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m_Health Current and Future Applications

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Preface

Introduction to Mobile Health Systems

Mobile technologies have revolutionized our lives in many ways, not only for the ubiquitous communication they support but above all because of the infinite services and possibilities they are able to offer.

Together with the increase in electronics miniaturization and energy optimization today, small connected devices and systems have pervaded our world and even our body.

A mobile health system is hierarchically characterized by four main elements:

1. sensing component capable to measure and process at least one signal from the human that is related to his/her health status: from the simple temperature, to electrocardiogram or even more complex signals or their combination;
2. a processing unit, to directly elaborate the main features of the signals to support an immediate and on-site feedback to the user thanks to dedicated software;
3. the software, nowadays the so-called apps running on mobile devices, smartphones or tablets or similar platforms, that can support the device functions or even be itself the sensing and dialoguing elements with the remote service usually resident on a web-based platform;
4. a cloud/web-based repository with analytical and interpretation capabilities to deliver instant feedback to the user or making available data and information to healthcare supervisors or caregivers.

The Sensing Component

Smart electronic and sensorized textiles, technological fashion accessories like necklaces, bracelets, earrings or pins, belts up to smart tattoos (the last discovery which can upgrade significantly the so-called smart patches) have now been

enriched with sensing capabilities to monitor several body signals describing our activity, our lifestyle, and our health.

We can also identify three main categories of sensing systems:

1. wearable systems that are smart integrated systems close to or in contact with the human body and able to measure, process, and transmit biomedical, physical and chemical data or parameters, and/or even execute mechanical actions if necessary;
2. environmental sensors that are exploiting our physical interaction with objects of our everyday activities: some examples could be the steering wheel while driving or the armrests of our chairs when seated can embed sensors for the two hands thus making possible the collection of heart rate or the bed sensors to detect sleep quality;
3. dedicated devices: they are medical products like portable arterial blood pressure measuring systems or glucose meters that can work both in a standalone mode (in this case, the user has to enter the measurements into a software on the mobile device) or in the more recent systems wireless connectivity can directly implement the data transmission to the mobile host.

The Processing Component

The processing and communication unit is undergoing a very quick and sudden revolution. We have seen the evolution from the cellphone to Personal Digital Assistant to smartphone to tablet to phablet to smartwatches. We are assisting at the development of Web-of-Things paradigm, even if the Internet-of-Things society is still at the beginning and the web-based society is again in the growing phase. Small connected items support data collection and real-time user feedback. This means to have the possibility to have short-term or long-term data-supported intervention in different domains: physical functions and activity, nutrition, and physiological monitoring are the most common ones.

Today, data processing is no more a single device issue: thanks to cloud computing and to sensors networks, this has become a distributed process with redundancy that has increased personal data and information amount, quality, reliability, and specificity.

The Web Component

Together with the basic data processing, the web resources can now offer a new set of capabilities and services: smart storage, analysis services (at personal level or for selected cluster of people), impact and/or forecast analysis for pathologies and for

welfare costs, coaching and/or alerting for chronic diseases management, are the most innovative and common state-of-the-art experiences.

This is crucial to identify new exploitation strategies to improve peoples health and quality of life, to reduce healthcare cost, and to set up a new integrated community of stakeholders including new actors like familiar and not familiar caregivers, technologists, and doctors according to the services purposes and needs.

The Book Structure

From all the above, it is clear that mHealth product-service systems are integrating a great complexity evolving day by day. This book aims at presenting some of the most recent solutions and experiences in mHealth and the related factors: technology, regulatory, innovation, services. Some of these aspects are already on the market, other are still under research and development.

The book opens with a vision provided by the editors about the future of health care in a 20 year horizon: we envisage future devices and services and even pathologies that will characterize our next society. If technology evolves in decades (like in the recent past), health is more resilient to innovation but maybe the coming decades can disrupt this mechanism and mHealth could be an extraordinary tool in this process.

Chapter 2 provides a better contextualization of the mHealth framework, highlighting the implemented and possible solutions for patients and healthcare systems. The benefits and challenges are presented and discussed and provide a vision for the future directions.

Services also mean mHealth exploitation. An analysis and the related methodology to understand risks and opportunities for researchers and stakeholders is therefore important. Chapter 3 is dedicated to this aspect, including in particular the analysis of the relevant Intellectual Property Rights elements and market data. Mobile Health manages sensible data about users at a higher level. For this reason, also in light of the recent adoption of the new legal framework for data management (General Data Protection Regulation, GDPR entered into force on 25 May 2018 in all EU countries), Chap. 4 starts presenting the Hospital 2.0 and the new patient ecosystem scenarios; a specific section of the chapter also explores the threats (together with solutions) for data and service delivery due to possible cyber-attacks. This issue is relevant due to always connected healthcare vision that mHealth is developing.

Chapter 5 describes the data protection issues in detail, offering a synthetic but complete description of the rules, principles, security measures, and policies with a specific application to healthcare professionals training.

This distributed health system paradigm is made possible, thanks to a variety of devices that support the monitoring of most of the basic vital signs and other functions. These systems are presented and analyzed in Chap. 6 for a general overview of state-of-the-art solutions and designing some perspectives.

These devices are more and more miniaturized and embedded in our lives: in our body-worn accessories, in our clothes, and in our environments. Nowadays we can be always measured, 24 hours a day, seven days a week. A huge amount of data and with quasi standard clinical quality due to the wearable measurement paradigm is made available by mHealth devices. This factor represents a crucial issue in mHealth and a recent and growing field of research. Chapter 7 focuses on Big Data and signal processing in mHealth, presenting the most recent algorithms and solutions to extract health parameters and subjects profiles for treatment follow-up, critical events detection, and short/long-term prevention.

The availability of devices and data is the core factor to design new services to improve our health or the management of pathologies. In particular, it is interesting to foresee new services to improve patients care and quality of life together with the reduction of the social cost related to the healthcare processes. This is the central topic of Chap. 8, in which the authors describe these new opportunities through examples and experiences in small-scale experimentations. It is important to understand how to evolve towards a full implementation of the mHealth paradigm to exploit all these positive features and outcomes.

But this exploitation means sometimes and somehow to redesign our Healthcare systems, our structures, and even the current processes. Chapter 9 provides a perspective on the design of the new healthcare systems for the next generations, and the actual and future mHealth directions to contribute in facing new challenges for a better, equal, and advanced world.

Final Remark

This book does not aim to be the ultimate compendium of mobile Health, but proposes the design of a pathway for the development of it: from understanding the basics and the analysis of technologies and available innovation, to the design of new systems and services in its complete chain up to the final stakeholders: users, caregivers, and institutional or private institutes managing or delivering health services to care people and not simply to cure them.

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Acronyms

ANN	Artificial Neural Networks
ARIPO	African Regional Intellectual Property Organization
CDAC	Cyberterrorism Defense Analysis Center
CPC	Cooperative Patent Classification
DDoS	Distributed Denial-of-Service
DFA	Detrended Fluctuation Analysis
DI	Digital Integration
EAPO	Eurasian Patent Organization
ECG	Electrocardiography
EHR	Electronic Health Record
EKG	Electrocardiography
EMA	Ecological Momentary Assessment
EMR	Electronic Medical Record
EPO	European Patent Organization
FERMA	Federation of European Risk Management Associations
FHIR	Fast Healthcare Interoperability Resources
HIE	Health Information Exchange
HRV	Heart Rate Variability
IPC	International Patent Classification
IPR	Intellectual Property Rights
LDA	Linear Discriminant Analysis
NACOR	Normalized Auto-correlation Function
OAPI	Organization Africaine de la Propriété Intellectuelle
PAM	Patient Activation Measure
PPG	Photo-plethysmography
PSD	Power Spectral Density
RMS	Root Mean Square
RMSSD	Root Mean Square of Successive Differences
SDNN	Standard Deviation of Normal-to-Normal Beat Intervals
SDVA	Social Driven Vulnerability Assessments

SE	Social Engineering
SVM	Support Vector Machine
TAs	Targeted Attacks
TAT	Time Above Threshold
USCYBERCOM	US Department of Defense Cyber Command
VM	Vector Magnitude
WIPO	World Intellectual Property Organization
ZC	Zero-crossing

Chapter 1
Introduction

Maria Renata Guarneri, Roberto Sironi and Paolo Perego

Abstract Health care is undergoing a true revolution towards new paradigms for all actors involved, first of all the scientific and clinical side, where traditional reactive approach based on symptoms and disease management is progressively giving way to a systemic approach oriented to proactive, preventive and personalised medicine. In this revolutionary scenario, technological innovation and, in particular, ICT and mobile health play the role of key enablers.

1.1 Introduction

Health care is undergoing a true revolution towards new paradigms for all actors involved, first of all the scientific and clinical side, where traditional reactive approach based on symptoms and disease management is progressively giving way to a systemic approach oriented to proactive, preventive and personalised medicine. In this revolutionary scenario, technological innovation and, in particular, ICT and mobile health play the role of key enablers.

Indeed, the digital transformation which is encompassing all economic sectors is mainly characterised by the so-called big data. A huge amount of digitalised information and data have to be managed, stored, analysed and used by means of advanced semantic annotation and algorithm which allow to understand and interpret the information in relation to specific application field. These software elements, with machine learning algorithm, allows to understand and interpret the information in relation to the specific context, making sense to seemingly incoherent amount of data.

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This allows the development of new models and new approaches to consolidated field of applications like the health care.

The healthcare sector is in fact the most blazoned example, where consolidated models of care are undergoing a deep transformation which is strictly related to the digital revolution; indeed, as evidenced also by Flores et al. [1], three converging megatrends are behind such transformation:

1. The progress of the biomolecular disciplines, the so-called omics, and the increased ability to understand the biological complexity of disease.
2. The digital revolution, with the explosion of the Internet of Things (IoT) and consequently Internet of Medical Things (IoMT), the 'big data' phenomenon, the digitalisation of medical/clinical data together with the enhanced capacity to store and analyse and make sense of such amount of information.
3. A population always connected, with the large use of social networks where people (with the role of citizens, consumers or patients) communicate with others, provide information and, most importantly, have access to information.

1.2 P4 Medicine

The concept of P4 medicine was introduced and illustrated by Leroy Hood in 'A personal view on Systems medicine and the emergence of proactive **P4 Medicine**…' [2]. The four P's are:

- predictive,
- preventive,
- personalised and
- participatory.

As mentioned above, P4 medicine focuses on prediction and prevention; thanks to the results coming from the Human Genome Project,[1] P4 postulates that, ideally, the risk of disease can be predicted at cellular level well before symptoms develop, and therefore, the actual occurrence of disease can be prevented through the participation of the 'patient' in preventive action.

P4 leverages large-scale social participation; patient must be activated and engaged to become protagonists of their well-being. They must be willing to collect and share personal health data, to participate in the development of medical devices, co-design their own monitoring and healthcare treatment system together with physicians, engineers and other welfare actors. As Hood and colleagues indicated in [1], '… the driver of an emerging P4 healthcare system will be information consumer can use to better manage their health'. In the same paper, the authors claim that the P4 approach, combining the integrated/multidisciplinary approach of system medicine with active participation of networked users, will reduce the incidence of disease while providing a more personalised cost-effective healthcare system (Fig. 1.1).

[1] https://www.genome.gov/12011238/an-overview-of-the-human-genome-project.