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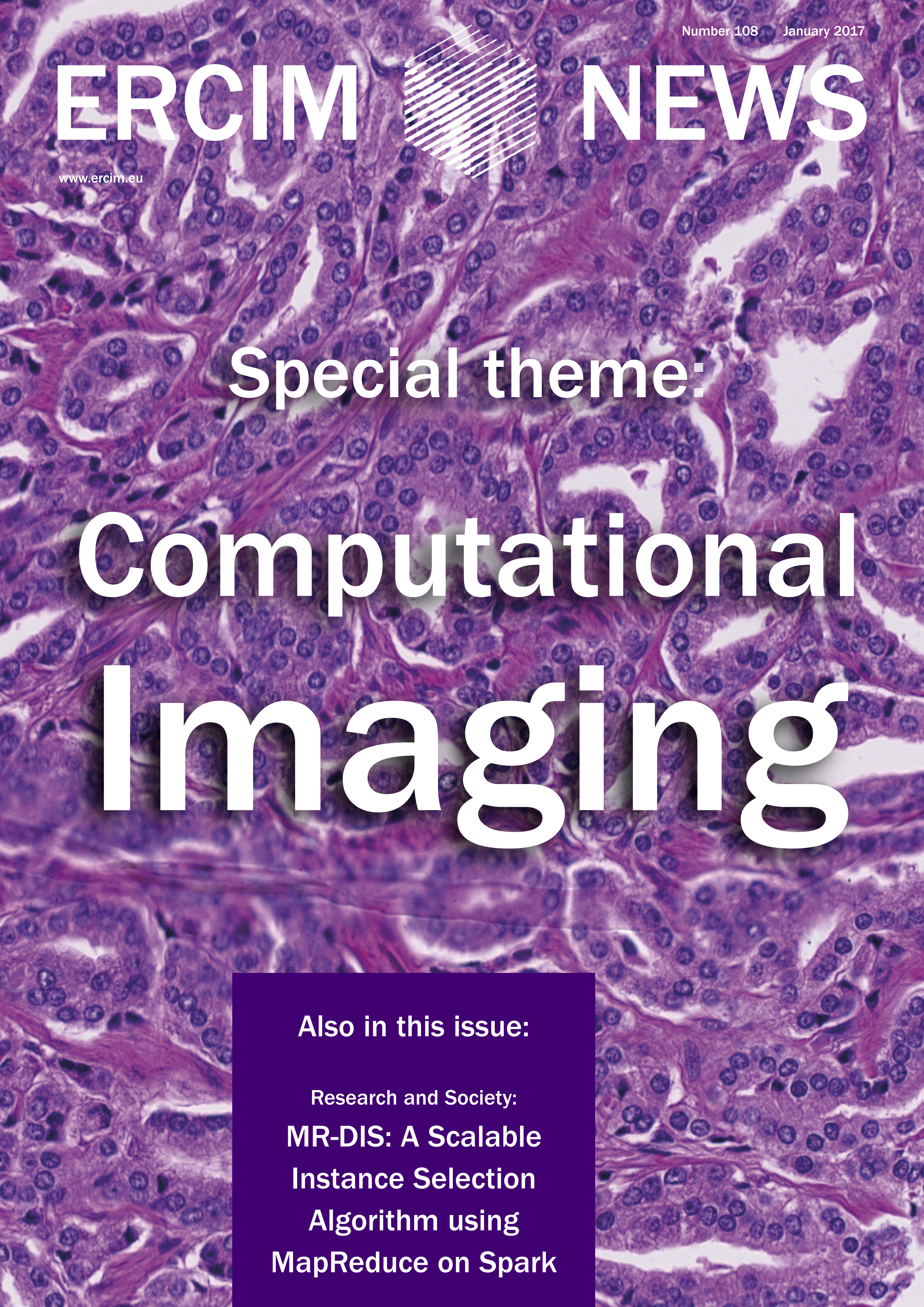

Special theme:

Computational Imaging

Also in this issue:

Research and Society:

MR-DIS: A Scalable Instance Selection Algorithm using MapReduce on Spark

ERCIM News is the magazine of ERCIM. Published quarterly, it reports on joint actions of the ERCIM partners, and aims to reflect the contribution made by ERCIM to the European Community in Information Technology and Applied Mathematics. Through short articles and news items, it provides a forum for the exchange of information between the institutes and also with the wider scientific community. This issue has a circulation of about 6,000 printed copies and is also available online.

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April 2017, Special theme: Autonomous Vehicle

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This section features news about research activities and innovative developments from European research institutes

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ERCIM Membership

After having successfully grown to become one of the most recognized ICT Societies in Europe, ERCIM has opened membership to multiple member institutes per country. By joining ERCIM, your research institution or university can directly participate in ERCIM's activities and contribute to the ERCIM members' common objectives playing a leading role in Information and Communication Technology in Europe:

- Building a Europe-wide, open network of centres of excellence in ICT and Applied Mathematics;
- Excelling in research and acting as a bridge for ICT applications;
- Being internationally recognised both as a major representative organisation in its field and as a portal giving access to all relevant ICT research groups in Europe;
- Liaising with other international organisations in its field;
- Promoting cooperation in research, technology transfer, innovation and training.

About ERCIM

ERCIM – the European Research Consortium for Informatics and Mathematics – aims to foster collaborative work within the European research community and to increase cooperation with European industry. Founded in 1989, ERCIM currently includes 21 leading research establishments from 18 European countries. Encompassing over 10,000 academics and researchers, ERCIM is able to undertake consultancy, development and educational projects on any subject related to its field of activity.

ERCIM members are centres of excellence across Europe. ERCIM is internationally recognized as a major representative organization in its field. ERCIM provides access to all major Information Communication Technology research groups in Europe and has established an extensive program in the fields of science, strategy, human capital and outreach. ERCIM publishes ERCIM News, a quarterly high quality magazine and delivers annually the Cor Baayen Award to outstanding young researchers in computer science or applied mathematics. ERCIM also hosts the European branch of the World Wide Web Consortium (W3C).

"Through a long history of successful research collaborations in projects and working groups and a highly-selective mobility programme, ERCIM has managed to become the premier network of ICT research institutions in Europe. ERCIM has a consistent presence in EU funded research programmes conducting and promoting high-end research with European and global impact. It has a strong position in advising at the research policy level and contributes significantly to the shaping of EC framework programmes. ERCIM provides a unique pool of research resources within Europe fostering both the career development of young researchers and the synergies among established groups. Membership is a privilege."

Dimitris Plexousakis, ICS-FORTH, ERCIM AISBL Board

Benefits of Membership

As members of ERCIM AISBL, institutions benefit from:

- International recognition as a leading centre for ICT R&D, as member of the ERCIM European-wide network of centres of excellence;
- More influence on European and national government R&D strategy in ICT. ERCIM members team up to speak with a common voice and produce strategic reports to shape the European research agenda;
- Privileged access to standardisation bodies, such as the W3C which is hosted by ERCIM, and to other bodies with which ERCIM has also established strategic cooperation. These include ETSI, the European Mathematical Society and Informatics Europe;
- Invitations to join projects of strategic importance;
- Establishing personal contacts with executives of leading European research institutes during the bi-annual ERCIM meetings;
- Invitations to join committees and boards developing ICT strategy nationally and internationally;
- Excellent networking possibilities with more than 10,000 research colleagues across Europe. ERCIM's mobility activities, such as the fellowship programme, leverage scientific cooperation and excellence;
- Professional development of staff including international recognition;
- Publicity through the ERCIM website and ERCIM News, the widely read quarterly magazine.

How to Become a Member

- Prospective members must be outstanding research institutions (including universities) within their country;
- Applicants should address a request to the ERCIM Office. The application should inlcude:
  - Name and address of the institution;
  - Short description of the institution's activities;
  - Staff (full time equivalent) relevant to ERCIM's fields of activity;
  - Number of European projects in which the institution is currently involved;
  - Name of the representative and a deputy.
- Membership applications will be reviewed by an internal board and may include an on-site visit;
- The decision on admission of new members is made by the General Assembly of the Association, in accordance with the procedure defined in the Bylaws (http://kwz.me/U7), and notified in writing by the Secretary to the applicant;
- Admission becomes effective upon payment of the appropriate membership fee in each year of membership;
- Membership is renewable as long as the criteria for excellence in research and an active participation in the ERCIM community, cooperating for excellence, are met.

Please contact the ERCIM Office: contact@ercim.eu

Imaging as a Ubiquitous Technique: New and Old Challenges

Andy Götz
Head of Software at European Synchrotron Radiation Facility

Armando Solé
Head of Data Analysis at European Synchrotron Radiation Facility

The increasing use of algorithms to produce images that are easier for the human eye to interpret is perfectly illustrated by the progress that is being made with synchrotrons. Synchrotrons like the European Synchrotron Radiation Facility (ESRF), commonly known as photon sources, are like huge microscopes that produce photons in the form of highly focused and brilliant x-rays for studying any kind of sample. We have come a long way from the first x-rays that took crude images of objects much like a camera - the first x-ray image of a hand being taken by Wilhelm Röntgen 120 years ago (http://wilhelmconradroentgen.de/en/about-roentgen). Photon sources like synchrotrons did not always function in this way, however. Owing to the very small beams of x-rays produced by synchrotrons, the first uses were for deducing the properties of a sample's microscopic structure. Computers have changed this. Thanks largely to computers and computational algorithms the photons detected with modern day detectors can be converted to 2D images, 3D volumes and even n-dimensional representations of the samples in the beam.

Tomography is the most widely used technique for imaging at photon sources and elsewhere (e.g., electron microscopes, neutron sources). The algorithms developed for different kinds of illumination, contrasts, geometries and detection types are very rich as illustrated by some of the articles in this issue. With the help of innovative algorithms, scientists have invented new techniques based on the basic principles of tomography. Basically, any raster scan of the sample combined with the measurement of one or several properties yields an image. Therefore, in addition to conventional reconstructions from images obtained measuring the transmission of the incident beam through the sample, we can use indirect images representing the distribution of variables such as chemical elements, crystalline phases and electron density. The list of tomography-based techniques is growing continuously, and includes: phase contrast tomography, diffraction tomography, micro-tomography, PDF tomography, XANES tomography, fluorescence tomography and grain tracking and many more.

One reason for the emergence of this wide range of techniques is that photon sources like synchrotrons can measure energy (spectroscopy), momentum (diffraction), position and time. Any or all of these parameters can be used as the base for a tomographic reconstruction. Using more than one of these allows multi-dimensional reconstructions which provide information about the chemical composition and its phase at each point in a 3D volume.

The continued developments of the synchrotrons and the increased computational power have allowed the emergence of new imaging methods exploiting the coherence of the x-ray beam. Only a small fraction (currently less than 1 % at x-ray energy of 10 keV at the ESRF) of the beam is coherent but that small amount has opened a field in which algorithms play a crucial role. The relevance of these new techniques is such that increasing the coherence fraction of the beam is among the main reasons behind the huge investments to upgrade (or replace) existing synchrotrons. The expected coherence fraction after the current upgrade of the ESRF is expected to be increased by a factor of 30.

The coherent beam produces fluctuations in the measured intensity of a diffracted beam. Like in a hologram with coherent light, one can record an interference pattern. With visible light one recovers the image of the object just illuminating the interference pattern by the same coherent light. Our eyes receive the same waves (amplitude and phase) as if they were coming from the original object. When we deal with x-rays, we need a computer to model the object and the wave that produce the interference pattern. From the recorded intensities we obtain amplitudes of waves but we also need the phases which cannot be directly measured. Basic algorithms assume an arbitrary phase and iterate by means of fast Fourier transforms until reaching a self-consistent solution. In ptychography, different overlapping data sets are used to obtain a self-consistent solution to the problem object and wave [1]. Nanometric spatial resolutions are achieved. Limitations arise from the large computing power required to achieve the reconstruction in a reasonable time. Traditional MPI calculations are being progressively replaced by calculations on GPU clusters.

In addition to the challenge of determining the phase these new techniques raise new challenges which include, firstly, algorithmic and computational issues – some of which are addressed by the articles in this issue. New software packages have been developed to speed up the reconstruction time. Secondly, a related class of challenges is the increasing data volume size. Generating multi-dimensional data sets of high resolution (nanometers) large scale volumes (10 to 100s of microns) are pushing the limits of data and metadata collection, data handling and storage. For example, a single experiment of diffraction computed tomography at a recently constructed beamline at the ESRF is capable of generating 10 petabytes in one week. The reduced data set of 10 terabytes is a 5-dimensional representation of the physical and chemical structure of the sample. Managing these huge data sets requires new algorithms and software to speed up the reconstruction to follow the experiment in real time. It is essential for scientific applications that software being developed for addressing these challenges is open source so it can be verified and free of patents so it can be used and improved freely. Some algorithms (e.g. [1]) are under patent which restricts their usage for science.

Reference:

[1] J. M. Rodenburg and H. M. L. Faulkner: "A phase retrieval algorithm for shifting illumination", in Applied Physics Letters Vol.85 n. 20, 4795 – 4797, 2004.

International Workshop on Computational Intelligence for Multimedia Understanding

by Davide Moroni, Ovidio Salvetti (ISTI-CNR) and Elena Console (TEA)

Over 40 researchers from academia and industry attended a workshop on Computational Intelligence for Multimedia Understanding (IWCIM) organized by the ERCIM MUSCLE working group in Reggio Calabria, Italy, 27-28 October 2016.

The workshop was held in close collaboration with the National Research Council of Italy (ISTI & BAM institutes), TEA sas, the University of Calabria and the Mediterranean University of Reggio Calabria, and was supported by the Archaeological Museum of Reggio Calabria, the Italian section of IEEE and ERCIM.

Reggio Calabria is the Italian city that hosts the Riace Bronzes, the two famous full-size Greek bronzes that were rediscovered in 1972 and are now exhibited at the National Museum of Magna Graecia. It was therefore natural to dedicate a special track of IWCIM to the theme “Understanding Cultural Heritage” as multimedia technologies have opened a wealth of possibilities for documentation, access, archiving and dissemination of our artistic patrimony. In addition, multimedia technologies are valuable tools in the diffusion of audiovisual material to the public at large, thus leaving the scholars’ niche and assuming new economic relevance in education and tourism. The key to exploiting the added value provided by the contextual nature of a multimedia object is understanding: besides increasing enormously the potential audience, multimedia can help specialists interpret their data, especially when a multidisciplinary expertise is required before beginning any concrete intervention on an artefact of historical, archaeological or artistic interest.

Two distinguished invited speakers used their expertise to broaden the perspectives of the computer scientist audience. Marina Bicchieri (ICRCPAL) showed us that books are composite objects, with much information hidden between the pages. Their fascinating history is also revealed by the physical support, the kind of ink/pigment/dye chosen and the pathologies they have suffered during their lifetime. Scholars and scientists could be helped by an interoperable and shared corpus of knowledge on past and current diagnostic technologies and procedures used in restoration.

The second invited talk was delivered by Franz Fischnaller (Accademia Albertina di Belle Arti di Torino, Italy & Museum European Mediterranean Civilizations, France). This talk explored new technologies in computer vision and imaging, immersive virtual reality (VR) and real-time interactive AR systems. These technologies provide interesting contexts, helping the public to engage in our cultural heritage, both inside and outside the museum.

Underwater cultural heritage was also addressed by a dedicated special session. The use of Autonomous Underwater Vehicles (AUVs) to scout, survey and map the seabed was presented. AUVs can document ancient shipwrecks, providing rich multimedia content that can be turned into realistic 3D reconstructions. Multimedia creative technologies can then be used to propose virtual diving experiences, allowing the general public to explore otherwise inaccessible archaeological sites.

A final session on Big and Linked Data addressed aspects of social media analytics, forensic and semantic data stream processing.

20 papers were selected for oral presentation by the programme chairs Emanuele Salerno and Hana Charvatova. All accepted papers will be available through IEEE Xplore, thanks to the publication chairs Maria Trocan and Frédéric Amiel.

The social programme included a trip to the recently renewed National Archaeological Museum of Magna Graecia – thanks to the Director Carmelo Malacrino and to the Deputy Director Giacomo Maria Oliva who accompanied us during the visit. After the museum, Francesca Fatta showed us the facilities at the Lab for Survey and Representation of Mediterranean Architecture, which she directs at the Mediterranean University of Reggio Calabria.

Prof. Franz Fischnaller, invited speaker from Accademia Albertina di Belle Arti di Torino, Italy (left) and workshop attendants visiting the National Museum of Magna Graecia (right).

Links:
http://wiki.ercim.eu/wg/MUSCLE/
http://www.teaprogetti.com/iwcim/

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Philipp Hoschka appointed ERCIM Manager

The ERCIM EEIG board of Directors has appointed Philipp Hoschka as manager of the ERCIM EEIG. Philipp Hoschka took office on 1st of December. He succeeds Jérôme Chailloux who served as manager since May 2005.

Over the last decade, as W3C Deputy Director, Philipp Hoschka has been focusing on launching W3C activities that leverage the advantages of web technologies for new 'vertical' application areas which are of particular interest to European research and industry.

In 2004, he created W3C's Mobile Web Initiative (MWI), an industry co-operation focused on making the web usable on mobile phones. In 2011, he launched W3C's activities on web and television with the goal of enabling the use of HTML5 for video content. In 2012, he created W3C's web and automotive standardisation efforts, focusing on use of HTML5 for in-car infotainment apps. In 2014, he started W3C work on the 'Web of Things' in order to open up the development of 'Internet of Things' applications to Web developers, In the same year, he initiated W3C's activities on payments on the web. All of these efforts were supported through research funding by the European Union.

Philipp Hoschka holds a master's degree from the University of Karlsruhe (Germany) and obtained a PhD from the University of Nice/Sophia-Antipolis (France) while working at Inria. He was visiting scholar at MIT LCS from 1998 until 2002.

The ERCIM EEIG is under the responsibility of the ERCIM EEIG Board of Directors. The EEIG provides assistance to ERCIM members in managing European projects. The EEIG also supports the activities of the whole ERCIM community, for example by managing the ERCIM Ph.D. Fellowship Programm, by producing ERCIM News and by hosting and maintaining web sites.

The EEIG is also hosting and managing the European branch of W3C, an international community where Member organizations, a full-time staff, and the public work together to develop Web standards. Led by Web inventor Tim Berners-Lee W3C's mission is to lead the Web to its full potential.

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Activities of the ERCIM Working Group Dependable Embedded Software in 2016

by Erwin Schoitsch (AIT Austrian Institute of Technology) and Amund Skavhaug (NTNU)

In 2016 the ERCIM Working Group Dependable Embedded Software (DES) co-organised and co-hosted workshops and special sessions at a number of renowned conferences, including the Cyber-Physical Systems Week in Vienna, the SAFECOMP conference in Trondheim (Norway), and the Euromicro conferences on Digital System Design (DSD) and Software Engineering and Advanced Applications (SEAA) in Limassol, Cyprus. At each of these conferences, ERCIM and the DES Working Group were introduced as one of the key elements in the European landscape of research in embedded systems, cyber-physical systems and systems-of-systems.

Cyber-Pysical Systems Week in Vienna, Imperial Castle in the City Centre, April 11-14, 2016

In April, Vienna hosted an outstanding event; the preeminent embedded systems/cyber-physical systems conference known as Cyber-Physical Systems (CPS) Week. This event combined four top conferences, 'Hybrid Systems: Computation and Control (HSCC)', 'International Conference on Cyber-Physical Systems (ICCPS)', 'Information Processing in Sensor Networks (IPSN)', 'Real-Time and Embedded Technology and Applications Symposium (RTAS)', and numerous workshops and side events. Altogether the CPS Week program covers a multitude of complementary aspects of CPS, and brings together leading researchers in this dynamic field.

This multi-conference event was co-organised by Vienna University of Technology, IST Austria, AIT Austrian Institute of Technology, University of Salzburg and TTTech, with Prof. Radu Grosu from Vienna University of Technology and Prof. Thomas Henzinger from IST Austria serving as the event chairs. Apart from the four main conferences, CPS Week hosted 21 workshops, six tutorials, three summits and the localisation competition. In total, it brought together over 1,000 researchers, students and practitioners from all around the world. The event attracted participants from five continents, representing 484 universities, research institutes and companies.

Erwin Schoitsch, as chairperson of the DES WG, organised a one-day event with 17 presentations, a keynote and a poster exhibition, the 'EMC² Summit', the name of which was derived from the largest Embedded Systems project of the ARTEMIS initiative (now ECSEL). ERCIM as co-hosting organisation, was highlighted in the introduction. The papers have been collected and will be published in an open access repository as ERCIM. They provide a very good overview of the multitude of issues to be tackled in multi-core mixed criticality CPS. This summit ranked among the top three side events of the CPS-Week.

ERCIM-DES Working Group co-hosting the DECSoS Workshop at SAFECOMP 2016 in Trondheim

Since the establishment of the SAFECOMP conference in 1979, the event has contributed to the progress of the state of the art in dependable application of computers in safety-related and safety-critical systems. SAFECOMP is an annual event covering the state of the art, experience and new trends in the areas of safety, security and reliability of critical computer applications. Amund Skavhaug, co-chair of the ERCIM-DES WG, acted as general chair, program chair (together with Jeremie Guiochet from LAAS) and host of SAFECOMP 2016. For many years, the annual SAFECOMP conferences have been complemented by a series of workshops.

The DECSoS workshop (ERCIM/EWICS/ARTEMIS Workshop on 'Dependable Embedded and Cyber-physical Systems and Systems-of-Systems') at SAFECOMP has been an annual tradition since its inception in 2006. In the past, it focussed on conventional 'embedded systems', covering all aspects of dependability. To highlight the relationships between physics, mechatronics and the notion of interaction with a somehow unpredictable environment, the terminology was changed to 'cyber-physical systems'.

In recent years the DECSoS Workshop has served as a dissemination event for safety and security critical projects. It was a full day workshop, co-hosted by several ARTEMIS and ECSEL projects, many of which were represented by a presentation or posters and flyers. The workshop was very well attended (more than 25 participants, additional chairs had to be brought into the room), and good discussions followed the interesting topics. The Workshop had four sessions, with 14 presentations in total:

- Analysis, Test and Simulation
- Automotive
- Safety and Cyber-security Analysis and Co-Engineering
- Embedded Systems' Industrial Applications

It is important to note that the main conference SAFECOMP 2016 and the Workshops have separate proceedings as Springer LNCS 9922 (main conference) and LNCS 9923 (SAFECOMP Workshops). Amund Skavhaug and Erwin Schoitsch, chairs of the DES Working Group, served as program chairs for the DECSoS Workshop and managed the Workshop Proceedings.

SAFECOMP 2017 will take place in Trento, Italy, from 12 – 15 September, 2017, with Erwin Schoitsch as co-chair. Once again the EWICS/ERCIM/ARTEMIS DECSoS Workshop is planned for the first day, September 12th, 2017. Save the date!

Euromicro 2016 DSD/SEAA in Limassol, Cyprus

The well-established Euromicro conferences are two joint conferences which form the back bone of the Euromicro activities. These are SEAA (Software Engineering of Advanced Applications) and DSD (Digital Systems Design). The year 2016 saw the 42nd and 19th SEAA and DSD conferences respectively.

In the Euromicro/ARTEMIS/ERCIM Special Session 'Software and Education Ecosystems', which was organised by Erwin Schoitsch, approaches to sustainable innovation eco-systems were presented. Activities like the European workshops on Education, Training and Skills, addressing the interests of the European Electronic Leaders Group, the ARTEMIS E&T WG, and ERCIM were reported in their European context. Erwin Schoitsch and Amund Skavhaug from the ERCIM DES WG chaired this special session.

Werner Weber, Infineon Munich, co-ordinator of the EMC² project, moderating a talk.

Erwin Schoitsch giving a talk.

In 2017, Euromicro will be held on 30 August -1 September by TU Vienna, OCG (Austrian Computer Society) and AIT in Vienna at TU Vienna. This will be a very good opportunity to present ERCIM and ERCIM DES WG work and ambitions. The proceedings are published by IEEE. E. Schoitsch is co-chair of the conference, Amund Skavhaug involved in organisation and publication on behalf of Euromicro. A Euromicro/ERCIM/ARTEMIS special session with an extended scope (including standardisation) has been proposed again and will be called:

Teaching, Education, Training and Standardization for CPS and SoS to Build Sustainable Innovation Ecosystems (TET-CPSoS). Save the Date: 30 August– 1 September, Vienna!

Links:
EMC² Summit 2016 at CPS Week: http://kwz.me/WB
Safecomp 2016: https://www.ntnu.edu/safecomp2016
Safecomp 2017: http://safecomp17.fbk.eu/
Euromicro 2016: http://dsd-seaa2016.cs.ucy.ac.cy/

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The participants of FMICS-AVoCS 2016 at the CNR premises.

Joint 21st International Workshop on Formal Methods for Industrial Critical Systems and 16th International Workshop on Automated Verification of Critical Systems

by Maurice ter Beek (ISTI-CNR)

The yearly workshop of the ERCIM Working Group on Formal Methods for Industrial Critical Systems (FMICS) was organized as a joint event together with the workshop on Automated Verification of Critical Systems (AVoCS). The resulting FMICS-AVoCS 2016 workshop took place on 26-28 September in Pisa at the CNR premises.

The aim of the FMICS workshop series is to provide a forum for researchers interested in the development and application of formal methods in industry. It strives to promote research and development for the improvement of formal methods and tools for industrial applications. The aim of the AVoCS workshop series is to contribute to the interaction and exchange of ideas among members of the international research community on tools and techniques for the verification of critical systems.

The workshop was chaired by Maurice ter Beek (ISTI-CNR, Italy), Stefania Gnesi (ISTI-CNR, Italy) and Alexander Knapp (Universität Augsburg, Germany). It attracted over 30 participants from ten countries, including the USA, Thailand and Japan, both from academia and industry.

Twenty-nine papers were submitted, of which eleven were accepted as full papers. Additionally, four short papers and five research ideas were accepted for presentation at the workshop.

The program moreover included three excellent keynote lectures: "Lessons Learned in a Journey Toward Correct-by-Construction Model-Based Development" by Silvia Mazzini (Intecs SpA, Italy), "Model-based Testing Strategies and Their (In)dependence on Syntactic Model Representations" by Jan Peleska (Universität Bremen, Germany) and "Random Testing of Formal Properties for Industrial Critical Systems" by Thomas Arts (QuviQ AB, Sweden). We thank our sponsors, Formal Methods Europe, ERCIM and Springer, who made this possible.

The weather in Pisa cooperated and the workshop was held in a pleasant atmosphere with lots of interesting and animated discussions among the participants.

The proceedings of FMICS-AVoCS 2016 have been published by Springer as volume 9933 in their LNCS series.

An open call for papers for a special issue in the International Journal on Software Tools for Technology Transfer (STTT) has just been published. The deadline is 1 March 2017.

Links:
AVoCS: http://fmics-avocs.isti.cnr.it/
FMICS Working Group: http://fmics.inria.fr/
Submission page for the special issue:
http://sttt.cs.tu-dortmund.de/sttt-FMICS-AVoCS/servlet/Conference

Reference:
M.H. ter Beek, S. Gnesi, and A. Knapp (eds.): "Critical Systems: Formal Methods and Automated Verification - Proceedings of the Joint 21st International Workshop on Formal Methods for Industrial Critical Systems and 16th International Workshop on Automated Verification of Critical Systems (FMICS-AVoCS'16)", Pisa, Italy, 26-28 September 2016, Lecture Notes in Computer Science 9933, Springer, 2016.
http://dx.doi.org/10.1007/978-3-319-45943-1

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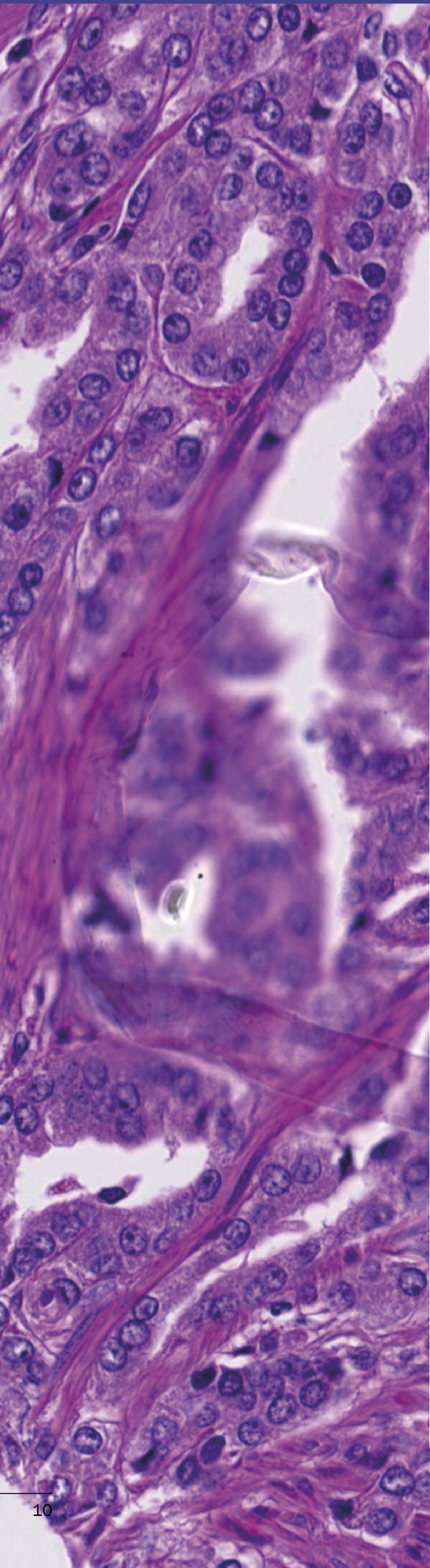

Computational Imaging - Introduction to the Special Theme

by Joost Batenburg (CWI) and Tamas Sziranyi (MTA SZTAKI)

For the young generation it is hard to imagine that just two decades ago, taking a picture took days, or even weeks, requiring us to wait until the film was full, after which it was taken to a photo shop for further development. These days, digital cameras are all around us, which has revolutionised the way we deal with images. The development of digital sensors has followed a similar path in other disciplines within science and engineering, resulting in the development of a broad range of detectors and sensors that can collect various types of high-dimensional data reflecting various properties of the world around us. This has fuelled the development of a new field of mathematics and computation, which deals with interpreting such sensor data, applying algorithms to it, and generating new data.

Image understanding has been in relation to several disciplines, depending on the purpose of the analysis, for example, saliency, scale-space theory or rules of the real world.

When it comes to interpreting human sensation and augmented visibility, saliency analysis and psychophysiology play an important role. Computer vision can be described by a few axioms, like invariant transformations. This theory leads to a coherent discipline of scale-space theory, yielding beautiful and very effective tools such as anisotropic diffusion or SIFT features. However, computer vision is a projection of the real world. To describe this world well, we must consider its laws: laws of physics, laws of biology, laws of optics and laws of chemistry. This means that not only pixels and pixel formations are considered in one or more image planes, but we must search for other relationships among objects representing real artefacts. This modelling of the real world sometimes needs huge computing power, while the sophisticated programming techniques of such cases necessitate careful computational analysis. As better sensors and more powerful computers are being developed, simple image processing is evolving into the field of computational imaging.

The field of computational imaging colligates a broad range of imaging techniques where computation plays an integral role in the image formation process. By its very nature, the field of computational imaging is highly interdisciplinary. Firstly, the process by which the input data for a computational imaging approach are formed often involves physics, which must be modelled to properly interpret the data. Many computational imaging techniques also involve the design and implementation of sophisticated sensor systems that involve a combination of physical and computational aspects. Secondly, the way the actual images are formed usually involves mathematics to derive the transformations that are applied to transform the input data into the desired image form, and analyse its properties. In particular, the field of inverse problems plays a crucial role here, as we often want to create an image of some object that can only be observed through indirect measurements. Finally, computer science is crucial for the creation of efficient, scalable algorithms and software implementations that can deal with large-scale image data. It involves aspects from high-performance computing, database technology, and software engineering for dealing with the complex requirements of the broad range of users of such techniques.

Applications of computational imaging can be found in many different fields: it is a crucial tool for scientific research of biomedical systems and advanced materials, making it possible to perform quantitative measurements based on images collected using microscopes and other imaging devices. On a very different scale, images of the earth, both its surface and interior, are computed from sensor measurements in geoscience and remote sensing applications. Often this data is further processed by sophisticated image analysis techniques that perform feature recognition and classification.

Despite the broadness of the field and large variety of mathematical and computational techniques, several common trends can be identified across the application domains involved in computational imaging. Driven by improvements in mathematical modelling and computational capabilities, multi-modal and multi-channel imaging is rapidly gaining importance. By combining sensor information from different sources, or using multiple energy channels, complex image models can be formed that can be digitally visualised and analysed to extract meaningful quantitative information. Also, the ability to collect imaging data at an unprecedented rate and scale is bringing up new challenges to deal with the massive scale of big data problems in imaging.

Each of the articles in this issue of ERCIM News touches upon one, or several, of the topics mentioned above. Collectively they provide an insight in the many complex facets of computational imaging that are currently being investigated.

The papers received for this special theme can be grouped into some topics that characterise the activities of the ERCIM research teams:

Biological and medical imaging: making the inside visible

- Convolutional Network Layers Map the Function of the Human Visual Cortex
  by Michael Eickenberg, Gaël Varoquaux, Bertrand Thirion (Inria) and Alexandre Gramfort (Telecom Paris)
- Data Fusion at the Nanoscale: Imaging at Resolutions Better than Wavelength/100
  by Bernd Rieger and Sjoerd Stallinga (Delft University of Technology)
- Computational Processing of Histological Images
  by Erwan Zerhouni, Bogdan Prisacari, Maria Gabrani (IBM Zurich) and Qing Zhong and Peter Wild (Institute of Surgical Pathology, University Hospital Zurich)
- Segmenting Cells in the Presence of a Diffuse and Heterogeneous Membrane Marker
  by Christophe De Vleeschouwer (UCL) and Isabelle Migeotte (ULB)
- Application of Digital Holographic Microscopy for Automatic Monitoring of Freely Floating Microorganisms
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Convolutional Network Layers Map the Function of the Human Visual Cortex

by Michael Eickenberg, Gaël Varoquaux, Bertrand Thirion (Inria) and Alexandre Gramfort (Telecom Paris)

Recently, deep neural networks (aka convolutional networks) used for object recognition have shown impressive performance and the ability to rival the human visual system for many computer vision tasks. While the design of these networks was initially inspired by the primate visual system, it is unclear whether their computation is still comparable with that of biological systems. By comparing a deep network with human brain activity recordings, researchers of the Inria-CEA Parietal team (Saclay, France) show that the two systems are comparable.

How might we analyse and understand visual experiences from a cognitive neurosciences standpoint? Such an endeavour requires piecing together three parts of a puzzle: visual stimuli, brain measurements, and a model of natural images. First, the set of visual stimuli must be rich enough to both probe human vision in many ways and be similar to daily experience, unlike synthetic stimuli used by traditional vision neurosciences. Second, one needs a window to the brain's activity: in humans, the most accessible measurement is functional magnetic resonance imaging (fMRI), which captures the blood oxygen-level dependent (BOLD) contrast, a vascular response following neural activity at the scale of mm and seconds. Third, one needs a high-capacity model that can analyse the information in the presented natural images: such models have recently emerged from the application of deep learning to object recognition, namely convolutional networks.

A large stimulus/response collection

We considered datasets of BOLD fMRI responses to two very different types of visual stimulation: still images and videos. In the still images dataset, 1,750 grey scale images were presented at an inter-stimulus interval of four seconds. The video stimulus set consists of movie trailers and wildlife documentaries cut into blocks of 5-15 seconds and randomly shuffled. The dataset corresponded to about five hours of acquisition. Subjects fixated a central cross while passively viewing these stimuli. The data were recorded at UC Berkeley and shared publicly [1].

Predicting the brain response with a high-capacity model

We built a model predicting brain activity from visual stimulation described by the layers of an object-recognition convolutional network [2]. Specifically, in each brain location, a linear combination of the outputs of such a network was used to fit the BOLD signal recorded with fMRI from several hours of simultaneous experimental stimulation and data acquisition.

We found that well-chosen combinations of the artificial neuron activations explain brain activity in almost all visual areas, ranging from the early ones, which are sensitive to image contrasts (such as edges), to the high-level areas which respond selectively to particular semantic information, typically object categories [3]. The linear model that encodes stimulus responses into brain activity can serve as a reliable predictor of brain activity for previously unseen stimuli.

We demonstrated this prediction with images from a left-out sample of the initial study, then with images from a different study. We synthesised the brain activity corresponding to two classical fMRI experiments: a 'faces – places' contrast, which depicts the activity difference between watching a face and watching a place image, and a retinotopic angle mapping: the brain response to a wedge-shaped visual pattern that slowly sweeps the visual field through a rotation.

Brain-activation maps resulting from the artificial-neuron-based predictions are compared to known maps obtained on real BOLD data and show a strong correspondence to their ground-truth counterparts. By studying the retinotopic mapping and faces versus places contrasts, we span a range of feature complexity: from topographical receptive field mapping to high-level object-recognition processes. A crucial observation is that all the layers of the deep

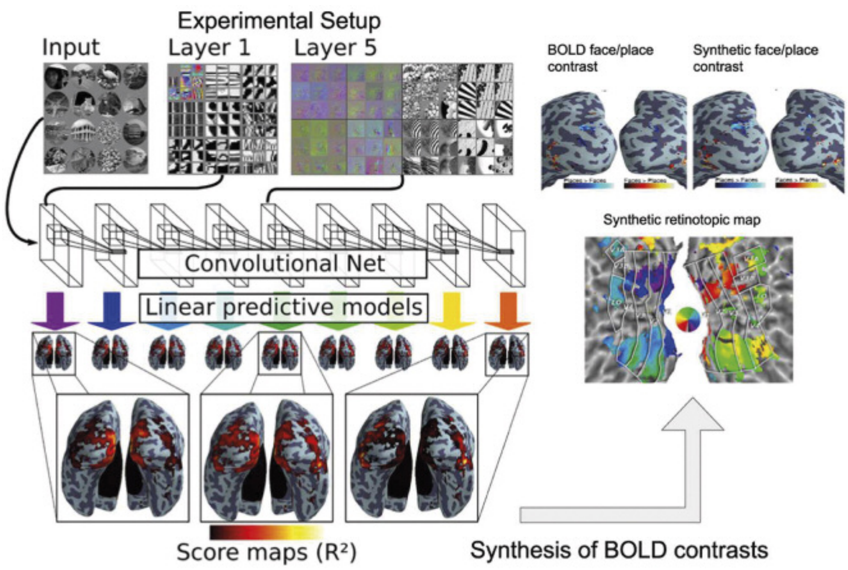

Figure 1: Convolutional network image representations of different layer depth explain brain activity throughout the full ventral visual stream. This mapping follows the known hierarchical organisation. Results from both static images and video stimuli. A model of brain activity for the full brain, based on the convolutional network, can synthesise brain maps for other visual experiments. Only deep models can reproduce observed BOLD activity.

network are needed to accurately predict those latter high-level processes: while prediction fails when a simple contour-extraction model is used instead.

The artificial network and the brain

To further understand the model, we assess how well each contributing layer of the convolutional net fits each region of the brain image. This process yields a characterisation of the large-scale organisation of the visual system: the lower level layers of the convolutional deep architecture best predict early visual areas such as V1, V2 and V3, while later areas such as V4, lateral occipital and dorsal areas V3A/B, call for deeper layers. The beauty of this result is the continuity in the mapping between brain activity and the convolutional network: the layer preference of brain locations is a smooth mapping, suggesting that the artificial architecture is a relevant abstraction of the biological visual system. This is not unexpected, since convolutional networks have partly been designed as a model of the visual cortex, but it is also known that the wiring of the visual cortex in humans and animals is very different from the purely feedforward model used in artificial networks.

Importantly, this finding is not tied to the experimental data used, but it transposes to a different dataset with different experimental settings: natural video stimulation.

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Data Fusion at the Nanoscale: Imaging at Resolutions Better than Wavelength/100

by Bernd Rieger and Sjoerd Stallinga (Delft University of Technology)

Standard fluorescent light microscopy is rapidly approaching resolutions of a few nanometers when computationally combining information from hundreds of identical structures. We have developed algorithms to combine this information taking into account the specifics of fluorescent imaging.

For a hundred years a key rule in microscopic imaging was that the resolution in a microscope is determined by the diffraction limit, which states that the smallest detail separable is given by the wavelength of the light divided by twice the numerical aperture, where the latter is a measure for how much light is captured by the objective lens from the sample. For typical values of visible light, which has a wavelength ~500 nm and high quality immersion objectives, this results in diffraction limits of ~ 200 nm.

With the advent of localisation based super-resolution microscopy around 10 years ago, resolutions in the order of tens of nanometres have been increasingly reported in the literature. As a consequence, in 2014 this particularly successful imaging modality was awarded a Nobel Prize in Chemistry. The basic idea is to localise single isolated fluorescent emitters [1, L1]. This can be realised by photo-chemically altering the properties of the dyes such that most of the time only a very small fraction of all molecules emit light. Many cycles of recording and switching will result in imaging most of the emitters present in the sample. Due to the prior knowledge that only a single emitter is seen, one can fit a model of the system's response function (point spread function) to the data taking into account the different noise sources in a maximum likelihood model and localise the centre with an uncertainty that scales inversely with the square root of the number of detected photons. Typical values result in uncertainties in the tens of nanometres.

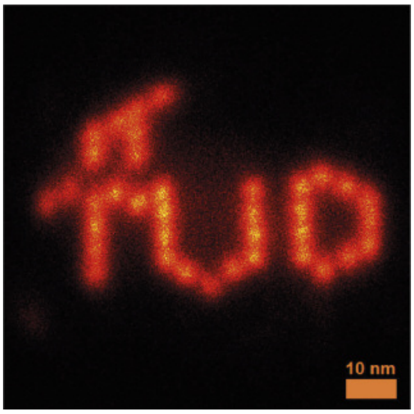

Figure 1: Data fusion image from 456 individual super-resolution reconstruction of a TU Delft logo. The logo is constructed with DNA-Origami and images by PAINT imaging. The final image combines about one million localisations resulting in a computed resolution [1] of 4.0 nm. That is wavelength/140 resolution with the hardware of a conventional light microscope.

However, the overall resolution in an image is a combination of the localisation accuracy and the labelling density of the structure with fluorescent emitters [references in 1]. This problem can be mitigated if instances of the same biological structure are fused (combined) properly. This technique is similar to single particle analysis that has been applied in the field of cryo-electron microscopy for many years [2]. Typically, these particles have arbitrary pose, are degraded by low photon count, false localisations and missing fluorescent labels.

If the structure to be imaged is known a priori, one approach is to register all particles on a template. However, this introduces 'template bias', which can occur if too strong prior knowledge is imposed on the data [2]. We are addressing this problem via a template-free data fusion method. Ideally one would be able to use an all-to-all registration and then globally optimise the translation and rotation parameters. However, this results in a computational complexity scaling with N2 where N is the number of particles. Many hundreds of particles are needed to improve the effective labelling density and in turn the resolution. Therefore we currently register pairs of particles in a tree structure from leaves to root. This reduces the computational effort to a practically feasible task without the need for supercomputers, i.e., it enables the researcher to perform a full registration on the same time scale as the acquisition (order of 10-240 minutes). For the pair registration, we develop an algorithm, which takes into account the localisation accuracies and can handle missing labels [2]. This is essential as algorithms from electron microscopy work on images rather than on point clouds with associated uncertainties. In Figure 1 we show the result of such a procedure on samples that represent logos of the TU Delft shaped by DNA-origami and imaged with DNA-PAINT [3]. While the initial particles have computed resolution values [1] in the range of 10-30 nm, the final reconstructed particle has 4.0 nm resolution. This is about the best that can be expected, as the distance between the binding sites on the DNA blueprint are 5 nm.

This technique will no doubt have further applications in biology since it is common for many chemically identical copies of a structure to be present within one cell, making imaging an easy task.

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Links:
[L1] 350 years of light microscopy in Delft:
https://www.youtube.com/watch?v=vh3_qOy2uls

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Computational Processing of Histological Images

by Erwan Zerhouni, Bogdan Prisacari, Maria Gabrani (IBM Zurich) and Qing Zhong and Peter Wild (Institute of Surgical Pathology, University Hospital Zurich)

Cognitive computing (in the sense of computational image processing and machine learning) helps address two of the challenges of histological image analysis: the high dimensionality of histological images, and the imprecise labelling. We propose an unsupervised method of generating representative image signatures that are robust to tissue heterogeneity. By integrating this mechanism in a broader framework for disease grading, we show significant improvement in terms of grading accuracy compared to alternative supervised feature-extraction methods.

Disease susceptibility and progression is a complex, multifactorial molecular process. Diseases, such as cancer, exhibit cellular heterogeneity, impeding the differentiation between diverse stages or types of cell formations, such as inflammatory response and malignant cell transition. Histological images, that visualise tissues and their cell formations, are huge; three to five orders of magnitude larger than radiology images. The high dimensionality of the images can be addressed via summarising techniques or feature engineering. However, such approaches can limit the performance of subsequent machine learning models to capture the heterogeneous tissue microenvironment. Image analysis techniques of tissue specimens should therefore quantitatively capture the phenotypic properties while preserving the morphology and spatial relationship of the tissue microenvironment.

To capture the diverse features of heterogeneous tissues in large tissue images, we enhance the computational framework introduced by Zerhouni et al [1] by also addressing the cellular heterogeneity, without the need for cellular annotation. This reduces the dependency on labels that tend to be imprecise and tedious to acquire. The proposed method is based on an autoencoder-architecture [2] that we have modified and enhanced to simultaneously produce representative image features as well as perform dictionary learning on these features to reduce dimensionality. We call our method DictiOnary Learning Convolutional autoEncoder (DOLCE).

The principle behind this dimensionality reduction is as follows. DOLCE aims to detect and learn the main morphological and colour patterns of cells that appear in tissue, especially in heterogeneous tissue. The objective is then to represent a cell by combining the main patterns that describe it. By using soft assignments that map each patch of a histology image to a set of dictionary elements, we enable a finer-grained representation of the data. To this end, we can quantify both similarities and dif-

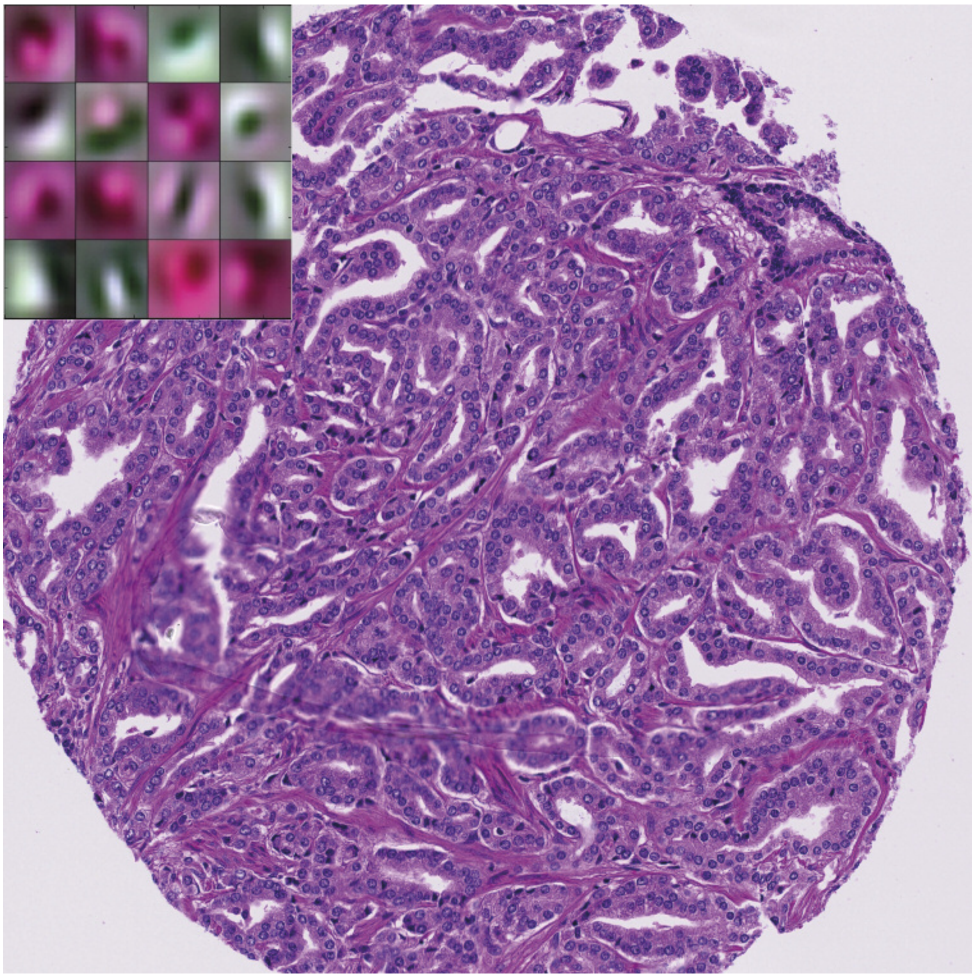

Figure 1: Example of H&E stained prostate tissue with a subset of the learned filters.

ferences across patches. In this manner we are able to identify the dominant patterns (deconvolutional filters) that comprise the diverse cell types within a stained tissue type, potentially also across stainings, as well as discriminant patterns, i.e, patterns that are used for very specific patches.

We cross-validate the sparsity of the dictionary representations, in order to find the optimum for each staining. The number of atoms that are needed to robustly represent the sample is staining dependent, thus, indicating a level of heterogeneity. Figure 1 shows a subset of the deconvolutional filters based on hematoxylin and eosin (H&E) staining along with an example tissue sample. As seen from this figure, deconvolutional filters resemble a round shape detector which more likely acts as a cell detector. Even though visualising the learned filters in a network is still an open research problem, one can see that these filters capture local morphology as well as colour information.

To evaluate the proposed framework we tested DOLCE in a prostate cancer dataset and demonstrated its efficacy both in dimensionality reduction and disease grading, as compared to state-of-the-art supervised learning algorithms [3]. We have also demonstrated the redundancy of some filters across H&E and protein (immunohistochemistry) stained tissues, supporting our basic idea of capturing dominant features across patches and stainings [3].

As next steps we aim to both test the framework on larger data sets and to perform a thorough computational analysis of the different types of cells and discover the patterns that govern cell heterogeneity.

DOLCE is a powerful visual computing technique that enables quantitative description of heavily heterogeneous data and their further computational analysis. DOLCE is further a computational imaging technique that generates quantifiable insights that can help pathologists in their everyday tasks, but also to address the bigger picture; to increase our understanding of physical phenomena, such as pathogenesis, that govern our lives. DOLCE is a great illustrator of how visual computing became a vital component for enabling cognitive medical assistants.

Link:
http://www.zurich.ibm.com/mcs/systems_biology
http://www.wildlab.ch/

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Segmenting Cells in the Presence of a Diffuse and Heterogeneous Membrane Marker

by Christophe De Vleeschouwer (UCL) and Isabelle Migeotte (ULB)

The progress in imaging techniques has allowed the study of various aspects of cellular mechanisms. Individual cells in live imaging data can be isolated using an elegant image segmentation framework to extract cell boundaries, even when edge details are poor. Our approach works in two stages. First, we estimate interior/border/exterior class probabilities in each pixel, using binary tests about fluorescence intensity values in the pixel neighbourhood and semi-naïve Bayesian inference. Then we use an energy minimisation framework to compute cell boundaries that are compliant with the pixel class probabilities.

Progress in embryo culture and live imaging techniques has allowed direct observation of cellular rearrangements in embryos from various species, including those with internal development. The images collected using fluorescence microscopy in this context exhibit many characteristics that make segmentation challenging. These include limited contrast and marker diffusion, resulting in poor membrane details. Moreover, the inner textures of distinct cells present quite similar statistics, making clustering-based segmentation inappropriate (see Figure 1).

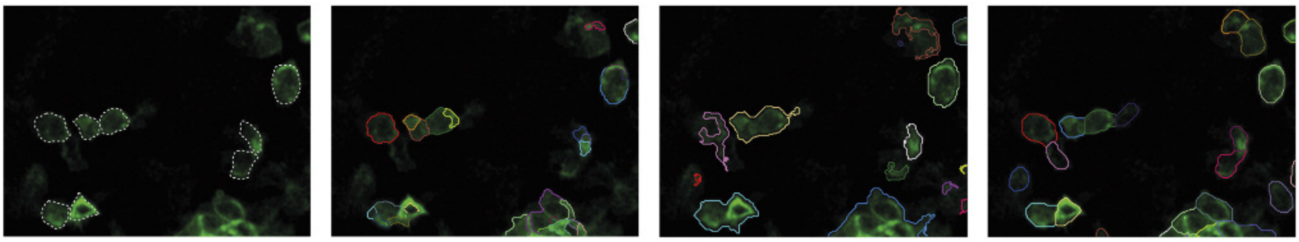

Figure 1: Annotated ground-truth (top-left), and segmentation results for Mean-Shift, Felzenszwalb et al. (see [1] for references), and our approach.

To circumvent those limitations, we propose to adopt a two-stage approach. In an initial stage, we learn how cell interior pixels differ from exterior or border pixels. Then we adopt a global energy minimisation framework to assign cell-representative labels to pixels, based on their posterior interior/border/exterior class probabilities. It was critical to explicitly consider a class of pixels lying on borders between adjacent cells since, in previous work on this dataset, the main problem we encountered was splitting cellular aggregates into individual cells.

Formally, we use a semi-Naive Bayesian approach to estimate the probabilities that each pixel lies: (i) inside a cell, (ii) on a boundary between adjacent cells, and (iii) in the background, exterior to a cell. In practice, those probabilities are estimated based on the realisation of a number of binary tests, each test being defined to compare the intensity of two pixels whose position has been drawn uniformly at random within a square window centred on the pixel of interest [1]. We have chosen semi-Naive Bayesian estimation because it has been shown to be accurate and offer good robustness and generalisation properties in many vision classification tasks [2]. This last point is important since the manual definition of cell contour ground-truth is generally considered as a tedious task, which practically limits the number of training samples.

The estimation of the inner, boundary, and exterior class probabilities for each pixel is, however, not sufficient to properly segment the cells. Indeed, as shown in Figure 2, the pixel classification resulting from the application of the argmax operator to those three probability values does not provide accurate cell segmentation. To exploit the probabilities in a spatially consistent manner, we turn the segmentation problem into a pixel-to-label assignment problem. Therefore, a set of labels is first defined in a way that ensures that each cell is represented by at least one label. In practice, each label is associated with a segmentation seed, defined to be the centre of a connected set of pixels whose interior class probability lies above a threshold, as represented by red dots in Figure 2. To circumvent the threshold selection issue, and to adapt the seed definition to the local image contrast, we consider a decreasing sequence of thresholds. Large thresholds result in small segments that progressively grow and merge as the threshold decreases. Among those segments, we only keep the largest ones whose size remains (significantly) smaller than the expected cell size. This might result in multiple seeds per cell, as depicted in Figure 2. A unique label is then attached to each seed, adding one virtual label for the background. The fact that a single cell induces multiple seeds, and thus multiple labels, is not dramatic since the subsequent energy-minimisation has the capability to filter out redundant labels.

Given a set of n labels $L = \{1,...,n\}$, we are looking for a pixel-to-label assignment vector f that minimises the energy

$$E(f) = \sum_{p\in P} D_p(f_p) + \sum_{(p,q)\in N} W(p,q)\cdot\left(1-\delta(f_p,f)\right) + \sum_{l\in L} h_l(f)$$

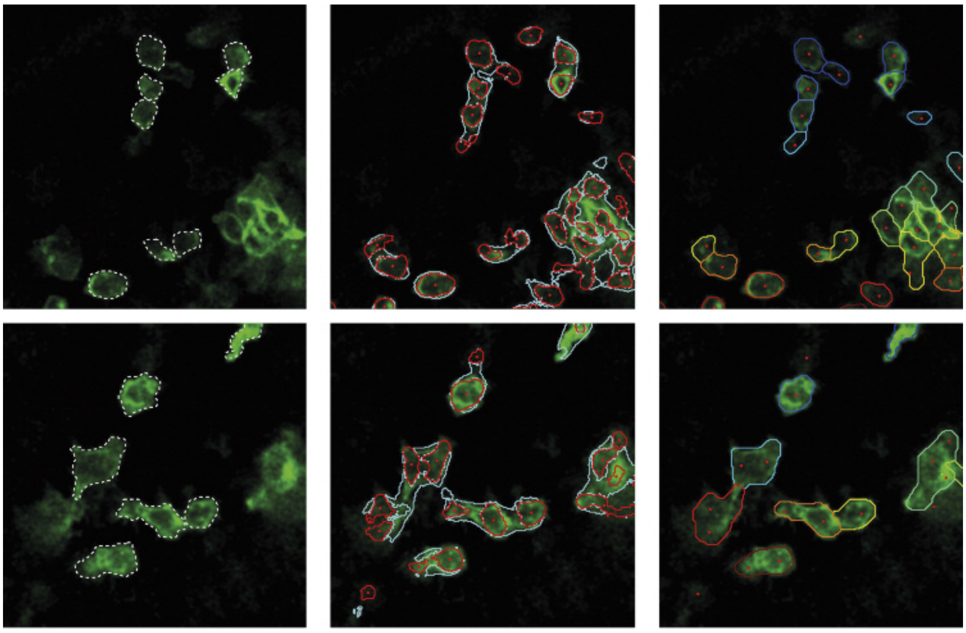

Figure 2: Ground-truth (left column), argmax classification (middle), and pixel-to label assignment (right).

In this equation, the first term favours the assignment to pixel p of a label $f_p=f(p)$ that corresponds to a seed that can be connected to p without crossing a boundary or an exterior area. Formally, we define

$$E(f)=\sum_{p\in P} D_p(f_p)+\sum_{(p,q)\in N} W(p,q)\cdot(1-\delta(f_p,f))+\sum_{l\in L} h_l(f)$$

with ρ denoting the shortest path between the pixel p and the seed associated to label f_p. The scores s_e, s_b, and s_i are defined as the logarithm of the posteriors estimated in a pixel position based on the random ferns.

The two additional terms regularise the pixel-to-label assignment. In the second term, $\delta(.,.)$ denotes the Kronecker delta, and $W(p,q)$ is defined to induce large values when neither p nor q have a high probability of being on a border between two cells. Formally,

$$W(p,q)=1-\frac{1}{1+\alpha_w\cdot e^{-\beta_w\cdot M(p,q)}}$$

and

$$M(p,q)=\max_{k\in\{p,q\}}\left(\min(s_b(k)-s_i(k),s_b(k)-s_e(k))\right)$$

Hence, this second term favours short borders passing through pixels that have a large boundary probability.

The third term $h_l(f)$ induces a (constant) penalty when the assignment f uses label l, thereby favouring assignments that use a small number of labels, which tends to merge seeds when it is relevant from the probability distribution point of view.

To solve this energy-minimisation framework, we rely on the fast approximate minimisation with label costs introduced by Delong et al (see reference in [1]). The right column in Figure 2 presents the segmentation resulting from our proposed energy minimisation. We observe that the regions extracted are in very good agreement with the ground truth depicted in the left column as a dashed white line. In contrast to conventional algorithms (see Figure 1), our segmentation procedure is able to accurately localise boundaries between touching cells. Moreover, our method is also able to merge multiple seeds within a unique region or to reject seeds situated in the background when they are not supported by the probability distribution. In conclusion, our work appears to be an elegant, versatile and effective solution to exploit posterior interior/border/exterior probability maps in a segmentation context. Once detected, cells can be tracked using dedicated multi-object tracking algorithms, as outlined in [3].

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Application of Digital Holographic Microscopy for Automatic Monitoring of Freely Floating Microorganisms

by László R. Orzó, Zoltán Á. Varecza, Márton Zs. Kiss and Ákos Zarándy (MTA SZTAKI)

Digital holographic microscopy (DHM) provides a simple way to automate biological water monitoring. Using proper computational imaging algorithms, the rather complicated measuring techniques can be replaced by easy methods, and the further data processing steps are also simplified.

Companies that utilise large amounts of water (e.g., water-works, fisheries, etc.) regularly need information about its microbiological content. These microbiological data can be regarded as one of the quality indicators of the water.

The conventional microbiological measurement techniques require sampling the water and completing some complex preprocessing steps. The organisms within the samples must be identified and classified by a skilled human observer using an appropriate microscope setup. This process is extremely difficult to automate.

However, digital holographic microscope technology makes automation much easier. One of the main advantages of digital holographic microscopy is that it can analyse much larger volumes than conventional microscopes, where the small depth of field limits the observable volume considerably. The device using holographic technology does not record sharp, focused images, but detects all the objects in the volume measured. Based on the digitally measured hologram, the images of all objects in the volume observed can be reconstructed by using proper numerical methods. This task can be fulfilled even if the objects are far from the actual focal plane of the microscope. Consequently, the small depth of field limitation of the conventional microscopy can be eliminated, and 200 times larger volumes can be analysed correctly by this method. Hence, the otherwise indispensable sample condensation step can be omitted completely. In the digital holographic microscope the sample is moved by a precision pump and measured in the flow-cell. The scheme of the DHM measuring setup is shown in Figure 1.

Detection and segmentation of the objects measured in a flow-cell is also a simple task. The image of the objects in such a cell can be easily segmented utilising their 3D position information within the volume, while in a settled sample they frequently overlap each other. Using a proper algorithm, the holograms of the reconstructed objects can be removed from the original hologram and this way the diffractions of the objects nearby will not interfere with the imaging of the objects of interest [1]. An appropriate classification algorithm is implemented into the system as well based on the use of the reconstructed images of the objects. Implementing all the technologies described above, a complete, automatic, water monitoring system has been constructed. Using stream processors massively parallel computing capacities, the hologram reconstruction process is considerably accelerated, and close to real time processing has been achieved. The scheme of the DHM based water monitoring system is shown in Figure 2.

In our projects we have developed three different DHM devices.

The first device detects algae and other microorganisms. It is able to measure the images of objects with 1µm lateral resolution in the flow cell. The observed volume of a single hologram is 1µl. Since colour information is usually indispensable for the correct classification of the different algae, we record three different colour holograms. We apply red, green and blue fibre coupled lasers and record the different colour holograms simultaneously using a colour digital area scan sensor. The crosstalk between the different coloured pixels is numerically compensated. The fibre ends do not need to be in exactly the same position since using proper numerical methods it can be corrected [2,3]. The use of the colour, shape and size information of the reconstructed algae images results in an appropriate object classification. Continuous monitoring can correctly outline the distribution and numerical changes of the different alga species within the consecutive samples.

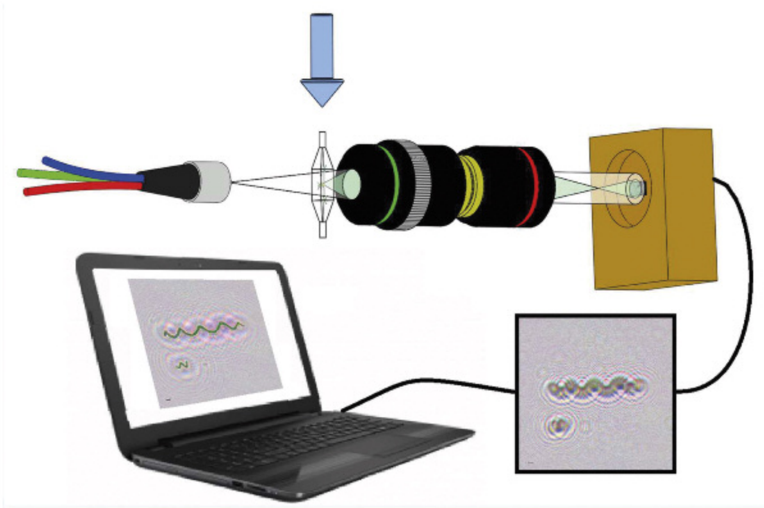

Figure 1: The scheme of the DHM measuring setup.

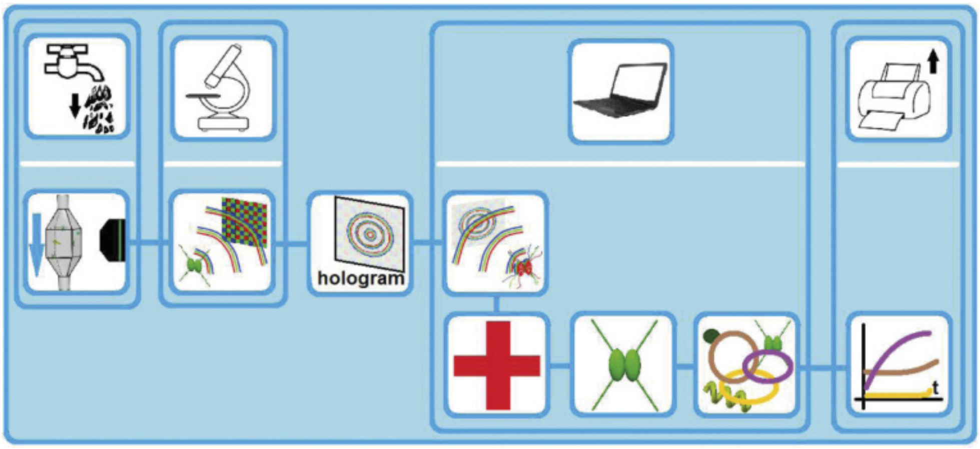

Figure 2: The scheme of the Digital Holographic Microscope based water monitoring system. It includes: the recording of the color holograms of the objects within the sample using Digital Holographic Microscope, the appropriate numerical reconstruction of the image of the objects, with the compensation of some of the measuring setup aberrations, and finally, the morphology, size and color based classification of the different microorganisms.

The second device images and monitors larger creatures (e.g., nematodes, rotifers). This device has only 3µm lateral resolution but the observable volume is 500µl. This device is able to measure up to 1 litre of fluid sample within 20 minutes and so the temporal change of the number of worms can be continuously examined. It can be used to monitor filter quality in waterworks wells since an increasing number of worms can indicate contamination of the filters, meaning that cleaning is required. Such measurements can also be applied to check the efficiency of the cleaning process.

The third device combines fluorescent detection with volumetric imaging of the digital holographic microscopy. It detects the position of the (auto-) fluorescent objects and reconstructs a high resolution image of these objects from a simultaneously measured hologram. Using this device, by the application of a proper fluorescent dye (e.g., fluorescein diacetate) the separation of live and dead objects is also achievable within a large volume, while their high resolution images are also reconstructed. This could also be used to measure the efficiency of a ballast water treatment procedure (NIVA – Norwegian Institute for Water Research).

The commercial release of the devices described above is in progress (WaterScope International Inc.).

The microbial community structure in the microbiome of a lake, ballast-water or drinking water shows location and time dependency. The more accurate and more prompt a monitoring method is, the more efficient the interventions can be. The risk of appearance of toxic alga species in sea water is a continuous threat not only for sea fish-farms but also for coastguards maintaining the quality of water on the shoreline. The series of instruments designed and developed at the Hungarian Academy of Sciences combine state-of-the-art imaging technologies with advanced computation algorithms and accurate microbial classification system to offer a new generation of water monitoring instruments. The multi-purpose use of these instruments offers the possibility for different industries and government agencies to maintain water quality at a much lower cost and - by the early warning function - eliminate risks based on certain species of microorganisms detected.

Our computational imaging methods offer a far simpler solution to biological water monitoring than conventional techniques.

This projects were funded by the Hungarian National Office for Research and Technology (NKTH 1981822A) and the Framework of Green Industry Innovation Programme of the EEA and Norwegian Financial Mechanisms (grant number: HU09-0078-A12013).

Links:
http://www.analogic.sztaki.hu
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Modelling Neurodegenerative Diseases from Multimodal Medical Images

by Olivier Colliot (CNRS), Fabrizio De Vico Fallani and Stanley Durrleman (Inria)

Neurodegenerative diseases, such as Alzheimer's and Parkinson's disease, are complex multi-faceted disorders involving a mosaic of alterations that can be measured in the brain of living patients thanks to the tremendous progresses of neuroimaging. A major challenge for computational imaging is to build efficient and meaningful models of disease from multimodal imaging datasets in order to better understand diseases, improve diagnosis and develop precision medicine.

Neurodegenerative diseases, which involve various types of structural and functional alterations in the brain, are a major public health concern. The disease course spans several decades, with a long silent phase in which alterations accumulate without producing symptoms. Finally, neurodegenerative diseases are heterogeneous entities: there is huge variability among patients in terms of pathological alterations, pace of progression and clinical presentation. All these elements hamper the development of new treatments. Computational and statistical approaches have a major role to play to disentangle the complexity of neurodegenerative diseases.

The continuous progress of medical imaging is offering us an increasingly complete picture of brain alterations. Anatomical magnetic resonance imaging (MRI) assesses the integrity of anatomical structures. Diffusion MRI allows the connections between distant brain areas to be mapped in vivo. Functional imaging (functional MRI, electro- and magneto-encephalography) maps neuronal activity. Positron emission tomography (PET) provides information about specific cellular and molecular processes. In recent years, large datasets of patients with multiple imaging modalities and long-term longitudinal follow-up have been gathered. The current challenge is to use these large multimodal datasets to learn-models of neurodegenerative disease and computer-assisted diagnosis, prognosis and stratification tools.

ARAMIS [L1] is a multidisciplinary research team including computer scientists, specialised in computational imaging and statistical learning, and physicians who specialise in neurodegenerative diseases. It belongs to the Brain and Spine Institute (ICM) [L2], a major research centre on neurological diseases located with the Pitié-Salpêtrière hospital in Paris, the largest adult hospital in Europe, and is jointly affiliated with Inria, CNRS, Inserm (national institute of health) and Sorbonne Universités. ARAMIS aims to build models of neurodegenerative diseases from multimodal brain images. In this paper, we briefly present our most recent results and current projects:

- *Comprehensive modelling of brain structure.* We recently introduced a comprehensive statistical modelling of the variability of brain structure across patients [1]. This approach integrates grey matter structures, represented as surfaces, and white matter tracks, composed of multiple curves, that connect distant areas. Based on a Bayesian setting, the approach estimates an average model of a population together with its variability (see Figure 1). It can be subsequently used to study the relationship between brain structure alterations and symptoms (as measured by clinical or cog-

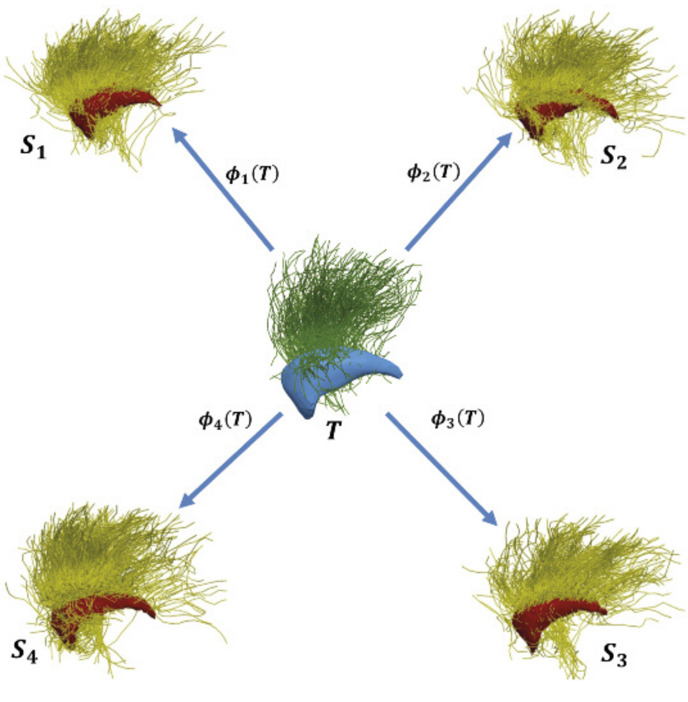

Figure 1: Modelling of brain structure. An average model (called template, denoted as T) is estimated from a population of subjects S_i. Each subject is seen as the deformation $\Phi_i(T)$ of the template. The model includes both grey matter structures (surfaces extracted from anatomical MRI) and white matter tracks (curves extracted from diffusion MRI). For the sake of visualisation, only one surface and a set of curves are displayed in the figure.

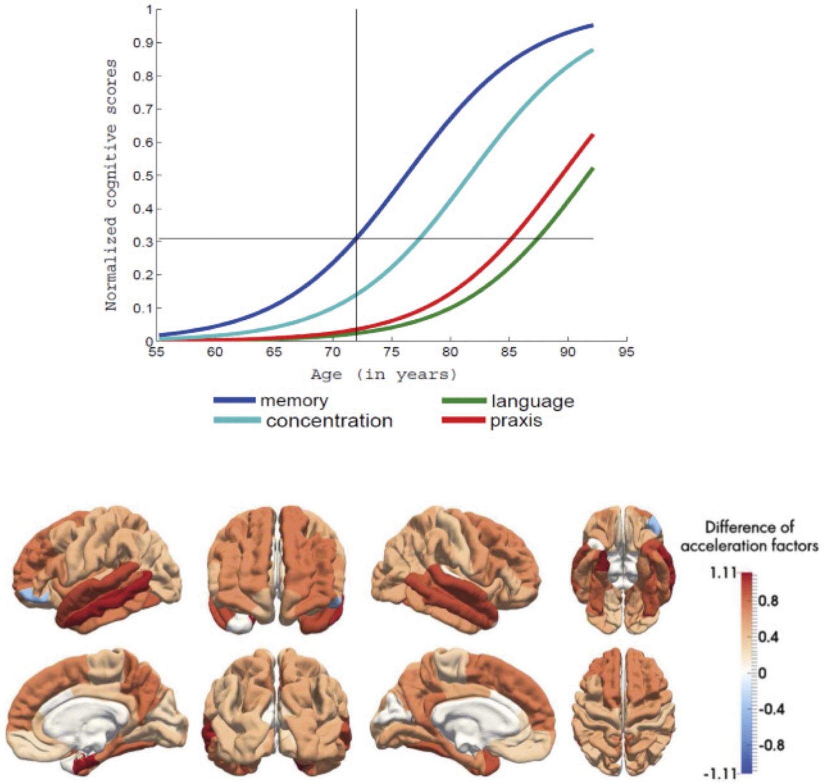

Figure 2: Estimation of disease progression models from a longitudinal dataset of patients with Alzheimer's disease. Upper panel: average trajectories of data change for a set of cognitive measures. The model allows to infer which types of cognitive deficits occur first. Lower panel: differences of pace of atrophy (extracted from anatomical MRI) between patients with Alzheimer's disease and healthy controls. This unveils brain regions in which the degenerative process is the more rapid.

nitive tests) or other biological measurements.

- *Modelling functional networks.* Functional integration of distant brain areas is a central mechanism underlying cognitive tasks which is selectively disrupted by different neurodegenerative diseases. It can be assessed from functional imaging through measurement of temporal dependence between the activity of distant areas. Our team is developing approaches based on the theory of complex networks that can characterise global and local topological properties of functional networks [2]. Such approaches allow network disruptions caused by diseases to be studied and provide new markers for diagnosis and prognosis.
- *Learning spatio-temporal models of disease progression*. Neurodegenerative diseases evolve during long periods of time, spanning several decades. Modelling the progression of alterations is crucial to predict the evolution of patients and define optimal therapeutic targets. We recently introduced a generic spatio-temporal mixed-effects model which estimates progression trajectories as geodesics on a Riemannian manifold [3]. Importantly, it does not require the definition of arbitrary disease stages but rather estimates time-reparameterisations that account for variability in timing and pace. The model was applied to modelling progression of different types of cognitive and anatomical alterations in Alzheimer's disease (see Figure 2).

Current projects include the definition of network models of temporal progression, the integration of functional imaging (fMRI, PET, EEG/MEG) together with models of brain structure and the design of computer-aided diagnosis and prognosis systems. We are also strongly involved in clinical research studies in different neurodegenerative disorders (Alzheimer's disease, frontotemporal dementia, primary progressive aphasia) to demonstrate the medical relevance of the developed models. Ultimately, these models should pave the way to digital precision medicine, in which medical decisions can be informed by numerical models personalised to each patient.

Sources of funding

This work is partially funded by European Union's Horizon 2020 research and innovation programme under grant agreement No 666992, by program "Investissements d'avenir" (ANR-10-IAIHU-06), by NSF-NIH-ANR NetBCI project (ANR-15-NEUC-0006-02) and by the European Research Council (ERC) to SD under grant agreement No 678304.

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Microwave Imaging for Brain Stroke Detection and Monitoring using High Performance Computing

by Pierre-Henri Tournier

Microwave tomography is a novel imaging modality holding great promise for medical applications and in particular for brain stroke diagnosis. We demonstrated on synthetic data the feasibility of a microwave imaging technique for the characterisation and monitoring of strokes. Using high performance computing, we are able to obtain a tomographic reconstruction of the brain in less than two minutes.

Stroke, or cerebrovascular accident (CVA), is classically characterised as a neurological deficit attributed to an acute focal injury of the central nervous system by a vascular cause, and is a major cause of disability and death worldwide. About 85% of CVAs are ischemic due to cerebral infarction, caused by an interruption of the blood supply to some part of the brain, and 15% are haemorrhagic. Differentiating between ischemic and haemorrhagic CVAs is an essential part of the initial workup of the patient, and rapid and accurate diagnosis is crucial for patient survival; here, neuroimaging plays a vital role. Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are the 'gold' standards, but their use is not well suited to efficient medical care of CVAS, as they are bulky diagnostic instruments and cannot be used in continuous brain monitoring. A non-invasive and transportable/portable device for the characterisation and monitoring of CVAs would have clear clinical applications, beginning with the very first instance of patient care in an ambulance and extending to continuous patient monitoring at the hospital.

Microwave tomography is a novel imaging modality with a large number of potential attractive medical applications, and is based on the difference between the dielectric properties of normal and diseased brain tissues. Microwave tomography features rapid data acquisition time, and together with rapid tomographic reconstructions allows detecting, identifying and monitoring CVA continuously (head tissues are exposed to low-level microwave incident field).

From a computational point of view, microwave imaging requires the solution of an inverse problem based on a minimisation algorithm. Reconstruction algorithms are computationally intensive with successive solutions of the forward problem needing efficient numerical modelling and high-performance parallel computing. The raw data acquired by the microwave imaging system can be wirelessly transferred to a remote computing center, where the tomographic images will be computed. The images can then be quickly transferred to the hospital (see Figure 1). This methodology involves distinct research fields: optimisation, inverse problems, approximation and solution methods for the simulation of the forward problem modelled by Maxwell's equations. The latter is challenging in itself as the modelling must accurately take account of the high heterogeneity and complexity of the different head tissues.

Our work demonstrates on synthetic data the feasibility of a microwave imaging technique for the characterisation of CVAs, and won our research

Figure 1: Principle of microwave imaging. Image courtesy of EMTensor.

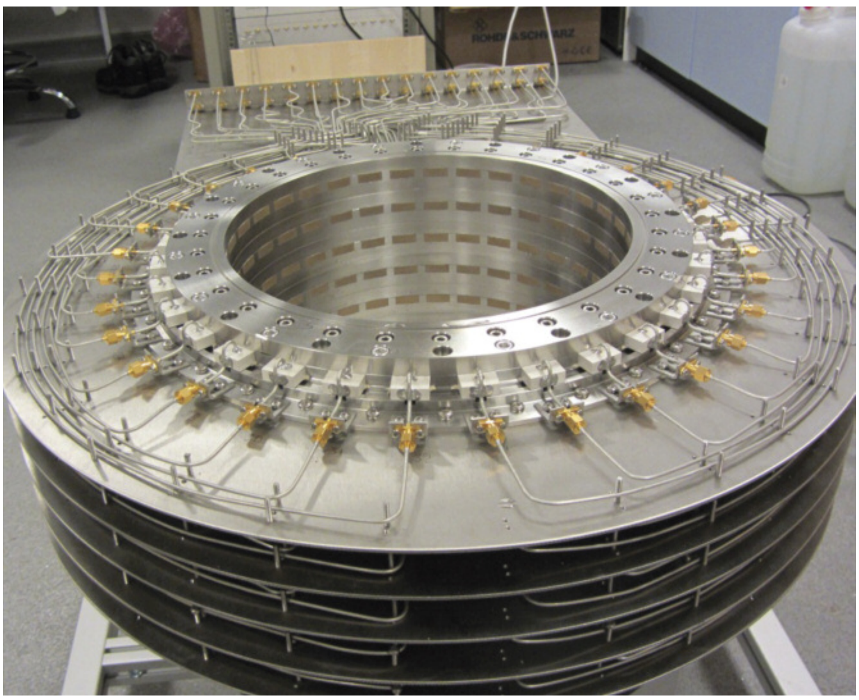

Figure 2: BRIMG1 measurement chamber prototype. Image courtesy of EMTensor.

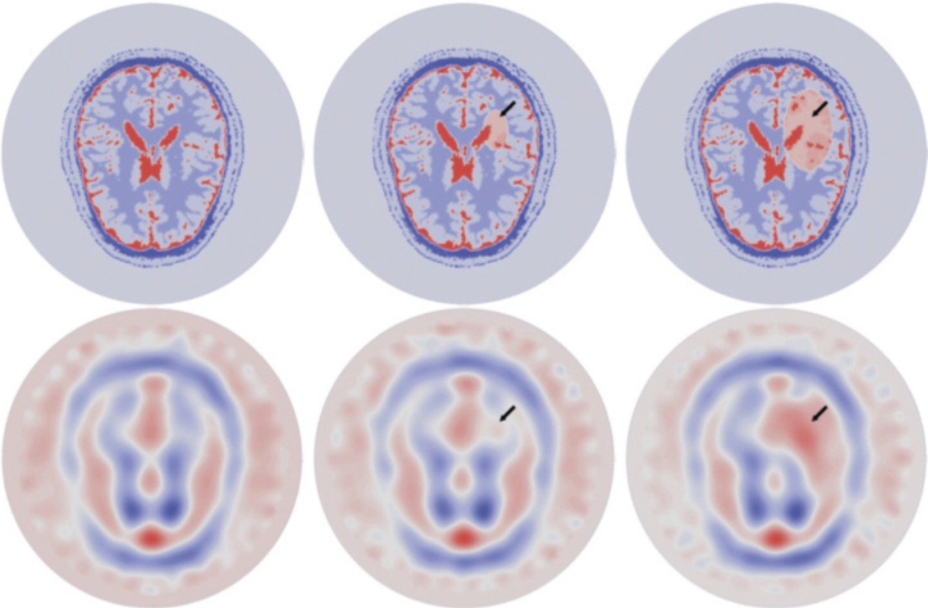

Figure 3: Imaginary part of the permittivity during the evolution of a simulated hemorrhagic CVA (from left to right: healthy brain, small CVA, large CVA). Top row: exact virtual brain model. Bottom row: reconstructed permittivity.

team the Bull-Joseph Fourier Prize in 2015. The numerical framework is based on high-performance computing open-source tools developed by our research team: the HPDDM library [1] (L1) is an efficient parallel implementation of Domain Decomposition Methods (DDM) and is interfaced with the finite element software FreeFem++[2](L2). Our work was carried out in collaboration with EMTensor, an Austrian innovative SME dedicated to biomedical imaging and is based on their BRain IMaging Generation1 (BRIMG1) prototype [3]. EMTensor™'s experimental system consists of an electromagnetic reverberating chamber surrounded by 160 antennas, able to work alternately as emitters or receivers (see Figure 2). The measurements are gathered in the scattering matrix, which is the input of the reconstruction algorithm. We first validated the forward problem by comparing the experimental data with the simulation.

We then created synthetic data corresponding to an accurate numerical model of a human head with a simulated haemorrhagic CVA as input for the inverse problem. We designed and tested our inversion algorithm for monitoring the evolution of the CVA, using synthetic data corrupted with 10% white Gaussian noise. Our scalable algorithm uses multiple levels of parallelism, which allows us to reconstruct an image of the brain in 94 seconds using 4,096 cores. Figure 3 shows the reconstructed images for three evolution steps of the haemorrhagic CVA. The reconstruction time, which can be further refined, already fits the physicians' objective to obtain an image every fifteen minutes for efficient monitoring.

The medical and industrial challenge of this work cannot be emphasised enough. It is the first time that such a realistic study has demonstrated the feasibility of microwave imaging. Although the technique is less precise than MRI or CT scans, its low price, reduced size, and lack of adverse effects even with continuous use could make microwave imaging of the brain the equivalent of echography (ultrasound imaging) on other parts of the human body.

This work was granted access to the HPC resources of TGCC@CEA under the allocations 2016-067519 and 2016-067730 made by GENCI. Authors would like to thank the French National Research Agency (ANR) for their support via the MEDIMAX grant whose PI is C. Pichot (LEAT, CNRS, France).

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Natural Disaster Monitoring: Multi-Source Image Analysis with Hierarchical Markov Models

by Josiane Zerubia (Inria), Sebastiano B. Serpico and Gabriele Moser (University of Genoa)

In a joint project at Inria and the University of Genoa, we have designed novel multiresolution image processing approaches to exploit satellite image sources in order to classify the areas that have suffered the devastating impacts of earthquakes or floods.

Natural disasters are one of the most critical disruptive factors in modern societies. Most countries are exposed to one or more natural disaster risks, the most frequent and consequential being earthquakes and floods. Hence, civil protection agencies invest substantial public funds into creation and maintenance of satellite imaging missions that enable timely identification, assessment and appropriate responses to minimise the consequences of these events. Computer vision algorithms give us information about the Earth's surface and help us to assess the ground effects and damage of natural disasters, which in turn facilitates quicker response times. Remote sensing allows elements and areas at risk within a monitored area to be identified and their vulnerability evaluated. After an event, the prior information can be combined with results of multi-temporal remote sensing image analysis and any further ancillary information available to estimate damage.

Efficient fusion of heterogeneous Earth observation data is crucial to developing accurate situation assessments. One typical scenario is the availability of multiple optical images of the same area (from the same or different satellite missions), that are characterised by different spatial resolutions and spectral representations. These are usually made available to governmental agencies shortly after a natural disaster. In addition to these classical optical images, radar imagery, acquired using the synthetic aperture radar technology that ensures high spatial resolution, may be available [1]. The latter has rapidly grown in popularity and accessibility in the last decade due to its inherent advantages that include robustness to weather and illumination conditions.

We use multiple satellite image sources to classify the areas that have suffered devastating impacts of earthquakes or floods. We have designed several image processing approaches that target classification applications on multi-resolution, multi-sensor, and multi-temporal imagery. The core ingredient of these approaches is the use of hierarchical Markov models. These are born as a hybrid of Markov random fields formulated on a tree hierarchical structure [2]. They allow several key concepts to be incorporated: local dependencies, resolution-robustness, and Markovian causality with respect to scale.

It is highly beneficial that such techniques allow seamless fusion of multiple image sources into the single classification process. In particular, if we consider a scenario when the two (or more) input images are acquired at distinct spatial resolutions, then a quad-tree topology allows an integration of these images at different levels, up to wavelet-transforming in order to fit into the quad-tree structure. Once the hierarchical tree with the input data is constructed, the classification process is performed based on iterative Bayesian algorithms in accordance with the hierarchical Markov model. From a methodological viewpoint, the proposed approaches perform supervised Bayesian classification on a quad-tree topology and combine class-conditional statistical and hidden Markov modelling for pixel-wise and contextual information-extraction, respectively [3]. Multi-sensor data can be incorporated into this framework through advanced multivariate probabilistic approaches,

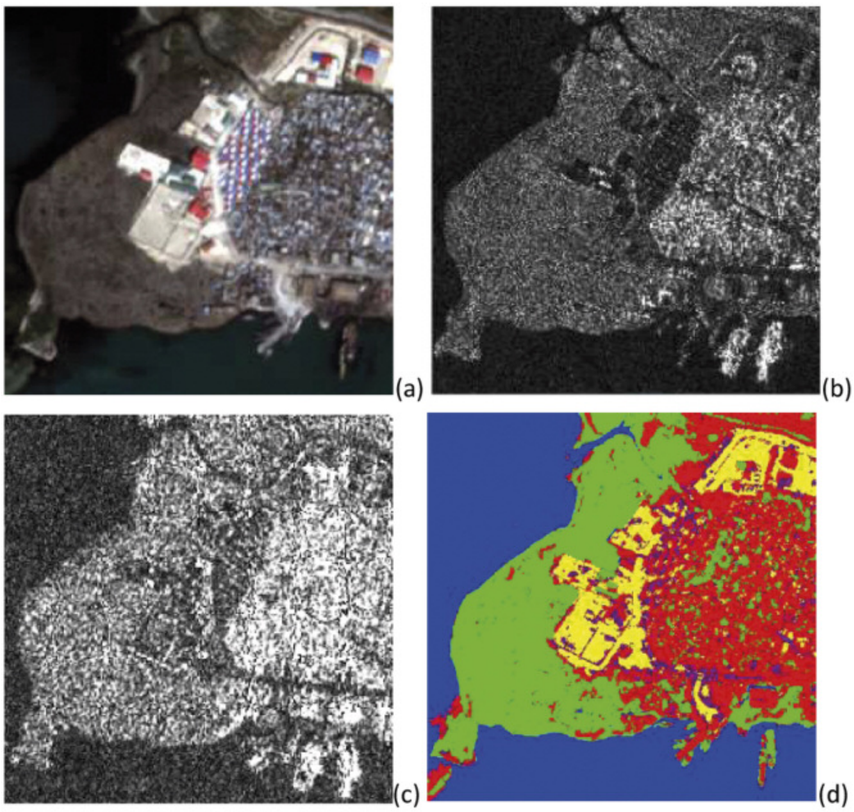

Figure 1: Port-au-prince, Haiti, example of multi-resolution and multi-sensor fusion of remote sensing imagery: (a) Pléiades optical image at 0.5m resolution (Pléiades, © CNES distribution Airbus DS, 2011); (b) COSMO-SkyMed radar image at 1m pixel spacing (© ASI, 2011); (c) RADARSAT-2 radar image at 1.56 m pixel spacing (© CSA, 2011); and (d) multi-sensor and multi-resolution land cover classification result amongst the urban (red), water (blue), vegetation (green), bare soil (yellow), and containers (pink) classes.

such as copula functions, or by defining case-specific topologies composed of multiple trees associated with the data from different input sensors and related by suitable conditional probabilistic models.

An example is reported in Figure 1, in which the site of Port-au-Prince, Haiti, which was affected by a major earthquake in 2010, is considered, and the opportunity to jointly exploit optical imagery from the Pléiades mission of the French Space Agency (CNES; Figure 1(a)) and multi-frequency radar images from the COSMO-SkyMed (X-band, Figure 1(b)) and RADARSAT-2 (C-band, Figure 1(c)) missions of the Italian and Canadian Space Agencies (ASI and CSA), respectively, is addressed. The discrimination of the considered land cover classes is especially challenging due to the very high spatial resolutions involved and the similar spectral responses of some of the classes (e.g., 'urban' and 'containers'). Nevertheless, quite accurate discrimination is obtained (Figure 1(d)) when all three input sources are used through the developed approaches, with substantial improvements over the results that could be obtained by operating with the individual input images or with subsets of the available sources. These results point to the potential of advanced image modelling approaches to benefit from complex multi-sensor and multi-resolution data to optimise classification results, and further confirm the maturity of these approaches not only for laboratory experiments but also for the application to real-world scenarios associated with disaster events.

This research has been conducted together with a PhD student co-tutored in cooperation between the University of Genoa and the Université Côte d'Azur, Inria (Dr Ihsen Hedhli) and a post-doc from the University of Genoa in collaboration with Inria (Dr Vladimir Krylov), and has been partly funded by CNES and Inria. Further research on these topics is expected to be conducted within the Idex UCA_Jedi (Academy 3) of the Université Côte d'Azur in collaboration with the University of Genoa.

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Processing Satellite Imagery to Detect and Identify Non-collaborative Vessels

by Marco Reggiannini and Marco Righi (ISTI-CNR)

In recent years, European maritime countries have had to deal with new situations involving the traffic of illegal vessels. In order to tackle such problems, systems are required that can detect relevant anomalies such as unauthorised fishing or irregular migration and related smuggling activity. The OSIRIS project [L1] aims to contribute to a solution to these problems with the use of large scale data provided by satellite missions (Sentinel, Cosmo-SkyMed, EROS).

Optical/SAR data and system Integration for Rush Identification of Ship models (OSIRIS) is a European Space Agency project launched in March 2016, with the primary purpose of developing a software platform dedicated to maritime surveillance. The platform will be in charge of: (i) collecting maritime remote sensing data provided by satellite missions such as Sentinel-1, Sentinel-2, Cosmo-SkyMed and EROS-B, and (ii) processing the acquired data in order to detect and classify seagoing vessels.

A main goal within OSIRIS is to develop computational imaging procedures to process Synthetic Aperture Radar and Optical data returned by satellite sensors. We propose a system to automatically detect and recognise all the vessels within in a given area; the maritime satellite imagery will be processed to extract visual informative features of candidate vessels and to assign an identification label to each vessel.

Vessel detection and feature extraction

Processing operations first focus on the analysis of SAR amplitude/intensity images, aiming to detect potential vessels within a specific maritime area. A positive detection in this first step returns a subset of the initial image, restricted to an Area of Interest (AoI), where only the candidate vessel is visible. The next stage concerns the recognition of visual attributes within the AoI, providing relevant informative content. Imaging algorithms are applied to extract geometric and radiometric features, which provide meaningful insights about the vessel's morphology, geometry and dynamics. The input data are processed by standard statistical and morphological filters to extract the features.

As an example, consider the SAR intensity AoI image in Figure 1. Proper thresholding techniques (e.g., Otsu method) are applied to the AoI patch to estimate the set of pixels belonging to the detected ship. The identified cluster of pixels is then exploited to compute

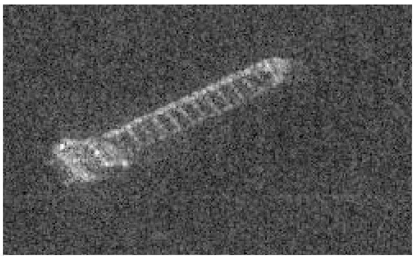

Figure 1: Cropped SAR patch on an area of interest. Only one vessel is displayed (image taken from [1]).

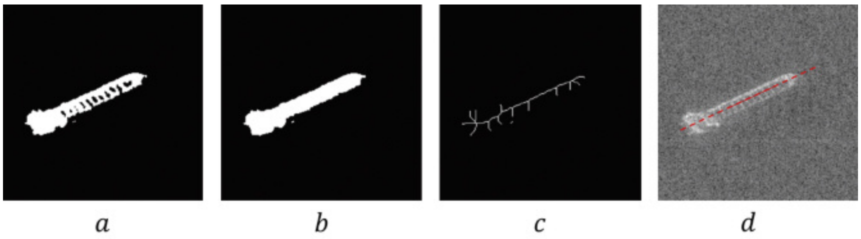

Figure 2: Pipeline of processing to estimate the bearing angle of the ship in Figure 1: a) optimal binary thresholding, b) morphological closing, c) morphological skeletonisation, d) line detection by Radon transform.

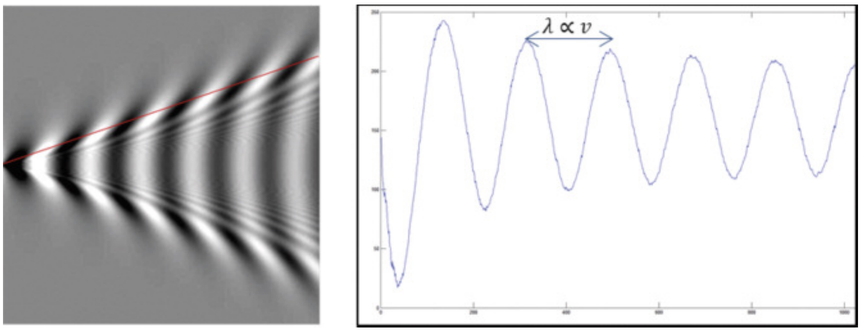

Figure 3: Kelvin wave oscillation and vessel speed (picture taken from [L2]).

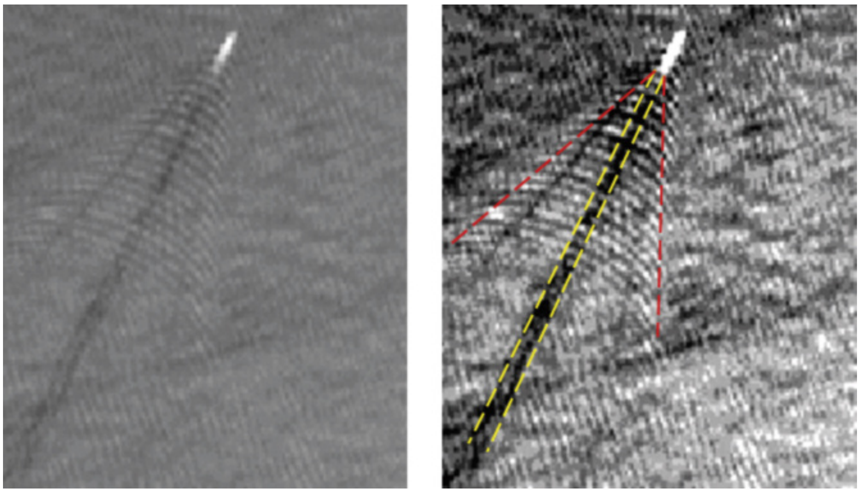

Figure 4: Turbulent wake (yellow lines) and boundaries of the ship wake (red lines). Picture taken from [L3].

meaningful ship parameters such as the Length Overall (LoA), and the width and area of the ship. The analysis of the pixel distribution of the segmented ship provides insights about the ship's orientation. A cascade of imaging algorithms is applied to: (i) reduce the ship's area to a linear segment by morphological operators (closing, erosion and skeletonisation, [2]) and (ii) identify the bearing angle (e.g., by means of the Radon transform, [2]).

The wavelength of waves observed in the wake generated by the ship's passage is related to the velocity of the ship itself through known hydrodynamics relationships [3]. Provided the image resolution is large enough to observe the individual wake features, a possible approach to estimate the ship's velocity v is to perform a frequency analysis of the AoI patch to estimate λ, the wavelength of the wake oscillation (Figure 3).

The amplitude of the central turbulent wake is also known to be related to the ship's beam [3]; indeed the vehicle's lateral width can be measured by estimating the width of the turbulent wake. This is performed by applying the Radon transform to extract the two linear borders (right side of Figure 4, yellow lines) enclosing the central turbulent wake and by estimating their separation distance. Additionally, by exploiting the same linear detector, the external boundaries of the wake (right side of Figure 4, red lines) are detected and employed to univocally estimate the direction of the vessel's speed.

The information collected is then exploited to perform a vessel classification, implemented by feeding a decision tree based classifier with the estimated features. Our software has been evaluated by comparing the estimations with the ground truth information provided by an existing knowledge base. The algorithm performs successfully in 75% of cases, featuring an almost linear time complexity with respect to the input data.

The OSIRIS project consortium comprises the National Research Council of Italy and the Italian companies SisTer and Mapsat (project coordinator).

Links:
[L1] https://wiki.services.eoportal.org/tiki-index.php?page=OSIRIS
[L2] http://www.planetinaction.com/
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Geometric Imaging for Subsurface Salt Bodies

by Tristan van Leeuwen (Utrecht University), Ajinkya Kadu (Utrecht University) and Wim A. Mulder (Shell Global Solutions International B.V. / Delft University of Technology)

For many decades, seismic studies have been providing useful images of subsurface layers and formations. The need for more accurate characterisation of complex geological structures from increasingly large data volumes requires advanced mathematical techniques and high performance algorithms.

Detailed images of subsurface structures can be obtained by studying the echoes of controlled seismic sources. For many decades, such techniques have been used for engineering purposes, scientific investigations of the Earth's structure and oil and gas exploration. As the seismic waves travel through the Earth, they are reflected at the interfaces between layers or formations of different rock type. Assuming that the contrast between these structures is small, we can define a linear relationship between the image and the data. Mathematically speaking, this linear transformation enjoys the special property that it preserves singularities. Hence, images of the various interfaces (singularities) can be obtained by applying the transformation in reverse. Techniques based on this linear formalism have been used for many decades and are still the workhorse in many settings.

As opposed to many other sound-based imaging modalities, such as medical ultrasound, the speed of sound in the subsurface can be strongly heterogeneous and is not known a priori. This can be problematic as strong lateral variations of the sound speed cause distortions in the image. Because the data are typically redundant, they enable the generation of multiple, independent images. Imposing consistency between the various images allows one to estimate the spatially varying sound speed. This additional step of estimating the sound speed is specific to seismic imaging but bears some resemblance to calibration problems found in other imaging modalities. An extensive overview is given by [1].

In more complex geological settings, the contrasts between layers is large and we can no longer approximate the image formation process as being linear. A prime example is shown in Figure 1, where a subsurface salt body has a large sound speed and density contrast with the surrounding sediments. Instead of a linear imaging problem, we now have to solve a non-linear parameter estimation problem. This entails repeatedly simulating the seismic experiment with detailed numerical models for wave propagation and updating the parameters until the simulations fit the data. Given its formidable computational burden, current research is aimed at reducing its cost by working on small

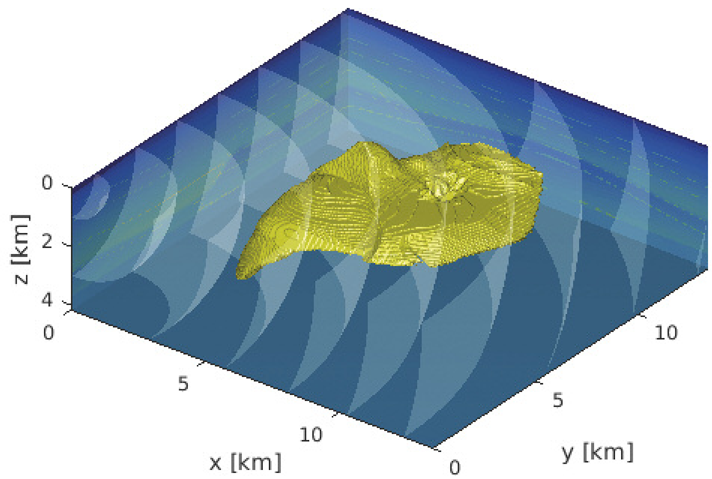

Figure 1: A subsurface salt body is insonified by seismic sources near the Earth's surface (at z=0). The goal is to retrieve the geometry of the salt body and the surrounding medium from recordings of the response at the Earth's surface.

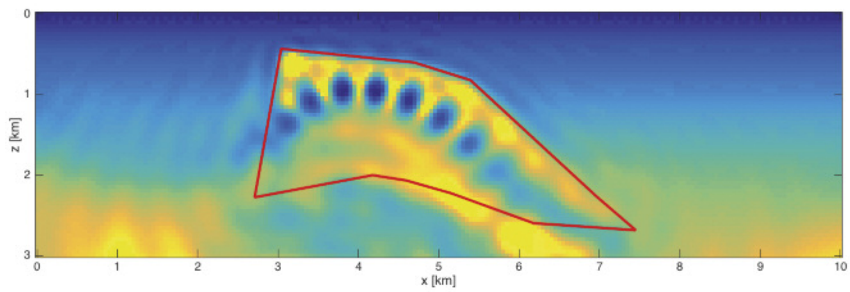

Figure 2: Reconstructed parameters using a conventional method. The true salt geometry (indicated in red) is not well recovered and spurious structure is introduced in the surrounding area.

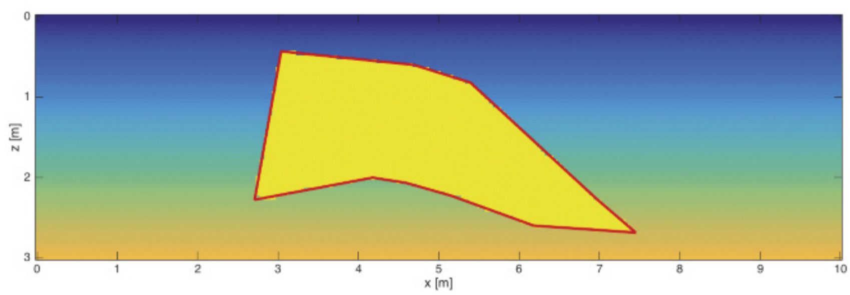

Figure 3: Reconstructed salt geometry and parameters using a level-set method. The true salt geometry (indicated in red) is recovered almost perfectly.

subsets of the data [2]. Moreover, the number of parameters that need to be estimated is large, even if we assume that the surrounding medium varies smoothly. Because we do not know the salt geometry a priori, we have no choice but to represent the entire medium on a very fine grid. Due to limitations of the aperture, we cannot estimate all these parameters independently. Also, the solution to the non-linear problem is not unique. Figure 2 illustrates the result of a standard parameter estimation technique. Even if we assume the sound speed in the surrounding medium to be known, the reconstruction of the geometry of the salt body is not very accurate.

To reduce the number of parameters, we split the problem in two parts: a geometric inverse problem for the salt body and a parameter-estimation problem for the surrounding medium. The geometric inverse problem is formulated with a level-set function [3]. The salt geometry is now implicitly defined as the zero contour of this level-set function. Assuming that both the level-set function and the surrounding medium are smooth, we can efficiently represent them with relatively few degrees of freedom. The result of this joint approach is shown in Figure 3. Here, we parametrized the level-set function with radial basis functions and assumed the sound speed in the surrounding medium to be linearly increasing with depth. The resulting number of unknown parameters in the level-set approach is $5x10^2$ as compared to $12x10^3$ in the conventional method. The level-set function and the surrounding medium are estimated in an alternating fashion.

In summary, seismic imaging in the presence of salt bodies can be split into a geometric inverse problem for the salt body and a parameter-estimation problem for the surrounding medium. This separation greatly reduces the number of parameters that need to be estimated and leads to improved reconstructions.

This project is part the Computational Science for Energy Research programme jointly funded by the Foundation for Fundamental Research on Matter (FOM), the Netherlands Organization for Scientific Research (NWO), and Shell.

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Bringing Modern Mathematical Modelling to Orientation Imaging for Material Science

by Nicola Viganò (CWI)

The vast majority of metallic and ceramic objects have a granular microstructure, which has a direct influence on their mechanical behaviour. Understanding the microstructure of these materials is especially important for nuclear reactors and other safety-critical applications in which they are used. Modern mathematical tools and recent developments in computed tomography can be used to study the evolution of these materials when they are being deformed or heated.

The ability to retrieve volumetric information about the crystallographic grain microstructure is necessary for understanding the initiation of damage and for establishing safety margins in critical applications. An interesting example is presented in [1], where the authors study the propagation path of corrosion cracks through polycrystalline steel samples (i.e., the materials used for the vessels of nuclear reactors), using a non-destructive three-dimensional orientation imaging technique, called diffraction contrast tomography (DCT), in conjunction with traditional X-ray absorption computed tomography.

Each crystalline object, when illuminated with X-rays, deflects some of the incoming photons whenever one of its crystal planes is oriented in a way that satisfies the famous Bragg law.
If captured on a high resolution X-ray imaging detector close to the sample, these diffracted beams form projected images of the diffracting object, which are called diffraction spots.
DCT is an X-Ray diffraction technique that uses the diffraction spots of each individual grain, in polycrystalline samples, to build a three-dimensional map of its grain microstructure.

DCT is naturally well suited for fast acquisitions, due to the use of extended beam sizes, which can capture large portions of the samples in a single scan. This makes it a good candidate for in-situ deformation studies where many deformation steps are applied to the test samples during the course of an experiment. However, traditional DCT assumes nearly perfect recrystallization of the materials, meaning that the internal deformation of the individual grains can be considered negligible. This imposes a strong limitation of applicability: real-world materials are often affected by several degrees of residual intragranular deformation, and the study of such deformation is the aim of the aforementioned type of in-situ experiments.

To adequately model and reconstruct plastically deformed grains, which exhibit rotations of the local crystal lattice, we developed a new mathematical framework in [2]. In this framework, each grain volume is defined over a six-

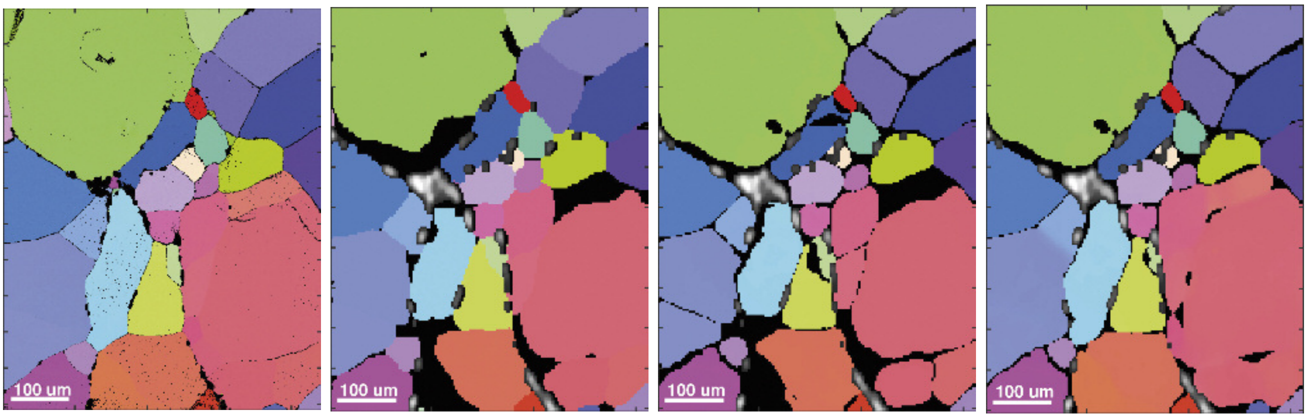

Figure 1: Orientation map of the surface of a rock-salt sample, by means of EBSD (a), 3D-DCT followed by grain dilation (b), single-grain 6D-DCT (c), and multi-grain 6D-DCT where new grains were identified by the reconstruction (d).

dimensional space resulting from the merge of the classic three-dimensional Euclidean position-space, with a more exotic three-dimensional orientation-space, called Rodrigues-space, used for the representation of local crystal orientations. Unfortunately, DCT can normally provide much less data than is needed for the correct reconstruction of this six-dimensional problem, rendering it heavily under-determined. For this reason, in this framework, the reconstruction is expressed in the form of a minimisation problem, which allows for additional priors in the reconstruction. These priors can enforce some known features of the reconstructed grains, and notable examples are the famous l1-norm and total variation functionals.

While this new mathematical framework proved very effective on simple reconstructions of isolated grains, its real potential was discovered in [3]. In this study, the reconstruction was applied to extended regions of the sample, containing multiple related grains, but without having precise a-priori knowledge on the extent and morphology of the analysed region in orientation-space.

In fact, for DCT to be able to reconstruct the individual grains as a traditional oblique-angle tomography problem, it is necessary to first identify the diffraction spots belonging to each grain (indexing), which in turn allows extraction of the needed information about their centres of mass, average orientations, and bounding boxes in the six-dimensional position-orientation space.

In the case of increasingly deformed or textured materials, the indexing procedure starts to fail due the related increasing overlap on the detector between the diffraction spots belonging to different grains. This results in missing the identification of some of the grains, and as a consequence to holes in the final grain-maps. By instead allowing the reconstruction of larger regions of the position and orientation spaces, these missing grains can be reconstructed, reducing the need for an accurate indexing step. A good example is shown in Figure 1, which presents the surface orientation map of a rock-salt sample, reconstructed in Figure 1a by means of Electron Backscatter Diffraction (EBSD), a (2D) surface technique, providing the reference-result, and then by traditional 3D-DCT plus a post-processing grain-dilation step (1b), single-grain 6D-DCT (Figure 1c), and finally the multi-grain 6D-DCT (Figure 1d).

While the scale of applicability of this formulation is limited by the memory and computational requirements of a full six-dimensional sampling of the reconstruction-space, we expect the size of the addressable problems to continuously rise in the future, thanks to the continuous increase in computational power and memory density of modern computer technology. This, in conjunction with the fast acquisition speed provided by DCT, and the continuous evolution of the mathematical tools to address more complicated problems, will create the possibility to perform time-lapse observations of plastic deformation, coarsening, phase transformation and crack propagation in polycrystalline structural materials.

Link:
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Towards Computational Photomechanics

by Frédéric Sur (Université de Lorraine, Inria), Benoît Blaysat and Michel Grédiac (Université Clermont-Auvergne)

Experimental mechanics is currently experiencing a revolution: the rapid development and spread of camera-based measurement systems, which enable experimentalists to visualise the displacement and strain distributions occurring in structures or specimens subjected to a load. In order to obtain information that is as valuable as that provided by numerical models, we need to move on from lowly to highly-resolved maps, and from qualitative to quantitative measuring tools. To this end, new mathematical results and algorithms are needed.

The research field of experimental solid mechanics focusses mainly on characterising the response of engineering materials and structures when they are subjected to thermo-mechanical loads. Tests may be performed to observe the response of the constitutive materials, to help propose relevant models to describe this response, to identify their associated governing parameters which are then employed in numerical models, or to validate design procedures relying on predictive numerical calculations.

This work encompasses research areas ranging from civil engineering, aeronautics, ground transportation industry and microelectronics. Recently a new research domain named photomechanics has emerged, which is aimed at developing full-field measurement systems and using them to best characterise materials and structures. This domain is at the crossroads of traditional experimental mechanics and image analysis, since full-field measurements, namely displacement and strain fields, are obtained from a series of images of a (generally slightly) deformed specimen. Despite their appeal, these measuring tools are far from having reached maturity for several reasons.

First, the lack of procedures and standards enabling the metrological performance of full-field measurement systems still limits their use to qualitative measurements in many cases, or leads to the provision of quantitative information with a poor measurement resolution compared to conventional localised measurement means such as strain gauges. For instance, it is of utmost importance to quantify the measurement resolution, the spatial resolution, or the measurement systematic error. These quantities are intrinsically linked to each other and to the estimation process. Measurement resolution is impaired by signal-dependent noise coming from the imaging sensor. The spatial resolution not only depends on the sensor's pixel density but also on the computational method used to estimate the displacement or strain fields. It is also related to th e systematic error, which links the measurement to the 'true', and unknown, value of interest. Thus, mathematically analysing the whole estimation process is of prime importance. Restoration methods such as denoising or super-resolution are to be investigated here in order to improve these quantities. For instance, Figure 1 a) shows a strain field on the surface of a shape memory alloy under tension.

Since a relation was established between the measured strain field and the unknown real field, it is possible to restore the strain field and to improve the metrological performances in turn.

Preliminary results on this topic are discussed in [1] and are illustrated in Figure 1 b). This is a challenging problem for a number of reasons: the restored quantities are not images but measurement fields extracted from these images, information on displacement and strain hardly emerges from the noise floor in the case of small strains, and it is crucial to quantify the improvement of the restoration techniques on the metrological performances. In addition to carefully modelling sensor noise. It is essential to take into account subtle effects that cannot be ignored such as vibrations affecting the experimental setup, or optical distortions. These aspects contrast with many traditional applications of computational imaging which usually give qualitative results.

Second, the availability of strain maps while testing materials has progressively raised the following question: what is the best way of processing measurement fields to retrieve the parameters governing constitutive

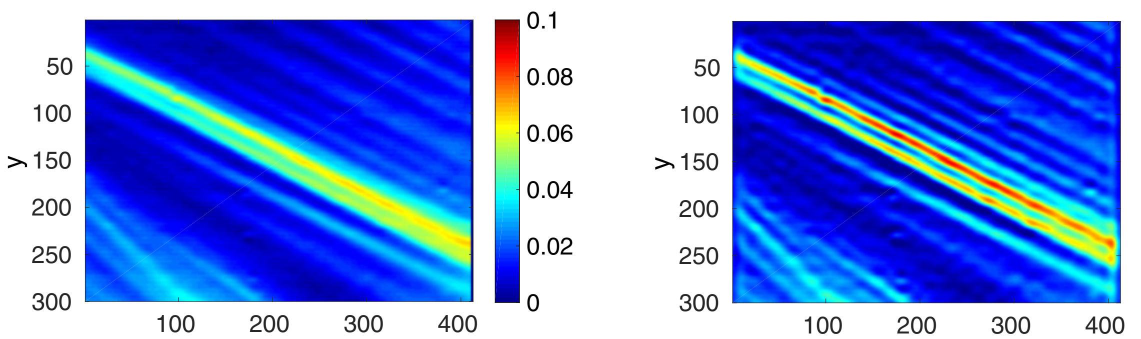

Figure 1:Shape memory alloy under tension: a strain map obtained with the grid method, before (left) and after restoration (right) as discussed in [1]. Two martensite needles (in red) are now visible and well separated.

equations which describe the response of the material being tested? To answer this question it is necessary to address inverse problems. This requires dedicated numerical procedures that have only been developed recently in response to the advent of full-field measurement techniques. Some of these procedures are still in their infancy, and their respective performances have only been compared in embryonic form, so there is still much work to be done. Again, this confronts the experimental mechanics community with largely open problems.

To address these issues, the acquisition chain must be thoroughly modelled, from the imaging sensor to the measurement field, and eventually to the parameters which are retrieved from the images. For example, [2] is a recent survey and analysis of the grid method; one of the available full-field systems. The advantage of this method based on spectral analysis is that predictive formulas are available to assess the metrological performance. For these reasons, the establishment of a new scientific domain which could be called computational photomechanics is undoubtedly warranted. It would give access to metrologically certified measurement fields by a thorough mathematical analysis, and to more information than traditional methods thanks to appropriate image processing tools.

Link:
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Novel Concepts for Wave Imaging in Complex Media

by Lorenzo Audibert (EDF) and Houssem Haddar (Inria)

Wave imaging, a very useful technique for identifying remote/inaccessible objects using waves, is at the center of many widely used technologies such as RADAR, SONAR, medical imaging, nondestructive testing and seismic imaging. These techniques are well established for homogeneous backgrounds, such as air or water, for which a large variety of algorithms have been successfully used to solve the underlying imaging problem. However, most classical methods are inadequate at dealing with heterogeneous backgrounds, such as high resolution seismic imaging, ultrasound of bones, radar in urban environments and nondestructive testing of concrete or periodic nano-materials.

Wave imaging falls within the field of inverse problems, which is centred on how to stably invert an operator or a model that does not have a continuous inverse. This problem may be tackled in two ways: either by trying to obtain a complete description of the physical parameters of the probed medium or trying only to reconstruct its geometry. The first route would require a large amount of data and high computational cost, which may be prohibitive for real-time imaging, but very efficient methods can be designed by focussing on the geometrical support.

A recent framework for imaging the geometrical support of an object from measurements of scattered waves is offered by 'sampling methods' [1]. The idea of this class of methods is to build an indicator function that determines whether a given point is inside the scattering object or not, and this is done using only the range of the matrix formed by multi-sources multi-receivers sensing system, at a given frequency also called the measurement operator. For our method, developed as part of Lorenzo Audibert's PhD thesis, a sampling point only lies inside if one can construct incident waves (by shaping the weight for each source) such that the medium scatters like a point source located at the sampling point. The main difficulty in the construction of incident waves is that the measurement operator, is extremely ill-conditioned. We propose the incorporation of a non-standard penalty term that controls a norm for the solution weighted by the measurement operator itself. A rigorous mathematical justification is given in [3] for the obtained algorithm that treats the case of noisy measurements and can handle various scenarios for collecting the data (near/far fields, full/limited apertures). The numerical accuracy of our new algorithms outperforms the accuracy of other existing sampling methods for noisy measurements [3].

The extension of those methods to complex media is an active topic in wave imaging. A commonly used approach for these problems is to exploit some asymptotic regimes (e.g., homogenisation, high frequency asymptotics, Born approximation) to get to a simpler setting. Sometimes, however, it is impossible to approximate any quantities that are related to the complex medium. In this seemingly impossible configuration, the use of two sets of measurements, one without and one with a perturbation, would provide enough information to be able to image modifications of the medium; this is known as 'differential measurements imaging'. A typical problem is to locate changes in a medium without knowing precisely how this medium is structured and also in some cases the type of defect itself. Again we would like to design an imaging functional that only retrieves the geometrical information for efficiency purposes. Our algorithm is based on applying the sampling procedure to each set of data independently with the same carefully chosen simple artificial background. Indeed the obtained

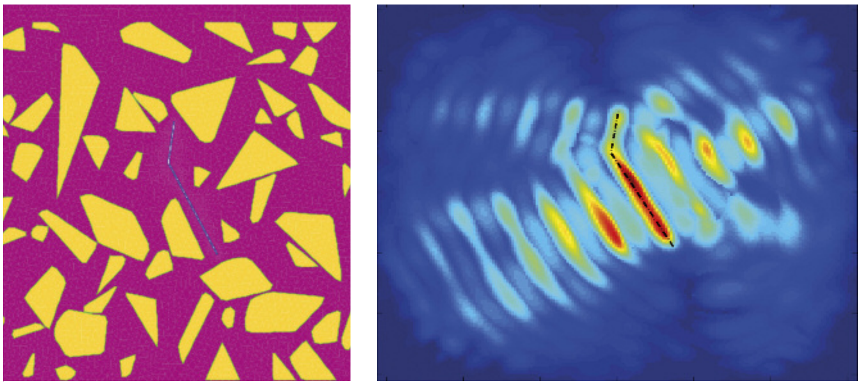

Figure 1: Differential imaging for retrieving a crack in concrete type material. Left: exact geometry – Right: obtained reconstruction using differential measurements.

images are not expected to reveal the complex geometry of the true background and therefore the presence of modifications (due to other effects than noise in the data).

Inspired by the analysis of the sampling method above we propose to filter the difference between two solutions (defined as minimiser of the cost functional, introduced above) for a given sampling point. The filter is built from the data associated with defect free configuration. We prove that this difference eliminates the true background contribution and therefore reveals the presence or absence of defects and images its shape [2]. In terms of computations, we retain the distributed structure, and the computational cost for one sampling point is double that of the sampling method for an homogeneous background.

We applied this method on synthetic data for ultrasound imaging in concrete type materials with the aim of detecting early stage cracks. Concrete can be seen as a two phase material; a large number of aggregates of various form and size bound together by cement paste. Cement paste is also a heterogeneous material but at the wavelength of ultrasound we can approximate it by a homogeneous media that is considered in our method as the reference background. Figure 1 shows the reconstruction for a crack inside a simulated concrete-like structure. Differential imaging is also being developed in order to image defects in periodic backgrounds (such as nanostructures) where for instance the periodicity information is exploited to avoid the need for a reference set of measurements.

Link:
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Low-dose X-ray Tomography Imaging Based on Sparse Signal Processing

by Samuli Siltanen (University of Helsinki)

X-ray tomography is a wonderful tool that allows doctors to peek inside patients. However, since X-rays are harmful, a patient’s exposure to them should be limited. An obvious way to achieve this is to take fewer images, but unfortunately this causes trouble for classical image reconstruction methods. However, new mathematical methods, based on compressed sensing and the multi-scale shearlet transform, can save the day!

The goal of medical tomography, or CT scan, is to reveal the inner structure of a patient using a collection of X-ray images recorded from several directions. In a classical setup, 360 images are taken while rotating around the patient with 1 degree angular steps, and a filtered back-projection (FBP) is used to create a highly detailed reconstruction image. My research team at University of Helsinki aims at reducing the number of images and using shearlet sparsity for reconstruction.

Imaging the patient from hundreds of directions exposes him or her to a substantial radiation dose. Therefore, such comprehensive CT scans are limited to rather serious medical conditions so that the dose is ethically acceptable.

Within the medical community there is a growing interest in taking fewer X-ray images and using them to compute a less-than-perfect tomographic reconstruction that is good enough for a particular purpose. For example, in dental implant planning it is enough to know the depth and direction of the desired hole to be drilled. Likewise, in surgery it may be enough to get an idea of the 3D position of instruments during a knee operation. In both of these cases, there exists a device (panoramic X-ray imager and surgical C-arm device, respectively) for collecting images from a range of directions.

The mathematical task of reconstructing the tomographic image

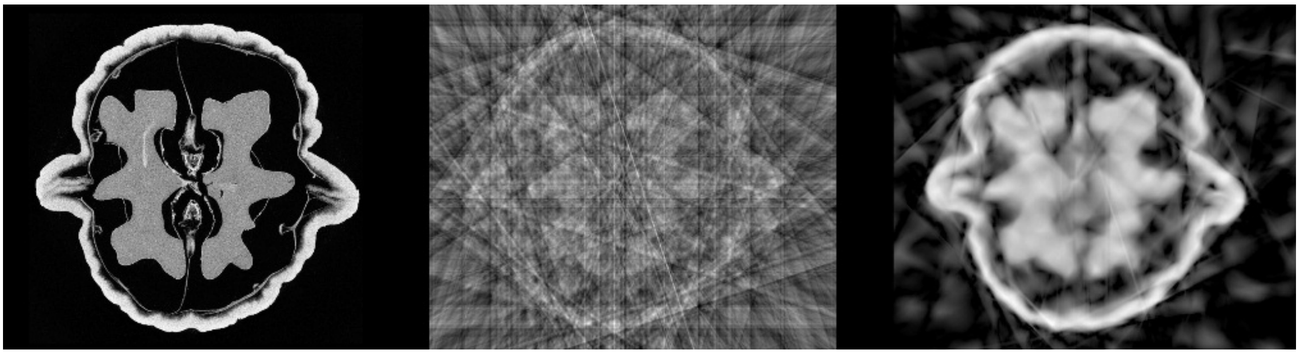

Figure 1: Three reconstructions of a walnut.

becomes more difficult when there are fewer images. The measurement information alone is not sufficient to perfectly determine the 3D target structure, and the inversion is extremely sensitive to noise and modelling errors. These problems can be overcome by complementing the insufficient data with a priori knowledge about the target, in other words by using regularisation.

One way to regularise the tomographic reconstruction problem is to promote sparsity in the spirit of [1,2]. This means expressing the unknown image in terms of suitable building blocks and requiring that as few building blocks as possible are used. Traditional choices for building blocks include sines and cosines arising from fast fourier transform (FFT) and multiscale constructions such as wavelets. Both of them have serious shortcomings in the context of tomography, however. FFT is not good for local details as sines and cosines span the whole image area. Wavelets in turn, make it possible to zoom in to details, but they are not economical for representing jumps in X-ray attenuation along tissue boundaries, the very things doctors most often want to see.

The shearlet transform [3] is optimal for representing jumps along curves in images. The optimality is achieved by making the finer-scale building blocks more and more elongated as they become smaller. Additionally, the smaller these needle-like image atoms are, the more possible orientations they have. Thus, shearlets allow faithful following of tissue boundaries.

Figure 1 shows three reconstructions of a walnut. (The data is openly available for experimentation, see [L1]. On the left is reconstruction from comprehensive data with 1200 X-ray images. Note the high level of detail delivered by the standard FBP algorithm. The middle and right images are reconstructions computed from the same subset of only 20 X-ray images taken all around the walnut. The middle image shows FBP reconstruction; we remark that FBP was never designed for this kind of data with large angular steps between projection directions. Shown on the right is reconstruction based on shearlet sparsity.

The high quality of the sparse-data walnut reconstruction inspired my team to collaborate with Professors Miika Nieminen and Simo Saarakkala at Oulu University Hospital, Finland. Together we aim to take shearlet-sparsity regularisation to clinical practice, speeding up radiological examinations and reducing harmful radiation doses to patients.

Link:
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3D Flashback: An Informative Application for Dance

by Rafael Kuffner dos Anjos, Carla Fernandes (FCSH/UNL) and João Madeiras Pereira (INESC-ID)

Viewpoint-free visualisation using sequences of point clouds can capture previously lost concepts in a contemporary dance performance.

The BlackBox project aims to develop a model for a web-based collaborative platform dedicated to documenting the compositional processes used by choreographers of contemporary dance and theatre. BlackBox is an interdisciplinary project spanning contemporary performing arts, cognition and computer science.

Traditionally, performing arts such as dance are taught either by example or by looking at individual artist-driven scores on paper. With different dance movements emerging during the com-

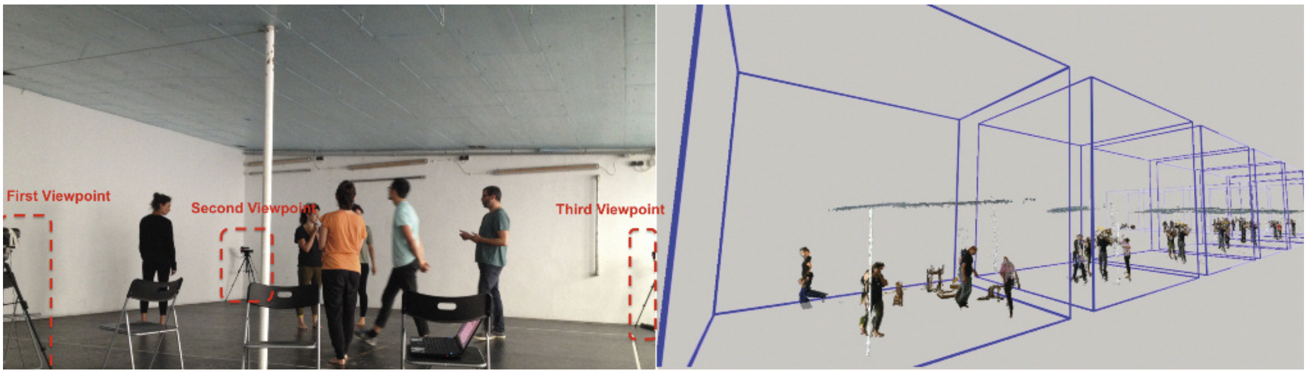

Figure 1: Example of our capture setup (left), and timeline visualisation of a recorded improvisation session.

position of a new choreography, and the difficulty of creating a controlled vocabulary of movements to compose a score, watching videos of previous performances or of rehearsals is often the way to learn a specific dance. However, an ordinary video is not sufficient to communicate what is envisioned by the choreographer [1] since a video is restricted to a single point of view. This introduces ambiguity when occlusions occur between different dancers or props within the performance.

Previously published work on three-dimensional motion capture for dance has resorted to markers in the dancer's bodies for skeletal reconstruction, or happened in a controlled environment such as a laboratory. These approaches are not viable for our goal of capturing the creative process of a choreographer. The creation of a play happens in a very timely restricted schedule and is in constant evolution. To capture the transient concepts in the studio, our setup must be mobile, and capture not only skeletal information, but also more context about the rehearsal space.

We are developing an application, called 3D Flashback, which captures a sequence of point clouds using a Kinect-based wide-baseline capture setup, then uses this data to create a viewpoint-free visualisation of a given performance without the restrictions of previous systems.

We developed a network-based synchronisation and calibration software in collaboration with the Visualisation and Intelligent Multimodal Interfaces (VIMMI) group from INESC-ID. It allows us to quickly deploy and grossly calibrate our Kinect-based capture setup using the human skeleton tracking feature from Kinect, which can be refined on more challenging scenarios by matching different views of a streamed point cloud.

Our early approach was applied to a contemporary dance improvisation scenario, where a simple visualizer was developed to show annotations made on a 2D video on a 3D point cloud sequence [2]. An existing annotator was extended to correctly assign 3D coordinates to the point cloud. The length of recording constraint imposed by a naive representation was a problem, since each improvisation session lasted for twenty minutes.

Currently the main research challenges are the representation and compression of the recorded point cloud datasets, and their visualisation. We are focused on further developing current image-based representations for video-based rendering, so they can be efficiently applied in a wide-baseline scenario. Regarding visualisation, we are working on improving current surface splatting techniques for better results on close-ups, and faster rendering which takes advantage of an image-based representation.

The BlackBox project is funded by the European Research Council (Ref. 336200) and hosted at FCSH-UNL, Lisbon, Portugal and runs from 2014 to 2019. During this five year period we will be collaborating with three different choreographers. These realistic scenarios will be used to validate our developed system and solution for video-based rendering and build upon our previous prototype for a video annotation application. The web-based collaborative platform will contain the results of our studies, where users will be able to browse annotated three-dimensional videos explaining the respective authoral creative processes and specific concepts underlying the performances.

Link:
http://blackbox.fcsh.unl.pt/

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Identifying Persons of Interest in CCTV Camera Networks

by Furqan M. Khan and Francois Bremond (Inria)

Computers now excel at face recognition under severely constrained environments; however, most of the surveillance networks capture un-constrained data in which person (re)identification is a challenging task. The STARS team at INRIA is making considerable progress towards solving the person re-identification problem in a traditional visual surveillance setup.

Imagine a surveillance system operator wants to quickly examine the recent activities of a particular individual, perhaps in an airport, a grocery store or an amusement park. To do so, the operator has to manually re-identify (locate) the person in different camera feeds, which may take significant time if crowd density is high and there are many cameras. As a part of the EU project CENTAUR, the STARS team at INRIA Sophia Antipolis is developing technology that reduces operator workload in re-identifying the concerned individual over the network of cameras.

Person re-identification is a challenging task because individuals move in all directions, including away from the camera and across the field of view (see Figure 1). Therefore, biometric cues such as face or iris cannot be reliably extracted. Instead, holistic appearance of the person (clothing) or gait is used, which is inherently not as discriminative. Furthermore, due to low resolution, subtleties in gait are difficult to measure. In addition, a person's appearance in a video is susceptible to illumination, occlusion, camera properties and viewing angle. Finally, for a fully automated system, individuals must be localised using a person detection and tracking algorithm before building their appearance models. Existing detection and tracking algorithms are imperfect and induce noise in appearance models and hence affect model matching.

A semi-automated system was developed by the STARS group last year, which shows a small list of candidate matches to the operator for browsing. However, owing to the challenges, the difference in desired and achieved performance of the underlying algorithm was large. This has now been significantly reduced by improving multiple aspects of the re-identification algorithm.

The main catalysts for improvement are the novel modelling of person's appearance as a set of parametric probability densities of low-level features over different body regions and the bi-directional matching of appearance models. Combined with recently proposed low level features and metric learning techniques, the algorithm achieves significant advances in both precision and recall of retrieval. The algorithm has been benchmark against a number of competing methods on multiple publicly available datasets, where it comprehensively outperformed all other methods [1]. The improved algorithm is transferred to a local startup which is developing an end-to-end re-identification tool for the retail domain.

Another aspect of this work deals with reduction in dependency on manual annotations for metric learning. More so than object detection, fully supervised metric learning is not scalable in real-world applications due to retraining requirements. Therefore, a novel strategy to automatically label data is employed to learn metric in an unsupervised manner without considerable degradation in performance [2].

Advancements in the re-identification algorithm were made possible by support received under European Project CENTAUR. Going forward, the group plans to further improve performance of the re-identification algorithm and benchmark its performance on larger datasets with noisy inputs. We are also interested in investigating how deep networks can be employed successfully in this domain when labelled training data is limited.

Figure 1: Three groups of people captured from two different cameras in a surveillance network. Persons are often facing away from the camera and their appearance changes from one camera to another due to illumination.

Link:
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Computational Fusion of Multi-View and Multi-Illumination Imaging

Svorad Štolc, Reinhold Huber-Mörk and Dorothea Heiss

The Austrian Institute of Technology (AIT) is working on novel in-line methods to infer object and material properties in automated visual inspection. Here we describe a real-time method for concurrent extraction of light-field and photometric stereo data using a multi-line-scan acquisition and processing framework.

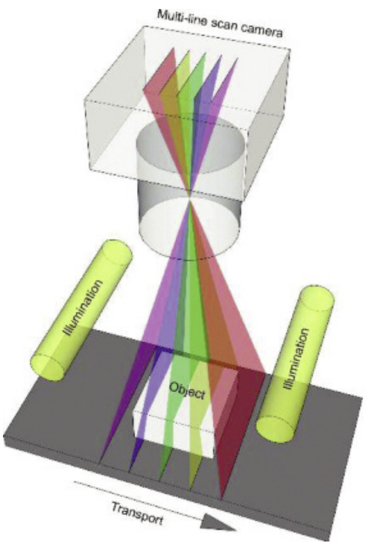
Reasoning about objects, their characteristics and behaviour from 2D images is a challenge, despite there being many successful applications of 2D computer and machine vision. The light space of an observed scene comprises all rays hitting objects from every possible direction, and then after interacting with the objects being emitted in every possible direction. Static illumination and a single 2D sensor only sparsely samples this ray space. Placing a multitude of sensors partly overcomes this limitation. Light-field cameras sample this space more densely by considering a fine angular resolution, e.g., plenoptic cameras typically observe a scene from up to 100 different directions [1]. On the other hand, illumination variation as used in photometric stereo facilitates a variety of directions for rays hitting the objects under consideration [2].

Light-field imaging and photometric stereo can be seen as complementary methods in computational imaging. The first method samples the space of light rays emerging from the object while the second samples the subspace of illuminating rays. Considering the application area of 3D reconstruction, the main advantages of photometric stereo based methods are their sensitivity to fine details and independence from surface structure, while disadvantages include lacking or insufficient metrical and global accuracy. On the other hand, light-field processing for 3D is able to provide globally and metrically correct depth estimations, but fine details are prone to be lost. Therefore, both methods complement each other advantageously, compensating each other's shortcomings.

Established setups for photometric stereo based computational imaging involve images taken sequentially under a set of differing illumination directions. Their mutual displacement is obtained by switching between displaced light sources or a mechanical movement to different positions. Similarly, early light-field acquisition systems used either camera arrays or gantries transporting the camera between sequential acquisitions. Both setups – and even more their combination – would not be feasible for typical industrial applications, e.g. quality inspection, where a faster, more compact and tightly integrated solution is desirable.

We designed an inline machine vision system deploying concurrent light-field and photometric stereo [3] for industrial use cases where there is a relative movement between inspected objects and the sensing/illumination system e.g. via conveyor belt. The basic idea is to construct the light-field data structure over time using a multi-line scan sensor. The light-field is constructed by moving the multi-line scan sensor together with an illumination source relative to the observed object (or vice versa) at constant spatial and time increments. Furthermore, a photometric variation due to different illumination angles is observed for different views onto the observed object. In particular, specular reflections which typically cause problems with 3D reconstruction could be handled by inferring the local surface orientation directly from the observed specular behaviour.

We built a 3D reconstruction system based on fusion of the globally more trustable light-field processing derived depth with the locally more precise photometric stereo derived surface properties. The key idea in obtaining an improved depth by fusion is to balance globally vs. locally precise estimations.



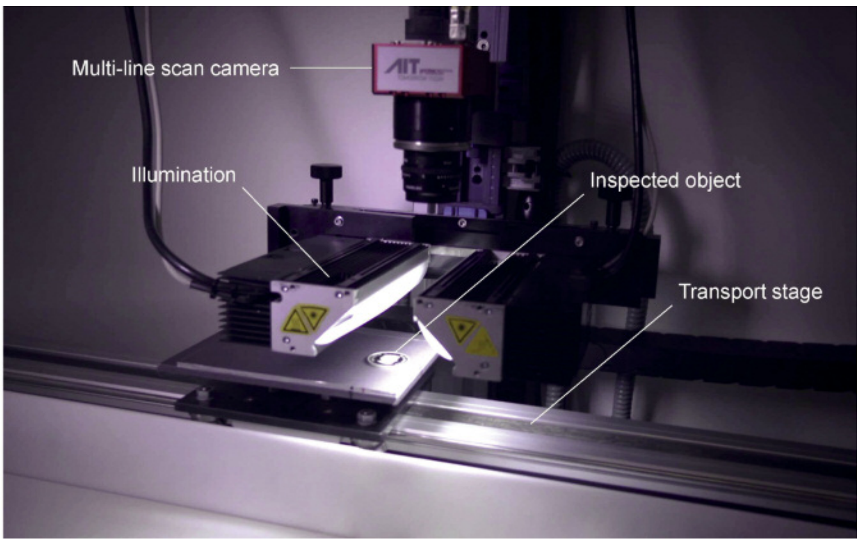


Figure 1: Multi-line scan image acquisition principle and photograph of the AIT prototype.

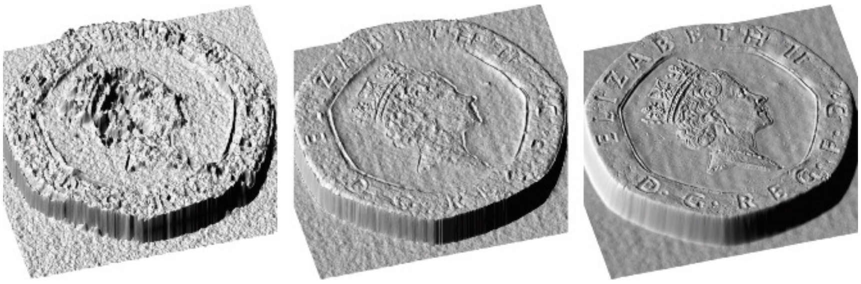


Figure 2: 3D reconstruction of a coin using conventional stereo (left), multi-view stereo obtained with our multi-line scan camera (middle), and combination of multi-view and photometric stereo also obtained with the multi-line scan camera (right).

Figure 3: Coin texture (left) and fine surface detail contributed by photometric stereo (middle and right) as recorded by our approach.

We investigated a variety of methods ranging from a combination of low- and high-pass filtered depth maps over graphical models to energy minimisation approaches. We propose the combined approach for application in in-line automated visual inspection. The analysis of fine surface disruptions, even for specular objects, is of wide interest in quality assurance. Furthermore, the inference of material properties and classes, which are described by the 'bidirectional reflection distribution function' (BRDF) comprising the variation of incoming and reflected light, becomes possible because a slice of the BRDF is obtained by our approach.

Collaborative research with companies in the field of production industry is currently being undertaken. Further work will include very high resolution imaging as well as novel computational methods. The latter is done in collaboration with the Institute of Computer Vision and Graphics of the Technical University of Graz.

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Multispectral Imaging for the Analysis of Cultural Heritage Objects and Image Registration for Results Optimisation

by Kostas Hatzigiannakis, Athanasios Zacharopoulos and Xenophon Zabulis (ICS-FORTH)

Multispectral imaging and spectroscopic analysis are valuable tools for the study of materials of cultural heritage objects. Accurate registration of spectral images into a spectral cube increases the precision and quality of spectral measurements, supporting portable and low cost multispectral imaging systems.

Multispectral imaging (MSI) is a technique which combines digital imaging with spectroscopic analysis to recover spatial and spectral information of an object. MSI is implemented by inserting a monochromator, most often a series of bandpass filters, in the light path either of the illumination system or in front of the imaging sensor. The outcome of this technique is a sequence of successive images, one spectral image per spectral band, called a spectral cube. Processing of the spectral cube enables the extraction of useful information about the materials comprising the object. MSI is applied in medicine, agriculture, remote sensing, the food industry and other fields. MSI primarily applies in cultural heritage, for art conservation, archaeology and art history studies.

Cultural heritage objects are extremely delicate. MSI, being contactless, non-invasive, and non-destructive, can play an invaluable role in stratigraphic analysis, monitoring conservation interventions, unveiling underdrawings and enhancing faint patterns [1]. Spectroscopic analysis for artworks materials study is also an MSI potential. The intensity along a column of the spectral cube, corresponding to a pixel or a group of pixels, is the extracted reflectance spectrum, enabling the composite materials, including pigments, to be differentiated and identified.

IRIS II is lightweight portable system developed at FORTH comprising a

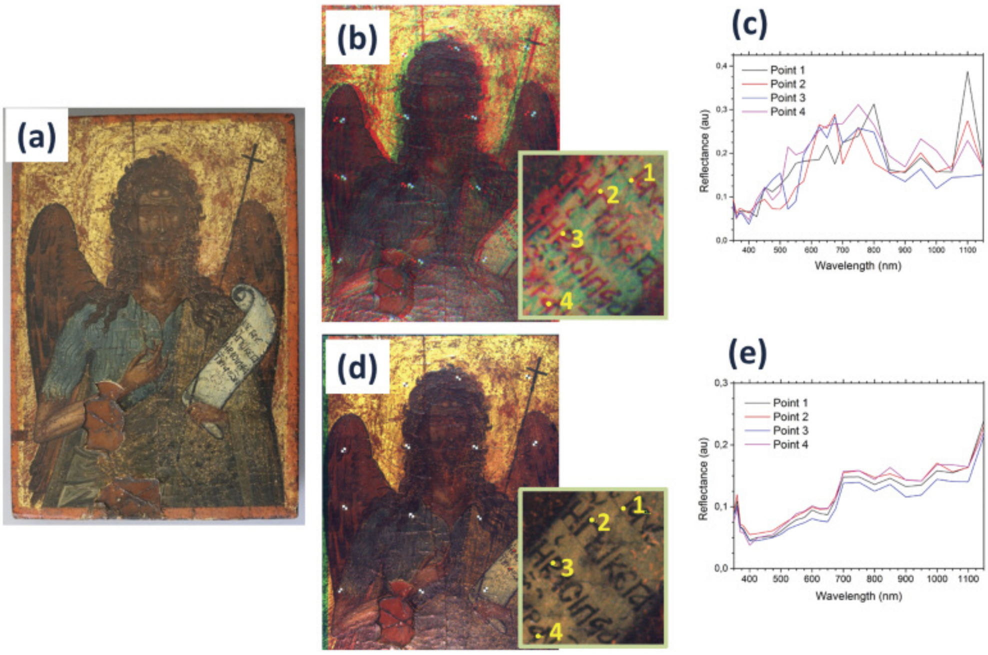

Figure 1: The effect of registration in the acquisition of multi-spectral images. (a) Conventional colour image of the object under study. (b) Synthesis of a colour image by combining the three unregistered spectral images at 450 nm (blue channel), 550 nm (green channel) and 650 nm (red channel) of the spectral cube. The observed blurring is due to misregistration. In (d), spectral images are registered before their combination and no blurring is observed. The area of study is magnified in b) and d) for higher detail. Graphs (c) and (e) plot the extracted spectra at four points, for the unregistered and registered spectral cubes, respectively. Due to registration, in (e), the extracted spectra are better aligned, indicating that the same pigment has been used at the four studied points. The checker markers in (b) and (d) were used only for evaluation and are not required by the registration method.

camera, a filter wheel able to interchange 28 filter and replaceable c-mount lens. The sensor, in combination with the band-pass filters, allows sensitivity to the UV region (350 nm up to 400 nm, BP10nm), to the visible (400 nm-700 nm, BP25nm) and to the Near IR region (700 nm-1200 nm, BP50nm). The final 3D spectral cube can have maximum dimensions of 2560 × 2048 × 28 data points.

The portability of the system introduces possible camera pose changes and vibrations during the acquisition, which in turn are evident as translation shifts and even rotations between the different spectral images. In addition, the versatility of the system and the properties of the optical elements occasionally introduce the need for refocusing and thereby slight changes in the focal distance and consequently in the field of view.

As a consequence, the spectral images are not accurately aligned. Image registration aligns the spectral images, so that a physical point is imaged at the same coordinates in all images of the spectral cube. The reflectance spectrum is more accurately extracted and, in this way, precise spectral measurements can be achieved. High precision is of particular interest when only traces of a material are present in the artwork.

The registration approach capitalises on the (approximate) planarity of paintings, to simplify the registration problem. In this way, the estimation of the geometrical transformations that warp the multispectral images so that they are registered to each other and form an aligned spectral cube is feasible. A non-linear, robust estimation method that utilises point correspondences across image pairs is employed for the estimation of these transforms [2].

These correspondences are established based on the detection and matching of keypoint features in image pairs of the spectral sequence. Typically, two arbitrary images from the spectral sequence expected to be quite different for feature matching to be fruitful. However, images acquired at neighbouring spectral bands are more similar and, thus, correspondences are searched in consecutive images. By combining the estimated transforms, all spectral images can be registered upon a reference image in the sequence (i.e., the first, or the middle one), yielding an accurately aligned spectral cube.

The accuracy of registration is evaluated with the help of benchmark datasets, which are annotated with ground truth for registration. The aforementioned registration approach has less than a pixel of error, measured on these benchmark datasets. As such, datasets are not widely available, but a collection of datasets indicating characteristic situations in in-situ MSI are publicly available for the evaluation of existing future MSI registration approaches.

Link:
http://www.ics.forth.gr/cvrl/msi/

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Computational Snapshot Spectral Imaging

by Grigorios Tsagkatakis and Panagiotis Tsakalides

Within the EU funded PHySIS project (Sparse Signal Processing Technologies for Hyper Spectral Systems), we are developing a novel approach to achieve high speed and high resolution spectral imaging by leveraging cutting edge signal processing paradigms.

Spectral imaging aims at acquiring tens to hundreds of spectral bands - many more than the three bands acquired by colour imaging. From an application perspective, analysis of spectral data acquired by Earth observing satellites has greatly aided our understanding of global environmental and ecological phenomena, while its applications in manufacturing, food quality control, and biomedical imaging are also gaining momentum.

A fundamental challenge that spectral imaging systems have to address is the collection of the four dimensional datacube - two spatial, one spectral, and one temporal - using a single, a 1D array, or 2D array detectors. This discrepancy between the requested and the available dimensionality of detectors has sparked different philosophies in spectral imaging system design. Nevertheless, a shortcoming shared by traditional methods pertains to the scanning requirements for constructing the complete high dimensional datacube, resulting in slow acquisition rates, and motion artefacts.

Within the EU funded PHySIS project [L1], a consortium consisting of FORTH-ICS as the leader, the Cosmostat Lab of CEA, IMEC, NOA, and Planetek Italia, considers a novel spectral imaging architecture which can provide extremely high acquisition rates, eliminating the issues associated with scanning. The IMEC snapshot spectral camera relies on the deposition of a Fabry-Perot spectral filter on top of each individual detector element, thus associating each pixel with a single spectral band, achieving a novel operation point in spatial, spectral and temporal resolution trade-off curves. As a result, the effective spatial resolution is dramatically reduced as the required spectral resolution increases.

To address this limitation, in PHySIS we invoke the paradigm of computational imaging, (CI) which involves the coupled design of optical architectures and algorithmic tools for unprecedented imaging capabilities. A decisive factor that allows CI to demonstrate its potential is the recent mathematical and algorithm framework of compressed sensing [1], which has led to designs with a profound impact in diverse domains from medicine, to astronomy and radar. While various compressed sensing spectral imaging systems have also been recently proposed, these architectures involve multiplexing the measurements before acquisition, thus necessitating additional optical components like microlens arrays and dispersive elements in order to achieve 'incoherent' sampling.

To recover the full resolution spectral cube, we consider matrix completion (MC) [2], an algorithmic framework which has recently emerged on the heels of compressed sensing and addresses the recovery of matrix-structured data from an incomplete and possibly noisy set of measurements. Provided sufficiently randomly selected measurements are available, recovery of a low-rank matrix is possible by solving an efficient nuclear norm minimisation problem. The MC framework can allow the recovery of full resolution spectral cubes from measurements obtained by snapshot spectral imagers [3] (cf. 1).

In addition to the problem of snapshot spectral image recovery, the MC framework has also been considered for other CI problems like high dynamic range image acquisition, synthetic aperture radar, and ultrasound imaging. The straightforward random sampling and the universality of the method with respect to the data, justify the potential for MC in CI. At the same time, the extension of this framework to high dimensional data structures like tensors, leading to formulations like tensor completion is also expected to have a significant influence in the design of paradigm shifting CI architectures.

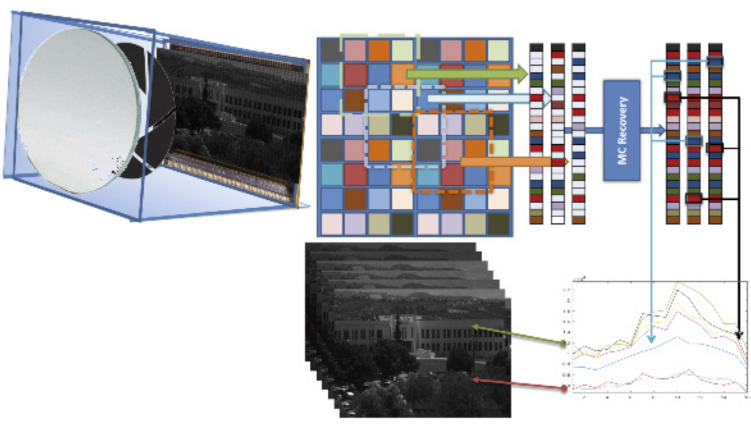

Figure 1:Illustration of the MC recovery of snapshot spectral imaging.

Link:
[L1] http://www.physis-project.eu

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Lip Segmentation on Hyper-Spectral Images

by Alessandro Danielis, Daniela Giorgi and Sara Colantonio (ISTI-CNR)

We present a lip segmentation method based on simulated Lambertian shadings. The input consists of hyper-spectral images generated by a prototype for medical applications.

Lip contour segmentation is fundamental for many human-computer interaction applications, including lip reading, facial expression recognition, and fatigue syndrome diagnosis. Lip segmentation techniques suffer from similar drawbacks to those of face detection, including subject variability and adverse lighting conditions. Most techniques employ lip colour as the main feature, after applying a colour transform to enhance the contrast between the lips and the surrounding skin. However, different imaging systems may produce different colour values, even for the same subject and under the same lighting conditions.

We present a lip segmentation method for hyper-spectral images (HSI), namely blood concentration face maps generated from HSI data by using narrow spectral bands. The advantage is that in blood concentration maps, the lip spatial pattern is more enhanced than in standard colorimetric maps. To achieve this, we replace the usual colour space transformation with the simulation of Lambertian shading in different directions; Lambertian shaded images support more accurate and robust segmentations than raw images, and are less sensitive to acquisition conditions than colorimetric transforms. The Lambertian-shaded images then undergo morphological reconstruction to localise the lip region, and the lip boundary is reconstructed using Fourier descriptors on candidate segments. Figure 1 shows the flowchart of the method.

The acquisition system for generating the HSI data is part of a more complex multisensory platform for medical applications, namely, a smart mirror for the detection of facial signs of cardio-metabolic risk [1]. The platform, named Wize Mirror, has been developed within the European project SEMEOTICONS [L1]. While a subject sits in front of a mirror – either as a part of the daily morning routine at home, or in the gym or the pharmacy – the Wize Mirror detects signs of cardio-metabolic risk on the face, and advises how to reduce the risk through behavioural change. The signs include both physical and emotional traits. In this context, the lip segmentation algorithm we present was intended to support emotional analysis. However, Lambertian shading could be applied as a contrast enhancement step in other applications involving segmentation.

Hyper-spectral image generation: blood concentration maps

Colour is given by the scattering and absorption of light within the layers of skin. The blood supply in sub-cutaneous districts affects the optical properties of skin. Thus, these properties can be used to derive blood concentration maps. The acquisition system consists of five compact monochrome Flea3 3.2 MP USB 3.0 CMOS cameras (Point Grey) with band pass filters at selected wavelengths, and two computer controlled LED light sources (white light and ultraviolet). The blood concentration maps are calculated based on the average spectral intensity in four different wavelength bands, selected to maximise sensitivity to blood amount and saturation, while compensating for tissue scattering effects and melanin influence [2]. Figure 2(left) shows a face image along with its blood concentration map. The false-colour surface representations of the lip region in Figure 2(right) shows how the lip pattern is better discriminated in the blood concentration map than in standard colorimetric maps.

Contrast enhancement through simulated Lambertian shading

The main idea is to enhance the lip spatial pattern in concentration maps by exploiting texture changes generated by different simulated Lambertian illuminations. Viewing the map I(x,y) as a topographic relief, the shading LS(x,y) can be obtained by simulating a Lambertian light source, i.e., consid-

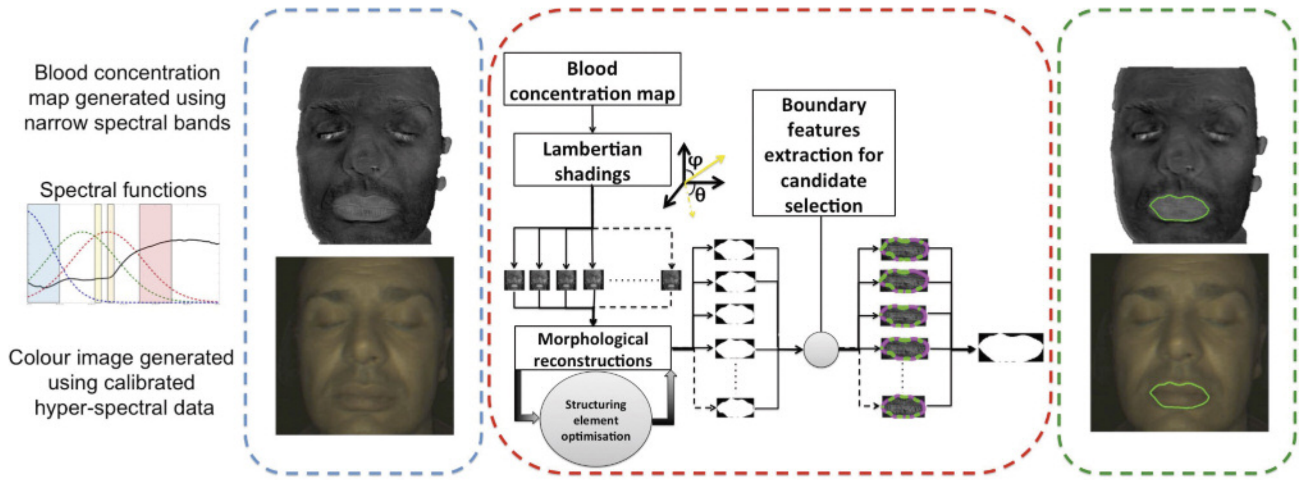

Figure 1: The pipeline of the lip segmentation method..

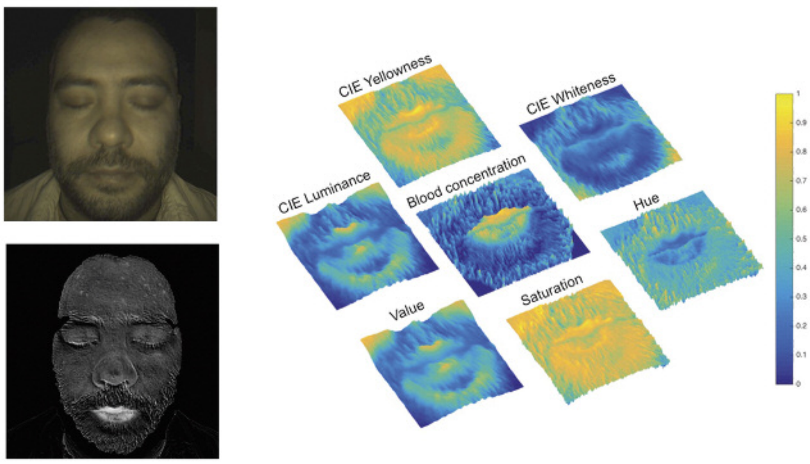

Figure 2: Left: a colour image of a face and the corresponding blood concentration map. Right: comparison of the blood concentration map with colorimetric maps (false colour representation).

ering the cosine of the angle between the relief normal at each point and the light direction. Different shadings can be computed by specifying different elevation and azimuth coordinates for the light source, and weights for controlling the results. The shaded image J(x,y) is simply the result of matrix multiplication: J(x,y) = I(x,y)·LS(x,y). We generate a set of shadings, which are then processed to segment the lip. On a Lambertian shaded concentration map, lips appear as compact and bright areas. Figure 3 illustrates Lambertian shading along different directions, together with the corresponding lip regions, with false colours.

Lip region detection and boundary extraction. To discriminate the lip region from the surrounding skin areas, we perform a series of morphological operations on the Lambertian shaded images, namely geodesic erosions followed by geometric dilations with a flat ball-shaped structuring element. The sequence is optimized by reducing the dimension of the structuring element for localising bright regions (peaks, in topographic terms), which satisfy geometric constraints (orientation, connectivity, solidity, eccentricity). Once the lip region is segmented, the lip candidate is selected by using shape descriptors on Fourier-based modelled lip boundaries.

Figure 4 shows some results of our automatic segmentation technique. Experiments on both a public hyperspectral dataset and an in-house developed dataset of real data from volunteers showed robustness to noise and moustaches, and significant improvements in the performance with respect to competitors [3].

Link:
[L1] www.semeoticons.eu

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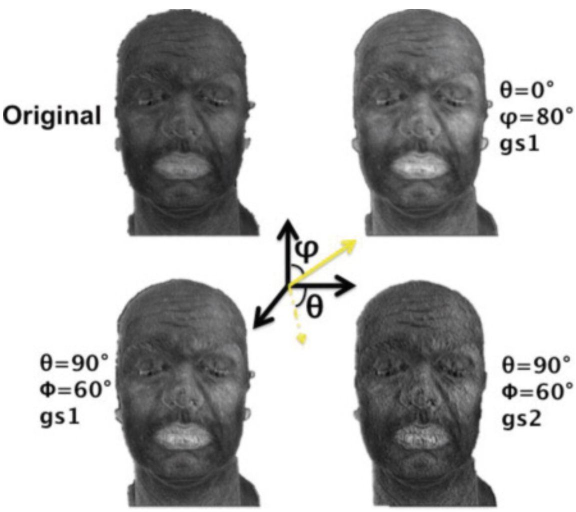

Figure 3: Lambertian shadings corresponding to different coordinates of the light source (elevation and azimuth) and different weights (gradient scales).

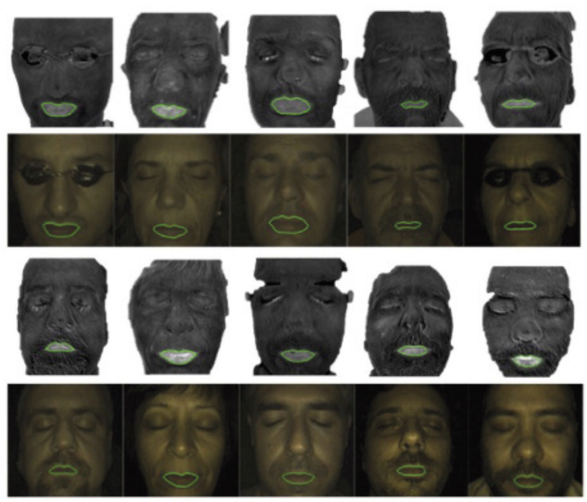

Figure 4: Lip contours segmented on concentration maps, and superimposed on the corresponding colour images.

CV-HAZOP: Introducing Test Data Validation for Computational Imaging

by Oliver Zendel, Markus Murschitz and Martin Humenberger (AIT Austrian Institute of Technology)

Do we really need to drive several million kilometres to test self-driving cars? Can proper test data validation reduce the workload? CV-HAZOP is a first step for finding the answers. It is a guideline for evaluation of existing datasets as well as for designing of new test data. Both with emphasis on maximising test case coverage, diversity, and reduce redundancies.

Computational imaging has played a very important role in a series of applications in the past decade. Methods such as pattern recognition, 3D reconstruction, and image understanding are used in industrial production, entertainment, online services, and recently in advanced driver assistance systems and self-driving cars. Many safety-critical systems depend on computer vision (CV) technologies to navigate or manipulate their environment and, owing to the potential risk to human life, require a rigorous safety assessment. Due to the inherent uncertainty of purely visual information, quality assurance is essential in CV and using test data is a common way of achieving this. Figure 1 shows examples for challenging situations for CV algorithms.

Unfortunately, researchers and engineers often observe that algorithms scoring high in public benchmarks [1] perform rather poorly in real world scenarios. This is because those limited benchmarks are applied to open world problems. While every new proposed algorithm is evaluated based on these benchmark datasets, the datasets themselves rarely have to undergo independent evaluation. This article presents a new way to facilitate this safety assessment process and goes beyond the basic scope of benchmarking: applying a proven method used by the safety community (HAZOP) for the first time to the CV domain. It provides an independent measure that counts the challenges in a dataset that are testing the robustness of CV algorithms. Our main goal is to provide methods and tools to minimise the amount of test data by maximising test coverage. Taking autonomous driving as example, instead of driving one million kilometres to test an algorithm, we systematically select the right 100 km.

Verification and validation for computer vision

A good starting point is software quality assurance, which typically uses two steps to provide objective evidence that a given system fulfils its requirements: verification and validation. Verification checks whether or not the specification was implemented correctly (e.g., no bugs). Validation addresses the question of whether or not the algorithm fulfils the task at hand, e.g., is robust enough under difficult circumstances. Validation is performed using test datasets as inputs and comparing the algorithm's output against the expected results (ground truth, GT). While general methods for verification can be applied to CV algorithms, the validation part is rather specific. A big problem when validating CV algorithms is the enormous amount of possible input datasets, i.e., test images (e.g., for 640x480 8bit image inputs there are $256^{640x480} \sim 10^{739811}$ different test images). An effective way to overcome this problem is to find equivalence classes, which represent challenges and potential hazards, and to test the system with a representative of each class. Well defined challenging situations, such as all images that contain a glare, are such equivalence classes and certain images are the corresponding representatives (see Figure 1).

CV-HAZOP checklist

Below is a brief explanation of how potential hazards can be found and mapped to entries in the checklist. A more detailed description and an example application is presented in [2].

Figure 1: Examples for challenging situations for computer vision algorithms (from left to right): transparent objects, noise, unexpected objects, particles in the air causing reflections and blur.

The identification and collection of CV hazards follows a systematic manner and the results should be applicable to many CV solutions. To create an accepted tool for the validation of CV systems, the process has to be in line with well-established practices from the risk and safety assessment community. The more generic method HAZOP [3] is chosen over FME(C)A and FTA

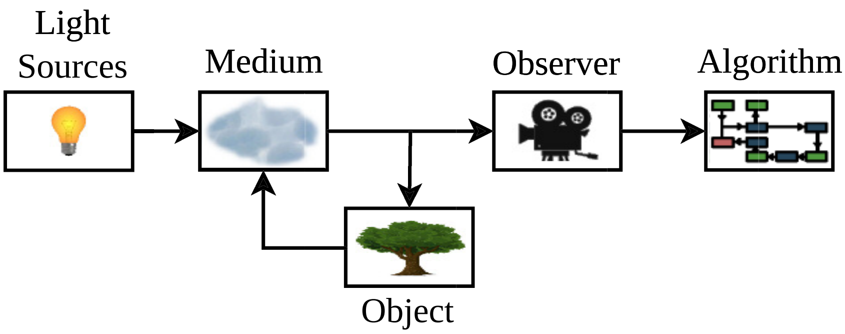

Figure 2: Information flow within the generic model. Light travels from the light source and the objects through the medium to the observer, which generates the image. Finally, the algorithm processes the image and provides the result.

because it is feasible for systems for which little initial knowledge is available. In addition, the concept of guide words adds a strong source of inspiration that the other methods are missing. In the following, we outline the main steps of a HAZOP applied for CV:

1. Model the system: We propose a novel model which is entirely based on the idea of information flow (Figure 2). The common goal of all CV algorithms is the extraction of information from image data. Therefore 'information' is chosen to be the central aspect handled by the system.
2. Partition the model into subcomponents, called locations: Our model consists of five locations: light sources, medium, objects, observer, and algorithm.
3. Find appropriate parameters for each location which describe its configuration. Exemplary parameters for the location object are texture, position or reflectance.
4. Define guide words: A guide word is a short expression that triggers the imagination of a deviation from the design / process intent.
5. Assign meanings for each guide word / parameter combination and derive consequences as well as hazards from each meaning to generate an entry in the checklist.

The CV-HAZOP risk analysis was conducted by nine computer vision experts over the course of one year and results in over 900 entries of possible hazards for CV. We provide a catalog of the identified challenges and hazards (e.g., misdetection of obstacles) which is open and can be freely used by anyone. It will be collaboratively extended and improved by the community. We will maintain it and moderate its modifications, but we invite everyone to contribute improvements. The entire CV-HAZOP checklist can be found on www.vitro-testing.com.

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European Research and Innovation

MR-DIS: A Scalable Instance Selection Algorithm using MapReduce on Spark

by Álvar Arnaiz-González, Alejandro González-Rogel and Carlos López-Nozal (University of Burgos)

Efficient methods are required to process increasingly massive data sets. Most pre-processing techniques (e.g., feature selection, prototype selection) and learning processes (e.g., classification, regression, clustering) are not suitable for dealing with huge data sets, and many problems emerge as the volume of information grows. Here, parallelisation can help. Recently, many parallelisation techniques have been developed to simplify the tedious and difficult task of scheduling and planning parallel executions. One such technique is the instance selection method 'Democratic Instance Selection', which uses the successful paradigm MapReduce. The main strength of this algorithm is its complexity: linear in the number of examples, i.e., O(n).

MapReduce is a parallel programming paradigm for processing massive data sets. It takes a set of pairs <key, value> and applies two separate and distinct tasks to it: a Map task and a Reduce task. The Map tasks receive the input data and produce an intermediate set of pairs <key,value>. Then, the Reduce tasks combine these intermediate values and return an output, which will be the final result of the method [1]. The main advantage of this technique is the opacity on the management of the resources, which provides reliable and fault tolerance executions.

Democratic instance selection algorithm (DIS) [2] is based on the well-known paradigm 'divide and conquer'. It starts by performing a fixed number of rounds r. Every round starts by splitting the data set into subsets of approximately equal size and continues by applying a classic instance selection algorithm independently over the different partitions. Those instances selected by the algorithm for removing receive a vote. After having performed a predefined number of rounds, those instances with more votes than a threshold are removed (the process of determining the threshold is beyond the scope of this article but details can be found in [2]).

Below we present a summary of the adaptation of DIS method to the MapReduce paradigm. This new approach has been called MapReduce DIS or, for short, MR-DIS and its complete implementation, written in Scala and for the Spark framework, is publicly accessible in the following GitHub repository:
https://bitbucket.org/agr00095/tfg-alg.-seleccion-instancias-spark

As mentioned above, by applying MapReduce we work with <key, value> pairs and divide the initial algorithm into two phases (Map and Reduce). In our implementation, we use a set of <votes, inst>. <inst> represents the instance attributes, while <votes> accumulates the number of rounds that the instance has not been selected. The <votes> value is initialised at the beginning of the MapReduce DIS algorithm to zero. Figure 1 shows a possible scenario: the original data set has n instances, and the MapReduce DIS algorithm divides them into partitions with one thousand instances each and performs ten rounds of voting. After that, a threshold of four votes is computed and instances whose votes are below this threshold are selected. Below, both phases of the MapReduce model are explained:

- Map performs the rounds of voting, updating the value ‘votes’ of the pairs in each iteration. At the beginning of each round, the original data set is split into disjoint partitions. In the current version, the partition and distribution of instances are randomly made, thus the value of the key (number of votes of each instance) has no influence. The instance selection algorithm used in each subset is, put simply, the first proposal for condensation (condensed nearest neighbour or CNN), and is applied independently to each partition.
- Reduce estimates the votes’ thresholds and selects those instances that have enough votes. For this task we take into consideration the number of votes each instance has received during the Map phase. In order to estimate the threshold it is necessary to generate r number of groups (as many as rounds), each containing those instances whose number of votes is equal or less than the number of the group. Then, the computation of the threshold requires a classifier for estimating the error. As expected, the calculation of the error by using a sequential algorithm would make the task impracticable (it would produce a bottleneck). For this reason, in the actual implementation, a parallel implementation of nearest neighbour algorithm (kNN) [3] has been used. Finally, those instances with a number of votes below the threshold are selected for the output.

This work was supported by Ministerio Español de Economía y Competitividad under Grant No. TIN2015-67534-P

Links:
http://hadoop.apache.org/
http://spark.apache.org/
https://hadoop.apache.org/docs/current/hadoop-mapreduce-client/hadoop-mapreduce-client-core/MapReduceTutorial.html
https://bitbucket.org/agr00095/tfg-alg.-seleccion-instancias-spark

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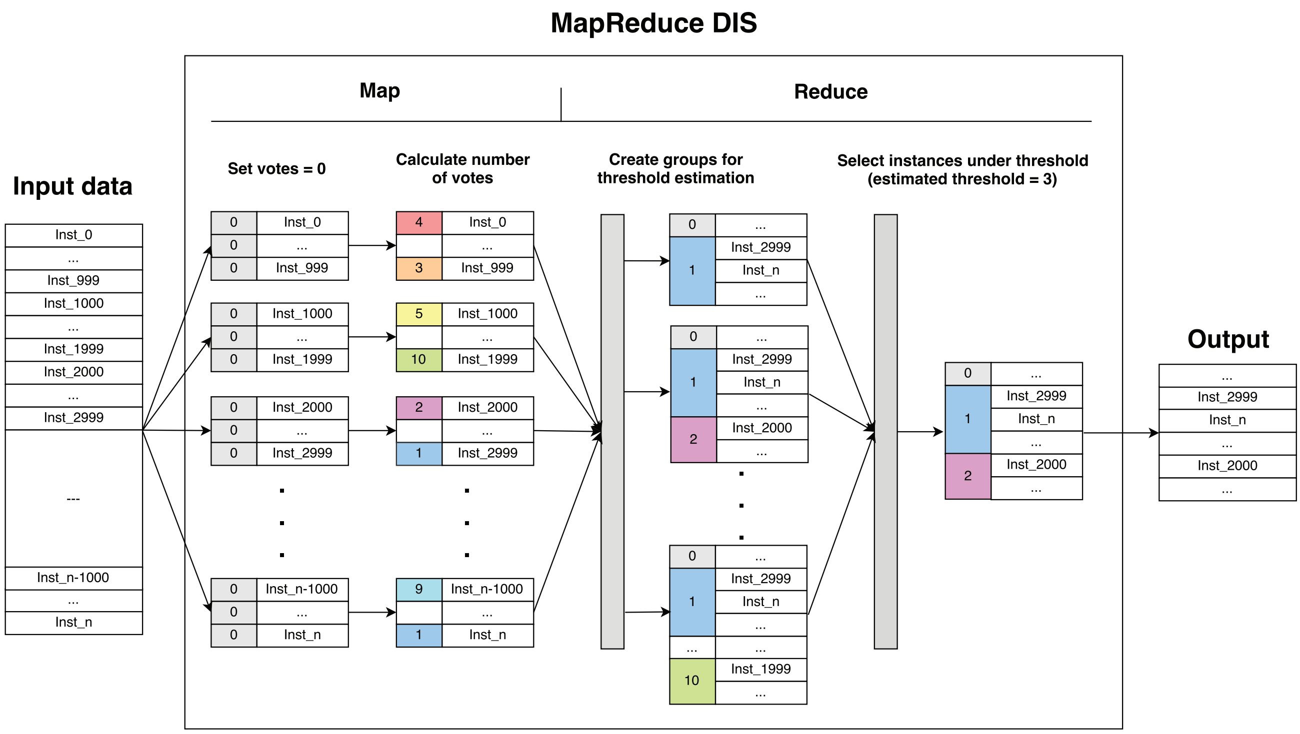

Figure 1: Flowchart of DIS execution using the MapReduce approach.

Towards Efficient Numerical Optimal Transport

by Bruno Levy (Inria)

Recent research results at the junction between mathematics and computer sciences raise the possibility of new computational tools with many possible applications in data analysis, computer graphics and computational physics.

Optimal transport is a domain of mathematics that studies functions that minimise a certain cost and that satisfy a volume preservation constraint. It is very general, and can be used to model a wide class of problems. An efficient numerical solution mechanism is likely to be beneficial to a wide range of applications, comprising data and image analysis, histogram matching, computer graphics and computer animation. It has rich and interesting links with theoretical physics that make it possible to envisage the development of novel numerical simulation algorithms. These new algorithms are expected to be both more efficient and more accurate, by exploiting foundations that are at the intersection between mathematics, physics and computer sciences.

Gaspard Monge is considered the founder of optimal transport in the time of the French revolution. But the mathematical tools required to characterise existence and uniqueness had to wait until World War II, for Leonid Kantorovich (winner of the Nobel Prize in Economics in 1975) to discover the theory of duality. Recently optimal transport has generated renewed interest in the mathematics research community, under the influence of mathematicians such as Yann Brenier [1] and Cédric Villani [2].

Optimal transport is a concise and elegant mathematical language, well-adapted to express certain laws in physics, such as the least action principle and conservation laws. Moreover, the manipulated mathematical objects are very general, and encompass not only 'smooth' ideal objects such as continuous functions, but also less regular ones such as probability measures. The latter can be used to formalise discrete objects, such as point sets or meshes manipulated in computer science.

This generality makes it possible to directly translate the mathematical description of optimal transport into computer language without losing any properties in translation.

The ALICE and MOKAPLAN teams at Inria are currently developing efficient numerical algorithms that can be used to solve optimal transport in a computer. They recently designed the very first 'semi-discrete' solver first in 2D [3] then in 3D [4] (see Figure 1). Such a solver is envisioned to become a fundamental 'building block' for a new class of numerical simulation algorithms, with conservation laws and the least action principle hardwired in its 'DNA'. These two teams currently study applications in computational fluid dynamics [5] in optics, in astrophysics and in material sci-

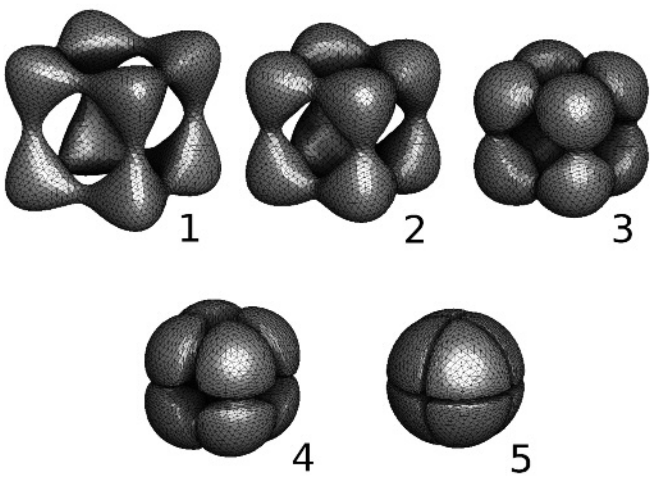

Figure 1: Optimal Transport between a shape and a sphere computed by the 3D semi-discrete algorithm.
Online demo:
http://homepages.loria.fr/BLevy/GEOGRAM/vorpaview.html

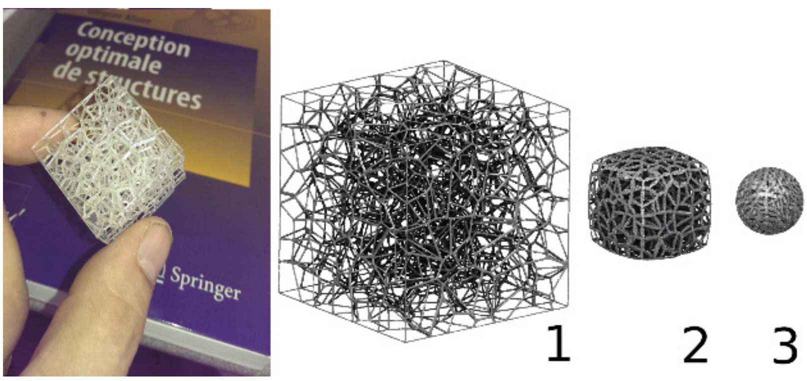

Figure 2: Selective Laser Sintering (SLS) 3D printing technology offers the possibility of creating structured materials with fine-scale geometric details. Optimal transform simulates the deformation of a 'foldable' cube into a sphere while preserving the volume at each step of the deformation.

ences where it can be used to model the deformations of 3D-printed structured materials [6] (see Figure 2). The early numerical experiments indicate a performance acceleration factor of several orders of magnitude.

Leveraging the full power of the method and making it usable in the widest possible range of applications requires further research, both in the geometric part of the algorithm to take into account arbitrary costs besides the L2 cost and in the numerical part of the algorithm to maintain its good speed of convergence even when encountering irregularities.

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Subsampling Enables Fast Factorisation of Huge Matrices into Sparse Signals

by Arthur Mensch, Julien Mairal, Bertrand Thirion and Gaël Varoquaux (Inria)

A new algorithm developed at Inria gives large speedups for factorise matrices that are huge in both directions, a growing need in signal processing. Indeed, larger datasets are acquired every day, with more samples of richer signals. To capture interpretable latent representations in these very big data, matrix factorisation is a central tool. But such decompositions of terabytes of data come with a hefty cost.

New generation data acquisition gives rise to increasingly high dimensional signals: higher resolution in new sensors or better tracking on internet infrastructures. As the overall number of data points collected also increases, the resulting data are huge in both sample and feature size. For instance in brain imaging, new scanners yield images that typically comprise a million voxels. They are used for population imaging, acquiring thousands of time-resolved images for thousands of subjects. In e-commerce, the classic Netflix movie-recommendation dataset comprises more than 100 million ratings. As these datasets are large in both directions, latent factors are often used to capture a lower-dimensional structure. Matrix factorisation is a good solution, often framed as sparse dictionary learning. However, the size of the data poses a severe computational problem. Indeed, for matrices large in only one direction, stochastic optimisation is an efficient solution, for instance online dictionary learning on many measurements of small signals. To tackle efficiently large dimensionality in such online settings, we introduced random subsampling in the stochastic optimisation [1]. The resulting subsampled online algorithm gives up to 10-fold speedups compared to the state-of-the-art online dictionary learning algorithm in brain imaging or movie-recommendation settings.

State of the art: online dictionary learning

The online dictionary learning of Mairal 2010 [2] represents the state of the art in settings with many samples. Using a sparse dictionary-learning formulation, it tackles matrix factorisation by learning a dictionary of signals that can represent the data with a sparse code. The learning problem is framed as a stochastic optimisation: minimising the expected sparse-coding cost of the dictionary. The algorithm accesses the data in batches of samples, computing the optimal sparse code on a batch. The dictionary is then fitted to minimise the cost between the observed samples and the corresponding code. Importantly, this minimisation uses the code obtained along the previous iterations of the algorithm by simply storing sufficient statistics. Hence, the algorithm is both fast and light on memory.

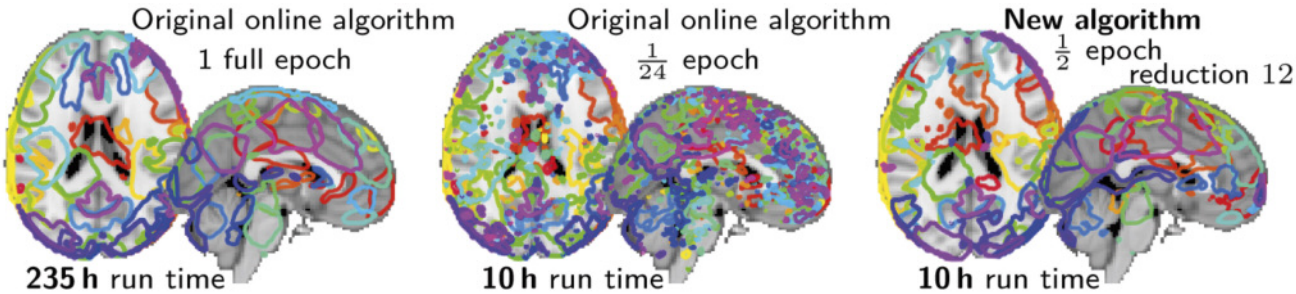

Figure 1: Dictionary learning to decompose brain activity in regions: visual comparison of fitting all the data with the original Mairal 2010 algorithm, and two strategy to reduce time: fitting 1/24th of the data with the same algorithm, or fitting half of the data with the new algorithm with a subsampling of 1/12. For the same gain in computation time, the approach with the new algorithm gives region definitions that are much closer to fitting the full data than reducing the amount of data seen by the original algorithm.

A subsampled version: online matrix factorisation in high dimension

Our algorithm builds upon this state of the art with an important modification: for each batch, it accesses only a random fraction of the features and updates only the corresponding entries of the dictionary. The intuition behind this subsampling is that for high-dimensional signals, there is often a certain amount of redundancy in the information. Subsampling by a given ratio of the features reduces the computation time for each iteration by the same ratio. However, it may introduce noise in parameter updates and its impact on convergence speed must be evaluated empirically. Importantly, as each iteration of the algorithm uses a different randomly chosen set of features, this noise is expected to average out.

Empirical results: large speedups for large data

In [1], we benchmarked this subsampling-based algorithm on two applications: 2Tb of fMRI images and movie-recommendation datasets, the largest being the Netflix data with 140 million ratings. On images, we find that the subsampled algorithm is much faster at learning a dictionary that minimises the sparse-coding cost on left-out data. For collaborative filtering on movie ratings, it converges faster to small errors on left-out data. The gain in convergence time is of the order of the subsampling ratio supported by the dataset: larger data come with more redundancy. We have recorded speed gains from a factor of 6 to 12. Additional benchmarks, soon to be published, show similar speedups on hyperspectral images, where dictionary learning is used to learn a representation of images patches for denoising or classification. Proofs of convergence of the subsampled algorithm require averaging several passes over the data (results in press).

In summary, our algorithm relies on subsampling inside an online solver for matrix factorisation. On very large data, this strategy brings up to 10-fold speedups for problems such as sparse dictionary learning or collaborative filtering. The larger the data, the more pronounced the speedups. With the trend of increasing data sizes, these progresses will likely become important in many applications.

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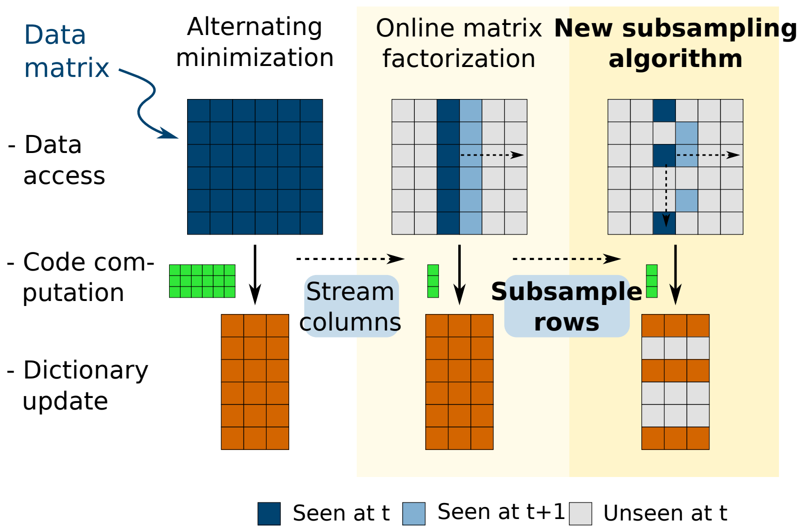

Figure 2: Schema of the algorithmic improvements: the online algorithm access the data by a stream, computing only small portions of the code at each iteration. The new algorithm also subsamples rows, updating only a fraction of the dictionary at each iteration.

Deep Learning Applied to Semantic Content Extraction of Document Images

by Victoria Ruiz, Jorge Sueiras, Ángel Sánchez and José F. Vélez (Rey Juan Carlos University)

The ATRECSIDE research project is investigating applications of deep learning models to automatic handwritten recognition problems, such as non-constrained extraction of text from document images, handwritten text recognition, and summarisation and prediction of texts.

There has been much research on a range of complex problems related with document image analysis, such as document classification and handwritten text recognition. Recently, deep learning models [1] have gained the attention of researchers for many computer vision and pattern recognition applications, due to its impressive performance. convolutional neural networks (CNN) and recurrent neural networks (RNN) are some of the most commonly applied deep learning models. A CNN consists of one or more convolutional layers (often each of these is followed by one subsampling layer), and then one or more fully connected layers as in a standard multilayer perceptron network. Figure 1 shows an example of possible CNN architecture for recognising handwritten words. A RNN allows connections between units to form directed cycles and these networks can use their internal memory to process arbitrary sequences of inputs.

Handwritten text recognition is still an open problem despite of the significant advances carried out in recent years [2]. To work in practical conditions, while maintaining high recognition results, there are still several related problems to be resolved, such as: the presence of noise which makes text segmentation difficult, the high interpersonal and intrapersonal variability in handwritten text, and how to get a computational system to efficiently predict at the level of characters, words, lines or, even, paragraphs.

These problems can be managed by using deep learning techniques and related computational models like CNN or RNN. On the other hand, there exist several standard datasets [2], like MNIST, IAM and UNIPEN, which are used by scientists to report their results on these problems. The impact of recognition errors on the summarisation process is also an open problem. Some researchers have performed text summarisation from documents using deep learning techniques, but these studies do not consider the noise introduced by the recognition process.

ATRECSIDE is a project funded by the Spanish Ministry of Economy and Competitiveness under the RETOS Programme, a complementary action that encourages research on challenge areas identified by the Science and Technology Spanish Strategy. This project, which is operating between 2015 and 2017, aims to investigate problems related to the extraction of semantic content of images scanned from documents using deep learning approaches. In the ATRECSIDE project, we are working on three main problems: (1) non-constrained segmentation of handwritten text from document images (including historical manuscripts), (2) handwritten text recognition, and (3) automatic summarisation and prediction of texts from recognised documents. Three Spanish companies, namely Investigación y Programas, S.A., Graddo, S.L., and Bodegas Osborne, have expressed their interest in the development and results of this project.

More specifically, in the context of the abovementioned second and third problems, we are working on text recognition from image documents in two complementary directions.

First, we are using character and word-level image recognition models that we have created [3] to perform a first identification of the text content that appears in the images. Next, we use language models to complete the identification of the correct text based on the own system's context. This is similar to human behaviour: when we read a 'difficult' handwritten text, we first try to visually recognise each word in the text and if we are not sure about the meaning of a given word, we try to identify it using the context provided by its neighbour words.

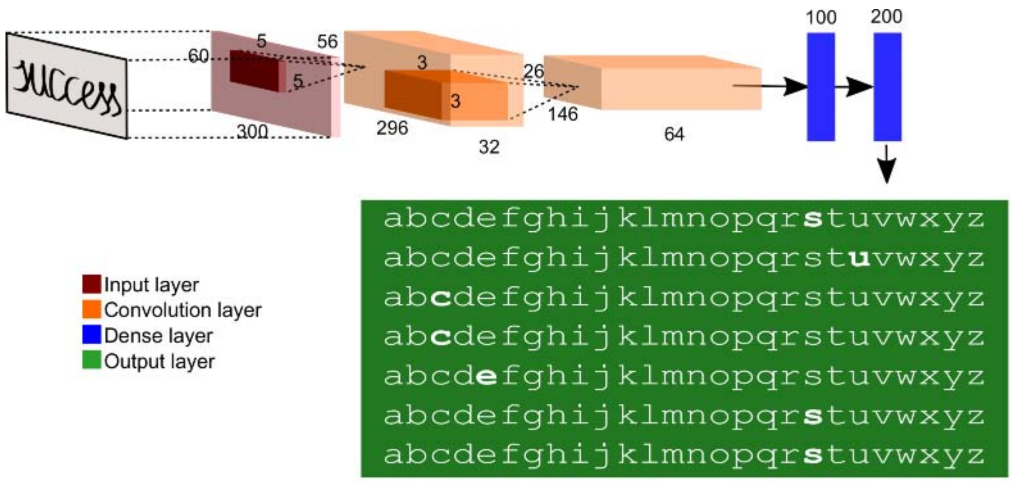

Figure 1: Possible structure of layers corresponding to a Convolutional Neural Network (CNN) trained to recognize handwritten words like: "SUCCESS".

To this end, we are applying deep CNN and deep RNN to evaluate different strategies to recognise the word images. We first defined character-level image models, and applied them with a sliding window over the word images. Good recognition results were achieved with this approach, obtaining an accuracy of 87.5% for the handwritten char-level model with a new synthetic database built in the ATRECSIDE project. We are now working with word-level models that combine deep recurrent and convolutional networks and use of a novel loss function called the connectionism temporary classification (CTC) [3]. Our first experiments with random sequences of 10 digits built with the MNIST database achieved recognition accuracy by 99% when identifying the correct character sequence.

Second, we are also using two approaches in working with language models: one is defined at character-level and the other at word-level. For the former, our models can predict the next character after a sequence of previous characters. These models, which used long short term memory (LSTM) recurrent networks, were tested over the book 'Don Quixote' by Miguel de Cervantes and achieved an accuracy of 58.9% when predicting the next character based on the 20 previous characters.

Future work within the ATRECSIDE project will focus on developing more advanced word-level language models to predict the next word based on previous and next words and combine the two approaches to build a complete system for the handwritten recognition problem.

Link:
http://atrecside.visionporcomputador.es

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Forensics using Internal Database Structures

by Peter Kieseberg, Edgar Weippl (SBA Research) and Sebastian Schrittwieser (JRC TARGET, St. Poelten University of Applied Sciences)

The information stored in databases is typically structured in the form of 'B⁺-Trees' in order to boost the performance of querying for information. Less well known is the fact that B⁺-Trees also store information on their actual construction, which permits the detection of manipulation attempts.

The majority of database management systems (DBMSs) are optimised for maximum efficiency in retrieving information from the stored tables. This means that special data structures are required that reduce the number of times that storage needs to be accessed when seeking a specific item. One of these structures is the B^+-Tree, which has become the de-facto standard for storing information in most database management systems. It is also used in file storage systems like ReiserFS, NFTS or Btrfs (see [L1]). B^+-Trees structure the data into a balanced tree with a maximum of b elements and b/2 to b+1 child nodes per inner node, with b being a natural number selected before the generation of the tree. While typical implementations possess some additional optimization techniques to speed up linear scanning and other operations important in databases, the fundamental structure the same for most current database management systems.

The properties of trees for optimisation of search queries have been studied extensively (see [1] as an example), but one aspect has been widely neglected. The precise structure of the tree for a given set of data elements (hereafter called indices for convenience and because database tables are typically structured along indices) is not unique, i.e. the same set of elements can result in differently structured B^+-Trees. This characteristic can be used to gather knowledge about the generation of the tree. More precisely, it is possible to show that trees that are generated by inserting the indices in ascending order have a very specific structure as shown in Figure 1. It must be noted, however, that the index needs to be a unique key and that no deletion is allowed in the tables. While these criteria seem to be rather specific in nature, they are obeyed by many databases, as they typically enforce the existence of such a primary key, at least as internal key unseen to the user. Furthermore, database information in SOX-compliant environments (or other regulations focussing on traceability) is typically not allowed to be changed after insertion, thus resulting in INSERT-only tables.

This criteria can be used for detecting a certain kind of manipulation, namely a targeted attack, that is problematic for most current detection methods, which typically rely on sanity checks: The attacker, who must have access to the database and knowledge about the internal workflows, manipulates the data just before an important workflow, e.g. a billing process, is started and afterwards restores the original (unmanipulated) version of the information. Thus, the

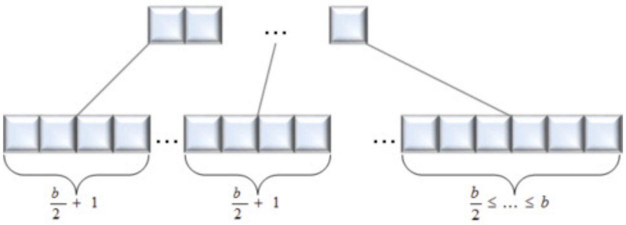

Figure 1: Structure of a B+-Tree generated by insertions in ascending order.

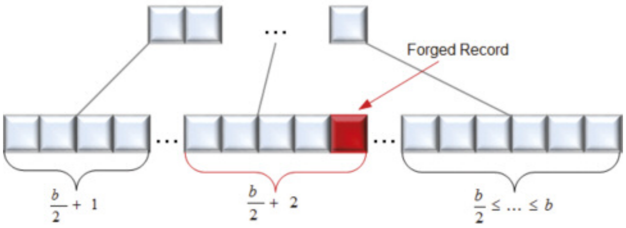

Figure 2: Detection of manipulated records.

manipulation only exists at the time of the workflow execution, all other workflows, especially those used for cross checking and sanity checks, will work on the unmanipulated data, the manipulation thus solely propagates to the targeted workflow. Such attacks are especially interesting in order to remove information from billing workflows, KPI (Key Performance Indicator) calculations and such. While the manipulation is typically not detectable by countermeasures based on sanity checks, log files might capture the changes. Still, log files are typically only checked when errors or strange results are detected elsewhere, e.g., by cross checks. Furthermore, logs can be manipulated by any user possessing administrator privileges on the database.

In our work (see [2]) we provided a new method for the detection of the aforementioned attack by proofing the structure outlined in Figure 1, as well as showing that typical instances of this manipulation attack result in different tree structures (see Figure 2). Here, nodes suddenly possess too many elements, which can easily be detected in open source databases like MySQL. Still, even in these databases it is virtually impossible for the attacker to remove the traces, even when he/she is has administrator privileges.

While this is an interesting result, we are currently investigating further options for using the underlying tree structure of database tables for manipulation detection. Here, our main interest lies in relaxing the side parameters, for example, by allowing random insertion of a unique index, or some degree of deletion. We are also researching whether more specific information on the development of tables can be extracted from the structure of the underlying search tree. Finally, 'table reorganisations' have been identified as a problem for the proposed method, thus we are currently striving to implement measures to keep the structural information preserved. In conclusion, we can see that the internal structures of databases store interesting information for thwarting advanced manipulation attacks. Still, a lot of additional research is needed in order to (i) make the current approach more resilient against database-internal optimisations and (ii) to develop more general approaches that allow detection under relaxed side parameters.

Link:
[L1] https://btrfs.wiki.kernel.org/index.php/Main_Page

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Development Tool Interoperability Specifications and Standardization

by Erwin Schoitsch (AIT), Jürgen Niehaus (SafeTRANS)

Standardisation plays an important role in large industry-driven European research projects that aim to put research results into practice, and are run by EC PPP (Public-Private Partnership) organisations such as ECSEL JU (Electronic Components and Systems for European Leadership, Joint Undertaking) and its predecessor ARTEMIS. In recent years, several projects in the area of safety critical embedded systems have addressed interoperability specifications (IOS) for development tools to reduce costs and errors in critical CPS development and to allow easier integration of tools of different suppliers. CP-SETIS, a Horizon 2020 project, will harmonise these efforts and create a sustainable structure to further develop and maintain the landscape of standards, specifications and guidelines which comprise the IOS.

Cyber-physical systems are everywhere, and the comfort, health, services, safety and security of individuals are becoming increasingly dependent on them. A huge variety of engineering tools are required to address a range of demanding challenges during the development of these systems. To facilitate development and satisfy requirements for fully-fledged traceability throughout the development lifecycle of safety-critical CPS these tools need to be smoothly integrated into engineering environments, allowing fast and efficient development of CPS and smooth cooperation of stakeholders. Organisations that develop CPS are stuck between two extremes: Either to develop their own hard-to-maintain in-house engineering environments, or to be locked-in with proprietary solutions. Therefore past and ongoing ARTEMIS/ECSEL R&D projects, including iFEST, CESAR, MBAT, nSafeCer, HOLIDES, ARROWHEAD, EMC² and CRYSTAL, have proposed open standards for data and tool interoperability, the IOS (Interoperability Specification). Major functional safety standards like IEC 61508 or ISO 26262 have provided some requirements and guidance for tools, but have not tackled the issue of tool chains and tool interoperability.

CP-SETIS is a 24-month Horizon2020 Innovation and Support Action which aims to leverage on these initiatives by proposing and implementing sustainable cooperation and governance structures to:

- facilitate long-term cooperation between all stakeholders – CPS development organisations, end users, tool vendors, research organisations, standardisation bodies, R&D projects, etc.,
- support extensions, advancements and formal standardisation of the IOS in a sustainable manner beyond the duration of research projects.

Interoperability Specification – IOS

The Interoperability Specification covers many aspects and all phases of the development process. It is not feasible to put all these concerns within a single standard. On the other hand, there already exist a number of standards that cover interoperability and/or data exchange aspects between engineering tools. It would be unwise not to take advantage of them. The IOS therefore consists of different parts, each of which:

- deals with a specific aspect of CPS development ('engineering concern'), for example lifecycle data integration and data exchange or heterogeneous co-simulation, and

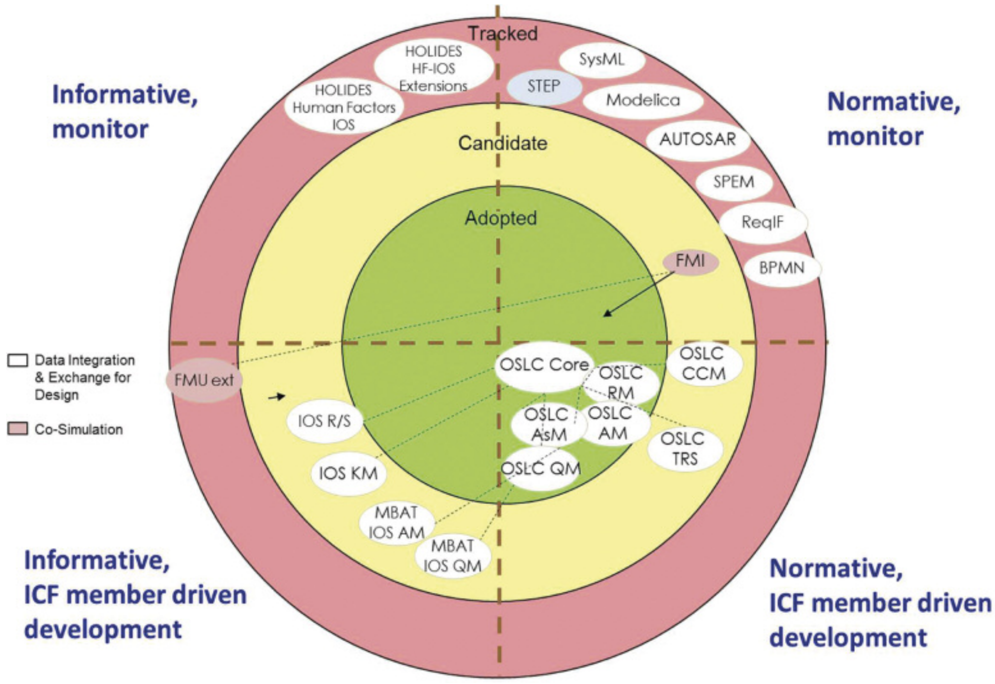

Figure 1: Model of the IOS Interoperability Specifications' Landscape (positioning of the IOS parts within this landscape is an example only, and does not necessarily reflect the current maturity of these parts)

- is based upon existing standards and possible extensions of them.

For lifecycle data integration and data exchange, the underlying existing standard is OSLC (Open Services for Lifecycle Collaboration, see http://open-services.net/), for heterogeneous co-simulation FMI (Functional Mock-Up Interface, http://www.fmi-standard.org) is under consideration. It is noteworthy that IOS includes only those parts of existing standards relevant for the respective engineering concern, but also additional specifications, either as extensions of existing standards or as an independent specification to cover a particular engineering concern. The IOS also includes 'bridges', which describe the relationships between the different engineering concerns and the corresponding interoperability specifications/standards.

IOS Coordination Forum – ICF

CP-SETIS develops a model for a sustainable organisational structure called ICF, as a cooperation platform for IOS stakeholders. Specifically, ICF will:

- collect and make available the current baseline of the IOS, together with information about the concrete technical specifications, maturity level, status of formal standardisation, current versions, and update this information according to results from projects, standardisation activities etc.,
- give organisational support to stakeholders to coordinate their activities to further develop the IOS – e.g., by incubating new R&D projects,
- give organisational support to synchronise activities for formal standardisation of parts of the IOS,
- support the building of an IOS community (contacts to experts, organising workshops, coordinating meetings, etc.).

ICF will also allow stakeholders to

- find allies and cooperation partners, e.g., to extend and shape those parts of the IOS that are relevant to a particular group, including pushing of formal standardisation,
- be able to guarantee sustainability and accessibility for their IOS related project results,
- use ICF as an independent, neutral forum,
- gather IOS related information.

ICF implementation

ICF should be a lightweight structure. In particular, it was clear from the beginning, that ICF would not be a new legal body, but rather a structure within an existing organisation. CP-SETIS contacted various existing organisations to evaluate and find a potential host for ICF:

- ARTEMIS-IA (ARTEMIS Industrial Association, a private partner of the ECSEL JU),
- OASIS (Advancing Open Standards for the Information Society, an international non-profit oriented consortium)
- ETSI (European Telecommunications Standards Institute).

AIT, like other partners, is member of all of these organisations. A selection process was performed based on clear criteria. Details and procedures have now to be confirmed before finalisation of the selection process.

The CP-SETIS/ARTEMIS Strategic Agenda for Standardization

The ARTEMIS-IA Standardisation Working Group has published two Strategic Agendas in the past, supported by the FP7 European research project ProSE ('Promoting Standardisation for Embedded Systems') under contract nr. 224213 (see ERCIM News Oct. 2008, p. 44-45). CP-SETIS is substantially updating this Strategic Agenda, in particular, the way in which standardisation activities for a multi-standard like IOS can effectively be supported. Furthermore, recent developments and evolving new paradigms (e.g., cloud computing, agile software paradigms, contract-based development, run-time qualification/certification, open adaptive systems, IoT, multi-concern assurance) will be considered as standardisation issues.

At the HiPEAC 2017 Conference in Stockholm, a CP-SETIS Workshop will be organised on 23 January. We will discuss IOS achievements, the new Strategic Standardisation Agenda, and collect additional input from participants (https://www.hipeac.net/2017/stockholm/schedule/#wshop).

The CP-SETIS project receives funding from the European Union Horizon2020 Program under grant agreement no. 645149.

Links:
http://www.cp-setis.eu
https://www.hipeac.net/2017/stockholm/

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Enabling Research and Innovation Beyond Continental Borders: A Case for Satellite Events in Evaluation Campaigns

by Frank Hopfgartner (University of Glasgow, UK), Cathal Gurrin (Dublin City University, Ireland), and Hideo Joho (University of Tsukuba, Japan)

A satellite session of the NTCIR (Evaluation of Information Access Technologies) conference was experimentally held in Glasgow, allowing participants to present their work either in Europe or in Asia. This experience, designed to foster research and innovation across continental borders, was a great success.

Local conferences, such as TREC in North America, CLEF in Europe, and NTCIR in Asia, play a leading role in promoting information retrieval research by supporting novel campaigns and releasing datasets to share the latest research challenges. To gain access to these datasets, participants are requested to communicate their work in the form of working notes. Despite the overall success of these conferences, the main drawback is that these working notes are not peer-reviewed. This may pose problems, especially for researchers who cannot easily afford or justify travel expenses to attend such conferences. To overcome the problem of distance, we organised an experimental satellite session that allowed participants of the Asia-based evaluation campaign NTCIR [L1] to present their work either in Europe or in Asia. Given participants' feedback, we see this as an attractive method to foster research and innovation beyond continental borders.

In 2016, we organised a benchmarking task of lifelogging technologies as part of NTCIR, an international series of evaluation workshops designed to enhance research in Information Access technologies. Our task, NTCIR-Lifelog [L2], focused on the development of novel and innovative techniques in the field of lifelogging. As outlined by Gurrin et al. (2014) [1], lifelog access and retrieval poses new challenges for the data science research community. Firstly, lifelog data is challenging to work with; by its nature, it is rich multi-modal data (sensor and media data) with a significant semantic gap to user information needs. Secondly, there are many diverse reasons to access data from a lifelog; an initial suggestion is the "five R's" of memory [2], each of which would require different access methodologies. Thirdly, lifelog data is a continuous stream of data, hence the retrieved unit of information is query-dependent. Finally, effective lifelog retrieval is a multidisciplinary activity, incorporating semantic enrichment, search, summarisation, computer vision, cognitive science.

As part of NTCIR-Lifelog, we released a novel lifelogging dataset, described in [3], and invited participants to work on one of the following two subtasks:

- Lifelog Semantic Access Task (LSAT). In this subtask, the participants had to retrieve a number of specific moments in a lifeloggers life.
- Lifelog Insight Task (LIT). The aim of this subtask was to gain insights into the lifelogger's life. It follows the idea of the Quantified Self movement that focuses on the visualisation of self-tracking data to provide 'self-knowledge through numbers'.

In order to participate in this evaluation campaign, participants are usually requested to present their approach at the NTCIR conference in Tokyo, which took place from 7-10 June 2016. However, since attending the conference in Japan is costly for researchers from Europe, this requirement might discourage interested parties to participate in this campaign. We therefore

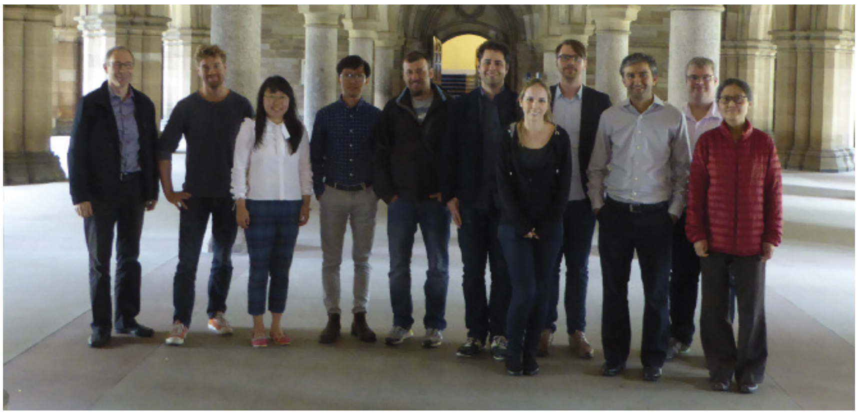

Figure 1: Participants of the satellite workshop in Glasgow.

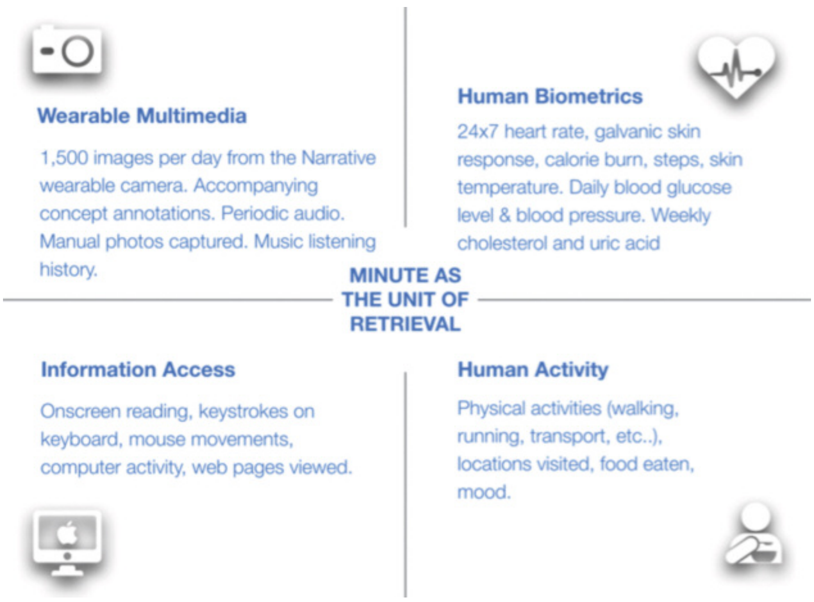

Figure 2: Overview of the dataset recorded for NTCIR-13 Lifelog 2

got the permission from NTCIR chairs to host a satellite session in Europe where teams could present their results.

Thanks to financial support from the European Science Foundation via its Research Network Programme 'Evaluating Information Access Systems', we were able to host such session in Glasgow at the same time and day when the Lifelog session took place in Tokyo. We identified two objectives for the satellite event in Glasgow. First of all, we wanted to familiarise researchers in Europe with the pilot task on comparative evaluation of information access and retrieval systems operating over personal lifelog that we organised as part of NTCIR this year. Moreover, we aimed to establish a network of lifelogging researchers in Europe.

Overall, eight teams decided to participate in NTCIR Lifelog and presented their work [L3]. While six teams sent representatives to Japan, two teams from Europe presented their work in Glasgow. Participants who attended the satellite session in Glasgow, shown in Figure 1, had all worked on lifelogging before, but approached the topic from different angles, including digital preservation, quantified self, human-computer interaction, and data analysis. Judging from discussions during the workshop, we believe that both the dataset that was released as part of NTCIR Lifelog, as well as its tasks, has sparked their interest in engaging further with this evaluation task.

We received positive feedback from participants in Glasgow and Tokyo (NTCIR-12 Conference site), as well as from the organisers of the conference. Given this feedback, we are happy that the organisers of NTCIR-13 allowed us to repeat the experiment at NTCIR-13. We are therefore happy to invite interested researchers to participate in NTCIR-Lifelog 2 and present their results in December 2017 either in Japan or in Europe. For NTCIR-Lifelog 2, we are preparing an even richer dataset, consisting of at least 45 days of data from two active lifeloggers, including multimedia data, human biometrics, information access logs, and human activity records. An overview is given in Figure 2.

Links:
[L1] http://research.nii.ac.jp/ntcir/index-en.html
[L2] http://ntcir-lifelog.computing.dcu.ie/
[L3] http://research.nii.ac.jp/ntcir/workshop/OnlineProceedings12/NTCIR/toc_ntcir.html#Lifelog

References:

[1] C. Gurrin, A. F. Smeaton, and A. R. Doherty. Lifelogging: Personal big data. Foundations and Trends in Information Retrieval, 8(1):1-125, 2014.
[2] A. J. Sellen and S. Whittaker. Beyond total capture: a constructive critique of lifelogging. Communications of the ACM, 53(5), 70-77, 2010.
[3] C. Gurrin, H. Joho, F. Hopfgartner, L. Zhou, R. Albatal: NTCIR Lifelog: The First Test Collection for Lifelog Research. In Proceedings of SIGIR 2016, pages 705-708, ACM, 2016.

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Android Security Symposium

Vienna, Austria, March 8-10, 2017

The Android Security Symposium brings together people from different backgrounds (academic, industry, rooting/exploiting community) who are interested in and actively working on Android device security. The event will feature exciting expert talks on various topics around Android and mobile device security and privacy. The symposium is an ideal platform to discuss current and upcoming security developments in Android and provides various networking opportunities.

The Android Security Symposium is organized by the Josef Ressel Center u'smile at the University of Applied Sciences Upper Austria in cooperation with SBA Research and the Institute of Networks and Security (INS) at Johannes Kepler University Linz.

Attendance is free of charge.

More information and list of speakers are available at https://usmile.at/symposium

University College London wins first Minerva Informatics Equality Award

The winner of the first edition of the Minerva Informatics Equality Award is the Computer Science Department at University College London (UCL), UK, for its comprehensive gender policy, the diversity of initiatives put in place as well as the strong evidence of positive impact.

Minerva 2016 edition

This year's edition of the Minerva Informatics Equality Award focused on gender equality initiatives and policies that help develop the careers of female faculty. The Award, organised by Informatics Europe and sponsored by Google, was presented at a special ceremony held in Budapest, Hungary, during the 2016 European Computer Science Summit. Dr Alexandra Silva accepted the Award on behalf of UCL and presented the scope and impact of their initiative.

Three years ago, the Computer Science Department at UCL started the ADVANCE initiative to increase the number of female lecturers and achieve subsequent promotions through the ranks. ADVANCE was led by Dr Ivana Drobnjak and Professor John Shawe-Taylor. It is part of the department's wider Athena Swan initiative, motivated by the UK Athena Swan Charter established in 2005 to encourage and recognize commitment to advancing the careers of women in STEMM disciplines (Science, Technology, Engineering, Mathematics and Medicine).

To help women move from a research career into an academic one, a structured programme for career progression was put in place that focuses in particular on the transition from contract research positions to permanent lectureships. Further actions under the ADVANCE initiative support women once they are on the academic track, addressing life-work balance issues, improving promotion procedures, organising awareness training for all staff, as well as providing support for informal networking and mentoring. The appointment and promotion figures for female staff at the Computer Science Department at UCL provide clear evidence of the positive impact of the measures adopted. One of the key reasons for the success of the ADVANCE initiative was the strong support of the Head of the Department, Professor John Shawe-Taylor.

"The Computer Science Department at UCL is to be congratulated for its strong commitment and comprehensive approach to gender equality," comments Micheline Beaulieu, Emeritus Professor of Information Science, University of Sheffield, UK and Chair of the Award Committee. "They implemented several effective strategies which are far reaching and provide a model of sustainable good practice."

John Shawe-Taylor adds: "I am very proud of this achievement of our department. Our committed Athena Swan team works very hard towards implementing strategies to remove obstacles in the path of women's careers in computer science disciplines. My personal involvement in the process has been extremely gratifying and I am very pleased to see the progress we have made. Women have already made huge contributions to computing: in the case of Ada Lovelace it could be argued founding the field. The fact that women have been reluctant to follow this career has cost the discipline dear in terms of missed opportunities and talent. Led by our Athena Swan Champions Dr Ivana Drobnjak and Dr Alexandra Silva, our efforts now are very much focused on providing training and mentoring to other departments and universities, and I am very much looking forward to the interesting work awaiting in the future."

The winner was selected by a prominent team of international experts in an evaluation process that ran from May to August 2016.

Lynda Hardman, President Informatics Europe (left) presents the Minerva Informatics Equality Award to Alexandra Silva from University College London. Photo: Altagra, Hungary.

About the Minerva Informatics Equality Award

The Minerva Informatics Equality Award, organised by Informatics Europe, recognizes best practices in departments or faculties of European universities and research labs that encourage and support the careers of women in Informatics research and education. On a three-year cycle, the award focuses each year on a different stage of the career pipeline: developing the careers of female faculty; supporting the transition for PhD and postdoctoral researchers into faculty positions; and encouraging female students to enroll in Computer Science/Informatics programmes and retaining them.

The 2016 award, sponsored by Google, is devoted to gender equality initiatives and policies to develop the careers of female faculty. It seeks to celebrate successful initiatives that have had a measurable impact on the careers of women within the institution. The award grant is to be used for further work on promoting gender equality.

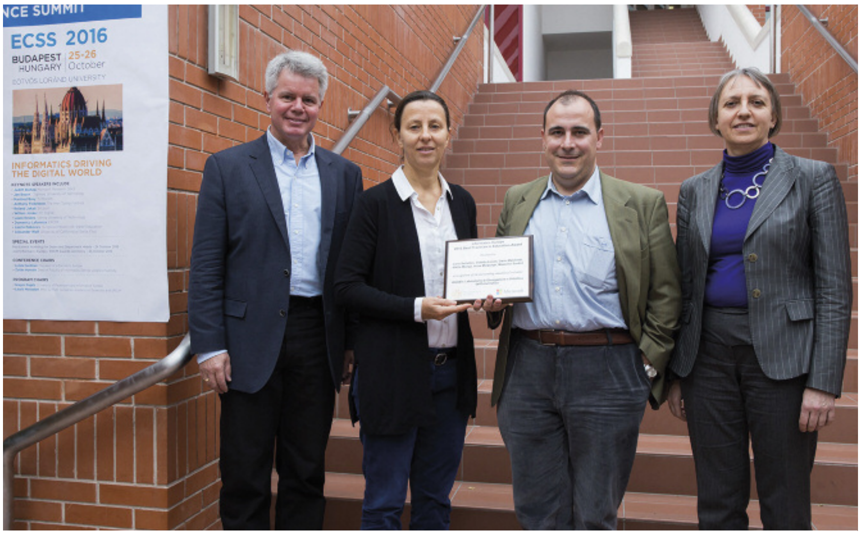
Links:

All Minerva award entries are shared in a best practice collection on the Informatics Europe website:
http://www.informatics-europe.org/awards/minerva-informatics-equality-award/best-practices-in-supporting-women.html

http://www.informatics-europe.org/working-groups/women-in-icst-research-and-education.html

ALaDDIn wins 2016 Best Practices in Education Award

The winner of the Informatics Europe 2016 Best Practices in Education Award is the ALaDDIn project, proposed by Carlo Bellettini, Violetta Lonati, Dario Malchiodi, Mattia Monga, Anna Morpurgo and Massimo Santini, from the ALaDDIn working group at the Computer Science Department, Università degli Studi di Milano, Italy.



Left to right: Michael E. Caspersen, Anna Morpurgo, Mattia Monga, Lynda Hardman. Photo: Altagra, Hungary.

BPEA 2016 edition

The Award, organised annually by Informatics Europe and sponsored by Microsoft Research, was presented at a special ceremony held in Budapest, Hungary, during the 2016 European Computer Science Summit, where the award winner presented the scope and impact of their project.

Initiated in 2008, the ALaDDIn project (ALaDDIn, LAboratory for Dissemination and Didactics of INformatics) has promoted Informatics in schools since 2011 through playful activities via the so-called algomotricity teaching methodology. The methodology has a solid theoretical foundation in experiential learning theory and problem-based learning and stands out by its clear didactical design; an important aspect of the approach is the focus on exploration and scientific inquiry applied to computing topics. To date, almost 3,000 pupils have participated to ALaDDIn's workshops, and more than 500 teachers have been exposed to the methodology.

"ALaDDIn was selected for the clear positive changes the project brought about in pupils' conception of computing. It shows that it can be fun to tackle challenging problems through computational thinking", comments Michael E. Caspersen, Professor at Aarhus University and Chair of this year`s Award Committee. "It is particularly interesting that pupils recognise the necessity of precision and appreciate it as an important asset, not as an inappropriate constraint imposed by teachers."

About the Informatics Europe Best Practices in Education Award

In line with its mission to foster and promote teaching quality in Informatics, Informatics Europe annually presents the "Best Practices in Education Award". The Award recognizes outstanding European educational initiatives that improve the quality of informatics teaching and the attractiveness of the discipline, and that can be applied beyond their institutions of origin. The 2016 award program focuses on initiatives promoting Informatics education in secondary schools.

More information:
http://www.informatics-europe.org/awards/education-award.html

IPIN 2016 Indoor Localization Competition

The objective of IPIN (Indoor Positioning and Indoor Navigation Conference) is to measure the performance of indoor localisation systems designed for offices, hospitals or large public buildings. The 2016 edition was held in Madrid from 4-7 Ocotober and attracted 25 teams. Participants tested their localisation solutions, exploiting the complex and multi-floor structure of the University of Alcalà de Henares.

The competition ended with the awarding of four 1500$ prizes, awarded by the official sponsors of the competition KICS, ETRI, TECNALIA, and ASTI, respectively:
- smartphone-based - Frank Ebner, University of Applied Sciences, Würzburg-Schweinfurt, Germany
- pedestrial dead reckoning - Hojin Ju, University of Seul, Korea
- offline smartphone-based - Stefan Knauth, University of Applied Sciences, Stuttgart, Germany)
- mobile robot - Janis Tiemann, Technical University of Dortmund, Germany.

Researchers from the WNLab, ISTI-CNR, Pisa (Francesco Potortì, Paolo Barsocchi, Michele Girolami and Antonino Crivello) were among the main organisers.

More information:
http://evaal.aaloa.org

Call for Papers

Euromicro Conference SEAA/DSD 2017

Vienna 30 August - 1 September 2017

The Euromicro Conference series on Software Engineering and Advanced Applications (SEAA) and Euromicro Conference on Digital System Design (DSD) are a long-standing international forum to present and discuss the latest innovations, trends, experiences, and concerns
- in the field of Software Engineering and Advanced Applications in information technology for software-intensive systems (SEAA) and
- all aspects of (embedded, pervasive and high-performance) digital and mixed hardware/software system engineering, down to microarchitectures, digital circuits and VLSI techniques (DSD).

Conference and workshop proceedings are published through IEEE Computer Press.

The conferences were attended by about 250 participants during the last years. It organizes plenary sessions as well as up to 6 parallel sessions covering different topics.

The next Euromicro SEAA/DSD Conference is organized by Prof. Radu Grosu (TU Vienna), Erwin Schoitsch (AIT Austrian Institute of Technology, ERCIM DES WG co-chair) and OCG (Austrian Computer Society). Amund Skavhaug, the second co-chair of the ERCIM DES WG, is responsible for the proceedings and co-organizer as Euromicro General Secretary.

Deadlines:
SEAA:
- Paper Submission: 15 Mar 2017
- Notification of Acceptance: 15 May 2017
- Camera-Ready Paper: 15 Jun 2017

DSD:
- Paper Submission: 15 April 2017
- Notification of Acceptance: 10 June 2017
- Camera-Ready Paper : 1 July 2017

Special session organised by the ERCIM Working Group Dependable Embedded Systems
There are several special sessions planned, one of them being organized by E. Schoitsch and Amund Skavhaug: "5th ERCIM/ARTEMIS/EWICS/EUROMICRO Special Session at SEAA/DSD 2017 - Teaching, Education, Training and Standardization for CPS and SoS to Build Sustainable Innovation Ecosystems (TETS-CPSoS)"

Papers from ERCIM Members are welcome!

More information:
http://dsd-seaa2017.ocg.at/

ERCIM "Alain Bensoussan" Fellowship Programme

ERCIM offers fellowships for PhD holders from all over the world. Topics cover most disciplines in Computer Science, Information Technology, and Applied Mathematics. Fellowships are of 12-month duration, spent in one ERCIM member institute. Fellowships are proposed according to the needs of the member institutes and the available funding.

Application deadlines for the next round: 30 April 2017

More information: http://fellowship.ercim.eu/

Call for Papers

SAFECOMP2017

Trento, Italy, 12-15 September 2017

The SAFECOMP conference has contributed to the progress of the state-of-the-art in dependable application of computers in safety-related and safety-critical systems. SAFECOMP is an annual event covering the state-of-the-art, experience and new trends in the areas of safety, security and reliability of critical computer applications. SAFECOMP provides ample opportunity to exchange insights and experience on emerging methods, approaches and practical solutions. It is a single track conference without parallel sessions, allowing easy networking.

Important dates

- Workshop proposal submission: 31 January 2017
- Abstract submission: 21 February 2017
- Full paper submission: 28 February 2017
- Notification of acceptance: 30 April 2017

Topics

The key theme 2017 is "design, verification, and assurance of space systems". The conference covers all aspects related to the development, assessment, operation and maintenance of safety-related and safety-critical computer systems. For an exhaustive list of topics and application domains, please consult the web site.

Workshopsand Exhibition

Workshop proposals are welcome. Information about submissions are available at the conference web site. A dedicated space will be available for a technical exhibition in the communication area where coffee breaks and lunches take place. Organizations wishing to present their products or projects are invited to request further information from the conference secretariat.

Conference proceedings and journal special issue

All accepted regular papers, practical experience reports, tooling reports and reviewed workshop papers will be published by Springer in the LNCS series (separate volumes for the main conference and workshops). In addition, extended versions of the best papers will be considered for publication in a special issue of a safety-related international journal.

ERCIM Dependable Embedded Systems Working Group organises a workshop

The ERCIM Dependable Embedded Systems Working Group (DES WG) co-organizes again a "Dependable Embedded and Cyber-physical Systems and Systems-of-Systems (DECSoS) workshop" at SAFECOMP 2017. The workshop will be held on 12 September 2017)

Workshop chairs are Amund Skavhaug (NTNU) and Erwin Schoitsch, co-charis of the ERCIM DES WG.

Topics are covering aspects from design, development, verification and validation, certification, maintenance, standardization and education and-training. The workshop allows reports on on-going work aiming at fruitful discussions and experience exchange.

Reports on European or national research projects (as part of the required dissemination) as well as industrial experience reports from work in progress are welcome.

Workshop proceedings will be provided as complementary book to the SAFECOMP Proceedings in Springer LNCS.

Deadlines

- Full paper submission: 8 May 2017
- Notification of acceptance: 29 May 2017
- Camera-ready submission: 12 June 2017

The international programme committee is composed of selected EWICS and ERCIM members, led by the workshop organizers.

Papers from ERCIM members are particularly welcome!

Link: http://safecomp17.fbk.eu/

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W3C Workshop Report: Web & Virtual Reality

During the Web & Virtual Reality Workshop organized by W3C in October 2016, hosted by Samsung, 120 participants representing browser vendors, headset and hardware manufacturers, VR content providers, designers and distributors analysed the opportunities provided by making the Web a full-fledged platform for VR experiences. They recognized the strong prospects already opened by existing and in-development Web APIs, in particular the WebVR API that was highlighted as an important target for near-term standardization, as well as the high priority of making the Web a primary platform for distributing 360° videos. They also identified new opportunities that would be brought by enabling traditional Web pages to be enhanceable as immersive spaces, and in the longer term, by making 3D content a basic brick available to Web developers and content aggregators.

The work on more mature proposals continues in the existing W3C Working Groups, while more exploratory ideas will be incubated in appropriate W3C Community Groups. W3C invites all the interested stakeholders to join and contribute to W3C's work in that space.

Links:
Report:
https://www.w3.org/2016/06/vr-workshop/report.html

WebVR API:
https://w3c.github.io/webvr/

Join W3C:
https://www.w3.org/Consortium/join.html

ERCIM
European Research Consortium for Informatics and Mathematics

ERCIM – the European Research Consortium for Informatics and Mathematics is an organisation dedicated to the advancement of European research and development in information technology and applied mathematics. Its member institutions aim to foster collaborative work within the European research community and to increase co-operation with European industry.

ERCIM is the European Host of the World Wide Web Consortium.

Consiglio Nazionale delle Ricerche
Area della Ricerca CNR di Pisa
Via G. Moruzzi 1, 56124 Pisa, Italy
http://www.iit.cnr.it/

Centrum Wiskunde & Informatica
Science Park 123,
NL-1098 XG Amsterdam, The Netherlands
http://www.cwi.nl/

Fonds National de la Recherche
6, rue Antoine de Saint-Exupéry, B.P. 1777
L-1017 Luxembourg-Kirchberg
http://www.fnr.lu/

Foundation for Research and Technology – Hellas
Institute of Computer Science
P.O. Box 1385, GR-71110 Heraklion, Crete, Greece
http://www.ics.forth.gr/

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