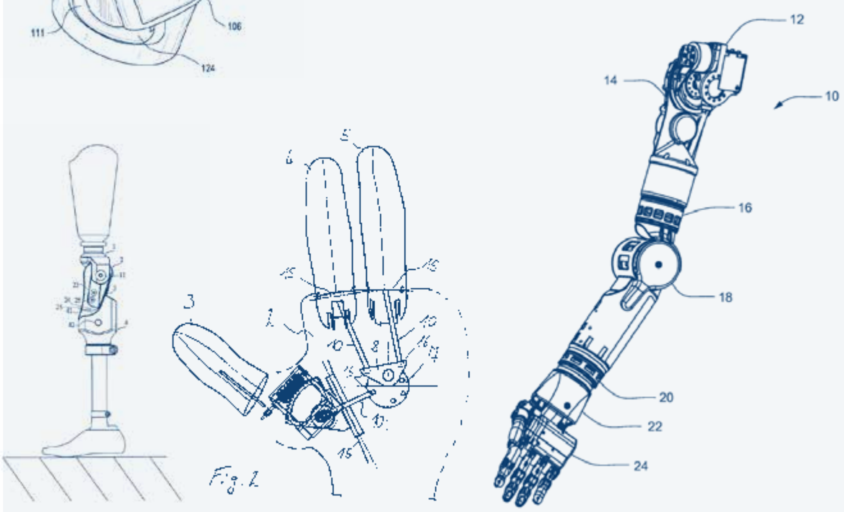


Figure 2.51. Orthoses and prostheses in detail

*There is significantly more patenting activity related to orthoses than prostheses – lower limb applications are most common for both**

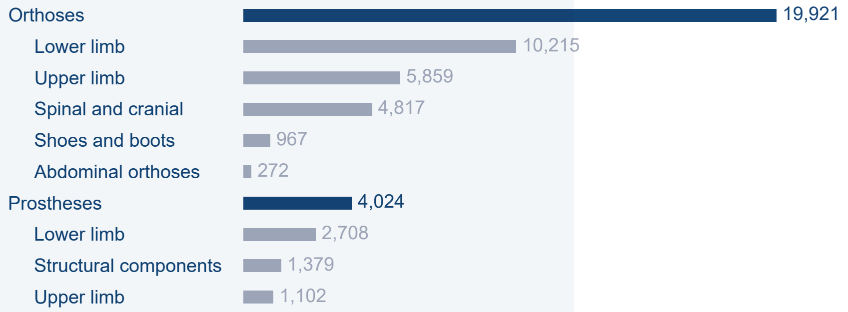


Figure 2.52. Walking aids and related accessories in detail

*Walking sticks and crutches attract the majority of patenting activity**

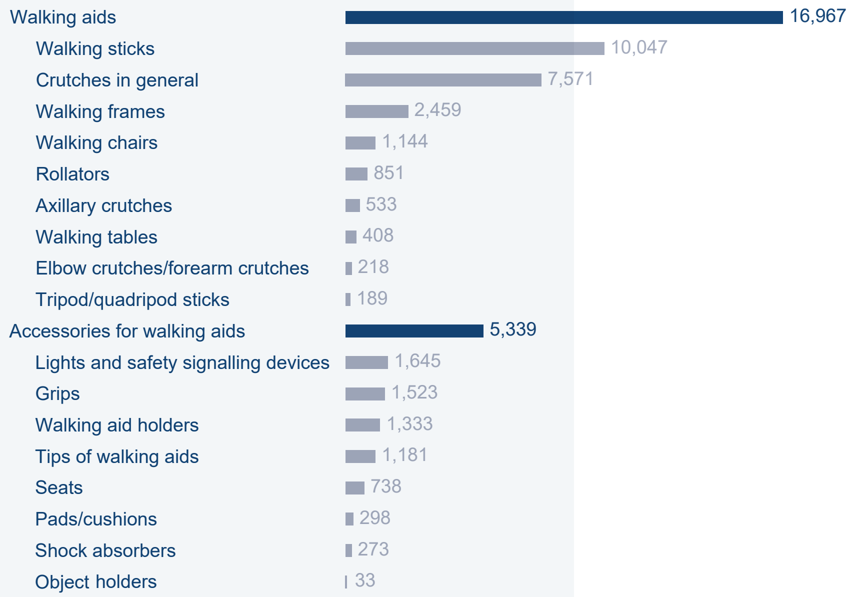


Figure 2.53. Inventions by Shandong University of Science and Technology for walking sticks that aim to improve safety, comfort and convenience

(a) Walking stick with resting seat attached – a typical example of basic design protection that is currently pursued by many inventors worldwide; (b) walking stick with illumination and water immersion alert

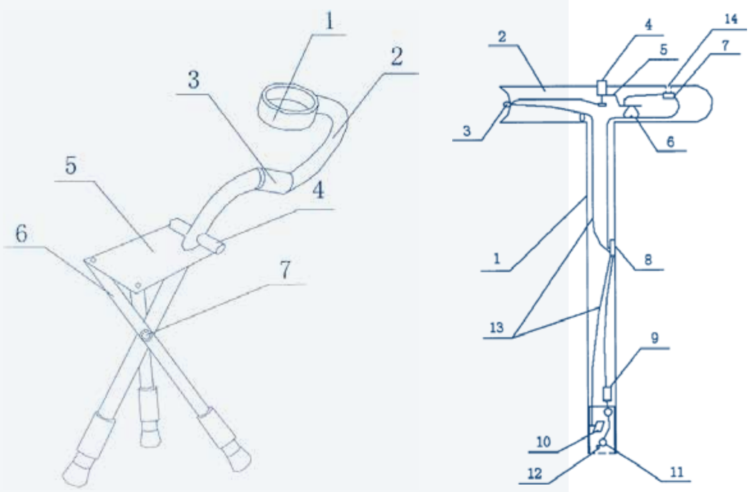
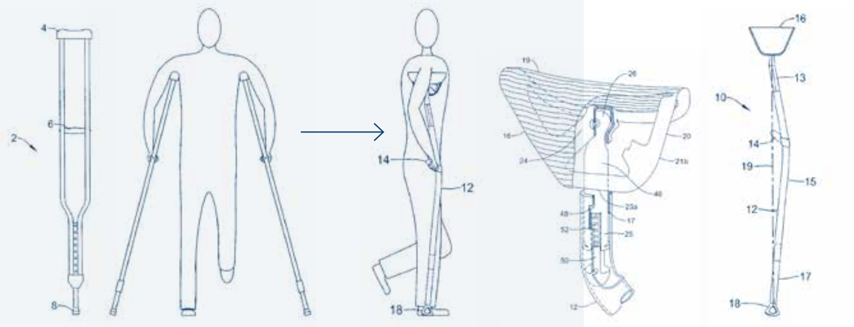


Figure 2.54. Example of a patent document (Mobi) on an improved crutch design

The crutch flexes help accommodate movement through entryways and smaller spaces, and there is improved comfort with a mesh saddle for the armpit, angled wrist grips and other improvements in the grippers



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Conventional mobility assistive technology

63,245

patent families for conventional hearing assistive technology were filed across **56 patent offices**

What technologies are involved?

Orthoses
19,921 (31%)

Walking aids
16,967 (27%)

Accessories for wheelchairs
12,391 (20%)

Wheelchairs
7,006 (11%)

Accessories for walking aids
5,339 (8%)

Accessories for changing body position or lifting persons
4,757 (8%)

Prostheses
4,024 (6%)

Other mobility devices and mobility accessories
3,430 (5%)

Standing frames and supports for standing
528 (1%)

Which are the fastest growing technologies?

Filings in **accessories for walking aids** saw an average annual growth rate of 14% between 2013 and 2017

Who is filing?

Applicant sector

Individuals 44%

Academia 13%

Corporate 43%

Top patent applicants

Toyota (Japan)	462
Össur (Iceland)	448
Ottobock (Germany)	380
Panasonic (Japan)	232
Invacare (U.S.)	219

The patent landscape is highly fragmented, with a broad and diverse range of applicants. Patent filings from academia have grown by an average of 24% from 2013 to 2017.

Figure 2.55. Wheelchairs and related accessories in detail

Most of the wheelchair-related inventions relate to manual or stair climbing/obstacle traversing wheelchairs, while most filings by far in the field of accessories are for tyres, wheels and castors, followed by batteries and battery chargers

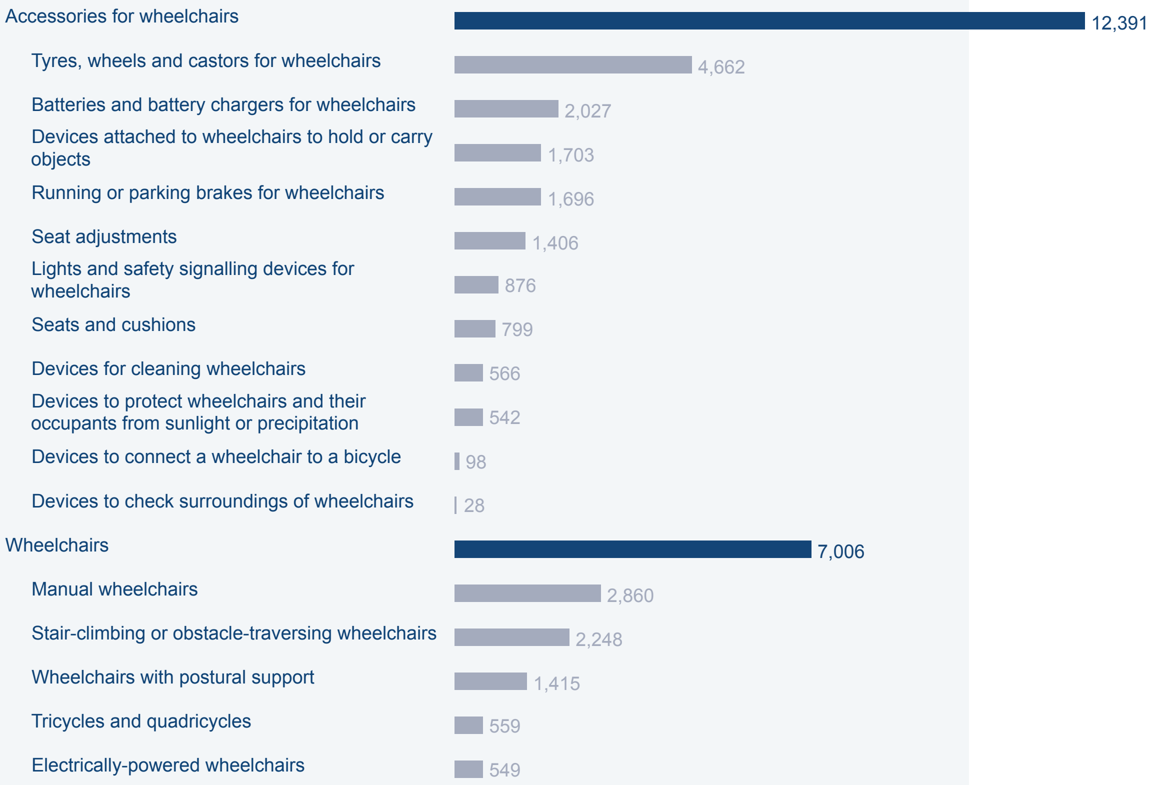
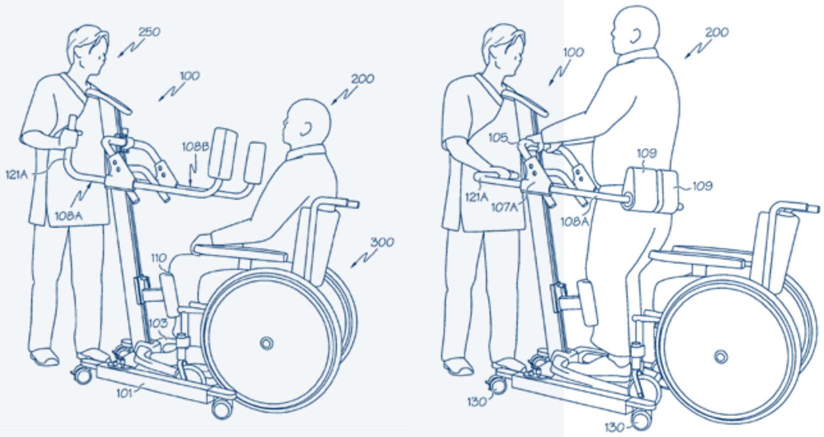


Figure 2.56. Wheelchair that supports moving the user in a standing position (patent document WO2006091143A1 filed by Hill-Rom-acquired Liko Research)



Wheelchairs and their accessories range from complex technologies, such as electric batteries, to simple accessories, such as umbrella holders. Innovation in this technology includes the provision of greater control and power, with solutions such as push rim-activated power-assisted wheels, and better comfort and support, with seats and posture support (for more detail see Figure 2.55). Wheelchair innovation is driven by foldability and size, lighter weight, adaptability to different terrains and environments, and reduced cost (see Figure 2.56 for an example). Interestingly, there are more patent filings made for accessories for wheelchairs (12,391 patent families, corresponding to 20% of the dataset) than for wheelchairs themselves (7,006 patent families, accounting for 11% of the dataset), possibly linked to individual features being patented as component parts.

Accessories for changing body positions or lifting persons include both simple designs, such as straps put under a lying person in order to lift them, as well as permanently installed, motorized chairs and lifts running along a ceiling track in a house. It accounts for a rather small part of the dataset (8%), with most filings related to body support units, mobile hoists and hoists bases, lateral movement and lifting devices (see Figure 2.57 for more detail and Figure 2.58 for examples). **Other mobility and mobility accessories** facilitating moving into and out of vehicles and attachment to mobile devices account for 5% of the dataset, while the smallest category is the one of **special devices, namely, standing frames and support for standing**, corresponding to 1% of the dataset.

Growth

A total of 1,384 patent families were first filed in 1998, reaching 5,300 new filings in 2017. Between 2013 and 2017, patent families for conventional mobility assistive technology showed an overall average AAGR of 9%.

Accessories for walking aids (5,339 patent families) and accessories for changing body position or lifting persons (4,757 patent families) show the strongest growth, with an AAGR of 14% and 13% for 2013–2017, respectively.

The higher number of patents for wheelchairs than for exoskeletons reflects the number of "associations/foundations" that campaign for improved accessibility for wheelchairs in public spaces. There is no need to fear losing the regulations acquired or the recurrence of their adoption. Combining the two mobility assistive devices to deal with both vertical and wheeled mobilities, in indoor and outdoor situations, at home and in offices, is quite relevant to address and motivating for innovators.

Mohamed Bouri, EPFL

Geographical distribution

A total of 97,280 patent applications[26] were filed across 56 different patent offices, making mobility the area with the widest breadth of patent protection among all assistive technology areas. China, the U.S., Japan, WIPO and EPO are the five leading patent offices. Approximately 14% of patent families include a PCT application and 11% include an EP application. PCT applications show an AAGR of about 5% between 2011 and 2016, while patents with EP applications show inconsistent trends after 2010. In total, 82% of patent families are protected in only one jurisdiction.

Overall, 90% of these applications were filed at the top 10 patent offices and 71% at the top five patent offices (Figure 2.59), while further jurisdictions with fewer filings include the U.K., Spain, the Russian Federation, India, Brazil and Mexico. China, the Republic of Korea and India are markets that are more recent and growing in importance. Among the top five patent protection locations, China had very few filings in the late 1990s and early 2000s, whereas the U.S., EPO and Japan were by then already established patent protection locations for

Figure 2.57. Devices for changing position, lifting, supporting or other mobility in detail

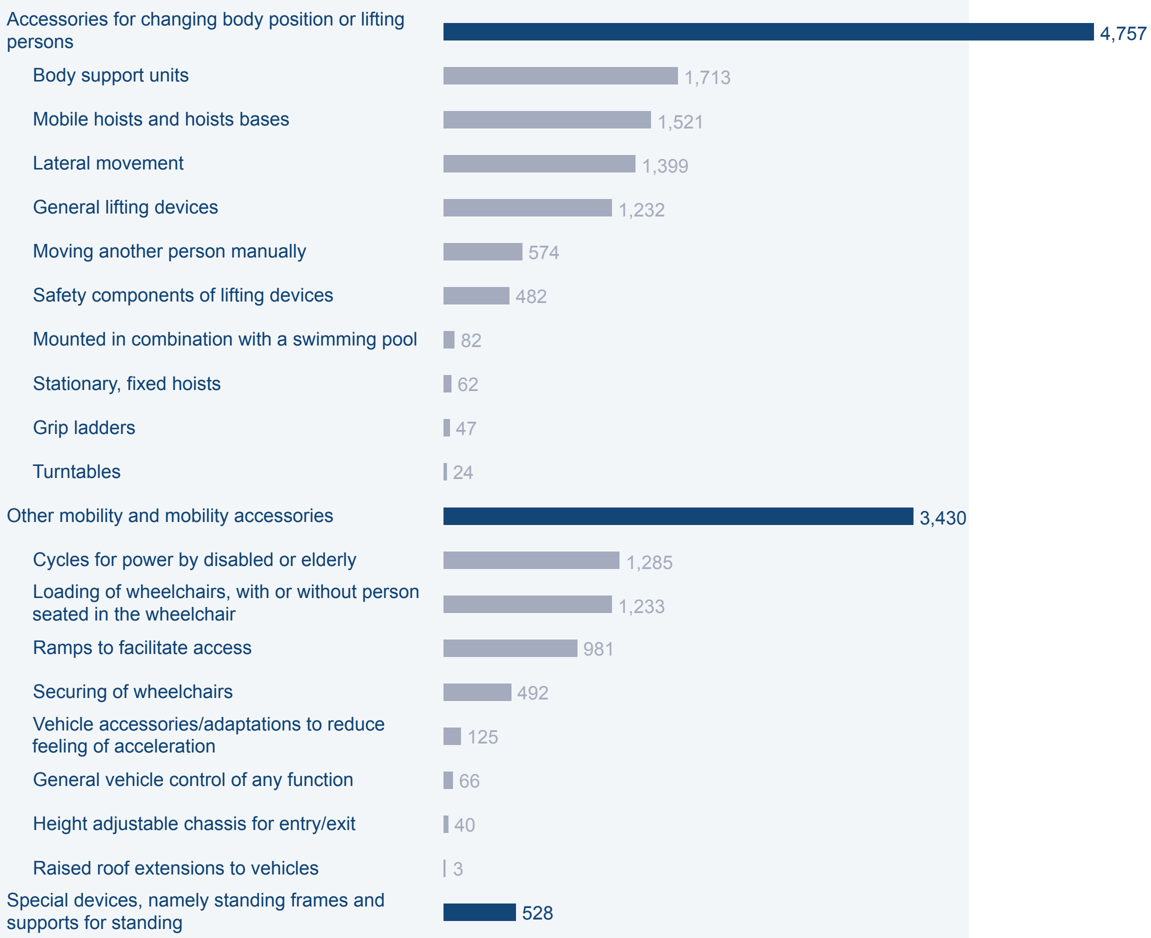
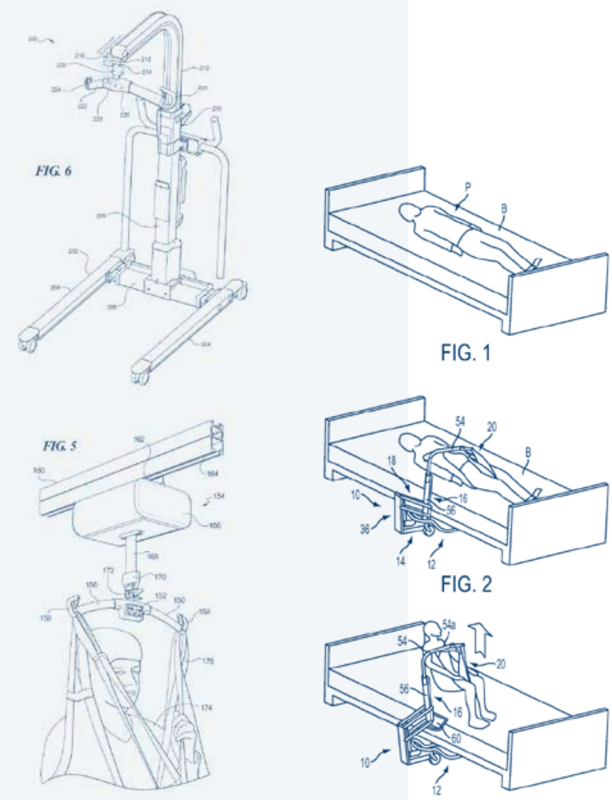


Figure 2.58.
(a) A device that helps move the user from a sitting to a standing position (patent document 6301927 B2 filed by Fuji Machine Manufacturing Company). (b) Example of a lifting hoist (patent document 9693922 B2 filed by Hill-Rom). (c) A device to help the user move from a supine to a sitting position (patent document 8646125 B2 filed by Stryker)



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

mobility assistive technology, while 41% of the total domain patent families include a filing in China, higher than the equivalent 26% and 17% for the U.S. and Japan.

Looking at the origin of innovation, over a third (36%) of mobility-related patent families have China-based inventors, followed by U.S.-based inventors at 17%, Japan at 14%, and Germany and the Republic of Korea at 7% each. A total of 89% of Chinese filings include local inventors, while foreign inventors in filings in China are mainly from Japan and the U.S., accounting for 3% of the filings each. The U.S. receives more filings from foreign inventors (27% of the total 16,575 patent applications), including 7% from Japan and 4% from Germany and Canada each. Patent applications in Japan, Germany and the Republic of Korea have each more than 80% of local inventors. On the other hand, Australia and Canada have a comparatively small amount of resident filings, with 12% and 22% of the patent families filed by local inventors, respectively. In these two jurisdictions, the major portion of non-resident filings comes from U.S.-based inventors and they contribute 40% of filings in Australia and 43% of filings in Canada.

Just under a quarter (23%) of the entire dataset are Chinese utility models, which account for more than half of filings in China. Utility model filings in China started in 2004, and grew by around 20% a year, on average, between 2007 and 2012, and 10% per year between 2013 and 2017. Nearly all Chinese utility model filings are made by universities and public research organizations, with the Army Medical University (77 utility models), Nantong First People's Hospital (42 utility models) and Shandong University of Science and Technology (38 utility models) the top applicants.

Germany and the Republic of Korea are also two important markets. The offices receiving least patent filings (<5% of the dataset) are Australia, Canada, France, the U.K., Spain, the Russian Federation, India, Brazil and Mexico. Turkey (53 patent filings) and Argentina (21 patent filings) are new markets, whose applications were first filed after 2012.

Technical projects are often used as testbeds with universities, in areas which would be considered experimental and higher risk than the usual product development pipelines, leading to interesting collaborations and some successful products.

Areas of interest for technical development are prosthetics and orthotics that are lightweight and have a dynamic response. Advanced breathable materials are an important feature, while there is a general trend toward smart assistive products.

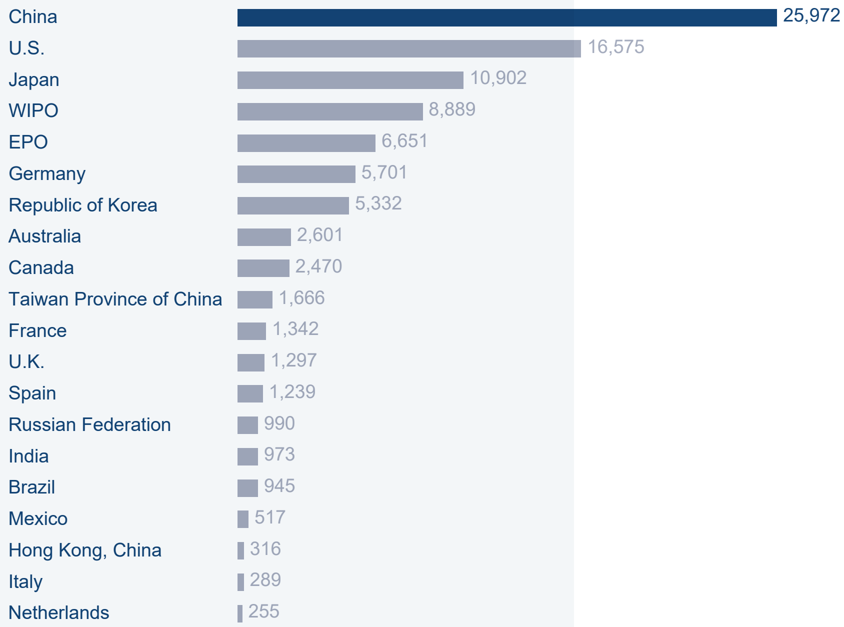
Tatjana Latinovic, Össur

The U.S. and China are the main origins of inventorship (based on the residence of inventors) for orthoses and prostheses, but Germany, Japan and the Republic of Korea also feature strongly. The U.S. also leads inventorship for accessories for changing body position or lifting, with around a third of originating inventions in each sub-category, followed by China and Germany.

The majority of inventorship for walking aids and their accessories comes from Asia, particularly China (inventorship for 80% of patent families for both **lights and safety signalling devices** and **grips**, sub-categories of accessories for walking aids). Japan and the Republic of Korea are also prominent. Notably, there are some filings from the U.K. and Sweden, specifically for grips. The same Asian countries lead in inventorship for **cycles for power by disabled or elderly** (a sub-category of other mobility and mobility accessories).

Japan and China are major origins of inventorship for wheelchairs and their accessories, followed by the U.S., the Republic of Korea and Germany, while **loading**

Figure 2.59. Top 20 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for conventional mobility assistive technology
China is the leading patent office with 41% of patent families including an application there, followed by U.S. with 26% of the dataset's patent families including a U.S. filing



Note: EPO is the European Patent Office. WIPO represents PCT applications.

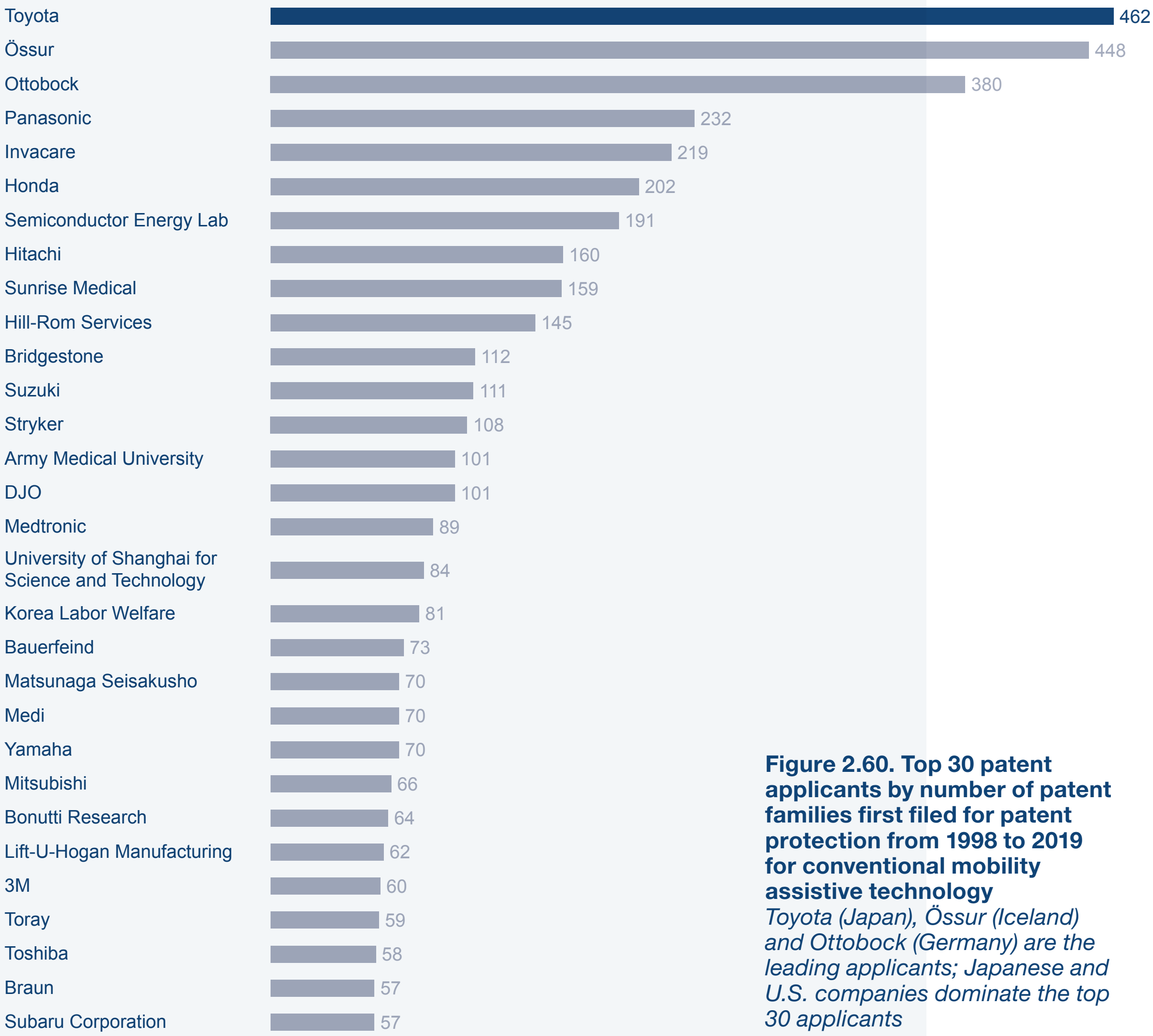


Figure 2.60. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for conventional mobility assistive technology
Toyota (Japan), Össur (Iceland) and Ottobock (Germany) are the leading applicants; Japanese and U.S. companies dominate the top 30 applicants

of wheelchairs is led by the U.S., Japan and Germany, followed by China and the Republic of Korea.

Key players

More than half of the filings since 2011 have come from China, with the top two patent applicants being Army Medical University (96 patent applications) and University of Shanghai for Science and Technology (71 patent applications). The profile of Chinese applicants from 2011 onwards is 41% from industry, 40% from independent inventors and 18% from universities and public research organizations.

In the overall conventional mobility dataset patent applications are almost equally split between independent inventors (44%) and corporate applicants (43%). The independent inventors come primarily from the top jurisdictions for patent applications: China (10,725 patent families, or 17% of the conventional mobility dataset), the U.S. (4,841 patent families), the Republic of Korea (2,530), Japan (2,504) and Germany (2,374). Independent inventors from these five countries contribute 36% of the total patent filings.

Universities and public research organizations account for 13% of patent filings and have the strongest growth in patenting activity, with an AAGR of approximately 23% between 2013 and 2017. This sector's most popular areas of filing are in orthoses and walking aids, with the Army Medical University in China (101 patent families), the University of Shanghai for Science and Technology (84 patent families), and Jilin University and Nantong First People's Hospital in China (54 patent families each) the top applicants. Corporate–academic partnership filings are led by Toyota of Japan on the corporate side and the University of Tokyo on the academic side.

The top 25 applicants (Figure 2.60) account for just 6% of the total patent filings, indicating a highly fragmented patent landscape. They are mainly corporate players, have a diverse technology profile and are a mixture of Japanese global conglomerates/automotive industry representatives (Toyota, Honda Motor and Suzuki), mobility assistive technology specific companies (Össur, Ottobock, Sunrise Medical and Hogan Manufacturing's Lift-U company) and assistive technology/medical device companies (Invacare, Hill-Rom, Stryker, DJO, Medtronic, Bauerfeind, Medi and Bonutti Research). Among the top applicants, there are two universities from China and a government agency in the Republic of Korea. Toyota, Panasonic and Invacare mainly file in the field of wheelchair accessories; Össur in orthoses, Ottobock in prostheses and Honda in other mobility and mobility accessories (mainly loading wheelchairs into a vehicle). All these players have at least a third of their portfolio protected in more than three jurisdictions. The most common preferred markets among the top applicants are Japan, the U.S., China, Korea, Germany, the Russian Federation and Australia.

Based on average yearly growth in new patent filings between 2013 and 2017, Hill-Rom is the fastest growing company (91% AAGR, focusing on accessories for changing body position), followed by Sunrise Medical (71% AAGR), Honda (38% AAGR, focusing on

> Össur was founded in 1971 and received its first patent in 1986 for its innovative silicone liner. The company's IP strategy was embedded in the business from the beginning and the founder began filing for patent protection in jurisdictions where assistive products were reimbursed at that time, i.e., the U.S. and Nordic countries. The patent filing strategy has broadened over the years and includes not only product markets but also manufacturing countries, where patent protection may be further beneficial for the company.
>
> 
>
> **Tatjana Latinovic,**
> **Össur**

loading of wheelchairs) and Invacare (29% AAGR). Sunrise Medical and Invacare are both focusing on tires, wheels and castors for wheelchairs. By contrast, the applicants showing a decline in patent filings are Össur (–20% AAGR for 2014–2017, active in orthoses) and Hitachi (–9% AAGR) and Semiconductor Energy Lab (–5% AAGR), both focusing on batteries and battery chargers for wheelchairs.

In China, most filings are by Toyota, Ottobock and Army Medical University (147, 152 and 101 patent families, respectively), while in the U.S. most filings are from Össur, Ottobock and Semiconductor Energy Lab (414, 239 and 179 patent families, respectively). Invacare (52 patent families) and DJO (43) are the top commercial filers in Australia. In Canada, Invacare (64) and Ottobock (54) are the top applicants, while in France Össur (38 patent families) is the leader.

Orthoses is one of the most popular areas for corporate filings. Össur (Iceland) and Ottobock (Germany), two European companies well established in prostheses, also lead in filings for orthoses. Among other top filers for orthoses are Bonutti Research (U.S.), DJO Global (U.S.), Medtronic (Ireland), Bauerfeind (Germany) and 3M (U.S.), and for prostheses Ken Dall Enterprise (Taiwan, Province of China), Energiya Rocket Cosmic Corp (Russian Federation), Danyang Artificial Limb Factory (China), RCM Enterprise/Naked Prosthetics (U.S.) and Beijing Institute of Technology (China).

As walking aids is an area of low technical complexity, there are both a high number (4,771) of applicants and no clear leaders. Individual inventors account for 56% of the total patent families for walking sticks and 61% for crutches, further indicating a highly fragmented area. Many applicants are small Chinese entities, but the top applicants for walking sticks are Shandong University of Science and Technology (China, 15 patent families all filed in China as utility models between 2010 and 2018), Sinano (Japan, 14 patent families) and Osung Duralumin (Republic of Korea, 13 patent families). Similarly, looking at the area of accessories for walking aids, more than half the patent families in this area (3,224) were filed by independent inventors, and many of these, particularly for lights and safety signalling devices, are based in China.

The top applicants for wheelchairs are Invacare (35 patent families), Pride Mobility (24 patent families) and Sunrise Medical (18 patent families), while filings by independent inventors account for 43% of total filings for wheelchairs. Corporate filers are more dominant in accessories for wheelchairs; many of the top applicants are electric battery manufacturers, and the patents are typically written in a way that covers a variety of uses. Toyota and Semiconductor Energy Lab are the top filers, with 267 and 191 patent families, respectively.

Hill-Rom, Stryker and other health care devices companies (Fuji Machine Manufacturing Company, Invacare, Toyota, Siemens, Woodlark Circle Inc and Sage Products Llc) are notable leaders in filings for accessories for changing body position and lifting. Within other mobility and mobility accessories, the top applicants include Honda Motor, Sunpex Technology, Toyota, Suzuki, Braun Corp and Hogan Manufacturing's Lift U Division.

Emerging technology

Emerging assistive technology related to mobility includes advanced solutions which are using various enabling technologies to overcome limitations and provide greater convenience for the user. Emerging assistive products learn and adapt from the user's gait, can find the location of a user, or give users with full body paralysis the potential to drive wheelchairs unaided.

A total of 4,526 patent families related to emerging mobility assistive technology were identified and grouped into **advanced prosthetics**, **advanced walking aids**, **advanced wheelchairs** and **exoskeletons**. Nearly half of the dataset relates to advanced prosthetics, followed by advanced walking aids, while advanced wheelchairs and exoskeletons have nearly the same number of patent filings (Figure 2.61).

Emerging mobility assistive technology

4,526

patent families for emerging mobility assistive technology filed across **41 patent offices**

What technologies are involved?

Advanced prosthetics
1,993 (43%)

Advanced walking aids
963 (21%)

Advanced wheelchairs
859 (19%)

Exoskeletons
846 (19%)

“Benefiting from the use of advanced sensors, artificial intelligence and other enabling technologies, conventional mobility technologies have evolved to become smart, intuitive and more reliable.

Which are the fastest growing technologies?

Filings related to **advanced wheelchairs** saw an average annual growth rate of **34%** from 2013 to 2017

Advanced prosthetics and **exoskeletons** each saw filings increase by an average of **24%,** and the sub-category of **3D printed prosthetics/orthotics** (advanced prosthetics) saw a growth rate of **89%** between 2013 and 2017

Who is filing?

Applicant sector

Corporate
44%

Academia
34%

Individuals
19%

Mobility is the area with the highest contribution of academia in the emerging assistive technology

Top patent applicants

Applicant	Patent families
Toyota (Japan)	62
Honda (Japan)	52
Tsinghua University (China)	47
Samsung (Republic of Korea)	46
Shanghai Jiao Tong University (China)	40

Figure 2.61. Overview of emerging mobility assistive technology*

Almost half of the dataset relates to advanced prosthetics

*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

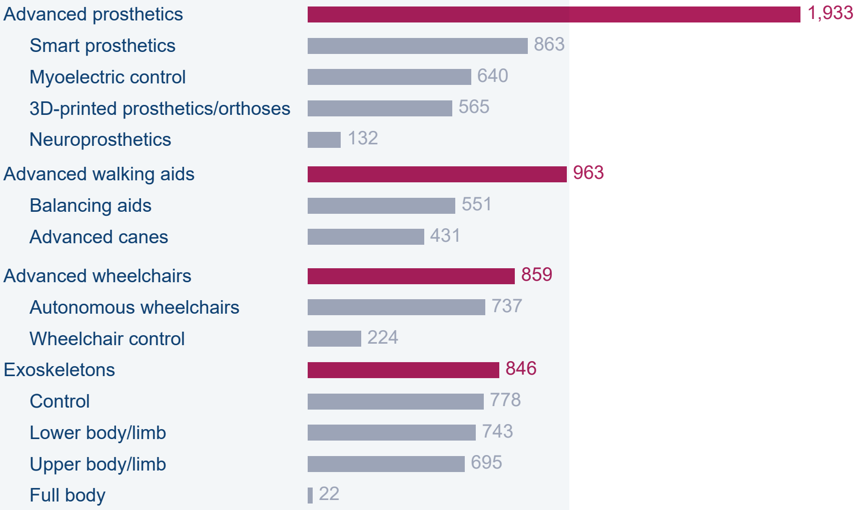


Figure 2.62. Advanced prosthetics

(a) A 3D-printed prosthesis with various buttons for control that connect to a main control board (patent document CN207370782U); (b) smart prosthesis (patent document US10624766B2); (c) neuroprosthetic device that helps restore upper limb movement (patent document WO2015059612A1)

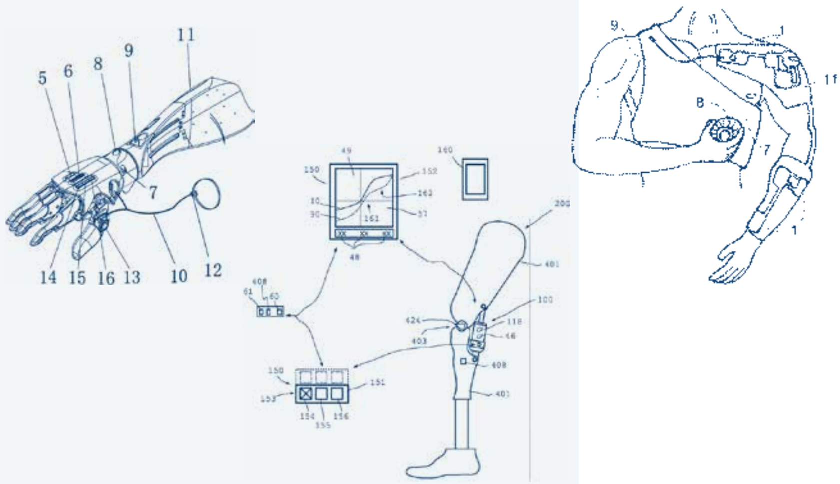


Figure 2.63. Examples of advanced walking aids

(a) A portable, gyroscopic-assisted system helps balance the user when it detects stumbling (patent document US20140260714A1); (b) an advanced walking stick with an antenna that detects audio information from a module located at a bus stop or on a sidewalk

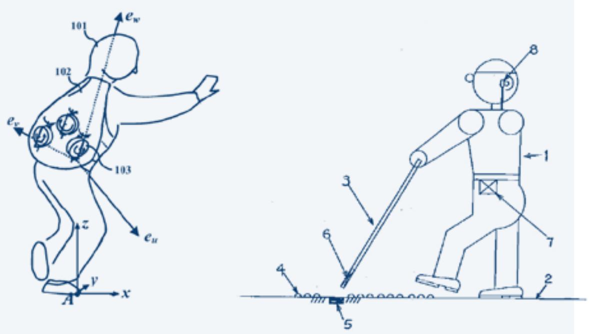
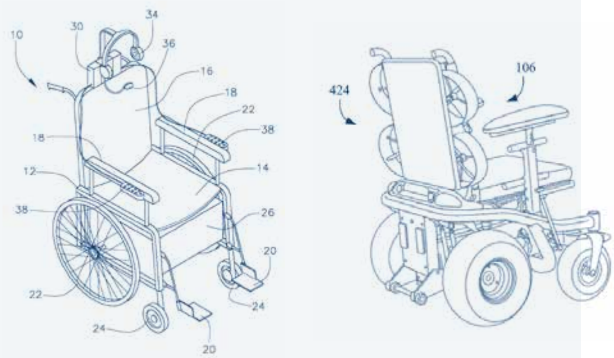


Figure 2.64. Examples of advanced wheelchairs

(a) A wheelchair that responds to neural signals (patent document US6587713B1); (b) a robot system that assists with driving the wheelchair (patent document US20160052137A1 filed by Elwha)



Smart prostheses and orthoses are very promising to improve the reliability of gait as well as flexibility to effectively assist and access more daily living activities. High-demanding assisting strategies are made possible thanks to the increase in embedded computing capacities. One of the future challenges is to innovate new ways for smart mobility assistive devices, using human-inspired machine learning and AI strategies.

Innovations in exoskeletons/orthoses and prostheses are progressing in parallel. The management of gait and balance are the main concern of all these devices. Gait-assisting strategies will drive our innovation to improve safety, comfort and finally the adoption of such technology.

Mohamed Bouri, EPFL

Advanced prosthetics

Conventional prostheses and orthoses have evolved from providing only mechanical support and cosmetic benefits to using advanced technology, such as sensors and the harnessing of neural signals, to become more advanced and realistic, controlled by the nervous system, neural signals and signals from skeletal muscle (see Figure 2.62).

Smart prosthetics have advanced sensors, such as cameras and pressure, temperature or strain sensors, and are equipped with intelligence that enables machine learning to understand the user's prosthetic control behavior. **Myoelectric control** prosthetic devices can sense signals generated by skeletal muscles and move the artificial limb in response to those signals.

On average, a traditional prosthetic costs from roughly $1,500 to $8,000 and may have a lifespan of no more than 4–5 years (Reidel, 2017). **3D-printed prosthetics and orthoses**, on the other hand, can cost as little as $50 and be made from a wide range of materials, including titanium, nylon, epoxy resins and polycarbonates. More customized designs and complex contours can be prepared with the help of 3D printing, where a computer-aided design format is employed for layer-by-layer deposition of the material. Although these features make it likely that 3D printing will emerge as a favored technology in the making of prostheses and orthoses, there is much debate around regulations and the quality control of 3D-printed products (see, for example, Roy, 2017).

(Motor) **neuroprosthetics**[27] are connected to the *central nervous system* (brain or spinal cord) or *peripheral nervous system* (e.g., nerves in the limbs) to focus on specific movements. They can also provide feedback to the user, based on different sensations.

Advanced walking aids

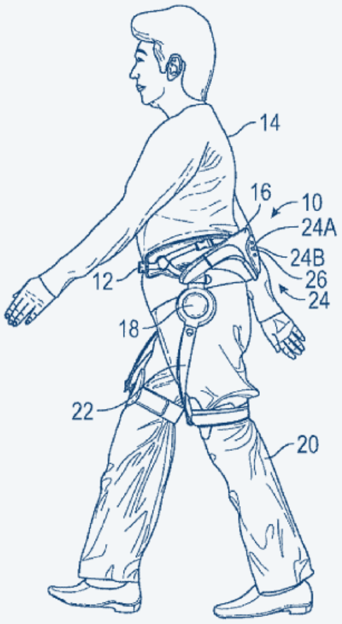
Patents relating to conventional walking aids primarily focus on structural aspects and design. Advanced walking aids use enabling technologies and more high-tech components (Figure 2.63). **Balancing aids**, which include smart shoes, rotating weights, backpacks balance assistance (Lemus et al., 2020; TU Delft, 2020), walking sticks and walking frames, help restore balance to prevent a fall in real time after detecting imbalance. They are more advanced than conventional fall detectors as they use accelerometers; gravity or inertia sensors; or gyroscopes connected to other smart technologies, such as AI, machine learning or IoT.[28] There were 551 patent families identified in this field, and 431 in **advanced canes**, the other sub-category. The latter use GPS, LIDAR, radar, ultrasonic sensors, accelerometers and advanced connectivity technologies like IoT and Bluetooth to identify or broadcast location, detect obstacles and connect with other devices.

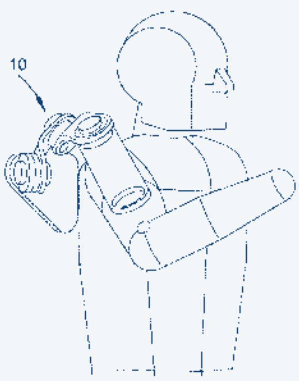
Advanced wheelchairs

Conventional wheelchairs are either manual or electrically driven, but of limited use when the user's hands or complete body are paralyzed. The evolution of wheelchairs is therefore toward autonomous driving (e.g., using AI and proximity sensors) and control (using enabling technologies, such as BCI/BMI, eye-gaze, gesture or voice recognition). Inventions in this

Figure 2.65. Exoskeletons provide support to weaker parts of the body

(a) An externally-powered lower limb exoskeleton (patent document US20160045385A1 filed by Honda); (b) an upper limb exoskeleton (patent document WO2015058249A1); (c) an unpowered exoskeleton auxiliary robot (patent document CN108818496A)





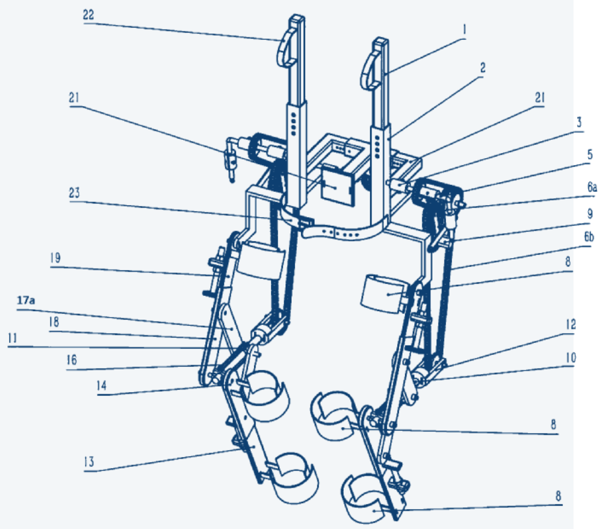
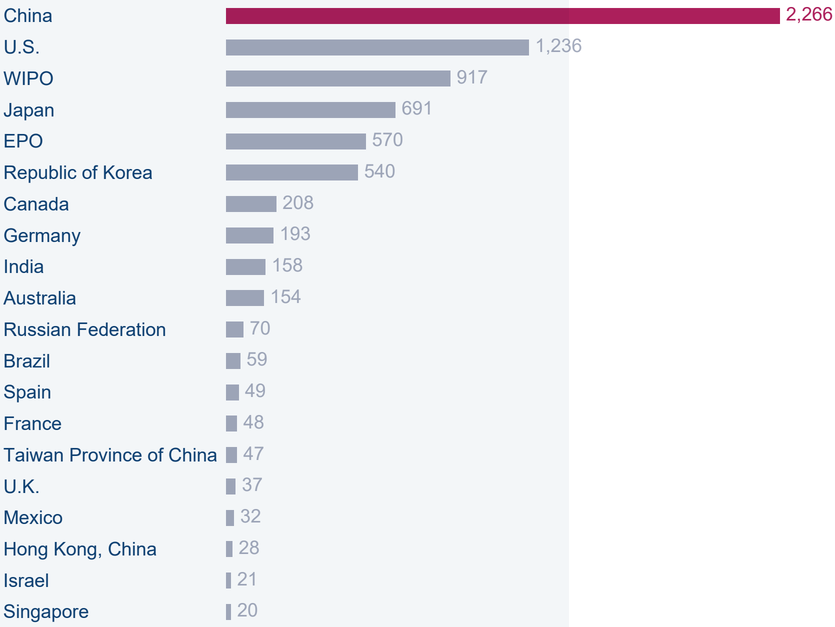


Figure 2.66. Top 20 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for emerging mobility assistive technology

Half of the dataset has been protected in China, while over a quarter (27%) is protected in the U.S.



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Advanced prosthetics include applications in defense. The U.S. Government has devoted a lot of funding to this area, which initiated a lot of the innovation about a decade ago.

Jonathan Pearlman, University of Pittsburgh

category (see Figure 2.64 for examples) mainly relate to **autonomous wheelchairs** (737 patent families), while 224 patent families were identified that related to **wheelchair control**.

Exoskeletons

Wheelchairs, whether conventional or more advanced, are limited with regard to the terrain they can cross over. These limitations can be overcome with more innovative assistive technology, such as exoskeletons (Figure 2.65). Exoskeletons are rigid frames constructed of metal or any hard material that support weak body parts,[29] while soft exoskeletons (following an overall trend for soft systems, such as soft robots[30]) are also under development.[31] They can be *externally powered*, for example by batteries, or *body powered*. Exoskeletons can be applied to the **upper body**, **lower body** or the **full body** as required. They were originally developed for the military before being considered for assistive purposes, and it is mainly the lower limb ones that are used, similar to the brace-orthosis we came across in conventional mobility to support and prevent a person from falling.

Growth

Even though the 4,526 patent families related to emerging mobility assistive technology are only approximately 7% the size of the dataset for conventional mobility, the growth rate for emerging mobility is far higher, with filings recording and AAGR of 24% for 2013–2017, compared with 9% for conventional mobility filings during the same period.

Patent filings have increased consistently since 1998, though the growth is more prominent from 2013 onwards. The biggest contribution to recent growth comes from China, where filings started in 2000 and grew from 72 per year in 2010 to 388 per year in 2017, with the majority of filings made during the period 2013–2017 coming from universities and public research organizations, followed by corporate players.

Developments in prosthetics

There is increasing interest in adding sensing capabilities coupled with machine learning to improve prosthetics, which will enhance the features of the prosthetic device but not necessarily increase its acceptability and adoption. Concerns about privacy, need for connectivity, increased complexity and reduced power autonomy are barriers for adoption.

Impact will be limited until there is sufficient evidence on scalability (especially for low to mid-income populations) and suitability for long-term use. Frameworks to define responsibilities and normatives for quality control need to be defined. Poor adoption of other types of advanced prosthetic devices (e.g., myoelectric) suggest that significant efforts will be required to turn current prototypes into viable products.

Ricardo Chavarriaga, CLAIRE, IEEE Standards Association, and Zürich University of Applied Sciences

Advanced wheelchairs (859 patent families) is the category with the highest growth, with an AAGR of 34% during 2013–2017, followed by advanced prosthetics and exoskeletons, both with an AAGR of 24%. 3D printed prosthetics/orthosis (565 patent families) is the fastest growing sub-category, with 89% AAGR.

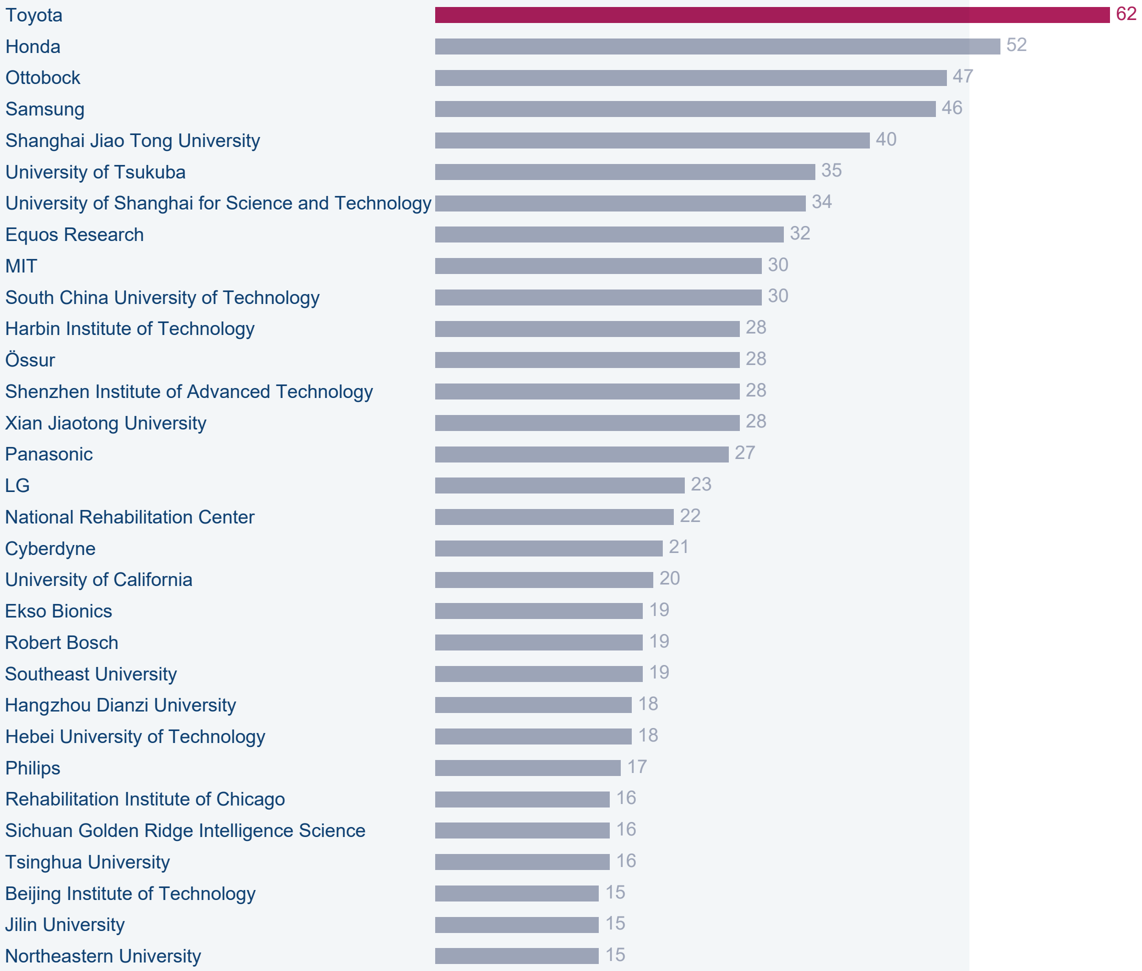
Geographical distribution

There were 7,428 patent applications[32] (corresponding to 4,526 patent families) filed in 41 patent offices (Figure 2.66). A total 77% of emerging mobility related inventions sought protections in only one jurisdiction.

Of the applications from China, 30% were utility models and 30% related to advanced wheelchairs. The highest number of filings in China came from Shanghai Jiao Tong University (40 patent families) and the University

Figure 2.67. Top 31 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for emerging mobility assistive technology

There is a very high number of academic institutes among the top applicants in comparison with other areas of assistive technology



of Shanghai for Science and Technology (34 patent families). In the U.S., smart prosthetics and exoskeletons are the most filed categories and Samsung (42 patent applications), Honda (41 patent applications) and Ottobock (40 patent applications) are the top filers in the U.S.

Based on the AAGR for 2013–2017, the highest growth rates in filings are observed in Germany (40%), Spain (40%) and the Russian Federation (35%). Smart prosthetics (52 patent families, 27% of filings in Germany) is the most filed category in Germany, while exoskeletons is the most filed category in both the Russian Federation and Spain, with 31 patent families (44% of filings in Russia) and 23 patent families (47% of filings in Spain), respectively. Ottobock is the top filer in all three of these jurisdictions.

A fifth of the patent families include a PCT application, and 13% an EP filing. This is a much higher percentage than for conventional mobility, suggesting an intention to seek wider global protection in the filing strategy for emerging mobility assistive technologies. Since 2013, applicants have used the PCT route more than the EP route. During 2013–2017, PCT applications marked an AAGR of 17%, compared with 5% for EP.

While 77% of the overall dataset inventions are protected in a single jurisdiction, these percentages are 98% for the patent filings originating from China, 78% for the Republic of Korea and 75% for filings from Japan. Over 50% of filings originating from the U.S., Canada, France, the U.K. and Germany are protected in two or more jurisdictions. Advanced walking aids and advanced wheelchairs are more locally protected (94% and 95%, respectively, are protected in one jurisdiction only and patent families with filings in PCT and EP are less than 5% of the dataset for both categories).

Generally, the pattern for China to be the top patent office, followed by the U.S., Japan and the Republic of Korea applies to most technology categories, with the exception of neuroprosthetics, where the U.S. is the top jurisdiction (77% of patent families) followed by Australia (14%) and Japan (12%); smart prosthetics, where the U.S. is the top patent office; advanced wheelchairs and advanced canes, where the U.S. is absent from the top three of China, the Republic of Korea and Japan; and balancing aids, where Japan is the top patent office.

Customization and trends in micromobility

Personal mobility and micromobility are areas Honda has been interested in, starting from solutions for persons with motor impairment for its vehicles to solutions such as smart wheelchairs for personal mobility. One current trend and challenge is individualization, involving the variability of all kinds of user profiles, including those with different functional limitations. Co-design plays an important role and for this purpose Honda is involving employees with disabilities who can provide their perspective, while in other cases external advice and support is sought. While there is an increasing importance of software where individualization is easier to achieve, this is more of a challenge in hardware. Speed in entering the market with individualized solutions is not that critical, but once this can be achieved, this is perhaps more sustainable. IoT is playing an important role in developments, combining objects with physical and digital functions, while technical developments related to energy supply, that is, efficiency, flexible batteries, miniaturization and intelligent sockets, can lead to a concept of complete mobility.

Bernhard Sendhoff,
Honda Research Institute

Key players

Commercial entities lead in emerging assistive mobility technologies, accounting for 44% (1,988 patent families) of the dataset, followed by universities and public research organizations, with a remarkable 34% (1,550 patent families), one of the highest contributions from academia across the different functional categories. Only 3% (141) of the patent families are a result of collaboration

The market of mobility assistive technology is to a great extent limited to big players. There are two main issues: missing ecosystems, such as venture capitalists in Europe, similar to Silicon Valley, to support small companies and researchers; and the reality that, despite the potential impact, few companies are willing to buy the innovations developed by scientists, because of uncertainty and risk. IP is improving in academia, along with patent drafting. There are examples of collaboration between universities or spin-offs/start-ups thereof, such as the Comau and Össur investment in the Italian Sant'Anna School of Advanced Studies spin-off Iuvo, which developed an assistive skeleton for industrial applications.

Silvestro Micera,
EPFL and Sant'Anna School of Advanced Studies

between commercial entities and academia. Owing to the technical complexity of the domain, independent inventors contributed only 19% of the dataset (847 patent families), with their contribution highest in advanced canes (accounting for 40% of related filings) and lowest in the area of neuroprosthetics (5%), indicating a link between complexity of technical area and level of contribution. Commercial entities account for the biggest number of filings in all technical categories, except for exoskeletons and myoelectric control prosthetics, where the space is shared approximately equally between commercial and academia.

Filings from commercial entities are growing the fastest at an AAGR of 29% for 2013–2017, followed by academia (26%) and independent inventors (20%), indicating that interest in this field is increasing overall.

The top 31 patent applicants account for 18% of the total 4,526 patent families (Figure 2.67). The top 10 applicants own only 9% of the dataset, indicating a fragmented area. Nearly half of the 31 top applicants are based in China, six in Japan, four in the U.S., three in the Republic of Korea, two in Germany and one each from Iceland and the Netherlands.

The top commercial entities are Toyota, Honda, Ottobock and Samsung. Toyota, Honda and Samsung have most filings in balancing aids, whereas Ottobock has most of its filings in smart prosthetics (featuring as top applicant with Össur and MIT) and is top applicant in two further categories of advanced prosthetics, namely, neuroprosthetics (with another German company, NDI medical) and myoelectric control (with Össur and Harbin Institute of Technology). Out of the top four commercial applicants, Samsung is the one growing at the fastest rate, with an AAGR of 19% for 2013–2017, followed by Ottobock (8%) and Toyota (2%).

The top universities and public research organizations are Shanghai Jiao Tong University, University of Tsukuba, University of Shanghai for Science and Technology, MIT and South China University of Technology. Their filings are distributed mostly among smart and myoelectric control prosthetics, and exoskeletons. Universities and research organizations based in China, Japan and the Republic of Korea feature as top academic filers in almost all functional categories, but in emerging mobility we find MIT, a U.S. institute, among the top academic entities. MIT has 30 patent families, only 30% of which were filed since 2013. Of its patent families, 27 relate to advanced prosthetics and five to exoskeletons, with two patent families tagged in both categories. MIT's 28 patent families are protected in the U.S. and nearly half include a PCT application. It is worth noting that top patent applicants in the field of 3D-printed prosthetics and orthotics are mainly Chinese universities, including Shanghai Jiao Tong University and Xian Jiaotong University.

The most joint filings by industry and academia are observed for Cyberdyne (Japan) and the University of Tsukuba (Japan), with 18 co-owned inventions, mainly in myoelectric control, balancing aids and exoskeletons.

Sichuan Golden Ridge Intelligence Science and Technology appears as an emerging applicant whose patents are all for autonomous wheelchairs, filed in 2017, making it the most recent portfolio among top applicants. Robert Bosch follows, with 95% of its patents filed since 2013 and 16 of its 19 patent families in the field of externally-powered exoskeletons. Beyond these applicants, we observed a patent licensing entity appearing also in the vision assistive technology, Elwha LLC (an Intellectual Ventures holding company) with eight patent families, half related to smart prosthetics and half to autonomous wheelchairs.

Table 2.1 provides detail on the leading applicants by type of technology.

Table 2.1. Leading patent applicants by category of emerging mobility technology

Main category	Leading applicants
Advanced prosthetics – smart prosthetics	Ottobock, Germany MIT, U.S. Össur, Iceland
Advanced prosthetics – myoelectric control	Ottobock, Germany Harbin Institute of Technology, China Össur, Iceland
Advanced prosthetics – 3D-printed prostheses/orthoses	Mainly Chinese universities, including Shanghai Jiao Tong University and Xian Jiaotong University
Advanced prosthetics – neuroprosthetics	NDI Medical, Germany Ottobock, Germany
Advanced walking aids – balancing aids	Toyota, Japan Equos Research, Japan Honda, Japan Samsung, Republic of Korea
Advanced wheelchairs	Sichuan Golden Ridge Intelligence Science and Technology, China Tianjin Shuangyuan Electric Power Equipment, China Shenzhen Glory-Medical Engineering, China
Exoskeletons	Honda, Japan Ekso Bionics, U.S. National Rehabilitation Center, Republic of Korea University of California, U.S. Robert Bosch, Germany University of Tsukuba, Japan

“Soft” assistive technology

Trends in assistive technology related to mobility include “soft” assistive technology, such as soft robotics and soft exoskeletons. Patents do not refer to the soft materials as such, but rather how they provide grasp in a reliable way with the human body, in a way which is more comfortable and which reduces actuation due to lighter weight than rigid exosuits. 3D-printed prosthetics using composite materials is a very interesting approach to pursue to reduce costs. Research is also focusing on assistive products that use a shared manipulation approach between the user and the assistive technology, allowing them to share the task and interact to achieve the objective. Certain advancements are dependent on developments in enabling technologies: for example, advanced materials such as alloys that allow the material to move when it heats up or solutions that allow for ultra-low power consumption in exoskeletons.

Silvestro Micera, EPFL and Sant’Anna School of Advanced Studies

Summary

A wide range of complexity, innovation drivers and types of inventions are involved in conventional mobility assistive technology, where the overall goal is keeping the user safe and able to move or manipulate to the fullest extent possible. The patent landscape is highly fragmented, with a diverse range of applicants split almost equally between independent inventors and corporate applicants. Corporate applicants include large Japanese conglomerates, European mobility specialists, such as Össur and Ottobock, and U.S. health care device companies. In addition, almost a quarter of filings are utility models from China, reflecting the simpler technologies involved, particularly for walking aids and accessories. More than half of the filings made since 2011 come from China, but Japan, the U.S., Germany and the Republic of Korea are also important markets.

Emerging assistive technologies for mobility introduce advanced versions of conventional mobility devices through the use of enabling technologies such as additive manufacturing. Companies specializing in prostheses and orthoses, for example, are expanding their area of interest to include exoskeletons and exploring ways of mainstreaming such assistive technologies. Significant growth and areas of global potential are seen, particularly for advanced wheelchairs, advanced prosthetics and exoskeletons. Advances in computing, sensors and manufacturing technologies have fueled the adaptation of conventional mobility devices and the growth in innovations.

This evolution is supported by R&D from all types of players, including smaller entities, universities and technology giants. The complexity of the technologies involved is evidenced by the large proportion of filings from corporates and universities and public research institutes, mostly from universities in China, but notably also a U.S. academic institution, MIT. It is worth remarking that academic participation in the emerging mobility dataset stands at 34% – the highest among all the assistive functional categories.

Implications for end-users

Conventional mobility assistive technologies generally aim to increase comfort and control, as well as improve functionality. Emerging assistive technologies, such as autonomous wheelchairs, smart prosthetics, exoskeletons and 3D-printed prosthetics and orthoses, are likely to eventually enable the development of new mobility assistive devices. While autonomous wheelchairs make a user more self-reliant (Shieber, 2019), the incorporation of 3D-printing techniques in the manufacture of prosthetics and orthoses enables the fabrication of precise, customized and more affordable products. Development of smart prosthetics is another important and crucial direction that will make prostheses more desirable and convenient for users.

A smart prosthetic leg that uses machine learning techniques to recognize a user's gait and then adjust itself so that the walking experience is more natural and seamless is arguably the next stage in the development of prosthetics. A feedback that generates a sense of natural touch is also something that can be enabled by smart prosthetics and neural interfaces. Further, exoskeletons that are easy to wear, light to carry and designed to carry out several tasks will allow users to work in industries where physical mobility is required. While certain technologies provide functionality similar to traditional ones (i.e., advanced prosthetics still replace a missing limb and facilitate walking), others, like full-body exoskeletons, enable people to stand again who would otherwise have been candidates for wheelchairs.

Applying enabling technologies to conventional mobility devices has, without doubt, provided added ease, convenience and greater independence for the user. These products do, however, need to be more cost effective in order to become accessible to wider society. The fact that large corporates, such as Toyota, Honda, Ottobock and Össur, as well as start-ups like Sichuan Golden Ridge Science and Technology, holding companies like Elwha LLC and academic institutes like MIT are contributing to filings in emerging mobility creates an ecosystem where competition could be boosted and in turn make these products more affordable, to the benefit of a broader range of end-users.

Emerging assistive technologies, such as autonomous wheelchairs, smart prosthetics, exoskeletons and 3D-printed prosthetics and orthoses, are likely to eventually enable the development of new mobility assistive devices.

Photo © Össur

From prosthetics to more natural feet

The design of prosthetic feet has improved greatly over the years, thanks to advances in materials and research into biomechanical functions and needs. Össur, a global leader in non-invasive orthopedics that is headquartered in Iceland, has utilized strength, flexibility and lightness of carbon fiber composites in its designs, creating prosthetic feet that are able to store and return energy to the user as they walk, as well as improve stability, energy efficiency and gait.

Enhanced protection of the sound side and reducing potential comorbidities was an important driver behind the innovation in Össur's latest range of prosthetic feet, Pro-Flex®. This new technology features serial carbon-fiber leaf springs and is designed with three blades, as well as a toe lever and a more anatomical split toe. The top and middle blades are linked together with three pivot points. During walking this mechanism allows for a rolling motion around the main pivot. Pivots are placed to match anatomic location, and therefore the mechanism produces a highly natural gait and increased range of ankle motion compared with energy-storing feet with conventional carbon-fiber structures.

Pro-Flex® LP Align, the latest product to be developed in this range, uses a hydraulic ankle unit to give amputees the freedom to choose footwear that best suits their daily activities, without compromising alignment, posture, dynamics or functionality. The proprietary push-button heel-height adjustment feature allows users to maintain proper alignment across a variety of everyday footwear.

Össur has also been exploring emerging prosthetic technologies in the form of mind-controlled prosthetics. These have the potential to provide an amputee with more direct control of their prosthesis and allow them to intuitively affect the behavior of their arm or leg. The company recently signed an agreement with the US-based Alfred Mann Foundation on the development and licensing of a myoelectric sensor system (IMES), which acts as a bridge between the amputee user's neuromuscular system and their artificial limb.

Case study by Össur

A win–win approach to designing a new exoskeleton

Despite being paralyzed from the chest down after a spinal injury, Michael Haddad partakes in many physical endurance challenges, such as climbing mountains and travelling long distances over difficult terrain. Michael uses his experience and profile to assist the United Nations Development Programme as a Regional Goodwill Ambassador for Climate Action in the Arab States, drawing attention to international development challenges and helping to ensure a disability-inclusive response. Now, a collaborative project with a multidisciplinary team – including engineers, neurologists and physical therapists and led by Associate Professor of Mechanical Engineering Akle Barbar – at the Lebanese American University, is demonstrating a unique way to support Michael in his endeavors while his feedback supports the development of innovative assistive technology.

Their exoskeleton project has two main objectives: first, to study Michael's locomotion technique through observational analysis and subsequently train other paraplegics to adopt this technique, thereby widening the use of exoskeletons to user profiles that typically would not qualify; second, to develop a lightweight, semi-powered exoskeleton that will support paralyzed people to walk while relying primarily on their own energy.

The proposed exoskeleton will be made of lightweight carbon fiber composites and will include springs, shock absorbers, motors and, in future, smart materials. The goal is to augment the user's balance while passive assistive devices enhance the energy efficiency. Several options are being explored to augment the balance in the exoskeleton using lightweight and slim mechatronic systems. Currently, the group is developing a shoulder-powered mechanism to control the motion of the arms and crutches to keep the user balanced. This method is inspired by Michael and is based on data and observations of his balancing technique. It allows for a higher degree of intervention by the balancing motors for new users and less intervention for more advanced users.

A critical improvement is the fact that the user will rely on their own energy to move rather than external motors and batteries. Michael's ambulating technique for walking, which is similar to the swing-through-gait method, consumes approximately 30 times more power than normal human locomotion, because of the shock forces involved at the end of each step. This will be improved by embedding springs to the lower orthosis to absorb and store the energy of the shock and use it to propel the upcoming step.

In future, energy harvesting from the motion of the user means the exoskeleton could become energy sufficient, as battery charging will not be required. This makes the design more cost-effective, less bulky and more esthetic than a fully motorized exoskeleton. Using this exoskeleton over long durations, the user could gradually abandon the mechanical support and develop self-balancing techniques and the exoskeleton could be used to train those paralyzed patients who ambulate using the swing-through-gait method.

Compared with existing exoskeletons, the proposed design will enable paraplegics to become more independent and healthier owing to exercising and improved mobility.

It will take a year to complete proof-of-concept; meanwhile, the team is setting up a company in the U.S. or Europe to commercialize the product and will soon begin filing patents.

Working together, Michael and the Lebanese American University demonstrate the potential of assistive technology: its use does not have to be restricted to simply assisting a user in day-to-day tasks, but in fact can support activism and other inspiring endeavors that would challenge even the most able-bodied person.

Case study by Michael Haddad and Lebanese American University

2.6 Self-care

Assistive technology for self-care supports independent living by helping persons with functional limitations to carry out everyday activities, such as eating, drinking, dressing, personal care and toileting, with less involvement from their caregiver.

Conventional technology

A total of 6,410 patent families relating to conventional assistive technology for self-care were identified, encompassing incontinence products, adaptive clothing and eating devices, products helping with dental care and washing, and products supporting sexual activity (Figure 2.68).

Garments and accessories specially designed for people with disabilities, known as **adaptive clothing**, constitute almost half of the total dataset. They include adaptive clothes and accessories, such as adaptive shoes, adjustable hems, zips, buttons, belts and shoe horns, as well as assistive products for dressing and undressing (Figure 2.69).

Adaptive eating devices provide support in eating, and include non-slip mats, plate guards, gripping devices, food dispensers and bottle holders, such as a pressurized cup that aids drinking through a straw.[33]

Incontinence products include absorbents, products for collection, prevention and related accessories.[34] Examples are diapers, sanitary pads, urine collection bags, urine blocking clamps, indicative coatings for wetness detection and diaper replacement systems (Figure 2.70).[35] Incontinence absorbent products have the highest number of filings (500 patent families). The dataset includes products such as automatic excrement processing and washing devices for bedridden persons and systems for draining urinary containers meant for persons in a wheelchair.

This domain also captures **assistive products for manicure, pedicure and hair/facial care** and **dental care**, including electric toothbrushes, specially adapted or designed for persons with disabilities, such as a toothbrush handle production method employing 3D printing. The category related to **assistive products for sexual activity**[36] (WHO/UNFPA, 2009), has the lowest number of patent applications and slowest growth rate. Most of the patent families classified in this category involve devices and technology to facilitate sexual activity, such as platforms with an adjustable backrest to position the person in a seated position, seats with resilient belts, beds with suspended platforms and foldable stirrups to position the legs.

Growth

Following an AAGR of 9% from 1998 to 2015, patent filings in conventional assistive technology for self-care started to decline.

Utility models constitute approximately a third of the dataset, and 73% of utility model filings are filed in China. Beijing Xiaoxiyang Technology Development, the University of Shanghai for Science and Technology and Dezhou College are the top applicants for utility models, which are filed primarily in adaptive clothing, adaptive eating devices, and dressing and undressing.

Incontinence product accessories, which include wetness detectors, show the largest growth (68% AAGR for 2013–2017). This is likely to be due to the ageing global population and an increasing general acceptance and awareness of incontinence products (PR Newswire, 2017). Although this category constitutes only 1.6% of the total dataset, the growth seen indicates future research and development in this technology, including connected to IoT-related concepts (covered below in discussion of emerging applications for self-care). The increase in patenting activity for adaptive clothing accessories (7% AAGR for 2013–2017), including hooks and elastic belts to assist in dressing and anti-slip soles, can be attributed to an increasing commercial awareness, with many major fashion brands like Nike, Tommy Hilfiger, Target, and Zappos collaborating and launching collections of

Conventional self-care assistive technology

6,410

patent families for conventional self-care assistive technology filed across **45 patent offices**

What technologies are involved?

Adaptive clothing
3,186 (50%)

Adaptive eating devices
1,358 (21%)

Incontinence products
825 (13%)

Assistive products for manicure, pedicure and hair/facial care
550 (9%)

Dental care
490 (8%)

Assistive products for sexual activity
57 (1%)

Which are the fastest growing technologies?

Incontinence products have seen the highest growth with an average annual growth rate of **68%**

Filings related to **assistive clothing accessories** grew on average by **7% between 2013 and 2017**

Who is filing?

Applicant sector

Individuals
59%

Corporate
31%

Academia
9%

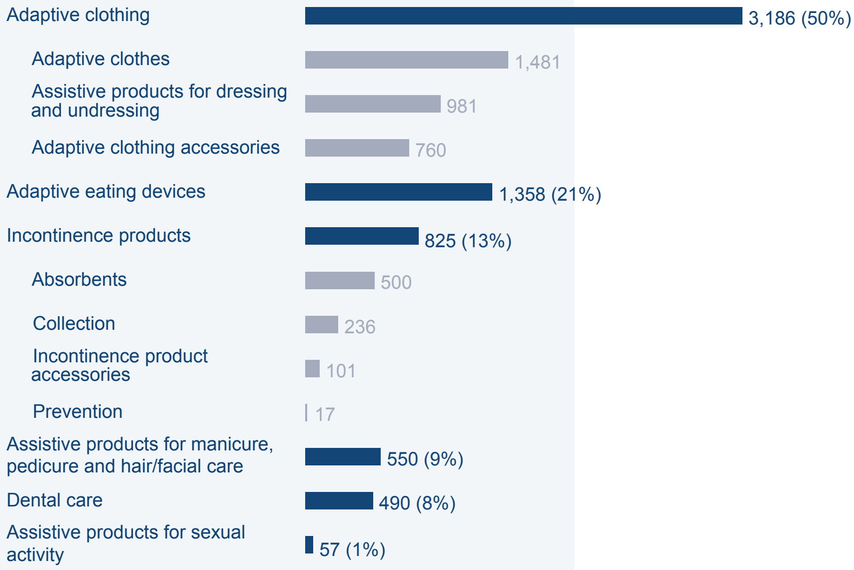
Top patent applicants

Applicant	Patent families
Oji Paper (Japan)	99
Uni-Charm (Japan)	47
Kao (Japan)	35
Panasonic (Japan)	27
Daio Paper (Japan)	26

In this highly fragmented domain, most top applicants are active in health care, but some consumer electronic goods companies feature

Figure 2.68. Overview of patent families first filed for patent protection from 1998 to 2019 for conventional assistive technology for self-care*

Adaptive clothing accounts for half of the dataset



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families. The sub-categories in the self-care area have been defined in line with the description of Self-care given in the International Classification of Functioning, Disability, and Health (ICF) of WHO (World Health Organization, ICF Browser, https://apps.who.int/classifications/icfbrowser) and with help from the ISO 9999:2016 Standard (www.iso.org/standard/60547.html) also included in the Eastin search engine for assistive technologies (www.eastin.eu/en/searches/Products/Iso/09).

Figure 2.69. Examples of adaptive clothing

(a) A garment with zippers for easy access (patent document US6675389B1); (b) a device to tie laces (patent document US7320161B2); (c) a device to fasten a belt using one hand (patent document US20060101623A1)

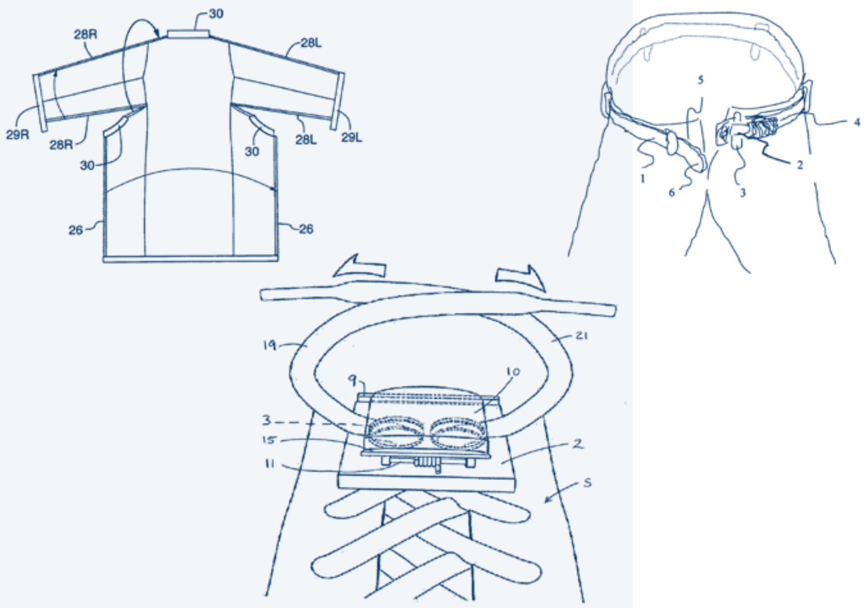
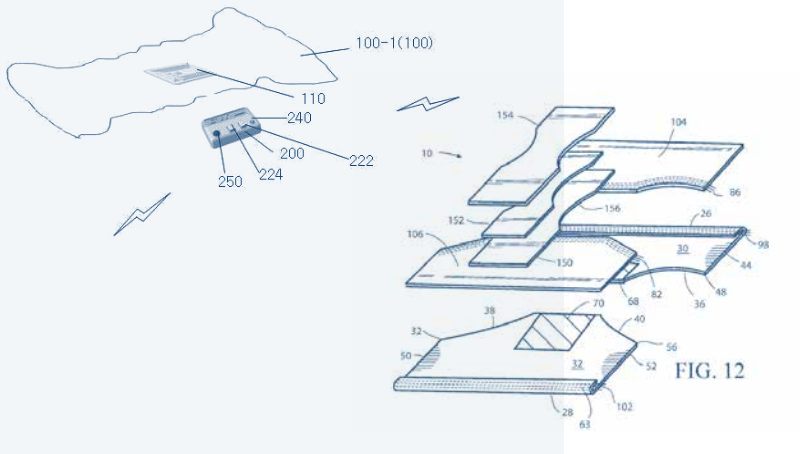


Figure 2.70. Examples of incontinence products

(a) A device that monitors when a baby's diaper is wet (patent document KR2010091612A); (b) a stretchable, disposable absorbent article that has a breathable elastic laminate composed of two layers created using an ultrasonic bonding process (patent document US20170216108A1)



adaptive clothes, including designs without buttons or zips, sensory-friendly and lace-free shoes (Howland, 2019). Among the brands mentioned, however, Nike is the only one to appear in the patent dataset with four U.S. patent applications related to adaptive clothes and accessories.

Geographical distribution

A total of 8,283 patent applications (corresponding to 6,410 patent families[37]) were filed across 45 patent offices. Overall, 91% of the patent families in the conventional self-care dataset are protected in a single jurisdiction, indicating interest in a single (mostly local) market. This is one of the highest percentages of single-jurisdiction patent protection across all of assistive technology.

China, Japan, the U.S. and the Republic of Korea are the leading patent offices, with 40%, 34%, 11% and 11%, respectively, of the conventional self-care patent families including a patent filing with these offices. Even though inventions were filed for patent protection across 45 patent offices, 99.6% of the dataset was filed at the top 20 patent offices, showing there were only a few patent applications at the remaining patent offices (Figure 2.71). There is a noticeable shift in patent filings: filings in the U.S., Europe (including EP and other European countries) and Japan are declining, whereas filings in China and Republic of Korea are increasing.

Inventions related to incontinence products are mainly protected in Japan, followed by China and the U.S., while the top patent offices of filing for adaptive clothing are inverted, with China followed by Japan, and the U.S. keeping the third position. Incontinence collection and incontinence absorbent products have around 16% of inventions filed in two or more jurisdictions, as would be expected with a larger product market.

Only 7% of patent families include a PCT application, with more than half coming from the U.S., Japan and the Republic of Korea, and 4% (268) an EP application. There is a significant decline in EP filings (on average, by 8% each year between 2013 and 2017), which indicates a preference for the PCT over the EPO route for filing related inventions. The main users of the EP route are based in Japan, indicating an intention by Japanese applicants to protect their inventions in Europe.

Looking at the patent filings in the top patent offices, only 8% of Chinese patent applications

Innovation in incontinence products

The ageing population is shifting the commercial market from diapers to adult incontinence products. Previously companies developed incontinence products for multiple users and to address multiple needs; now we see more differentiation, based on diverse individual needs.

Innovation in absorbent incontinence products is rather incremental and typically stems from the (historically) more lucrative diaper industry, such as super-absorbent polymers, using a powder, which, on contact with liquid, turns into a gel. As a result, absorbent products are becoming thinner and more effective. More invasive solutions, such as those that constrain the urethra, are neither popular nor a big part of the market.

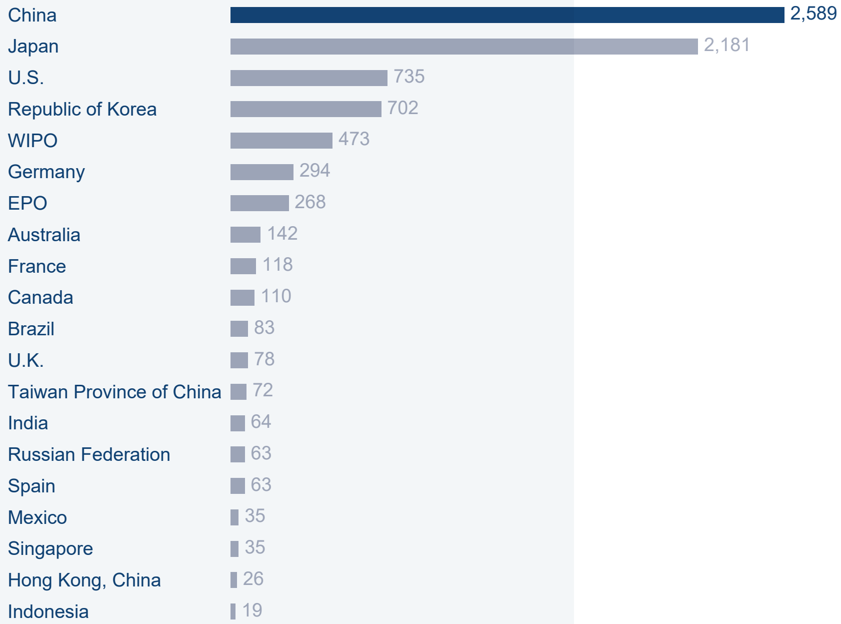
Health monitoring/body-worn monitoring is here to stay, but the question is how this becomes embedded in standard practice. Smart diapers could become part of a wider sensor-based ecosystem – connectivity is helping to shape recent developments.

Fully automatic bladder relief systems, initially developed for air force pilots who are on duty for long hours, is another interesting development. Areas that are likely to be explored in the future include leakage performance and skin health (because of damage from friction). Body-worn devices and occulent devices still need to be improved for women.

Alan Cottenden, UCL

Figure 2.71. Top 20 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for conventional assistive technology for self-care

China and Japan are the leading patent offices, while this is one of the few functional categories where the U.S. ranks third with three times fewer patent filings than Japan



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Figure 2.72. Top 26 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for conventional assistive technology for self-care

Japanese companies comprise the top five applicants, but the top 20 applicants constitute only 6% of the dataset, all with very small patent portfolios, indicating a highly fragmented market

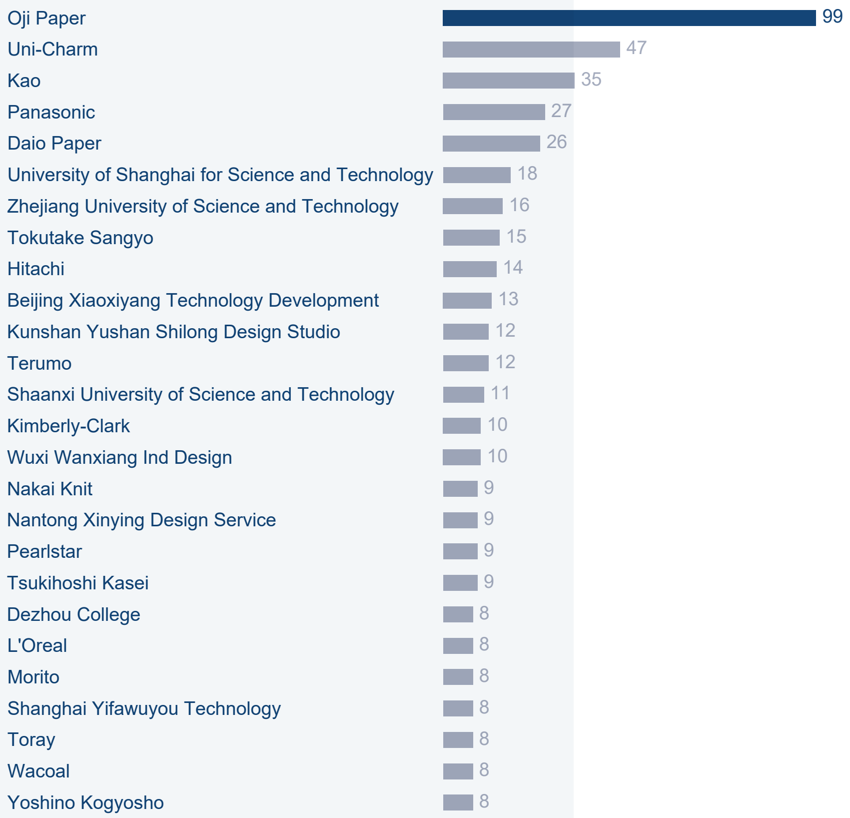
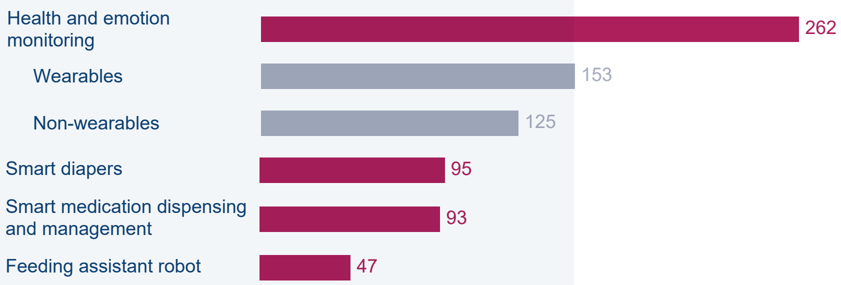


Figure 2.73. Overview of patent families first filed for patent protection from 1998 to 2019 for emerging assistive technology for self-care*

Health and emotion monitoring accounts for over half of the dataset, while smart diapers and medication dispensing and management each comprise almost a fifth of the dataset



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

are filed by foreign inventors, whereas this figure is 41% for U.S. patent applications. Less than 1% of the filings originating from China are also protected in a different jurisdiction (mostly the U.S.), indicating a strong interest in the local market. Japanese patent filings are generally (approximately 90%) protected only in Japan, but around 5–10% are also protected in China, the U.S. and the Republic of Korea.

Australia, Brazil, India, Mexico and the Russian Federation are important growing markets, where patent protection mostly relates to adaptive eating devices and incontinence absorbent products. Turkey and Argentina are new markets, with patent filings after 2013, all from independent inventors, indicating user or local innovation.

Key players

The majority (59%) of patent inventions related to conventional assistive technology for self-care are filed for protection by independent inventors, primarily based in China and Japan. These, together with independent inventors from the Republic of Korea and the U.S., contribute 49% of patent filings. Corporate applicants contribute to 31% of the dataset, whereas universities and public research organizations have only 9% of patent filings. This distribution of patent applicants is similar across different categories, apart from eating devices, where more patents are filed by universities and public research organizations. The large proportion of independent inventors and smaller corporates reflects a simpler technology which is easier to develop without a sophisticated research and development infrastructure. Similarly, the top applicants (Figure 2.72) have small patent portfolios and the top 20 account for only 6% of the total dataset, implying a very fragmented market. The top three independent inventors are Zhao Zhan, associated with the University of Shanghai for Science and Technology (18 patent families), Sogo Takao, affiliated to Tokutake Sangyo Kk (14 patent families) and Nakayama Toshio, working with Panasonic (13 patent families).

Twelve of the top 20 applicants are companies based in Japan, five of them constituting the top five applicants, with Oji Paper well in front as a leading patent applicant in incontinence products, followed by Uni-Charm, Kao Corp, Panasonic, and Daio Paper. This dominance by Japanese companies could be attributed to Japan's ageing population and a corresponding increase in demand for incontinence and other personal care products. Among other leading applicants are Tokutake Sangyo (Japan) and Beijing Xiaoxiyang Technology Development (China), both active in adaptive clothing.

Although many of the top applicants are active in health care, it is interesting to see some consumer electronic goods companies, such as Panasonic and Hitachi, among the top applicants. Hitachi has a business partnership with Unicharm (Kondej, 2009) that led to the development of a suction-based automatic excrement system, while Panasonic's filings mostly relate to similar devices assigned to its subsidiary Sanyo Electric.

The majority of the applications from Chinese universities (including Shanghai University of Science and Technology, with 18 patent families for adaptive eating devices, and Zhejiang Sci-Tech University with 16 patent families) and corporate entities (including Beijing Xiaoxiyang Technology Development, Kunshan Yushan Shilong Design Studio and Wuxi Wanxiang Ind Design) were filed after 2013. Although the overall patent numbers from these applicants are small, they show potential emergence in this area.

Emerging technology

Emerging assistive technology for self-care is more sophisticated than conventional technology, with products using enabling technologies such as AI (machine learning), IoT and connectivity (Zigbee, Bluetooth, WiFi and cloud connectivity), as well as products following the general trend towards wearables and health monitoring. A total of 497 patent applications related to emerging assistive technology for self-care were filed between 1998 and 2019 (Figure 2.73).

Emerging self-care assistive technology

497

patent families for emerging self-care assistive technology filed across **29 patent offices**

What technologies are involved?

Health and emotion monitoring (wearables and non-wearables)
262 (53%)

Smart diapers
95 (19%)

Smart medication dispensing and management
93 (19%)

Feeding assistant robot
47 (9%)

“ **84%** of inventions were filed for patent protection in one jurisdiction, indicating interest is mainly toward individual markets

Which are the fastest growing technologies?

Devices for health and emotion monitoring are areas of recent patenting activity (77% of related applications published after 2010). **Non-wearable** (e.g., smart carpets, mirrors and platforms) and **wearable** (e.g., smart wristbands, virtual reality headsets, smart clothing and insoles) devices grew on average by **38%** and **26%**, respectively, between 2013 and 2017

Who is filing?

Applicant sector

Corporate
50%

Individuals
29%

Academia
20%

Top patent applicants

Google (U.S.)	13
Liuzhou Yiwang Technology (China)	5
National Rehabilitation Center (Republic of Korea)	4
Kimberly-Clark (U.S.)	4
Johnson & Johnson (U.S.)	4

Emerging assistive technology for self-care is a highly fragmented patent landscape, with many different applicants holding small patent portfolios

There are already some smart diapers on the market. However, there is probably limited application for self-care (more so in nursing homes or institutions – but it is more difficult to implement in these organizations). Smart diapers could be impactful for a relatively small group of individuals.

Mandy Fader, UCL

Feeding assistant robots allow the independent development of one of the basic activities of daily living for people with severe motor disabilities, and in this way participate on equal terms in what is a social activity in many cultures.

Giuseppe Fico, Polytechnic University of Madrid

Health and emotion monitoring devices[38] (53% of the dataset) are equipped with smart technologies to monitor physical and mental health. Inventions relating to wearable health and emotion monitoring include smart bands, wide bands (wristbands with various sensors), bracelets, eye wearables, smart clothing (which has functionalities beyond those of conventional adaptive clothing), virtual reality (VR) glasses and smart insoles (e.g., intelligent shoes that monitor foot pressure in order to provide an early warning of health conditions). Some VR applications include cognitive evaluation or heart rate optimization (Figure 2.74). An interesting application are avatars, that is, virtual companions that collect and aggregate health data, identify patterns and anomalies and make recommendations to patients.

Inventions in **non-wearable** health and emotion monitoring relate to smart carpets and mirrors, as well as devices that can be fixed, for example, to walls, carpets, bed sheets, blankets, pillows and walking sticks. Smart platforms are intelligent monitoring systems that collect health and emotion parameters and are connected to a cloud server. Smart carpets have pressure sensors to determine whether the user has been inactive and, if so, alert the service platform or caregiver via wireless communication. Smart mirrors apply affective computing principles[39] and use computer vision and gesture/voice recognition to assess a person's emotional or physical condition, such as identifying fatigue, and provide recommendations and alerts. They may also track, analyze and report on any changes in the user's behavior, voice and habits, and may share this information with caregivers or physicians.

Smart medication dispensing and management devices[40] assist with storing, sorting, reminding and dispensing medicine and generate alarms or notifications to remind the user to take their medicine and alert caregivers in the event of an emergency. Advanced technologies include pill boxes (dispensers) connected to IoT/sensors or that include AI features, such as face recognition, which help manage medication intake (Figure 2.75).

Smart diapers are an evolution from conventional incontinence products, mainly those that address absorption. They have sensors embedded to detect wetness plus connectivity modules (e.g., IoT, Zigbee, Bluetooth, WiFi) to alert the user, caregiver or medical professional via connected devices that either the diapers need to be changed or provide information related to the geolocation of the person wearing the diaper (see Figure 2.76). Smart diapers can also be used for health monitoring and reporting through the automatic analysis of body fluids.

Feeding assistant robots have evolved from conventional adaptive eating devices to execute more complex and diverse tasks.[41] Most of the technology in this category relates to robotic arms (embedding sensors) that pick up food and move it towards the user's mouth (Figure 2.77). Some feeding assistant robots are controlled by BCI/BMI and some can adjust portion size or provide alternative flavors of food following user feedback.

Growth

Patenting activity within this domain is more limited than other areas of emerging assistive technology, but has increased from 4 patent applications in 1998 to 66 documents filed in 2017. This, along with the fact that 77%

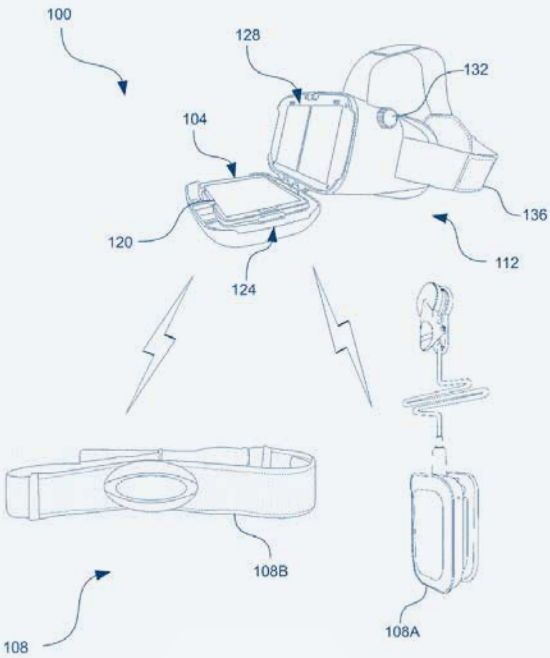


Figure 2.74.

A biofeedback virtual reality system, including heart rate monitors (patent document US10417926B2 filed by Merlin Digital). The person's status is represented in a virtual environment, giving them the opportunity to move to an alternative virtual environment representing "improved" health status

Figure 2.75.

A device that embeds an alarm system and a medicine box, transmitting information when the medicine has been taken to avoid irregular medication intake (patent document CN109044846A filed by Wuxi People's Hospital)

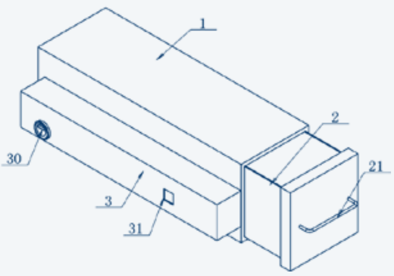


Figure 2.76.

A system that detects urine and feces using a gas sensor (patent document WO2014098690A1 filed by Sca Hygiene Products)

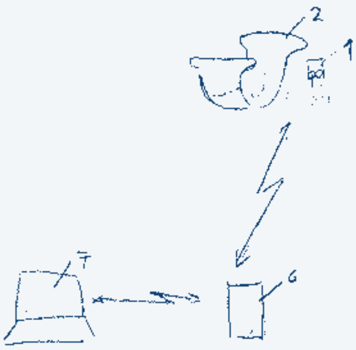


Figure 2.77.

Feeding assistant robot (patent document WO2011126204A1 filed by Korean National Rehabilitation Center). The picking arm has a gripper to pick up food, while the feeding arm with a spoon moves the food towards the user's mouth

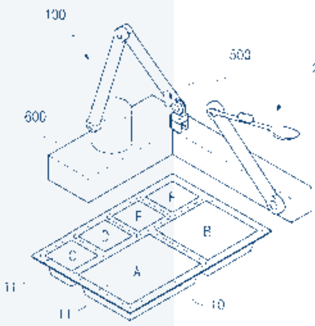
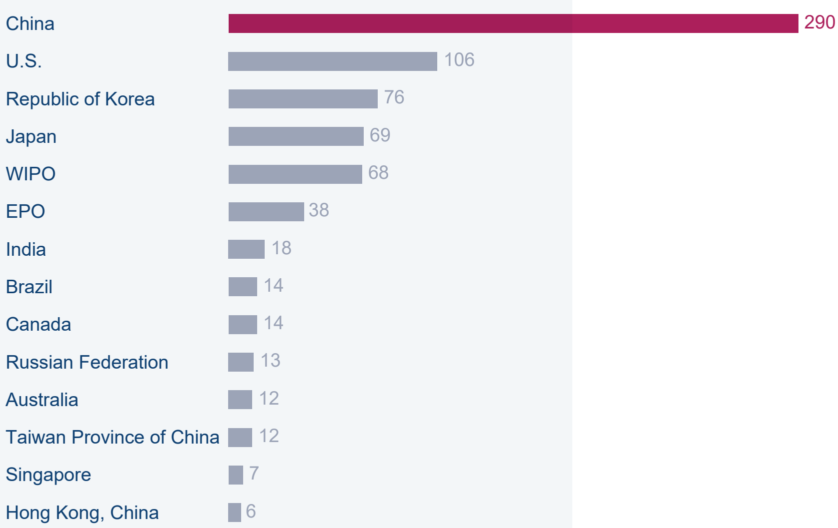


Figure 2.78. Top 14 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for emerging assistive technology for self-care

China leads with 290 applications, followed by the U.S., Republic of Korea, Japan and PCT filings



Note: EPO is the European Patent Ofiice. WIPO represents PCT applications.

of emerging self-care patent applications were filed after 2010, indicates a new and growing field, and an increased commercial interest in technology addressing self-care for older people or persons with disabilities in general. There was significant growth in patent applications seen between 2013–2017, showing an AAGR of 18%. Filing trends are shown in Figure 2.78.

Health and emotion monitoring using **wearable devices** or non-wearable ones is the key area of growth, with 88% of patents published after 2010, and an AAGR of 26% and 38%, respectively, for 2013-2017. Non-wearable health and emotion monitoring devices have seen the highest growth, going from 1 to 22 patents between 2010 and 2017, mainly driven by independent inventors. This reflects also the general interest and trends in the area of wearables and health monitoring (WIPO, 2019). In comparison, smart diapers are a relatively mature technology, with about half the related patents published before 2010.

Geographical distribution

There were 770 patent applications, corresponding to the 497 patent families related to emerging assistive technology for self-care, filed across 29 different patent offices. China, the U.S. and the Republic of Korea are the leading patent offices for filing protection, with 38%, 14% and 10%, respectively, of the 497 patent families identified including a patent application in these jurisdictions. Altogether, 14% of the patent families (68 patent families) include a PCT patent application and 8% (38 patent families) an EP application. This filing strategy, combined with the fact that 84% of patents were filed at a single patent office plus the origin of the inventors (which usually coincides with the jurisdiction of patent filing), indicates a relatively localized market interest from patent applicants.

The U.S. and Japan are two more established patent protection locations, while China and the Republic of Korea are emerging markets. China only started receiving filings in 2006, yet by 2014 annual patent filings in China had surpassed those in the U.S. More than 80% of patent applications in the Republic of Korea and India were published after 2010, indicating that both these markets are emerging, and in the case of the Republic of Korea that it is also a potential innovation center driven by independent inventors and the National Rehabilitation Center in Seoul.

An analysis of the patent filings across different offices shows that patent filings in China account for 58% (290 patent filings) of the patent landscape, and this route has seen a growth in recent activity, with the number of patents increasing significantly from 16 in 2013 to 54 in 2016. In addition, 88% of all China-based patent filings (as a first filing) were filed after 2013.

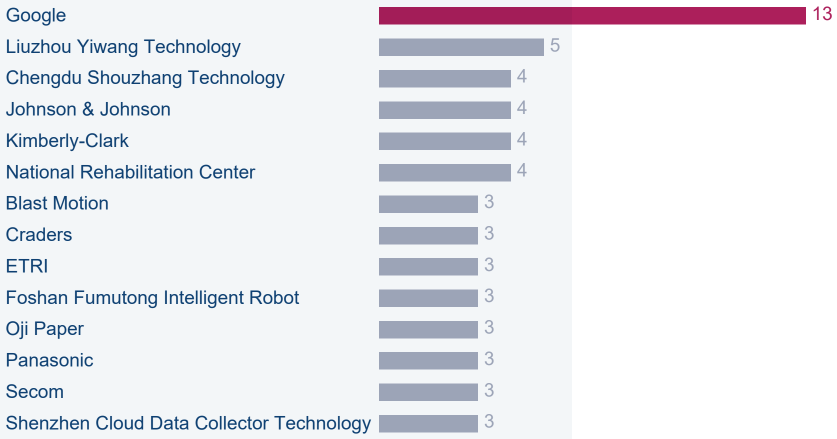
Further, the U.S. accounts for 21% (106 patent filings) of patent filings as a first filing. Patent applications from the U.S. have subsequent filings at about 20 different patent offices, with those of India, Singapore and Hong Kong starting to show a noticeable emerging trend after 2012. The largest contributors of first filings in China and the U.S. are independent inventors, accounting for 26% and 19%, respectively. About 20% of the dataset consists of utility models, with approximately 16% of coming from China and accounting for 28% of the overall filings received in China. The rapid increase in the number of utility models from China after 2010 is predominantly driven by local independent inventors, but remain lower than they are for conventional self-care.

Key players

Emerging assistive technology for self-care is a highly fragmented patent landscape, with a high number of applicants relative to the total number of patents (the top 30 applicants account for only 18% of patent filings) and no noticeably large portfolios. Half of the patenting activity comes from the corporate sector, while independent inventors (mainly from Japan, the Republic of Korea and China) account for 29% of the patent applications, followed by universities and public research organizations (20%).

Figure 2.79. Top 14 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for emerging assistive technology for self-care

The area of emerging assistive technology for self-care is a highly fragmented market with top patent applicants with small patent portfolios – Google is ranked first, with 13 patent applications



Patent applications for smart diapers, medication dispensing and feeding assistant robots are mainly filed by independent inventors. A high number of corporate players are active in smart diapers (such as U.S.-based Kimberly-Clark and Procter & Gamble and Japan-based Oji Paper and Panasonic) and medication dispensing and management, led by China and U.S.-based companies. There are two leading applicants for feeding assistant robots: SECOM (Japan) and National Rehabilitation Center (Republic of Korea). China-based companies Liuzhou Yiwang Technology, Hiser Medical and Wuhan Fengpu Technology are particularly active in developing non-wearable health and emotion monitoring devices.

Universities and public research organizations are particularly active in the development of feeding assistant robots, accounting for nearly half of the patent applications in this category. The Electronics and Telecommunications Research Institute (ETRI) in the Republic of Korea is the leading university filing in medication dispensing and wearable technology for health and emotion monitoring; there are an additional 15 universities filing in this category. Universities from China and the Republic of Korea (four from each location) are also active in smart diapers.

China, with 10 applicants in the top 30, is by far the most represented location in the top portfolios list, followed by the U.S., the Republic of Korea and Japan (five applicants from each).

Most of the top 10 patent applicants have filed patents also in jurisdictions outside their headquarters, indicating possible market expansion beyond the traditional markets in the U.S., China and Europe.

Google is the top portfolio holder (Figure 2.79) and the only company to have more than 10 patent applications, all in the area of wearables for health and emotion monitoring (9 filed in 2013 alone). There appears to be an increasing number of players willing to enter the field of wearable health and emotion monitoring. Google's patent portfolio includes smart contact lenses for health monitoring. The company has also acquired Fitbit (a leading wearables company), which could expedite Google's activity in health monitoring devices, which is an overall wellness and fitness trend. This could indicate a potential interest in more high-tech devices and a consolidation of product markets. Further, with a continuous evolution in health monitoring technology, consumer electronic goods companies could decide to move into preventive health, wellness or fitness coaching to cater for more customers. (Issues related to health care monitoring software that can be considered a medical device are addressed in Chapter 4.)

Summary

Patent filings in conventional assistive technology for self-care are consistent in recent years, with no net growth and a decline in filings after a peak in 2015. China is the biggest contributor of patenting activity in this patent landscape, followed by Japan, the U.S. and the Republic of Korea. A majority of patent applications are filed by independent inventors, with less contribution from corporate applicants. This is because the relatively simple technology involved allows for more independent inventors to be active in this area. The area of conventional self-care assistive products is highly fragmented, with the top 20 applicants having a relatively low number of filings, accounting for only around 6% of the total dataset.

Emerging assistive technology for self-care is a new and growing field. Wearable and non-wearable health monitoring devices, which help contribute to independent living and convenient health monitoring, are the main areas of growth. Advances in AI and communication technologies have led to interest from large technology companies such as Google. This may help, in both the short and long term, to consolidate the patenting activity and markets and can offer scalable solutions (for mass use) with increased connectivity and real-time monitoring on smartphone and tablets for preventive care. On the other hand, smart diapers, medicine dispensing and management, and feeding assistant robots are likely to be more focused on simple, low-cost manufacturing for improved accessibility and affordability. China, the U.S. and the Republic of Korea are the leading markets and origins of patenting activity within a very fragmented patent landscape. Whereas activity in Japan is declining, India appears to be seen as an emerging market, based on recent patenting activity.

The challenge for wearables

The big challenge in health monitoring is accuracy. With the use of an increased number of connected devices we may have a more global assessment, yet not necessarily an accurate one. Existing wearable devices provide limited insight and are more wellness driven. Their medical utility is currently not well defined. While their output is often validated from a commercial standpoint, this is not the same as validation for medical use. Medical validation requires testing designed to answer specific questions with peer review and public dissemination of the results. Thus, for medical use, data standardization and analytic tool validation issues remain; however, active research in this area should solve these issues and provide greater insight, leading to commercial applications, foremost to manage medical conditions where lower tolerance for inaccuracy in measurements would be acceptable. The first to incorporate accurate and medically validated algorithms will be a market leader.

Matthew Smuck,
Stanford University

Implications for end-users

The categories that dominate conventional assistive technology for self-care are related to products facilitating self-sufficiency and independent living, namely, adaptive clothing, adaptive eating devices and incontinence products. Adaptive eating devices and dental care are moving towards robotic devices with complex and diverse functionalities. Incontinence products, especially those addressing collection and absorption, are evolving towards having "smart" features, enabling qualitative and quantitative monitoring of body fluids and the notification of a caregiver or doctor. Smart diapers, for instance, can also monitor health through automated analysis of body fluids or even allow for geolocation of a user who could be at risk of wandering. This trend is also observed in adaptive clothing, which embeds sensors, IoT and AI to enable health and emotion monitoring. Pill boxes (dispensers) are being connected to IoT/sensors or contain AI systems that allow the patient, doctor or caregiver to monitor medication intake. The more complex technologies address disabilities beyond cognitive ones. The future of medication management and dispensing seems to be pet and companion robots with a range of functionalities (health and emotion monitoring, training, lifting, diagnosing, playing and so on). Medication management is also evolving towards smart platforms (non-wearable health and emotion monitoring) and smart nursing platforms (see Section 2.3, Environment). The general trend in fitness and wellness areas related to health and emotion monitoring are reflected in the health and emotion monitoring through wearables and non-wearables in assistive technology, contributing to safe, self-sufficient and independent living.


21 C

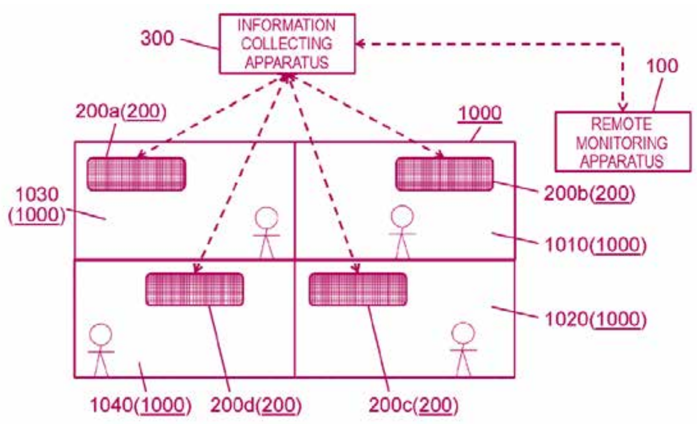
Smart nursing care technology for safer, independent living

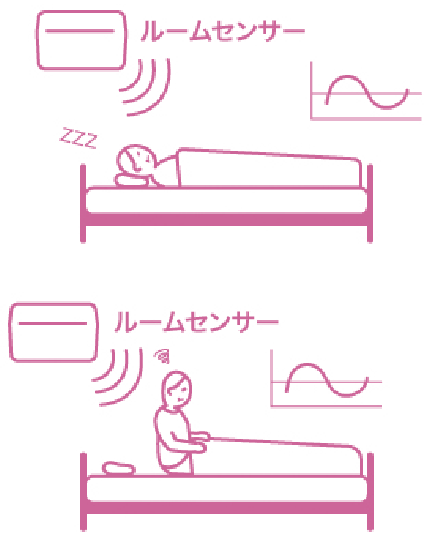
By combining its familiar nursing care product technology with AI, Panasonic is creating a new style of digital nursing care using sensors and Internet of Things (IoT).

Collective dwellings such as facilities for the elderly are the focus for the Remote Care System for Multiple Dwelling Houses (US patent 9866402). This system supports non-intrusive independent living by carrying out remote monitoring based on information from a sensor incorporated in home appliances, such as air conditioner units or rice cookers. A sensor in the electrical appliance collects information on movement, indoor and outdoor temperature, humidity and sunlight exposure, and this is periodically transmitted to a remote monitoring apparatus. The data are analyzed and the resident's safety can subsequently be confirmed, or care workers otherwise alerted. The system can also remotely control the domestic appliance to suit the conditions, determined by the information transmitted from the sensor and individual requirements of the resident, such as sensitivity to heat or cold.

To develop nursing care service support platforms, Panasonic is collaborating with 15 companies, including small and medium-sized manufacturers that provide tools, such as nursing care records, sensors, nurse calls, vital signs and walking assistance robots. "In these overall systems, we will obtain patents for the parts that Panasonic will be responsible for, and protect its role," explains Yoshiaki Tokuda, Director of Intellectual Property Center, Panasonic Corporation. "On the other hand, we may provide our patents for the use of other companies that participate in the overall system. Panasonic will be selective of who will be participating, and provide our patents to protect those participants, to ensure the quality and safety of the system."

Case study by Panasonic





2.7 Vision

Visual impairment affects a person's eyesight to varying degrees. It can be related to any of advancing age, birth defects, genetic mutation, nutritional deficiency, eye injury or infection. According to an estimate by the World Health Organization, at least 2.2 billion people worldwide have some form of visual impairment, including 253 million people who are blind or have moderate to severe visual impairment (WHO, 2019). While there is a trend toward reduction of age-related blindness, the number of persons affected by visual impairment is increasing due to the growing aging world population (Bourne et al., 2017).

Conventional technology

Various conventional aids and devices help people overcome visual impairment or poor vision (prescription spectacles, magnifiers or color filters) or a complete loss of sight (braille devices, tactile devices and interfaces). In addition, other related interactive devices enable greater accessibility and interaction.

A total of 8,133 patent families related to conventional assistive technology for visual impairment were identified (Figure 2.80). ***Spectacles*** (***long*** and ***short distance***, ***low vision*** and ***shield protection***) is the category accounting for over half (52%) of the dataset. This indicates that the main commercial interest in this functional category is in developing long- and short-distance spectacles, a need affecting a great part of the world's population (Bourne et al., 2017; WHO, 2019).

Some recent patent filings discuss the use of smart adaptive lenses, which alter their focal length electronically by identifying eye conditions. While most discuss the design aspects of these lenses, aimed at improving progression length (in progressive focus spectacles) and user customization (using free-form manufacturing techniques (see Sayers, 2014)), some recent inventions also refer to the use of eye muscle sensing techniques and other sensors to adjust the focus of the spectacles (Figure 2.81). Such inventions indicate optical manufacturers shifting interest towards miniaturized and smart lenses, and a transition to emerging technology for vision.

The second biggest category in conventional vision assistive technology is **tactile devices**, with related inventions accounting for 28% of the dataset. They mainly refer to braille and tactile screens, offering improvements to functionality and reducing their cost and complexities, such as using memory alloys for a braille display instead of pins or protrusions. Refreshable braille displays connected to computers and generating braille output from any compatible electronic file are a good example of such efforts, reducing the need for bulky paper-braille devices and improving usability. The use of braille is also being expanded to mobile and smartphones, with software-based interfaces and hardware accessories enabling vision-impaired users to control these devices via braille input (Figure 2.82). Several patent filings relate to braille displays being used in combination with e-book readers and IoT-connected braille displays, or using machine vision to convert printed media into braille.

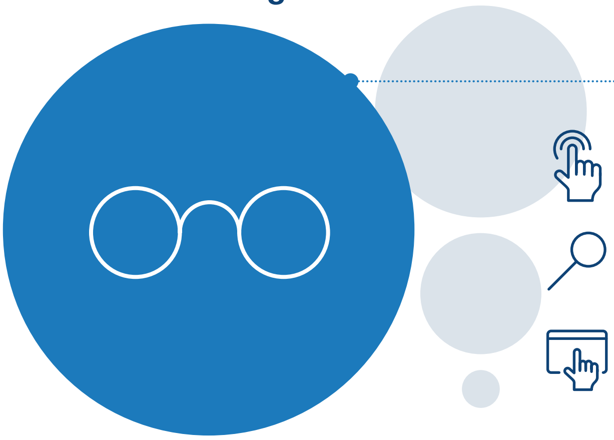
Patenting activity in the field of **magnifiers** (16% of the conventional vision dataset) shows that magnification devices are now aimed at customization to different scenarios and applications. Optical magnifiers (handheld, stand-mounted, clip-on or spectacle mounted) have been available for a long time to support the vision of persons with weak eyesight. They are relatively inexpensive, portable and easy to use (Figure 2.83). Recent devices focus on integrating magnifiers with other personal care products and devices, such as nail-clippers and pens, or on facilitating the use of mobile phones. Similarly, with the widespread adoption and availability of computing devices, mobiles, smartphones and digital cameras, digital magnifiers (that mostly use a camera to capture the scene and magnify it digitally) are also becoming prominent. Personal digital magnifiers are portable devices, similar to smartphones, which the user can use in almost any scenario and condition. Some

Conventional vision assistive technology

8,133

patent families for conventional vision assistive technology filed across **53 patent offices**

What technologies are involved?



Spectacles
4,251 (52%)

Tactile devices
2,241 (28%)

Magnifiers
1,329 (16%)

Interactive products
396 (5%)

> **24%** of conventional vision-related inventions are **filed for protection in more than one jurisdiction**, indicating applicants' interest in several markets

Which are the fastest growing technologies?

Filings related to **interactive products** marked an average annual growth rate of **27%** between 2013 and 2017

Filings related to **tactile devices** increased by an average of **14%** between 2013 and 2017

Who is filing?

Applicant sector

Corporate
54%

Individuals
35%

Academia
10%

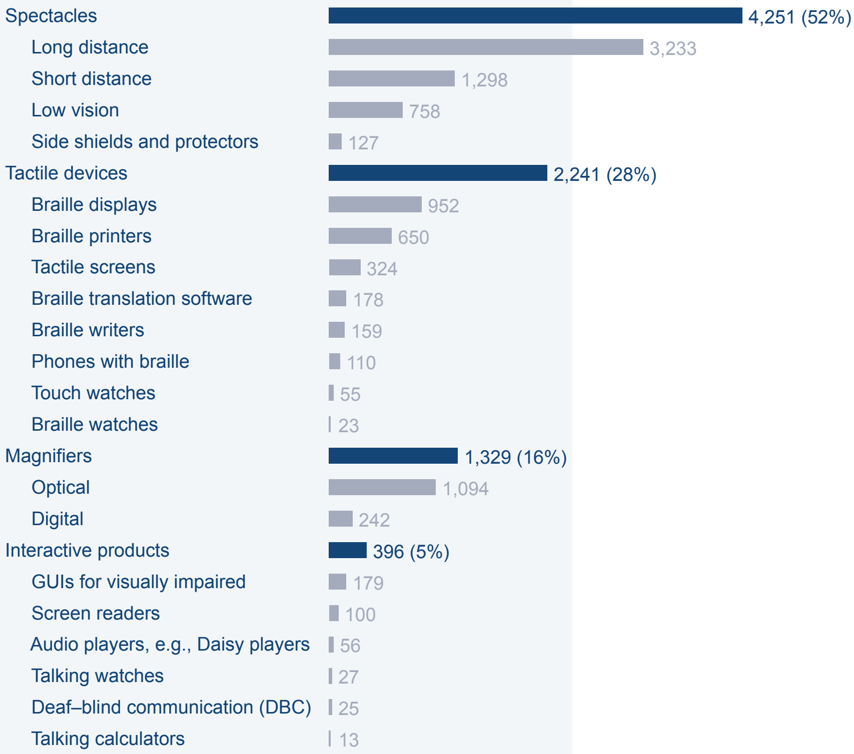
Top patent applicants

Seiko Group (Japan)	158
Essilor (France)	140
Hoya (Japan)	129
Johnson & Johnson (U.S.)	108
IBM (U.S.)	68

Major optics manufacturers are researching advanced technologies to develop specialized electronic lenses. Players from the mobile and computing industries are innovating mainly in the areas of tactile devices and interactive products.

Figure 2.80. Overview of patent families first filed for patent protection from 1998 to 2019 for conventional vision assistive technology*

Over half (52%) of patent families relate to spectacles



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Figure 2.81.

Johnson & Johnson's patent documents discussing adaptive focal lengths (EP2687898A1) using eye muscle sensing techniques and battery management (US20160124248A1) by sensing when the eye is closed for long periods

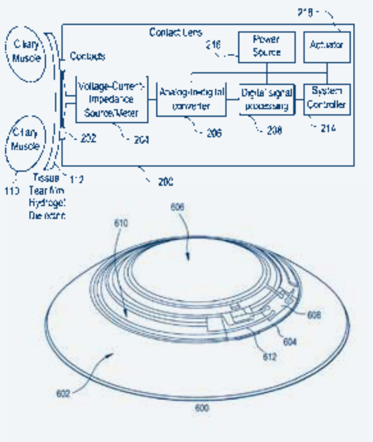


Figure 2.82.

Patent documents filed by BOE: (a) CN107067893A on braille displays using a thermosensitive layer, and (b) CN109445128A on spectacle lenses that automatically adjust focal length according to lens conditions

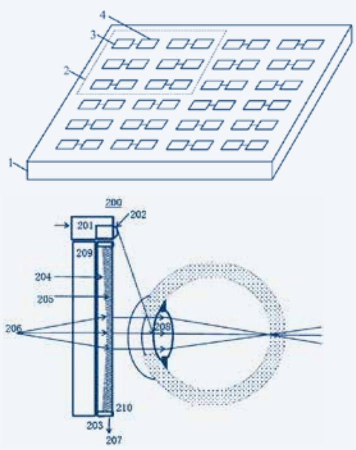


Figure 2.83.

Nail clippers (patent document CN104757771A), pens (CN202934996U) and mobile phone screen covers (CN201550154U) with magnification optics

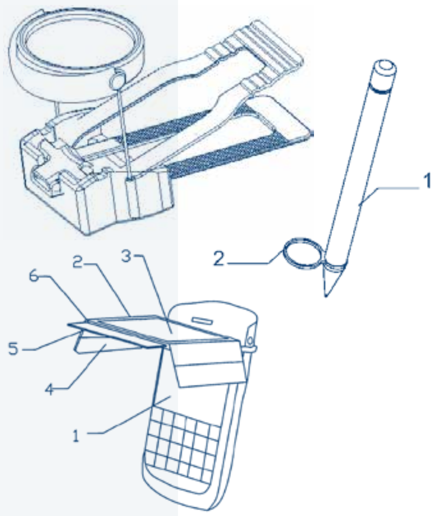
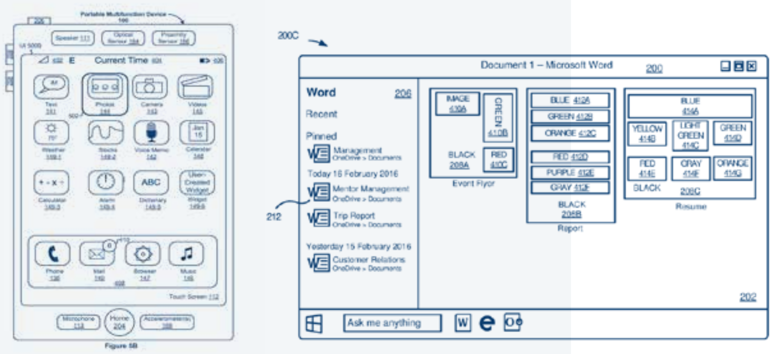


Figure 2.84.

(a) User interface accessibility for visually-impaired persons using audio feedback (patent document US20130311921A1 filed by Apple). (b) The color schemes in an application interface are adjusted to compensate for visual impairment (patent document US20170358274A1 filed by Microsoft)



of these also have illuminating functions to help people read and see clearly in low-light conditions. Examples include electronic desktop magnifiers and portable electronic video magnifiers.

The area least represented is **interactive products** (5% of the dataset), with inventions related to improvement in their usability and control (Figures 2.84 and 2.85). Some of these patents discuss magnifying the user interface for ease of readability, while others discuss using custom icons and navigation features. Several patent applications filed by Apple relate to customizing the touchscreen interface using gestures and icons and the audio interface.

Growth

Patent filings in conventional vision assistive technology have been gradually increasing, with 61% of the dataset's patent filings after 2010 and an AAGR of 5% from 2013 to 2017. Looking at the different categories within vision, the highest AAGR in the same period is observed in the smaller dataset related to interactive devices at 27% AAGR, followed by tactile devices with 14% AAGR. It is worth noting that within these main categories some sub-categories show a high AAGR for 2013–2017, such as **screen readers** (52%), **phones with braille** (51%) and **audio players** (46%). Filings in **braille displays**, the largest sub-category in the field of interactive products, have grown since 2014, largely due to the activity of independent inventors, who account for almost a third of patent filings since 2014.

Geographical distribution

A total of 15,777 patent applications corresponding to the dataset's 8,133 patent families related to vision assistive technology were filed for patent protection across 53 different patent offices[42] (Figure 2.86), with China receiving most patent filings. Overall, the top 10 patent offices were selected for patent protection by almost 96% of all patent families, indicating that these are the main markets, despite the breadth of patent protection.

> Even though the World Blind Union has programs in place to improve the availability of low-cost braille display devices, many refreshable braille devices remain expensive.

Martine Abel-Williamson, World Blind Union

Approximately a quarter of conventional vision-related inventions are filed for protection in more than one jurisdiction. This shows a greater interest in protecting inventions in several markets than is seen for the other functional categories. The top applicants that have filed for patent applications in three or more countries are Essilor International, Hoya Corp, Johnson & Johnson and Seiko Epson, all global leaders in optics manufacturing.

Looking at the origin of innovation in the field, 41% of the patent filings come from China-based inventors, 18% from Japan, 14% from the U.S., 9% from the Republic of Korea and 4% from Germany. Resident filings account for a majority of filings in Asia: 81%, 71% and 62% of filings in China, Japan and the Republic of Korea, respectively, are from local inventors, whereas this is comparatively lower in the U.S., where 49% of patent applications are resident filings.

Nearly half (45%) of the patent applications filed in China were filed between 2013 and 2017, with an AAGR of 6%. By comparison, filings in the U.S. and Japan in this period decreased each year by an average of 6% and 5%, respectively. Germany and India recorded the highest growth rate in patent filings during 2013–2017, at an AAGR of 25% and 14%, respectively.

A PCT application is included in 17%, and an EP application in 14% of the dataset's patent families. Patent filings under the PCT and EPO followed similar trends until 2014, when PCT filings surpassed EP filings, mainly as a result of fewer EP filings by U.S. and Japanese patent applicants.

Key players

The top four patent applicants – Seiko Epson, Essilor, Hoya and Johnson & Johnson – are major manufacturers of optical products,

Figure 2.85.

Patent documents filed by Samsung (a) KR2009032635A, showing a braille keypad for a mobile phone, and (b) EP2746925A2, showing a mobile interface that converts to a braille keypad

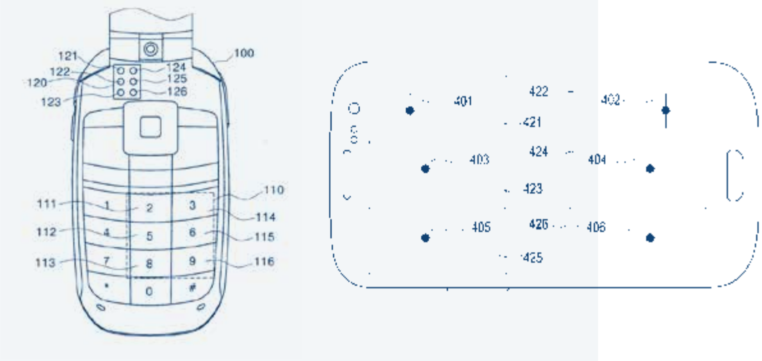
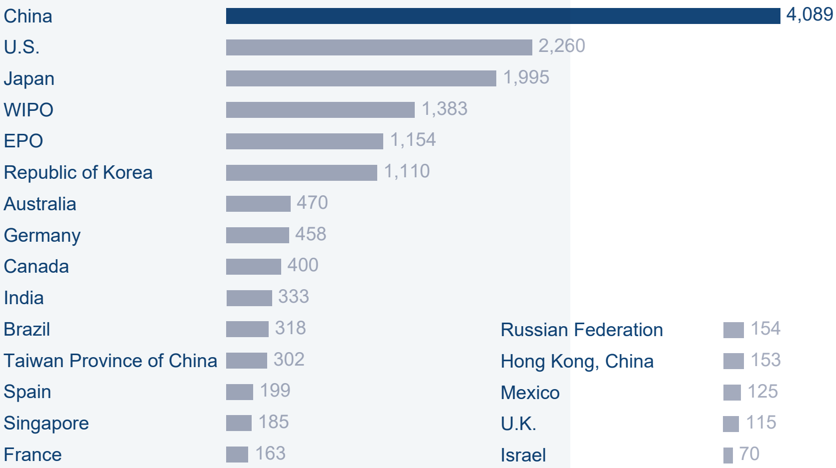


Figure 2.86. Top 20 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for conventional vision assistive technology

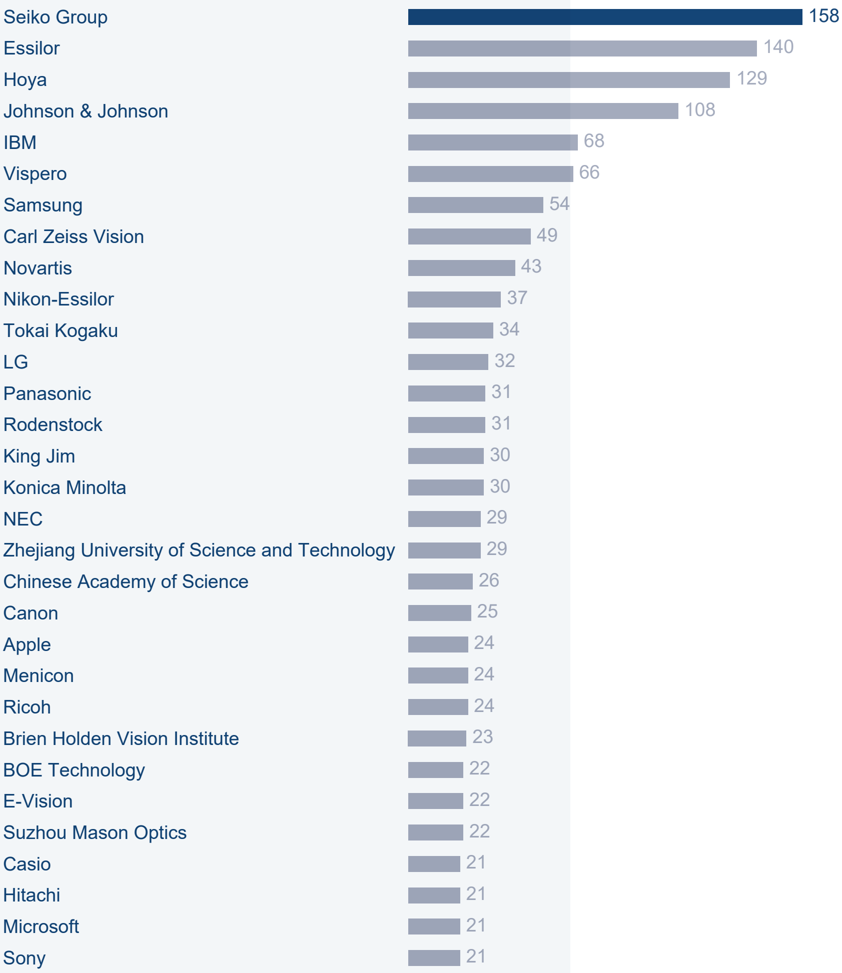
China is the leading office, with 4,089 patent applications, nearly double the patent applications filed in either the U.S. or Japan, ranked second and third, respectively



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Figure 2.87. Top 31 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for conventional vision assistive technology

This shows a well-distributed patent landscape that is not dominated by the top players. The top five applicants comprise two Japanese companies, two U.S. companies and a French one, Essilor International, the second-top applicant



particularly ophthalmic lenses and spectacles. Aligned with this, their patent applications are related to spectacles, mostly long-distance ones (almost 78% of Essilor's documents relate to long-distance spectacles). Top player Seiko Epson is also mainly filing in the area of long-distance spectacles and braille printers.

Several major players from the computing and electronic goods domain, including Apple, IBM, LG, Microsoft and Samsung, are present among the top patent applicants. IBM mainly filed applications related to screen readers and braille displays. Apple and Microsoft have been mainly filing in the domains of graphical user interfaces and tactile screens, primarily focused on user devices such as mobile phones and personal computers. Casio Computers filed most (17 out of 21) of its patent applications during 2015–2017, all in **braille printers**. Mobile phone manufacturers LG and Samsung (based in the Republic of Korea) and Japanese electronics manufacturer Kyocera lead in filings for phones with braille, including phones with keypads featuring braille characters, and smartphone interfaces with software converting the touchscreen to a keyboard in the design of a braille keyboard.

Until 2005, inventive activity was primarily driven by optics manufacturers and focused on long-distance spectacles. Over a quarter of the patents up until 2005 were from independent inventors; the majority (62%) of these related to optical instruments, with approximately a quarter focused on braille and tactile devices. Between 2005 and 2012, almost 41% of patents were filed by independent inventors, whereas filings from the top 20 corporate players amounted to just 14%.

From 2013, several Chinese players have emerged among the top patent applicants, in particular, Zhejiang University of Science and Technology (focusing on braille devices) and BOE Technology Group (focusing on braille and long-distance spectacles).

Looking at the profile of patent applicants, patenting activity is led by commercial players (54% of applicants). Nearly a quarter of these are based in Japan and China, followed by companies from the U.S. (19%). Only on 80 patent filings commercial entities feature as co-applicants with universities and public research organizations, denoting a very low level of collaboration in developing these technologies. These collaborations are mainly in the field of long-distance spectacles (34 patent families). Suzhou University of Science and Technology collaborated on five of these, mostly with Suzhou Mason Optics and related to progressive multifocal lenses and therefore also short-distance spectacles. Novartis is also collaborating in the development of long-distance spectacles, with two patent families each in collaboration with the Brien Holden Vision Institute and Vision Cooperative Research Centre (both in Australia). Overall, Essilor has most collaborations with universities or public research organizations (six, including CNRS and Wenzhou Medical University) in the domains of long-distance spectacles, and also in multifocal and low-vision spectacles.

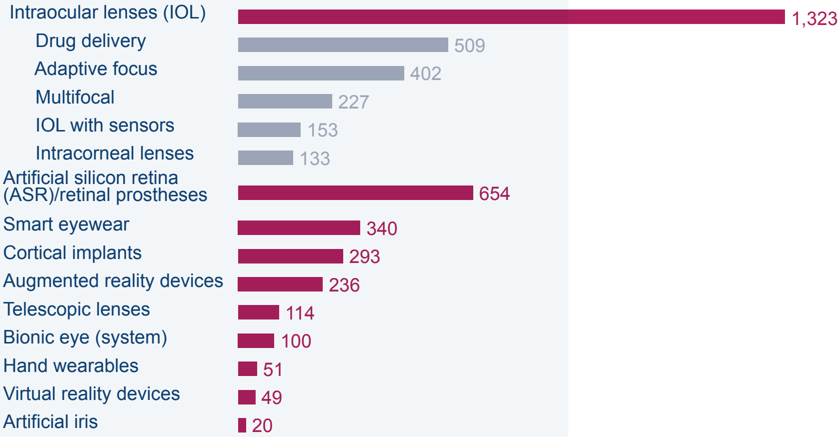
Independent inventors own a considerable proportion (35%) of the documents, indicating that these applicants are influencing the technical development and growth of patents in this area. Of these 2,827 documents, China accounts for 54%, followed by the Republic of Korea at 12%. Almost 37% of the patent applications for spectacles filed during 2013–2017 are from independent inventors, and relate to progressive focus lenses. Independent inventors also lead filings in **optical magnifiers**, audio (DAISY) players, ***talking calculators*** and ***talking watches***.

The patenting activity of universities and public research organizations is led by Chinese academia, which accounts for almost two-thirds of related patent applications, including Zhejiang University of Science and Technology (29 patent applications), Shandong University of Science and Technology (11 documents) and Zhejiang University (11 patent applications). Brien Holden Vision Institute in Australia is one of the leading academic filers, with 23 patent applications.

The top 30 patent applicants account for 16% of the patent dataset with relatively small patent portfolios (Figure 2.87). This, paired

Figure 2.88. Overview of patent families first filed for patent protection from 1998 to 2019 for emerging vision assistive technology*

The two categories with intraocular lenses (IOLs) account for 43% of patent families, and other ocular implants for 35% of patent families



*Patent documents can be classified in multiple categories and sub-categories, so the sum of patent families in sub-categories can exceed the total in the main category and the sum of the main categories can exceed the overall number of related patent families.

Figure 2.89.

(a) Electromyographic sensors in IOLs are used to adapt focus based on eye muscle movement (patent document US20180031865A1 filed by Elwha). (b) Ultrasonic sensors embedded in the IOLs detect the distance of an object from the user's eyes and then adjust the focus of the IOL (patent document US20190282399A1 filed by Verily (Google Life Sciences))

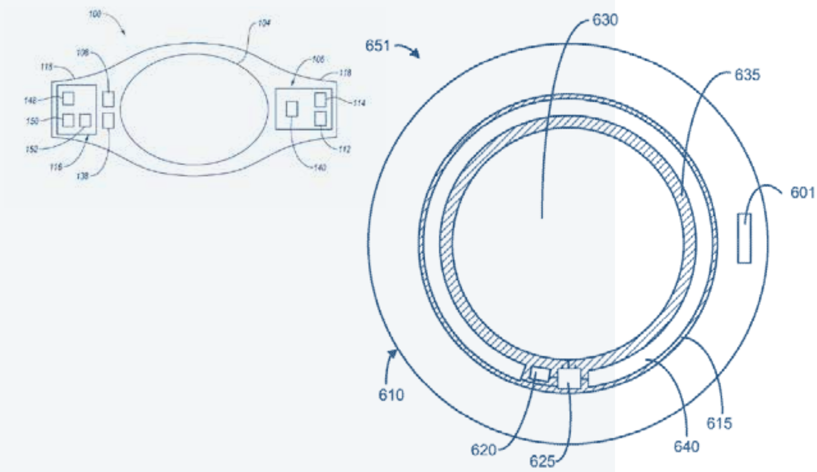


Figure 2.90.

A visual prosthesis (patent document US10105263B2). It switches to a low-power mode when the touch sensor detects that the spectacles are not being worn

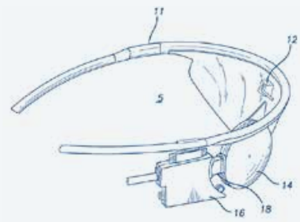


Figure 2.91.

A detection device that uses an ultrasonic sensor on the spectacles to measure the distance between an obstacle and the user (patent document KR1662914B1). When this reaches a specific value, an alarm sounds to alert the user

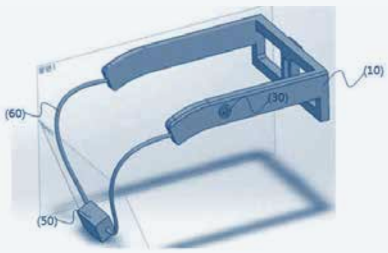
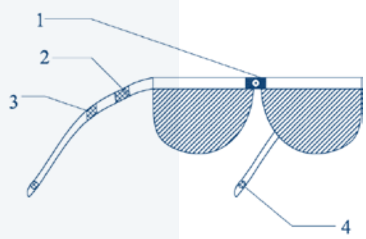


Figure 2.92.

Auxiliary spectacles to assist with crossing roads (patent document CN108764150A). A color-depth camera and computer vision are used to detect patterns, such as pedestrian crossings, and their distance from the user. Audible information is relayed via an earphone or bone conduction earphone



with the distribution of the dataset among industry, universities and public research organizations, and independent patent applicants (who account for more than a third of the documents), indicates that the overall patent landscape for conventional vision assistive technology is well distributed and not dominated by the top players.

There are 59 documents co-owned by two or more of the top players. Seiko Epson collaborated with King Jim, a Japanese office supplies company, to develop braille printing technology, and with Hoya to develop long-distance spectacles. Subsequently, Seiko Epson sold its eyeglass and lenses business to Hoya in 2013 (Hoya, 2020), and ever since had only three patent filings in 2014 related to tactile screens, indicating that Seiko Epson, the top patent applicant in this field, exited the space after 2014. Several other Japanese players have reduced their patent filings in recent years: Canon, Hitachi, Konica Minolta, Menicon, NEC and Panasonic. Chinese players Zhejiang University of Science and Technology and BOE Technology Group, and Japanese company Casio are the only applicants among the top 30 to have filed the majority of their patent applications since 2013.

The top patent owners in braille displays, Vispero[43] and Samsung, have not filed in the tactile devices category in recent years. Samsung filed 13 of its 18 patent applications, most relating to the design of braille displays, between 2006 and 2012. Similarly, inventive activity from major corporates with regard to ***GUIs for the visually impaired*** and screen readers (including Apple, IBM, Microsoft, Ricoh, Samsung and Sony) has also been decreasing and their focus seems to be moving toward other tactile-based technologies.

Emerging technology

Emerging assistive technology for vision includes both implantable (requiring surgery or other medical procedures) and non-invasive technologies. In total, 3,036 patent families related to emerging vision assistive technology were identified (Figure 2.88).

Although ocular implants (such as intraocular lenses or artificial lenses) have been known and used for decades to treat eye impairments like cataract or myopia, the implant technologies considered here have more advanced functions. Of the total dataset, 44% relates to **intraocular lenses (IOLs)**, constituted mostly of filings in **drug delivery**, **adaptive focus** and **multifocal IOL devices**. Several techniques are addressed in patents, including lens assemblies, mechanical actuators, fluid chambers, electronic sensors and circuitry to adaptively alter the focal length of lenses based on conditions and user eyesight requirements. In some instances, sensors are used to detect strain, movement, light intensity and distance of objects and subsequently adjust the lens and therefore the focus of the IOL (Figure 2.89). Almost a quarter (23%) of inventions related to **IOLs with sensors** also address **adaptive focus IOLs**.

One of the issues some IOL inventions try to address is sustained delivery of drugs into the eyes. To serve this purpose, there are IOLs that enable slow release of drugs and have drug reservoirs that can be refilled for subsequent drug provisioning during eye surgery. Patents also discuss IOLs made of biocompatible materials that disintegrate as the drug is slowly released in the eyes; something that is highly useful during eye surgery.

The filings in IOL are followed by the ones related to **artificial silicon retina (ASR)**, accounting for 21% of the dataset, followed by **smart eyewear** (11%) and **cortical implants** (nearly 10%). If we group together the different categories we can view them from the perspective of whether they are implantable (hereafter referred to as “ocular implants”) or not (hereafter referred to as “wearable, non-invasive technologies”).

Ocular implants (beyond IOL) range from retinal prostheses (also known as artificial silicon retinas) and cortical implants, to bionic eyes. Artificial silicon retina (ASR) or retinal prostheses (see Figure 2.90 for an example) is the most protected technology within emerging vision assistive technology after IOL. ASRs/

Emerging vision assistive technology

3,036

patent families for emerging vision assistive technology filed across **44 patent offices**

What technologies are involved?

Intraocular lenses (IOL)
1,323 (44%)

Artificial silicon retina (ASR)/ retinal prostheses
654 (22%)

Smart eyewear
340 (11%)

Cortical implants
293 (10%)

Augmented reality (AR) devices
236 (8%)

Telescopic lenses
114 (4%)

Artificial eye
100 (3%)

Hand wearables
51 (2%)

Virtual reality (VR) devices
49 (2%)

Artificial iris
20 (1%)

Which are the fastest growing technologies?

Filings related to **intraocular lenses (IOL) with sensors** increased by an average of **48%** between 2013 and 2017

In 2013–2017, the average annual growth rate was **38%** for filings related to **augmented reality (AR) devices**, and **35%** both for **artificial silicon retina (ASR)/retinal prostheses** and **smart eyewear**

Who is filing?

Applicant sector

Academia
24%

Corporate
58%

Individuals
16%

Top patent applicants

Second Sight Medical (U.S.)	223
S. Fyodorov Eye Microsurgery Federal State Institution (Russian Federation)	159
Johnson & Johnson (U.S.)	130
Allergan (Ireland)	101
Alcon (Switzerland)	80

The top 10 applicants account for **27%** of the domain's patent families, indicating a market concentration to these players.

retinal prostheses mainly aim to provide light intensity control and neural stimulation. The technologies discussed in these patent documents improve these implants by ensuring that the visual perception of a scene is efficiently conducted and transmitted to the brain or other circuitry, thus improving visual acuity. Some technologies also focus on widening the field of view (the area visible through the eyes) so that users can get a more realistic feel for their surroundings.

Cortical implants, useful for people with damage to the neural pathways transmitting visual information from eyes to brain, account for about 10% of patent filings in the field of emerging assistive technology for vision (293 documents). These inventions aim to improve the connection between the brain and the implant, the design of visual sensors (cameras) and the stimulation signals to make the visual sensing more real-time and detailed. Patents related to **bionic eyes** majorly address controlling the floating or undesired movement of bionic eyes, reducing toxicity (with the use of biocompatible and porous materials) and enhancing the aesthetics.

Wearable, non-invasive technologies include worn, unworn or other portable devices that do not require surgery to address visual impairment. These include augmented and virtual reality devices and eyewear with smart features, such as scene and object recognition or machine learning, to convey visual information in an enhanced or transformed manner. Smart eyewear (340 patent families) is the most protected technology within this area, and scene recognition is a prominent technology. This can be used to help visually-impaired users navigate, for example, with positioning and obstacle sensors (Figures 2.91 and 2.92), with information conveyed to blind users through bone conduction technology using audio, or using machine learning techniques and proximity sensors to detect the distance between the user and objects.

Examples of hand wearables include gloves that can sense the environment and convert that information into braille output, identify keys on a keyboard or the color of an object using camera vision techniques and audio announcements.

The artificial retina, based on microfabrication and nano diamond techniques, is complex. It took nearly 12 years for the first product (Second Sight) to ensure biocompatibility and go through regulatory approval as a completely novel product, as FDA had no predicate to compare it to. The product was first launched in Europe, then in the U.S. It is for people with complete sight loss (about 10 percent of persons with visual impairment) and as such addresses a smaller market.

Greg Cosendai,
Verily

Augmented reality devices are being increasingly used to enhance vision. For example, an augmented reality device can observe a user's surroundings, identify objects in the vicinity and inform the user, for example, by displaying the information on a smartphone, or enhance the visual scenery displayed on the augmented reality device in a way that compensates for specific visual impairments, such as color blindness (Figure 2.93). Many of these patents discuss techniques for making the augmented reality displays more relevant to users with poor eyesight or compensating for either short or long sight.

Growth

Patent filings for emerging vision assistive technology are increasing overall: 57% of patent applications were filed after 2010, and filings during 2013–2017 grew at an AAGR of 9%.

Retinal prostheses (artificial silicon retina, ASR), drug delivery in IOLs and adaptive focus IOLs

Figure 2.93. A video display device (patent document JP2006135884A)

The spectacles have a display that shows images captured from a mounted camera. The image is corrected for any motion (e.g., from walking)

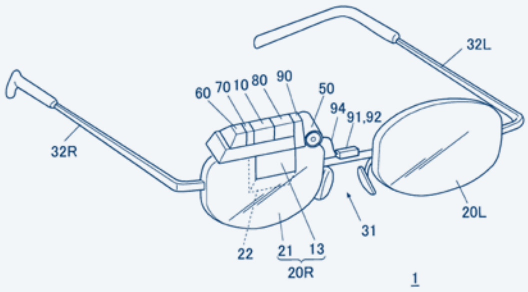
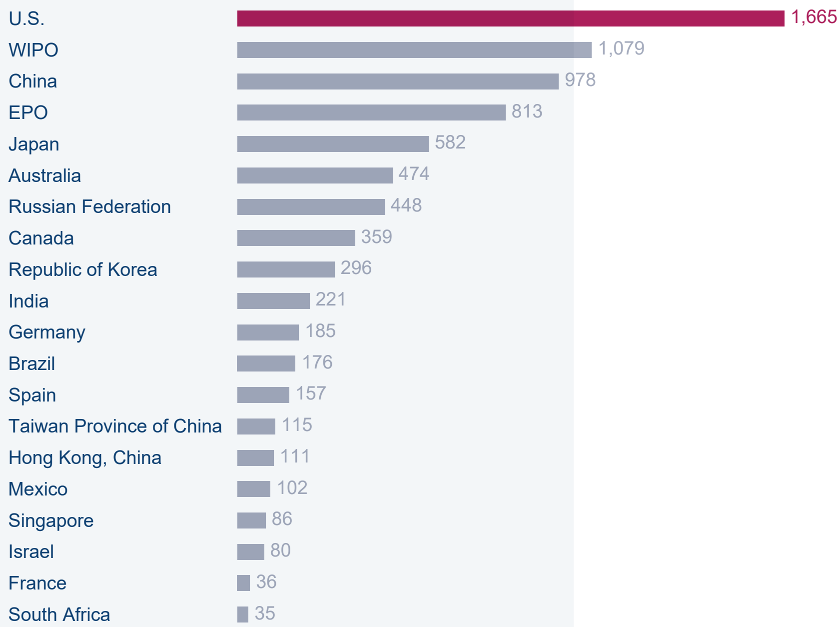


Figure 2.94. Top 20 patent offices by number of patent applications filed for patent protection from 1998 to 2019 for emerging vision assistive technology

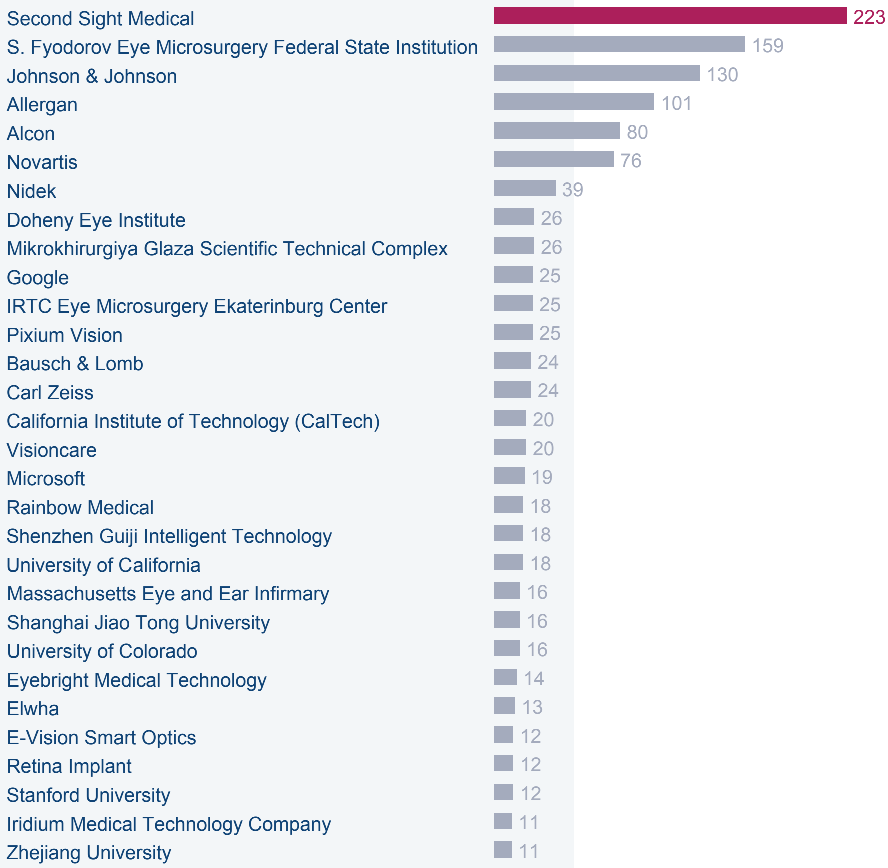
More than half (55%) of the patent families include a patent application in the U.S. and 32% in China



Note: EPO is the European Patent Office. WIPO represents PCT applications.

Figure 2.95. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 for emerging vision assistive technology

A varied picture emerges of the top six applicants, with Second Sight Medical (U.S.) leading, followed by a Russian Federation academic institution (S. Fyodorov Eye Microsurgery Federal State Institution), a large U.S. corporate (Johnson & Johnson), and a company in Ireland (Allergan) and two companies in Switzerland (Alcon and Novartis)



were some early areas of innovation. Generally, patent filings in the IOL and other implant categories have remained mostly steady for the last 20 years, but particular examples of strong growth can be seen for **IOL with sensors** (48% AAGR for 2013–2017), and retinal prostheses (35% AAGR for 2013–2017).

In contrast, 93% of the patent applications related to wearable, non-invasive technologies have been filed since 2008, and more than half since 2016. Within this, smart eyewear and augmented reality devices (82% of which were filed after 2013) are the key areas of growth, both having seen an AAGR of more than 35% during 2013–2017. This demonstrates a clear movement towards using advanced computing and sensor technologies in the development of vision assistive devices.

Almost 13% of the portfolio of the top 30 patent applicants was filed by two or more as co-applicants.

Geographical distribution

In total, 8,155 patent applications were published across 44 patent offices (Figure 2.94). More than half (55%) have at least one patent application filed in the U.S. and 32% at least one filing in China. Overall, 98% have at least one patent application filed at the top 10 patent offices, while the top 20 patent offices have received at least one patent application from 99% of all patent applications.

The high proportion of filings via the PCT route (36%) and at the EPO (27%) – one of the highest across all of assistive technology – indicates that patent applicants are significantly focused on protecting their patents in multiple jurisdictions. In fact, almost 30% of patent applications have been filed in at least three patent offices. More than 80% of these were filed by commercial entities, including Johnson & Johnson, Second Sight, Alcon, and Allergan, and are notably focused on retinal prostheses with adaptive focus IOLs.

Although the U.S. is the overall major market for patent filings, China overtook it during the period 2013–2017, with 488 patent applications filed in China at an AAGR of 17% compared with 449 documents filed in the U.S. and declining at an AAGR of –2.4%.

Key players

The top 10 players account for 27% of this area's 3,036 patent families. This indicates a high concentration of patent ownership among the top patent applicants. Nearly half (14) of the top 30 patent applicants are U.S.-based, but an interesting picture emerges of the rest, which includes many European players, applicants from less represented jurisdictions in other functional categories, such as the Russian Federation and Israel, but very few Asian applicants (Figure 2.95).

This is an industry-dominated area, with commercial players accounting for approximately 60% of the emerging vision dataset. While the majority of the top patent applicants in conventional assistive technology for vision are optical manufacturers (such as Seiko Epson, Essilor, Hoya), many of the top players in emerging technology are those providing implantable solutions (such as Second Sight, Allergan, Alcon, and Novartis). Johnson & Johnson and Novartis lead in both conventional and emerging vision assistive technology.

Most of the top 30 applicants focused their filing on one or two categories/applications. Table 2.2 shows those patent applicants with at least 80% of their patent applications relating to a single category, their areas of focus primarily being retinal prostheses and IOL drug delivery.

Table 2.2. Technology focus of top applicants for emerging vision assistive technology

Most of the top applicants are focused on retinal prostheses and IOL drug delivery

Patent applicant	>80% focus
Second Sight (U.S.)	Retinal prostheses
S. Fyodorov Eye Microsurgery Federal State Institution (Russian Federation)	IOL – drug delivery
Doheny Eye Institute (U.S.)	Retinal prostheses
Pixium Vision (France)	Retinal prostheses
IRTC Eye Microsurgery Ekaterinburg Center (Russian Federation)	IOL – drug delivery
Microsoft (U.S.)	Augmented reality devices
VisionCare (U.S.)	Telescopic lenses
Shenzhen Guiji Intelligent Technology Co. Ltd (China)	Retinal prostheses
Elwha, LLC (U.S.)	IOL – adaptive focus
Retina Implant (Germany)	Retinal prostheses

Looking at collaborations among the top 30 patent applicants, almost 13% of their patent portfolio (155 patent families) was filed by two or more as co-applicants. Among these, Second Sight collaborated with Doheny Eye Institute on 17 of its patent filings, all filed between 2003 and 2008, around the time Second Sight developed its first Argus II retinal implant. Alcon, a major player in intraocular lens technology, was owned by Novartis from 2010 to 2019 (Alcon, 2019b), and co-owns 28 of its patent applications with Novartis, 26 of which relate to IOL technologies.

In fact, 23 of its other inventions related to adaptive focus IOLs were obtained through the acquisition of PowerVision in 2019 (Alcon, 2019a). Johnson & Johnson appears as co-applicant on 17 patent applications in multifocal and adaptive focus IOLs together with Allergan (acquired by AbbVie in 2020). Google co-invented four of its patents with its sister company Verily.

Interestingly, some of the patent applicants actively filing patent applications during the early years have reduced their patent filings in recent times. Two of the top patent applicants, Doheny Eye Institute (U.S.) and Mikrokhirurgiya Glaza Science and Technology Complex (Russian Federation), have not filed any new patent applications in the last 10 years, but nevertheless appear among the top applicants because of the volume of their patent applications. Further, the German company Retina Implant stopped operating after its dissolution in 2019, citing the “innovation-hostile climate of Europe’s rigid regulatory and health systems” and a shortfall in expected results (Retina Implant AG, 2019). The investors of Retina Implant are now planning to relaunch Okuvision, a company that was integrated into Retina Implant in 2017. In addition, U.S.-based Second Sight, the top patent applicant and the dominant applicant for retinal prostheses and cortical implants, filed less than 7% of its patents after 2013.

Similarly, although patents related to IOL drug delivery technologies attract a high level of interest from Russian Federation institutes (particularly S. Fyodorov Eye Microsurgery Federal State Institution) and corporates (IRTC Eye Microsurgery Ekaterinburg Center and Mikrokhirurgiya Glaza Sci Tech Complex), patent filings for most of these players have been declining in recent years. Other major entities, such as Ireland-based pharmaceutical company Allergan, filed most of their patents before making their products available for clinical trials.

Patent filings in **adaptive** and **multifocal lenses** are dominated by major players like Johnson & Johnson. Novartis, through its earlier subsidiary Alcon, filed 22 patent applications related to multifocal IOLs (Novartis, 2017). Google (Alphabet) owns 18 patents in adaptive focus IOLs through Verily, all of which were filed after 2014. Elwha, LLC, reportedly a holding company of Intellectual Ventures (Brodkin, 2013) which does not have any products on the market and also appears in the mobility dataset, also has 13 patent applications, all filed during 2015–2016. Ownership of patents by companies like Elwha, LLC suggests a competitive market for players in this category. Patenting activity in augmented reality devices is driven by several known developers of augmented and virtual reality systems, including BOE Technologies, Facebook, Google and Microsoft.

Chinese applicants are driving growth in retinal prostheses – Shenzhen Guiji Intelligent Technology Co. Ltd (18 patent applications) started filing in 2016, while Zhejiang Nurotron Nerve Electronic Technology and Hangzhou Nanochap Electronics filed all their patents (8 and 7 patent applications, respectively) after 2015 – and smart eyewear – Suzhou Jingro Technology (8 documents related to intelligent eyeglasses), Hangzhou Shike Technology (7 documents) and Shanghai Jiao Tong University (5 documents).

The top applicant for hand wearables is Amity University from India (3 patent applications), but, similarly to smart eyewear, there is no dominant applicant in a more fragmented market. Interestingly, smart eyewear receives more patent filings from independent Brazil-based inventors than any other category.

More than a quarter (27%) of filings are from universities and public research organizations, including co-applications (3%) filed with corporate players. They lead patent filings in drug delivery IOLs (owning 285 of 509 patent applications in this category, 148 of which filed by S. Fyodorov Eye Microsurgery Federal State Institution of the Russian Federation) and bionic eyes (44 of the 100 patent applications in this category filed by universities and public research organizations, almost 55% of these based in China). Only 3% of inventions were filed by commercial entities appearing as co-applicants with universities or public research organizations – one of the highest instances of co-ownership across all of assistive technology.

Collaboration between commercial entities and universities and public research organizations

Intraocular lenses

Intraocular lenses (IOLs) are expected to be offered to patients in various premium versions (e.g., adaptability, sensors) with additional costs for extra functionalities (such as those featured in this chapter) to be borne by patients. This could be an interesting market for companies. Advanced presbyopia IOLs are expected to be very lucrative and achieve promising results in view of the number of potential beneficiaries.

Greg Cosendai, Verily

Drug delivery IOLs can bring widespread benefit, as they could have many applications. Vision assistive technology is dominated by big players in the field who, as technology and product providers to hospitals and patients, are the end-users. Only technological developments that are interesting for these bigger players stand a chance of making it to market, typically through these companies which may license or acquire related technologies and underlying IP.

Ioannis Palikaris, University of Crete

Improvement in spectacles, specifically in progressive focus and adaptive focus lenses, showcases the transition from conventional to emerging assistive technology for vision.

happened mostly in retinal prostheses, with Doheny Eye Institute and Second Sight co-inventing 15 patents (primarily for the development of the Argus II retinal implant), and German Retina Implant and University of Tübingen filing jointly 5 patent applications.

Independent inventors account for just 16% of inventions, but show the highest growth rate at 15% for 2013–2017, and are most significant for smart eyewear (30% of patent applications in this category) and augmented reality devices (12% of patent applications in this category). Although a majority (60%) of the patent applications from independent inventors in smart eyewear are from China, this is split more evenly between U.S.- and China-based inventors for augmented reality devices.

In addition, independent inventors own almost 16% of patent applications related to IOLs with sensors, almost half of which are from China-based inventors, and 19% of patent applications related to adaptive focus IOLs, over three-quarters of which (76%) were filed by U.S.-based inventors, indicating the U.S. is a major source of innovation from unaffiliated inventors.

Summary

The overall patent landscape of conventional vision assistive technology is well distributed and not dominated by the top players. There is demonstrable growth in certain major areas, such as spectacles and lenses, and the changing industrial landscape has attracted the interest of players from other industries, mainly the mobile and computing industries. Several players from the computing industry, including IBM, Samsung, LG, Apple, BOE Technology and Microsoft, have been innovating in this area recently. Meanwhile, the major optics manufacturers, such as Johnson & Johnson and Seiko Epson, are moving their attention to researching advanced technologies to develop electronic lenses that can sense conditions and adjust accordingly.

Improvement in spectacles, specifically in progressive focus and adaptive focus lenses, showcases the transition from conventional to emerging assistive technology for vision. Whereas conventional devices target adjusting the focus of the eyes, emerging assistive technology concentrates on scene recognition, object recognition, path determination and other advanced solutions through the use of sensors and AR/VR techniques.

Again, the presence of major consumer electronic goods and computing industry players in this domain is strong evidence of the merging of these two major industries. The area also shows a high level of collaboration between companies, but also between universities or public research organizations and commercial players. In fact, this area of assistive technology has the largest contribution from universities and public research organizations (over a quarter of filings), demonstrating a significant R&D investment. This is also one where the U.S. leads in patent filings, and the high proportion of PCT and EPO filings reflects the intention of applicants to protect their inventions in multiple jurisdictions.

Implications for end-users

Adaptive focus and multifocal IOLs provide versatile and automated solutions for people with weak eyesight, removing the need for spectacles that have short distance, long distance or multifocal lenses and thus making a major impact on users' lifestyles. Developments in retinal prostheses are allowing users to get a more realistic feel for their surroundings, while cortical implants are making visual sensing more real-time and detailed. Bionic eyes are becoming more aesthetically pleasing. Wearable, non-invasive technologies, such as smart eyewear, is a major area of development, employing smart technologies, such as machine learning, to improve both visual acuity and safety. Such innovations within the huge industry of spectacles and lenses signal major advances in improving the technology available for supporting people with visual impairment.


"Read me the headlines."

Seeing the world through wearable artificial vision

Jerusalem-headquartered OrCam Technologies, established in 2010, specializes in personal, wearable assistive technology platforms that use AI-driven computer vision to provide increased independence to people who are blind, visually impaired or have reading difficulties.

Its flagship product, the OrCam MyEye artificial vision device, is magnetically mounted on a spectacle frame and discreetly reads digital or printed text aloud, for example, from newspapers, books, computer and smartphone screens, labels on supermarket products, and street signs. It uses face recognition and can identify consumer products, colors and currency, and is activated by a pointing gesture or by following the user's gaze.

Orcam's latest development is a smart reading feature, which replicates human understanding and communication. Using integrated voice activation and data retrieval, the user can ask the device specific questions about digital or printed text and the device responds by retrieving the text of interest and reading it aloud.

OrCam MyEye 2 is available in 25 languages and 50 countries, was chosen as a 2019 TIME Best Invention and was a Last Gadget Standing winner at the 2018 Consumer Electronics Show.

Case study by OrCam Technologies

Notes

1 Corresponding to 1,792 patent applications.

2 Training tools and brain stimulation for treating and recovering memory issues are not included.

3 This growth was driven predominantly by activity from the U.S. company Honeywell (with 15 of its 16 patents filed in 2016, indicating potential stepping stones to the release of a product on the market), and as such these figures should be interpreted with caution.

4 This can also be confirmed in the emerging self-care area with smart medication dispensing management technologies (see Section 2.6).

5 See www.ibm.com/able/aging-in-place.html.

6 See for details https://azuremarketplace.microsoft.com/en-in/marketplace/apps/hastechnologyltd.armed?tab=Overview.

7 Assistive products that address the needs of specific functional limitations are mostly covered under the relevant dedicated functional category within this chapter. Assistive technologies that support communication with persons and devices across different user profiles are covered in this section.

8 See Nierling et al. (2018) for more information.

9 Thirty-five patent applications discuss concepts related to more than one of the above topics, and are thus categorized in multiple categories as appropriate. Of these, 25 discuss navigational aids that employ haptic sensory substitution techniques to guide users along a path.

10 Navigational aids that are embedded in walking aids, such as wheelchairs and canes, overlap with mobility technologies in Section 2.5.

11 These percentages include 2% of inventions that are co-owned between at least one commercial and at least one academic or government entity.

12 Providing “goods, services, equipment and facilities … which should require the minimum possible adaptation and the least cost to meet the specific needs of a person with disabilities” (Article 4(f)); enhancing independent living by eliminating “obstacles and barriers to accessibility” including “(a) Buildings, roads, transportation and other indoor and outdoor facilities, including schools, housing, medical facilities and workplaces” (Article 9 (1) and (1a)); facilitating the enjoyment of “cultural materials in accessible formats” (Article 30 (1a), “access to television programs, films, theatre, and other cultural activities” (Article 30 (1b)) and “access to places for cultural performances or services” (Article 30 (1c)).

13 21,326 patent applications as first filings of patent families and 5,594 second filings of the same patent families in other jurisdictions.

14 Total filings from the EPO and all individual European jurisdictions.

15 These concepts overlap with some of the areas covered in the self-care, environment and cognition domains, and are included within this category because of the use of robots and humanoids.

16 1,157 first filings and 541 subsequent filings.

17 The counts of patent filings for 2018 onwards are incomplete due to the approximately 18-month publication lag seen for patents.

18 There is significant overlap between the various conventional hearing categories, with almost a quarter of patent applications being considered under more than one category, as the underlying technology is very similar.

19 Corresponding to 14,198 patent applications as first filings of inventions (and the same number of patent families) and

14,440 second filings of the same inventions in other jurisdictions.

20 WS Audiology is based in Singapore and Denmark and formed in 2019 as a result of the merger of Sivantos and Widex. Sivantos (previously Siemens Audiologische Technik) was formed in 2015. Key brands in hearing aids owned by WS Audiology are Signia, Widex, A&M, Coselgi and Rexton.

21 Sonova Holding (Phonak Holding before August 2007), founded in 1947, includes brands such as Phonak, Unitron, Hansaton, Advanced Bionics and AudioNova. Phonak, Unitron and Hansaton are hearing aid brands, while Advanced Bionics is active in the field of cochlear implants and AudioNova is a retail chain for hearing aids.

22 Demant and its subsidiary Oticon are hearing aid manufacturers, founded in 1904 by Hans Demant. Oticon, Bernafon, Sonic Innovations, Neurelec (cochlear implants) and Oticon Medical (bone-anchored hearing aids) are the key brands in hearing aids. Demant is also an active player in the area of diagnostic audiometric equipment.

23 In addition to middle ear implants, there are also bone-anchored devices, such as bone-anchored hearing aids (see https://www.healthyhearing.com/help/hearing-aids/bone-anchored). As per the expert Patricia de Munoz, "these are designed for people with good nerve function (unlike the user case for cochlear implants), but who cannot hear due to external or middle ear abnormality, such as severe outer or middle ear malformations, and those with single-sided deafness, also known as unilateral hearing loss. This type of hearing solution also may be recommended in extreme cases of chronic ear infections or allergies to traditional hearing aids." Only non-invasive bone conduction was considered in the emerging assistive technology area, as the invasive bone conduction products are well-established hearing assistance products and related innovation is incremental.
Owing to the scope of the conventional assistive technology, which does not include implantable assistive products, as per WHO's definition, these products were also excluded from the conventional taxonomy.

24 4,993 documents as first filings and 4,701 as second filings of the same invention in other jurisdictions.

25 This dataset includes upper and lower limb prostheses and their components, but does not include dental prostheses and has aimed to exclude patents related to surgery and rehabilitation.

26 Corresponding to 63,245 patent families.

27 "Neuroprosthetics – other neural interface" refers to patents that discuss neuroprosthetics, but do not specify whether the interface is with the central or the peripheral nervous system.

28 Some exoskeletons are equipped with fall prevention mechanisms, which are covered in the Exoskeletons category.

29 Although they can be used in military and industrial settings, they do not fall within the scope of this report.

30 For instance, Harvard's research in soft robotics: https://biodesign.seas.harvard.edu/soft-robotics.

31 For instance, Harvard's research in soft exosuits: https://biodesign.seas.harvard.edu/soft-exosuits.

32 4,526 patent families correspond to 7,428 patent applications (only one filing per jurisdiction is taken into account and considered in the calculation), that is, 4,526 first filings and 2,902 subsequent filings.

33 Enteral feeding devices are not included.

34 An overview of different assistive products can be found at Continence Product Advisor, a collaboration between the International Consultation on Incontinence (ICI), International Continence Society (ICS), University of Southampton and University College London. The Continence Product Advisor is accessible at www.continenceproductadvisor.org and its

content is based on the management using continence products chapter in *Incontinence, 6th edition* (Abrams et al., 2017).

35 Products for surgical procedures and infants are not included.

36 Products for rehabilitation and impotence are not included.

37 This section includes 6,410 patent families and each family consists of at least one patent application (first filing) or more than one patent application (subsequent filing) in other patent offices. These multiple patent applications sum up to 8,283. Patent applications have been counted only once in the same patent office per patent family.

38 Nursing platforms are captured under emerging assistive technologies for Environment (Section 2.3), as part of smart homes.

39 For more information about affective computing, see *WIPO Technology Trends 2019: Artificial Intelligence*, pp. 37 and 69 (WIPO, 2019).

40 Initially identified under conventional assistive technologies for cognition (see Section 2.1). These more complex technologies are included in this section as they address disabilities beyond cognitive impairment.

41 A similar trend is observed with technologies related to dental care, which have evolved into human support robots (covered in Environment, Section 2.3).

42 8,133 patent applications as first filings of patent families and 7,644 second filings of same patent families in other jurisdictions.

43 Vispero formed when Freedom Scientific Inc and Optelec merged in 2016.

References

Abrams, P., L. Cardozo, A. Wagg and A. Wein (eds) (2017). *Incontinence* 6th Edition, Chapter 20, Management using continence products (pp. 2303–2400). ICI-ICS. International Continence Society, Bristol, U.K. Available at: https://www.ics.org/education/icspublications/icibooks (accessed February 23, 2021).

Alcon (2019a). Alcon announces acquisition of PowerVision, Inc. Media release, March 18. Available at: https://www.alcon.com/media-release/alcon-announces-acquisition-powervision-inc (accessed September 14, 2020).

Alcon (2019b). Alcon debuts as independent, publicly traded company. Media release, April 9. Available at: https://www.alcon.com/media-release/alcon-debuts-independent-publicly-traded-company (accessed September 14, 2020).

Association for Advancing Automation (2016). The many uses of soft and flexible robots. Available at: https://www.a3automate.org/many-uses-soft-flexible-robots (accessed September 14, 2020).

Boot, F.H., J. Dinsmore, C. Khasnabis and M. MacLachlan, M. (2017). Intellectual disability and assistive technology: Opening the GATE wider. *Frontiers in Public Health*, February 22. DOI:10.3389/fpubh.2017.00010.

Bourne, R.R.A., S.R. Flaxman, T. Braithwaite, M.V. Cicinelli, A. Das, J.B. Jonas et al.; Vision Loss Expert Group (2017). Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Global Health* 5(9): e888–897.

Brodkin, J. (2013). Bill Gates still helping known patent trolls obtain more patents: New Gates Patent continues his partnership with Intellectual Ventures. *Ars Technica*, August 14. Available at: https://arstechnica.com/tech-policy/2013/08/bill-gates-still-helping-known-patent-trolls-obtain-more-patents (accessed September 14, 2020).

CDC (Centers for Disease Control and Prevention) (2020). Disability and functioning. Available at: https://www.cdc.gov/nchs/fastats/disability.htm (accessed October 31, 2020).

Grand View Research (2020). Cochlear implant market size to reach $3.3 billion by 2027 – CAGR: 10.6%. Available at: www.grandviewresearch.com/press-release/global-cochlear-implants-market (accessed December 31, 2020).

Hornyak, T. (2009). Panasonic's robotic bed transforms into wheelchair. *CNet*, October 2. Available at: https://www.cnet.com/news/panasonics-robotic-bed-transforms-into-wheelchair (accessed September 14, 2020).

Howland, D. (2019). Global adaptive apparel market on pace to hit $349.9B. *Retail Dive*, February 26. Available at: https://www.retaildive.com/news/global-adaptive-apparel-market-on-pace-to-hit-3499b/549200 (accessed September 14, 2020).

Hoya (2020). About. Available at: http://www.hoya.co.jp/english/company/history.html (accessed September 14, 2020).

Kawai, M. and S. Takagi (2009). Why was Japan hit so hard by the global financial crisis?, ADBI Working Paper No. 153. Tokyo: Asian Development Bank Institute. Available at: https://www.adb.org/sites/default/files/publication/156008/adbi-wp153.pdf (accessed September 14, 2020).

Kondej, M. (2009). Potential in incontinence products drives innovation. *Euromonitor International*, March 26. Available at: https://blog.euromonitor.com/potential-in-incontinence-products-drives-innovation (accessed September 14, 2020).

Lee, A.G. (2015). Connected cars patent landscape & disputes risk assessment.

LinkedIn, November 1. Available at: https://www.linkedin.com/pulse/connected-cars-patent-landscape-disputes-risk-lee-ph-d-j-d-clp (accessed September 14, 2020).

Lemus, D., A. Berry, S. Jabeen, C. Jayaraman, K. Hohl, F.C.T. van der Helm et al. (2020). Controller synthesis and clinical exploration of wearable gyroscopic actuators to support human balance. *Scientific Reports* 10: 10412. DOI:10.1038/s41598-020-66760-w.

Medgadget (2019). Hearing aids market analysis 2026 – global market size, share, trends, analysis, insights, research reports. Available at: www.medgadget.com/2019/12/hearing-aids-market-analysis-2026-global-market-size-share-trends-analysis-insights-research-reports.html (accessed December 31, 2020).

Minion, L. (2018). Ground-breaking collaboration creates world-first smart home for people with intellectual disabilities. *Healthcare IT News*, October 9. Available at: https://www.healthcareit.com.au/article/ground-breaking-collaboration-creates-world-first-smart-home-people-intellectual (accessed September 14, 2020).

Navya, K., P.B. Kumar, K.P. Rao and B.V. Raju (2018). Smart stair lift for disabled and elderly. *International Journal of Pure and Applied Mathematics*, 120(6), 4647–4660. Available at: https://acadpubl.eu/hub/2018-120-6/4/338.pdf (accessed September 14, 2020).

Nierling, L., M. João Maia, L. Hennen, G. Wolbring, T. Bratan, P. Kukk, J. Čas, L. Capari, J. Krieger-Lamina and E. Mordini (2018). Assistive technologies for people with disabilities, Part II: Current and emerging technologies, technical report (PE 603.218). European Parliament, Brussels: Scientific Foresight Unite (STOA). Available at: http://www.researchgate.net/publication/322665017_Assistive_technologies_for_people_with_disabilities_-_Part_II_Current_and_emerging_technologies (accessed September 14, 2020).

Novartis (2017). Alcon receives US FDA approval for new AcrySof® IQ ReSTOR® +2.5 Multifocal Toric IOL with ACTIVEFOCUS(TM) design for uncompromised distance vision and presbyopia correction. Available at: https://www.novartis.com/news/media-releases/alcon-receives-us-fda-approval-new-acrysof-iq-restor-25-multifocal-toric-iol-activefocustm-design-uncompromised-distance-vision-and-presbyopia-correction (accessed September 14, 2020).

PR Newswire (2017). Global incontinence care products market: Trends analysis & forecasts to 2021. *Cision*, November 17. Available at: https://www.prnewswire.com/news-releases/global-incontinence-care-products-market-trends-analysis--forecasts-to-2021-300558762.html (accessed September 14, 2020).

Ramirez, A.R.G. (ed.) (2018). *Assistive Technologies in Smart Cities*. London: IntechOpen. Available at: https://www.intechopen.com/books/assistive-technologies-in-smart-cities (accessed September 14, 2020).

Reidel, H. (2017). The successes and failures of 3D printed prosthetics. *Prescouter*, July. Available at: https://www.prescouter.com/2017/07/3d-printed-prosthetics (accessed September 14, 2020).

Retina Implant AG (2019). Retina Implant AG discontinues business activities. Available at: https://www.bioregio-stern.de/en/news/retina-implant-ag-discontinues-business-activities (accessed March 3, 2021).

Roy, F. (2017). The EU regulatory challenges and liability risks associated with 3-D printed medical devices. Available at: https://www.hoganlovells.com/en/publications/the-eu-regulatory-challenges-and-liability-risks-associated-with-3d-printed-medical-devices (accessed March 3, 2021).

Sayers, M. (2014). Free-form lens technology. *20/20*, September. Available at: https://www.2020mag.com/article/freeform-lens-technology-what-does-it-really-mean-to-your-patients-and-your-business (accessed September 14, 2020).

Shieber, J. (2019). WHILL brings its autonomous wheelchairs to North American airports. *Tech Crunch*, November. Available at: https://techcrunch.com/2019/11/20/whill-brings-its-autonomous-wheelchairs-to-north-american-airports (accessed September 14, 2020).

TU Delft (2020). Gyroscopic balance assistance. Available at: https://www.tudelft.nl/en/3me/about/departments/biomechanical-engineering/research/dbl-delft-biorobotics-lab/gyroscopic-balance-assistance (accessed September 14, 2020).

World Health Organization/United Nations Population Fund (WHO/UNFPA) (2009). *Promoting Sexual and Reproductive Health for Persons With Disabilities*, WHO/UNFPA guidance note. Geneva: WHO. Available at: https://www.unfpa.org/sites/default/files/pub-pdf/srh_for_disabilities.pdf (accessed September 14, 2020).

WHO (2012). *Dementia: a public health priority*. Geneva: World Health Organization. Available at: https://www.who.int/mental_health/publications/dementia_report_2012/en/ (accessed February 24, 2021).

WHO (2019). *World Report on Vision*. Available at: https://www.who.int/publications/i/item/world-report-on-vision (accessed November 15, 2020).

WHO (2020). Deafness and hearing loss, Fact sheet, March 1. Available at: https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss (accessed September 14, 2020).

World Intellectual Property Organization (WIPO) (2010). *World Intellectual Property Indicators*. Geneva: WIPO. Available at: https://www.wipo.int/edocs/pubdocs/en/intproperty/941/wipo_pub_941_2010.pdf (accessed September 14, 2020).

WIPO (2019). *Global Innovation Index 2019*. Geneva: WIPO. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2019.pdf (accessed September 14, 2020).

3 Trends in assistive technology

The global patent landscape

The analysis of the patent landscape in the previous chapter (Chapter 2) provides insights into the different types of assistive technology currently being developed and the seven functional categories they support, namely cognition, communication, environment, hearing, mobility, self-care and vision.

The patent analysis grouped assistive products into either conventional or emerging technologies across these functional categories. Conventional assistive technology tracks innovation within well-established assistive products, whereas emerging assistive technology refers to more advanced products. These identified advanced assistive products are distinguished from the conventional ones by the use of one or more enabling technologies (for instance, artificial intelligence (AI), Internet of Things (IoT), advanced sensors, advanced robotics, augmented and virtual reality) and/or by the inclusion of implantable products/components. Such emerging assistive products are either more sophisticated or more functional versions of conventional assistive products, or completely novel assistive devices.

Although the distinction between conventional and emerging technologies is not always clear-cut, emerging assistive technology tends to be “smarter”, using AI and being more connected and interactive, and including body-integrated solutions or components. (For a full methodology, see the background paper available on the report’s dedicated website, available at www.wipo.int/tech_trends/en/assistive_technology.)

The problems posed by an ageing society are very seriousin Japan. While major global companies are actively developing services utilizing IoT and AI, Japanese companies have further developed these technologies with manufacturing technologies. Japan can lead the world in IoT solutions for assistive technologies.

Masaru Yamaoka, Panasonic

This chapter describes the global patent landscape in assistive technology. It builds upon the findings reported in Chapter 2, where the evolution from conventional to emerging technologies occurring in each of the seven functional categories is described in detail. It identifies cross-cutting technology trends, the top patent offices for filing, market trends, and profiles and strategies (including the patents and industrial designs) of the top players. The enabling technologies for assistive technology are identified and described in greater depth, particularly as regards the extent to which they are supporting the development of emerging assistive products. This chapter also explores the technology readiness level (TRL) of emerging assistive technologies entering the market, together with their expected impact and ease of adoption.

Overview of patenting activity

The term "conventional assistive technologies" refers to assistive products that are well established in the market. To a great extent this classification is based on the WHO's Priority Assistive Products List (APL) and the ISO 9999 standard for assistive products for persons with disabilities, the APL delineating the absolute minimum that countries should be offering to their citizens and ISO 9999 defining those products which are already well established in the market. This status is reflected in the related patent dataset identified for this area, which is nearly eight times larger than the one for emerging assistive technologies. However, patent filings related to more recent emerging assistive technologies are growing almost three times as fast as those pertaining to conventional ones (with an AAGR of 17% for 2013–2017 versus 6%), indicating a growing interest in developing improved or alternative devices.

Patent filings in both conventional and emerging assistive technology are highly concentrated on mobility, hearing and vision. Investment in emerging assistive technology also focuses on environment. This could be because these impairments are the most common among the global population,[1] even if cognitive impairment (or assessment thereof) is on the rise; or because related assistive products are covered or reimbursed by health systems.

When comparing patenting activity across functional categories, the predominance of mobility-related patenting activity is particularly noteworthy. Not only do mobility-related filings account for over half of conventional assistive technology, there are as many patent filings related to mobility as there are for all other functional categories combined (Figure 3.1). Since 2014, mobility assistive technology has registered the highest growth rate across all the conventional functional categories, with an AAGR of 9% for 2013–2017. The volume and growth rate of patent filings in the area of mobility, combined with the breadth of patent protection of related applications, which is the widest among all functional categories, shows the size and importance of the mobility assistive products market.

Even though emerging mobility assistive technology is second to emerging hearing assistive technology in terms of total number of patent filings, annual filings related to emerging mobility matched those of emerging hearing in 2014 and have surpassed it every year since (Figure 3.2). The high AAGR (24%) in patent filings in emerging mobility for the period 2013–2017 is an indication of increased interest in advanced mobility assistive product categories, such as advanced prosthetics, walking aids, wheelchairs and exoskeletons, which promise greater autonomy alongside improved control and comfort. The prioritization in research related to independent mobility (i.e., the ability to move around and manipulate physical objects) and the related market is reflected not only in the number of patent filings but also in the breadth of patent protection sought for

Figure 3.1. Number of patent families related to conventional mobility and the other six conventional functional categories combined by earliest priority year (2000–2017)

Annual patent filings related to mobility assistive technology alone are equal to or higher than the other six functional categories combined

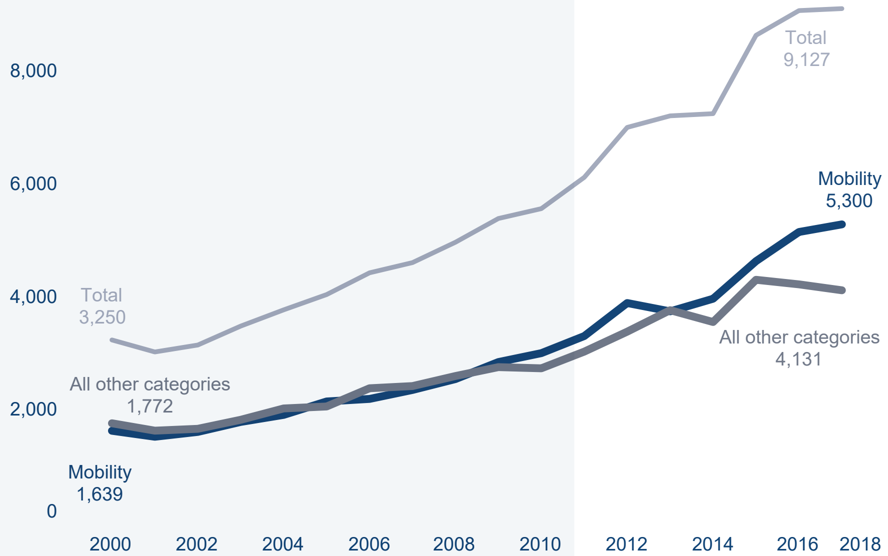
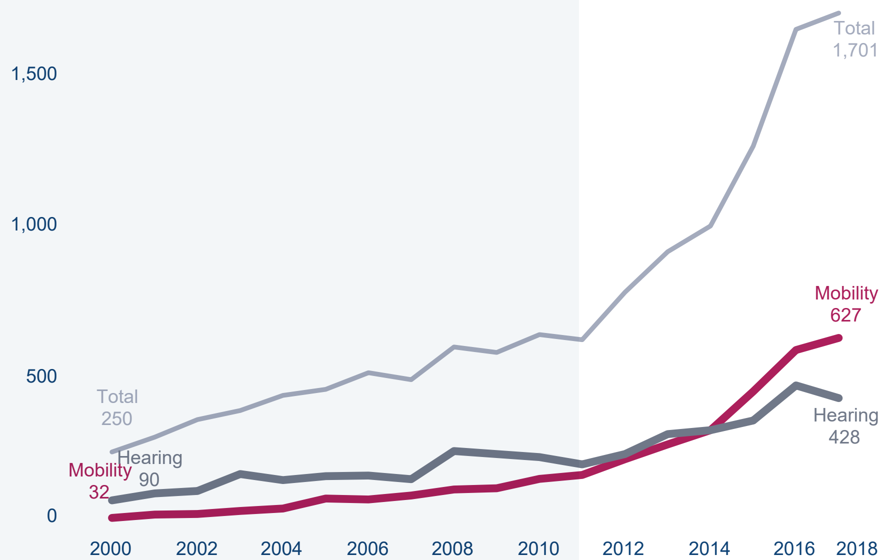


Figure 3.2. Number of patent families across emerging assistive technology in the functional categories of mobility and hearing by earliest priority year (2000–2017)

In 2014, filings related to emerging mobility assistive technology surpassed those for hearing technology and have continued to grow quickly since then



mobility-related patent applications, which is filed across the highest number of patent offices among all functional categories.

Environment assistive technology comprises those technologies that facilitate independent living, access to, navigation of and working in the built environment. Similarly to mobility, they cover a wide range of assistive products, and account for almost a fifth of the conventional assistive technology dataset. The emerging assistive technology patent landscape includes inventions related to smart environments and assistive robotics and is the most recent (and consequently one of the smallest) emerging functional category, with 76% of the dataset filed after 2013. It has the strongest growth rate of all emerging functional categories, with an AAGR of 42%. This could be attributed to an increasing discussion of and demand for solutions in support of self-sufficiency and independent living and access for persons with disabilities and the elderly to indoor and outdoor environments (see Chapter 5). Important features included in emerging assistive technology related to the built environment are: smart nursing, medication management, wandering and emergency monitoring, navigating, communicating, lifting and walking.

Assistive technology related to cognition is the smallest category in the conventional assistive dataset. This is possibly a reflection of the until recently limited recognition given to cognitive decline and impairment and how assistive technology can support such functional limitations. Some of the emerging assistive technology relating to cognition is also addressed within other functional categories, emerging self-care and communication in the main.

With respect to self-care, there is a clear move to embrace emerging technologies and the application of advanced and enabling technologies in new product lines, as evidenced by the recent decline in patenting activity in the conventional space, while it is one of the fastest growing categories in emerging assistive technology. Emerging self-care assistive products include health and emotion monitoring wearables and non-wearable devices, smart diapers, smart medication dispensing and management and feeding assistant robots, all possible thanks to the use of enabling technologies like advanced sensors, AI and IoT.

Many applicants use utility models[2] rather than patents to protect their advances in the conventional space. Utility models account for a quarter of patent families for conventional assistive technology, with over half of these filed by independent inventors. While utility model protection varies by country, these assets are usually characterized by a lower bar for inventiveness, cost less to register and feature a shorter protection period. This may signal either less complex technologies or that utility models are more affordable for smaller entities and independent inventors. The presence of utility models in emerging assistive technology is significantly lower (13%), possibly due to the more advanced and costly technology involved (e.g., components such as sensors or smart controls) in the identified emerging assistive products.

Which are the top offices of filing and where are the markets for assistive technology?

As patent protection is territorial and filing in each jurisdiction incurs considerable cost, the selection of jurisdictions by patent applicants is a good means of observing intended markets for commercialization. The identified 117,209 inventions related to conventional assistive technology were filed across a total of 56 different patent offices (with the breadth of patent protection varying across functional domains, from 36 patent offices in the area of conventional cognition to 56 in the field of conventional mobility). There seems to be a slightly smaller and more varied market in the emerging assistive technology area: the related 15,592 patent families include patent applications filed across 51 different patent offices overall (ranging from 29 patent offices for emerging self-care assistive technology to 44 for emerging vision assistive technology). Excluding PCT filings, as these represent applicants' intention to seek patent protection

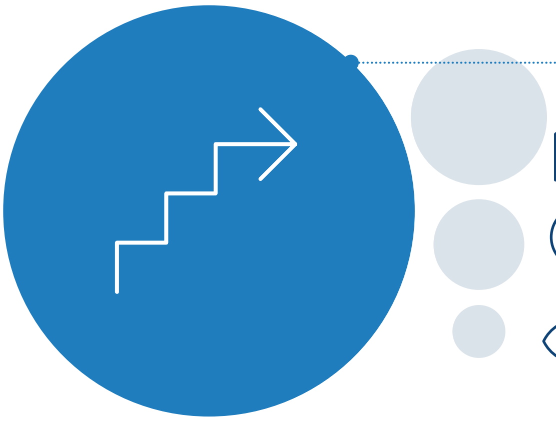
Conventional assistive technology at a glance

117,209

patent families for conventional assistive technologies filed **across 56 patent offices**

Which domains received most filings?

(number of patent families and % of dataset)



Mobility
63,245 (54%)

Environment
21,326 (18%)

Communication
6,899 (6%)

Hearing
14,198 (12%)

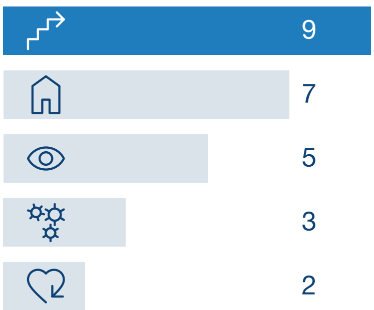
Self-care
6,410 (5%)

Vision
8,133 (7%)

Cognition
1,416 (<1%)

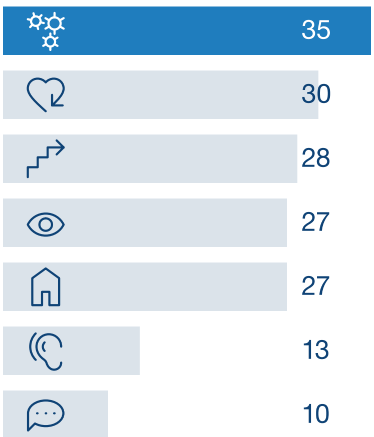
Which are the fastest growing domains?

(% based on average annual growth rate for 2013–17)



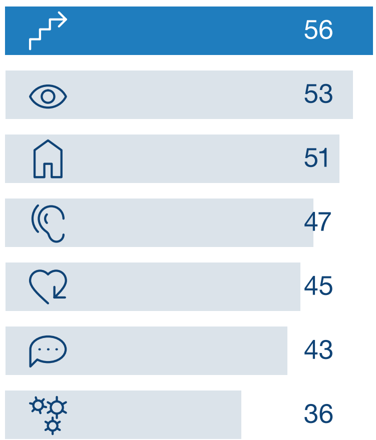
What is the proportion of utility models?

(% of total patent filings)



What is the breadth of patent protection?

(number of patent offices)



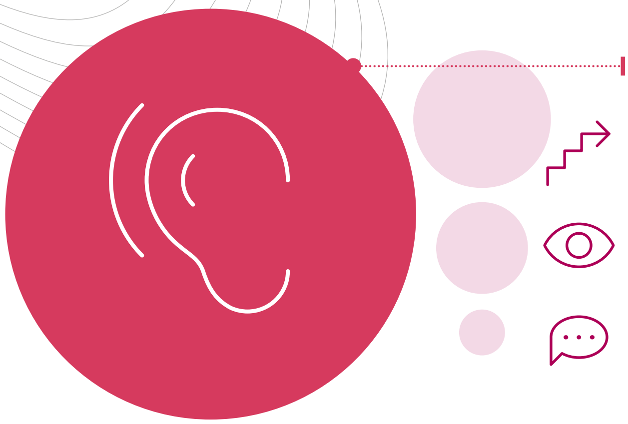
Emerging assistive technology at a glance

15,592

patent families for emerging assistive technologies filed **across 51 patent offices**

Which domains received most filings?

(number of patent families and % of dataset)



Hearing
4,968 (32%)

Mobility
4,526 (29%)

Environment
1,157 (7%)

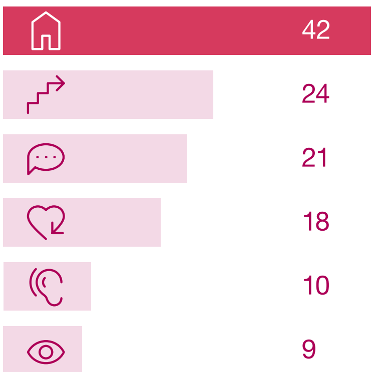
Vision
3,036 (19%)

Self-care
497 (3%)

Communication
1,599 (10%)

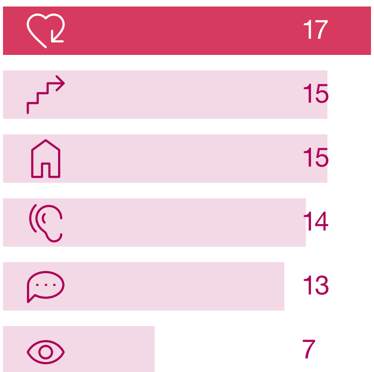
Which are the fastest growing domains?

(based on average annual growth rate for 2013–17)



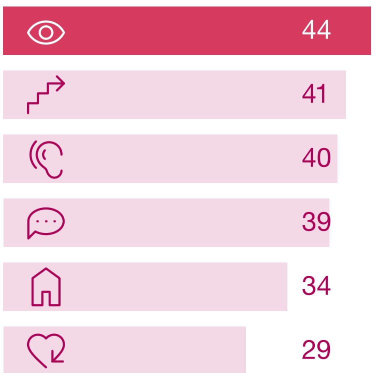
What is the proportion of utility models?

(% of total patent filings)



What is the breadth of patent protection?

(number of patent offices)



The development of emerging assistive products is facilitated by enabling technologies such as AI, used either alone or in combination.

Conventional assistive technology at a glance

Where is patent protection sought?

(% of patent families including a patent filing in the top 3 patent offices)*

Who is filing?

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
China	41%	1 Toyota	Individuals	44%
Japan	26%	2 Össur	Corporate	43%
U.S.	17%	3 Ottobock	Academia	13%

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
China	39%	1 Panasonic	Individuals	45%
Japan	28%	2 Toto	Corporate	44%
U.S.	13%	3 Sekisui	Academia	10%

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
U.S.	50%	1 WS Audiology	Corporate	74%
China	37%	2 Sonova	Individuals	17%
EPO	26%	3 Demant	Academia	8%

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
China	50%	1 Seiko	Corporate	54%
U.S.	28%	2 Essilor	Individuals	35%
Japan	25%	3 Hoya	Academia	10%

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
China	38%	1 IBM	Corporate	64%
U.S.	36%	2 Panasonic	Individuals	25%
Japan	25%	3 Samsung	Academia	10%

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
China	40%	1 Oji Paper	Individuals	59%
Japan	34%	2 Uni-Charm	Corporate	31%
U.S.	12%	3 Kao	Academia	9%

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
China	55%	1 Seiko	Corporate	52%
U.S.	18%	2 Honeywell	Individuals	30%
Japan	17%	3 Hon Hai Precision	Academia	17%

Total

Where is patent protection sought?	%	Top 3 patent applicants	Applicant profile	%
China	41%	1 WS Audiology	Corporate	48%
U.S.	27%	2 Panasonic	Individuals	40%
Japan	21%	3 Sonova	Academia	11%

* Note: WIPO refers to PCT applications, EPO to EP applications

Emerging assistive technology at a glance

	Where is patent protection sought? (% of patent families including a patent filing in the top 3 patent offices)*		Who is filing? Top 3 patent applicants	Applicant profile	
	U.S.	48%	1 Cochlear	Corporate	72%
	China	42%	2 Sonova	Academia	13%
	WIPO	30%	3 MED-EL	Individuals	13%
	China	50%	1 Toyota	Corporate	44%
	U.S.	27%	2 Honda	Academia	34%
	WIPO	20%	3 Tsinghua University	Individuals	19%
	U.S.	55%	1 Second Sight Medical	Corporate	58%
	WIPO	36%	2 S. Fyodorov Eye Microsurgery Federal State Institution	Academia	24%
	China	32%	3 Johnson & Johnson	Individuals	16%
	China	39%	1 IBM	Corporate	47%
	Japan	19%	2 Panasonic	Individuals	27%
	U.S.	19%	3 NEC	Academia	25%
	China	62%	1 Panasonic	Corporate	54%
	U.S.	19%	2 Toyota	Academia	23%
	Japan	15%	3 Chongqing Youbanjia Technology	Individuals	21%
	China	59%	1 Google	Corporate	50%
	U.S.	21%	2 Liuzhou Yiwang Technology	Individuals	29%
	Republic of Korea	15%	3 National Rehabilitation Center; Kimberly-Clark; Johnson & Johnson; Chengdu Shouzhang Technology**	Academia	20%
Total	China	44%	1 Cochlear	Corporate	57%
	U.S.	38%	2 Sonova	Academia	23%
	WIPO	25%	3 MED-EL	Individuals	18%

> Emerging hearing and vision assistive technology are dominated by a small number of key corporate players. The top patent applicants account for 28% of emerging hearing assistive technology and 23% of emerging vision assistive technology filings.

Notes: * WIPO refers to PCT applications, EPO to EP applications; ** Joint third

Figure 3.3a. Number of patent applications filed for patent protection from 1998 to 2019 at the top five offices across the different functional categories in conventional assistive technology

The patent offices of China and the U.S. received most filings for both conventional and emerging assistive technology, followed by Japan, WIPO and EPO for conventional and WIPO, EPO and Japan for emerging assistive technology

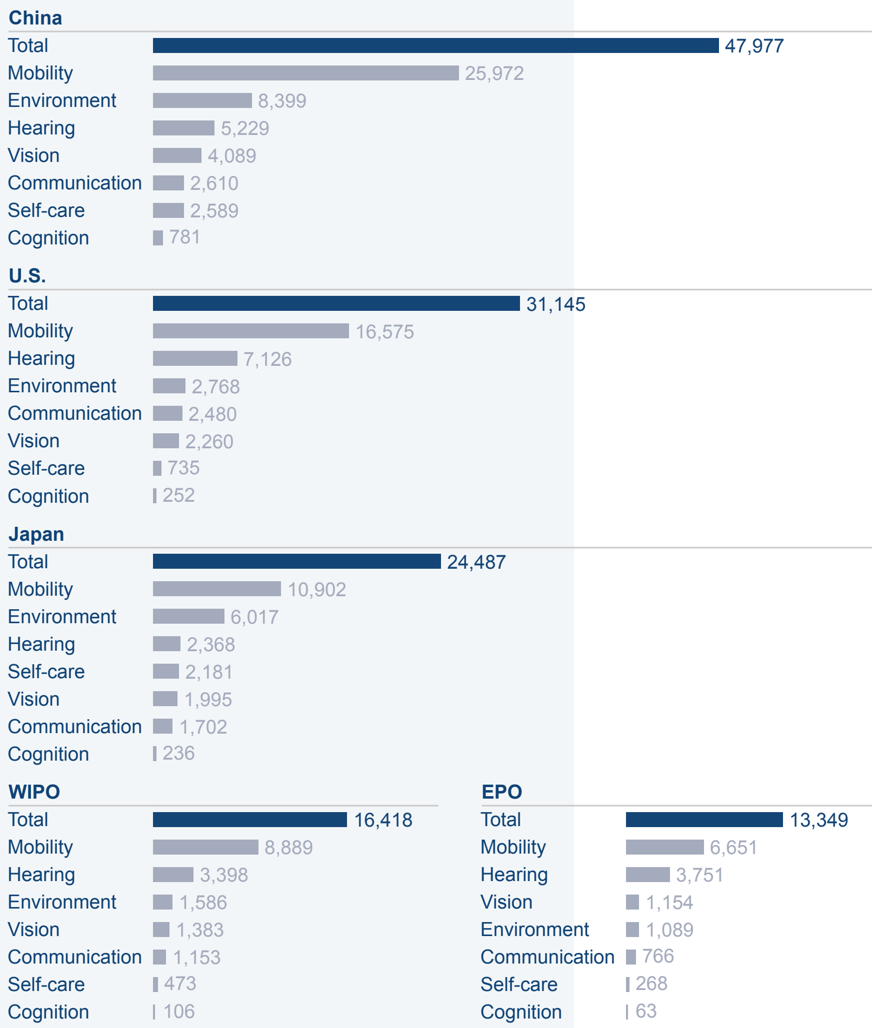
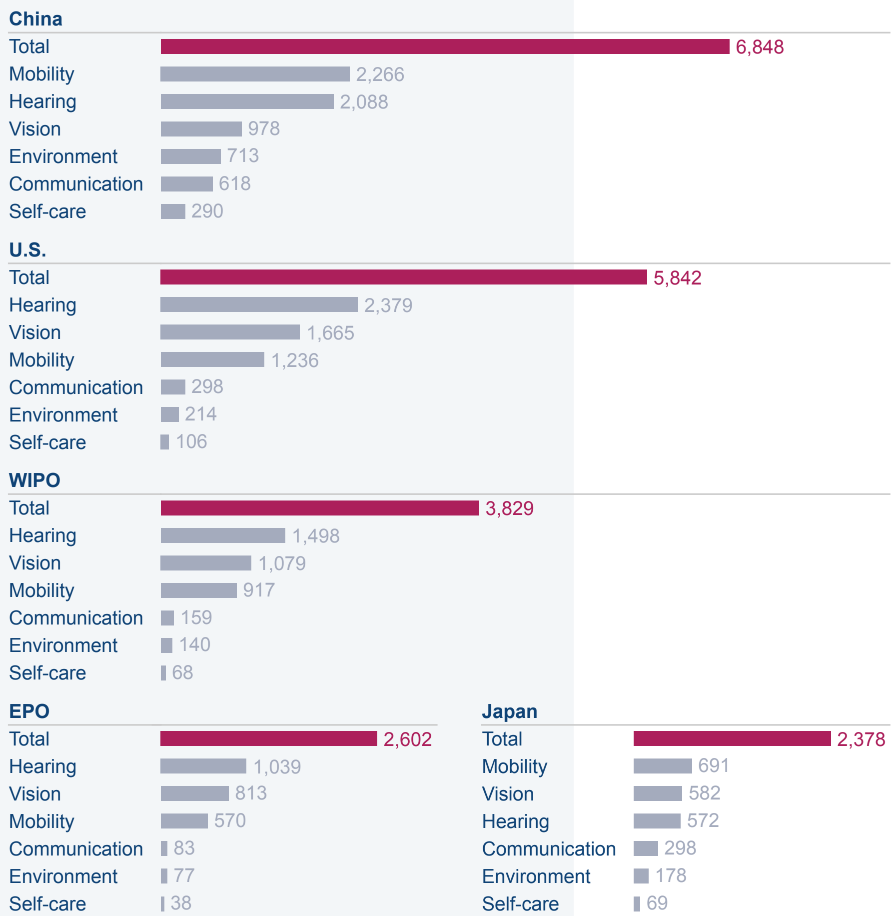


Figure 3.3b. Number of patent applications filed for patent protection from 1998 to 2019 at the top five offices across the different functional categories in emerging assistive technology



Note: EPO is the European Patent Office. WIPO represents PCT applications.

in multiple jurisdictions rather than specific patent protection in a market or region, the five main target markets where patent protection is sought for both conventional and emerging assistive technology are China, the U.S., Europe (as represented by European patent (EP) applications), Japan and the Republic of Korea (Figure 3.3).

Looking further at regional offices, the Eurasian Patent Office (EAPO) received 75 patent applications in the field of conventional and 8 in the field of emerging assistive technology, while the Gulf Cooperation Council received 8 and 2 patent applications, respectively. In Europe, Germany and France are the top offices of filing for conventional technology. The European Patent Office (EPO) and Germany lead patent applications related to emerging assistive technology in Europe, followed by Spain, France and the U.K. In Latin America and the Caribbean, Brazil (324 patent families) and Mexico (174 patent families) are the top patent offices for emerging assistive technology. In Africa, patent protection was sought only in South Africa, and this was the case for all domains of assistive technology (327 conventional and 54 emerging patent filings).

Shift in dominance

In the past, the top patent offices for filing, and therefore perceived target markets, in assistive technology have been the U.S. and Japan. Patenting activity has, however, been declining in these two jurisdictions. At the same time, there has been a surge in patent filings in China and an increase in filings in the Republic of Korea. This pattern is observed for both conventional and emerging assistive technology, with China's annual filings surpassing those of the U.S. in 2008 for conventional and 2014 for emerging assistive technology, and the Republic of Korea receiving more filings each year than Japan since 2014 and 2016 for conventional and emerging assistive technology, respectively (Figures 3.4 and 3.5).

Patent filings related to conventional assistive technology have also declined in Europe, especially in Germany, France, the Netherlands and Norway. Only two countries in Europe – Poland and Austria – have recorded an increase in patent filings, with approximately 83% and 54%, respectively, of conventional filings made from 2010 onwards. In the case of Poland, this is mainly due to local applicants, while the filings in Austria come from a combination of Austrian and foreign applicants.

The Chinese ecosystem for assistive technology

China is facing a severe ageing population situation coupled with a decline in the number of children being born, so the development of the assistive technology industry is important to the government. It seems to be ahead in supporting assistive technology commercialization, R&D funding, industrial park construction, tax preference and patent transformation of scientific research institutions. Recent activity in China’s capital investment market has also promoted the rise of many emerging assistive technology enterprises.

To cope with its ageing population, China has introduced a series of policies that will greatly promote assistive technology, remote IoT services, work/entertainment assistive products and other assistive technology products.

Recently, China has introduced many relevant policies to support assistive technology development, the most important being the Proposal on Accelerating the Development of Assistive Products Industry in China, issued by the State Council in 2016. It proposed a set of policy solutions, such as promotion of innovation and technological transformation, to help establish an ecosystem for assistive technology development. Issues such as payment systems, product supervision and establishment of professional posts are being resolved to ensure that this development is sustainable.

Hongliu Yu,
University of Shanghai for Science and Technology

Figure 3.4. Number of patent applications to the patent offices of China, the U.S., Japan and the Republic of Korea for conventional assistive technology by priority year (2000–2017)

China surpassed the annual filings of the U.S. in 2008, and has recorded a very strong growth rate ever since (AAGR for 2013–2017 of 15% for conventional and 29% for emerging technologies), while filings in the U.S. have been decreasing

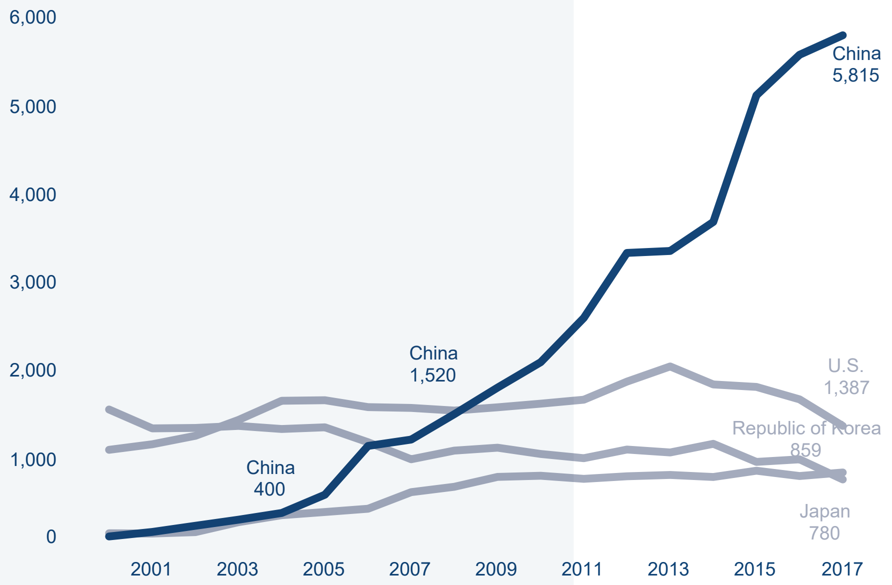
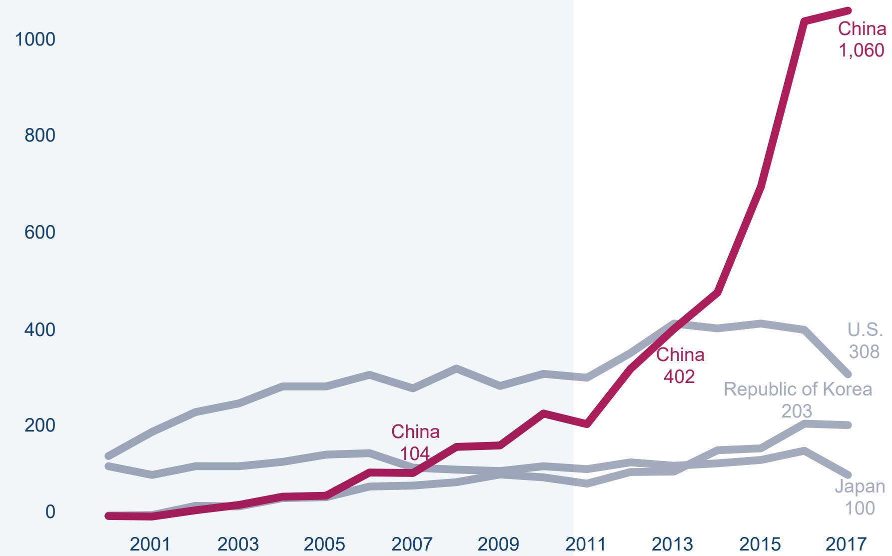


Figure 3.5. Number of patent applications at the top four patent offices of filing for emerging assistive technology by earliest priority year (2000–2017)

There is a marked growth in applications filed in China after 2014. At the same time, there is a slight growth in filings in the Republic of Korea, whereas filings in the U.S. and Japan, which were stable, have recently been decreasing



Patent filing for conventional assistive technology applications started later in some other jurisdictions, including Argentina, the Gulf Cooperation Council, Kazakhstan and Turkey.

In Asia, Singapore, China and the Republic of Korea are the patent offices with the most recent and highest growth in patent filings for emerging technologies, with around 70% of patent applications filed collectively from 2010 onwards, and an AAGR of 33%, 29% and 19% (for 2013–2017), respectively. China's position as a manufacturing center and parts supplier makes this an important location in companies' IP strategies (see the Össur collaboration example on page 119), even if China is not a target market. Patenting activity also reveals that Brazil, India and the Russian Federation show an increase in filings for emerging technologies and are key emerging markets since 2005.

The U.S. is the top office of filing for inventions related to conventional hearing technologies, while China leads in patent filings for all remaining six conventional functional categories (Figure 3.3a). Japan is second top patent office for filings in conventional environment and self-care assistive technology and ranks third for the remaining areas apart from hearing, where it is ranked fifth.

Similarly, for emerging assistive technology (Figure 3.3b), the U.S. receives most patent applications related to vision and hearing, while China leads in the four other functional categories. Although, due to its historical patenting activity, Japan is ranked higher than the Republic of Korea, this is not the case for emerging self-care technologies, where the Republic of Korea has received slightly more patent families related to this area than Japan. The top 10 across all functional categories, conventional and emerging, features Australia, Canada, Germany and the Russian Federation.

Most patent applications in China relate to emerging hearing and mobility assistive technology and are filed by non-resident applicants, mainly European and Australian companies, including Med-El (Austria), Cochlear Ltd (Australia), Sonova, and Novartis (Switzerland). Local top applicants include Shanghai LishengteMedical Technology, Nurotron Biotechnology (Hangzhou, China) and Shanghai Jiao Tong University.

Japan is seen as a key market for large corporate applicants from Australia, Europe and the U.S., mainly in the fields of hearing and vision assistive technology, based on the applicants' profile for patent filings in Japan.

The majority of filings made in Germany by non-resident applicants are from U.S.-based applicants, demonstrating that Germany is a key market for U.S. players in Europe. This is likewise the case for Spain. Filings in South Africa come mainly from U.S. and European applicants.

Do applicants have a global filing strategy?

Applicants appear to focus on a single market when securing protection across the entire assistive technology space, which often coincides with a local market, based on the information on the origin of inventors. However, emerging assistive technology seems to attract a more cross-border approach, with nearly 28% of the patent families including patent applications filed across two or more jurisdictions, in comparison to 19% in the conventional assistive technology space.

With respect to emerging technologies, this difference may indicate a growing market, changes in manufacturing profiles, or a higher reliance on patent rights for success. Notably, independent inventors make up 40% of the total applicants in the conventional assistive technology space and tend to file for patent protection in their home jurisdiction. In general, independent inventors tend to file in their home jurisdiction with less of an emphasis elsewhere. This phenomenon is often linked to more limited availability of financial resources than larger commercial players can access or less detailed knowledge of the patent system.

WIPO and the EPO, administering the Patent Cooperation Treaty (PCT) and EP filings, respectively, feature among the top five offices

Figure 3.6. Patent families first filed for patent protection from 1998 to 2019 that include PCT and EP applications across the functional categories of conventional and emerging assistive technology

Functional categories with a higher incidence of corporate players (such as conventional hearing and emerging vision) correlate with an increased use of the PCT and/or EP systems, signifying a desire to protect inventions more widely

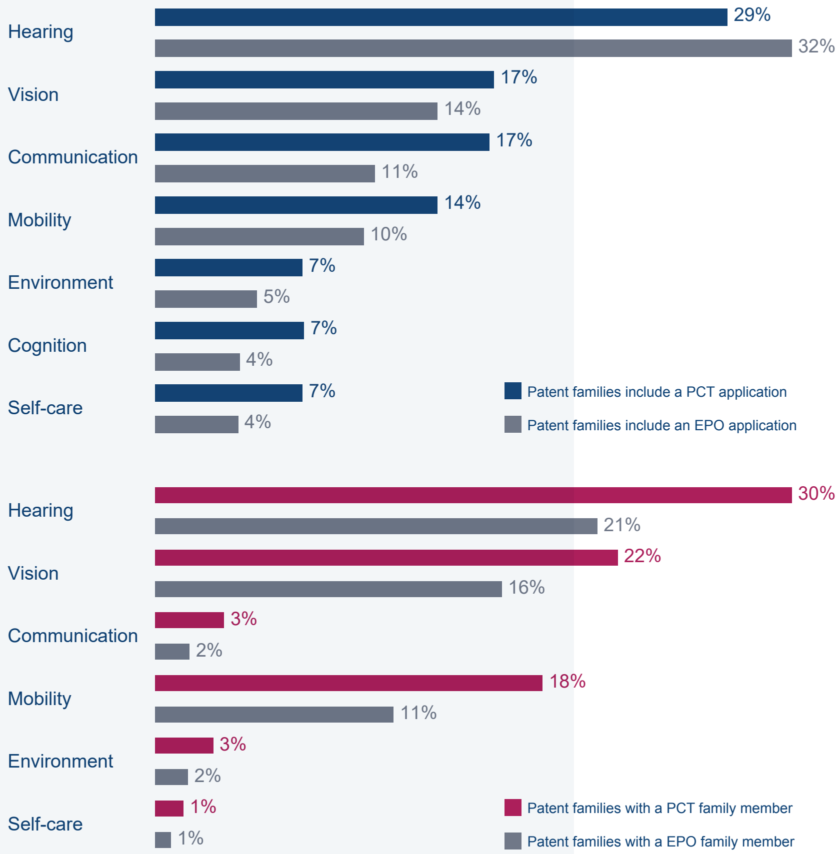
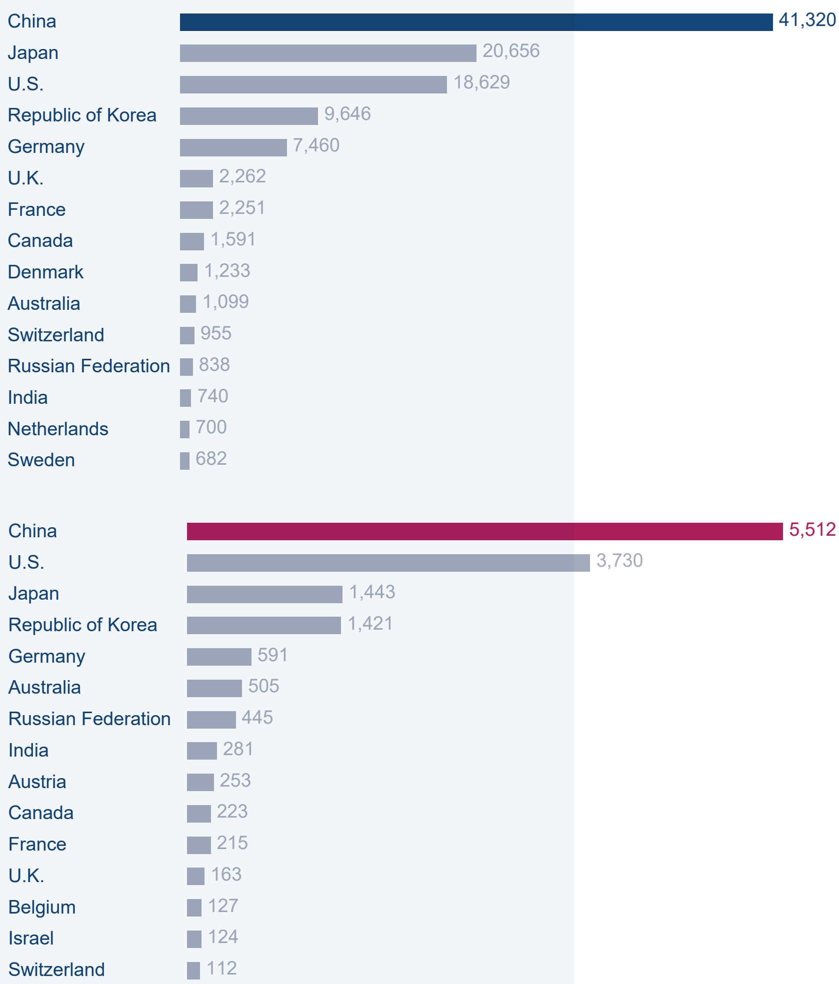


Figure 3.7. Top countries of residence for inventors by number of patent families first filed for protection from 1998 to 2019: conventional (top) and emerging (bottom) assistive technology patent filings

The top five for conventional and emerging technologies follow similar patterns, but the U.S. overtakes Japan for emerging assistive technology



of filing for both conventional and emerging assistive technology. In the conventional dataset, 14% of patent families include a PCT filing and 11% an EP filing, compared with 25% and 17%, respectively, for emerging assistive technology. This indicates a greater intention to seek protection in multiple jurisdictions for emerging applications. It is worth noting that 53% of PCT applications for conventional assistive technology were filed after 2010, showing a recent increase in the use of the PCT route by patent applicants seeking wider protection.

There is also a clear correlation between those functional categories with a higher incidence of corporate players and an increased use of the PCT and/or the EP systems. This is seen to be the case, for example, with conventional hearing and emerging vision assistive technology (Figure 3.6).

Where is assistive technology being developed?

Based on the inventors' country of residence (Figure 3.7), most inventions related to conventional assistive technology come from, in order of volume, China, Japan, the U.S., the Republic of Korea and Germany. This order is replicated for emerging assistive technology, except that the U.S. is in second position, followed by Japan in third. These five jurisdictions coincide with the previously identified top patent offices for filing.

The same pattern of declining patenting activity in the U.S. and increasing activity in China observed earlier (Figure 3.5) is also seen in the inventors' country of residence for both the conventional and emerging assistive technology datasets. There is a surge in inventors from China alongside a decrease in filings from U.S.-based inventors, foremost in the areas of mobility and environment (conventional and emerging) and emerging hearing technologies.

In China, until 2005, 44% of conventional patent applications filed were received from foreign inventors (mainly from the U.S., Japan and Germany) as subsequent filings. The landscape has now changed, with local inventors accounting for 86% of conventional and 78% of emerging patent filings.

In Japan, 83% of patent applications related to conventional assistive technology have at least one local inventor. The remaining applicants filing for protection in Japan are primarily from the U.S., the Republic of Korea and Europe (Germany, Denmark, France and the U.K.). However, the situation is different for emerging assistive technology patent filings in Japan, with the proportion of local inventors dropping to 58%, indicating a greater foreign interest in the Japanese market for emerging assistive technology.

The development and interest in assistive technology in the Republic of Korea, as reflected in related patent filings, seems to be mainly local, with local inventors accounting for 81% of conventional and 73% of emerging patent filings. LG Electronics, Samsung and the National Rehabilitation Center (Seoul) are the leading domestic applicants.

Over half (56% of emerging and 57% of conventional) patent applications filed in the U.S. are from local inventors, with foreign inventors being mainly from Germany, Denmark, the U.K. and Switzerland.

Who is leading the development of assistive technology?

Top corporate players

Looking at the top 30 patent applicants across all functional categories, it is evident that it is corporate players who lead the development of assistive technology (Figures 3.8 and 3.9). They account for 59% of emerging assistive technology patent families and 49% of conventional assistive technology. Corporate activity grew by an AAGR of 17% for emerging and 6.8% for conventional patent families during 2013–2017.

The leading corporate applicants to appear among the top 30 applicants for both conventional and emerging assistive technology are hearing aid and walking aid

Figure 3.8. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 and distribution of their portfolio across functional categories for conventional assistive technology*

Companies that specialize in assistive technology tend to have a more focused portfolio in their product area/area of expertise, while consumer electronic goods have a patent portfolio including applications across several functional categories. Car industry representatives predominantly file in mobility

**Percentages do not sum to 100% because of category overlaps*

Patent Applicant	Mobility	Environment	Hearing	Vision	Communication	Self-care	Cognition
WS Audiology (1193)			100%				
Panasonic (850)	27%	33%	22%	4%	14%	3%	1%
Sonova (846)			100%				
Demant (527)			100%				
Toyota (501)	92%	4%	1%	1%	2%		
Össur (448)	100%						
Cochlear (441)			100%				
Samsung (385)	12%	10%	36%	14%	29%	1%	3%
Ottobock (380)	100%	1%					
GN Group (335)			100%				
Hitachi (322)	50%	22%	7%	7%	11%	4%	1%
IBM (289)	5%	4%	23%	23%	51%		2%
Sony (233)	12%	8%	44%	9%	28%	1%	1%
Invacare (233)	94%	11%					
Toshiba (217)	27%	23%	24%	8%	19%		3%
Honda (217)	93%	1%	2%		2%		1%
Semiconductor Energy Lab (195)	98%	1%	1%		1%		1%
Mitsubishi (184)	36%	31%	11%	8%	16%	1%	3%
Essilor (142)		1%	1%	99%			
Yamaha (138)	51%	24%	17%	1%	7%		1%
Sekisui Chem (135)	14%	90%			1%		
Philips (129)	19%	26%	29%	6%	14%	5%	1%
University of Shanghai for Science and Technology (129)	65%	13%	1%	4%	5%	14%	
LG (231)	17%	13%	31%	14%	28%	1%	1%
Med-El (194)			100%				
NEC (167)	10%	16%	31%		49%		
Seiko (232)	6%	5%	4%	72%	5%		9%
Starkey (333)		1%	100%				
Sunrise Medical (163)	98%	5%			1%		
Toto (172)	8%	92%	1%	1%	2%	1%	

Figure 3.9. Top 30 patent applicants by number of patent families first filed for patent protection from 1998 to 2019 and distribution of their portfolio across functional categories for emerging assistive technology*

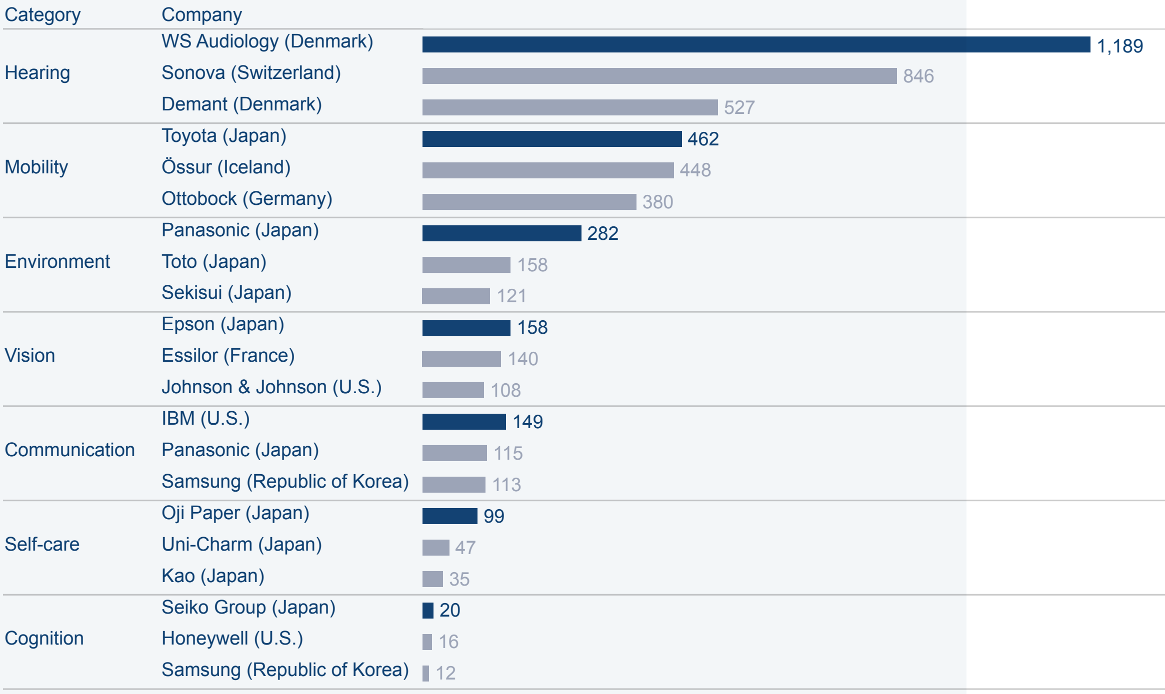
Patent applicants in the field of emerging assistive technology follow a similar patent strategy to those in the conventional assistive technology field. Car industry representatives and top universities file mainly in the field of mobility, consumer electronic goods companies across different functional categories, while specialized assistive technology companies focus their patent portfolio in their product categories

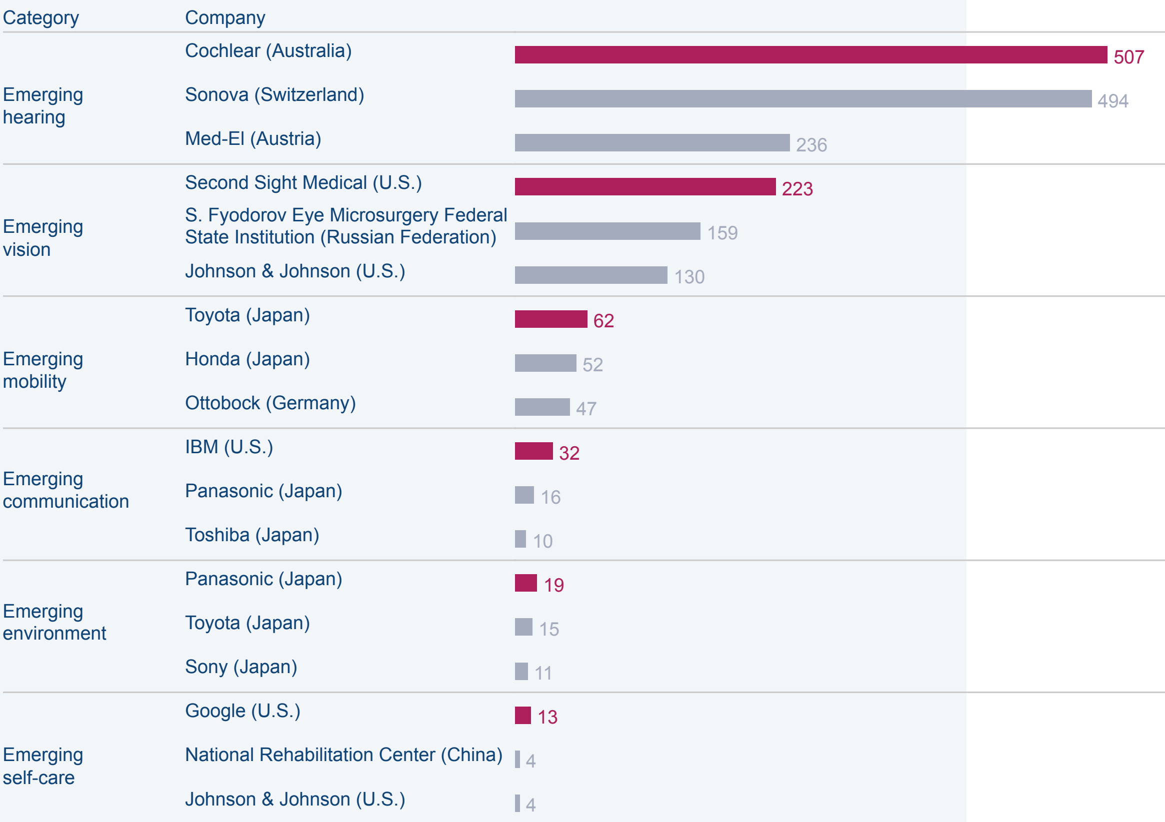
**Percentages do not sum to 100% because of category overlaps*

Patent Applicant	Hearing	Mobility	Vision	Communication	Environment	Self-care
Cochlear (512)	99%	0%	1%			
Sonova (494)	100%					
Second Sight Medical (247)	6%	2%	93%			
Med-El (239)	99%		1%			
S. Fyodorov Eye Microsurgery Federal State Institution (159)			100%			
Johnson & Johnson (134)			97%			3%
Panasonic (108)	40%	25%		15%	18%	3%
Allergan (102)			100%			
Toyota (91)	3%	68%	3%	9%	16%	
Alcon (80)			100%			
Shanghai Lishengte Medical Technology (76)	100%					
Samsung (79)	27%	58%	5%	8%	4%	
Nurotron Biotechnology (79)	90%		10%			
Novartis (79)	1%		96%			3%
Google (79)	47%	1%	33%	3%		16%
Demant (68)	100%					
IBM (67)	18%	10%	12%	48%	13%	
Heinz Kurz (61)	100%					
LG (59)	39%	39%	3%	15%	2%	2%
Shanghai Jiao Tong University (57)	2%	70%	30%			
Honda (57)	2%	91%	2%	4%	2%	
University of California (51)	20%	39%	39%		2%	
Temco (48)	100%					
Tsinghua University (47)	45%	34%	15%	6%		
Ottobock (47)		100%				
South China University of Technology (45)	9%	67%	7%	7%	11%	4%
Shenzhen Institutes of Advanced Technology (44)	14%	64%	23%	5%		
Voxtech (43)	95%		5%			
MIT (43)	14%	70%	14%		2%	
University of Shanghai for Science and Technology (42)	2%	81%	5%	7%	2%	2%

Figure 3.10. Top three patent applicants by functional category for (top) conventional and (bottom) emerging assistive technology

Consumer electronic goods and car industry companies are among the top filers and some of the same companies lead in both conventional and emerging assistive technology





manufacturers. This reflects the large volume of the hearing and mobility datasets and their dominance by large players. Indeed, hearing has the largest contribution (72%) of patent families from corporate applicants of any emerging assistive technology. Furthermore, among the top players are big optics and ophthalmological companies, vision representing the third largest area in the assistive technology dataset.

Patent families filed by players in the automotive industry primarily relate to mobility – either in relation to the use of cars or else mobility in the broader sense, including inventions related to orthotics and exoskeletons. Consumer electronic goods companies and large conglomerates lead in corporate patent applications. Some, such as Panasonic, may not appear in the overall top 30, but are nevertheless top filers across the different domains of assistive technology, indicating their multidimensional focus and diverse commercialization interests (Figure 3.10). The top 30 applicants in the conventional technology patent landscape primarily consist of corporate players from Japan and Europe, with no China-based corporate player present. This is because the profiling of China-based patent applicants suggests a very fragmented market, with around 7,000–8,000 portfolio holders (compared with no more than 4,000 portfolio holders in Japan and the U.S.). The picture is similar for emerging assistive technology: China is a fragmented market; the U.S. a more consolidated one.

The top 30 patent applicants account for 8% of the identified inventions for conventional assistive technology, but 21% of the emerging inventions. This suggests patent activity related to emerging assistive technology is the more consolidated, mostly driven by US-based and European applicants, particularly for hearing and vision technologies. The markets for the other emerging functional categories are more fragmented, similar to the conventional areas. Hearing is the only functional category in the conventional assistive technology dataset with a clear dominance by larger players.

Twelve patent applicants feature in the top 30 applicants for both conventional and emerging assistive technology (Figure 3.11). Eleven of these are corporate players, with just one a university (University of Shanghai for Science and Technology). Looking at the patent portfolios held by these applicants, most of the patent families are related to conventional assistive technology, which is the more established area in assistive products. Still, top patent applicants in both areas who represent those companies specializing in hearing technology have portfolios with a slightly better balance between conventional and emerging assistive technology, with Cochlear and Med-El even filing more patent applications related to emerging technologies.

Looking at their activity over time (see Figure 3.12), we find some of these 12 companies filing as much, if not more, in emerging as they do in conventional assistive technology. Others share a similar filing pattern for conventional and emerging assistive technology, with the latter being at a lower level, while yet others seem recently to have begun exploring emerging technologies.

Traditional assistive technology companies lead applications in conventional assistive technology (Figure 3.13), although at some points consumer electronic goods companies filed the same number of patent families, while the car industry has a relatively stable patent filing rate. The picture is different for emerging assistive technology. While there was a steep increase in patent filings made by companies specializing in assistive technology in 2002, consumer electronic goods companies showed a growing interest in subsequent years, with surges in patent filings during 2009–2012 and again in 2016, when patent filings from consumer electronic goods companies surpassed those from assistive technology specialists.

Consumer electronic goods companies dominate communication and vision technologies (Figure 3.14). Many of their filings relate also to hearing and mobility assistive technology; indeed, in these areas they either approach or surpass the number of annual filings made by assistive technology specialists.

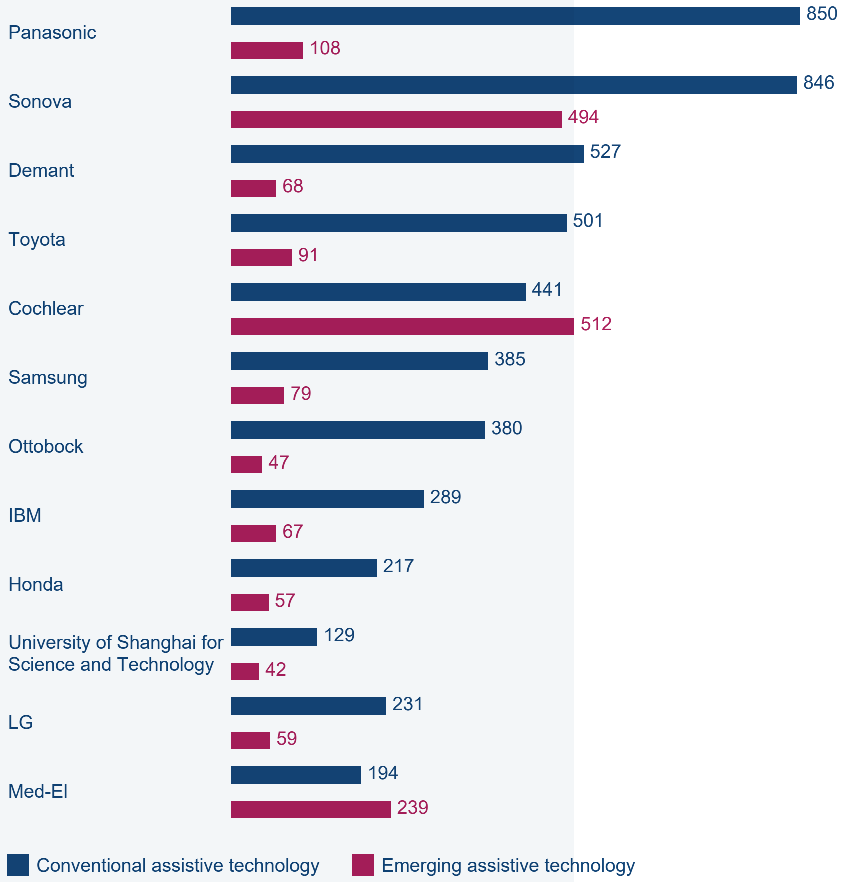


Figure 3.11. Patent portfolio distribution by number of patent families first filed for patent protection from 1998 to 2019 for the 12 top players featuring in the top 30 applicants for both conventional and emerging assistive technology

There are 11 corporate players and just one university. Most of these applicants' patent families are related to conventional assistive technology

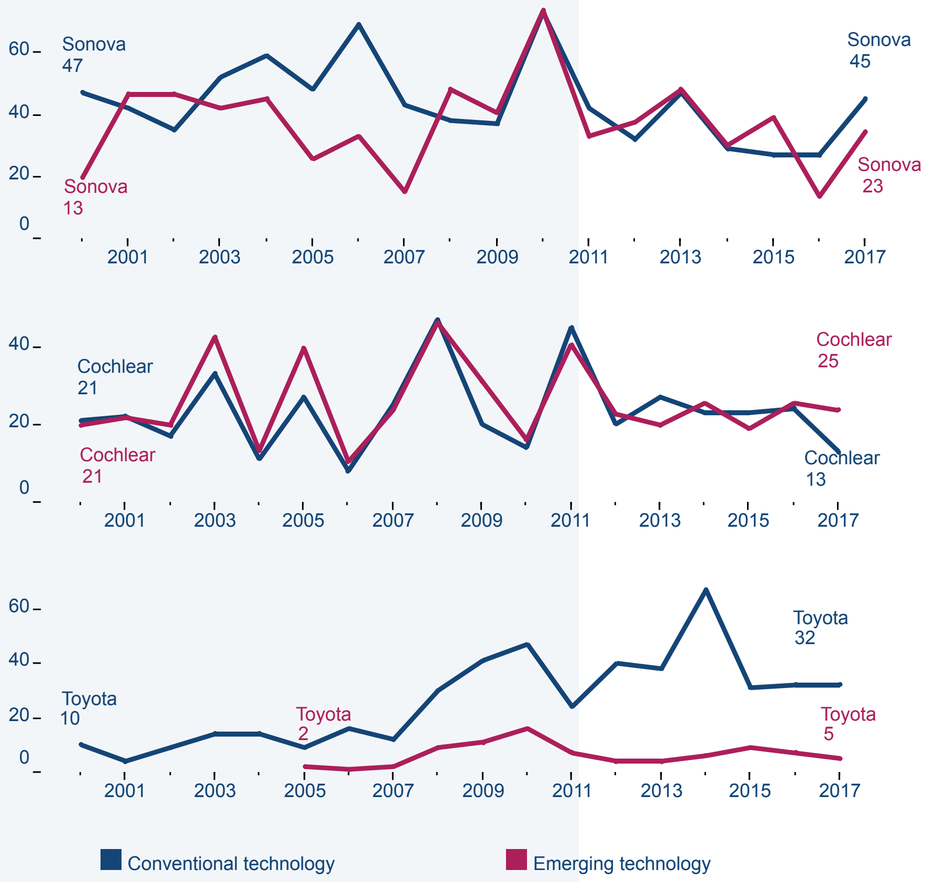
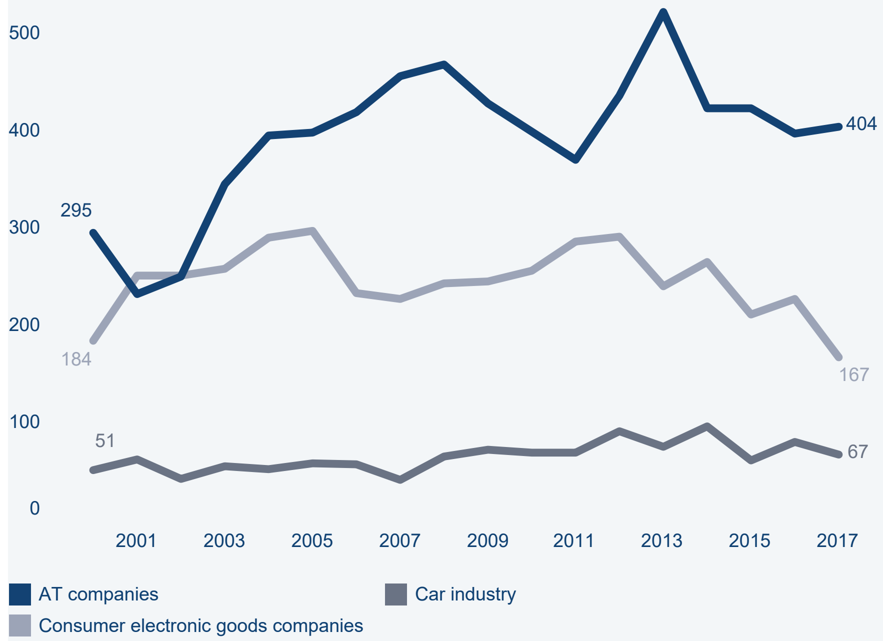


Figure 3.12. Patent filing in conventional and emerging assistive technology over time for the three top conventional and emerging players: Sonova, Cochlear and Toyota by priority year (2000–2017)

Cochlear has a relatively balanced portfolio but is beginning to file more patent applications related to emerging technology, whereas Sonova continues to file more applications related to conventional technology. Toyota began filing patent applications related to emerging assistive technology from 2005

Figure 3.13. Patent filing trends by profile of corporate players among the top 100 patent applicants for conventional (top) and emerging (bottom) assistive technology by priority year (2000–2017)

In recent years, consumer electronic goods companies have shown a significant growing interest in emerging assistive technology



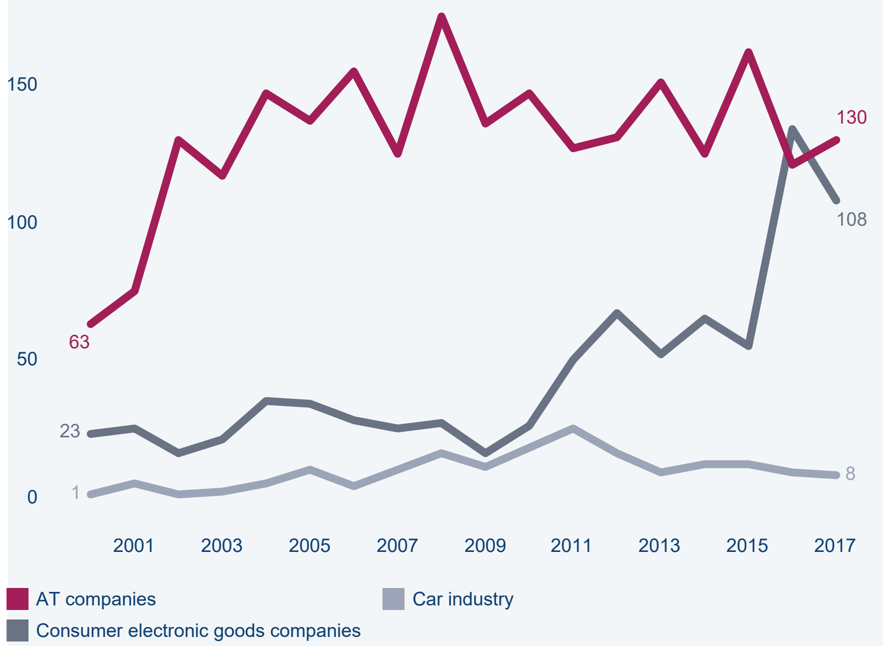
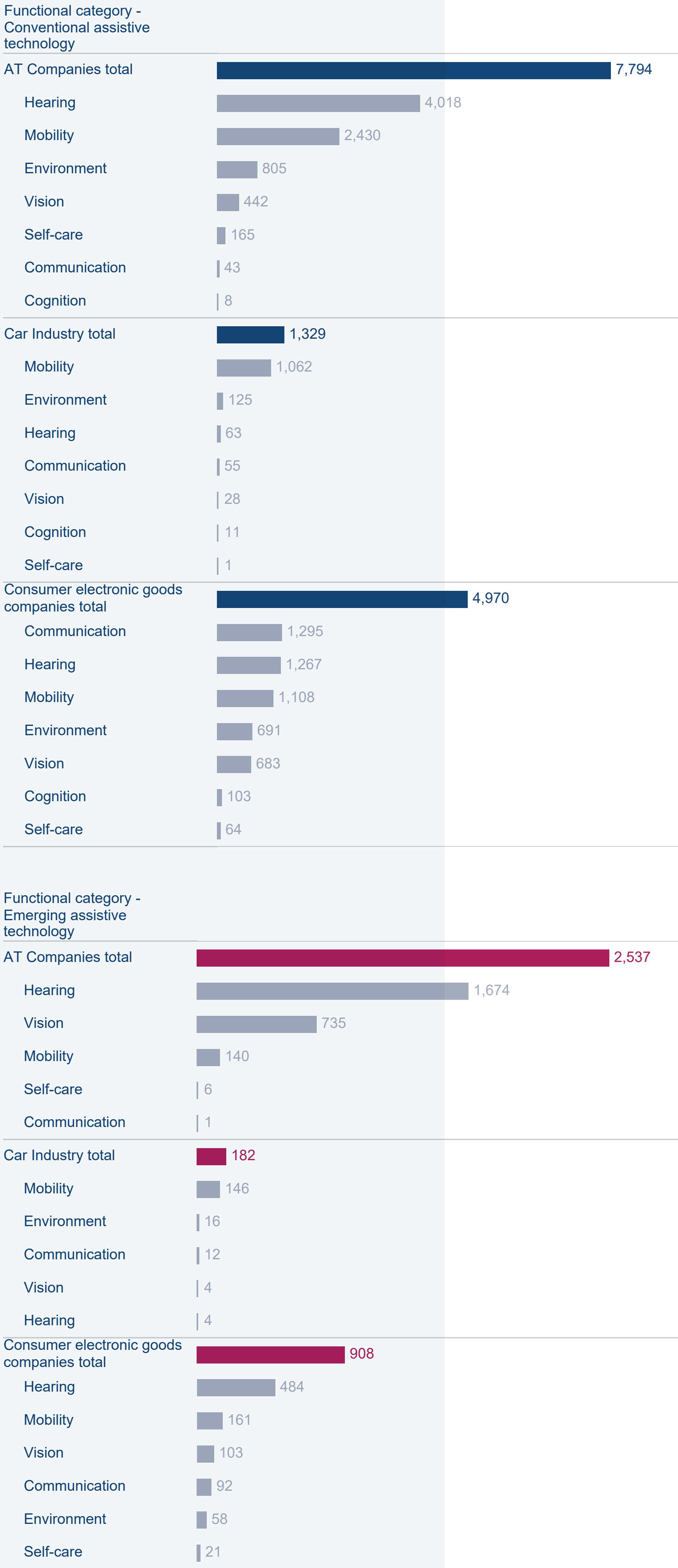


Figure 3.14. Patent filing trends by profile of corporate players among the top 100 patent applicants across functional categories of conventional (top) and emerging (bottom) assistive technology

The activity of the different corporate applicant profiles shows the diversification of their areas of interest



Since 2013, consumer electronic goods companies have surpassed the filing activity of assistive technology companies in emerging mobility and have seen a strong growth in filings, while patenting activity by the car industry has decreased.

Contribution from universities and research organizations

Typically, universities will conduct research in new areas that may be considered too commercially risky for industry to explore at an early stage. Universities and research organizations are more prominent in the emerging assistive technology dataset, accounting for 23% of related patent families, more than double the number (11%) in conventional assistive technology. Among the top 30 patent applicants for emerging assistive technology are seven academic institutions (all from either China or the U.S.), whereas the top 30 applicants for conventional assistive technology includes only one (University of Shanghai for Science and Technology).

Nine out of the top 10 academic institutions in conventional assistive technology are universities or public research organizations based in China (and the tenth is based in the Republic of Korea). The picture is more diverse among the top 100 emerging assistive technology patent applicants, where universities in Japan, the Russian Federation and the U.S. also feature among the top 10 university or public research patent applicants (Figure 3.15).

Across both conventional and emerging assistive technology, Asia's top patent applicants are all universities based in China; the German Fraunhofer Gesellschaft and the French Alternative Energies and Atomic Energy Commission (CEA) together account for the majority of applications from Europe; and the University of California and MIT lead in North America. Although less activity is seen in Latin America and the Caribbean, the Middle East and Africa, the top institutions from these regions are based in Brazil and Mexico, Israel, Turkey, UAE/Saudi Arabia and South Africa. The S. Fyodorov Eye Microsurgery Federal State Institutionin the Russian Federation is a prominent applicant in emerging assistive technology (see emerging vision technologies in Chapter 2), while, in Oceania, the University of Melbourne is a leading applicant for both conventional and emerging assistive applications, and the Brien Holden Vision Institute the top applicant for conventional assistive technology (Figure 3.16).

> It is surprising how long it takes for academic research to become applied and ubiquitous in commercial products and services. There is typically a 10- or even 15-year lag until we figure out how something can be deployed successfully.

Pattie Maes,
MIT Media Lab

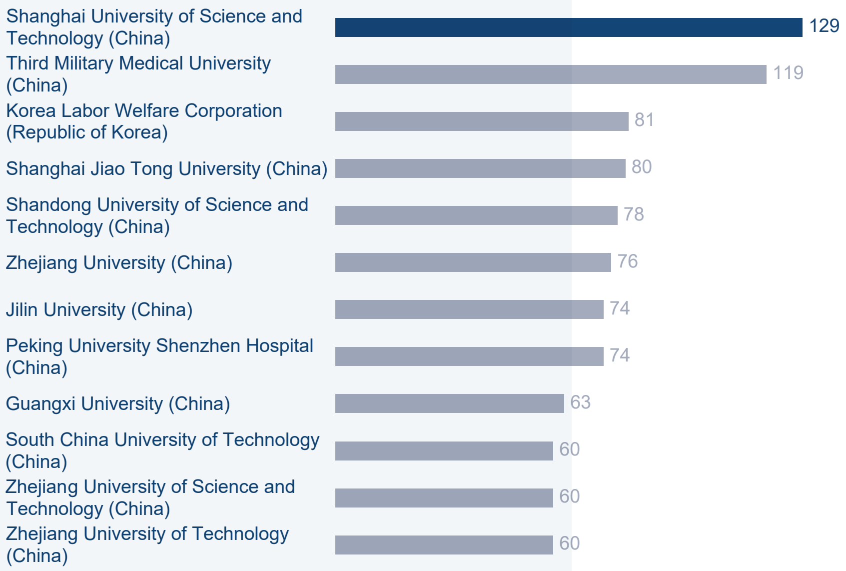
Universities and research organizations are mainly filing patent applications related to mobility assistive technology (both conventional and emerging technologies). A high number of filings also relate to conventional environment-related assistive technology, emerging hearing and vision-related inventions. There is low participation from universities and public research organizations in filings related to conventional vision, linked to the dominance of well-established applications and products in this domain. Despite having fewer filings than other functional categories, about 30% of patent applications related to cognition are from universities and public research organizations, indicating continuing research in this field. Patent filings from universities and public research organizations in the field of conventional assistive technology increased significantly at an AAGR of 20% for 2013–2017, with self-care and mobility the areas to see the most growth in patenting activity and vision-related assistive technology the least. Universities and public research organizations – mainly based in China – filed almost a half of their applications during 2013–2017. There was a lower growth rate in patenting activity for emerging assistive technology by universities and public research organizations, with an AAGR of 15% for the period.

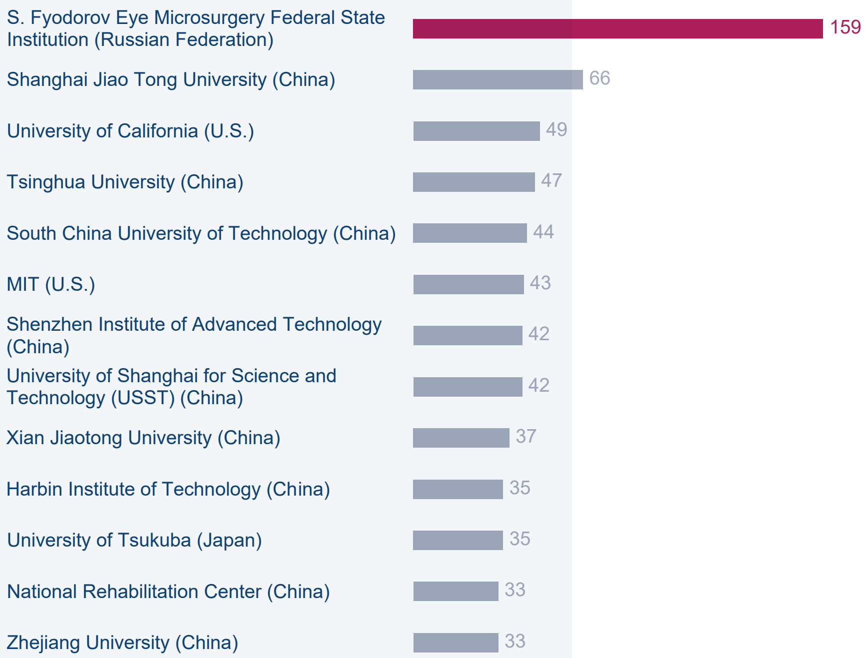
Independent inventors dominate simpler technologies, with over a third based in China

The low-tech nature of conventional assistive technology explains the remarkable difference between 40% of patent applicants being independent inventors in the conventional technology patent families compared with only 18% in the emerging technology patent families. The nature of the technologies involved in conventional assistive technology may be

Figure 3.15. Top universities or public research organizations within the top 100 patent applicants in conventional (top) and emerging (bottom) assistive technology by number of patent families first filed for patent protection from 1998 to 2019

The conventional assistive technology area is dominated by universities based in China, while top university or public research organizations in emerging assistive technology are shared among China, Japan, the Russian Federation and the U.S.





Many independent inventors are Servicesnow not looking to take products to market but instead for their IP to be licensed or purchased by corporates.

David Banes,
David Banes Access and Inclusion Services

linked to the high participation of independent inventors in this area's dataset. This is backed by the fact that utility models make up one-quarter of the dataset. Self-care (in both conventional and emerging assistive technology) attracts most activity from independent inventors, but so too does conventional mobility and environment assistive technology.

Most independent inventors of conventional assistive technology originate from China (38% of independent inventors) and their filings remain consistent (5% AAGR for 2013–2017). Of all utility models (25% of the dataset), 21% are Chinese utility models. These Chinese independent inventors are followed by inventors from the U.S., Japan, the Republic of Korea and Germany (15%, 12%, 11% and 7%, respectively). However, filings for conventional assistive technology from independent inventors from the U.S. and Japan are on the decline (–10% and –6% AAGR, respectively, for 2013–2017).

How is assistive technology evolving?

Patent documents are a unique source of technical information. Analyzing the assistive technology patent landscape can provide insights into the types of assistive technology being developed and the ways in which this technology is evolving. A number of overarching themes were identified across the functional categories. Projections for the future development of assistive technology, taking into account the wider context (see Chapter 4), are discussed later in Chapter 5.

One assistive technology for several functional limitations and tasks/functionalities

While in the past there were mainly specific product segments for dedicated user profiles and related specific functional limitations, the search and analysis revealed, through the categorization of some products in one of the seven functional categories we defined, that assistive technology was not always clear-cut. While some assistive technology products are inherently linked to a certain functional limitation due to the nature of the assistive product (e.g., Braille supporting products for visually impaired users), others can serve the same need for persons with several functional limitations. As a result, the same invention in the report may have been grouped under more than one of the different functional categories.

Besides the nature of certain products, throughout the analysis of the results we observed an increasing number of assistive products taking into account the needs of several user profiles, and offering more than one functionality, providing support in different tasks.

Companion robots, for example, are capable of supporting various impairments (cognitive, hearing, mobility and visual) while helping users with a wide range of tasks, for instance health and emotion monitoring, nursing, emergency monitoring, navigating and lifting. Wheelchairs controlled by lip-reading are a further example of technology addressing more than one functional limitation.

Assistive technology that ameliorates multiple functional limitations remains, however, the exception; but it is expected that the user accessibility gap will lessen with the development of technologies designed for different combinations of functional limitation. As we move toward more ICT/software-centric assistive technology, much of which will allow for access and use by multiple profiles of end-user, and in view of the inclusive design discussions taking place, it is anticipated that persons with multiple functional limitations could have access to a broader range of assistive technology in future.

Applying an assistive technology principle from one domain to another

The identification and analysis of conventional and mainly emerging assistive products showed that the principle of modularity applies

Figure 3.16. Leading university and public research organizations by region for conventional and emerging assistive technology by number of patent families first filed for patent protection from 1998 to 2019

In North America, the University of California and MIT in the U.S. are the top academic patent applicants. In Europe the majority of applications come from Germany, France and Poland, while China-based institutions lead patent filings in Asia.

North America

Conventional

U.S.	
University of California	48
MIT	46
U.S. Department of Veteran Affairs	46
University of South Florida	32
Vanderbilt University	29

Emerging

U.S.	
University of California	49
MIT	43
Massachusetts Eye and Ear Hospital	31
California Institute of Technology (Caltech)	26
Doheny Eye Institute	26

Latin America and the Carribean

Conventional

Brazil	
Federal Institute of Education, Science and Technology	9
University of São Paulo (USP)	9
Federal University of Rio Grande do Sul	7
Federal University of Minas Gerais	6
Mexico	
National Autonomous University of Mexico (UNAM)	7

Emerging

Mexico	
Center for Research and Advanced Studies of the National Polytechnic Institute (CINVESTAV)	3
Instituto Politécnico Nacional (IPN)	3
Instituto Tecnológico y de Estudios Superiores de Monterrey	3
Brazil	
Federal University of Rio Grande do Sul	3
University of São Paulo (USP)	3

Africa

Conventional

South Africa	
University of Cape Town	2
Design Indaba Trust	1

Emerging

South Africa	
University of Cape Town	1
Stellenbosch University	1

Europe

Conventional

Germany

Fraunhofer Gesellschaft	47

France

French Alternative Energies and Atomic Energy Commission (CEA)	27

Poland

Wrocław University of Science and Technology	25
Poznan University of Technology	8

Netherlands

Delft University of Technology	11

Emerging

Germany

Fraunhofer Gesellschaft	23
University of Rostock	10
Medizinische Hochschule Hannover (MHH)	8

France

French Alternative Energies and Atomic Energy Commission (CEA)	15

Switzerland

EPFL	12

Central Asia

Conventional

Russian Federation

St. Petersburg Clinical Research and Practical Center for Specialized Types of Medical Care (Oncologic)	17
Saint-Petersburg Research Institute of Ear, Throat, Nose and Speech	5
Nizhegorod Research Institute of Epidemiology and Microbiology	4
Russian Scientific Research Institute of Traumatology and Orthopedics	4
Perm State Medical University	4

Emerging

Russian Federation

S. Fyodorov Eye Microsurgery Federal State Institution	159
IRTC Eye Microsurgery Ekaterinburg Center	25
Eye Microsurgery National Medical Research Center	6
Saint-Petersburg Research Institute of Ear, Throat, Nose and Speech	5
Research Institute of Eye Diseases	4

Asia

Conventional

China

University of Shanghai for Science and Technology	129
Third Military Medical University	119
Shanghai Jiaotong University	80
Shandong University of Science and Technology	78
Zhejiang University	76

Emerging

China

Shanghai Jiao Tong University	66
Tsinghua University	47
South China University of Technology	44
Shenzhen Institutes of Advanced Technology (SIAT)	42
University of Shanghai for Science and Technology	42

Middle East

Conventional

Saudi Arabia

King Fahd University of Petroleum and Minerals	5

Turkey

Hasan Kalyoncu University	3
Anadolu University	1
Altınbas University	1

Israel

Shenkar College of Engineering and Design	1

Emerging

UAB

United Arab Emirates University	3

Israel

Yissum Research Development Company, Hebrew University of Jerusalem	3

Turkey

Özyegin University	2
Hasan Kalyoncu University	1

Pacific

Conventional

Australia

Brien Holden Vision Institute	23
University of Melbourne	5
University of Queensland	4
University of Technology Sydney	3
Monash University	2

Emerging

Australia

University of Melbourne	18
Bionic Ear Institute	9
Bionics Institute Australia	8
Monash University	2
Swinburne University of Technology	2

AI and accessibility

Artificial intelligence has immense potential at relatively affordable cost for people with disabilities. However, AI is not yet mature enough to replace the need for humans to follow accessibility standards and may also pose significant ethical, legal and economic concerns, as well as risks relating to human rights. For example, if training datasets do not include data on a wide variety of people, then the AI will exhibit a bias toward certain population cohorts (e.g., speech recognition technology that does not understand people with a speech impairment).

It is likely that AI functionality for accessibility will emerge more gradually, initially being accorded simple tasks, such as detecting content structures, progressing to content adaptation and complex interactions, such as in virtual and augmented reality environments. AI must be considered an augmentative technology that should be tailored to personal needs – at present, the aim is to augment users' skills, not provide AI to replace them.

Doreen Bogdan-Martin,
ITU Telecommunication Development Bureau

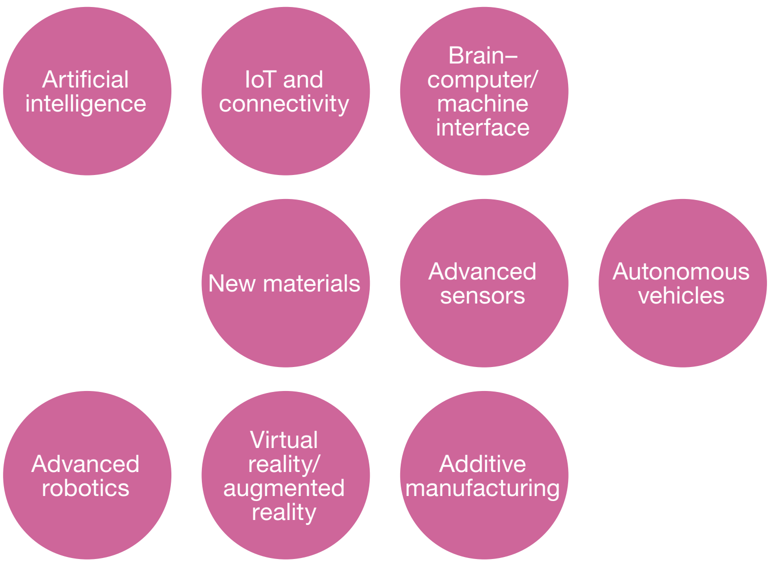
also in the area of assistive technology: technologies developed for one specific product or functional limitation are being re-employed and used for the development of a product meant for another functional limitation. Examples of this trend include electric stimulation restoring locomotion in mobility or bone conduction to convey sound in the area of hearing which are employed to provide alternative sensory feedback in other areas, such as communication or even vision (see the AlterEgo case study and examples mentioned in Chapter 2).

Increasing use of enabling technologies – toward smarter, more connected assistive products

One of the key findings of WIPO's *Technology Trends 2019* report on artificial intelligence is the penetration of AI into all possible fields and the development of different applications influencing all possible industries (WIPO, 2019).

The identification of emerging assistive products and the review of related patent documents allow us to confirm that the same is true for the area of assistive technology: enabling technologies (such as AI, IoT and advanced

Figure 3.17. Enabling technologies identified in the emerging assistive applications patent dataset (see Annex 3 for a detailed breakdown by technology)



Wearable technologies are broadening assistive product development and are enabling more people in need to have access to and benefit from assistive technology.

Wei Zhang,
World Health Organization

Customized assistive technology is the trend confirmed by the findings of the report, similar to the one where major players enter into the field of assistive technology, for example Microsoft collaborating with Tobii Dianabox to allow for eye-gaze control for its software and Facebook, which developed a flexible haptic sleeve providing haptic feedback to the users (PneuSleeve).

Alistair McEwan,
University of Sydney

materials) are being increasingly applied in assistive technology to allow the development of advanced or new assistive products and can be found across all functional categories. We identified nine enabling technologies which impact the area of assistive technology, shown in Figure 3.17. (A detailed table with the number of patent documents related to emerging assistive products addressing these enabling technologies can be found in Annex 3.)

The complex technology of robotics is driving the development of products to help increase users' independence. Adaptive eating devices have evolved into companion robots and feeding assistant robots, executing ever more complicated and diverse tasks; companion robots – embedding AI, advanced robotics and sensors – may, in turn, evolve to handle medication management and dispensing.

Advanced sensors and AI are driving the evolution of conventional assistive technology toward "smart" assistive products. This can be seen across the entire spectrum of assistive products, even in incontinence products – some of which employ sensors together with IoT to monitor and report wetness – or walking aids and wheelchairs that now embed lightweight detection sensors. In hearing assistive technology, smart gloves use sensors to detect and measure hand motion and translate this into speech and text. In vision assistive technology, not only are sensors connected to intraocular lenses to adjust focal length, but machine learning is also used to develop smart glasses that detect the distance between the user and objects in the surrounding environment as an aid to navigation.

The amalgamation of various enabling technologies can increasingly be seen; for example, in medication dispensers connected to IoT/sensors or with AI systems to manage medicine intake, or wearable (smart clothing, lenses, wristbands, watches) and non-wearable devices (smart carpets and mirrors) that use sensors, AI, machine learning, IoT and cloud connectivity to monitor health and emotions.

Smarter assistive products are not intended to be standalone solutions, but instead expected to be able to connect to each other and to centralized platforms. In this way, assistive technology is adopting a more systemic approach, with different assistive and mainstream products becoming part of a larger distributed system and network of connected devices (including smart homes appliances, advanced prosthetics and assistive robots). With this comes interoperability issues, which could possibly be addressed through a set of common standards.

Increasing use of enabling technologies – toward more customized assistive technology

To the greatest possible extent, emerging assistive technology is applying the AI technique of machine learning in order to understand a user's specificities, preferences and routines, to optimize and customize their functionalities accordingly, and predict the user's needs. Others benefit from 3D-printing techniques tailored to the specific user and offer increased comfort and enhanced ergonomics.

As was shown by the type of emerging assistive products identified during the research and by the review of the related patent documents, we are increasingly moving away from a one-size-fits-all approach. With greater use of software, AI and IoT in assistive applications, there is a pattern emerging to the solutions serving the common characteristic of disability, namely, diversity, in the sense that each user is unique in terms of their needs, wishes and requirements.

Growing importance of ICT for assistive technology

The origins of assistive technology lie in mechanical engineering solutions to mobility (see Section 2.5, Mobility), but assistive technology now covers a broad range of technologies and disciplines. Larger consumer electronic goods companies are entering the assistive technology field, increasingly integrating AI into assistive devices. This is most apparent in the results in the areas of communication and cognition, where emulation software, eye-controlled input, speech input, and software-based visual aids are increasingly being used to make interfaces more user-friendly and accessible, as the analysis shows. In communication, navigation aids and smart assistants are two examples of technologies where added value comes from the embedded software enabling the device to perform several tasks, such as navigating, entertaining, communicating and walking.

The consumer electronic goods industry is complementing the lens development of traditional ophthalmology companies. It is developing new vision assistive products that employ AR/VR to aid the user in observing their surroundings, along with applications that embed facial recognition, scene recognition, GPS and speech recognition to help with navigation. These companies are also contributing to more sophisticated solutions for addressing refractive errors, moving from spectacles and contact lenses to smart intraocular technologies that rely increasingly on software and enabling technologies to offer a wide array of functionalities. Similarly, they are interested in hearing-related assistive technology, bringing their expertise to bear in developing cutting-edge headphones and designing hearing technologies with interesting functionalities.

With software comes a growing trend toward customization. Avatars embedding AI can be considered as virtual "smart" personal assistants with various functionalities, while machine learning is employed across the different functional categories to identify patterns in the movement, behavior and habits of end-users so as to optimize performance and make recommendations based on a user's preferences and profile.

Some assistive technology is by its nature hardware. As ICT involves both hardware and software, advances related to hardware can also be observed. Some of these are linked to the materials, design or wireless communication of the assistive product. This can involve new or 3D-printed materials for improved stability, comfort or customization; advanced sensors allowing both for more reliable and versatile data collection and analysis and adding new functionalities to assistive products; and the design of structural components or a specialized design required for and adapted to the needs of assistive product users.

According to the subject matter experts consulted, there remain unresolved hardware-related issues concerning either the mechanisms themselves and their efficiency or general engineering challenges (e.g., battery efficiency). These could adversely affect the further development of assistive products, playing as they do an equally important role in the type of models and algorithms that can be developed to provide optimal assistance.

Convergence of assistive technology with several disciplines

Developments and innovation in assistive technology, particularly in emerging assistive technology, owe a debt of gratitude to advances in and collaboration with a range of disciplines, including information technology, data science, materials science, medicine and medical technology, and neuroscience.

The results of the search of this report showed that assistive technology is starting to expand beyond the WHO definition, including products external to the human body. It increasingly includes devices that are fully or partially integrated into the human body, such as neuroprosthetics, cochlear or cortical implants and artificial eye systems. Where the line is drawn between assistive and medical technologies is not always apparent. In addition to the findings of this report, the themes chosen for recent assistive technology conferences point toward an anticipated reassessment of the definition or scope of assistive technology, or else a blended approach that makes less of a distinction between these two areas. As the individual needs of users are so varied, an array of products is being developed to meet their requirements. These range from traditional assistive devices that support or restore reduced or missing functionality to products that bypass or substitute one sensory input or output with another (see also Chapter 5).

Advances in neuroscience and neural engineering are allowing for technologies that relate to the control of several assistive devices, and other appliances and products. Brain–computer interface technologies, for instance, are increasingly non-invasive, and allow users to control wheelchairs, prosthetics and hearing aids using their mind, and hold great potential for assisting those individuals with communication impairment, some in an invasive and others in a non-invasive manner. Further advances, such as the Neuralink project3[3] are expected to enable the control of mainstream technology in the same way, and make some cortical implants intended for hearing, vision, mobility or other applications more precise, reliable and technologically more mature, so that they reach the market as safer, more effective products.

Moreover, the fact that assistive technology is becoming increasingly smart, connected and interoperable requires multidisciplinary contributions from data scientists, AI and information technology experts, to name but three.

New players entering the assistive technology space

In the past few years, many representatives from other industries have consulted with me on the prospect of entering the assistive technology industry in the future, and expect to cooperate with universities in R&D and the commercialization of new assistive technologies. This kind of phenomenon proves that more and more players in other fields in China are actively marching toward assistive technology. I have also talked with a lot of assistive technology experts and business people abroad, many of whom are interested in entering China to engage in the assistive technology industry.

Hongliu Yu,
University of Shanghai
for Science and Technology

Toward convergence of assistive technology with consumer goods

Assistive technology is becoming more relevant for more people, particularly the ageing global population (see also Chapter 5). For example, technologies related to exoskeletons, originally developed for military purposes, then adopted as assistive products helping with mobility and manipulation, are now being scaled up as assistive technology for industrial workers (see the Össur collaboration example on page 119 and Michael Haddad case study on pages 120-121). Orthoses and prostheses primarily used for assistive technology applications are now seen as extensions of the fully functioning human body, and not just as replacements for a lost functional need. 3D printing technology holds the promise of reducing manufacturing costs for highly precise, customized prostheses and orthoses. Voice recognition software has likewise evolved from an assistive technology into one that can be found in many homes as "smart speakers". Companies such as Facebook and Netflix are exploring eye tracking for their apps; a rather established technology in the assistive technology field that is now finding a use in general purpose applications. Meanwhile, smart health and emotion monitoring (including principles of affective computing, as also identified in *WIPO*

Crossover with consumer goods

Economies of scale remain a challenge for assistive technology. Hardware electronics is predicated on a certain level of volume. Very specialized hardware (such as a Braille device) is expensive because the economies of scale do not exist. The high cost of hardware makes it less accessible, affordable and available.

Brian Kemler,
Google

The democratization or mainstreaming of technologies can bring certain advantages, such as reducing prices. A potential drawback to the coexistence of assistive technology and consumer technology is that their characteristics may not be evaluated in such a way as to ensure their efficacy. There is a need for clarity on which regulatory frameworks would apply to systems at the boundary of consumer and medical devices.

Ricardo Chavarriaga,
CLAIRE, IEEE Standards Association, and
Zürich University of Applied Sciences

It will always be appealing to leverage mainstream technologies as assistive technologies because of the low cost and relatively high reliability of these devices. Mainstream commercial technologies are also by definition *socially acceptable*. These benefits are, however, often outweighed by poor performance because they are most commonly *adapted* for use as assistive technology, rather than intentionally designed for use by people with disabilities. For instance, smartphones and computers have *accessibility features* that can be activated. These design adaptations have frequent flaws, in part because they have to be "redesigned" as the commercial products evolve. A more progressive approach is possible if the design of commercial products considers the unique needs of assistive technology users.

Jonathan Pearlman,
University of Pittsburgh

Technology Trends issue on AI (WIPO, 2019)), has become a popular commercial solution related to the wellness and lifestyle industry, attracting interest from larger companies like Google, while fashion brands have started to includeadaptive clothing lines in their offering.

The concept of universal design and accessibility, seen particularly in the field of assistive technology for the built environment, is bringing benefits to wider groups, including examples prevalent in home design, such as self-closing drawers or kitchen cupboards that pivot to improve access, and smart home features. We are increasingly able to observe assistive technology all around us, with products coming from the different functional categories and converging in domestic and outdoor environments, giving rise to smart homes, buildings and even smart and accessible cities, which is the vision of a number of cities around the world.

Increasing focus of assistive products for autonomous and independent living

When looking at the nature of emerging assistive products identified in Chapter 2, we note that a lot of them are meant to support independent living. Examples include smart homes, health/emotion monitoring and smart nursing; support in daily tasks by assistive robots; mobility and access to the environment with autonomous wheelchairs, smart glasses and navigation aids; or autonomous communication with gesture-to-voice products.

Moving toward augmentation

Some strains of assistive technology development go beyond supporting a missing or limited functionality to addressing or bypassing its cause, leading to either a partial or complete restoration of functionalities, or augmentation or human enhancement, which could be of interest to a broader spectrum of end-users. Such technologies may give end-users the option of pursuing a more permanent fix. This has several ethical implications: this may be considered as lengthening the divide between the two ends of the spectrum of functionalities; as altering the notion of what is considered the norm for human functionality; or even as creating further issues by introducing additional market segments in an already small and difficult market, thereby raising concerns about access to these technologies (see Chapter 5 for further discussion of these implications).

From a patented invention to a commercialized product: assessing readiness and impact

Patenting activity indicates the amount of interest and the investment made in respect to an invention's applicability and its commercialization potential. There is typically a lag between filing a patent application and commercialization. Several factors play a role in this process, even when a technology is considered mature (see Chapter 4).

Whereas conventional assistive technology includes well-established products, readily available in the vast majority of markets around the world, emerging assistive products are more recent and neither fully mature nor ready to enter the market in a scaled-up manner to the benefit of end-users. After identifying these emerging assistive products through patent data search and analysis, we tried to identify the technology readiness level of these technologies. For this purpose, we adapted the NASA Technology Readiness

> A shift from a dedicated single-purpose, high-cost device to multifunctional devices appears to be accelerated by augmentation, where the device increases functional capacity rather than simply fulfilling a task.

David Banes,
David Banes Access and Inclusion

Level (TRL) (see Annex 4 for the rating score used; more details can be found in the detailed methodology background paper available at www.wipo.int/tech_trends/en/assistive_technology) model of impact and ease of use assessment for assistive technology, allowing the identified emerging assistive products to be grouped in one of four categories: research concept, proof of concept, minimum viable product and commercialized product. The purpose of this assessment, which was carried out based on ratings from 32 subject matter experts, was to both explore the stage that each of the identified emerging assistive products has reached along the product development chain and to observe whether there is a correlation between the volume and growth rate of patenting activity and an invention's closeness to market. Figure 3.18 provides a snapshot of the TRL analysis.

On average, based on the experts' assessment in the TRL assessment, the emerging technologies identified would seem to be somewhere between proof-of-concept and minimum viable product stage. Within each functional category, the following technologies are closest to a fully commercial product, with most requiring only some scaling up:

- myoelectric control of advanced prosthetics and wheelchair control (mobility);
- environment-controlling hearing aids (hearing);
- multifocal intraocular lenses and artificial retina, along with VR/AR wearables (vision);
- smart assistants and navigation aids (communication);
- smart home appliances (environment); and
- medication management and smart diapers (self-care).

Cochlear implants, non-invasive bone conduction, middle-ear implants and ossicular

Figure 3.18. A snapshot of the TRL analysis, showing technology readiness level scores and volume of patent families for each category of emerging assistive technology. The full results are available on a dedicated interactive, accessible platform at www.wipo.int/tech_trends/en/assistive_technology/visualization.html

How close are the identified emerging assistive products to commercialization?

(Share of identified emerging assistive products by level of technology readiness)

replacements (hearing assistive technology) and multifocal intraocular lenses (vision) are fully commercialized.

Looking at the patenting activity in terms of volume and evolution over time across the different emerging assistive products, and comparing them to their TRL rating, we can see that products with a rating of 8–9 TRL (e.g., cochlear implants, navigation aids or non-invasive bone conduction), that is, products which are starting to become available in the market or are already fully commercialized, tend to have bigger patent portfolios/datasets and activity over a longer period of time, which probably allowed them to reach the market stage. What is interesting to note are those areas with relatively recent patenting activity and a high growth rate. These are areas which we tend to see in the prototyping level on the TRL scale; it would be worth exploring in more detail the specificities of each functional category and the explanations they offer concerning the combination of their TRL score and the related patenting activity and growth.

The technology readiness level and the related patenting activity can also be explained through the following factors which contribute to a product's entry to market, and which were explored by the same experts in the TRL assessment (the questions posed to the experts along with the rating scale can be found in the methodology background paper):

- expected impact on a person's participation in different aspects of life;
- ease of adoption (need for training, fitting, additional equipment for interoperability, and so on);
- societal acceptance and potential ethical concerns; and
- the need for regulatory approval.

Among these aspects, acceptability and ethical considerations were found to be particularly relevant to those technologies that:

- are extremely invasive (such as cortical or auditory brainstem implants);
- replace the human caregiver and human interaction;
- collect and use data on cloud-based services or interconnected devices (e.g., companion robots, smart nursing and health-monitoring technologies), raising privacy issues (access to, use of and analysis of individuals' private data related to their health) and requiring connectivity;
- raise safety concerns, such as autonomous wheelchairs.

Several experts expressed the opinion that some of the concerns may be linked to a lack of real-life exposure to these technologies, which makes it difficult to imagine or accept the use of such products. Similarly, increased societal acceptance of new technologies in general may play a role in mitigating current hesitation or societal concerns with some of the emerging products. Some experts consulted anticipate this negative assessment changing over time, as these products become more familiar.

Another factor affecting the entry of a product to market and its subsequent adoption is the requirement for regulatory approval. This is mainly the case for assistive technology that qualifies as medical technology. As would be expected, the highest rated in terms of certain need for regulatory approval are those emerging assistive technologies that are the most invasive and pose more risk to an end-user's health (primarily neuroprosthetics, such as cortical and cochlear implants or central neural system interfaces for mobility neuroprosthetics) or safety (e.g., autonomous wheelchairs).

Industrial designs – the IP approach of top patent applicants

Beyond the patent landscape, industrial designs have an added importance for the field of assistive technology. Assistive technology is often not adopted, or else abandoned entirely, because of issues to do with design (lack of appeal) or comfort (poor ergonomics). Design often plays a role after the patenting activity, as a product needs to be re-designed for mass production, and thus fulfill different requirements. Industrial designs are classified according to schemes that take a product

Top patent applicants' activity in industrial designs – toward a holistic IP strategy?

Most of the top players in assistive technology patent applications are also the key players in industrial design applications in assistive technology, but some, including IBM and Semiconductor Energy Lab, are missing from the list of top applicants for industrial designs.

Ottobock (Germany), Invacare (U.S.), Össur (Iceland) and GN Group (Denmark) are among the top players in industrial design related to conventional assistive technology. Some of them focus on exactly the same technical field in both patent and industrial design applications, but this is not the case for all applicants. For example, 27% of Panasonic's patent applications are concentrated on mobility, but the company filed very few industrial design applications in this field.

Hi-tech and medical device technology companies, namely Nurotron Biotechnology (China), Google (U.S.), Cochlear (Australia) and Voxtech (China), were the top players for industrial design applications in emerging assistive technology. Their patent and industrial design applications are more concentrated on specific technical fields, such as hearing for Cochlear and vision for Second Sight Medical. More universities feature as top players, among them three Chinese universities – South China University of Technology, Shanghai Jiao Tong University and Tsinghua University. Cochlear filed more industrial design applications for emerging assistive technology than for conventional assistive technology, following the same approach as its patenting activity.

These results show a link between the activity of the top patent applicants with related industrial design applications and indicates a holistic IP strategy of many of the top players in assistive technology.

indication approach, which is different from the patent classification rationale. Some assistive technology is well defined in the design classification system and comparable to some conventional or emerging assistive technologies, while several products (some of which are classified as assistive technology) may have the same classification but the existing design databases are not suitable for analysis. As a result, the search approach used for patent databases cannot be applied to industrial design databases or lead to comparable results.

Even if there is great potential in searching and analyzing design data and comparing it with patent data to create a clearer idea about the IP strategy of different players, the current limitations of the system and the related databases' functionalities led to an alternative approach being taken to explore the use of industrial designs as part of IP strategy. The WIPO Global Design Database was searched for industrial designs held by top patent applicants identified from the conventional and emerging assistive technology patent datasets. The results were reviewed and matched to various product categories in the patent dataset.

Industrial designs offer their holders protection for the ornamental features of their products. The results showed that top patent applicants are using industrial designs as part of their IP strategy to create an IP bundle where the main contribution made by the designs is to those distinctive aspects of products that serve brand identity. Owing to the limited text in industrial designs, the documents reviewed contained no mention of ergonomics, attractiveness or adoption of the products. Interviews with patent applicants and design right holders, however, confirmed that beyond the traditional use of industrial designs, the design aspects of the products were intended to allow their products to be adopted by more assistive technology end-users who would otherwise have not considered assistive products appealing or interesting.

Innovation, as reflected in patent applications, is happening in both conventional and emerging assistive technology – either through improvements to existing devices or the creation of new product segments. However, even when a product is mature from a technological point of view, other factors can determine its entry into market, as demonstrated by the technology readiness analysis and impact assessment. The next chapter explores these factors in greater depth.

Notes

1 Over 2.2 billion people have a visual impairment (WHO, 2019); 466 million people have disabling hearing loss (WHO, 2020); and over 131 million people require a wheelchair for mobility (Wheelchair Foundation, n.d.).

2 A utility model is an intellectual property right available in some countries for technical innovations that might not qualify for a patent. It provides a shorter term of protection but is subject to less stringent criteria than a regular patent.

3 Visit https://neuralink.com for more details.

References

Wheelchair Foundation (n.d.). Wheelchair needs in the world. https://www.wheelchairfoundation.org/fth/analysis-of-wheelchair-need (accessed October 22, 2020).

World Health Organization (WHO) (2019). *World Report on Vision*. Geneva: WHO. https://www.who.int/publications/i/item/world-report-on-vision (accessed October 22, 2020).

World Health Organization (WHO) (2020). Deafness and hearing loss, Factsheet. https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss (accessed October 22, 2020).

World Intellectual Property Organization (WIPO) (2019). *WIPO Technology Trends 2019: Artificial intelligence*. Geneva: WIPO.

4 Assistive technology – the wider context

Chapters 2 and 3 have described an increase in patenting activity in the field of assistive technology and, with that, the availability of a growing number of technical solutions addressing the various needs of end-users. Assistive technology is extending beyond meeting the needs of the user to whom they were typically addressed, i.e., people with disabilities,[1] to any individual with a functional limitation, including the elderly. As the relationship between assistive technology and end-users evolves, so do expectations regarding the capacity and uptake of technology. Assistive technology solutions developed first for persons with disabilities have already or can now become mainstream technologies (e.g., eye-movement detection for device control); while, conversely, technologies designed for a general or specialized use can prove invaluable to persons with disabilities (e.g., touchscreen technologies).

However, despite technological development and related promising technical solutions, assistive technology remains unavailable or difficult to access for a majority of potential end-users. Patenting activity is a good indication of research and development (R&D) investment and the patent applicant's faith in the commercial potential of an invention. However, as is already apparent from the NASA model-based Technology Readiness Level (TRL) analysis of emerging assistive applications, several factors can affect whether an assistive technology product enters the market and becomes available to end-users. This chapter considers the various opportunities and challenges within the assistive technology landscape of which policy-makers and other assistive technology

Supply and demand for assistive products and services are limited by numerous barriers: stigma, ineffective policies, insufficient financing and a lack of awareness. Advances and innovation in technology often do not reach those most in need. User-centered innovations, which address the unmet need for assistive products and related services, play an important role in lifting those barriers and opening up the assistive technology market. Competition in delivering meaningful innovations will lead to a healthy market, ensuring availability, quality and affordability of assistive technology.

Chapal Khasnabis, GATE, WHO

Views from the assistive technology community

The absence of assistive technology policy and national systems was highlighted by 44% of respondents as a key challenge. Lack of training and education, health system issues and lack of investment were also noted, as well as the need for systematic support for the provision and use of assistive technology in educational establishments and concrete implementation of the Convention for Rights of Persons with Disabilities (CRPD).

It was suggested that multi-stakeholder initiatives such as WHO GATE, ATscale and AT2030 should develop systemic linkages to national and global commitments, as well as taking a more in-depth, on-the-ground approach. Technology producers in the for-profit sector should be supported to create accessible training for their products, and users should be involved in and aware of these initiatives to develop trust and accountability.

Although a fifth of survey respondents identified IP as a barrier to accessing assistive technology, a similar proportion stated that IP supports investment in assistive technology. Others mentioned that it enables technology transfer (20%), enables protection of assistive technology-related IP rights (IPRs) (12%) and supports accessible content and services (10%). Respondents have used the IP system to support R&D investment (18%), file a patent (18%) or protect IPRs (13%).

stakeholders need to be aware and which they must address if they are to aid innovators in reaching their intended markets and end-users in accessing assistive technology. The chapter also explores the broader movement toward support for the rights of persons with disabilities through the development of international and regional assistive technology frameworks and their adoption into national policy approaches and initiatives, and the recognition of access to assistive technology as a human right of end-users.

Opportunities and challenges in the current policy landscape

Neither making an assistive technology product commercially available nor ensuring that assistive technology reaches end-users are straightforward issues, especially when the area of assistive technology is often perceived to be a charitable rather than a consumer market.

Many factors can affect the fate of an assistive technology solution, not least whether there is a market and whether that market is ready for new products. Supporting an environment where investment into assistive technology is deemed attractive to industry is challenging and depends on many factors, including presenting an appealing market share to investors. However, availability to end-users should also promote social, political and cultural participation through access to education, employment and justice, while fostering the health and well-being necessary for self-sufficient and independent living. Policy-making should be cross-cutting and take a holistic approach to these issues. It should incorporate R&D prioritization, related funding, intellectual property (IP) strategy and technology transfer mechanisms, regulatory or safety requirements, the manufacturing environment and the integration of assistive technology into national health systems.[2]

Such factors cannot always be influenced by policy-makers, but they should be identified as drivers and enablers impacting whether assistive technology is able to reach those who need or wish to use it. The results of a survey on the challenges and opportunities in the assistive technology space are summarized in the section Views from the assistive technology community.

R&D, IP strategy and technology transfer

Encouraging R&D is important in supporting the development or improvement of assistive technology, particularly in areas that are less attractive to industry, for example because of their small market share. Chapter 3 described how assistive technology is converging with different disciplines and how increasing use of enabling technologies, such as artificial intelligence (AI), the Internet of Things (IoT), advanced materials and advanced sensors, is aiding the development of emerging applications. The assistive technology field could indirectly benefit from funded research into more commercially attractive enabling technologies by spurring developments that integrate such technologies.

Funding R&D is a key driver for the development of new technologies, and various regional and national financial incentives encourage investment in assistive technology (ATscale, 2020a). The Israel Innovation Authority, as an example, supports R&D into assistive technology for persons with disabilities to improve their quality of life and integration into society (see Ezertech example below). Monitoring and evaluating its impact, in the form of government stocktaking, may also create an environment for R&D investment supported by government, as demonstrated by an overview undertaken in the U.K. of government-funded projects supporting the development, introduction and evaluation of assistive technology (Department of Health and Social Care, 2018).

However, the situation is more complex and requires more than simply funding R&D or offering financial incentives for industry to invest in R&D. For instance, there may not be adequate follow-up on commercialization in the form of support for the development of IP strategies, particularly within academic circles. With some exceptions (as observed in Chapters 2 and 3), universities tend not to be particularly active in patenting, although this could be the result of other policies or the publication priorities of academics rather than a failure to follow through on the potential of R&D investment.

Broader support for technology transfer is necessary if promising innovative solutions are to make it to market. Common challenges for universities and research institutes alike include a lack of awareness about IP protection, lack of guidance on important aspects and options for technology transfer and licensing, and a limited framework for collaboration with the private sector, particularly investors (Nelson and Byers, 2013). Underpinning the ability of universities

An R&D incentive to support people with disabilities in Israel

The Israeli Innovation Authority is responsible for developing, strengthening and leading local innovation to drive economic prosperity. It works with the National Insurance Social Funds – governmental funds to reduce social gaps and improve the quality of life of populations at risk – to operate Ezertech, an incentive that supports R&D of assistive technology to improve its ability to integrate into society and the labor market.

Ezertech provides funding for R&D projects across different areas, including solutions for visual impairment; mobility; cognition, learning and education; communication; recreation, sports and leisure; and health care.

Projects are selected according to the degree of contribution to the target population, the technological depth of the proposed application, the company's experience and familiarity with the needs of the target population, the background of the entrepreneur and of the development team, the quality of the business model (including price accessibility) and market size.

Sustainable development of accessible mobility solutions in Brazil

Cycor, based in Brazil, has created a business model that ensures that its assistive technologies are affordable for and accessible to those who need them most.

The company's technical achievements include the creation of the first upper limb myoelectric prosthesis in Latin America (MyoHand); the first exoskeleton (ExOn USR) in the continent for paraplegics and quadriplegics; the first industrial exoskeleton in Latin America; and the first electronic platform for manufacturing smart prostheses and orthoses (Argedom Robotics). Its latest development is a waterproof version of MyoHand.

Cycor's sustainable business model focuses on the development, manufacture, rental and sale of technology, systems and development data. Frequent product adaptations are avoided and AI controls are embedded for ease of use, while product maintenance is carried out in Brazil.

The focus of the business model is on keeping products accessible and affordable. Cycor's products are at least half the cost of previously available solutions. MyoHand can be provided at no cost, with the user paying only for the embedded electronics. Low-income users can obtain these products through the Brazilian unified public health system or with the support of federal government grants, such as accessibility credit. The business model also allows other developers to receive royalties for each licensed product, opening the market for small and medium-sized enterprises (SMEs) and independent inventors. MyoHand and ExOn USR are both licensed to the Bioengineering Institute Erasto Gaertner (IBEG), a Brazilian philanthropic organization.

Cycor designed this business model to be replicable in other countries at any level of development. For this reason, Cycor's products, including MyoHand and ExOn USR, are available in modules and can be produced easily anywhere in the world, even in areas lacking infrastructure, such as refugee camps.

Photos © Cycor

R&D, IP and technology transfer in practice

Not all research is destined for commercialization. The challenge is to identify the right set of projects, which, if translated and commercialized, would be well timed to reach the market and address a specific need. Often the needs of the market are taken into account too late; our strategy is to identify key markets for commercialization early on and then to develop toward those markets. Our IP strategy is to identify high-potential research areas and technologies early, particularly in health innovation, then work closely with the researchers and industry partners to invest in translation and commercialization.

Enabling start-ups from the university is one route to support technology translation and commercialization. Many of our technologies are at a very early stage and potentially disruptive, and existing companies are not always ready to develop these. We have a variety of technology translation and venture creation programs to support our faculty and students to de-risk their inventions, and advance them into the marketplace through a start-up route. The National University of Singapore (NUS) is working closely with industry partners to foster industry-targeted innovations and provide an international reach, and with overseas partners to foster innovation gateways and ecosystems that can help start-ups to access NUS technology as well as gain a foothold on the global stage.

We have seen the value of translational grants and dedicated project managers in industry-specific areas to enable productive connections to industry.


Irene Cheong and Mayank Gurnani,
National University of Singapore

We need to rethink the process of technology transfer, not as an individual point in time where we take it out of the hands of researchers and other people take over the process of development, but rather see it more as a continuous, gradual process. This is particularly relevant for emerging technologies that are constantly evolving.

Ricardo Chavarriaga,
CLAIRE, IEEE Standards Association, and
the Zürich University of Applied Sciences

Since 2010 we have collaborated with one of China's largest upper limb prostheses manufacturers, Danyang Prostheses Factory, to research key technologies for bionic prosthetic hands. We developed a series of technologies relating to weak electromyography (EMG) signal processing technology, bionic prosthetic wrist design and voice/EMG hybrid control technology. More than 10 related patents have been transferred to the company for commercialization and five new products, including dynamic proportional control bionic hands, multi-degree of freedom voice control upper limb prostheses and bionic wrist joints, were produced for patients with varying degrees of upper limb amputation.

Hongliu Yu,
University of Shanghai for Science and Technology

Challenges in commercializing assistive technology

Market fragmentation is the most significant challenge to commercializing promising assistive technology. Because assistive technologies are provided and paid for through several channels (e.g., over the counter, private/public insurance, bespoke, donated, privately funded), often the most promising technologies are unable to fit into the current fragmented market structure. Meanwhile, strategies to develop assistive technology that fits within current public/private insurance schemes constrain assistive technology innovation. We therefore see promising innovations linger in laboratories or companies, and never benefiting the intended consumer.

IP has a mixed influence on assistive technology transfer. Two schools of thought have emerged that are largely divided based on the socioeconomic environment in which the assistive technology will be provided. In high-income countries with insurance funding schemes, IP is often a prerequisite to technology transfer because it provides a competitive advantage in the market. In low- and middle-income countries, IP is often seen as an impediment to assistive technology service delivery because it inflates costs in regions where assistive technology delivery is most often performed through charitable donations because public/private insurance schemes are either non-existent or inadequate. As assistive technology markets expand globally, it is anticipated that IP protection will become increasingly important for technology transfer.

Jonathan Pearlman, University of Pittsburgh

Start-ups and the role of accelerators

Start-ups face numerous challenges when funding or commercializing their invention. Not all start-ups will file to register IP; they see scaling technology as more important. There also seems to be more focus on IP for hardware than for software. Finding the right product–market fit and, certainly in Australia, accessing early-stage risk capital to fund high-fidelity prototyping and early market access are two particular challenges. Accelerators like Remarkable can help by keeping founders accountable and focused on the things that matter most in building scalable business. They can provide access to resources (capital, mentors, structure) needed to move quickly and avoid common mistakes.

Pete Horsley, Remarkable – Accelerating Disability Tech, Cerebral Palsy Alliance

to transfer technology in the U.S. is the Bayh–Dole Act – a policy replicated internationally in many jurisdictions – which grants the recipients of federal R&D funds the right to patent inventions and license them to firms. Technology transfer may also be facilitated through the encouragement of industrial and academic partnerships; for example, through matchmaking schemes, support for the management of IP created in collaboration, prioritization of research activities in the assistive technology space, and encouraging universities to develop their ideas through spin-out companies, which often rely on partnership with venture capitalists.

Knowledge transfer, namely the sharing and disseminating of information relevant to understanding and using technologies, is also relevant for assistive technology. This is also one of the drivers for international collaboration, as set out in the CRPD (see section below, Convention on the Rights of Persons with Disabilities), and necessary to ensure the uptake of assistive technology.

Beyond R&D, supporting wider innovation ecosystems involving all stakeholders can promote the development of assistive technology solutions that reflect genuine end-user needs. Collaborations between academia and industry are nothing new, yet have only a marginal place in our assistive technology dataset, patent applications submitted jointly by universities and industrial entities accounting for only around 1% of filings

Start-ups, open innovation and business success in assistive technology

Sesame Enable is one of the promising assistive technology start-ups that had to close down. It developed touch-free control access for smartphones, tablets and computers based on subtle head movements, for persons with spinal cord injuries, multiple sclerosis and other conditions leading to paralysis. Despite initial hype and great interest, it was difficult to develop a sustainable business model and the company had to close down, still providing their products afterwards free of charge. Marketing is very important, but it has proved challenging for a start-up to promote our products with user associations. There is a gap in the ecosystem and a need for a different financial model and support of start-ups working in the area of assistive technology, which is less attractive for investors yet has such a big social impact. It would also be helpful for start-ups to consolidate necessary information on commercialization and marketing of assistive products and processes to follow as an additional means of support in their effort to bring products to end-users that can improve and even transform people's lives.

Oded Ben-Dov,
Sesame Enable

Ideally, a human-centric perspective should be incorporated in the design of assistive technology through co-creation. Multi-stakeholder networks can support the development and implementation of related technologies throughout their life cycle. The current societal readiness level (SRL) needs to be aligned with the available technology readiness level (TRL) to increase user engagement, overall efficiency and the potential impact of emerging technologies – this can be done by promoting digital capacity and education, data transparency, ethical treatment and user engagement. As instruments of open innovation, Living Labs present an opportunity to achieve many of these goals, particularly for health and related assistive technologies. A user-centric philosophy ensures the user perspective is included from the start and can help accelerate innovation while iteratively managing emerging risks. Universitat Autònoma de Barcelona is employing such initiatives to increase its capacity to tackle local challenges alongside possible collaborators. This will accelerate the university's knowledge transfer capacity and increase the potential impact that academic research and activity can have on society.

Konstantinos Kourkoutas,
Universitat Autònoma de Barcelona

Patents are an innovation indicator, but are not enough to guarantee business success. You need to have a good size of market, competitors, suppliers to form an industry environment in which you can discuss IP strategy with which to protect your products or license your IP. The minute any government certification is required it will take longer to enter into a market. New technologies will make assistive technology accessible to many more markets than before. However, business success is still a long way away. Open-source mechanisms may work in business fields related to assistive technology.

Yuichi Kawamura,
RXM Corporation

Regulation of software as a medical device

The regulation of software as a medical device is continuously evolving and creates many regulatory challenges, including the difficulty for regulatory agencies to hire and retain staff with appropriate knowledge and expertise as the technology advances. The intersection between what is regulated as a medical device versus products that are not based on a general wellness claim is becoming blurred.

Software is a part of most medical devices and thus assistive technology. In the U.S., software on its own (i.e., not part of hardware) can be a medical device, known as software as a medical device or mobile medical apps for use on a variety of platforms; however, this is just one of three types of software related to medical devices. Others are software that is integral to a medical device (software in a medical device) and software used in the manufacture or maintenance of a medical device. This is one of the most rapidly evolving areas in medical technology both in respect to the software itself, increasing widespread use of AI and machine learning, and the regulatory science behind it.

Many software applications used as assistive technology today fall under the general wellness definition of enforcement discretion. This includes software applications that assist with mental acuity, text to speech, health monitoring and vital signs tracking. The same applications are considered medical devices requiring Food and Drug Administration (FDA) regulatory review prior to marketing if they are intended to diagnose, treat or cure a disease or condition; so, a mobile application that monitors heart rate is not regulated, whereas one that detects abnormal cardiac rhythms is considered a medical device.

The main regulatory factors that are unique to software as a medical device include whether software is regulated as a medical device, how changes to the software are handled from a regulatory perspective, and cybersecurity.

The FDA's framework uses a predetermined change control plan in pre-market submissions. This includes the types of anticipated modifications and the associated methodology used to implement those changes (maintenance) in a controlled manner that manages risks to patients. Software maintenance can include adaptive (keeps pace with the changing environment), perfective (recoding to improve software performance), corrective (corrects discovered problems) or preventive (corrects latent faults in the software product before they become operational faults). Examples of changes for software as a medical device include defect fixes; esthetic, performance or usability enhancements; and security patches.

With this approach, the FDA expects manufacturers to commit to transparency and real-world performance monitoring for AI- and machine learning-based software as a medical device, as well as provide regular updates to the FDA on the changes that were implemented.

Jonathan P. Jarow,
FDA Solutions Group

for the majority of functional categories. The examples we identified, though, do include collaboration between humanitarian agencies and academic institutions in the development of technical products for end-users in conflict and post-conflict settings, where there is often a willingness to adopt a more open-source approach. To enable such collaborations and improve the chances of a promising technical solution reaching end-users, it is necessary to ensure a sufficient IP awareness, knowledge of technology transfer and licensing principles, and an enabling ecosystem with sufficient support for commercialization efforts.

Different entities, including coordinating bodies such as the World Health Organization (WHO), the Global Alliance of Assistive Technology

Regulation of medical devices versus pharmaceutical products

In the U.S., medical devices are subject to a different regulatory scheme from pharmaceutical products. Less time and money are required to clear a medical device (approximately 5 months) than to approve a new pharmaceutical product (approximately 13 months). The costs for approval of a medical device (tens of millions of U.S. dollars) are substantially less than for a pharmaceutical product (hundreds of millions of U.S. dollars or up to USD 2 billion).

IP tends to be less important for medical devices than for pharmaceutical patents, as it is usually easier to design around device patents. Data requirements for new devices are less onerous than for pharmaceuticals, and the data exclusivity period that applies to new devices is less important than for drugs.

Whereas all new drugs have to provide substantial evidence of effectiveness to be approved, the large majority (more than 99%) of new medical devices are either exempt from review altogether as they are low risk or allowed to enter the market under a 510(k) provision of the Federal Food, Drug and Cosmetic Act, which requires demonstration of substantial equivalence to a device already being legally marketed in the U.S. ("predicate device") but does not call for proof of safety or efficacy. Predicate devices, marketed before 1976, were grandfathered (i.e. they predated relevant legislation) and were never assessed for safety or efficacy. Therefore, any new device that is compared to a grandfathered device under the 510(K) program has not necessarily been shown to be safe or effective.

There has been substantial criticism of this approach. In fact, the FDA itself does not use the term “approved” for devices that enter the market under the 510(K) provision but rather “cleared for marketing”. Even higher risk devices that are approved under the pre-market approval application do not require randomized, controlled trials. The FDA needs to clearly and prominently present the safety and effectiveness data that are available for the devices, so that physicians and patients can make informed choices about their treatment. A balancing act has to be undertaken between access and safety and security, and this also applies to assistive technology.

Jonathan Darrow,
Harvard Medical School Program on
Regulation, Therapeutics and Law (PORTAL)

Organizations (GAATO) and the recently established Global Partnership for Assistive Technology (ATscale) currently play an invaluable role in connecting all actors in the innovation value chain, advancing the discussions and introducing initiatives for the availability of high-quality, affordable, appropriate assistive technology. However, comparing the requirements for R&D in low- and middle-income countries to those in high-income settings is not always straightforward and there may be other factors at play influencing the commercialization of assistive technology in these contexts.

Regulation

Regulation is necessary to ensure the safety of related products for the end-user’s health. Some assistive technologies can be considered to be medical devices, and therefore require regulatory approval before they can enter the market. These include technologies that are integrated into the human body, require surgical intervention or are intended for treatment, diagnostics, or disease cure or prevention. As the definitions and criteria for what qualifies as a medical device vary, the same product can be considered a medical device in one jurisdiction but not in another, leading to different markets having different requirements. An assessment of whether a product is a medical device can even vary, depending upon how it is presented by the manufacturer. This is important, because the classification of assistive technology as a medical device can make it more costly and time-consuming to bring to market. It may also discourage the prevalence and uptake of assistive technology in a market that has more stringent regulatory procedures. This can also affect whether a technology owner or manufacturer decides to expand their activity to further markets. In most cases, though, medical devices are subject to less stringent regulatory requirements than pharmaceutical products.

In some jurisdictions, including the U.K. and the European Union (EU), the factor determining whether an assistive technology is a medical device is if there is a direct link between the function of the equipment and the individual concerned. This is based on the product's primary intended purpose as defined by the manufacturer. Two products may appear similar in function, but only one might be classified as a medical device. This depends entirely on the claims made by the manufacturer of each product. As a result, a hearing aid used by persons with disabilities is considered a medical device, whereas headphones that can be used as a hearing aid, although retaining the same function, are not classified as such.

The EU Medical Device Regulation (MDR) (EU) 2017/745, entering into force in 2021, widens the definition of medical devices and sets out a classification system for them according to risk and invasiveness. This new regulation will result in more devices, including those that are currently unregulated, being subject to increased scrutiny, which could add to the complexity for certain products entering the EU market compared with other markets.

While WHO excludes products requiring surgical intervention from its definition of assistive products, the analysis of patent data and scientific literature would suggest that the definition of assistive technology is likely to become more inclusive over time, because some emerging assistive solutions are partially implantable, and move beyond supporting a functional limitation toward enhancement or recovery. In most jurisdictions, implantable or body-invasive products will qualify as medical devices. Non-invasive assistive technology may be assessed differently – even software (e.g., health monitoring software)

Standards are voluntary, although they de facto can become obligatory when referred to in procurement or national regulation. In Europe, some standards are harmonized, and thus can be used as a direct means to show compliance with, for example, medical device directive/ regulation. Most international standards in the field of assistive products are test methods, which enable comparison of products and their characteristics. Some standards also set specific requirements, while some are more informative in nature, such as guidelines and vocabularies. In some cases, the test methods specified in international standards could be difficult or costly to apply in low resource settings. There is an ambition to refine or provide alternatives to these test methods to make standards more inclusive, but this is challenging as some countries may not have the resources to join standardization bodies. There is also concern that introducing alternative methods and requirements may impact safety and performance outcomes. However, it is generally considered that international standards contribute to safe, reliable and functional products, improve cost-effectiveness and enable compatibility.

Joakim Falk,
Swedish Institute for Standards

can be considered a medical device. Some very novel emerging assistive solutions may not fall neatly into the existing categories for medical device regulation. Policy-makers may therefore be required to clarify whether such assistive technology, including AI-dependent or partially implantable devices, would come under existing requirements for medical device regulation or instead require more stringent standards. For example, 3D-printed prosthetics could be considered customized products and would not be submitted to regulatory procedures, and additional concerns related to product liability have also been expressed (Nielsen and Griggs, 2016). This issue may be particularly relevant in the U.S., where most medical devices are cleared for marketing without necessarily receiving regulatory approval.

Challenges and opportunities in the EU and the U.S. for assistive technology

Challenges

EU

Stricter requirements for medical devices in the EU: The entry into application of the EU Medical Devices Regulation (MDR) has been postponed until May 2021 because of the COVID-19 pandemic. This regulation will be directly applicable in all EU member states and may bring new challenges and opportunities for assistive technology products that are regulated as medical devices.

Clinical evidence: Medical device manufacturers will have to meet more stringent requirements to retain their CE mark. The MDR will increase the amount of clinical data required to demonstrate the conformity of devices to general safety and performance requirements. It also includes additional requirements for economic operators in the manufacturer's supply chain, such as distributors, importers, and the manufacturer's authorized representative. This requires good planning by manufacturers, including assessment of the supply chain and identification of relevant economic operators.

Obtaining/renewing a CE certificate of conformity: Some manufacturers may find it difficult to obtain or renew a CE certificate before the MDR enters into application. A limited number of notified bodies have obtained their certification under the MDR and, in our experience, few of these are accepting new clients. It may, therefore, be difficult for a new player on the EU market to find a notified body to swiftly CE mark its product.

Custom-made medical devices: Many assistive technologies are regulated as custom-made medical devices in the EU. Developments in 3D printing have increased the reliance on custom-made solutions. However, under the MDR, this will become more difficult because of the refined definition of custom-made devices and the exclusion of mass-produced devices by means of industrial manufacturing processes. In addition, manufacturers of custom-made medical devices will have to comply with additional requirements, such as a certified quality management system.

Legal uncertainty: A number of guidance documents and implementing acts under the MDR have already been published by the European Commission. However, many further guidance documents are expected. In addition, the EU standardization bodies CEN and CENELEC recently rejected the MDR/In Vitro Diagnostic Medical Devices regulation standardization request. This means that relying on harmonized standards to demonstrate conformity with the general safety and performance requirements of the MDR is not yet possible and it is unclear when this will be available.

Some devices without medical purpose may be regulated by the MDR: Annex XVI of the MDR will regulate certain product groups that do not have a medical purpose, such as products intended to be introduced into the body through surgery to modify the anatomy or equipment intended for brain stimulation. This is because these products are considered similar to medical devices in terms of functioning and risk profile. For example, a non-medical exoskeleton that connects to the user's nervous system and can stimulate the brain may be regulated under the MDR.

Software and apps: Software and apps are increasingly used with or integrated into assistive technologies. Under the MDR, more stringent regulations will apply to software manufacturers, including strengthened requirements for medical device software (e.g., Annex VIII introduces Rule 11, a new classification rule for standalone software). The latest EU cybersecurity and General Data Protection Register requirements must also be complied with.

Divergence between national laws: Although the MDR provides uniform rules for medical devices in the EU, some aspects of clinical investigations, reimbursement of products or liability and penalties for non-compliance will remain highly regulated by member states. Navigating these different legislations will continue to raise challenges for manufacturers of assistive technology products in the EU.

U.S.

Food and Drug Administration (FDA) regulation depends heavily on the specific technology and its intended purpose: In general, the definition of a medical device is broader in the U.S. than in the EU, subjecting more products to FDA regulatory oversight. Further, the level of regulation applied has historically been more stringent. The level of regulation applied to medical devices in the U.S. depends on the level of risk, ranging from Class I (least risk) to Class III (most risk). However, within each class, each device is assessed individually. Accordingly, the range of regulatory requirements, including the type of pre-market submission and the level of supporting data required, will vary depending on the device, its proposed indications for use, and specific technology.

Novelty increases regulatory requirements: Previous FDA practice can provide a framework for a new device. Establishing substantial equivalence to a legally marketed predicate device typically means that the same level of data can be used. Additional testing may be required, depending on the differences between the device and the predicate and the age of the predicate, as FDA guidance is continually updated. However, the nature of innovation is such that companies are continuously trying to improve an established precedent or address an unmet need. Accordingly, the FDA may consider the modifications that distinguish a device from a patent perspective to present additional risk, and consequently increase the data requirements for FDA clearance, sometimes rather significantly.

The data requirements are not yet established for novel technology. Products that substantially alter the current clinical diagnostic or treatment paradigm are often met with steep data requirements, including extensive clinical studies.

FDA review team: The FDA has dramatically increased its technical expertise over the last few years, and a significant number of medical device reviewers have advanced degrees. While this makes the review teams scientifically robust, many reviewers have limited experience with the medical device industry from a business perspective or clinical practice. Some requests from the review teams are theoretical and can be viewed as overly burdensome by the company, particularly when other jurisdictions have not required similar data. The FDA may continue to raise questions about a device application throughout the entire review process, sometimes causing delay and uncertainty. The pre-submission process (see below) can help minimize these questions.

Opportunities

EU

A tool for a harmonized approach to the classification of assistive technology products: Defining a product as a medical device and interpreting the application of the classification rules are the responsibility of each member state's competent authority. Similar products manufactured in different EU member states may sometimes be regulated differently depending on the views of individual competent authorities. Under the MDR, a member state could request that the European Commission adopt an implementing act to determine whether or not a specific product falls within the definition of medical device. The European Commission can also propose, on its own initiative, the adoption of such an act. An implementing act of the European Commission would be legally binding on EU member states' competent authorities and would ensure that all EU member states would apply this interpretation uniformly.

Competitive advantage for companies that comply with the MDR: If a manufacturer or supplier is prepared and ready to comply with these requirements, it may have a competitive advantage and could gain additional customers.

U.S.

Software and mobile apps: The FDA's regulation of software and mobile apps has been evolving over the last few years, and an increasing number of software products and apps fall outside the definition of a medical device based on the 21st-century Cures Act, or are considered a medical device but within FDA's enforcement discretion as communicated to industry through guidance.

Regulatory pathway: FDA is amenable to reviewing novel products, and has the regulatory tools to address innovation. Products that are modifications or improvements to previously approved technology may be able to follow this established pathway.

Engagement with FDA (categorical): The FDA is engaging with industry regarding novel medical device technology, such as 3D printing and augmented/virtual reality, by holding workshops to address approaches for data collection. These give industry an opportunity to shape the FDA's thinking about how these products should be regulated, the risks associated with their use, and the level of data required to support their clearance or approval.

Engagement with FDA (individual): The Q-submission (pre-submission) process allows companies to discuss various issues with the FDA, such as the device itself, the sufficiency of the proposed data to support its clearance or approval, and the likely regulatory pathway. The interaction with the FDA medical device center review team is more collaborative than with other areas of the agency. A well-thought-out submission that clearly explains the device and the company's plan for data collection can lead to productive discussions to ensure that the company is on the right path to market.

Novel programs to address novel technology: The FDA seeks to increase access to novel technology with programs such as Early Feasibility Studies (allowing a pathway for first-in-human developmental studies in the U.S.) and the Breakthrough Device Program and Safer Technologies Program (STeP), which focus on disruptive technology and allow faster and increased interaction during evaluation.

Next steps

Regulatory authorities have responded quickly to the development and growth of the assistive technology industry. Frequently, regulation is reactionary, responding to shifts in the marketplace. The regulatory authorities are attempting to be proactive, particularly in the U.S. In the EU, however, there is uncertainty as the MDR comes into effect. While companies have often proceeded to Europe as an initial market entry point with consistently lower data expectations than the U.S., this business strategy may change. The EU pathway to market is expected to become clearer, though potentially more challenging than previously. In the interim, companies may wish to engage with the FDA to assess a pathway to market for their device in the U.S.



Fabien Roy,
Lina Kontos and
Hélène Boland Hogan Lovells

Accessibility and regulatory requirements differ in nature depending on the use of invasive or non-invasive sensors, with regulatory requirements for invasive systems having stringent criteria for the evaluation of safety of the implants (medical devices), whereas regulation for non-invasive systems or direct-to-market neurotechnologies often lack a general regulatory framework and fall under consumer protection laws. This leads to variability in the validation requirements with respect to their efficacy.

Ricardo Chavarriaga, CLAIRE, IEEE Standards Association and the Zürich University of Applied Sciences

Standards

Standards are designed to ensure the safety and quality of products or processes. They can be either advisory or compulsory and can be instigated through alliances, consortia or standards bodies or by regulatory bodies. Official international standards are developed by the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC) and International Telecommunication Union (ITU). Beyond addressing assistive technology or accessibility in general, many standards relate to specific products. Among standards applicable to assistive technology, several are developed in ISO/TC 173 Assistive products, including ISO 9999 (ISO, 2016), establishing a classification and terminology of assistive products for persons with disability; standards developed in ISO/TC 168 for prosthetics and orthotics and IEC/TC 29 for hearing aids, setting out technical requirements to be met before a product is approved for sale. There are also regional standards with international relevance, such as the European standard EN 301549 by CEN/CENELEC/ETSI (2014), which sets out accessibility requirements for the public procurement of information and communications technology (ICT) products and services in Europe.

As the field of assistive technology has grown and diversified, standards have diverged. In addition to the above-mentioned international standardization organizations there are professional organizations, such as the Institute of Electrical and Electronics Engineers (IEEE), which has 80 different standards relevant for IoT (IEEE SA, 2020), one of the enabling technologies for assistive products. Another level is the establishment of standards applicable to a complete system rather than to individual components or products, and whether such an approach would be suitable when the system is composed of heterogeneous parts. This is increasingly relevant in view of the trend toward connected assistive devices and individual devices being part of a bigger system. Interoperability standards allowing product or system interfaces to be understood by other products or systems are expected to help address this issue. An assistive technology health monitoring system communicating data to health care providers will rely on interoperability between relevant devices.

Subjecting assistive technology to standards can be restrictive to the development of low-tech solutions that are easier to maintain. Standards may need to be flexible rather than absolute, to ensure adequacy and quality without compromising safety (MacLachlan et al., 2018, p. 462).

While it has long been recognized that assistive technology-related standards need to be collected in a central location and possibly harmonized (Cooper, 1998), this is still not a reality. An international assistive technology provision standard could be a way of increasing the availability of assistive technology to end-users by reducing the cost and time of compliance for manufacturers. Experts see related opportunities through collaboration between WHO and recognized standardization bodies, in partnership with international assistive technology networks and associations, such as GAATO and the Association for the Advancement of Assistive Technology in Europe (de Witte et al., 2018).

Integration into health systems

The decision to introduce an assistive technology product to a specific market will depend on whether and to what extent its

Public procurement has a tendency to focus upon the availability of commercial products rather than seek to address the underlying need. This has an impact upon achieving best value and is often divorced from the investment made in R&D by public bodies.

David Banes,
David Banes Access and Inclusion Services

health systems utilize assistive technology and integrate strategies that support its wider dissemination and access. Not only does a more adaptive and coherent public and private health system support end-user access, it also improves the market environment for assistive technology providers by supporting public or private purchasers. However, the inverse is true also: the non-integration of assistive technology into a health system can create barriers to market entry for emerging and traditional assistive technology and generate reluctance or an inability to use technologies. This limits access and excludes inclusion of the most up-to-date technologies.

Good procurement practices can foster innovation through competition, reducing costs and building a local capacity to produce accessible goods and services. Guidelines for procurement officers ensuring these issues are taken into account could be helpful, for example, those developed in 2017 by the Swedish National Agency for Public Procurement (sbu.se, 2017), or the ICT assistive technology-related toolkits developed by seven countries with support from the International Telecommunication Union (ITU) (Waddell, n.d.).

Direct subsidies to end-users for the purchase of assistive technology and tax reductions or free distribution of assistive technology can promote a more dynamic market. In India, the Assistance to Disabled Persons for Purchase/Fitting of Aids/Appliances (ADIP) scheme awards grants to persons with disabilities for the purchase of quality assistive technology, such as accessible mobile phones and laptops (enabled.in, 2015).

In some cases, public and private health insurance covers assistive technology. The range of assistive technology covered can vary significantly across jurisdictions. Insurance may not allow for a selection from different products, even though poor fit is one of the main reasons for abandoning the use of assistive technology. More often than not, private insurance companies cover assistive technology only when it is medically prescribed, limiting the options open to end-users. Many private insurance companies do not fund the purchase of assistive technology or else require end-users to pay a higher premium.

Public funding for assistive technology

Most assistive technology public funding systems are influenced by the medical model. These assistive technology public funding and support policies and programs cover only assistive technologies that fulfill the medical necessity requirements of compensating functional difficulties or losses. Other assistive technology delivery programs cover some of the medical necessity assistive technologies or some of the education necessity and work necessity assistive technologies and do not cover all the assistive technologies needed by a person with functional difficulties to participate in activities of daily life, such as education, training, employment and other contextual activities.

There is a need to review the assistive technology public funding and support policies and program based on full participation necessity and rights capability-based approaches to ensure that all the assistive technologies for a person with functional difficulties are fully and equitably funded and supported in all contexts, such as education, health, work, independent living, community participation and other contexts. A holistic, coordinated assistive technology delivery system ensures that there is an immediate holistic assessment of needs and these needs are matched with the required assistive technology at the same time.

James Rwampigi Aniyamuzaala, researcher and assistive technology user

The situation in the U.S., where there is a multiplicity of public and private funding sources, is a particularly complex one; situational analysis is often limited to particular categories of assistive technology, such as mobility or hearing devices, and policies differ between states (Flaubert et al., 2017). Public health insurance programs vary across countries. In lower resource settings, there may be no state budget for the provision of rehabilitative devices or only the most basic or low-tech product may be covered. In higher resource settings, although more advanced assistive technology may be available, it may not be included on the government's list of supported devices or covered by insurers. Reimbursement policies vary widely depending on the jurisdiction. Retired individuals often need to justify the cost in terms of "increased productivity" in order to access the most recent advances in assistive technology through state-run assistance programs or private insurers.

Manufacturing

Requirements for manufacturing assistive technology vary, given the broad range of technologies involved. An emerging assistive technology may leverage an emerging technology such as IoT and integrate it into production processes, whereas a conventional prosthetic device may rely on a traditional technique like plastic moulding. Increasingly, prosthetic devices are benefitting from advances, such as 3D printing or advanced materials; these may not, however, always meet end-user needs, in some cases making devices more difficult to fit, particularly if manufacturing is carried out off-site. The specific supportive environment required for manufacturing varies according to the technology. A strong supportive manufacturing environment increases the likelihood that high-quality assistive technology will enter the market, possibly having an impact on the related market dynamics.

Manufacturing can be supported by supply chains and infrastructure adapted for or favorable to the production and distribution of assistive technology. In many countries, there is no local production of assistive technology and components often have to be imported for assembly, possibly requiring customs duties exceptions to facilitate end-users' access to assistive technology. Production capacity may neither meet demand nor quality requirements (Economic and Social Commission for Asia and the Pacific, 1997). SMEs, often active in the assistive technology space, may not have the resources to scale up production or to move into different markets.

Support for local manufacturing across the value chain in order to meet local demand creates jobs and enhances local technical capacity and innovation. In 2016, the State Council of the People's Republic of China developed a plan to foster innovation capability, industry upgrade and effective market supply to enhance assistive technology industry development (State Council, 2016). Other countries, such as India and Thailand, have examples of local assistive technology manufacturing for hearing devices.[3]

Enabling factors: the principles of universal/inclusive design and accessibility

Universal design and accessibility are enabling factors that complement assistive technology. As principles, they can support the development of assistive technology that meets end-users' needs by foregrounding the interoperability and standardization of assistive technology; something particularly important for people with functional limitations. The degree of implementation of these principles can also impact the range of assistive technology, as certain standalone devices may no longer be necessary because, for example, their function is carried out by a device in accordance with universal design principles.

Universal/inclusive design

Universal design is a term for the designing of an object in such a way that it can be of use to the greatest number of people. It should not lead to compromises that dilute the original design concept or diminish the

Inclusive design

Universal design focuses on the majority's needs and abilities in design, whereas inclusive design aims to design for the marginalized population with possible adaptability to service all.

Arezoo Talebzadeh,
architect and researcher

There is a risk that increased emphasis on universal design and accessibility can imply that certain assistive technologies are not needed, which may reduce access to these technologies for those who need them. Alternatively, normalization of the concepts of disability within the frameworks of universal design and accessibility help to socialize the positive value of assistive technology in our society.

It is important to recognize that an emphasis on universal design and accessibility may change the assistive technology needs for individuals with disabilities, but is unlikely to eliminate them. As the environment changes (e.g., it is made more accessible), the most appropriate assistive technology may be different, but the need is rarely eliminated.

Jonathan Pearlman,
University of Pittsburgh

There is a general vision toward smart environments in the built environment policy and industry; however, the latest technological advances are not always known to design and construction professionals so it is important to collaborate with innovators to design elegant and inclusive solutions.

Inclusive design is not a limitation on good design; it is good design that can be used by all in a fair and equal way. In planning regulation, accessible built environments are often designed to minimum standards; there is a lack of and need for awareness among professionals about advanced technologies for smart environments, as well as inclusive design to cover a wider range of user needs. Despite different initiatives around the world for smart accessible cities, with good examples in Tokyo, Barcelona and parts of London, there is not yet a truly smart accessible city due to the pre-existing infrastructure that continues to create barriers for disabled people. While there is an overall impression that accessibility in the built environment is costly, this is mainly the case when retrofitting is required, and not when it is planned for. Education on what inclusive design is, how it benefits everyone and does not need to cost more would be beneficial across built environment and infrastructure stakeholders. Clients and funders need to consider both the upfront and whole-life costs of inclusive and accessible design. In terms of sustainability, inclusive design can provide solutions that are suitable for longer periods of time, such as a house that can adapt and support someone as they age and provide a higher quality of life and participation to citizens. Co-design could help mitigate ethical challenges and requirements which may not be known to professionals involved in construction and urban planning projects by working with users to understand what kind of environment they need and want.

Iain McKinnon and Mikaela Patrick,
Global Disability Innovation Hub

end-user experience for the benefit of some but not others. Ultimately, it should not exclude or segregate. Universal design is not a replacement for accessible design standards that comply with disability legislation, nor is it in most cases a substitute for assistive technology. Rather, it is a feature that makes assistive technology easier to use. If, for instance, a building is not designed according to universal design principles, it might be built with an elevator not wide enough for a wheelchair to enter. Designing an elevator that is wheelchair accessible does not have to diminish the experience of other end-users.

Article 2 of the CRPD defines universal design as the design of products, environments, programs and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. Universal design shall not exclude assistive devices for particular groups of persons with disabilities where this is needed. Yet, this definition already points to a tension: how can the push toward universal design be achieved when different groups of persons with disabilities have different design requirements for the same technology?

The term "inclusive design" is often used to better embody the diversity and inclusion of all possible end-users. The push toward inclusive design can be a driver for innovation and creativity and there are many innovation programs in support of universal design, including the AT2030 program, which conducts related case studies (see page 221). The COVID-19 pandemic has been identified as a chance to embed the needs of persons with disabilities in non-pandemic times and an opportunity for further acceptance and application of inclusive design of physical and digital space (Patrick and Barbareschi, 2020). Inclusive design can allow manufacturers to reach larger markets, with less need for product adaptation and lower prices. In addition, while often geared toward people with functional limitations, through inclusive design assistive solutions can be of benefit to a broader range of end-users in different scenarios.

Accessibility

Digital accessibility refers to making content available to those who cannot access it because of functional limitations, particularly in vision and hearing. Assistive technology can increase an end-user's access to content, for example, through Braille displays and screen readers. Emphasizing accessibility at the design stage, for example by including subtitles and captioning for the hearing impaired in a television broadcast, can also support assistive technology end-users but does not require individuals to be in possession of specific assistive technology. Web Content Accessibility Guidelines (WCAG) 2.0 (WCAG, 2008) are a good example of an overarching framework to promote the availability of content to those with disabilities, but which also have a positive impact on the broader population. WCAG set out four principles to guide the creation of online content: perceivable (e.g., by providing text alternatives for non-text content); operable (e.g., not designed in a way that is known to cause seizures); understandable (e.g., by making text content readable); and robust (e.g., by maximizing compatibility with assistive technology). These principles have been incorporated into legal obligations for companies operating online in countries such as Australia, Canada and the U.K.

The use of IP provisions in assistive technology (WIPO, 2013) in national legislation can enhance the availability of and access to copyright protected works, for example to the visually impaired – and this is tied to the use of assistive technology. Broadcast licensing and regulations can make accessibility a precondition for a broadcast license. In the U.K., the Communications Act 2003 requires the communications regulator, Ofcom, to make sure content is accessible to people with sight or hearing impairments. Although this does not currently apply to on-demand or catch-up services, the issue is under consideration (Ofcom, 2018).

Enabling technologies like AI have their role to play in supporting accessibility. For instance, Facebook had developed a tool for

Barriers to accessibility

There are 10 key barriers to persons with disabilities in the assistive technology ecosystem:

1. **Availability**: Countries with a limited list of assistive technology options complicate the uptake of new technologies within the EU internal market and globally, particularly when products are considered medical devices. Some models do not recognize the assistive technology nature of accessible technologies.

2. **Affordability**: The high cost of certain (high-tech) assistive technologies, and lack of flexibility to cover costs. Tax on assistive technologies can vary, from 20% in Austria to 7% in Germany. Cochlear implants can cost up to EUR 30,000, plus an average of EUR 8,000 for each technology upgrade. These upgrades are regulated by law (from every 4 years in Iceland to every 8–12 years in Sweden), but in some cases users may need to cover repair costs themselves.

3. **Technology**: Limited usability of certain products and services, especially those concerning legacy assistive technologies. These barriers also remain because persons with disabilities are not always involved in the design process for certain assistive technologies.

4. **Informational barriers**: Lack of independent information to assist in choosing the most suitable technology, and lack of support once the assistive technology is delivered – although good practice can be found in Malta, Spain and Italy, or in the U.S. (Unified Listing of the Global Public Inclusive Infrastructure).

5. **Procedural**: A long, complicated process to access assistive technology. In Belgium and Portugal, AT provision can take over a year.

6. **Infrastructure**: Non-conformity with standards can cause, for example, interference on hearing aids because other devices are using their radio frequency bandwidth. A screen reader will not be able to read an inaccessible website. Problems also arise when there is not a suitable infrastructure for appropriate use of the assistive technology (e.g., poor Internet connection) and/or interoperability problems when other products, services and systems do not work seamlessly with the technology (e.g., an assistive interpreting service cannot communicate with emergency numbers).

7. **Language**: 80% of assistive software is available only in English, according to the DISCIT project.

8. **Attitudinal**: There is still stigma and discrimination toward persons with disabilities and certain assistive products and services.

9. **Legal**: In addition to different eligibility thresholds for accessing assistive technology, different delivery models set restrictions based on age: discriminating against older people, or whether the person works and how they are working. In Austria, self-employed persons or those in vocational training encounter more obstacles to acquire assistive technology than those who are employed. In some countries, cochlear implants are funded only for children.

10. **Lack of involvement**: According to our members in Germany “disability organizations are not involved in the contractual arrangements between the funding agency (e.g., public entity or private insurance) and the assistive technology service provider”.

Alejandro Moledo,
European Disability Forum

The copyright exemption granted by the Marrakesh Treaty is not an end in itself, but the necessary means to ensure that people who are blind, visually impaired and otherwise print disabled will get an increasing number of books and other printed material in an accessible format. We expect that no compensation to copyright owners is envisaged in the rollout of the treaty in Europe, and that, in line with the treaty, authorized entities will not need to get official registration as such, because these measures will only cause more barriers to the free flow of books in adapted formats meant just for persons with disabilities, to end their book famine around the world.

Alejandro Moledo,
European Disability Forum

Opportunities to improve accessibility in Europe

Much progress in accessibility has been achieved recently in the EU, through the Web Accessibility Directive, the Audiovisual Media Services Directive, the European Electronic Communications Code, and particularly the European Accessibility Act. However, further opportunities exist to ensure that (i) the assistive technology market can take full advantage of the EU internal single market and the free movement of products and services by exploring mutual certification of certain assistive technologies; (ii) information on available assistive technologies is accessible; (iii) an independent center to provide support in the selection of assistive technologies can be established; (iv) person-centered training on the use and maintenance of assistive technologies is provided; (v) further flexibility, ease and speed are achieved within the assistive technology delivery model; (vi) high-tech assistive technologies and medical devices are affordable; (vii) research on innovative assistive solutions takes advantage of emerging technologies; and (viii) disabled persons' organizations participate in all of these initiatives.

Alejandro Moledo,
European Disability Forum

visually impaired persons that automatically generates text as an alternative to an image (known as Alt-text) and then uses AI to read the image description aloud (Facebook Engineering, 2016). There are, however, also examples where enabling technologies present challenges to accessibility. Although its applications were identified among the emerging assistive technology products, virtual reality typically uses handsets with grips and small buttons, requiring a certain degree of manual dexterity, and it is unclear how subtitles could be adapted to a 360-degree view. Universal design may contribute to enabling access to the emerging technologies that promote accessibility. Education and training on accessibility features in new technology may also be of value in this regard (EDF, 2018).

International policy-makers place a strong emphasis on accessibility to support persons with disabilities. Owing to the prevalence of ICT in everyday life, its accessibility has received significant attention in meeting Sustainable Development Goal (SDG) 9 (United Nations, 2015) of increasing access to ICT for persons with disabilities. Multiple normative international frameworks exist to address this issue, including the Geneva Plan of Action (2003), the Tunis Commitment (2005), the Marrakesh Treaty to Facilitate Access to Published Works for Persons Who Are Blind, Visually Impaired or Otherwise Print Disabled (2013), International Telecommunication Regulations (2012), and the New Urban Agenda (2016). These call for the full inclusion of persons with disabilities in the information society and encourage the design (or even co-design with end-users) and production of ICT equipment and services that meet these end-users' needs, promote the development of technologies adhering to universal design principles, and commit to promoting national ICT policies and e-government strategies for making ICT accessible to all. This emphasis on ICT is linked to its role in enhancing accessibility to teaching and to learning materials, but also its ability to deliver on the CRPD in relation to habilitation, rehabilitation and independent living.

ICT accessibility may not, however, suffice to support persons with disabilities to access content; additional assistive technology may still be required. For this reason, the complementarity and interoperability of these systems and solutions in all relevant decision-making is paramount if workable solutions are to be found. For software-based assistive technology, there is often a lack of support services for open-source software, so most people opt instead for more expensive commercial software. Unreliable Internet connection is also an issue, often combined with or linked to inadequate government support for ensuring a reliable Internet connection for end-users with disabilities. Of the 193 UN member states, only 32% have governmental portals with reconfigurable fonts and colours; only 7% of the portals have content which can be read aloud; and only 4% include videos in sign language (EDF, 2018, p. 184).

Several UN agencies are taking practical measures to support accessibility through their organizational policies. The UN itself has published accessibility guidelines for its website and prioritized the full participation of persons with disabilities in UN meetings (United Nations, n.d.). Yet, to date, according to a report by the Joint Inspection Unit of the UN system (2018) on enhancing accessibility in conferences and meeting notes, only UNICEF and ITU have a clear policy on accessibility, while examples of good practice by WHO and the International Labour Organization (ILO) are recommended to promote greater use of assistive technology tools, including ICT.

Training and maintenance

Comprehensive training on the use of assistive technology is often overlooked and only some elements are included in health systems' training. Yet, proper training for end-users on how to use, care for and maintain a device can significantly affect the uptake and subsequent use of assistive technology. Manufacturers have an important role in providing such training, while end-user feedback, for example on fit or suitability, is often not acted upon once a product has been provided. Prosthetic

The Marrakesh Treaty and the Accessible Books Consortium

The WIPO-administered Marrakesh Treaty to Facilitate Access to Published Works for Persons Who Are Blind, Visually Impaired or Otherwise Print Disabled (MVT) came into force in 2016, with currently 76 Contracting Parties covering 97 countries. WIPO aims to make this a universal treaty among its 193 member states. However, there is still work to be done; countries need to implement the provisions of the MVT into national law, otherwise people who are blind, visually impaired or otherwise print disabled ("the print-disabled") cannot benefit from all that the Treaty has to offer. Once the provisions of the MVT are transposed into national law, books in accessible formats may be produced and exchanged across borders for the benefit of people who are print-disabled without the need to request permission from the copyright owner.

The Accessible Books Consortium (ABC), launched in 2014, is a public–private partnership led by WIPO to implement the MVT (see the ABC Charter: ABC n.d.). It includes organizations that represent people with print disabilities (e.g., the World Blind Union), libraries for the blind, standards bodies, organizations representing authors and publishers, and collective management organizations. Its goal is to increase the number of books worldwide in accessible formats, such as Braille, audio, e-text and large print, and to make these available to people who are print-disabled, thereby contributing to the UN's Sustainable Development Goals. ABC works in three areas: providing funding, training and technical assistance to produce educational titles in accessible formats; promoting the production of "born accessible" works, that is books that are usable from the start by both sighted persons and the print-disabled; and the ABC Global Book Service, a global library catalogue of accessible formats.

Achieving digital inclusion

To meet the needs of persons with disabilities we must create universal tools and services that are more adaptable and responsive to inevitable changes. This not only extends the longevity and reduces the brittleness of the tools and services, thereby decreasing the cost of production, support and maintenance, but allows all users to retain access when their needs change.

Digital inclusion for people who cannot use standard computer interfaces is dependent on alternative access, such as text-to-speech, speech-to-text, or movement or gesture input systems. As more essential functions are computer mediated and moved online, access to these alternatives becomes ever more critical.

Providing this functionality through separate assistive technologies leaves interoperability constantly at risk. Assistive technology vendors have a small customer base. Mainstream services and tools are subject to frequent change and providers have no obligation to support the update of individual products. Assistive technology vendors struggle to keep pace, resulting in compromised interoperability. They also have less to invest in usability design, training and other supports, making access to digital services through assistive technologies precarious at best. Most assistive technologies are not sold or maintained in many countries, or their cost is prohibitive.

Companies such as Apple and Microsoft have opted to integrate select alternative access functions into mainstream technologies, to the benefit of all users. However, only legislation requiring the integration of alternative access functions can offer a viable path to digital equity for the growing number of people who require such access.

Jutta Treviranus,
OCAD University

The benefits of digital networks, solutions and applications are not reaching everybody – 46.4% of the world's population remain unconnected. To achieve digital inclusion, we should ensure that once the challenge of basic connectivity has been accomplished, we consider the affordability aspect, which is relevant for Internet access, accessibility of equipment and the capability to use it. We must also ensure that digital information products and services are accessible to all users, in the sense of comprehensibility and usability. Increasingly, the problem is less one of technical capability, but rather a lack of cohesive government policies and awareness. Government policy that specifically requires the procurement and use of accessible technology by public bodies creates market demand and increases capacity and supply within a country or region for accessible ICTs.

The importance of ICT accessibility rests on the fact that web accessibility and digital content must be created in a way that it is compatible with a wide variety of assistive technologies (such as text-to-speech) and can be interpreted reliably by different systems without losing meaning.

Doreen Bogdan-Martin,
ITU Telecommunication
Development Bureau

Lack of Internet connection is still a huge issue for many developing countries and rural areas, similar to the numerous mobile apps designed by competing and unregulated technology companies. Users can be bombarded by options, not all of them accessible, and it is difficult and time consuming to review them all. Standardization is one answer, but the assistive technology field develops so quickly that one can end up constantly playing catch-up.

Martine Abel-Williamson,
World Blind Union

limbs are a good example of the challenges that can be overcome through training on fitting and use, patient input into the design and feedback on their comfort and fit. Training on emerging assistive products using enabling technologies, such as AI, may also help to address the accessibility issues discussed earlier. Regular maintenance is also necessary for the reliability of a device; yet, this is another overlooked issue rarely factored in when products are provided.

International and regional frameworks

As seen in Chapter 3, although emerging assistive technology is cross-cutting, often applicable to several user profiles and increasingly reflective of the needs of end-users who do not have disabilities (as seen in the convergence of assistive technology with consumer goods), it would be remiss not to acknowledge that assistive technology is fundamentally tied to the needs of persons with disabilities or functional limitations. Consequently, assistive technology is unique in its capacity to be leveraged by policy-makers to formulate goals that have an individual development and inclusion dimension, ensuring an individual can reach their full potential, contribute fully to society and actively participate in social and political life. Assistive technology is also a factor determining to what extent other, broader development objectives, such as an active and agile workforce, can be achieved by all groups in society.

Convention of the Rights of Persons with Disabilities

The inclusion of assistive technology in international policy instruments reflects a broader emphasis on including persons with disabilities in all aspects of life and the important contribution made to this by assistive technology. Following on from the non-legally binding Standard Rules on Equalization of Opportunities for Persons with Disabilities (United Nations, 1994), the UN Convention on the Rights of Persons with Disabilities (CRPD) (United Nations, 2006) is the key, legally-binding framework supporting the availability of assistive technology to persons, irrespective of disability, gender or age. So far, 181 member states have ratified the CRPD since it was adopted in 2006. With ratification, member states must promote the availability of assistive technology, prioritize affordable technologies, undertake research in this area and provide relevant accessible information for persons

Effective implementation of the CRPD to improve accessibility and availability of assistive technology

The CRPD does not specifically define assistive technology, to allow for interpretation that is as broad and far-reaching as possible. If a definition of assistive technology had been included, at a time when assistive technology was less advanced than today, it might have led to narrow and literal implementation, which would have been a huge barrier.

Countries that have ratified the CRPD report on implementation and monitoring every 4 years. Disabled persons organizations (DPOs) submit shadow or parallel reports in response and often drill into inequities, inequalities and other issues related to implementation and monitoring. Unfortunately, many DPOs, especially in developing countries, do not submit such reports to the UN, which receives mainly government reports, with the voices of disabled persons often not reflected as a result. It is recommended that each country has an independent monitoring mechanism, which usually consists of a country's independent Human Rights Commission or similar body, where the voices of DPOs can feed in.

In many countries, health agency funded options are managed by the end-user, rather than supported for bulk access. These opportunities for individualized funding strengthen the self-determination principle of the CRPD and, if they are organized, managed and monitored effectively, make a world of difference.

Martine Abel-Williamson,
World Blind Union and CRPD

The Global Cooperation on Assistive Technology (GATE) strengthens the capacity of health systems to provide appropriate assistive technology within universal health coverage through the five "P"s: people-centered, policy, products, personnel and provision. GATE envisions inclusive, productive, healthy societies where everyone in need can easily access good-quality assistive technology in a timely manner and at the most affordable price.

Chapal Khasnabis,
GATE, WHO

with disabilities (Article 4). On the basis of the principle of universal design (see above), the Convention specifies that technologies must be accessible to everyone on an equal basis (Article 9), particularly as this is a precondition for other rights, including living independently and being included in the community (Article 19), freedom of expression and opinion, and access to information (Article 21), habilitation and rehabilitation (Article 26) and an adequate standard of living and social protection (Article 28.2(a)), employment, and engagement in political (Article 29) and cultural life (Article 30). Despite the importance of the CRPD as a mechanism for promoting and supporting access to assistive technology, many limitations and opportunities for formulation of policy and implementation have been identified. One in particular is the requirement to implement access to assistive technology as a national right, another is a lack of clarity around the roles and responsibilities of different stakeholders as the requirements are set out across different articles (Borg et al., 2011). The CRPD emphasizes the need for international frameworks and cooperation in order to deliver on its objectives, in particular, participation in knowledge transfer.

Sustainable development goals (SDGs)

The 2030 Agenda for Sustainable Development comprises 17 Sustainable Development Goals (SDGs) for addressing global challenges (United Nations, 2015), including health and well-being (SDG 3) and industry, innovation and infrastructure (SDG 9). A number of the SDGs intersect with

The challenges for end-users in low- and middle-income countries

An individual faces a myriad of barriers to accessing assistive technology products and related services. Often there is lack of awareness of when and where to seek care, while primary health care workers might also lack knowledge, skills and awareness to refer persons in need to the appropriate service providers. In most countries, personnel trained in assistive technology provision are rare, particularly for products that require specialized services. Service centers are few and far between, so travelling to them incurs high costs, while even transport itself might not be accessible. Assistive devices are often prohibitively expensive, especially as they are usually not included in health insurance or other reimbursement mechanisms and must be covered by the user and their family. This translates into an unmet need for about 90% of those who would benefit from the use of an assistive technology – and into an imperative for the global community to take urgent action.

Phyllis Heydt,
Office of the WHO Ambassador for Global Strategy, and independent member of ATscale board

the needs of persons with disabilities, and assistive technology has a role to play in their achievement. Critical for assistive technology is SDG 7 on affordable and clean energy, as many assistive technologies, particularly those relating to ICT, require electricity to operate. To ensure that it is available to support the achievement of the SDGs, the UN has recommended:

- incorporating assistive technology into legislation on employment and education;
- ensuring assistive technology affordability and availability through grants and compensation schemes;
- the incorporation of assistive technology into emergency preparedness systems where appropriate;
- encouraging the development of assistive technology through financial incentives;
- and the monitoring of unmet needs

Assistive technology as a reasonable adjustment for equal opportunities at work

Reasonable adjustments (or "reasonable accommodations") at work are key to promoting equal opportunities, and this is written into legislation. The UN CRPD makes it clear that employers or training providers are obliged to provide reasonable adjustments, one of which is work-specific assistive technologies. Public authorities also need to advise on available assistive technologies.

The ILO Global Business and Disability Network is identifying measures that companies can take to ensure that their employees can benefit from assistive technologies. One of the main barriers companies face is the scarce availability of assistive technologies in many developing countries.

Assistive technologies are creating new opportunities in society and the labor market. It is important that these technologies are widely available and form part of the catalogue of reasonable accommodations to be provided by employers and training providers.

Esteban Tromel, ILO

for assistive technology in order to identify and fill any gaps (United Nations Department of Social and Economic Affairs, 2018, pp. 204–205).

The SDGs demonstrate the opportunities open for international cooperation in meeting the needs of those with disabilities. Although they have promoted the availability of assistive technology solutions, their implementation has served to highlight the difficulties in making assistive technology available to end-users.

UN agencies

WHO has been active both in identifying the barriers to end-users of assistive technology in relation to the objectives of the CRPD and promoting the availability of assistive technology worldwide. In 2011, it identified a lack of assistive technology as a barrier to delivering on the objectives of the CRPD and a barrier to the lives of persons with disabilities. It considered that assistive technology could be made more available by pursuing economies of scale, manufacturing and assembling products locally, and reducing import taxes, and recommended investing in services for persons with disabilities, providing adequate funding and improving affordability (WHO, 2011).

Universal health coverage (UHC) reflects the assertion that health is a human right (WHO, 2020).[4] It incorporates three health service objectives: equitable access, high quality, and reasonable cost. Assistive technology is recognized as an integral part of UHC by WHO and others, including the Special Rapporteur on the rights of persons with disabilities (United Nations General Assembly, 2018). In 2014, WHO, in partnership with stakeholders representing international organizations, donor agencies, professional organizations, academia and end-user groups, established the Global Cooperation on Assistive Technology (GATE), aimed at improving access to high-quality, affordable assistive technology globally. In 2016, WHO launched the Priority Assistive Products List (APL). This includes a minimum 50 products that make a significant impact on the lives of end-users, reflecting widespread end-user needs. The APL encourages

Assistive technology in conflict zones: the humanitarian perspective

The International Committee of the Red Cross (ICRC) provides materials, funds, equipment and training to help victims of armed conflicts and other situations of violence with physical rehabilitation. In many countries, ICRC projects have formed the basis for establishing a national rehabilitation service. Its orthopedic components are considered the gold standard for production of prostheses and orthotic devices in many low- and middle-income countries .

Complex factors need to be considered for the availability and adoption of assistive technology products in low- and middle-income countries, including the level of support for people with disabilities at government level (e.g., health insurance), access to physical rehabilitation centers, availability of skilled professionals, diagnostic tools, and availability of materials and components. Service delivery and related quality is as important as the technology; a device made from advanced high-performing materials cannot simply be provided without ensuring proper service delivery, from initial registration to discharge of patients from physical rehabilitation centers. The ICRC works with various authorities to raise awareness of the rights of persons with disabilities, ensure that sufficient budget is allocated for staff at physical rehabilitation centers, and support the establishment of a fit-for-purpose supply chain.

A collaboration between the ICRC and the Federal Polytechnic School of Lausanne (EPFL), the “Humanitarian Tech Hub”, was established in 2016. As part of this, the “Agilis” project aimed to develop a dynamic prosthetic foot with advanced biomechanical features at a low production cost. The ICRC filed a patent for this new technology and is developing its market strategy.

This is the first time the ICRC has managed IP rights, including a related Patent Cooperation Treaty (PCT) application for the prosthetic foot, and it has provided the opportunity to explore the transactional benefits that can be obtained from a patent. The ICRC is now seeking partners to industrialize and manufacture this product, while ensuring that those who are not served by humanitarian actors can access the technology. If the experience proves effective for the ICRC, it could further encourage this way of working and bring momentum to the development of appropriate assistive technology to the humanitarian world.

Photos © ICRC, EPFL

countries to develop a list of national priority products, and is a guide to enhanced production, procurement and service provision and the development of reimbursement policies and the shaping of markets (WHO, 2016). The APL includes products in the functional categories of mobility, hearing, vision, communication, cognition, environment and self-care (an approach mirrored in this report).

WHO's Global Disability Action Plan 2014–2021 and Global Strategy and Plan of Action on Ageing and Health 2016–2020 both emphasize the need for better data on the needs of assistive technology end-users. In 2018, the World Health Assembly adopted a resolution on improved access to assistive technology, urging member states to develop the required multi-disciplinary framework to improve access to assistive technology, and, among others, "to promote or invest in research, development, innovation and product design in order to make existing assistive products affordable; and to develop a new generation of products including high-end or advanced assistive technology, taking advantage of universal design and new evidence-based technologies" (WHO, 2018). Following member states' requests, a global report on effective access to assistive technology in the context of an integrated approach is expected to be published by WHO in 2021.

ITU is also active in the field of assistive technology through their two regional offices (Europe and Americas), which made this a regional focus. Its activities involve both access to ICT and ICT for development.

The ILO actively promotes assistive technology as essential for the future of work. It has highlighted the initiatives required to support a socially inclusive workplace and emphasizes the importance of affordability and availability of assistive technology for persons with disabilities (ILO, 2019). The WHO World Report on Disability (2011) noted that assistive technology, as a supplement to legislation, can reduce employment discrimination, increase access to the workplace, and change perceptions about

Market building and market shaping for assistive technology

The price disparities for hearing aids illustrate the consequences of market fragmentation and uncertain demand. In Indonesia, where there is no central procurement for assistive devices, the lowest priced hearing aids of adequate quality cost approximately USD 280, but most users opt for lower-quality products that are priced within the scope of government reimbursement schemes (approximately USD 70 every 5 years). In contrast, the U.K. procures about 1.2 million hearing aids per year through the National Health Service and obtains adequate hearing aids for approximately USD 68.

Market shaping can address the root causes that limit the availability and affordability of, and access to, appropriate assistive technology with the wider aim of ensuring improved social, health and economic outcomes for those who require them. Market shaping constitutes interventions that influence a market's dynamics for a social or developmental purpose and this approach has been used successfully in other areas of global health. For example, the prices that donors and developing countries pay for key childhood vaccines, antiretrovirals to treat HIV, and malaria bed nets have dropped by at least half over the past two decades, enabling rapid scale-up in access.

To accelerate access to assistive technology, the global community needs to leverage the capabilities and resources of the public, private and non-profit sectors to harness innovation and break down market barriers.

Kristoffer Gandrup-Marino, UNICEF

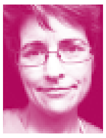
Markets have more potential than charities to provide assistive technology

In many circumstances assistive products are provided as a one-off donation and are not accompanied by sustained services, which require capacity-building by local service providers and the development of an ecosystem to support both users and providers. In addition, donated products are often not regulated by policies that verify the quality, durability and local appropriateness. Such donation mechanisms thereby inhibit government engagement.

Leveraging donor funds to activate government purchasing, working with government to commit additional resources and supporting integration of these products into the govern-ment-owned supply chain offers the potential to establish predictable, sustainable and sufficient demand for appropriate, quality wheelchairs, and systems and services with the potential to better serve users of assistive technology.

Michael Allen,
interim lead of the ATscale board

In low- and middle-income countries where the need for assistive technology is greatest, the markets are often undercut by the good will of people in high-income countries. The good will enables some charities and non-governmental organizations to provide assistive technology at no cost to the user or in fact to the would-be long-term purchaser, i.e., the government. This charity model often sits alongside an underfunded government model. Governments in low- and middle-income countries often have a system of registration and access to free or very low-cost assistive technology. However, these services vie for budgets alongside education and health budgets, ICT and transport budgets, making it difficult to secure adequate funding. One way of securing budget is to demonstrate benefit – but often assistive technology services fail to capture this data. New innovations entering the market, be they from charities, non-governmental organizations or start-ups, therefore have a difficult road ahead. They have to help create a market and then shape it, and this is often done in partnership with organizations such as WHO or ICRC.



Catherine Holloway,
UCLIC, and Global Disability Innovation Hub

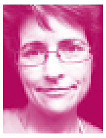
A key strategic priority in R&D, policy and regulation is the development of robust and reliable ways to measure the benefits of assistive technology and collect this data systematically as part of assistive technology services. There is relatively little objective information about the benefits of assistive technology for either the user or society as a whole. This slows the adoption of regulations and policies that are necessary to establish appropriate assistive technology service provision systems because the benefits (e.g., return on investment) are unclear. It also makes it challenging to compare different types of assistive technologies, which is important in supporting selection, design and innovation.

Jonathan Pearlman,
University of Pittsburgh

AT2030

The AT2030 program is attempting to change the landscape of assistive technology provision through a series of activities to test what works. Organized under four clusters of activity, the program aims to support:

- the top-down level of infrastructure needed for assistive technology provision through activities such as product specifications, ensuring that countries and innovators know the minimum specification required for their product area, creating country capacity assessments to enable action plans and supporting global partnerships such as ATscale;
- the bottom-up level of infrastructure, focusing on understanding how people in informal settlements gain access to, use and benefit from assistive technology by developing an inclusive innovation curriculum and testing this with rolling cohorts of innovators in the Nairobi-based Innovate Now accelerator program;
- evidence gathering to inform policy and product development and market fit of new innovations; and
- the creation of an enabling environment that provides evidence of stigma reduction and more inclu-sive built environments.



Catherine Holloway, UCLIC, GDI Hub and co-founder of AT2030

While 90% of countries apply no or less than 10% tariff rates on medicines, in many countries no such exemptions exist for assistive devices. They are often taxed as commercial products, and the related import duties can have a significant impact on the consumer price. For example, some countries' import duties on spectacles are as high as 93%. Changing this regulatory environment will remove one of the barriers to accessing the assistive technology needed in low- and middle-income countries.

Kristoffer Gandrup-Marino, UNICEF

persons with disabilities in the workplace. For some with disabilities, the use of assistive technology in supported employment programs can facilitate skills development and employment.

It is of fundamental importance that assistive technology policies address children's needs. UNICEF has emphasized the place of assistive technology in allowing children more independence, to attend school and participate in their communities. Its innovation fund has supported the development of assistive technology in specific communities. In line with the CRPD, UNICEF has made a number of recommendations, including research into how assistive technology can support children; legislation to ensure access; funding and subsidies; training for health care professionals; and the involvement of children in the development of assistive technology policies and design (WHO, 2015).

International multi-stakeholder initiatives

UN agencies support a number of multi-stakeholder initiatives where member states and end-user groups work together to provide assistive technology to those who need it. The initiative ATscale, whose founding partners include UNICEF and WHO, aims by 2030 to have changed the lives of 500 million people through assistive technology. It sees market barriers as a key challenge. To overcome this, ATscale aims to identify the interventions necessary, such as pooled procurement and

Findings from the European Parliament’s study on assistive technology

In 2018, the European Parliament Research Service Science and Technology Options Assessment (STOA) published a study on assistive technologies for three disabilities and their implications. It found that more needs to be done to make effective use of existing assistive technology and change the way it is portrayed. Definitions must move beyond the medical definition and implement existing regulatory frameworks. Assistive technology use must be linked to a more positive attitudinal view of disabled people and social changes that foster a less segregated society, encouraging co-creation of future assistive technologies and co-governance that prevents negative impacts and promotes the emergence of assistive technology professionals.

It also highlights that it is not enough to look at assistive technology purely from an individual user product and usability perspective – this risks neglecting the impact of broader social context, usefulness of assistive technology, its negative implications, the awareness of the needs of people with disabilities, and underestimating the impact of more incremental changes, such as embedding accessible elements in architectural design. Social innovation is needed to change the discourse around assistive technology to make it more useful and support the development of new solutions.

The study concluded that the definition of assistive technology could be widened to incorporate anything that helps us carry out different functions without necessarily considering it from the perspective of disability. This could help address the distinction between assistive technology as a medical device and a consumer good, and the provision of assistive technology will be less likely to exacerbate the divide between disabled and other users of assistive technologies.


Maria Joao Maia,
Karlsruhe Institute of Technology (KIT), and
Gregor Wolbring,
KIT; University of Calgary

local assembly, in order to shape markets and overcome the supply- and demand-side barriers to priority assistive technology (ATscale, 2019). In support of the ATscale strategy and under the AT2030 program, the Clinton Health Access Initiative developed a series of market-oriented product narratives for five priority assistive technologies (wheelchairs, hearing aids, prostheses, digital assistive technology and eyeglasses), selected through an analysis of the APL (ATscale, 2020b). These propose long-term strategic objectives for a market-shaping approach and identify immediate opportunities for investments to influence the accessibility, availability and affordability of high-quality, low-cost assistive technology in low- and middle-income countries.

Although high-level initiatives such as this give impetus and drive to the assistive technology policy space, initiatives that bring together industry and academia are also crucial to creating an environment where investment in emerging assistive technology is attractive. The AT2030 program – led by the Global Disability Innovation Hub (GDI Hub) and supported by the U.K. government, ATscale, the Clinton Health Access Initiative and academic institutions worldwide – is one example of a multi-stakeholder initiative seeking to support access to assistive technology through partnerships with the private sector.

Regional policy approaches and initiatives

The UN Incheon Strategy to “Make the Right Real” for persons with disabilities in Asia and the Pacific builds on the CRPD (United Nations, 2012). Goal 3 of this strategy recognizes the importance of assistive technology and universal design in enabling access to the physical environment, public transportation, knowledge, information and communication, while also taking into account geographical and linguistic diversity.

In the EU, there is a number of policy initiatives supporting the availability of assistive technology. The European Accessibility Act (2019) ("the EAA"), for instance, aims to improve the functioning of the internal market for accessible products and services. The EAA reflects a focus on a barrier-free Europe, as set out in the European Disability Strategy (EDS) 2010–2020. The EDS supports and supplements national activities for implementing accessibility, but a common definition of accessibility at the European level is lacking (European Commission, 2015). Fragmentation of the regulatory space, in terms of public procurement and enforcement, and other issues have a similar impact on the way in which EU policy can ensure access to assistive technology. As highlighted in a related report, there is a role for European Parliament initiatives, but there is also room for more effective use of existing assistive technology, complementing existing regulatory frameworks, and targeting those areas that intersect with assistive technology, such as employment and education, in recognition of the fact assistive technology alone is not sufficient to foster a more inclusive society (EPSR, 2018). Other steps include targeting attitudinal and social change, encouraging the co-creation of future assistive technology, promoting capacity building and recognizing the role of assistive technology professionals.

There are other regional frameworks that represent the needs and perspectives of persons with disabilities, particularly with regard to ICT and e-accessibility. The Plan of Action for the Information and Knowledge Society in Latin America and the Caribbean (ECLAC, 2020), a Development Bank of Latin America project, proposes using digital technologies as an instrument of sustainable development. It commits to promoting ICT access and use by persons with disabilities and ensuring ICT access for vulnerable groups. The UN Toolkit on Disability for Africa (2016) promotes ICT in fostering the social inclusion of persons with disabilities and describes the practical opportunities that exist for transposing CRPD requirements into national settings. One example is the customizing of existing assistive technology into local languages and making them available at no or a reduced cost. Another is a project to customize the open-source text-to-speech synthesizer e-Speak into any African language and rendered into indigenous voices for bundling with screen readers at no cost. This enables communication for those who cannot afford commercial screen readers or do not speak English, and benefits rural or illiterate mobile end-users.

Regional disparities

Imagine someone who is hard of hearing and whose insurance scheme offers a standard EUR 9,000 hearing aid. They attend conferences regularly, so they would benefit from a higher quality hearing aid, costing EUR 13,000. They offer to pay the difference, but the insurance scheme does not allow this: it is the standard solution or nothing. Similarly, a blind person in one European country must pay EUR 400 for the same screen reader software that can be obtained for free in a neighbouring country. These are typical of the disparities across Europe when it comes to assistive technology.

Alejandro Moledo,
European Disability Forum

Adoption of international and regional frameworks into national policy approaches and initiatives

Although international instruments and initiatives have guided assistive technology policy at the national level, there is a clear difference in the approaches taken and the extent to which international and regional frameworks are applied to ensure the availability of assistive technology in terms of quality, affordability and reliability for end-users (Smith et al., 2019, p. 350). Implementation of the legal obligations of member states under the CRPD making assistive technology accessible to all and introducing accessibility legislation in public spaces is crucial. Before assessing how successfully a national strategy transposes international obligations, it is important to consider whether or to what extent policies need to take account of specific regional and national needs, as it is likely that low- and middle-income countries will have different factors affecting progress toward strategic goals. Nevertheless, the importance of regional and national policies in supporting the opportunities that assistive technology is able to deliver should not be underestimated (MacLachlan et al., 2018).

Norway takes a unified approach to the national provision of assistive technology, providing the most appropriate and least expensive assistive device at no cost to the end-user, whose participation is emphasized throughout. Assistive technology centers have trained personnel with expert knowledge who advise end-users, local authorities and other stakeholders. This ensures that end-users are given the same advice, regardless of where they live. Assistive technology centers purchase in line with national procurement framework agreements and are also responsible for servicing and repairing the assistive devices, and for systematically refurbishing used devices (NAV, 2017). Norway's approach could reflect its relatively high income and small population, as well as its ability to cooperate in this area with other Nordic countries (JSRPD, n.d.).

In most countries, even where health may be recognized as a human right and legislation supports the availability of assistive technology, a systemic approach is missing, along with a comprehensive understanding of what appropriate assistive technology provision entails and a general lack of awareness about assistive products, pathways to access, qualified professionals, and affordable products (see, for example, Toro-Hernández et al., 2019, p. 388).

This absence of a systematic approach to assistive technology in some countries may be related to an attempt to separately classify and understand the availability of assistive technology across individual sectors. It may therefore be worth focusing more on the availability of assistive products as a support for delivering specific policy outcomes under highly centralized systems, for example, access to education opportunities. One example of this can be found in the Cyprus education system, where legal directions, processes and practices related to the use of assistive technology, implementation and follow-up are all interlinked (Mavrou, 2011).

Inclusive national policies for assistive technology that appropriately reflect end-users' needs and help to ensure the provision of products and services may be seen as evidence of a country's increased capacity to develop and implement systematic approaches.

Notes

1 The definition of disability is complex and this can impact on the way in which it is managed by policy-makers and others. WHO defines disability as: "(t)he umbrella term for impairments, activity limitations and participation restrictions, referring to the negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors)" (WHO, 2011, p. 4). It is important to note that disabilities may be short term or enduring, and may emerge at various points in the life cycle.

2 Some of these concepts arose from informal consultations by WIPO with non-governmental organizations supporting persons with disabilities, among which were the Disability Rights Fund, G3ict, GAATES and Promembro.

3 For example, Elkon (http://elkon.com) and Eartone (www.eartone.com).

4 As outlined in the WHO Constitution (1948) and Alma-Ata Declaration (1978).

References

ABC (Accessible Books Consortium) (n.d.). Charter for accessible publishing. Available at: www.accessiblebooksconsortium.org/export/abc/abc_charter.pdf (accessed May 22, 2020).

ATscale (2019). Strategy overview. Available at: https://static1.squarespace.com/static/5b3f6ff1710699a7ebb64495/t/5c7fec5c53450a727c4f8a00/1551887455183/ATscale_Strategy+Overview_February+2019.pdf (accessed May 22, 2020).

ATscale (2020a). The case for investing in assistive technology. Available at: https://static1.squarespace.com/static/5b3f6ff1710699a7ebb64495/t/5fbf5c44eaf37e3b64932e6c/1606376534765/Case_for_Investing_in_AT_a11y.pdf (accessed December 18, 2020).

ATscale (2020b). Product narratives. Available at: https://atscale2030.org/product-narratives (accessed December 18, 2020).

Borg, J., S. Larsson and P.O. Östergren (2011). The right to assistive technology: For whom, for what, and by whom? *Disability & Society*, 26(2), 151–167, DOI: 10.1080/09687599.2011.543862.

CEN/CENELEC/ETSI (2014). Standard – EN 301 549: Accessibility requirements suitable for public procurement of ICT products and services in Europe. Available at: http://mandate376.standards.eu/standard (accessed May 22, 2020).

Cooper, R.A. (1998). Harmonization of assistive technology standards: Proceedings of the 20th Annual International Conference of the IEEE Engineering. In Medicine and Biology Society, *Vol. 20: Biomedical Engineering Towards the Year 2000 and Beyond*, Hong Kong, China, pp. 3367–3369, vol. 6, DOI: 10.1109/IEMBS.1998.746225. Available at: https://ieeexplore.ieee.org/document/746225 (accessed May 22, 2020).

Department of Health and Social Care (2018). Research and development work relating to assistive technology, 2017–18. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/775870/Research_and_development_work_relating_to_assistive_technology_2017_to_2018.pdf (accessed May 22, 2020).

ECLAC (2020). Agenda digital para América Latina y el Caribe / Digital agenda for Latin America and the Caribbean. Available at: www.cepal.org/en/node/40411 (accessed November 15, 2020).

Economic and Social Commission for Asia and the Pacific (1997). Production and distribution of assistive devices for people with disabilities. Available at: www.dinf.ne.jp/doc/english/intl/z15/z15002p2/z1500207.html (accessed May 22, 2020).

EDF (European Disability Forum) (2018). Plug and pray? A disability perspective on artificial intelligence, automated decision-making and emerging technologies. Available at: www.edf-feph.org/sites/default/files/edf-emerging-tech-report-accessible_0.pdf (accessed May 22, 2020).

enabled.in (2015). Modern aids and assistive devices and commencement of new schemes. Available at: https://enabled.in/wp/modern-aids-assistive-devices-commencement-new-schemes (accessed May 22, 2020).

European Commission (2011). Europe 2020 Flagship Initiative Innovation Union. Available at: https://ec.europa.eu/research/innovation-union/pdf/innovation-union-communication-brochure_en.pdf (accessed May 22, 2020).

European Commission (2015). Directive of the European Parliament and of the Council on the approximation of the laws, regulations and administrative provisions of the Member States as regards the accessibility requirements for products and services. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015PC0615&from=EN (accessed May 22, 2020).

EPSR (European Parliamentary Research Service) (2018). Assistive technologies for people with disabilities. Available at: www.europarl.europa.eu/RegData/etudes/IDAN/2018/603218/EPRS_IDA(2018)603218_EN.pdf (accessed May 22, 2020).

Facebook Engineering (2016). Under the hood: Building accessibility tools for the visually impaired on Facebook. Available at: https://engineering.fb.com/2016/04/04/ios/under-the-hood-building-accessibility-tools-for-the-visually-impaired-on-facebook (accessed November 15, 2020).

Flaubert, J.L., C.M. Spicer and A.M. Jette (eds) (2017). *The Promise of Assistive Technology to Enhance Activity and Work Participation*. Washington, DC: National Academies Press (U.S.). Available at: www.ncbi.nlm.nih.gov/books/NBK453296.

Humanity and Inclusion (n.d.). Disability and inclusion challenge. Available at: www.hi-us.org/amplify_disability_challenge (accessed May 22, 2020).

IEEE SA (2020). Internet of Things related standards. Available at: https://standards.ieee.org/initiatives/iot/stds.html (accessed May 22, 2020).

ILO (2019). Making the future of work inclusive of people with disabilities. Available at: www.ilo.org/global/topics/disability-and-work/WCMS_729457/lang--en/index.htm (accessed May 22, 2020).

ISO (2016). ISO 9999:2016: Assistive products for persons with disability – classification and terminology. Available at: www.iso.org/standard/60547.html (accessed May 22, 2020).

JSRPD (Japanese Society for Rehabilitation of Persons with Disabilities) (n.d.). Provision of assistive technology in the Nordic countries. Available at: https://www.dinf.ne.jp/doc/english/resource/nordic2.html (accessed May 22, 2020).

MacLachlan, M., D. Banes, D. Bell, J. Borg, B. Donnelly, M. Fembek, et al. (2018). Assistive technology policy: A position paper from the first global research, innovation, and education on assistive technology (GREAT) summit. *Disability and Rehabilitation: Assistive Technology*, 13(5), 454–466, DOI: 10.1080/17483107.2018.1468496.

Mavrou, K. (2011). Assistive technology as an emerging policy and practice: Processes, challenges and future directions. *Technology* *and Disability*, 23(1), 41–52. Available at: www.researchgate.net/publication/259611005_Assistive_Technology_as_an_Emerging_Policy_and_Practice_Processes_Challenges_and_Future_Directions (accessed May 22, 2020).

Nelson, A.J. and T. Byers (2013) Challenges in university technology transfer and the promising role of entrepreneurship education. Available at: https://ssrn.com/abstract=1651224 (accessed May 22, 2020).

Nielsen, J. and L. Griggs (2016). Allocating risk and liability for defective 3D printed products: Product safety, negligence, or something new? *Monash University Law Review*, 42(3), 712–739. Available at: www.monash.edu/__data/assets/pdf_file/0005/817133/07_Nielsen-and-Griggs.pdf (accessed May 22, 2020).

Norwegian Welfare Administration (NAV) (2017). Assistive Technology in Norway: A part of a wider system. Available at www.nav.no/en/home/about-nav/publications/_/attachment/download/7b119b1c-fe72-488a-a1ef-be424e72faff:c52b8c6ee759299749538a6fd0554d1efa695abf/assistive-technology-in-norway-170217v2.pdf (accessed May 22 2020).

Ofcom (2018). Statement: Making on-demand services accessible. Available at: www.ofcom.org.uk/consultations-and-statements/category-1/odps-accessibility (accessed May 22, 2020).

Patrick, M. and G. Barbareschi (2020). Opportunities and challenges for disability inclusion during the COVID-19 pandemic. Available at: www.disabilityinnovation.com/blog/opportunities-and-challenges-for-disability-inclusion-during-the-covid-19-pandemic (accessed May 22, 2020).

sbu.se (2017). Uplifting assistive technology. Available at: www.sbu.se/en/publications/medical-and-social-science--practice/uplifting-assistive-technology (accessed November 15, 2020).

Smith, E., J. Borg, H. Mannan and M. MacLachlan (2019). Assistive technology content in United Nations Convention on the Rights of Persons with Disabilities reports by states parties. In WHO report *Global Perspectives on Assistive Technologies*. Available at: https://apps.who.int/iris/bitstream/handle/10665/330371/9789241516853-eng.pdf (accessed May 22, 2020).

State Council, The People's Republic of China (2016). China to promote rehabilitation and assistive products industry. Available at: http://english.www.gov.cn/policies/latest_releases/2016/10/27/content_281475476503586.htm (accessed May 22, 2020).

Toro-Hernández, M.L., S. Múnera-Orozco, J.F. Celis-Betancur, C. Camilo-Moreno and M.S. Román (2019). The Colombian assistive technology sector: National policies and experiences from the National Disability System representatives. Available at: https://apps.who.int/iris/bitstream/handle/10665/330371/9789241516853-eng.pdf (accessed May 22, 2020).

United Nations (n.d.). Better UN websites for everyone. Available at: www.un.org/en/webaccessibility/index.shtml (accessed May 22, 2020).

United Nations (1994). Standard Rules on the Equalization of Opportunities for Persons with Disabilities. Available at: www.un.org/development/desa/disabilities/standard-rules-on-the-equalization-of-opportunities-for-persons-with-disabilities.html (accessed May 22, 2020).

United Nations (2006). Convention on the Rights of Persons with Disabilities and Optional Protocol. Available at: www.un.org/disabilities/documents/convention/convoptprot-e.pdf (accessed May 22, 2020).

United Nations (2012). Incheon Strategy to "Make the Right Real" for persons with disabilities in Asia and the Pacific. Available at: www.unescap.org/sites/default/files/Incheon%20Strategy%20%28English%29.pdf (accessed May 22, 2020).

United Nations (2015). Sustainable development: The 17 goals. Available at: https://sdgs.un.org/goals (accessed May 22, 2020).

United Nations (2016). Toolkit on disability for Africa. Available at: www.un.org/esa/socdev/documents/disability/Toolkit/ICTandDisability.pdf (accessed May 22, 2020).

United Nations Department of Social and Economic Affairs (2018). Disability and development report: Realizing the Sustainable Development Goals by, for and with persons with disabilities. Available at: https://social.un.org/publications/UN-Flagship-Report-Disability-Final.pdf (accessed May 22, 2020).

United Nations General Assembly (2018). Rights of persons with disabilities. Available at: www.ohchr.org/Documents/Issues/Disability/A_73_161_EN.pdf (accessed May 22, 2020).

United Nations Joint Inspection Unit (2018). Enhancing accessibility for persons with disabilities to conferences and meetings of the United Nations System. Available at: www.unjiu.org/sites/www.unjiu.org/files/jiu_rep_2018_6_english_0.pdf (accessed May 22, 2020).

Waddell, C.D. (n.d.). e-Accessbility policy toolkit for persons with disabilities. Available at: www.e-accessibilitytoolkit.org/toolkit/public_procurement/case_studies (accessed May 22, 2020).

Web Content Accessibility Guidelines (WCAG) (2008). WCAG 2.0. Available at: https://www.w3.org/TR/WCAG20 (accessed November 15, 2020).

WHO (World Health Organization) (2011). World report on disability. Available at: www.who.int/disabilities/world_report/2011 (accessed May 22, 2020).

WHO (2015). Assistive technology for children with disabilities: Creating opportunities for education, inclusion and participation. Available at: www.unicef.org/disabilities/files/Assistive-Tech-Web.pdf (accessed May 22, 2020).

WHO (2016). Priority Assistive Products List. Available at: https://apps.who.int/iris/bitstream/handle/10665/207694/WHO_EMP_PHI_2016.01_eng.pdf?sequence=1 (accessed May 22, 2020).

WHO (2018). Improving access to assistive technology. Available at: https://apps.who.int/gb/ebwha/pdf_files/WHA71/A71_R8-en.pdf (accessed May 22, 2020).

WHO (2020). Universal health coverage. Available at: https://www.who.int/health-topics/universal-health-coverage (accessed November 15, 2020).

WIPO (2013). Marrakesh Treaty to Facilitate Access to Published Works for Persons who are Blind, Visually Impaired or Otherwise Print Disabled. Available at: www.wipo.int/edocs/pubdocs/en/wipo_pub_218.pdf (accessed May 22, 2020).

de Witte, L., E. Steel, S. Gupta, V. Delgado Ramos and U. Roentgen (2018). Assistive technology provision: towards an international framework for assuring availability and accessibility of affordable high-quality assistive technology. *Disability and Rehabilitation: Assistive Technology*, 13(5), 467–472, DOI: 10.1080/17483107.2018.1470264.

5 The future of assistive technology

The patenting activity mapped in Chapter 2 revealed in detail the ongoing development of a wide range of assistive technology. This is the case both for inventions related to well-established (defined in this report as "conventional") and advanced or new (defined as "emerging") assistive technologies across all seven of the functional domains featured. Patenting activity is increasing – in some functional categories, such as mobility and the built environment, rapidly. Some cross-cutting trends are highlighted in Chapter 3, including a growing use of enabling technologies (e.g., artificial intelligence (AI), Internet of Things (IoT) and connectivity, advanced sensors and augmented and virtual reality (AR/VR)) to power emerging assistive technologies. The Technology Readiness Level (TRL) assessment conducted in the same chapter gives an indication of how close the emerging assistive technologies identified are to commercialization and the factors that might determine how long it is before these emerging products enter the market.

The landscape of assistive technology is likely to develop in accordance with population needs (including the ever-growing ageing population), anticipated technological developments and the efforts of innovative visionaries. Technology does not, however, exist in a vacuum; it develops within the wider innovation ecosystem, which importantly includes regulation and policy-

Stakeholder survey responses on future issues

To support future access to assistive technology, consideration needs to be given to end-users' needs, including by leveraging the overlaps with mainstream consumer products to have more affordable solutions (62% of the survey respondents), by identifying ways of making emerging assistive technology available to users in both developing and least developed countries (61%), and increasing user involvement in its design (46%). The need for education and awareness was also highlighted in the survey responses. Awareness-raising could include more practical advice, such as the availability and use of open-source alternatives.

To bridge the gap between policy development and implementation, respondents suggested stronger links to other health policy objectives (19%), enforcement of policy objectives (19%) and increased funding for stakeholder initiatives (17%).

Stakeholders of assistive technology who responded to the survey believe that technological advances should not be the only focus; there should be less academic discussion and investment in very hi-tech products for the few, and more focus on quality, simple, ecologically manufactured products for the many.

making, among other factors, as explored in Chapter 4. This chapter considers how and in what ways the trends in patenting activity identified in Chapters 2 and 3 could drive future innovation in assistive technology, taking into consideration the wider context. It also addresses issues that either already exist or could arise from the emergence of new assistive products. Understanding these developments will help support the continued investment in and use of assistive technology by identifying new opportunities for industry, providing guidance for developers and stakeholders, and giving end-users the confidence to adopt new assistive technologies.

The changing definition and nature of assistive technology

Implantable products

The range, nature and types of emerging assistive technologies identified in Chapter 2 (see also the full taxonomy and the supporting methodology in Chapter 1), including implantable products or assistive products with implantable components, shows that the boundary between assistive technology – defined as "products that maintain or improve an individual's functioning and independence" (WHO, 2018a) – and medical technology – as reflected in the conventional assistive technology taxonomy – which was once clear-cut is now beginning to blur. The convergence of traditional assistive technology with other areas, such as medical technologies and neuroscience, is expected to lead to a new understanding of assistive technology, and therefore its definition and scope may need to be revised.

From pure assistance to enhancing, augmenting or recovering functions

Some of the implantable emerging assistive technologies identified in Chapter 2 are moving beyond mere support toward the recovery of missing or reduced aspects of human functioning. Body-integrated solutions could take humans beyond what they might otherwise be physically or mentally incapable of doing without technology. The distinction between assistance, on the one hand, and augmentation or enhancement, on the other, could become more pronounced in the future or these two terms may instead converge into seamlessly integrated solutions offering enhanced sensory perception for persons either with or without impairments – what has recently been coined "assistive augmentation".[1]

The scope of "assistive" technology raises many questions about the extent to which technology should augment or enhance human function and capacity. Is assistive technology designed to allow an end-user to function "normally", for

Visions of the future for assistive technology

Looking at technological developments – driven by enabling technologies – the future for assistive technology looks brilliant. These developments give rise to excitement and optimism when it comes to the challenge of bridging the current wide gap between the need for and availability of assistive technology. However, these developments also cause very serious concerns. Will all these smart goods and services be accessible, affordable and acceptable to persons with disabilities, including those in developing countries and other low-resource settings? To what extent does new assistive technology meet the real needs of the majority of those with disabilities, most of which are related to rather basic mobility functions, communication, self-care, or relatively simple impairments of vision and hearing? Will these smart and connected assistive products also work in settings where there is limited Internet access or unreliable power supply? How will aspects like training, maintenance and repair, and recycling and disposal be organized and guaranteed? Patents do not address such questions. From a business perspective, it is more attractive to focus on regions and markets where such difficult questions are less pressing. And herein lies perhaps the most important concern: will "the market" really solve the problem for persons with disabilities?

The key question for the future of assistive technology is how we can best harness the potential of technology to reach as many persons with disabilities as possible and satisfy their most urgent needs. The answer to this requires clear direction as well as the will to make it happen. If we let the market do its work, we will see a world in which the divide between the haves and the have-nots is exacerbated, between people who can afford the most fantastic assistive technology and those who have no option but to live without even the most basic aids and so must carry on struggling as they do today. However, if we are able to steer the development of the assistive technology field and encourage responsible research and innovation, it is well within our grasp to bring about a world in which everyone has access to the assistive technology they need to participate in society and lead meaningful lives. Herein lies a huge challenge – as well as a wonderful opportunity – for the United Nations and its various agencies and programs, for national governments, and for leaders in academia, industry, non-profits, logistics and service provision.

Luc de Witte,
University of Sheffield and
Global Alliance of Assistive Technology Organizations (GAATO)

As we head to a more international market, it will be necessary to identify the differences in needs, expectations and preferences depending on populations and geographical locations. This can have a strong impact on how assistive technology is developed and commercialized. Some things that may be accepted in certain areas may be less acceptable in others, or how legislation and regulation is implemented in one part of the world may close the doors to some developers. Alternatively, these regulations can set the example and provide frameworks that are adopted beyond the original circumscription (as was the case for General Data Protection Regulation). There will be a need to better understand how users' needs are mapped across the globe and for developers to better target and address the diversity in their populations.

Ricardo Chavarriaga,
CLAIRE, IEEE Standards Association and
Zürich University of Applied Sciences

We are likely to have devices that help with one specific need, although some systems might have more than one application or use. There is increasing pressure on companies to use inclusive design principles and create devices, services and interfaces that work for all, rather than having separate technologies for people with disabilities.

Pattie Maes,
MIT Media Lab

Many countries are speeding up R&D and industry support in the field of assistive technology, which will usher in a rapid development stage of assistive technology. Integration with emerging technologies, such as AI, 3D printing, robotics, VR/AR, IoT, means that traditional assistive technology devices will develop rapidly in the direction of remotization, intelligence and robotization. Assistive technology services will also integrate with those technologies, resulting in many new assistive technologies, such as intelligent prescription, fully personalized customization and remote assistive technology service. However, assistive technology will also face many challenges in the future, including increased costs from the application of enabling technologies, which will probably delay large-scale application of the next generation of assistive technology to a certain degree. National policies for assistive technology development will also play a decisive role in the future prospects of assistive technology.

To improve global access to assistive technology, the following strategies are needed: (i) develop a broader list of inclusive assistive products beyond the World Health Organization (WHO) Priority Assistive Products List; (ii) implement zero tariffs on these products through WHO and the World Trade Organization; and (iii) establish the Global Alliance for Rehabilitation Engineering and Assistive Technology, composed of all countries' assistive technology industry associations through WIPO and WHO, and assistive technology training cooperation centers in middle- and high-income countries.

Hongliu Yu,
University of Shanghai for Science and Technology

Ageing should be an opportunity, not a cost. We should seek for a future where assistive technology should be used to stimulate live connections in neighborhoods, in both urban and rural areas, and create smart environments where our collective memory, culture and knowledge can contribute to sustainable economic regeneration, putting nature, culture, biodiversity and older adults at the center.

Giuseppe Fico,
Polytechnic University of Madrid

The example of open prosthetics at Leuven, which led to low-cost prosthetics, shows that technology can be cost-effective. When we talk about cost, we should consider on one side the cost to develop versus the cost of the end-product. Design after prototyping for scaling-up can lead to more efficient and cost-effective end-products.

Mohamed Bouri,
EPFL

Assistive augmentation

Assistive augmentation is harnessing the full potential of developing new human–computer interfaces that seamlessly integrate with a user's mind, body and behavior to provide an enhanced ability. Assistive augmentation finds its applications in a variety of contexts, for example scaffolding for people when they feel their innate senses are inadequate or to support development of desired skillsets. We wish to put sensorial capability on a continuum of usability for certain technology, rather than treat one or the other extreme as the focus. Creating assistive augmentation requires a holistic approach. One should consider not only the technical novelty, but also the usability, user experience, perception, affect and aesthetics to maximize social acceptability.

Suranga Nanayakkara,
University of Auckland

A number of assistive technologies have cross-cutting applications, for example exoskeletons in military or industrial settings to prevent fatigue and reduce the number of injuries. The right level of assistance to be provided should be considered, as too much support or force coming from exo-skeletons could lead to users who would no longer need to be fit or elderly whose muscles may degenerate faster. If only select people have access to these enhancing technologies, we are at risk of enhancing existing divides in society. Another risk is reducing the natural diversity of humanity. We have to ask what the end goal is for enhancing performance, and whether someone can truly freely choose this aspect of enhancement without feeling social pressures to conform and ultimately hindering the stability and wellness of society as a whole.

Ricardo Chavarriaga,
CLAIRE, IEEE Standards Association
and Zürich University of Applied Sciences

We are moving toward realizing technologies that are direct extensions of us with a much higher degree of interfacing between the two. This is reflected in multiple domains. For example, limb prostheses are becoming natural and direct extensions of the human body. While earlier prosthetic technologies relied on sensing gross movements of limbs, we are now able to isolate signals from each motor neuron that this artificial limb then individually senses. Artificial intelligence is an extension of human cognition – trained on human-labeled data and inheriting and extending both human learning methods and biases. As we seek to build these augmentative technologies, we also face the ethical reckoning of what should and can be sensed from us and the protection and ownership of that information.

Arnav Kapur,
MIT Media Lab

Toward smart assistive environments

Our vision in the robotics research pillar of the Center of Intelligent Systems at the Federal Polytechnic School of Lausanne (EPFL) in Switzerland is to create smart assistive environments by merging concepts from smart homes, neuroprosthetics, powered exoskeletons and distributed robotics to assist persons with limited mobility in their daily living.

For example, rather than a single robotic helper (humanoid), our robotic system will be distributed as intelligent and active modules to serve as multi-functional robotic building blocks. These reconfigurable robotic modules will require distributed actuators, sensors (on the person, the robot and in the environment) and a control strategy to survey the environment, reconfigure and execute tasks. The functionalities of the modules will be in the form of attachable interactive objects, furniture and robotic arms.

It is envisioned that this robotic platform will help people with essential activities of daily living, such as safely moving within an apartment, fetching and bringing items, and helping with transitions (e.g., getting out of bed). The robotic system should be capable of interfacing with (motorized) wheelchairs, powered exoskeletons and neuroprosthetic devices (e.g., epidural spinal cord stimulators) to coordinate the robotic modules within the environment with locomotion assistance.

These distributed modules and sensors will create a network of assistive devices that can be gradually implemented depending on the user's needs. Some of these technologies could be transferred to other applications, such as space/planetary stations, smart factories, smart working places and smart conference rooms.

Auke Ijspeert and Jamie Paik, EPFL

Products will have more customizable features in the future. People are realizing that "one size does not fit all" – especially in assistive technology. You can already see this from products like OrCam (see page 153) where you can mix and match. Perhaps in the future we will see products that calibrate themselves to adapt to individual users.

Suranga Nanayakkara, University of Auckland

example, and how is "normal" defined? What does assistive technology actually entail and will it result in a "new normal"? Will it in fact widen the divide between persons with functional limitations and a "technologically enhanced new normal"? Is it indeed either acceptable or desirable for an assistive technology to augment the reality of a user with impaired intellectual and sensory functioning?

Toward smarter, customized, data-intensive and (inter)connected assistive products

The increasing number of applications for enabling technologies is supporting the development of emerging assistive products (see Chapter 3). This can already be seen in products such as smart diapers, canes and medication dispensers where enabling technologies optimize functioning and ultimately improve the end-user's experience and safety by learning from the user's preferences, behavior, conditions and lifestyle.

Smart assistive products are intended not as standalone solutions, but as connected ones, both to each other and to centralized platforms. This allows a more systematic approach to assistive technology to be adopted, with various assistive and mainstream products forming a wider distributed system (including smart home appliances, advanced prosthetics, navigation aids and assistive robots). Building assistive technology into the environment creates a holistic approach to independent living, but requires an improved understanding of the complexity of human interaction with both the physical and social environment (Gitlow and Flecky, 2019). The interoperability and interdependence of assistive technologies

Owing to the progress on technology and disability-related legislation that requires accessibility, the distinction between assistive and accessible technology is blurring. In some cases, what was previously needed as a standalone piece of assistive technology is now built into mainstream technologies, such as smartphones, tablets or computers. Persons with disabilities are now generally early adopters of technologies.

Alejandro Moledo, European Disability Forum

Disruption can happen from certain mainstream technology developments having an impact on the assistive technology community. For example, e-books that are appropriate even for persons with mobility restrictions and drones that can assist persons with mobility issues.

David Banes, David Banes Access and Inclusion Services

There are two common misperceptions of assistive technology: assistive technology eliminates a person's disability; and without assistive technology people with disabilities are not able to do anything. Consumer goods companies tend not just work on assistive technology as their core business or priority. However, they see that ageing is a "larger market". Companies might still position some assistive devices to target specific communities as part of their social responsibility as well as to promote their visibility.

Suranga Nanayakkara, University of Auckland

with mainstream products may also need to be addressed in standards and other regulatory frameworks.

A changing range of assistive products

Developments in technology and the wider context are likely to affect the future range of assistive products.

The impact of inclusive design

The application of inclusive design and co-design principles (see Chapter 4) is expected to remove the need for some specialized assistive products, as mainstream technology takes account of the needs of all users and their requirements. While significant efforts are ongoing at various levels to achieve this goal, it remains to be seen whether and when it will become a reality.

Crossover of assistive technologies with consumer electronic goods

The purpose of assistive technology is to allow end-users with limited functional abilities to participate more fully in daily life. That said, some assistive technologies and their functionalities are also relevant for other types of user, as well as industries such as social media, gaming, and health and wellness. For instance, non-invasive brain–computer interfaces are already under consideration for gaming and are being researched for wearables allowing hands-free communication.[2] Also, bone conduction technology is incorporated into runners' headsets allowing them to listen to music while continuing to remain attuned to the surrounding environment.

The high performance and reliability of assistive technology is important in ensuring safety and improving quality of life for persons with functional limitations. The same expectations apply to the applications referred to above. What is termed "user experience" is, though, important for other reasons, such as speed and precision for improved gaming performance.

The potential for technology originally developed for persons with functional limitations to "spill over" into general-purpose consumer electronic goods and related general purpose technology is a consequence of the various enabling technologies. Consumer electronic goods companies frequently feature among the top patent applicants in the patent dataset studied (Chapters 2 and 3). This indicates an interest by these companies in combining their expertise in enabling technologies with assistive technology in order to offer new assistive products. It may also indicate an interest in using assistive technology in the development of new consumer electronic goods, either with underlying assistive technology or as an additional functionality; consumer goods, such as wearable earphones or headphones, with embedded hearing device functionalities are an example.

This overlap with consumer goods could increase the acceptability of assistive technology by diminishing the stigma around the use of assistive technology, making it an indistinguishable part of everyday life. However, as addressing consumer needs may be the more profitable option, policy-makers will need to ensure that any societal division is not exacerbated as a consequence. Incorporating the principles of universal design and accessibility into the development of consumer goods would help mitigate this risk. One question to address is whether or not the purchase price of products will be reimbursed through prescription or insurance, and if this will depend on their characterization as assistive products. If some products were accessible at a higher price without subsidy or reimbursement, two parallel markets could be created for products that in theory serve the same assistive purpose.

Modularity: assistive products with multiple functions

Chapters 2 and 3 have shown the ways in which the principle of modularity applies to the development of new assistive products: developers of assistive technology in one domain are able to benefit from research output in another. For example, electrodes restoring locomotion can be utilized for sensory feedback, while non-invasive bone conduction developed for persons with hearing impairment can also be applied as an alternative sensory feedback mechanism for communication solutions (e.g., the MIT Media Lab AlterEgo wearable system for users with cerebral palsy – see case study on page 57).

Modularity in assistive technology

The concept of modularity is particularly useful in the field of assistive technology, which faces increased challenges in attracting funding. It allows both the optimization of research outputs with new applications across different domains and a reduction in product development time, for example the use of electrodes restoring locomotion to provide sensory feedback.

Silvestro Micera, EPFL and Sant'Anna School of Advanced Studies

A modular concept allows for personalized devices that can be easily repaired or adapted, and it could fundamentally change the delivery chain of these devices: instead of a process of taking measurements, ordering the device from the supplier?, making sure it is delivered to the right person and then possibly adapting it, the device can be made on the spot. The estimated price of the final products is much lower than current prices, partly because of these changes in the delivery chain. The concept is currently being tested in a field study in a rural area in India. Another interesting area being explored is the fitting of lower limb prostheses, using 3D scanning technologies with a smartphone and 3D printing techniques in combination with new materials. These examples demonstrate a very different use of emerging technologies from what we mostly see: to make conventional solutions better, cheaper, stronger, easier to produce and maintain.

Luc de Witte, University of Sheffield and Global Alliance of Assistive Technology Organizations (GAATO)

Modularity in assistive technology

Most assistive devices, in fact, leverage some mainstream technologies. AlterEgo (see page 57) and FingerReader, for example, leverage existing bone-conduction technology. The recent advancements in deep learning, if adopted properly, could make a huge difference in making better assistive technology. Rapid growth of AI has led to the widespread availability of related products, but without addressing end-user adoption concerns. Smartphones voice assistants, for example, are sufficiently intelligent to understand the context of a conversation, yet are only used by just over a third of smartphone owners in the U.S. This user-adoption problem is present in many AI domains, including sensitive domains such as medicine and assistive technology. To maximize user acceptance, it is important to integrate these emerging AI technologies in a human-centered way – aligning machine-learning systems with human goals, context, concerns and ways of working.

Suranga Nanayakkara,
University of Auckland

Modularity is particularly useful in the field of assistive technology, which faces increased challenges in attracting funding. It allows both the optimization of research outputs with new applications across different domains and a reduction in product development time.

Historically, and as seen in this report's review of patent documents related to conventional assistive products, different product segments were developed for specific functional limitations, and typically each product would have a single function. Nowadays, as shown by the patent documents related to emerging assistive technology, new products that can carry out several functions are being developed to serve a wider community of users with multiple or different functional limitations. Examples include assistive robots that help with household tasks, provide social interaction, conduct health and emotion monitoring, and assist in time and medication management.

The changing market for assistive technology

Changing market demographics present opportunities for investors, manufacturers and the inventors of assistive technology. An ageing population, the onset of functional impairments at an earlier age than typically expected due to the use of modern technologies (earphones, screens, and so on) (WHO, 2015) and an increasing focus on independent living are all leading to assistive technology becoming relevant to more and more people.

The ageing population

The United Nations estimates that by 2050 16% of the world's population will be over the age of 65, doubling from 727 million in 2020 to 1.5 billion in 2050 (United Nations, 2020). An ageing population is likely to see the global market for assistive technology reach US$35.6 billion by 2026 (Bloomberg, 2019).

Governments already employ various policies and measures aimed at delaying the onset of physical and cognitive decline through active ageing initiatives. Efforts such as AgeTech and other longevity-related projects[3] target the new market segment of elderly citizens, while some patenting activity relates to innovative solutions for regenerative medicine and the recovery of functionality. Innovative activity in so-called "gerontechnology" is promoted by the European Union (EU) and the U.K., and this is likely to enhance the availability of assistive technology for end-users, as it becomes a higher priority for governments.[4]

Meanwhile, dependence and immobility are no longer considered the inevitable consequences of ageing. Older people are more likely to live more independently than ever before, and over time there has been a shift from co-residence toward independent living,[5] and the number of initiatives and policies in support of this is growing. In

Implications of the crossovers between assistive technology and mainstream products

With the development of emerging technologies, assistive technology will increasingly overlap with mainstream commercial products. Typical overlaps include self-driving cars, companion and sweeping robots, 3D-printed insoles, voice-controlled gate locks and any other product with voice or eye interaction functions. This trend will bring a wider range of consumers and development opportunities for top players of mainstream products, as well as convenience for end-users. However, owing to the relatively high price of these products, the economic burden will increase for people with disabilities on a low income. On the other hand, some general assistive technology products are also developing toward mainstream products with accessibility features, such as electrical care beds, home accessible environmental control systems for people with physical disabilities and wearable walking skeletons.

Hongliu Yu,
University of Shanghai for Science and Technology

Promoting inclusiveness and accessibility must involve persons with disabilities from the early design stage of any technology or service, and governments, manufacturers, operators, the broader tech community and academia should work with them to ensure relevant validation.

Doreen Bogdan-Martin,
ITU Telecommunication Development Bureau

The current developments in assistive technology provide opportunities for people with disabilities to adopt emerging technologies as part of their daily lives. Likewise, there is terrific potential to make current and future technology more accessible, widening the innovations in the assistive technology field. Still, these technologies must be co-created by including assistive technology users throughout the whole process to guarantee that they result in outcomes that matter to them.

Maria Fernanda Cabrera-Umpierrez,
Polytechnic University of Madrid

addition, the pressure on care staff to accommodate a growing ageing population makes the use of effective, user-friendly assistive technologies an imperative. This is clear from the huge number and range of emerging assistive technologies identified in Chapter 2 in support of independent living.

Investors, manufacturers and technology providers may be encouraged to enter the assistive technology innovation space; something which could improve the quality of assistive products. Nevertheless, challenges will remain, among which are an insufficient focus on the needs of different user categories, limited provision or an inappropriate selection of assistive products and a failure to improve safety performance and standards, particularly if assistive technology is incorporated into mainstream technologies. Even where the needs of persons with disabilities overlap with those of an ageing population, the specific needs of each individual end-user should always be paramount, rather than a limited

Innovation in regenerative medicine

In future, solutions that reduce surgical complications will be important, as these are the decisive factor for successful implants.

We are moving from eye implants to brain implants: this is very promising as it addresses more patients and user cases (and could, for example, include neural stimulation for Parkinson's disease), and allow for re-use of the same technology for different conditions. Regulation is also going to be an important factor in terms of the timing for such solutions entering the market.

Greg Cosendai,
Verily

Regenerative medicine is still some way away. Ophthalmic innovation is likely to be in the form of better treatments to prevent optic nerve damage in glaucoma – so-called "neuro-protection" – better glaucoma implants to lower the eye pressure, either drug-eluting or simple plumbing, and perhaps intraocular pressure sensors. Some form of presbyopic intraocular lens correction will come at some point, but multifocals are not quite there yet. There is a lot of activity in AI/deep-learning for detecting changes in glaucoma and diabetic retinopathy. Retina is the most innovative area at the moment. Implants, such as the Argus II, have made some limited headway, but this is still a relatively embryonic area. Concepts like cortical stimulation and regeneration are still some way off.

Keith Barton,
Moorfields Eye Hospital

Brainstem implants are the most invasive among all assistive products and involve risks, as motor nerves are located close by and the area varies between individuals, making a successful intervention challenging.

Bradley McPherson,
University of Hong Kong

Bioelectronic medicines could be the next big thing in the long run in the field of assistive technology. These would be linked not just to sensory and motor nerves but also autonomic nerves, that is primitive nerves connected through a highway to the brain. These would allow – thanks to neuromodulation – reactivation of functions that are either missing or reduced, moving in this way into precision medicine and therapeutic interventions.

Silvestro Micera,
EPFL and Sant'Anna School of Advanced Studies

range of technologies being provided for a homogeneous group of end-users.

As assistive technology is expected to assume a life-course perspective, a cross-sectoral approach is needed to break down silos where assistive technology research, science and related discussions are divided into rehabilitation, disability and education, among other categories (MacLachlan et al., 2018). Expanding dialogue and collaboration with other relevant communities may promote innovation by enabling more cross-sectoral R&D.

Changing players and geographies

As demonstrated in Chapters 2 and 3, the origins of innovation in assistive technology, its locations and the breadth of patent protection, as well as the key players, are changing and this is likely to have an impact on the related markets, similar to that on the profile of patent applicants.

While there may be some variation across the functional domains in terms of the geographical breadth of protection sought, it is evident that patent filing strategy, as reflected in the geographical distribution of patent protection, has an impact on target product markets. Some jurisdictions, notably China and the Republic of Korea, have been receiving more patent applications in recent years. This is related to the growing number of local innovators, as well as the desire of leading patent applicants to protect their products in these jurisdictions by having an intellectual property (IP) portfolio in key manufacturing locations.

Patent protection is being sought in more and more emerging markets, an indication that applicants regard these jurisdictions as potential markets. This is an interesting phenomenon in light of the fact that in many of these countries there are either no related systems in place, or systems do not allow the majority of the population to access even medically required assistive products. In jurisdictions where patent protection has not been sought, there may be opportunities to use inventions that lie in the public domain (WIPO, 2020).

In addition, the profile of patent applicants across conventional and emerging assistive technology and the changes therein offer insights into market dynamics and related opportunities. The landscape of top players in assistive technology is undergoing an evolution: traditional European, Japanese and U.S. players face increasing competition from Chinese and Republic of Korea players. Some functional categories of assistive technology (including cognition and environment) have a large number of players with small patent portfolios, indicating a fragmented product market and the potential for increased competition and greater opportunities for collaboration. Similarly, increased participation by universities in patenting activity for emerging assistive technologies, and by independent inventors in conventional assistive technology, signal opportunities for collaboration and for policy action to support independent inventors, micro-companies and small and medium-sized enterprises (SMEs) in bringing products impactful for the end-user onto the market. The growing presence of consumer and electronic goods companies in the field of assistive technology may also alter the market dynamics to the benefit of end-users, for example, by boosting availability.

Conventional versus emerging assistive technology markets

Over time, with the wider use of enabling technologies, some emerging assistive products will come to offer alternative ways of addressing an identical user need, for example, speech input technology rather than Braille to draft text. As can be seen from the IP and business strategy of some of the key companies discussed in Chapters 2 and 3, there appears to be interest and room enough for innovation in both types of product; for conventional products, through improved performance, design, reliability, user-friendliness and comfort; for emerging products, through solutions that either add functionality to existing products or offer entirely new ones. Based on this IP strategy, the growth in patent filings for both types of products, conventional and emerging, as endorsed by expert interviews, appears

Data, privacy and assistive technnology

Challenges like data privacy can be approached both through hardware advances (more powerful processors) and software advances (e.g., local processing of data). A related challenge is that of business models, as many of today's services and experiences are ultimately paid for through advertising (i.e., the data is where the value is). That will need to change, and it will take a while. We need to acknowledge that when a service or product is relying on advertising, the incentives of the consumer and the company will never be well aligned.

Pattie Maes,
MIT Media Lab

The FDA has considered the role of software in medical devices since the early 1980s. However, while software then most often played a role within the clinical environment, software today can be part of devices carried or worn by patients outside a clinical setting, such as software applications used on smartphones. The ubiquity of such software (not limited to health-related software) means that personal data can be collected and shared without the knowledge of the device user. In some cases, data sharing policies may be disclosed via click-through agreements, but few users are likely to read and understand lengthy privacy policies, particularly when they are made available in a small font on a smartphone screen that requires repeated scrolling. Information sharing can play an important role in clarifying how medical products perform in the real world. It will be important to ensure that information can be collected and used to benefit future users, while simultaneously protecting the reasonable privacy interests of those who use the devices.

Jonathan Darrow,
Harvard Medical School

In terms of regulation, standardization and IP, there is a risk that there will be a push for more guards in the system to protect this type of information and the information that can be extracted. Actions along these lines are likely to be driven by discussions around AI and data science and not necessarily driven by assistive technology. If the relevant populations are not well represented in such discussions, we could end up with regulation that does not reflect their interests.

Ricardo Chavarriaga,
CLAIRE, IEEE Standards Association and
Zürich University of Applied Sciences

Medical devices are increasingly connected to the Internet, networks and other devices to improve functionality, and this increases the risk of cybersecurity threats. Medical devices, like other computer systems, can be vulnerable to security breaches, potentially affecting the safety and effectiveness of the device. Device manufacturers are responsible for identifying risks and hazards associated with their medical devices, including cybersecurity risks.

Jonathan P. Jarow,
FDA Solutions Group

to show them both developing in parallel, but covering different user profiles and needs.

As certain emerging products come to be tested, approved and accepted by end-users, some technologies will become mainstream rather than specialized (see Crossover of assistive technologies with consumer electronic goods, p. 240). The habits and preferences of end-users may also change. It is possible that this could lead to certain conventional products being replaced by emerging assistive ones; alternatively, socioeconomic circumstances, user preferences, needs and demographics could lead to an extension of the current situation.

Issues related to developments in assistive technology

The developments discussed show great potential in the field of assistive technology. However, they also raise significant issues and concerns that will need to be considered by appropriate forums.

Ethical considerations

Social exclusion

Although assistive technology is intended to increase the participation in society of persons with functional limitations, some assistive technologies could have the opposite effect. Emerging technologies, such as companion robots, smart houses and wearables, support independent living, but there is a risk this could establish the notion that human carers can be replaced by technology, thereby leading to further social isolation for end-users (Bechtold and Sotoudeh, 2013). This may be more of a concern in some cultures than in others. There will be a need to ensure that human care continues to be considered irreplaceable.

Similar concerns about social division relate to age, cultural relationship and the perceived ease of adopting new technologies, as well as the availability of emerging solutions for end-users in developing economies. These highlight the need for training and making available a wide range of products to serve different needs and preferences.

It is also possible that development could go in the direction of high-end solutions, with assistive technologies perceived as luxury products and the best options available only to those who can afford to pay for them. This could happen if assistive technology is used to augment human capabilities and provide a competitive edge at the workplace or in physical competitions, such as marathon running.

Data, privacy, security and access

Many of the general data and privacy aspects relating to trends in AI identified in the first issue of this series, *WIPO Technology Trends 2019: Artificial intelligence*, also apply to assistive technology, as it becomes ever more smart, connected and data-heavy (WIPO, 2019). These aspects are a particularly important consideration when it comes to assistive technology, because end-users, who often belong to particularly vulnerable groups, may not be in a position to make decisions on how their personal data are used nor protect themselves from security threats.

The digital revolution is enabling the development of assistive technologies based on software and data, resulting in less visible but more personalized technologies, such as wearable health and emotion monitoring devices. Software focused on diagnostics or monitoring can be integral to supporting independent living for persons with functional limitations, while also enabling a focus on health and well-being by the general population and supporting personalized medicine. However, software-based assistive devices relying on the collection of data from an individual end-user present IP issues and also have broader ethical implications. Moreover, the increased use of smart, connected assistive products carries a higher risk of cybersecurity threats.

Beyond the threats that the new era of assistive products brings, the unprecedented collection of data by wearables and other smart,

The impact of future brain–machine networks on patent law

Devices and methods for both reading and writing from the brain have become relatively commonplace in laboratories and are on a trajectory for consumer product use. What would such a world, with brain–machine networks as common as smartphones and the Internet, mean for patent law?

First, who is deemed an inventor is muddled if electronically represented thoughts (disembodied from their owners' voices or written messages) are intermixed with the thoughts of others on computing devices. Further, the scale of intermixing may be bigger than anything yet seen, comparable to massive multi-player online video games, which host thousands of players at any one time. Combine these issues with the prospect of anonymity, and it becomes evident that inventorship may need to be rethought – potentially in the same way tort law was for class actions or authorship was for particle physics collaborations. For example, perhaps there should be an opt-in/out registration period to claim inventorship to a patent application, provisions for anonymous inventors who could not be identified or limits on the number of inventors.

Second, at first blush, a person of ordinary skills in the art (POSITA) may seem ideally represented by this potential brain–machine network technology, which may serve as a virtual crowdsource of creativity and knowledge of the art. Yet adjustments may have to be made. Under existing practice, a POSITA can easily be led astray by incorrect information or a lack of appreciation of criticality within a range. An electronic intermixing of thoughts may be more robust, and it will be undoubtedly aided by the perfect processing, perfect memory of the computers upon which they are hosted. The threshold for what a POSITA deems obvious, or what they can do in terms of calculation, may need to be elevated.

Third, what is considered prior art may change as drastically as it did when the development of the Internet reformulated what is "printed" and what is a "publication." For example, if electronically stored thoughts are indexed and searchable, they may potentially qualify as a type of non-patent literature for obviousness. If not, they still might be suitable as evidence for what is well known, for secondary considerations like long-felt but unsolved needs or in derivation proceedings.

Fourth, disclosure requirements (written description and enablement) for a patent application potentially could be supported by referencing databases of electronically stored thoughts. This is not without precedent in the U.S., where there are already provisions for including non-written material for applications, such as biological material. There is also the prospect that such databases could serve as evidence that the inventors were in possession of the invention or that terms in the written portion referred to valid terms of art known in the field.

In the same way that AI has prompted a rethinking of patent laws, so too may the wave of brain–machine interface and network technology that is just on the horizon.

Kate Gaudry and
Mark P. Mathison,
Kilpatrick Townsend & Stockton LLP

Building an IP-based ecosystem

Recently, the structure of industry has changed drastically. The combination of hardware and information technology across existing industries is providing unprecedented value. In these changed circumstances, Panasonic could not conduct business in isolation, and it became essential to co-create with other companies. The role of our IP has changed greatly. In the past, patents were used as a weapon to keep competitors in check and ensure superior competitiveness. Today, Panasonic aims to build an ecosystem around IP where co-creation partners can be connected and provide high-quality results. For example, in the field of smart nursing, a variety of devices provided by various manufacturers are used, such as nursing care recording software, monitoring sensors, and vital meter measuring devices, such as blood pressure and body temperature.

Yoshiaki Tokuda, Panasonic

connected assistive technology creates a wealth of information, and, with that, huge potential and opportunity to advance science and support innovation more broadly. The question of how to make this data accessible to the research community and thus harness this potential in the best possible way, while preserving personal privacy and security of data, is related to discussions on fair access to data.

Intellectual property

The use of enabling technologies to develop emerging assistive products is moving the wider discussions on IP into the field of assistive technology.

It was noted in the first of the WIPO Technology Trends reports that fast-paced developments in AI have several possible impacts on IP, including patentability requirements, inventorship of AI-powered solutions and authorship of AI-created works (WIPO, 2019). Most of the emerging assistive products

While the advent of technology that freely and flexibly interprets the user's every wish may be seen as the "holy grail" of brain–computer interface technology, it is still some way off and many technological, social and ethical barriers lie between the current state of this technology and the technological maturity required for mass market acceptance.

Ricardo Chavarriaga, CLAIRE, IEEE Standards Association and Zürich University of Applied Sciences

identified in the current report were possible thanks to one or a combination of several of the nine identified enabling technologies, including brain–computer interfaces using brain waves to control devices and appliances. Technological developments in the field are currently allowing for identification and decoding of simple commands, but are heading toward high-performance solutions allowing the decoding of more complicated and abstract human thinking, raising a question relating to IP: Could this pose a threat to the determination of novelty/prior art or disclosure requirements? Although such concerns may seem premature and fictional at this point in time, they may be worth considering sooner rather than later and addressed in a proactive rather than reactive manner (see the related comments by Gaudry and Mathison above), learning from the experience with AI. This experience could also allow for regulation, legislation and standards to anticipate potential implications and ensure that privacy is safeguarded while technology develops further.

Another IP-relevant issue is the development of appropriate licensing models; something which is expected to be integral to the widespread use of data-based or data-heavy emerging assistive products and technology health services. Licensing models can strengthen uptake, reduce costs and shorten

The role of standards in the assistive technology discussion

How we move from standards that are specific to technology or components of an overall system to a proper characterization of the requirements of a whole system is important. There may be some systems for which establishing standards is currently possible at the level of the whole system and other cases where this may not be possible. In any case, interoperability is key: how do they communicate among themselves, are they robust and are they appropriate for the conditions they will be used in? How do we ensure that they are robust to cybersecurity threats and maintain privacy of data? This is an increasingly important aspect as we integrate emerging technologies such as AI and systems that were not developed to be part of assistive technology in the first place.

Human factors and characteristics of users' needs are also important, and some standards already exist in this regard. However, they are not necessarily integrated into the design of assistive technology. How do we ensure that the development of assistive technology, especially using emerging technologies, considers human factors early in the design and the specification of the performance? Systems produced using faster development cycles will be subject to regular updates. How do we manage this in terms of standardization? Developing standards takes a very long time – how are we going to change the way we define standards, design regulations to be more agile in relation to these technologies without sacrificing the reasons for standards and regulations in the first place? Coherent integration with other governance approaches – ethical guidelines, recommendations and self-regulation – will be needed to achieve the required flexibility.

Ricardo Chavarriaga, CLAIRE, IEEE Standards Association and Zürich University of Applied Sciences

development cycles. Licensing practice will need to generate approaches to issues of ownership and data privacy, including the data used as training for AI. In addition to supporting licensing models, copyright law can protect the specific graphic–user interface and functionality that make mobile apps easy to use. Open source models, such as those widely used in software development, may be an effective option.

The patentability of diagnostic and treatment methods that use data relevant for a series of assistive products has been examined in several jurisdictions, including those of the U.S. and Australia, and in some cases these methods have been found not patentable.[6] The question to be answered would be whether this could inhibit investment in the type of assistive technology that gathers data and applies it to diagnostic and treatment methods.

Data collection can result in exploitation when there is a lack of awareness about the type of data collected and for what purpose it is being used (Sadowski, 2016). Management of the data collected, data ownership and privacy, particularly for end-users who may not have the capacity to consent to its use, will require the attention of policy-makers. There may, however, be a bargain to be struck whereby the collection of data supports and improves health care systems.

It may become more necessary to look at the protection and regulation of this data, for example, through privacy policies, data protection legislation and privacy being built into the design of assistive technologies, instead of relying on blanket exclusions of data collection (European Parliament, 2018). Could public health emergencies like the COVID-19 pandemic override privacy considerations? Would such a breach of privacy be justifiable? Some organizations, among them WHO (WHO, 2018b), are already considering this issue (Kickbusch et al., 2019).

Adjusting regulatory requirements and standards

Emerging assistive technologies identified in Chapter 2 include implantable products and software that could qualify as a medical device, reflecting the convergence of assistive with medical technology and other disciplines. According to the TRL assessment made in Chapter 3, the majority of emerging assistive products that are either implantable or relate to safety require regulatory approval. This is expected to delay the entry of products into the market. Moreover, as some new assistive products have not yet been considered in regulation, there are gaps to be filled (see Hogan Lovells, Jonathan Darrow and Jonathan Jarow contributions). This is the case, for example, for developments related to neuroprosthetics, autonomous wheelchairs and 3D-printed prostheses. Addressing a change in standards and other frameworks will be beneficial in providing a common understanding, despite different regulatory requirements.

Regulation will also need to maintain a balance between the different interests: while the convergence of assistive and medical technologies is likely lead to an increase in regulation, the convergence of assistive technology with consumer goods may, conversely, lead to a decrease in regulation, particularly if inclusive design principles are taken into account.

A centralized repository of related standards and regulatory information at national and international level could serve to make stakeholders more aware of requirements and help in navigating this complex environment.

The importance of a multi-stakeholder approach

The notion of academic development and industrialization existing in separate worlds cannot continue. With AI, a very strong pattern emerged of companies taking research and talent in-house, as they offer better resources and conditions than academia. This brings serious issues in terms of addressing diversity and adequate responsibility and accountability.

An alternative approach is to have a seamless transition between academia and industry, and better communication among stakeholders. Several institutions are promoting this approach, including the IEEE Brain Initiative with its Neuroethics Framework and the IEEE Standards activity on Neurotechnologies for Brain-Machine Interface. In the area of AI, the Confederation of Laboratories for Artificial Intelligence Research in Europe (CLAIRE) aims to create the conditions, infrastructure and collaboration channels to develop, alongside a network of researchers, a network of industrial counterparts that can bring in first-hand knowledge of user needs, difficulty of technology transfer and difficulty of deployment of technology. Together with experts in research, they can develop strategies for achieving a seamless transfer and update and maintenance of AI-based technologies. CLAIRE's vision includes a human-centered approach for the benefit of society that is inclusive and can especially benefit assistive technology.

Ricardo Chavarriaga, CLAIRE, IEEE Standards Association and Zürich University of Applied Sciences

Shaping the future

End-users' future access to assistive technology is dependent on several interrelated factors, often unique to conventional or emerging assistive technology:

- acceptance and adoption of assistive technology as a human right in accord with the Convention for Rights of Persons with Disabilities (CRPD) and with related assistive technology policies and legislation;
- the range of products that could be considered assistive and therefore reimbursed by health systems and insurance;
- product pricing and how this might develop in line with an anticipated increased market

The impact of access to new assistive technologies is almost immeasurable. If and when blind persons can operate self-driving vehicles, the automobile industry could win up to 250 million more users. Access to robots that help with medication dispensing and household tasks could mean that more persons with disabilities will remain safe and independent in their own homes instead of moving to care facilities. The entire population can benefit from smart home systems, reducing the cost of these now mainstream technologies, meaning that persons with disabilities do not have to be financially penalized for requiring specialized devices.

Martine Abel-Williamson, World Blind Union

We are working hard to build a better world with opportunities for all. If we can dream it, we can make it.

Maria Teresa Arredondo Waldmeyer, Polytechnic University of Madrid

share for assistive technology as the population ages;
- the extent to which mainstream products replace specialized assistive products;
- frugal innovation and/or reverse engineering in those countries where there is no patent protection for the inventions identified which lie in the public domain and are therefore free to be exploited, affording opportunities particularly for developing economies.

The projections considered in this chapter emphasize the need for greater end-user involvement in, first, the development of assistive products and co-design, and, second, the development of a solid assistive technology policy. Global initiatives will be important in ensuring a sensitive approach to assistive technology innovation that takes account of end-user needs. Moreover, the number of issues that impact the development, commercialization and access to assistive products makes consideration about a holistic approach to the topic through multi-disciplinary discussion and collaboration a probably necessary one. Historically, assistive technology was considered niche, but this is no longer the case as it rapidly becomes mainstream. For this reason, it is important for policy-makers to react in a timely manner and discuss the myriad issues touching upon the development of, access to and use of assistive technology.

The real question is not how assistive technology will develop, but how we want it to develop. The projections are the ones we want them to be. The principles of the CRPD, which envisage an inclusive world where access to assistive technology is a human right, ought to actively stimulate innovations directed at affordable solutions for the many. But, if we let the “market” do its work, we could end up with outstanding solutions for the few only, and move further away from this ideal. Should the priority be those solutions providing the bare minimum for the most people, or, instead, those that increase as far as possible the quality of life for those fortunate to have access to them? It is in our hands to answer this and other crucial questions as we shape the future of assistive technology.

Notes

1 Assistive augmentation aims to treat both sensory ability and disability as part of the usability of a technology in an integrated way; that is, to "design and develop assistive technology, user interfaces and interactions which seamlessly integrate with a user's mind, body and behavior, providing an enhanced perception" (Huber et al., 2014). See also related comments in this chapter by Professor Pattie Maes.

2 For example, silent speech interface developed by Facebook Reality Labs (Facebook, 2020).

3 The establishment of dedicated institutes, such as the Stanford Center on Longevity (https://longevity.stanford.edu/about), along with related funding/investment, for example, https://www.longevitytech.fund/en/home, The Longevity Fund (https://www.longevity.vc) and the AgeTech Digest (https://www.thegerontechnologist.com/who-is-investing-in-the-age-tech-revolution), which provides an overview of related activities, indicate an increased interest in this area.

4 In the EU, for example, the aims of the Innovation 2020 partnership were, by 2020, to have enabled EU citizens to live longer independently in good health, increasing the average number of healthy life years by two. Integral to achieving this target is the creation of an EU and global market for innovative products and services with new opportunities for EU businesses (European Commission, n.d., 2011, p. 41). Innovation partnerships, such as the U.K. Research and Innovation (UKRI) Industrial Strategy Challenge Fund (ISCF) Healthy Ageing, provide investment into research and innovation that supports people as they age and also their carers, including into collaborative research and development projects for early-stage innovations focusing on digital health care and older adults (Department of Health and Social Care, 2018, p. 5). Specifically U.K. research projects have looked at dementia and mobility, as well as assistive technology in the home, and point to how ageing populations are driving emerging technologies (Woodcock et al., 2020).

5 Data for 67 countries indicate that over the last 20 years, or so, older persons have become more likely to live independently (about 37% at around 2010 compared to 24% at around 1990), whereas co-residence with children has become less common (53% at around 2010 compared to 65% at around 1990) (United Nations, 2017).

6 See *Mayo Collaborative Services v. Prometheus Laboratories, Vanda Pharmaceuticals Inc. v. West-Ward Pharmaceuticals* and USPTO Revised Patent Subject Matter Eligibility Guidance (2019).

References

Bechtold, U. and M. Sotoudeh (2013). Assistive technologies: Their development from a technology assessment perspective. *Gerontechnology*, 11, 521–533.

Bloomberg (2019). Elderly and disabled assistive devices market to reach $35.60 bn, globally, by 2026 at 5.5% CAGR, says Allied Market Research. Available at: www.bloomberg.com/press-releases/2019-07-24/elderly-and-disabled-assistive-devices-market-to-reach-35-60-bn-globally-by-2026-at-5-5-cagr-says-allied-market-research (accessed December 12, 2020).

Department of Health and Social Care (2018). Research and development work relating to assistive technology, 2017–18. London. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/775870/Research_and_development_work_relating_to_assistive_ technology_2017_to_2018.pdf (accessed December 9, 2020).

European Commission (n.d.). *What is the European Innovation Partnership on Active and Healthy Ageing* (*EIP on AHA*)*?* Available at: https://ec.europa.eu/eip/ageing/about-the-partnership_en (accessed December 9, 2020).

European Commission (2011). *Europe 2020 Flagship Initiative Innovation Union*, SEC(2010) 1161. Luxembourg. Available at: https://ec.europa.eu/research/innovation-union/pdf/innovation-union-communication-brochure_en.pdf (accessed December 14, 2020).

European Parliament (2018). *Assistive technologies for people with disabilities: Part IV, Legal and socio-ethical perspectives*. Available at: www.europarl.europa.eu/RegData/etudes/IDAN/2018/603218/EPRS_IDA(2018)603218(ANN4)_EN.pdf (accessed December 11, 2020).

Facebook (2020). Imagining a new interface: hands-free communication without saying a word. *Tech@Facebook*, March 30. Available at: https://tech.fb.com/imagining-a-new-interface-hands-free-communication-without-saying-a-word (accessed December 30, 2020).

Gitlow, L. and K. Flecky (eds.) (2019). *Assistive technologies and environmental interventions in healthcare: An integrated approach*. Hoboken, NJ: Wiley-Blackwell.

Huber, J., J. Rekimoto, M. Inami, R. Shilkrot, P. Maes, M.E. Wong, G. Pullin, S.C. Nanayakkara (2014). Workshop on assistive augmentation, CHI Conference on Human Factors in Computing Systems, Toronto, April, doi.10.1145/2559206.2560473.

Kickbusch, I., A. Agrawal, A. Jack and N. Lee (2019). Governing health futures 2030: Growing up in a digital world – a joint *The Lancet* and *Financial Times* Commission. *The Lancet*, 394(10206), doi:10.1016/S0140-6736(19)32181-6.

MacLachlan, M., D. Banes, D. Bell, J. Borg, B. Donnelly, M. Fembek, et al. (2018). Assistive technology policy: a position paper from the first global research, innovation, and education on assistive technology (GREAT) summit. *Disability and Rehabilitation: Assistive Technology* 13(5): 454–466, doi: 10.1080/17483107.2018.1468496.

Sadowski, J. (2016). Companies are making money from our personal data – but at what cost? *The Guardian*, August 31. Available at: www.theguardian.com/technology/2016/aug/31/personal-data-corporate-use-google-amazon (accessed December 11, 2020).

United Nations (2017). *World Population Ageing 2017 Highlights*. Available at: http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2017_Highlights.pdf (accessed December 30, 2020).

United Nations (2020). *World Population Ageing 2020 Highlights*. Available at: www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/undesa_pd-2020_world_population_ageing_highlights.pdf (accessed December 30, 2020).

USPTO. (2019) 2019 Revised Patent Subject Matter Eligibility Guidance. Alexandria, VA.

WHO (2015). 1.1 billion people at risk of hearing loss. Available at: www.who.int/mediacentre/news/releases/2015/ear-care/en (accessed December 11, 2020).

WHO (2018a). Assistive technology, fact sheet. Available at: www.who.int/news-room/fact-sheets/detail/assistive-technology (accessed December 11, 2020).

WHO (2018b). Digital health, agenda item 12.4, Seventy-first World Health Assembly. Available at: https://apps.who.int/gb/ebwha/pdf_files/WHA71/A71_R7-en.pdf (accessed December 11, 2020).

WIPO (2019). *WIPO Technology Trends 2019: Artificial intelligence*. Geneva, pp. 120–135.

WIPO (2020). *Using inventions in the public domain: A guide for inventors and entrepreneurs*. Geneva.

Woodcock, A., L. Moody, D. McDonagh, A. Jain and L.C. Jain (eds.) (2020). *Design of assistive technology for ageing populations*. Cham, Switzerland: Springer.

Annexes

Annex 1: Conventional taxonomy

Product categories (Level 2)	Level 3 taxonomy	Level 4 taxonomy
Cognition		
Calculation functions		
Medication dispensing and management		
Time management products		
Memory support products		
Clocks and timepieces		
Timers		
Communication		
Visual communication	Software picture-based communications	
	Video communication devices	
	Communications boards, books and cards	
Audio communication: speech input	Speech input (general)	
	Speaker identification	
	Interactive voice response (IVR) and services	
	Messaging systems	
	Computing device control	
	Telephony – call captioning	
	Document writers/dictation to text	
Audio communication: text to speech (TTS)	Text to speech (general)	
	Device interface	
	Messaging systems	
	Interactive voice response (IVR) and services	
	Document/text scan to speech	
	Personalized voice generators	
Switches and input devices	Mechanical ease of-use	
	Eye mouse	
	Sip-and-puff switch	
	Head mouse	
	Head–mouth sticks	
	Trackball for assistive technology	
	Single-switch access	
	Finger–thumb input	
Special software and services	Emulation software	
	Assistive telephony services	
	Word processing software	
Environment		
Domestic/workplace assistive technologies and devices	Handrails and grab bars	
	Tables and their accessories	
	Light fixtures	
	Sitting arrangements and their accessories	Chairs
	Other furniture accessories	
	Beds and their accessories	
	Storage	
	Entry/exit and openings	
	Building structural components	
	Workplace and domestic safety	
	Workplace/domestic object conveyance, hoisting or repositioning, crane	
	Workplace/domestic object securing, gripping, holding, carrying and handling	
	Workplace/domestic machinery	
	Laundry	
	Kitchenware cleaning	
	Food preparation	
	Bathroom and toilet accessories	Shower/bathroom and toilet chairs
		Bathroom accessories
		Shower units and accessories
		Washbasins and accessories

Product categories (Level 2)	Level 3 taxonomy	Level 4 taxonomy
		Bathtubs and accessories
		Body drying
		Bathroom/toilet units
		Toilet seats and accessories
		Urinals
		Accessories for changing body position or lifting persons – mounted in combination with a toilet
		Accessories for changing body position or lifting persons – mounted in combination with a bathtub
General environment	Assistive products for vertical acessibility	
Assistive technologies for culture, recreation and leisure	Assistive products for play	
	Assistive products for sports	Winter sports
		Skating
		Mountaineering
		Swimming
		Tennis or table tennis
		Basketball
		Watersports
		Golf
		Paralympics
		Sports wheelchairs
	Assistive products for playing and composing music	
	Assistive products for producing photos, films and videos	
	Assistive products for creating arts and crafts	
	Assistive products for hunting and fishing	
	Assistive products for camping	
	Assistive products for animal care	
	Portable travel aids	
Alarms	Environment alarms	
	Fall detectors	
	Wandering and locating of persons/items	
	Personal emergency alarm systems and medical alert IDs	

Hearing

Hearing aids and induction loops	Hearing aids (general)	
	Induction loops	
	Body worn	
	Spectacle	
	In the ear	
	Behind the ear	
	Tactile	
	Used in connection with implants	
	Accessories for hearing aids and induction loops	
Signalling products		
Closed captioning devices		
Video interpretation services		
Lip reading		

Mobility

Walking aids	Axillary crutches	
	Elbow crutches/forearm crutches	
	Crutches in general	
	Walking sticks	
	Tripod/quadripod sticks	
	Walking frames	
	Rollators	
	Walking chairs	
	Walking tables	

Annex 1: Conventional taxonomy

Product categories (Level 2)	Level 3 taxonomy	Level 4 taxonomy
Accessories for walking aids	Seats	
	Lights and safety signalling devices	
	Tips of walking aids	
	Grips	
	Pads/cushions	
	Object holders	
	Shock absorbers	
	Walking aid holders	
Wheelchairs	Manual wheelchairs	Hand propelled
		Lever propelled
		Foot propelled
		Push wheelchairs
	Wheelchairs with postural support	
	Stair-climbing or obstacle-traversing wheelchairs	Stair-climbing powered wheelchairs
		Obstacle-traversing wheelchairs
		Others
	Electrically-powered wheelchairs	Manual steering
		Electronic steering
		Combustion powered
		Assistant controlled
		Power-assisted wheelchairs
	Tricycles and quadricycles	Foot propelled
		Hand propelled
Accessories for wheelchairs	Seats and cushions	
	Seat adjustments	
	Lights and safety signalling devices for wheelchairs	
	Running or parking brakes for wheelchairs	
	Tyres, wheels and castors for wheelchairs	
	Batteries and battery chargers for wheelchairs	
	Devices for cleaning wheelchairs	
	Devices to protect wheelchairs and their occupants from sunlight or precipitation	
	Devices to connect a wheelchair to a bicycle	
	Devices attached to wheelchairs to hold or carry objects	
	Devices to check surroundings of wheelchairs	
Other mobility and mobility accessories	Height adjustable chassis for entry/ exit of disabled/elderly	
	Raised roof extensions to vehicles	
	Cycles for power by disabled/elderly	
	Vehicle accessories/adaptations to reduce feeling of acceleration	
	Ramps to facilitate access	
	Loading of wheelchairs, with or without person seated in the wheelchair	
	Securing of wheelchairs	
	General vehicle control of any function	
Accessories for changing body position or lifting persons	General lifting devices	
	Lateral movement	
	Safety components of lifting devices	
	Turntables	
	Grip ladders	
	Moving another person manually	
	Mobile hoists and hoist bases	Mobile hoists for transferring a person in a lying position
		Mobile hoists for transferring a person in a sitting position
		Mobile bases of hoists
	Stationary, fixed hoists	
	Mounted in combination with a swimming pool	
	Body support units	

Product categories (Level 2)	Level 3 taxonomy	Level 4 taxonomy
Orthoses	Upper limb	
	Lower limb	Hips
		Thigh
		Knee
		Toes
		Feet–ankle
		Others
	Abdominal	Muscle support
		Hernia support
	Spinal and cranial	
	Shoes and boots	Diabetic/neuropathic
		Orthopedic
Prostheses	Upper limb	
	Lower limb	
	Structural components	Upper limb
		Lower limb
Special devices, namely, standing frames and supports for standing	Standing frames and supports for standing	

Self-care

Incontinence products	Absorbents	
	Collection	
	Prevention	
	Incontinence product accessories	
Dental care	Dental care	
Assistive products for manicure, pedicure and hair/facial care		
Assistive products for sexual activity		
Adaptive eating devices		
Adaptive clothing	Assistive technology for dressing and undressing	
	Adaptive clothes	
	Adaptive clothing accessories	

Vision

Magnifiers	Optical	Magnifier glasses, lenses and lens systems for magnification
		Binoculars and telescopes
	Digital	
Spectacles	Long distance	
	Short distance	
	Low vision	
	Side shields and protectors	
Tactile devices	Braille displays	
	Braille printers	
	Tactile screens	
	Braille translation software	
	Braille writers	
	Phones with braille	
	Touch watches	
	Braille watches	
Interactive products	Graphical user interfaces (GUIs) for the visually impaired	
	Screen readers	
	Audio players, e.g., DAISY players	
	Talking watches	
	Deaf–blind communication (DBC)	
	Talking calculators	

Annex 2: Emerging taxonomy

Product categories (Level 2)	Level 3 taxonomy	Level 4 taxonomy
Communication		
Brain–computer interface (BCI)	Computing and communication device control	
	Personal device and appliance control	
Sensory substitution aids		
Navigation aids		
Smart assistants		
Environment		
Smart homes	Smart nursing	
	Smart toilets	
	Lateral and vertical movement	
	Smart structural components, appliances and accessories	
Smart cities		
Assistive robots	Companion robots	
	Pet robots	
	Manipulators	
Hearing		
Automated lip reading		
Gesture (sign language) to voice and text		
Advanced hearing aids	Mind-controlled hearing aids	
	Eye-mounted hearing aids	
	Environment-controlling hearing aids	
Cochlear implants		
Non-invasive bone conduction		
Cartilage conduction		
Middle ear implants		
Ossicular replacement implants and prosthetics		
Auditory brainstem implants (ABIs)		
Mobility		
Advanced prosthetics	Neuroprosthetics	Central nervous system interface
		Peripheral nervous system interface
		Other neural interface
	Myoelectric control	
	Smart prosthetics	
	3D-printed prosthetics/orthoses	
Exoskeletons	Lower body/limb	
	Upper body/limb	
	Full body	
	Control	Body powered
		Externally powered
Advanced walking aids	Advanced canes	
	Balancing aids	
Advanced wheelchairs	Autonomous wheelchairs	
	Wheelchair control	

Product categories (Level 2)	Level 3 taxonomy	Level 4 taxonomy
Self-care		
Health and emotion monitoring	Wearables	
	Non-wearables	
Smart medication dispensing and management		
Feeding assistant robots		
Smart diapers		
Vision		
Intraocular lenses (IOLs)	Drug delivery	
	Adaptive focus	
	Multifocal	
	IOLs with sensors	
	Intracorneal lenses	
Artificial silicon retina (ASR)/retinal prostheses		
Cortical implants		
Bionic eye (system)		
Telescopic lenses		
Artificial iris		
Smart eyewear		
Augmented reality devices		
Virtual reality devices		
Hand wearables		

Annex 3: Use of enabling technologies across emerging assistive technology

Product category (Level 2)	Product category (Level 3)	Product category (Level 4)	Patent families
Emerging communication assistive technology			
Brain–computer interface (BCI)	Computing and communication device control		93
	Personal device and appliance control		89
Sensory substitution aids			236
Navigation aids			1,093
Smart assistants			128
Emerging environment assistive technology			
Smart homes	Smart nursing		42
	Smart toilets		40
	Lateral and vertical movement		151
	Smart structural components, appliances and accessories		296
Smart cities			273
Assistive robots	Companion robots		372
	Pet robots		37
	Manipulators		38
Emerging hearing assistive technology			
Automated lip reading			69
Gesture (sign language) to voice and text			500
Advanced hearing aids	Mind-controlled hearing aids		79
	Eye-mounted hearing aids		3
	Environment-controlling hearing aids		8
Cochlear implants			2,266
Non-invasive bone conduction			1,774
Cartilage conduction			34
Middle ear implants			242
Ossicular replacement implants and prosthetics			145
Auditory brainstem implants (ABIs)			35
Emerging mobility assistive technology			
Advanced prosthetics	Neuroprosthetics	Central nervous system interface	45
		Peripheral nervous system interface	38
		Other neural interface	84
	Myoelectric control		640
	Smart prosthetics		863
	3D-printed prosthetics/orthoses		565
Exoskeletons	Lower body/limb		743
	Upper body/limb		695
	Full body		22
	Control	Body powered	755
		Externally powered	25
Advanced walking aids	Advanced canes		431
	Balancing aids		551
Smart wheelchairs	Autonomous wheelchairs		737
	Wheelchair control		224
Emerging self-care assistive technology			
Health and emotion monitoring	Wearables		153
	Non-wearables		125
Smart medication dispensing and management			93
Feeding assistant robots			47
Smart diapers			95

Advanced robotics	New materials	VR/AR	Artificial intelligence	Advanced sensors	Brain–computer/ machine interface	IoT and connectivity	Additive manufacturing	Autonomous vehicles
36	2	44	39	15	8	10	2	3
3	2	13	49	23	31	4	1	1
48	1	38	159	295	21	46	0	25
4	0	8	33	7	2	5	0	2
107	5	14	65	40	7	28	0	6
13	3	5	48	38	3	13	0	15
431	2	14	119	53	3	15	1	38
2	1	7	41	4	1	2	0	0
15	4	69	296	51	8	6	0	3
0	1	11	4	2	5	0	4	0
58	60	17	45	35	2	4	8	0
2	17	133	90	87	23	20	18	2
1	0	1	3	2	1	1	0	0
2	12	1	2	6	0	2	2	0
1	17	0	1	0	0	0	3	0
0	0	0	5	0	0	0	0	0
316	93	86	195	139	17	4	448	9
582	17	22	47	77	11	6	7	3
111	7	6	56	184	3	18	0	6
100	4	28	83	138	13	18	0	65
5	3	11	41	38	11	35	0	1
11	0	0	8	12	0	10	0	2
30	0	1	6	1	3	0	0	0
1	1	0	0	8	0	2	0	0

Annex 3: Use of enabling technologies across emerging assistive technology

Product category (Level 2)	Product category (Level 3)	Product category (Level 4)	Patent families
Emerging vision assistive technology			
Intraocular lenses (IOLs)	Drug delivery		509
	Adaptive focus		402
	Multifocal		227
	IOLs with sensors		153
	Intracorneal lenses		133
Artificial silicon retina (ASR)/retinal prostheses			654
Cortical implants			293
Bionic eye (system)			100
Telescopic lenses			114
Artificial iris			20
Smart eyewear			340
Augmented reality devices			236
Virtual reality devices			49
Hand wearables			51

Advanced robotics	New materials	VR/AR	Artificial intelligence	Advanced sensors	Brain–computer/ machine interface	IoT and connectivity	Additive manufacturing	Autonomous vehicles
4	114	6	14	14	11	1	4	0
9	50	10	41	7	9	1	1	1
5	18	7	27	9	10	0	0	1
3	10	1	4	2	1	0	5	0
1	7	3	2	2	5	0	0	0
0	1	0	0	0	0	0	1	0
2	1	57	96	34	11	8	0	2
8	3	225	216	32	57	0	2	2
1	0	28	38	5	13	0	0	0
1	0	19	15	10	9	1	0	0

Annex 4: Technology readiness level (TRL) rating scale and impact assessment questions

NASA TRL scale adapted to assistive technology

TRL 1	**Basic research** Basic principles observed and reported.	**Research concept**
TRL 2	**Technology formulation** Concept and application have been formulated.	
TRL 3	**Applied Research** First laboratory tests completed; proof of concept.	**Proof of concept**
TRL 4	**Small scale prototype** Prototype built in a laboratory environment.	
TRL 5	**Large scale prototype** Prototype tested in intended environment.	**Minimum viable product (MVP)**
TRL 6	**Prototype system** Prototype tested in intended environment close to expected performance.	
TRL 7	**Demonstration system** System operating in operational environment at pre-commercial scale.	
TRL 8	**First commercial system** Manufacturing issues solved.	**Commercial product**
TRL 9	**Fully commercial application** Technology available for consumers.	

Impact and ease of adoption questions

Question 1
Impact of technology: Could this technology help people achieve more active participation and contribute to self-sufficiency/independent living?

Question 2
Adoption: social acceptance: Could there be ethical considerations or other societal concerns in adopting this technology making uptake/scale-up of the technology more complicated?

Question 3
Adoption: Accessibility of technology What would be the ease of adoption of this technology (needs a lot of training, go through fitting, requirement to have additional equipment to make this interoperable, etc.)?

Question 4
Adoption: regulatory requirements Would this technology potentially require to go through regulatory approval (making the entry into the market more lengthy, complicated and costly)?

Annex 5: Abbreviations and glossary

Abbreviations

AAGR average annual growth rate

AI artificial intelligence

APL Priority Assistive Products List

APS Assistive Product Specification

AR/VR augmented and virtual reality

BCHD bone conduction hearing aid or device

BCI brain–computer interface

CAGR compound annual growth rate

CPC Cooperative Patent Classification

CRPD Convention on the Rights of Persons with Disabilities

DWPI Derwent World Patents Index

EASTIN European Assistive Technology Information Network

EPC European Patent Convention

EP European patent

EPO European Patent Office

EU European Union

GATE Global Cooperation on Assistive Technology

GUI graphical user interfaces

HCI human–computer interface

ICF International Classification of Functioning, Disability and Health

IoT Internet of Things

IP intellectual property

IPC International Patent Classification

ITC information and communications technology

MeSH Medical Subject Headings

NGO non-governmental organization

PCT Patent Cooperation Treaty

R&D research and development

SDG sustainable development goal

SME small and medium-sized enterprise

TRL NASA Technology Readiness Level (TRL) model

UHC universal health coverage

U.K. United Kingdom

UN United Nations

U.S. United States of America

VR virtual reality

WCAG Web Content Accessibility Guidelines

WHO World Health Organization

WIPO World Intellectual Property Organization

Glossary

3D-printed prostheses/orthoses: prostheses/orthoses produced using additive manufacturing and a wide range of materials, including titanium, nylon, epoxy resins and polycarbonates. 3D printing, which uses a computer-aided design format for layer-by-layer deposition of the material, can help produce more customized designs and complex contours.

adaptive clothing: garments specifically designed for persons with disabilities.

adaptive lens: a lens that can automatically change focal length to suit conditions.

advanced cane: a walking stick that uses GPS, LIDAR, radar, ultrasonic sensors, accelerometers and advanced connectivity technologies such as Internet of things and Bluetooth to identify or broadcast location, detect obstacles and connect with other devices. *See also* advanced walking aids.

advanced prosthetics: advanced versions of prostheses and orthoses that go beyond mechanical support and cosmetic benefits. They use advanced technology, such as sensors and harnessing neural signals, to make movement more realistic, and can be controlled by neural signals. They include *smart prosthetics* and *neuroprosthetics*, as well as *3D-printed prosthetics*.

advanced technology: cutting-edge solutions, specific examples of which include advanced materials and sensors.

advanced wheelchair: these include smart/intelligent wheelchairs that use, for example, artificial intelligence and proximity sensors and employ the principle of autonomous driving and technologies, such as brain–computer interface, eye-gaze, gesture or voice recognition for wheelchair control.

affective computing: systems that can detect, respond to or simulate human emotions.

artificial intelligence: learning systems that can improve over time their performance on a task typically performed by humans, with limited or no human intervention.

artificial iris: an eye implant that can address defects in the iris caused by congenital aniridia, albinism or other etiology.

artificial silicon retina (ASR): *see* retinal prosthesis.

Assistive Products List (APL): a model list, developed by the World Health Organization, of well-established assistive products upon which countries can base national priorities for assistive technology.

assistive robots: these include companion robots, which support independent living through different functionalities, e.g., monitoring health and emotions, navigating, communicating, lifting, managing medication and other self-care and cognitive activities, or lend cognitive, emotional and social support; manipulators, which usually have a gripping arm mechanism with a brain–computer interface or based on Internet of things; and pet robots, which are similar to companion robots and have the same functional features, apart from lifting and assisting in walking and movement.

auditory brainstem implant (ABI): an implant in which the electrodes are placed directly on the brainstem. ABIs are used for severe hearing impairment caused by permanent damage to the cochlea and auditory nerve.

augmented reality (AR): a computer vision application that provides an interactive experience of a real-world environment, where elements from the real world are augmented by computer-generated sensory information and layered over with the natural environment to deliver enhanced information on visual scenery.

average annual growth rate (AAGR): the mean increase in growth rate over a specific period. The first year in the period mentioned serves as the base year.

balancing aids: advanced fall detectors, including smart shoes, rotating weights, balance-assisting backpacks, walking sticks and frames, that help restore balance to prevent a fall in real time after detecting imbalance. These devices use accelerometers, gravity or inertia sensors and gyroscopes connected with enabling technologies such as artificial intelligence or Internet of things.

bone conduction hearing aids/devices (BCHDs): (non-invasive) hearing aids that bypass a blockage in the outer ear to transmit sound waves to the inner ear using a microphone and a sound processor on the mastoid bone (behind the ear). Used to treat conductive hearing loss (where sound cannot reach the inner ear because of, for example, wax blocking the ear canal), single-sided deafness or mixed hearing loss. They are usually embodied in soft fabric headbands or adhesive adaptors (such as in spectacle arms) and are an effective non-surgical solution for young children or elderly users.

brain–computer interface (BCI): communication between the brain and an external device through invasive or non-invasive brainwave activity detection and analysis. It enables the user to control devices or equipment and/or communicate with other users.

cartilage conduction implants: an alternative means of sound transmission to hearing aids or bone conduction. Vibrations from a transducer are transmitted through cartilage (as opposed to the mastoid bone used by bone conduction hearing devices) into the inner ear.

closed-captioning device: a device that converts speech into text for display. Mainly used in cinemas, television and online media.

cochlear implant: an implantable hearing aid system to treat bilateral or single-sided sensorineural hearing loss (degeneration of sensory cells in the inner ear), consisting of an external microphone and a speech processor worn behind the ear or on the skull which converts sound into electrical stimuli that are captured electromagnetically by a surgically implanted antenna. The antenna directs the signal to internal electrodes, which in turn stimulate the auditory nerve in the cochlea in the inner ear.

companion robot: *see* assistive robot.

conventional assistive technology: assistive technology that is globally well established. Related innovation is typically incremental and includes accessories or related parts of assistive products that may offer additional functionality.

cortical implant: an eye implant that directly relays visual information to the cortex of the brain. It can be used when there is damage to the neural pathways that transmit visual information from the eyes to the brain.

CRPD (Convention on the Rights of Persons with Disabilities): a United Nations convention establishing an international human rights framework that aims to change approaches to persons with disabilities to allow for participation in all aspects of life. CRPD recognizes access to assistive technology as a human right.

DAISY player: also known as a digital accessible information system. A form of digital talking book audio player for persons with print impairments in dedicated DAISY format, which varies from traditional audio books.

EASTIN (European Assistive Technology Information Network): a global information service dedicated to assistive technology, bringing together various national databases and experts to provide information on assistive technology products and their developers, offering a searchable database of assistive products that are classified according to the ISO9999 standard.

emerging assistive technology: assistive products that either improve conventional assistive products or introduce novel solutions to support or recover an impaired or missing body function. Examples include implantable products or components and products that use one or a combination of enabling technologies, such as artificial intelligence or new materials. *See also* enabling technology.

emulation software: software that converts and customizes the regular user interface of a device, such as a mobile phone or laptop, into a more accessible version.

enabling technology: technology that, when incorporated with other technologies, significantly improves performance or capability, allowing for the development of significantly improved or new assistive products. Nine enabling technologies were identified in the field of emerging assistive technology: Internet of Things (IoT) and connectivity, artificial intelligence (AI), augmented/virtual reality (AR/VR), additive manufacturing/3D printing, advanced sensors, autonomous vehicles, new materials, advanced robotics and brain–computer interface (BCI)/ brain–machine interface (BMI).

European Patent Convention (EPC): a uniform application procedure, administered by the European Patent Office (EPO), which enables inventors to seek patent protection in up to 40 European countries.

exoskeleton: a frame attached externally to the body of the user to provide support, prevent falls or enhance body movements. They can be full-body exoskeletons or restricted to the upper or lower body. Exoskeletons are usually rigid frames made of metal or another hard material, but soft exoskeletons (following an overall trend for soft systems, such as soft robots) are also in development. They are also known as exosuits and can be powered by an external source of energy (e.g., a battery) or by the human body alone.

foreign inventor: an inventor mentioned on a patent document who does not reside in the jurisdiction where patent protection is sought. See also *local inventor.*

graphical user interface (GUI): the way in which a user can interact with an electronic device, using graphics and audio.

hearing aid: a hearing aid typically houses electric components, a microphone, amplifier, speaker and digital circuitry. A non-implantable hearing aid is worn either in or behind the ear, but can also be tactile, spectacle or body-worn. It includes a magnetic telecoil (T-coil) for use with the induction loop system. Advanced versions include eye-mounted (that stimulate the cornea of the eye based on the sound input received by a microphone); mind-controlled (hearing aids which use artificial intelligence and advanced sensors to support the wearer in focusing on specific voices by singling out and amplifying one voice against background noise or conversation, instead of amplifying all sounds, based on the wearer's brain activity); and environment-controlling hearing aids (which make adjustments based on the listening situation of the user). *See also* induction loop.

inclusive design: sometimes used instead of the term "universal design" to express the wide diversity in the product end-users' needs that should be considered in products and systems design, making a "one size fits all" approach impossible. It implies co-design to address the full diversity of human needs at the margins, thereby also covering the needs of the majority. *See also* universal design.

induction loop: used with hearing aids, an induction loop (also known as a hearing loop) uses a microphone and amplifier to provide a magnetic signal that is picked up by a hearing aid. This is particularly helpful in public places to help reduce background noise. *See also* hearing aid.

intellectual property (IP): creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce.. Patents, trademarks, industrial design and copyright are some of the available forms of protection.

Internet of Things (IoT): any device connected to the Internet, such as a smartphone or sensor. Devices connected together can be combined with automated systems to scale up capability. The application is particularly suited to smart homes and smart cities.

intraocular lens (IOL): a surgical eye implant that is generally used to treat eye impairments like cataract or myopia. Typical advanced functions include IOLs with drug delivery, allowing the release of medicines through the IOL; adaptive focus IOLs, which can automatically adjust the focal length based on sensors or physical properties of the lens materials; multifocal IOLs; and IOLs that are embedded with sensors that detect eye muscle movements or external conditions and adjust the lens accordingly. An intracorneal lens is implanted at the cornea and is used to correct the sphericity of the cornea to improve depth perception.

local inventor: an inventor who resides in the jurisdiction where a patent application is filed for patent protection. *See also* foreign inventor.

machine learning: an artificial intelligence technique that uses algorithms and statistical models to allow computers to make decisions without having to be explicitly programmed to perform the task. Machine learning algorithms build a model on sample data used as training data in order to identify and extract patterns from data, and therefore acquire their own knowledge.

manipulator: *see* assistive robots.

middle ear implants: implants that stimulate and vibrate the bones in the middle ear (ossicles). They include a small prosthesis attached to the ossicles. Rather than amplifying the sound traveling to the eardrum (as with a hearing aid), these prostheses move the bones directly.

myoelectric control: advanced sensors that detect bioelectric signals from skeletal muscles or the skin surface and relate the intended movement to the artificial limb.

navigation aid: a device that provides information on the orientation and position of a user, guides with specific navigation instructions in their surroundings, and alerts the user to obstacle types, positioning and direction, and possible hazards. Usually enabled by geographical, movement and proximity sensors, cameras and telecommunication signals, this type of advanced aid may also use machine learning techniques for scene analysis. They include the use of avatars, augmented reality displays and wearable technologies, and some use object recognition and scene understanding techniques to identify pavements or road markings, or to receive information from online servers to facilitate navigation for persons with visual impairment.

neuroprosthetic (motor/mobility): a prosthetic device that connects with and is controlled by the body's central nervous system (brain or spinal cord) or peripheral nervous system (e.g., nerves in the limbs) to focus on specific movements. *See also* advanced prosthetics.

orthosis: a device that provides structural support to the neuromuscular system, ranging from simple structural shoe inserts to complex powered exoskeletons. *See also* exoskeleton.

ossicular replacement implant: specific middle ear implants that act as replacements for damaged or partially damaged bones in the middle ear (ossicles).

patent application/filing: a request for patent protection for an invention in a given jurisdiction filed with a patent office.

Patent Cooperation Treaty (PCT): international treaty, administered by the World Intellectual Property Organization (WIPO), under which a single international patent application can be filed for patent protection in up to 153 countries.

patent document: a legal title that gives inventors the right, for a limited period (usually 20 years), to prevent others from making, using or selling their invention without their permission in the countries for which the patent has been granted.

patent family: a set of interrelated patent applications filed in one or more countries to protect the same or a similar invention by a common inventor and linked by one or several common priority data. For this report's search and analysis, the Derwent World Patent Index (DWPI) strict family definition was used, in which each member shares exact priorities (except for non-convention equivalents) with each and every other family member.

patent publication: a patent document published at different stages of the patent life cycle, including patent applications and granted patents. For the purposes of this report, "patent publication" is used interchangeably with "patent filing" or "patent application", as the analysis is based on earliest patent applications.

pet robot: *see* assistive robots.

priority filing: the right to file subsequent applications for the same invention at other offices. It is valid for a period of 12 months from the date of first filing of a patent application (known as the priority date).

prosthesis: an artificial limb that provides mobility function to amputees or persons born with limb deficiencies. Smart prosthetics use advanced sensors, such as cameras, pressure, temperature or strain sensors, or machine learning to understand the user's prosthetic control behavior and/or their gait.

resident filing: a resident filing is filed by an applicant who resides in the same country as the patent office where protection is sought.

retinal prosthesis: an eye implant placed on top of or under the retina to improve or correct the features or replace the natural retina. It can be used to treat age-related macular degeneration or retinitis pigmentosa and can provide rudimentary vision for blind people. It collects images, via a camera, that are then conveyed to an implanted chip, or it can use spectacles that deliver infrared light to the implanted chip.

robotics: the design, construction and operation of machines able to follow step-by-step instructions or perform complex actions automatically and with a certain level of autonomy. Robotics combines hardware with the implementation of artificial intelligence techniques to perform these tasks.

sensory substitution aid: converts one form of sensory information into another. This can help users who have impairment in one or more senses to receive information in another sensory form (such as touch, smell or taste).

smart assistant: software that employs machine learning, pattern analysis and other advanced techniques to monitor a user's activities and behaviour, understand their requirements to subsequently perform customized tasks, provide contextual information or recommendations, or help them navigate or carry out daily tasks.

smart city: a smart city includes smart assistive technology solutions that are installed in sidewalks, transportation systems, malls, stadiums, airports, buildings, swimming pools and other public or community establishments to facilitate access to and navigation in the city environment, along with conveying important information for this purpose.

smart diaper: an incontinence product that uses a sensory module to detect wetness and a connectivity module to provide notifications of the diaper's or the user's status or their location on various connected devices.

smart eyewear: non-implanted electronic, digital and sensor-based solutions, such as goggles, spectacles, eye-mounted devices, near-eye displays and head-mounted devices that can convert or enhance visual information for visually impaired users.

smart home: a house that uses connected devices, smart structural components (lighting fixtures, smart doors/locks, garbage bins, etc.) and intelligent appliances (refrigerators, air conditioners, cooking hobs, microwave ovens, etc.) to facilitate independent and accessible living.

smart nursing: beds, telemedicine solutions, health monitoring systems, fall detection systems that are specifically designed and provided for assistive technology users. This includes systems that use image and voice analysis, along with other health or emotion metrics, to monitor the status of the user and share the data to cloud networks, and alert medical professionals or caregivers in the case of anomalies.

smart prosthetics: prosthetics with advanced sensors, such as cameras, pressure, temperature or strain sensors, that use machine learning to understand the user's prosthetic control behavior to provide more natural movement.

smart toilet: sensors (to detect health parameters using intelligent techniques) and mechanical designs (for assisting in user mobility) and connectivity (control and data transfer over smartphones).

speech recognition: the process of identifying spoken words and translating them into text, other languages or different outputs.

telescopic lens: miniature telescopic lens implants provide magnification power and can be used to address age-related macular degeneration (power loss) in the eyes.

universal design: sometimes referred to as "design for all". The design of products, environments, programs and services to be usable by all people, to the greatest extent possible, without requiring adaptation or specialized design, yet without excluding assistive devices for particular groups of persons with disabilities where this is needed. *See also* inclusive design.

utility model: intellectual property right available in some countries for technical innovations that might not qualify for a patent. It provides a shorter term of protection, but is subject to less stringent criteria than a regular patent.

virtual reality (VR): a computer-generated experience that simulates a user's presence in a virtual environment, which is especially popular in entertainment and education/training applications. A headset or projected screens are used alongside audio, visual and sometimes haptic feedback to interact with the artificial world.

WIPO Technology Trends 2021: Assistive Technology is the first large-scale landscaping and analysis of patenting and technology trends in assistive technology.

The report identifies prominent technologies, top players and markets for patent protection across seven domains – mobility, cognition, communication, hearing, the built environment, self-care and vision – for conventional and emerging assistive products. Using a rating scale of technology readiness level (TRL) based on NASA's TRL model, it reveals how close the identified assistive products filed for patent protection are to commercialization. As the population ages and the number of potential end-users increases, with more varied needs for assistive technology, the report shows how innovations in assistive technology and consumer electronics are converging to meet demand.

The combined information presented – patenting activity and trends across emerging assistive technology, and the stage they are in the innovation chain and product development – is complemented by information related to the wider ecosystem, including regulation, policy and standards. The report benefits from comments and inputs from 72 subject matter experts and includes case studies to illustrate examples from innovation in assistive technologies.

This groundbreaking report will be an essential reference for the assistive technology community, innovators, researchers, business leaders and policymakers wishing to understand the rapid changes in this technology and to inform their decision-making with empirical data.

World Intellectual Property Organization
34, chemin des Colombettes
P.O. Box 18
CH-1211 Geneva 20
Switzerland

Tel: +41 22 338 91 11
Fax: +41 22 733 54 28

For contact details of WIPO's
External Offices visit:
www.wipo.int/about-wipo/en/offices

WIPO Publication No. 1055E/21
ISBN 978-92-805-3257-9