Digital Health—Active and Healthy Living

Sumi Helal, Lancaster University

Ramesh Jain, University of California, Irvine

Digital Object Identifier 10.1109/MC.2019.2934590
Date of current version: 22 October 2019

Digital health technologies are expanding rapidly and could potentially transform the current health-care paradigm. The four articles in this special issue focus on active and healthy living with the help of health navigation.

Digital health uses health informatics; wearables; and mobile/ubiquitous computing, artificial intelligence (AI), and other cybernetic technologies to achieve radical improvements in characterizing health states, disease understanding, diagnosis, and monitoring and managing long-term conditions/diseases and, ultimately, transforming the care-delivery system itself. Specifically, digital health aspires (or perhaps promises) to transform the current reactive primary-care system (a point-of-care paradigm) into a proactive, always-on health navigator; this is a continuum-of-care paradigm capable of providing personalized and timely guidance and interventions while furnishing real-time, individual- and population-level health information to individuals, care-delivery systems, and policy makers. This could potentially transform care providers' roles from strictly treating diseases and illnesses to additionally ensuring that individuals remain healthy and health navigated at all times, radically reducing illness incidence and associated costs and staffing burdens.

The broad field of digital health spans a variety of emerging technologies and many multidisciplinary research areas. In this special issue, we focus on active and healthy living—an area described by the recently coined term *health navigation*.[1] Just as a GPS navigator warns us of upcoming traffic and wrong turns, a health navigator will warn us of the consequences of poor lifestyle habits, behaviors, and choices that, when combined, account for approximately 50% of the determinants of health.[2] Through effective, supportive, assistive, and persuasive empowerments, it will lead us to better choices, decisive behavior alternatives, and a generally more active and healthy lifestyle. With health navigation, people will have the opportunity to focus on health and being healthier rather than worrying about diseases and hoping to remain disease free. Unlike the current health-care system, which focuses on diseases and aspires to make people disease free, a health navigator guides people to adopt a lifestyle that maximizes their quality of life by achieving a better health state. Digital health brings a new perspective to what health should mean in our futures.

Before we introduce the special issue contributions, we would like to say a few words about how the industry views and segments digital health technology. This is important knowledge as the gap between research and innovation on one hand and business-sense-based market adoption and growth on the other hand must be clearly understood by both academics and industrialists. A better understanding on both sides will eventually accelerate successful ventures and ultimately have societal impact.

Global Marketing Insight, Inc., reports, "The global digital health market revenue is anticipated to register 29%+ compound annual growth rate from 2019 to 2025, driven by rising demand for remote monitoring services along with favorable government initiatives." This amounts to a hefty rise in the digital health market size, from US$86.4 billion in 2018 to US$504.4 billion in 2025 (Figure 1).

This amazing growth rate is primarily achieved by four key digital health technologies.

- *Telehealthcare*: Telecare is offered via communication technology, such as video doctor

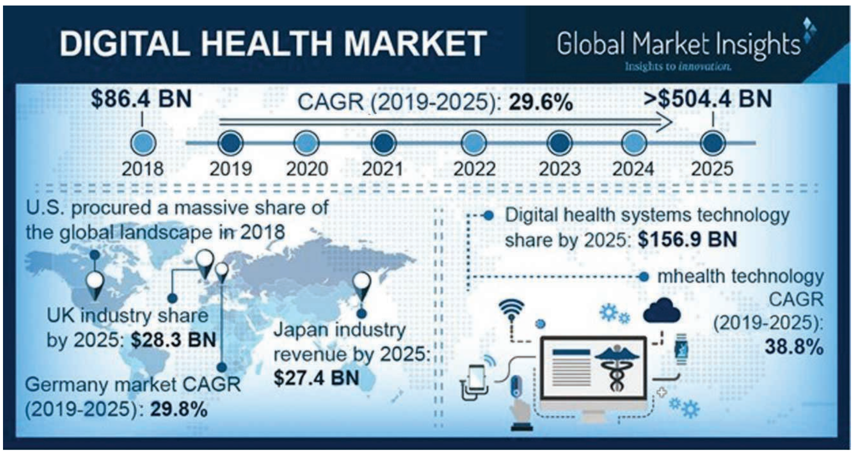

FIGURE 1. The growth, by 2025, of the digital health market. BN: billion. (Source: Global Market Insights, Inc.; used with permission.)

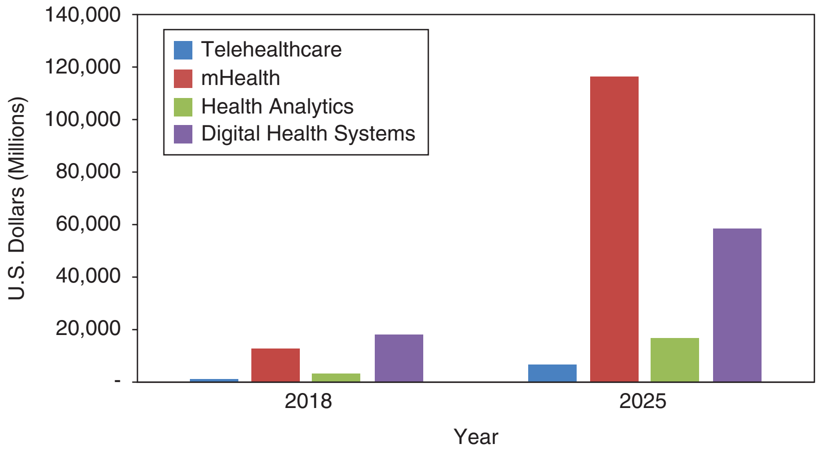

FIGURE 2. The U.S. digital health market size by technology in 2018 and 2025, in millions of U.S. dollars. (Source: Global Market Insights, Inc.; used with permission.)

visits. In telehealth, sensors and monitoring services are activated and used.

- *mHealth*: This refers to mobile health apps and wearables. It is a highly fragmented market, with each product/service contained within its silo and with minimum interoperability or connections to the broader health-provider networks and systems.
- *Health analytics*: AI is utilized over massive health data sets (for example, medical images and pathology test samples) for the accurate diagnosis or better understanding of individual or population health.
- *Electronic health records and decision-support systems*: These are collectively known as *digital health systems*. Several interoperability standards have been developed to drive and achieve a single-identity patient-record system, even though such integration is not happening for many reasons, which are beyond the scope of this introduction.

Figure 2 shows the U.S. digital health market size and its expected growth rate by 2025. The cumulative growth rate of mHealth, for instance, was 10-fold in only seven years, which is incredible.

Several market analysts share the same view of the digital health technology landscape as Global Market Insight. However, the products and services that will be needed as the health-care system integrates with the social-care system are noticeably missing from these analyses. Such integration has started to happen more prominently in Europe where, for instance, Finland has merged the Ministry of Health with the Ministry of Social Care. As such integration gets implemented, digital health as a service technology will emerge. Looking at the health and integrated-care systems from a services perspective reveals significant opportunities for engaging digital health to affect an ecosystem shift: a new health economy unleashed by engaging multiple and new participants, including communities and patients, in their own integrated health-care services delivery—realizing the "Uber" of digital health.

This special issue includes four articles that have been accepted based on peer review out of 11 submissions. In "On the Effectiveness of Deep Representation Learning: The Atrial Fibrillation Case," Gadaleta et al. explore advanced AI techniques reliably detecting atrial fibrillation (AFib) from short and noisy electrocardiography traces, that is, the ones available from smart watches today. It is critical that AFib be monitored and managed because it significantly increases the risk of stroke and other heart-related problems. The authors explore the use of representation learning (RL) for detection and show that an approach purely based on RL outperforms classifiers depending on expert features, which require specific domain knowledge. This underlines the great ability of RL to learn meaningful representations of data without requiring human expertise. Short and noisy traces of data match the data characteristic reality of body rhythmic wearables today, and achieving a higher detection accuracy in this context will go a long way in keeping AFib in check.

In "Agitation Monitoring and Prevention System for Dementia Caregiver Empowerment," Homdee et al. address the caregiver (CG) burden associated with managing patient agitation for persons with dementia (PWDs). The article describes an unobtrusive monitoring system designed to detect early signs of agitation in PWDs by sensing behavioral and contextual information about the PWD and his/her environment. This includes motion and verbal-behavior sensing of the PWDs and the ambient noise level of the environment, among other variables. The monitoring system utilizes a machine-learning-based predictive model trained with agitation patterns in the first 30 days of operation. The authors present a validation study to show that notifying the CG in a timely manner reduces the risk of agitation escalation, which leads to CG burden reduction.

In "Cloud-Based Artificial Intelligence System for Large-Scale Arrhythmia Screening," Tseng et al. take AFib to the population level, as compared to the first article in this special issue. Their article addresses the underdiagnosis problem in AFib and contributes a system and method that can be used to identify accurate city-scale prevalence data of AFib. Having accurate prevalence data helps health authorities plan and budget resources, which should directly lead to better outcomes in treating and coping with this condition. A cloud-based system has been designed to record arrhythmia data from a heterogeneous set of devices (wearables at home and more accurate devices in hospitals and other screening stations). An initial deployment in 13 districts of Taoyuan, Taiwan, (near the Taipei Airport) was used for two years to collect data, which revealed an AFib prevalence of 13.4% in the region of deployment, 3.4% more than the empirically assumed 10% prevalence.

The aim of the article "Artificial Intelligence of Things in Sports Science: Weight Training as an Example," by Chu et al., is to keep healthy people healthy. The article addresses the challenges of using the Internet of Things (IoT) and AI technology in sports medicine, including unobtrusive data collection, IoT accuracy, usability and user experience, and modeling and analysis. The authors introduce a combination of AI and IoT, which they refer to as the *artificial intelligence of things* (*AIoT*), in which they combine a modeling and analysis domain (sports medicine in this article) with the logic and application of the underpinning IoT. They applied their AIoT approach to weight training in sports, specifically to a well-known training set, beginning movement load training. By modeling and analyzing the labor index, they were able quantify its utility and effectiveness in preventing sports injuries and fatigue.

We hope that you find this special issue to be informative and motivating. We also encourage you to consider submitting and publishing your digital health research or emerging-technology development in a future issue of *Computer*.

ABOUT THE AUTHORS

SUMI HELAL is a professor and chair in digital health at Lancaster University, United Kingdom. His research interests include smart homes and assistive technology in support of graceful aging and independent living, e-coaching and patient empowerment for active and healthy living, and architectures and programming models for the Internet of Things. Helal received a Ph.D. in computer science from Purdue University, West Lafayette, Indiana. Contact him at sumi.helal@ieee.org.

RAMESH JAIN is the Bren Professor in Information and Computer Sciences at the University of California, Irvine. His research interests include addressing health for quality of life using cybernetic principles, building on the progress in sensor, mobile, processing, and storage technologies. Jain received a Ph.D. in control engineering from the Indian Institute of Technology, Kharagpur, India. Contact him at jain@ics.uci.edu.

REFERENCES

1. N. Nag and R. Jain, "A navigational approach to health: Actionable guidance for improved quality of life," *IEEE Comput.*, vol. 52, no. 4, pp. 12–20. April 2019.
2. B. C. Booske, J. K. Athens, D. A. Kindig, H. Park, and P. L. Remington, *Different Perspectives for Assigning Weights to Determinants of Health*. Madison, WI: Univ. of Wisconsin, Population Health Institute, 2010.
3. S. Ugalmugale and R. Swain, "Digital health market size by technology," Global Market Insight, Inc. [Online]. Available: https://www.gminsights.com/industry-analysis/digital-health-market