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Research Paper

Use of smart and wearable devices in health sector and adoption of produced medical data by an integrated Health Care computer system in Greece

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ABSTRACT

The term "mobile health" or alternatively "m-Health" is increasingly used over the last years. The term refers to the medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, Personal digital assistants (PDAs) and other wireless devices. The great challenge for IT specialists in health sector is the use of such devices in order to merge medical data, produced by these devices, with electronic patient records, due to the huge volumes of data produced and as a consequence the difficulties in storing and processing these data. In the current research we present a variety of sensors, smart mobile devices and m-Health applications. In addition, we describe the difficulties in storing and processing these data and we suggest that the implementation of distributed information systems could possibly encounter these problems.

Key words: Computer science in health, e-health, m-health, mobile health applications, wearable devices.

INTRODUCTION

Information and Communication Technology (ICTs) is one of the most significant parameters in a global effort to improve health services, providing technological solutions in the process of monitoring people's health condition, early diagnosis and treatment. Constant technological advances provide new potentials to health services and facilitate medical professionals and health institutions as far as their medical duties are concerned. Computer systems are constantly getting improved, adding new functionality to users. One of the recent services provided is the ability to keep online data recorded by smart mobile or wearable devices in ordered to be processed in such a way that doctors may have a direct and complete view of their patients' health condition. This kind of data can be used either for the early diagnosis of a problem or as data additional to the information already includes in patient's medical record. This survey mainly aims to present the most significant abilities of smart devices in recording health parameters as well as to investigate how these data

can be used in an integrated health computer system.

METHODS

The survey was based on scientific literature review of science publications in Greek and foreign language databases as well as in Greek and foreign literature. The main key words in search process in bibliography and scientific literature are Computer Science in Health, e-Health, mHealth, mobile Health applications, and wearable devices. The research focuses on recent publications since 2013.

SURVEY RESULTS

Information and communication technologies provide a wide variety of tools used in health sector. The technological advances in computer science and telecommunications

have empowered huge improvements in health services.

e-Health

Today's health computer systems use computer applications based either on standalone databases or centralised database systems or distributed database systems in order to keep information concerning patients' health condition (Javier et al., 2015). These data are stored in order to be accessed by patients' doctors or medical institutions such as medical centres and hospitals, resulting in this way to a huge volume of data called Big Data. These data can also be processed in order to improve health services (Jake et al., 2015). These applications are included in a general category of applications of electronic health, alternatively called e-Health. According to European Commission (European Commission and Public health 2019), the term e-Health or digital health refers to tools and services that use data and communication technologies (ICTs) in order to improve prevention, diagnosis, treatment, monitoring and management of health. It enables data exchange among patients, doctors, medical institutions, hospitals and medical information networks.

Electronic medical record

One of the most basic functions of health information systems is to keep electronic medical records for patients. The individual medical record is an important tool in improving the quality of health services provided. The existence of such records in printed and not digital form largely invalidates their usefulness. The establishment of a system of electronic medical records for patients has always been a long-standing demand of health care providers and health professionals, although this has not been fully feasible to date in the Greek health system (Marinis et al., 2012).

Also, storing critical information in stand-alone databases such as in clinics and health centres without the possibility of sharing information to stakeholders also annuls the benefits of the electronic record (Karakolias et al., 2017).

Recently, Law 4600/2019 introduced the Personal Electronic Health Record for all holders of the Social Security Number (AMKA), which was put into force by decision of the Minister of Health and aims among other things, to promote the health of the population. This is the first attempt to gather basic information on citizens' health by recording data from Electronic Prescriptions, hospitalizations in Secondary Care Units and visits to private doctors (Law 4600/2019–GG A43/09.03.2019). The storage of this information is accomplished by digital storage of data in a central database system from where healthcare professionals and patients can retrieve information through authentication and password-based login procedures.
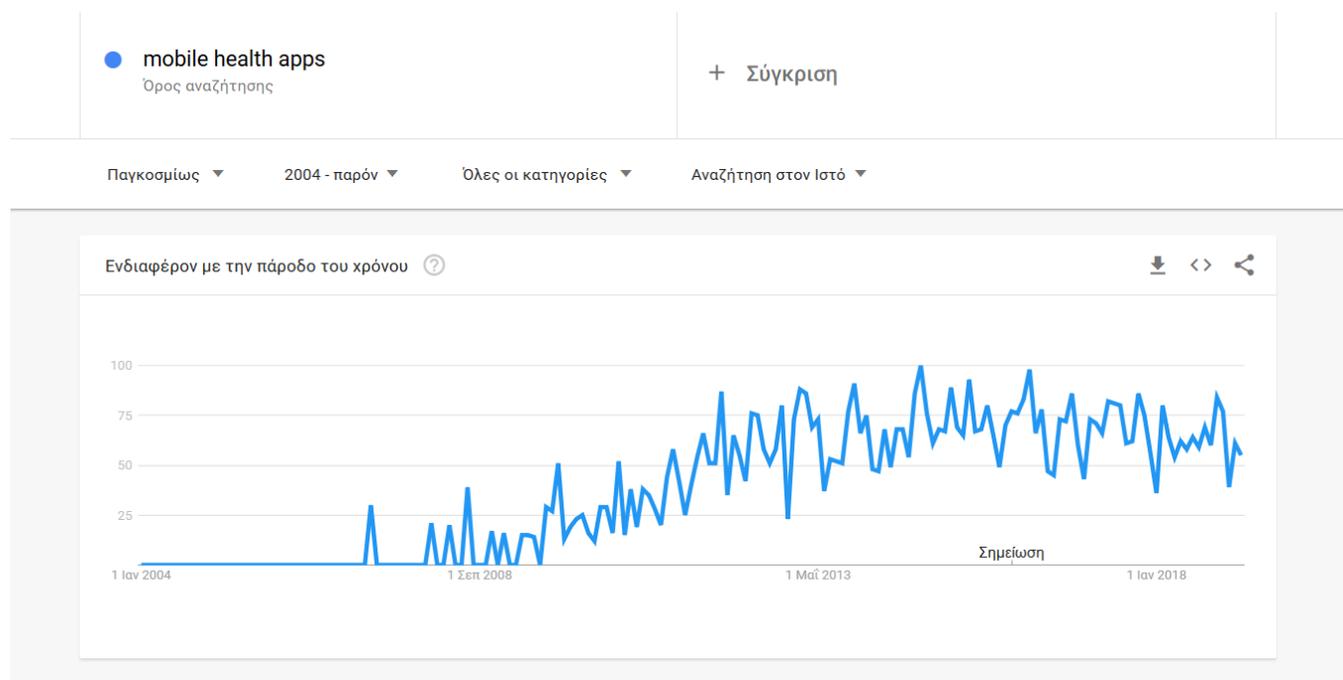
Mobile health

Distance health or telemedicine is a rapidly growing field of application of Information and communication technologies in health, with a key focus on the provision of health care services from a distance (Kubouros, 2015). Taking into account the importance of continuous monitoring of physical condition, activity and various health indicators of patients, health care providers (primary care physicians, hospitals, medical centres) are trying to collect as much data as possible in order to be able to acquire a comprehensive picture of the health condition of the patients.

Continuous developments in the field of information systems and telecommunications are constantly expanding the possibilities of Telemedicine. More specifically, technological advances in the field of mobile devices with processing power (tablets, smart phones, and smart watches) and at the same time wearables or smart implants that can collect and send data to a workstation have created new potentials and prospects for monitoring the state of patients' health (Wang, 2014). These developments in the field of telecommunication and mobile devices have created a more specialized sector in the field of e-Health, which is that of medicine using mobile devices or mobile health (m-Health). The World Health Organization has designated Mobile Health as "the practice of medical and public health supported by mobile devices such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices" (World Health Organization). The dissemination of the term "Mobile Health" in recent years is also reflected in Figure 1, which shows the constant increase in the number of searches for the term "Mobile Health app" in Google's search engine.

At present, all types of sensors that interconnect smart mobile devices are being used in more and more applications to collect data for further processing. In this way, "Mobile Health" applications are constantly offering more and more functions. We could classify the applications into those used to diagnose a disease or complication and to those used to collect data that help monitor patient's health status (Sarasohn-Kahn 2013). There are also those applications that help to restore the patient's health. Research on diabetics has shown that regular monitoring of some indicators by the patients themselves and regular physical exercise using smart portable devices have positively contributed to improve indicators such as blood glucose, blood pressure and body mass index (Vaes et al., 2013).

Various applications of intelligent wearable systems have been developed in the form of clothing such as Life shirt and Vivo Responder for the monitoring of patient's cardiopulmonary function, the wealthy system and similarly the health wear for 24-h monitoring of various indicators. Also a similar device is the Smart Shirt that records vital signs of the patient. These systems are primarily designed to monitor the health status of patients

Figure 1: Searches of the term "Mobile Health apps" globally over time (Source: https://trends.google.com/trends/explore?date=all&q=mobile%20health%20apps).

when they are in a private environment such as their home (Kalokairinos et al., 2015).

Many cardiac abnormalities are monitored and evaluated by a simple and low-cost examination, the electrocardiogram analysis (ECG) (Dilaveris et al., 1998). Each signal of the electrocardiogram consists of three individual signals (P wave, QRS complex, T wave) the monitoring of which over short periods of time (<30 min) increases the probability of successful diagnosis of problems (Elgendi et al., 2014). Continuous monitoring and analysis of the signals can be achieved by the use of electrocardiograph electrodes that are connected to wearable devices, smart watches, smart mobile phones, smart clothes (Elgendi et al., 2017).

By the end of 2017, Cardiogram announced an integrated application to monitor cardiac parameters and to diagnose health problems, which can be installed on smart watches compatible with the Android Wear platform. The application was originally available on Apple Watch devices and aims at the implementation of preventative medicine to buyers of such devices (Figure 2).

The application takes measurements from the watch's built-in sensors and provides minute-to-minute heart rate monitoring, diet and exercise suggestions and identifies the psychological state of the user (Figure 3) (https://cardiogram.com/research).

The application also provides statistics compared to other application users as well as competitive challenges with other users. The most important development, however, is that the company, in collaboration with the Department of Cardiology of the University of California, has developed an information system where the measurements from the application provide data through a network to an application of neural networks called Deep Heart for the early diagnosis of Atrial fibrillation with a 97% rate of successful diagnosis (Brandon et al., 2017).

It has recently been announced that smart watches (such as Apple Watch) with a dedicated application installed, are equipped with an ECG analysis function that has the approval of the American FDA, as well as the ability to detect Atrial Fibrillation (https://www.apple.com/newsroom/2019/03/ecg-app-and-irregular-rhythm-notification-on-apple-watch-available-today-across-europe-and-hong-kong/).

Devices with special sensors can monitor patient activity (walking, running), take biochemical measurements such as pH, oxygen saturation in the blood. Their sensors are capable of measuring pressure, body weight, heart rate, body temperature. The motion sensors can measure physical activity and help improve the treatment of individuals involved in respiratory rehabilitation procedures (Benzo, 2019). An example of blood glucose measurement is the iBGStar system which is directly connected to iPhone or iPod Touch and facilitates the monitoring of diabetes (Gandhi et al., 2012). Also, the data collected by motion sensors on smart phones can be used for the early diagnosis of Alzheimer's disease (Varatharajan et al., 2017). The use of smart phones and portable devices can also help diagnose and treat sleep disorders (Akane et al., 2015). The list of features offered by smart device
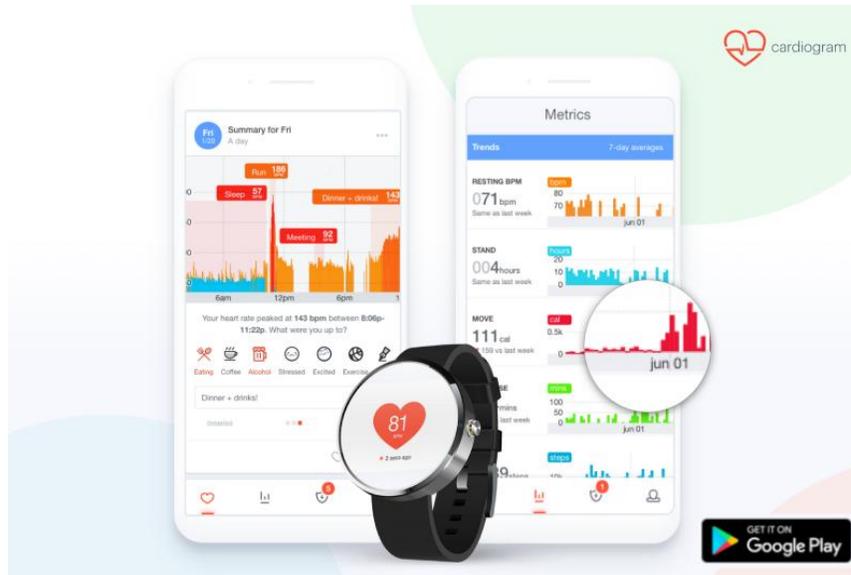
Figure 2: Android application that monitors the health of Cardiogram smart watch users (Source: https://blog.cardiogr.am/cardiogram-for-android-wear-a797dc2a9b85).
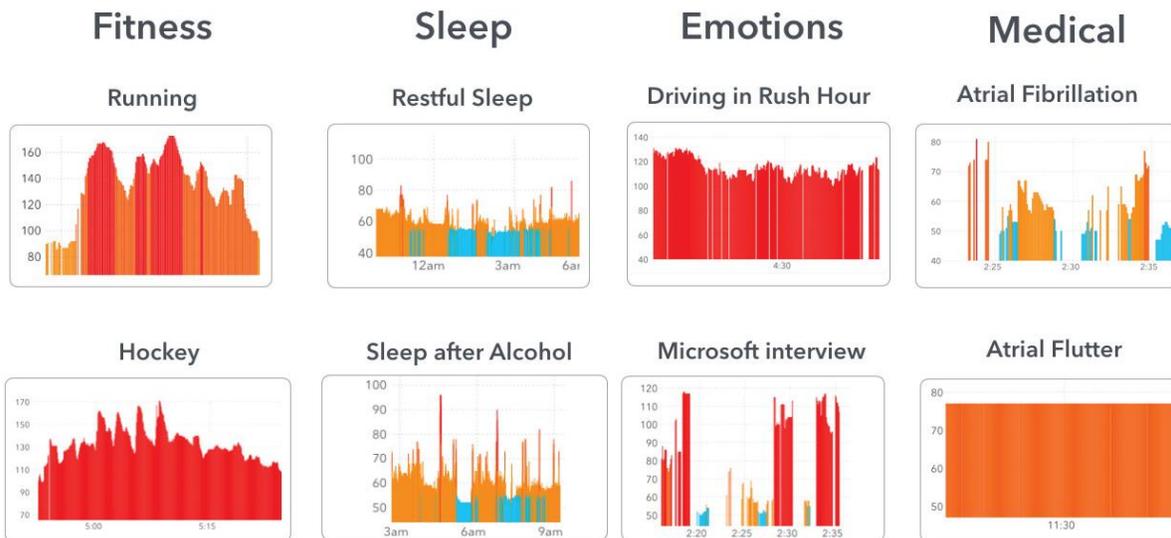
Figure 3: Graphic representations of exercise, sleep, anxiety and health parameters of the cardiogram (Source: https://cardiogram.com/research).

sensors is long and is constantly enriched as existing applications evolve and new applications are developed.

DISCUSSION

The dissemination of the use of smart mobile devices in the everyday life of citizens has increased rapidly in recent years in Greece. In addition, the use of sensors connected to smart mobile devices to record vital signals that have

emerged in recent years is constantly evolving with the addition of new features and services. Despite the fact that such smart mobile devices are now used worldwide, their penetration into the disease diagnosis process and the monitoring of patients' health in Greece is very low. Their use is limited to individual efforts and has not been integrated into the health information systems in Greece.

A key obstacle to the diffusion of this technology is the limited use of health information systems and applications. The fact that the necessary infrastructure for a single,

integrated health information system in Greece was not available in previous years, made the implementation of patient health monitoring systems through smart mobile devices seem unrealistic. The Personal Electronic Health Record has been recently introduced giving access to the patients' health history for the better and more comprehensive treatment of their health problems by their treating physicians.

In addition to the obstacles encountered in the field of information systems in health in Greece, there are also major issues that the global community of scientists in the field of Information Technology in Health needs to solve. The volume of data collected by personal sensors is expected to increase dramatically in the coming years and will constitute the overwhelming proportion of the overall stored information in digital health systems. The efficient storage of these data is a challenge based on current technological reality. Also, many times the data processing in real time to draw diagnoses or to combine them with the historical data from the patient's medical record creates enormous requirements in processing power. Furthermore, the safe data management and storage, patients' privacy and sensitive data protection are also important aspects of the use of smart mobile devices (https://ec.europa.eu/digital-single-market/en/news/green-paper-mobile-health-mhealth).

At this stage, the existing health information system does not seem to take into account the possibility of recording health data from smart mobile devices and their use in conjunction with the patient's medical record to improve the quality of services. Even if this was part of the design, the implementation of the present system is based on a centralized information system that can not address the above problems arising from the large amount of data. On the other hand, a system based on distributed databases could provide a solution to the large storage and processing power requirements that would be created from the recording and processing of data from biosensors, since the volume of data would be distributed.

Biosensors in the form of biometric watches or wearable systems can record the measurements of indicators and when connected to smart mobile devices such as smart mobile phones or watches, the measurements are temporarily stored and/or undergo some kind of processing from an installed application and/or are sent over a mobile network to a local server of the distributed health information system. The structure of distributed systems can be based on the distribution of primary health structures.

CONCLUSIONS

The use of the Internet of Things, such as biosensors and smart mobile devices, can offer significant benefits in providing personalized health care services and improving the quality of these services. Measurements collected from

these systems and combined with the older data stored in the patient's medical record significantly improves the process of diagnosing and addressing patient health problems. Taking into account the efforts to upgrade the role of primary health care and the role of family physician in recent years as well as the technological developments in the field of biosensors, wearable and smart mobile devices, using distributed medical data management systems, can overcome the storage and processing difficulties of the large amount of data and achieve the integration of this information into the health information system.

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