Guest Editorial Enabling Technologies for Next Generation Telehealthcare

THE use of Information and Communication Technology (ICT) for health and well-being is rapidly increasing in the majority of high-income countries. The interest about telehealthcare allows the provisioning of various kinds of health-related services and applications over the Internet. There are several benefits associated with tele-healthcare, including: the reduction of infection risk due to optimized patients access to clinical centers; optimized healthcare workflows; containment of hospital costs; increased patient safety; improves in the quality of life of both patients and their families. Common tele-healthcare applications include tele-nursing, tele-rehabilitation, tele-dialog, tele-monitoring, tele-analysis, tele-pharmacy, tele-care, tele-psychiatry, tele-radiology, tele-pathology, tele-dermatology, tele-dentistry, tele-audiology, tele-ophthalmology, etc. In the past ten years, key enabling technologies (KETs) such as Internet of Things (IoT), tools for big data management and processing, Cloud/Edge/Fog computing, Artificial Intelligence (AI), Blockchain reached an advanced maturity, and therefore the potential for revolutionizing the whole tele-healthcare sector.

This special issue provided a snapshot of KETs applications spanning from novel tools, innovative methods, and meaningful use-cases demonstrating significant advancement in health and wellbeing.

The response from the international scientific community was very positive, and the amount of submitted papers well indicates the large appeal of the topics involved: their number has turned out to be equal to 89. Although all those papers presented very high quality and interesting applications, only seven papers met the highly demanding criteria for publications followed by the Editorial Board, being selected for final inclusion in the special issue.

These selected papers showed a wide variety of cutting-edge topics, which covered a large part of the issues mentioned in the Call for Papers.

The first paper, by Cilia *et al.* [A1], dealt with the early diagnosis of Alzheimer's disease (AD). Following the general view that the onset of this disease alters handwriting first, the paper focuses on the analysis of this ability. Since handwriting could be altered by age too, the authors of this paper pointed out the importance of defining effective features to discriminate the cause of alteration. Namely, they investigated the performance for AD diagnosis of a combination of shape and dynamic features. They considered a database of on-line handwriting samples and represented each sample with a color image expressing the dynamic information associated to elementary traits. To account for the shape information, instead, they generated for each sample a binary image. Finally, they used a Convolutional Neural Network (CNN) to perform the automatic extraction of useful classification features from both color and binary images.

Grooby *et al.* [A2] proposed a new methodology aiming at easing the automated neonatal chest sound auscultation for future telehealth applications. More precisely, the goal of this study consisted in an objective and automatic assessment of the signal quality so that the estimation of Heart Rate (HR) and Breathing Rate (BR) from noisy neonatal chest sounds could be improved in terms of accuracy and reliability. As a matter of fact, the advancements in digital stethoscopes, internet of things, signal processing and machine learning make it possible an easy collection and transmission of chest sounds to the cloud where they can be remotely monitored and diagnosed. Unfortunately, when recordings are of low quality, remote monitoring and diagnosis become more complicated, and this holds especially true for neonatal care. To overcome this problem, a new methodology relying on feature selection, class balancing, and hyperparameter optimization was proposed in this paper. This methodology allowed automatically estimating the HR and the BR from the chest sound. The authors compared their results against several approaches, and this comparison evidenced that the proposed model has very good performance.

The third paper by Khan *et al.* [A3] dealt with the task of classifying skin lesion images arriving from different servers. The framework put forward by the authors relied on two modules, one for skin lesion localization/segmentation and the other for classification. The first module was based on a hybrid strategy fusing the binary images generated from the designed 16-layered convolutional neural network model and an improved high-dimension contrast transform (HDCT)-based saliency segmentation. To take advantage at most of the information coming from the binary images, the authors proposed a maximal mutual information methodology giving as output the segmented RGB lesion image. As concerns the classification module, instead, the authors considered a pre-trained DenseNet 201 model and utilized transfer learning to re-train it on the segmented lesion images. Successively, the t-distribution stochastic neighbor embedding (t-SNE) method was used to down-sample the features extracted from the two fully connected layers. Finally, the fusion of these resultant features took place by means of a multi canonical

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correlation (MCCA) approach, and the obtained features were given as input to a multi-class ELM classifier. Several data sets were used to perform the experiments, and a comparison of the obtained results was effected against state-of-the-art methods, which showed the goodness of the approach presented.

Zakka *et al.* [A4] addressed challenges on two aspects related to the interaction between robots and care recipients, specifically a) human's ability to naturally co-operate with robots; and b) the safety of human beings when they co-operate with robots. With respect to these aspects, the authors proposed a proximity sensing solution relying on self-capacitive technology so that an extended sense of touch for collaborative robots could be provided. This can allow approach and contact measurement so that safe and natural human-robot collaboration can be increased. Two operation modes were considered in which the proposed sensing solution could work, referenced to as the interaction mode and the safety mode. In the former mode, gesture command was utilized to manipulate the robot by making use of the sensor ability to locate the point of action. In the latter mode, instead, the robot was enabled by the sensor to actively avoid obstacles.

The paper by Wang *et al.* [A5] focused on a depression-processing architecture relying on functional near-infrared spectroscopy (fNIRS). The architecture included the layers of source, feature and model, to direct the deep modelling for fNIRS. The authors advanced a methodology that worked in the time and the frequency domains to extract features and used deep neural networks to recognize depression. The results showed that the correlation of brain regions was able to successfully tell depression from non-depression, making it notable for the task of recognizing brain functions in the clinical diagnosis and treatment of depression.

Zanet *et al.* [A6] addressed challenges on one of the current gaps in teleaudiology, i.e., the absence of methodologies to perform hearing screening in adults. Such a methodology should be usable independently of the spoken language and of the specific environment. A new automatic speech-in-noise test was developed by the authors which utilized stimuli and could be used for non-native listeners as well. The authors demonstrated the reliability of this new test both in laboratory settings and in uncontrolled environmental noise settings coming from preceding studies. The obtained results indicated that the approach put forward in this paper could be feasible to perform hearing screening in varying environments provided that the system contains an option to self-adjust the test volume and is equipped with headphones.

Finally, the paper by Bondy *et al.* [A7] evidenced the importance of finding a method for the evaluation of gains and gaps of collaborative technology-mediated workflows. Once assessed this, the authors introduced a suitable evaluation framework, called Collaborative Space – Analysis Framework (CSAF), that consisted in five sequential steps useful to create and evaluate collaborative workflows: definition, assessment, technology-mediated development, technology-mediated assessment, and analysis with the related conclusions. CSAF was then applied to the task of developing a good workflow for hypertension exams based on telehealth. This approach revealed for the faced task the emergence of critical crossdisciplinary evaluation data.

Before we end this Editorial, we do wish to thank all the main actors of this Special Issue, who have all played an important role in its success.

Firstly, we thank the contributing authors, for their original ideas and solutions, and for choosing our Special Issue to present them to the international scientific community, including those whose papers were rejected. We strongly encourage them to keep pursuing their work, in this extremely exciting area.

Also, special thanks must be given to the reviewers for spending their time in evaluating the papers and for providing the authors with sound suggestions aiming at further improving the papers, especially in those difficult times.

Last but by no way least, we wish to wholeheartedly express our most sincere gratitude to everybody at the Journal of Biomedical and Health Informatics for their effective support in the management of this Special Issue, their help made everything easy to manage.

The combination of the efforts from all of the above actors has led to JBHI being able to publish this Special Issue that presents new, interesting, and relevant contributions in the "Enabling Technologies for Next Generation Telehealthcare" field. Our wish is that these papers can represent solid ground on which the international scientific community will base further research in the near future.

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APPENDIX: RELATED ARTICLES

[A1] N. Cilia, T. D'Alessandro, C. De Stefano, F. Fontanella, and M. Molinara, "From online handwriting to synthetic images for Alzheimer's disease detection using a deep transfer learning approach," *IEEE J. Biomed. Health Informat.*, vol. 25, no. 12, Dec. 2021, doi: 10.1109/JBHI.2021.3101982.

[A2] E. Grooby *et al.*, "Neonatal heart and lung sound quality assessment for robust heart and breathing rate estimation for telehealth applications," *IEEE J. Biomed. Health Informat.*, vol. 25, no. 12, Dec. 2021, doi: 10.1109/JBHI.2020.3047602.

[A3] M. A. Khan, K. Muhammad, M. Sharif, T. Akram, and V. H. C. de Albuquerque, "Multi-class skin lesion detection and classification via teledermatology," *IEEE J. Biomed. Health Informat.*, vol. 25, no. 12, Dec. 2021, doi: 10.1109/JBHI.2021.3067789.

[A4] Z. Gbouna *et al.*, "User-interactive robot skin with large-area scalability for safer and natural human-robot collaboration in future telehealthcare," *IEEE J. Biomed. Health Informat.*, vol. 25, no. 12, Dec. 2021, doi: 10.1109/JBHI.2021.3082563.

[A5] R. Wang, Y. Hao, Q. Yu, M. Chen, I. Humar, and G. Fortino, "Depression analysis and recognition based on functional near-infrared spectroscopy," *IEEE J. Biomed. Health Informat.*, vol. 25, no. 12, Dec. 2021, doi: 10.1109/JBHI.2021.3076762.

[A6] M. Zanet *et al.*, "Evaluation of a novel Speech-in-Noise test for hearing screening: Classification performance and transducers' characteristics," *IEEE J. Biomed. Health Informat.*, vol. 25, no. 12, Dec. 2021, doi: 10.1109/JBHI.2021.3100368.

[A7] C. Bondy, L. Chen, P. Grover, V. Hanson, R. Li, and P. Shi, "Evaluating technology-mediated collaborative workflows for telehealth," *IEEE J. Biomed. Health Informat.*, vol. 25, no. 12, Dec. 2021, doi: 10.1109/JBHI.2021.3119458.