Introduction to the Special Theme

The Digital Health Revolution

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This special theme focuses on research advances and perspectives in digital health, offering a glimpse into the diverse range of topics and challenges that the research community is facing in the field.

The convergence of science and technology in our burgeoning digital era is driving a complete transformation of health, medicine and care paradigms, which aim to improve people's long-term wellbeing and quality of life. "Digital health" arises where value-based and system medicine meets digital innovations, harnessing the potential of new technologies to make the patient the point of care and modernise the delivery of health and care services.

Society's ageing population, the growing prevalence of chronic diseases and multimorbidities, and the shortage of clinicians and care personnel are big challenges for health and care systems. Society expects improved quality and experience of health services, integrated care systems, and greater equality of access to health and care [L1].

Digital health can offer solutions by leveraging recent advances in computing methodologies and engineering as well as capitalising on the fertile, multidisciplinary environment and the increasing availability of data. The combination of artificial intelligence and machine learning, big data analytics and computer vision techniques with multi-omics research, portable diagnostics, wearables and implantable sensors is helping us understand biological, social and environmental processes that underlie disease onset. Technologies such as mHealth (mobile health), augmented reality, robotics and 3D printing, may enable more precise diagnoses, interventions and personalised follow-up programmes, and help improve efficiency, resilience and sustainability of healthcare systems.

Digital health emerges as key to ensure the shift towards the 4P paradigm, which aims at more predictive, preventative, personalised and participatory approaches to health and care [1]. However, its realisation requires vast amounts of curated and high-quality data, regulations for privacy, data ownership, security and liability issues, standardisation and interoperability. Trusted solutions should ensure reliability in handling patient safety.

This special theme features research, providing significant examples of the great potential of effective digital health systems, and a panorama of the impactful and vibrant community that is actively working in the field. The presented approaches target:

- clinicians and health professionals, to empower them through the provision of actionable insights for faster and more accurate diagnoses and prognoses, as well as for more precise, patient-tailored treatments, follow-ups and assistance.
- health and care platforms to ensure accessible, interoperable and sustainable systems.
- individuals, patients and informal caregivers, to make them active players in the management of health, via timely and targeted prevention and assistance strategies.

One of the well-established fields for digital health solutions is medical image analysis and understanding, whose recent advances is thrilling the research community. The recent successes of artificial intelligence in computer vision is promisingly heading towards systems that may reduce the workload of radiologists in intensive error-prone manual tasks, and exploit the rich content of imaging data into disease phenotypes for more accurate diagnoses. In her contribution, Anne-Laure Rousseau illustrates the success of deep learning techniques in processing ultrasound imaging data to diagnose kidney diseases, and detect urinary track blocks as well as kidney cancer. She has gathered a multidisciplinary team of engineers and health professionals, NHance, to develop applications that may leverage the great potential of machine learning to overcome the current difficulties in ultrasound reading (p. 6).

The work by Orlhac et al. (p.7) introduces radiomics, an emerging discipline consisting of the extraction of a large number of quantitative parameters from medical images, whose mining may lead to predictive models for prognosis and therapy-response that support evidence-based clinical decision-making. In his work, Colliot (p. 9) discusses some of the most cogent issues pertaining to the interpretability and reliability of artificial intelligence algorithms when applied to medical image analyses. Sermesant illustrates how the rich and detailed information contained in magnetic resonance and computed tomography cardiac images may be used to reconstruct a 3D heart model to provide the physicians with visual data that may be navigated during an intervention and can even predict the result of an intervention (p. 10).

Belmonte et al. (p. 12) introduce a novel approach to medical image analysis based on the recent advances in spatial logics. VoxLogicA is the tool developed by the authors to process both 2D and 3D imaging data. The work by Amelio et al. addresses the problem of medical image registration to track the evolution of a disease over time (p. 13). The authors introduce a new similarity measure to register CT brain images and monitor the evolution of brain lesions.

Barucci et al. illustrate the potential of radiomic analyses to provide prognostic proxy data in the oncological domain (p. 15). The work by Lizzi et al. overviews deep-learning based analyses of mammographic images to assess the risk of breast cancer (p.16). Manno-Kovacs et al. explore the possibility of using augmented reality for the visualisation of 3D imaging data (p. 18).

Advances in artificial intelligence and machine learning are of great help to process multiomics data and, thus, gather an understanding of the processes that underlie disease onset and its response to therapy. In this context, the work by Balvert and Schönhuth (p. 19) presents a deep learning approach to unravel the complex architecture of serious diseases such as the Alzheimer's and amyotrophic lateral sclerosis. Schönhuth and Stougie address the problem of decoding the genetic diversity of viruses, in order to detect potential resistant and virulent strains through the construction of virus variation graphs (p. 20). Manica et al. explore deep learning architectures to predict drug sensitivity (p. 23). They adopt feature saliency techniques to explain the results provided by the network, thus identifying the genes involved. Instrumental to the histopathology analyses is the identification of the optimal stain of the specimen for the specific tissue under examination. Khartchenko et al. (p. 22) use machine learning to predict the quantity of stain in accordance to the quality of the resulting assay.

Supporting clinical decision making is a central idea of digital health, since it permits clinicians to provide evidence-based care for the patients and reduced treatment costs. Ponsard and De Landtsheer (p. 25) combine predictive and prescriptive analytics to optimise the organisation of care processes and the definition of clinical pathways. The work by van Gils combines data derived from various sources (imaging, lab data, neuropshychological tests) into a single tool that supports the differential diagnosis of dementia (p. 26).

Efficient and integrated ICT infrastructures have a crucial role to support clinical practice by delivering the right data and information at the right time to the right end-user (including citizens), thus breaking data isolation and fostering precision medicine and care. Much work has been done in the field, but some important issues remain open (e.g., data interoperability and curation) and new ones are emerging (e.g., integrating and managing citizens' generated data and granting them data access rights). Katehakis and Kouraubali (p. 31) discuss the advances of the European Interoperability Framework developed in response to the needs and expectations that emerged from the last open consultation of the European Commission. Patara and Vicario present an adaptable Electronic Health Record (EHR) system (p. 28). Antila et al. (p. 29) demonstrate that the availability of data collected into EHRs may be successfully used to develop individuals' phenotypic models that may perform better than the risk scores currently in use in routine practice in mortality prediction. The work by Chou Vo et al. reports on recent advances in Vietnam in the deployment of hospital EHRs and their integration into a unified database, named VNUMED (p. 32). Rocha et al. debate the use of FAIR principles to tackle data integration and harmonisation while preserving privacy (p. 33).

For preventative strategies to have a long term impact, it is essential that individuals are empowered as active participants in their health management. This is an area that continues to be a focus in the digital transformation of health and care. Remote and self-monitoring systems are now being designed for work environments to sustain workability of the ageing workforce, as Kocsis and colleagues present in their contribution (p. 35). Their solution relies on a flexible and integrated worker-centric AI System to support health, emotional and cognitive monitoring as well as working task adaptation. User engagement remains a crucial feature to ensure the long-term impact of these personal applications. Manea and Wac (p. 37) describe their approach to engaging behavioural change with a health and well-being personal virtual coach, developed in the WellCo project. Sustained quality of life and independence are the main goal of the contributions by Paternò and colleagues (p. 39) and Boumpa and Kakarountas (p. 40), who propose adaptable assistive technologies to support people affected by cognitive impairments.

The final two papers of the special theme propose approaches to important issues in digital health. Ciceri et al. tackle privacy preservation when developing and deploying data analytics tools, capitalising on a platform developed in the PAPAYA project (p. 42). Spanakis and Sakkalis propose resilient network services for ensuring the continuous availability of Internet connection to mHealth applications, thus safeguarding their reliability and acceptability (p. 43).

In conclusion, this special issue provides the readers with a vibrant illustration of a sample of the multi-disciplinary research activities which underpin the upcoming revolution of digital health.

Link:
[L1] https://kwz.me/hyV

Reference:
[1] M. Flores, G. Glusman, K. Brogaard, N.D. Price, L. Hood: "P4 medicine: how systems medicine will transform the healthcare sector and society", Per Med., 10 (6) (2013), pp. 565-576.

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