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SYSTEMS-LEVEL QUALITY IMPROVEMENT

IoT-Based Services and Applications for Mental Health in the Literature

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Abstract
Internet of Things (IoT) has emerged as a new paradigm today, connecting a variety of physical and virtual elements integrated with electronic components, sensors, actuators and software to collect and exchange data. IoT is gaining increasing attention as a priority research topic in the Health sector in general and in specific areas such as Mental Health. The main objective of this paper is to show a review of the existing research works in the literature, referring to the main IoT services and applications in Mental Health diseases. The scientific databases used to carry out the review are Google Scholar, IEEE Xplore, PubMed, Science Direct, and Web of Science, taking into account as date of publication the last 10 years, from 2008 to the present. Several search criteria were established such as "IoT OR Internet of Things AND (Application OR Service) AND Mental Health" selecting the most interesting articles. A total of 51 articles were found on IoT-based services and applications in Mental Health, of which 14 have been identified as relevant works in mental health. Many of the publications (more than 60%) found show the applications developed for monitoring patients with mental disorders through sensors and networked devices. The inclusion of the new IoT technology in Health brings many benefits in terms of monitoring, welfare interventions and providing alert and information services. In pathologies such as Mental Health is a vital factor to improve the patient life quality and effectiveness of the medical service.

Keywords Applications · IoT · Mental health · Sensors

Introduction

IoT is a network of physical devices and other elements, integrated with electronic components, software, sensors and network connectivity, which allows these objects to collect and exchange data [1].

IoT technology and infrastructure has the potential to revolutionize the delivery of health services. The corporal detection devices in network, together with sensors in our life environment, allow the continuous and real-time collection of information related to physical and mental health of an individual and their related behaviors [2]. Captured in a

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continuous and aggregated manner, said information must be exploited in an effective manner to allow monitoring, treatments and interventions in real time, continuous and personalized [3, 4].

The health care industry remains one of fastest to adopt the IoT [5]. The reason for this trend is that integration of IoT functions in medical devices greatly improves the quality and effectiveness of medical service, providing an especially high value for patients with chronic conditions, and those that require constant monitoring in real time [6, 7].

As the age profile of many societies continues to increase, support for health, both mental and physical, is of increasing importance if one wants to maintain independent living. Detect, monitor, recognize activities of daily life, ultimately, delivery of immediate health services has been perceived as a prerequisite to detect the health status of users [8].

Recent technologies such as IoT have improved the most conservative diagnostic tools of the last decade, such as magnetic resonance imaging, epigenetic, bionics and neuropsychological tests [9]. Bionics, for example, is improved by IoT sensors to collect patient data from around the world and use big data analysis to efficiently diagnose psychiatric diseases [10].

IoT offers innovative solutions to promote more efficient approaches in the domain of Active and Healthy Ageing (AHA) and has gained a great momentum as a key enabling technology for a wide range of applications and helps older adults to live independent lives. Monitor health status, offer wellness interventions and provide alert and information services are examples of how IoT is involved in the promotion of AHA [11].

Globally, more than a third of the population suffer from mental disorders, including 35.6 million with Alzheimer's disease and other types of dementia, a figure that is expected to double by 2030, from 7 to 10 million suffer from the Parkinson's disease, 400 million people of all ages suffering from depression and around 21 million suffer from schizophrenia and other psychoses [12].

These pathologies of mental disorders can have a great impact on daily life, social and economic status, and the patients quality of life [13]. Hence, variety of applications enabled by IoT is a viable solution for better health care in patients with this type of disorders. Data from networked sensors, whether used in body or embedded in our living environments, originate a positive transformative amendment within the healthcare landscape [14].

In this paper we present a review state of the art regarding IoT services and applications in Mental Health diseases, with the purpose of obtaining an overview of the topic and propose the development of new IoT applications related to Mental Health field.

There are similar reviews that base their research on challenges and use of IoT in Healthcare system [15], as well as to investigate barriers and challenges of wearable patient monitoring (WPM) solutions adopted by clinicians in acute, as well as in community, care settings [16].

The points that will be covered in this paper are as follows: firstly, the methodology that has been followed to identify the applications and services of IoT in Mental Health; secondly, the results obtained from the review and finally, the discussion and conclusions drawn from the work will be developed.

Methods

In the present study, were taken into account certain inclusion and exclusion criteria to develop the systematic review regarding IoT services and applications in Mental Health. The scientific databases used in the review are: IEEE Xplore, Science Direct, Google Scholar, PubMed and Web of Science. For searching these databases, the following key terms were used: "IoT OR Internet of Things AND (Application OR Service) AND Mental Health", both in Spanish and English. These terms are searched in Abstract / Title / Keywords, from 2008 to the present. In Fig. 1 show the search strategy used in this research.

The selection process of the papers was carried out in the following way: reading of titles and abstracts of the results obtained. The selection criteria to take into account to classify the paper were the following: 1] Studies of IoT services in Mental Health. 2] Studies of IoT applications in Mental Health. 3) Studies of IoT architectures in Mental Health. 4) Studies of IoT protocols in Mental Health. 5) Studies aimed at Health in general and other types of pathologies are eliminated. The papers were classified by reading their abstracts as well as the full paper when necessary; all the articles repeated in more than one database will be eliminated. A total 51 publications found 15 were duplicated or with an irrelevant title for this research, the remaining 36 studies were read and analysed their abstracts to see which were of interest, obtaining as a result 14 documents which gave rise to relevant

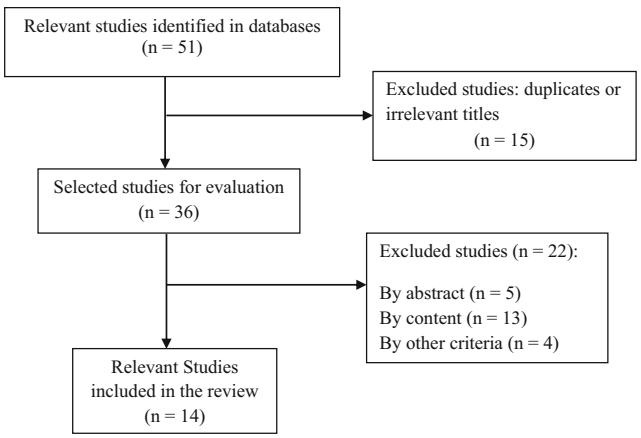

Fig. 1 Flow diagram of the search strategy

contributions. Next, in the following section the most relevant works found are shown and the main architectures and applications found in the literature are analysed.

Results and discussion

In this section, we present the results obtained in the review regarding services and applications of IoT in Mental Health diseases.

IoT has been evolving as new area in the research field. It is intended that billions of physical objects are equipped with various types of sensors and actuators to Internet through various access networks assisted by technologies [15]. The emergence of IoT applied to Health allows to monitor health conditions of the patient, detect symptoms of diseases in general and in this specific case of mental disorders, monitor the disease progress and help doctors to manage medical treatment [12].

The proportion of people suffering from mental disorders around the world is increasing. Around 21 million people suffer from schizophrenia and around 35 million people from depression. In addition, there are 47.5 million people suffering from dementia and 60 million people suffering from bipolar disorder [17].

The lapse of mental health and behavioral conditions is broad and so is associated cost for people and society in general. In addition to financial costs, these disorders reduce life expectancy; unlike many other health conditions, years of life lost due to neurological, mental and behavioral disorders have recently increased, representing a growing burden that will impose new challenges on the health system. Hence, the IoT is a viable solution for the development and improvement of patients quality of life [18]. Table 1 shows the main results found in the literature regarding IoT-based services and applications in Mental Health.

In [12] the authors, with aim of finding depreciation early signs of health state, evaluate four of the most common mental disorder diseases to find what sensors type can detect specific symptoms in order to create an early warning system. In this way, system can predict which disease is likely to occur by matching some specific symptoms of the disease.

In [22] the authors propose the use of Smart textile and wearable technologies as an integral part of IoT ecologies, including those implemented in Mental Health service environments. They propose the protocol of speaking aloud and creation of a data analysis model to semantically analyze the transcripts in order to identify "anxious" and "not so anxious" participants. The analysis revealed significant differences between the vocabulary used by "anxious" and "not so anxious" participants. This approach provides a better understanding of how smart textiles can be used to communicate the participant's reactions to environments and situations as part of a

Table 1 Studies of the bibliographic review related to IoT services and applications in Mental Health

Authors	Year of publication	Study proposal	Results
Ivascu, Manate, & Negru [12]	2015	The authors present a multi-agent system that facilitates remote monitoring of elderly patients who are susceptible to mental disorders.	- The system improves diagnostic accuracy by assigning each sensor to a specific symptom.
Darshan & Anandakumar [15]	2015	The authors present a study on the use and challenges of IoT in the health system, and the review of various works carried out in this area of research	-The results show that healthcare quality and efficiency must be improve and to respond to widespread public health emergencies through the acquisition, management, and use of information in health data using IoT.
Alam et al. [19]	2016	Present a web of objects-based ambient assisted living (AAL) framework and propose a prediction method for the emergency psychiatric state.	- The average accuracy of the psychiatric state prediction was 83.03%, in addition the new AAL framework and prediction model of psychiatric emergency mental state can be used as an complement to treatment of psychiatric patients in the home.
Lekjaroen et al. [20]	2016	They propose an application: IoT Planting, which consists of a prototype gardening platform for elderly people with mental health disorders.	- The results show that application helps the welfare and improves mental health in elderly.
Raji, Jeyasheeli, & Jenitha [21]	2016	They develop a real-time monitoring system of patient's vital signs in general	- The results show that model returns the patient's vital signs data whether they are healthy or not.

Table 1 (continued)

Authors	Year of publication	Study proposal	Results
		and with mental disorders, for this they use portable sensors.	From this state, patient takes medicines to detect early diseases. - The system allows high-risk patients to be controlled on time and improve their quality of life.
Sahu & Sharma [9]	2016	The authors present a device to detect certain parameters of brain waves, such as alpha, beta, delta, etc., and judge the mental state behavior.	- This research found a promising technique to reduce complexities and develop a general eHealth device, which could be further modified with IoT applications.
Zois [2]	2016	The authors present an overview of the models that are expected to support proactive, preventive and personalized healthcare along with associated solution techniques They highlight several challenges and opportunities that arise during the realization of smart and connected healthcare IoT.	- The results show several models that allow optimal and sequential decision making within the context of IoT healthcare.
Aledavood et al. [13]	2017	The authors identify the most important features for designing a digital platform for data collection for mental health studies, and to demonstrate a prototype platform that they built on the basis of these design features.	- The results show the key design features: flexibility of access control, flexibility of data sources and privacy protection of first order. - Demonstrated how the incorporation of these design principles opens up new possibilities for digital psychiatry studies.
Cosma et al. [22]	2017	The authors propose the use of Smart textile and wearable technologies as an integral part of IoT ecologies, including those implemented in Mental Health service environments	- The results provide a better understanding of how smart textiles can be used to communicate the participant's reactions in terms of environments and situations.
Babar et al. [23]	2017	The authors propose a health architecture based on an analysis of energy harvesting for health monitoring sensors and the performance of Big Data analytics in healthcare	- The results show the effectiveness of energy-harvesting based IoT in healthcare; and propose a solution for smart health monitoring and planning.
Hayati & Suryanegara [17]	2017	They propose a system design, which works on basis of IoT LoRa, to track and monitor patients with mental disorders.	- The results show that proposed design is feasible in terms of LoRa network performance viability, power battery and scalability.
Kim & Chung [24]	2017	They propose the depression index service using knowledge-based crowdsourcing within a smart health platform that uses IoT.	- The results show that it is flexible service to which the context information of users is applied and contributes to the user's decision making.
McWhorter, Brown, & Khansa [25]	2017	They propose a system that monitors nightmares signs, tries to suppress them or awakens the patient slowly if it is not successful, thus improving the patients quality of life suffering from post-traumatic stress disorder.	- The system has the potential to positively affect millions of people with post-traumatic stress disorder and reduce depression and suicide rates using IoT.

person-centered approach to intelligent development of textile design and services with service providers of Mental Health.

In [9] the authors present a device to detect certain parameters of brain waves such as alpha, beta, delta, etc., to judge the mental state behavior. Using this new approach, several factors such as attention, stress, breathing index can be judged efficiently. This research found a promising technique to reduce complexities and develop a general eHealth device, which could be further modified with Internet of Things (IoT) applications. Therefore, it can be concluded that this system will help to make electronic health more compatible with cost and utility.

Based on the results obtained, it is expected that models with portable detection technology and intelligent living environments will transform current health care practices by allowing continuous monitoring in real-time of patients and personalized treatments and interventions that significantly limit medical visits and associated costs [2].

The new IoT technologies promise enormous potential benefits in the provision of intelligent health services, however, it still faces many challenges such as: IoT final terminals, capacity to process massive data and creation of networks in order to achieve reliable performance and effective [23]. The large data volume generated by physical and virtual devices is also one of these major challenges since efforts are required to process and analyze said data in order to implement smart health services [8].

The categories of possible psychiatric biomarkers include genetics, proteins or other molecules, or neuroimaging findings. With rapid emergence and acceptance of digital technologies, alternative measures of mental state and behavior are being developed for detection, diagnosis and monitoring [1, 26].

While physical and mental deterioration is part of healthy ageing process, premature decline may be an early indicator of more serious conditions, such as Alzheimer's disease. Early detection of risks related to a specific health condition can help physicians implement appropriate interventions that can slow the progression of disease itself, with beneficial effects on the patients quality of life and treatment costs [27].

The primary computational objectives include multimodality and interaction modeling, as well as behavior prediction. If we can overcome engineering obstacles, we can provide lasting scientific advances and translational impact in mental health domains [18].

Conclusion

The convergence of information technologies and medicine, such as medical informatics, will transform medical care as we know it, reducing costs, inefficiencies and saving lives.

The purpose of this review was to provide an overview of state of the art in research on IoT services, applications and architectures in Mental Health diseases. The studies found show the benefits of IoT in Mental Health as well as applications and architectures developed to improve the patient's quality of life with this type of disorder.

Exposed the results achieved in this review where the existing publications were analyzed in the last 10 years, taking into account the studies referring IoT services and applications in Mental Health diseases, we propose as a future work develop a new IoT service in Hospital Zamora, Spain. Firstly, this service will be focused to patients with dementia.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

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