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A review of remote health monitoring based on internet of things

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ABSTRACT

Managing, diagnosis, prognosis, continuous monitoring, early detection, and preventing chronic diseases for patients and elderly people have been gained a crucial role nowadays. However, elderly people with chronic health conditions such as diabetes, cardiovascular disease, and mental diseases, need special health care. With the help of the internet of things (IoT) technologies, remote health monitoring (RHM) helps patients, caregivers, and countries for improving healthcare services, such as medical files services, mobile healthcare (mhealth), telemedicine services, and sensing technology. Moreover, RHM aims to reduce hospitalized demands and costs. The main contribution of the proposed study is to review RHM studies based on IoT technologies. Moreover, the challenges and possible future trends of RMH are highlighted.

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1. INTRODUCTION

Currently, elderly, and aging people are increasing globally [1]. According to the reports of the world health organization (WHO), 30 years from now, i.e., in 2050, the proportion of the world's elderly people, who are over 60 years old, will nearly double from 12% to 22% (2 billion). For example, nowadays, in Japan 30% of the population are already over 60 years old. This fact indicates a dangerous and important challenge for societies and countries [2]. However, real time and continuous disease monitoring lead to early detection of diseases and to increase the safety of the elderly people [3, 4].

Undoubtedly, elderly people with a chronic health condition, such as diabetes, cardiovascular disease, epilepsy, need special health care [5, 6]. Thus, remote health monitoring (RHM) can help patients, caregivers, and countries for improving healthcare services, such as medical file services, mobile healthcare (mhealth) telemedicine services, and sensing technology [7, 8]. Table 1 shows the importance and advantages of RHM [9, 10].

Recently, as a vision of the next generation of the healthcare industry [11], advanced trends in communication and technology aim to enhance healthcare and medical services [12, 13]. Internet of things (IoT) represents the revolution for the next technology era [14]. IoT aims to connect all healthcare objects, devices, services, and resources together using advanced networking technology [15]. Importantly, this application of the IoT is called internet of medical things (IoMT), which uses all medical connected resources to establish a medical

information network [16]. This network can be used for remote healthcare monitoring (RHM), rehabilitation systems [17], disease diagnosis [18], prognosis [19], detection [20], management [21], prediction [22], and prevention [23]. Importantly, IoMT in RHM applications is used to collect remote patient's data (physiological and clinical measurements such as blood pressure, skin temperature, heart rate [24]) by smart connected devices and sensors over the network [25, 26]. The collected data are then transferred to be stored and analyzed in the cloud computing systems [27, 28]. Figure 1 shows a health care monitoring framework based on IoT [29, 30], while Table 2 summarizes the main characteristics of all possible sensors that are used in RHM.

Table 1. The importance of remote health monitoring

The Term	Importance Level		
	For Patients	For Caregivers	For Countries
Price	Less cost	Less cost	Cost-effective
Comfortability	Comfort	Comfort and make less crowd	Provide better health care services
Mobility	Solved	Comfort and make less crowd	Cost-effective and Avoid emergencies
Continuity	Continuous	Continuous	Provide better health care services
Speed	Fast detection of illnesses	Fast detection of illnesses	Provide better health care services
Quality	Better	Better	Better
Medical intervention	Early	Early	Avoid emergencies
Tracking and monitoring	Real time and quick	Real time and quick	Provide better health care services
Convenience	Better	Better	Provide better health care services
Accessibility	Real time access	Real time access	Enhance treatment abilities
Disease Management	Adequate	Less medical errors	Enhance treatment abilities
Treatment accuracy	Better	Less medical errors	Enhance treatment abilities
Reliability and availability	High	Real time and continuous	Enhance treatment abilities
Resource utilization of medical centers	-	Less	Less maintenance cost, less crowed, and provide better health care services
Disease diagnosis	Better	High data processing capabilities	Provide better health care services
Rehabilitation services	Continuous, reliable, and fast	Accurate and remote monitoring	Less cost and provide better health care services
Duration time in medical centers	Less	less cost and less crowed	less cost and less crowed
Collecting, processing, and visualization data	Fast	Fast and high accuracy	Provide better health care services
Medical reporting and decision making	Reliable	Smart	Enhance treatment abilities

Figure 1. Health care monitoring framework based on IoT

Table 2. Sensing technologies used in RHM based on IoT

Sensing technology	Usage	Application	References
Electroencephalogram (EEG)	Brain signal activities	Mental diseases	[31, 32]
Electrocardiogram (ECG)	Heart signal activities	Heart diseases	[33]
Electrooculography (EOG)	Ophthalmological diagnosis	Retinal disorders	[34]
Electromyogram (EMG)	Muscle electrical activity	Muscles diseases	[35]
Body temperature sensor	Body temperature measurement	Infection	[36]
Blood pressure sensor	Blood pressure measurement	Hypertension	[37]
Heart rate sensor	Heart monitoring	Heart diseases	[38]
Respiration rate	Breathing and chest monitoring	Lung diseases	[39]
Galvanic skin sensor	Skin conductance	Electrodermal activity	[40]
Blood glucose sensor	Blood glucose measurement	Diabetes	[41]
Oxygen level sensor	Blood-oxygen monitoring	Blood diseases	[42]
Inertial sensor	Motion acceleration	Physical activity monitoring, tracking, and rehabilitation	[43]
Location sensor	Human activity	Physical activity monitoring, tracking, and rehabilitation	[44]
Camera sensor	Human activity	Physical activity monitoring, tracking, and rehabilitation	[45]

The prime contribution of the proposed work is to review RHM studies based on IoT technologies. Moreover, challenges and possible future trends are also highlighted.

2. RELATED WORK

Explaining research chronological, including research design, research procedure (in the form of algorithms, Pseudocode or other), how to test and data acquisition [1-3]. The description of the course of research should be supported references, so the explanation can be accepted scientifically [2, 4].

Nowadays, IoT plays a vital role in RHM to reduce hospitalized demands and the cost [31, 32]. Also, RHM aims to enable an uninterrupted and real time observation for patients and elderly people in order to diagnose, manage, and prevent disease [46, 47]. That includes:

a) Diabetic patients [41]
b) Heart diseases [48]
c) Cardiovascular diseases [49]
d) Blood diseases [50]
e) Mental diseases [51]
f) Arthritis disease [52]
g) Fall detection and prediction [53]
h) Activity detection and recognition [54]
i) Medication Management [55]
j) Rehabilitation [56]
k) Personal Fitness monitoring [57]

Next, Table 3 summarizes well-known works the literature for RHM based on IoT, where the sensing technology and the main characteristics of each work are highlighted.

Table 3. RHM based IoT related literatures

Literature		Contribution	Sensing technology	Highlights
[58]	Automatic diagnosis of heart diseases using IoT	Body area sensor network (glucose level, electroencephalongram (EEG), electro cardiogram (ECG), electromyography (EMG), respiration rate, oxygen level, and temperature)		• A framework based edge computing and deep learning called HealthFog is developed
[59]	RHM for heart rate based on IoT	Pulse rate sensor		• RHM prototype based on cloud computing is developed using Arduino UNO, raspberry Pi 3
[60]	RHM for cardiac based on IoT	ECG		• Diagnosis of the heart disease using ECG monitoring
[61]	Regular monitoring of arthritis disease based on IoT	Wearable sensor gadgets and uric acid sensor		• Diagnosis of joint inflammation • Joint pain illness and leg movement monitoring are recognized
[62]	IoT recognition and monitoring elder people at home	Accelerometer sensor		• Monitor of human physical activities • Low-cost, simple, and adaptive intelligent implementation
[63]	IoT monitoring elderly health and sleep patterns	Wearable wrist-worn activity sensor		• Unobtrusive monitoring of circadian activity and sleep patterns • Continuous monitoring of physical activity
[64]	IoT based health care monitoring and tracking system	GPS and GSM		• Real time health monitoring and tracking.
[65]	IoT based real time system to locate an Alzheimer's patient	GPS module		• Real time and continuous tracking system are presented
[66]	Smart phone RHM application for patients with Alzheimer's disease	Smartphone		• High fidelity prototype is developed
[67]	IoT based smart depression diagnosis	Smart phone		• Depression index service using the knowledge-based crowdsourcing • Self-diagnosis
[68]	IoT mental disorder tracking	Mobile cellular		• Tracking the patient in the outdoor environment • Scalability and power efficiency

Literature		Contribution	Sensing technology	Highlights
[69]	IoT stress disorder monitoring	Heartrate sensor, 3-axis accelerometer, temperature sensor, and altimeter		• Posttraumatic stress disorder diagnosis and monitoring • Temperature control, aromatherapy, and auditory therapy capabilities • Efficient for reducing depression
[70]	IoT mental and behavioral disorders platform	Murata bed sensor		• Designing a digital platform for collecting data for mental health studies • Flexibility and high privacy
[71]	IoT based health monitoring	Piezoelectricity sensor		• Big data analytics in healthcare • Smart health monitoring, and energy harvesting
[72]	IoT based smart healthcare monitoring	Temperature, heartbeat, GPS, glucose level, blood pressure, and Kinect camera		• Smart health monitoring with big data analytics and energy harvesting system • Qualifying the IoT devices used for the healthcare system, aggregation, and processing of real-time data
[73]	IoT wearable sensors for health monitoring	Temperature, humidity, pressure, and light		• low-power wearable sensor node for environmental IoT applications
[74]	Fall prediction and detection prototype	Tri-axial accelerometer		• Patient-specific single sensor and low cost
[75]	Fall detection technique based on IoT	Tri-axis accelerometer		• The accuracy of the proposed method is 95.53%.
[76]	Energy efficient fog-assisted IoT system for monitoring diabetic patients	Glucose level		• Remote and real time monitoring
[77]	Design and development of a non-invasive smart and pervasive mobile solution for diabetic patients	Glucose level		• Self-management support tool within a smart digital companion
[78]	RHM for or diabetes patients based on IoT and big data analytics	Blood glucose		• Early detection of Diabetes system is presented
[79]	RHM for or diabetes patients using IoT	Glucagon and insulin		• Tracking system-based cloud computing is proposed
[80]	Wearable Sensors for human activity monitoring	-		• A review of activity monitoring of humans based on wearable sensors is presented
[81]	Pattern recognition models for detecting behavioral and health-related changes in a patient	Heart rate, temperature, glucose, and respiration		• Continuous monitoring in an assisted living environment
[82]	IoT-cloud based wearable ECG monitoring system for smart healthcare	ECG		• Visual and timely ECG data capabilities
[83]	Smart rehabilitation system based on IoT	GPS		• Feasibility, rapidity, and effectiveness of the proposed system
[84]	Remote rehabilitation monitoring embedded system based on IoT	Bendable force sensors		• The advantages of the proposed system are, simple, flexible, cheap, unobtrusiveness, and low power is consumed
[85]	Physical activity recognition from smartphone accelerometer data	Accelerometer		• Accurate predictions could be made for offline activity recognition
[86]	Detection of daily activities and sports with wearable sensors	Accelerometers and GPS		• Hybrid classifier (tree structure and artificial neural networks)
[87]	Activity detection and classification using different sensor modalities (Data fusion) for real-time and autonomous monitoring	Inertial sensors		• Data fusion with multiple classifier system

Literature		Contribution	Sensing technology	Highlights
[88]	Machine and deep learning in sport	Inertial sensors unit		• Sport-specific movement recognition
[89]	Mobile phones in physical activity	Smart Phone		• Online activity recognition
[90]	Smartphone and wrist-worn motion sensors	Smart Phone		• Complex human activity recognition
[91]	Fall detection based on smartphone and mobility sensors	Smart Phone		• Supervised learning
[92]	IoT based disease prediction and diagnosis system	Smart Phone		• Mobile healthcare based on fuzzy neural classifier

After studying and reviewing several studies about RHM based on IoT, it can be found that the proposed topic is considered as a hero nowadays and still in its infante stage. However, more efforts and contributions are still needed to tackle the callenges and gaps.

2.1. Challenges and future trends

This section summarizes the main challenges and the possible future trends for RHM based on IoT [93-109]:

a) Usability: patients and elderly people may not engage with sensors and recent technologies. Moreover, wearable sensor should be designed in comfortable shape for the wearer.
b) Cost: advanced sensors, security protocols, network infrastructure, and compatible systems may carry a huge cost.
c) Data Security: protecting patient's data from hacking and stolen is a challenging issue.
d) Integration and standardization: build a medical network with medical devices is a challenging task.
e) Data acquisition: noise, uncontrolled environment, sealing, sensor placement and position, and size of the sensor may lead to difficulties in data collecting.
f) Feature extraction: obtain valuable diagnostic information from wearable sensor data is very crucial. However, high accuracy and high-performance feature extraction methods should be developed.
g) Big data problem: real time and continous monitoring lead to produce huge mass of data. However, big data analytics and protocols have to be developed for dealing with huge mass of collected data, even approximately.
h) Safety: wearable sensors with batteries may lead to skin problems.
i) Power consumption: Sensors have a limited power capacity.

3. CONCLUSIONS

Currently, elderly and aging people are increasing globally. Thus, the use of novel advanced technology in healthcare industries has critically required to enhance medical services for those people. RHM with the help of IoT technologies offers remote and continuous monitoring for patients and elderly people. Moreover, RHM aims to enable a continuous and real time monitoring to diagnose, manage, and prevent disease. The proposed review study highlighted RHM based on IoT studies. Finally, challenges and future trends of this emerging topic are also discussed and highlighted.

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