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Guest Editorial: Special Section on Assistive Computing Technologies for Human Well-Being

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ABSTRACT Well-being is a complex concept, that can be affected by long-term or temporary disabilities, as well as the natural process of aging. Nowadays, while meaningful computing methodologies have reached maturity, and a full awareness of the problem dimension has been reached, we are facing the objective of designing ad hoc technologies with the real potential of improving the quality of life of fragile individuals. Technology may contribute in different directions: by providing health-care providers with well-being assessment tools, by designing computer-assisted monitoring and rehabilitation methods that help maintaining independence, or by proposing assistive aids to compensate disabilities. The aim of this special issue is to promote a dialogue between healthcare and technology researchers in order to conceive effective solutions that tackle real needs of fragile people thus improving their well-being.

INDEX TERMS Well-being assessment, assistive technologies, ambient assisted living

I. MOTIVATIONS AND OBJECTIVES

The notion of well-being is a complex multidimensional process that encompasses the physical, cognitive, psychological, economic, and social domains [1]. Long-term or temporary disabilities, as well as the natural process of aging, have in general a negative impact in one or more of these domains, oftentimes leading to a condition of reduced independence and increased vulnerability, which is commonly termed "frailty". It should be noticed that, as life expectancy continues to increase worldwide, so does the proportion of fragile citizens with respect to the entire population [2]. Such a dramatic change in the population distribution has a number of long-term societal implications, which can be attenuated by devising more effective mechanisms to improve the quality of life and the independence of older individuals. The changing needs of the population as well as progress in science and technology have encouraged significant research efforts carried out by different research communities: psychologists and clinicians directly involved with the patient's health, engineers and scientists focusing on the design and development of enabling technologies. In recent years these scientific challenges have been formalized in different but related objectives, known by a variety of names—affective medicine, positive technology [8], or the more familiar Ambient Assisted Living (AAL) [3]–[5]. Nowadays, while meaningful computing methodologies have reached maturity, and a full awareness of the problem dimension has been reached, we are facing the objective of designing ad hoc technologies with the real potential of improving the quality of life of fragile citizens. Indeed, despite significant advances in the AAL domain, much remains to be done towards the development of intelligent systems to improve the overall well-being of users in need for assistance. Several aspects of the existing technology require further research efforts to make them robust, reliable, and usable [6].

The seven papers included in this special issue represent well solutions for the design and evaluation of new technologies for assessing, monitoring, and supporting the well-being of fragile individuals with rehabilitation aids and assistive systems. The potential benefits of the proposed methodologies touch several aspects of well-being—social, physical, and cognitive. Moreover, the papers have the potential of stimulating new conversations among healthcare and technology researchers, a necessary condition to ensure that these new systems address the correct needs to ultimately benefit their target population. We hope this special issue will encourage further research in this field, in order to ensure reliable and effective solutions.

II. CONTRIBUTIONS

The first two contributions of this special issue focus on the problem of *well-being assessment*. In *Sparse logistic maximum likelihood estimation for optimal well-being determinants*, Sironi and Lin propose a methodology to evaluate well-being; specifically they consider the concept of optimal well-being, a multi-dimensional construct that incorporates cues for determining subjective and psychological well-being. In their work, the authors address the problem of identifying the most relevant parameters for such a concept, casting the problem as a regression task and employing sparse optimization to solve it. The selected predictors are experimentally assessed using data from the European Social Survey.[1] The analysis confirmed the effectiveness of their sparse representations for the correct classification of people meeting the criteria of optimal well-being. An assessment tool for speech intelligibility is proposed by Chandrakala and co-authors in *Bag of Models based Embeddings for Assessment of Neurological disorders using Speech Intelligibility*. Abnormalities in speech intelligibility are often a sign of a degradation in the articulation ability. Automatic tools can help speech therapists to perform intelligibility assessment in an objective way. The authors propose an approach based on the well-known bag-of-models framework that employs Gaussian mixture model embeddings and classical support vector machines to represent impaired speech utterances, finally assessing neurological disorders based on different intelligibility levels and predicting the respective intelligibility scores. The method is experimentally evaluated on two public datasets, where it shows improved results with respect to alternative approaches, noting that it is particularly suitable when limited amounts of training data are available.

A core element of assistive computing technologies is their capability of automatically detecting unusual or abnormal behavior patterns. Two papers of the special issue address *monitoring tasks*, exploiting different technologies: wearable sensors and unmanned aerial vehicles. In *Online Fall Detection using Recurrent Neural Networks on Smart Wearable Devices*, Musci *et al.* present the design of a software architecture based on recurrent neural networks for fall detection that runs entirely on an embedded wearable device. They extend a well-known and publicly-available dataset with fine-grained temporal annotations to perform the supervised training of the neural network. Their experimental results demonstrate that the proposed architecture can detect falls with more than 90 percent accuracy based only on data collected by a gyroscope and an accelerometer. Their approach compares favorably to existing detectors based on statistical descriptors of the input signal, and it can perform real-time detection on a modern ultra-low-power embedded platform. The article *Virtual Reality Simulation of a Quadrotor to Monitor Dependent People at Home* presents another monitoring tool for individuals with limited ability to live independently. In the article, Belmonte *et al.* design a tool for the development and validation of navigation algorithms used by an autonomous vision-based unmanned aerial vehicle (UAV) for assisted living applications. In particular, the authors propose a distributed architecture based on the real-time communication of two modules, one dealing with the UAV dynamics, trajectory planning and control algorithms, and the other devoted to visualizing the simulation in an immersive virtual environment. An initial validation of a quadrotor model in the context of home care of dependent people demonstrates the advantages of the proposed system, proving to be an effective, safe and adaptable tool for the development of UAVs equipped with an on-board camera and exploiting computer vision.

Computing systems and technologies can be valuable tools in the *motor rehabilitation process* as an aid to expedite patients' recovery. Two papers propose novel methodologies with the potential to bring part of the rehabilitation process to the patient's home, with clear benefits to the patient's well-being. In *A machine-learning model for automatic detection of movement compensations in stroke patients*, Kashi *et al.* propose a machine learning method to guide the rehabilitation of stroke survivors. The method supervises patients as they perform their exercises, providing them feedback on the unwanted compensatory movements they make. The system will enable therapists to access patients' at-home performance records, with the potential of becoming a personal performance assessment tool. The model is trained on movements from 30 stroke patients, each of whom performed 18 movements, which were recorded by a high-precision motion capture system. An experimental analysis highlights the most relevant features for the multi-valued classification task, in a set combining hand-crafted and automatically generated features. Their combination leads to an accurate identification of compensatory movements in 85 percent of the cases. In *A new application for the motor rehabilitation at home: structure and usability of Bal-App*, Pedroli and her collaborators present another contribution to the development of rehabilitation technologies. Bal-App is a tablet-based application that uses 360° videos to assist the motor rehabilitation of frail elderly individuals. The article investigates the potential of 360° videos to improve balance in frail patients through a series of increasingly difficult interactive assisted exercises, which were developed based on existing motor rehabilitation protocols for improving balance in elderly individuals. Usability studies indicate that patients are able to successfully perform the activities without assistance and would be willing to use the tool at home as a guide for motor rehabilitation.

Finally, the article *Live Wire – A Low-Complexity Body Channel Communication System for Landmark Identification* by Crepaldi *et al.* proposes an *assistive technology*, introducing a Body Channel Communication (BCC) system that allows visually impaired people to interact with an environment augmented with low-power anchor nodes that provide information about objects present in the environment. The anchor nodes are connected to metallic surfaces, which when touched by the user, form a communication channel with a wearable receiver that provides haptic and auditory feedback

[1]https://www.europeansocialsurvey.org

to the user. Compared to existing BCC solutions, *Live Wire* provides a more versatile and lower complexity alternative for the design of assistive environments for visually impaired individuals.

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REFERENCES

[1] G. Riva, R. M. Baños, C. Botella, B. K. Wiederhold, and A. Gaggioli, "Positive technology: Using interactive technologies to promote positive functioning," *Cyberpsychol. Behav. Soc. Netw.*, vol. 15, no. 2, pp. 69–77, 2012.

[2] Y. Kamiya, N. M. Sim Lai, and K. Schmid, "World population aging," United Nations Report, NY, 2020.

[3] M. Leo, G. Medioni, M. Trivedi, T. Kanade, and G. M. Farinella, "Computer vision for assistive technologies," *Comput. Vis. Image Understanding*, vol. 154, pp. 1–15, 2017.

[4] P. Rashidi and A. Mihailidis, "A survey on ambient-assisted living tools for older adults," *IEEE J. Biomed. Health Inform.*, vol. 17, no. 3, pp. 579–590, May 2013.

[5] D. Calvaresi, D. Cesarini, P. Sernani, M. Marinoni, A. F. Dragoni, and A. Sturm, "Exploring the ambient assisted living domain: A systematic review," *J. Ambient Intell. Human. Comput.*, vol. 8, no. 2, pp. 239–257, 2017.

[6] C. Debes, A. Merentitis, S. Sukhanov, M. Niessen, N. Frangiadakis, and A. Bauer, "Monitoring activities of daily living in smart homes: Understanding human behavior," *IEEE Signal Process. Mag.*, vol. 33, no. 2, pp. 81–94, Mar. 2016.

[7] A. Sucerquia, J. D. López, and J. F. Vargas-Bonilla, "SisFall: A fall and movement dataset," *Sensors*, vol. 17, no. 1, 2017, Art. no. 198.

[8] G. Giuliano, L. Raffaella, N. Paolo, N. Nicoletta, and O. Francesca, "Positive technology for elderly well-being: A review,", *Pattern Recognit. Lett.*, vol. 137, pp. 61–70, 2020.

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