

IoT-Based Patient Health Monitoring: A Comprehensive Survey



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Abstract Nowadays, health monitoring is one of the rising fields that is rapidly creating and gaining quick progress in its advancements. Various analysts have proposed different structures for patient health monitoring as per the technical advancements in healthcare systems. During these days, use of Internet is unlimited; Internet of things (IoT) is among of the risen field as of late in which many have had the choice to merge it into different applications. Normally, IoT is utilized to interconnect distinctive accessible resources of medical and related devices. It offers amazing, successful and productive medicinal services to the patients. Health monitoring is the key for dynamic and assisted living. The ongoing advances in IoT improve the way of life of patient by strongly helping and changing the patient by monitoring his health. In this paper, we provided an overview on best in class research and improvements in patient health monitoring systems.

Keywords Patient health monitoring · IoT · Comprehensive survey · Artificial intelligence · Deep learning

1 Introduction

During last few decades, life span of human across the world has improved due to advancements in healthcare systems and diagnostic technologies. Apart from these developments in healthcare systems, people getting awareness about nutrition food, keeping clean environment and primary care about health [1–4]. Indeed with developments in healthcare monitoring, life expectancy will increase and with that fact aged population will be more in compared with birth rates. As per World Health Organization (WHO), by 2050, the old age population is higher than the age of 14

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[5]. In addition to this, around 15% of world population will suffer with different disabilities and diseases [6]. In general, people with disabilities will have more health issues due to their limited mobility. The general health issues such as heart diseases, cancer, pneumonia, diabetes and many more are the common chronic diseases which affect many people. Approximately, 70% of deaths in adults are mainly caused due to chronic diseases. Diabetes is another major chronic disease which impact many people. Due to daily activities and food habits, people used to get diabetes and may lead to long-term complications and issues with kidney, blindness and other problems. Apart from this, the population of elderly people is increasing almost in all countries. These people require regular assistance and care for their regular activities and proper healthcare. Hence, lot many elderly caretaking centers and services are evolved and grabbing money from the people. Though, their life span is not increasing due to insufficient care and timely addressing the healthcare problems and issues. The life expectancy will decrease if we do not address chronic diseases and other health-related problems. There is an acute need for healthcare services to increase the life span of human.

Nowadays, tremendous developments are taking place in healthcare services. Remarkable advancements in technologies and tools are evolving for patient healthcare over last five years. Though the cost of these present-day healthcare services keep on rise due to developments and usage of new diagnostic tools as well as clinical treatment. A significant spending on healthcare services will change socio-economic structure of almost all countries in the world. Most of the countries proposed good amount of budget for healthcare services and wellbeing of people. In view of these, there should be better healthcare and monitoring services in low cost, efficient and affordable range.

So as to adapt to the developing requirement for patients medicinal services and administrations, it is basic to create moderate, unpretentious and simple to utilize healthcare solutions. Nowadays at home, people have been using natural and wearable devices [7] to monitor real-time information of patients remotely with minimal cost. Smart homes may enable the patients to remain in their agreeable home conditions rather than costly and restricted healthcare facilities. Healthcare personnel can likewise monitor the general health state of the patients continuously and give their opinion and further actions need to be done.

In this paper, we present a state-of-the-art research and developments in patient healthcare monitoring and how current technologies are addressing issues related to patient healthcare by monitoring vital signs such as blood pressure, heart rate, temperatures, pulse rate and other body parameters. The main objective of this paper is to discuss about different contributions of researchers in the development of patient healthcare monitoring systems.

Further, this paper is organized into three sections. Section 2 discusses about general architecture of IoT-based patient health monitoring system and their characteristics. The state-of-the-art research is discussed in related work of Sect. 3. Conclusion of paper is presented in Sect. 4.

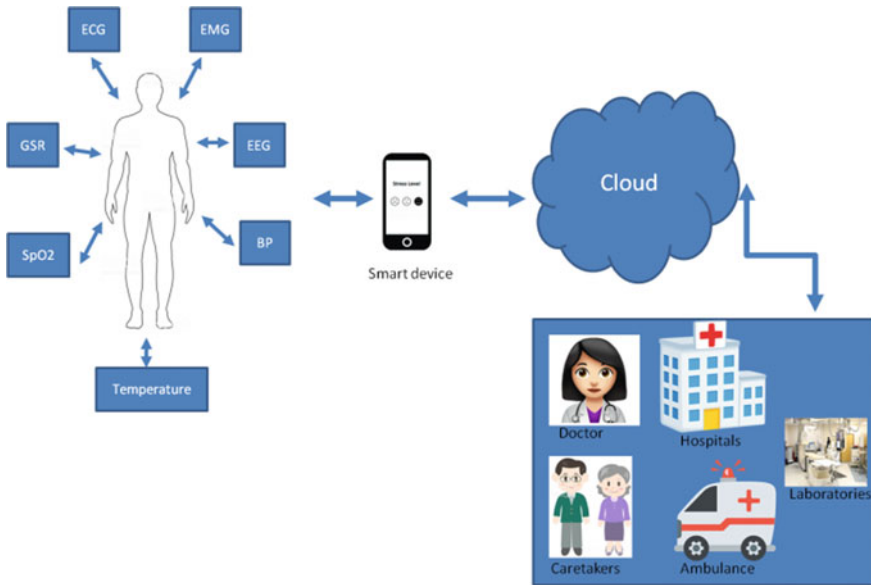


Fig. 1 General architecture of patient healthcare monitoring system

2 Patient Health Monitoring

Nowadays, patient’s health is taken care by different healthcare monitoring systems. These systems adopt recent technologies such as IoT, cloud and wearable devices to monitor the status of patient in real time [8]. From the decade, vast developments are taken place in wearable technologies to extract physiological parameters such as ECG, EEG, EFG, BP, temperature, SpO2, GSR and many more. The general architecture of patient monitoring system is depicted in Fig. 1. It shows how patient physiological parameters are transmitted to cloud through smart devices, and there after, they will be processed, assessed and intimated to the respective people and departments linked to the concerned patient.

3 Related Work

The quality of life is major concern of the people and they are looking for new technologies and innovative healthcare solutions to address the needs of people. In current day scenario, Internet of things (IoT) is playing a vital role in providing good healthcare solutions [9]. IoT is connecting all the objects in our daily life including patient health-related objects such as physiological monitoring devices. To keep people active and healthy, a promptly available present-day healthcare system is

demonstrating to be viable in sparing costs, diminishing sickness and drawing out life. There is a need for enhanced healthcare monitoring system to offer better services to the patients with IoT-based technology and easily assess their health status through smart phones, wearables and other devices.

Recent years have seen an ascending in wearable sensors, and today, a few gadgets are monetarily accessible for activity-based patient healthcare. An ongoing healthcare framework should give better healthcare services to individuals whenever at anyplace in a moderate and patient friendly way. As of now, the healthcare services framework going to transform from a conventional way to patients focused methodology. In the current world scenario, wide usage of portable technologies and shrewd devices plays a major role in monitoring health status. Healthcare providers are exploiting this situation with these advancements though a lot of improvements taking place in wearable and clinical environments to provide better monitoring of patient. Apart from these technologies, various other healthcare monitoring devices are being used in healthcare market such as mobile applications, patient forums and ICT-based devices to assist and provide alerts to patients.

Ali et al. [4] proposed an automatic health monitoring system; the functionality of this system is as follows. This system will help residents of all age groups by monitoring automatic voice disorder. In this method, the authors proposed a linear prediction analysis which detects the disorders in voice by determining the source signal from the speech. They compared both normal and disordered subjects. This is a smart healthcare system to help patient suffering from voice complications in smart cities.

Deepasri et al. [10] proposed IoT-based healthcare system to enable the patient to pass on different message to specialists, medical caretaker or his/her friends and family sitting at home or office over the web. The framework utilizes microcontroller base hardware to accomplish this usefulness. It utilizes hand movement acknowledgment circuit and a recipient in addition to transmitter circuit. The given framework is intended to get and process these directions and show them over the LCD display just as transmit the information online over to IoT gecko server. The IoT gecko server at that point shows this data on the web, to accomplish the ideal yield. IoT is used extensively in monitoring patient health condition mainly in case of chronic diseases such as diabetes, pneumonia, asthma and many more. Gómez et al. [11] proposed a design based on metaphysics to monitor health of patients suffering with incessant infections.

These days healthcare environment has created science and information dependent on wireless-sensing hub technology arranged. Patients are confronting a hazardous circumstance of unexpected death because of the particularly of heart issues and attack which is a result of nonexistence of good restorative support to patients at the required time. This is for extraordinarily checking the old age patients and educating specialists and friends and family. So Krishnan et al. [12] proposing an imaginative venture to evade such unexpected demise rates by utilizing patient health monitoring that utilizes sensor technology and web to convey to the friends and family if there

should arise an occurrence of issues. This framework utilizes temperature and heart-beat sensor for monitoring patient's health. If there should arise an occurrence of any sudden changes in quiet pulse or internal heat level, alarm is sent about the patient utilizing IoT.

Saha et al. [13] considered and defined health as a degree of helpful and metabolic power of a living being. In people, it is the intensity of individuals or communities to adjust and self-oversee once confronting physical, mental, psychological and social changes. Monitoring the health remaining of the patient gathering might be an inconvenient undertaking. The goal of this paper is to monitor patient's health with the help of sensors and internet. The health monitoring framework can monitor patient's heartbeat rate, eco rate of heart, pressure level rate, temperature and so forth.

Abdelgawad et al. [14] presented an IoT framework customized for human services applications. According to the proposed model, the gathered information is transferred to the cloud where it is taken over and separated based on the need of information. The information which is not in use can be sent back by the criticism activities to the client. A model of the proposed architecture has been built and results in this paper show its performance advantages.

Patel et al. [15] proposed IoT-based secure healthcare system for smart hospitals. In this paper, they discussed about healthcare framework and importance of data with security concerns. Distributed computing is the most significant worldview in IT-health. All the medical data of the patient just as the specialist and patient personal data store in neighborhood mode just as cloud, so at whatever point it required the information will be effectively accessible. Understanding medicinal information is put away in framework just as cloud, so malicious attack and undesirable access may cause a destructive to patient health. Security is generally significant and critical piece of healthcare.

The popularity of utilization of mobile phones are increasing day by day particularly in developing nations, they can be utilized for productive medicinal services the executives. In this paper, authors of Kodali et al. [16] proposed a novel framework for improving healthcare system with the help of mobile phones with NFC and Bluetooth interfaces. Apart from this, they also used smart card innovation on tamper resistant secure element (SE) for putting away credentials and secure information.

Dar et al. [17] proposed a smart phone-based accident detection system. One way to deal with killing the postponement between accident event and specialist on call dispatch is to use in-vehicle automatic accident recognition and warning frameworks, which sense when car crashes happen and promptly advise emergency workforce. In this paper, authors target to find the event of any accident and reporting the area of accident to the closest emergency vehicle, with the goal that quick help can be given by rescue vehicle. This framework also gives good result in avoiding and preventing false accident detection.

Wu et al. [18] in their paper investigated the utilization of wearable sensing, smart phone along with video streaming and proposed STREMS which is an effective keen continuous pre-emergency clinic correspondence framework for Emergency Medical Services (EMS). Initially, they presented a wearable physiological sensing solution to help multi-dimensional telemetry monitoring for an emergency vehicle working

at as basic life support, a kind of EMS administration level without complex medical equipment or paramedics. Then they proposed to fabricate cloud-based real-time information sharing platform, empowering automated streaming.

Rahman et al. [19] in their paper proposed an Exoskeleton Arm. It is a battery controlled upper-body automated arm which expands human efficiency and quality. Expanding arm quality by forty pounds, Exoskeleton Arm rehabilitates individuals with back injuries, enabling them to reconstruct muscle and relearn engine control. The exoskeleton innovation additionally helps those lifting objects as a component of their day-by-day work, especially in development or conveyance driven positions.

Uma et al. [20] proposed a model to take care of the issues existing in getting and identifying diabetes disease. This framework applied different data mining techniques such as clustering and classification to diagnose what type of diabetes patient have by transforming patient body details to smart system. They considered and collected 650 patients' data to analyze and identify severity of diabetes such as mild, moderate and severe.

Huge data generated in healthcare industry in different forms with floating of images, videos, text, prescriptions and many more which accumulate as big data. Rishika et al. [21] presented a state-of-the-art to better describe about storage and retrieval methods, different tools and techniques used in big data analytics for healthcare industry and utilization of clouds to better provide the services to the people and patients.

Suresh et al. [22] discussed about new technologies such as big data and cloud to solve the problems arising in healthcare. With the growing data needs, an efficient and timely attempt to give proper solutions will reduce the death rates. Authors try to give a solution to identify diabetes patient's severity with the help of machine learning algorithms. A detailed study on diabetes dataset was made with different machine learning algorithms.

Ajay et al. [23] gave overview of wireless infrastructure and corresponding devices which collect data and transform to cloud and other gateways. This paper especially discusses about state-of-the-art solutions to collect the healthcare data, process it and transform to cloud for further analysis and action. It also discussed about different deployment strategies for healthcare solutions. This chapter describes the state of the art and use cases associated to healthcare monitoring which involves the usage of wireless infrastructure.

Suresh et al. [24] proposed an approach to quickly make precise decisions to doctors by analyzing big data collected from different sources such as blood tests, x-ray, etc. According to the authors, this model also shows information such as previous patient's details, different specialist's opinions and their advices during the same situations with the help of cloud and provides analytics over it. Suresh et al. [25] proposed a framework which aims to provide prompt treatments to the patients using wearable devices and IoT technologies. They proposed a model which also monitors patient health information by using wearable devices and that will disseminate to IoT cloud. Further, health status of the patient is monitored with the help of predictive analytics. The same authors proposed different solutions [26–29] to address patient-related issues and its security concerns.

After extensive study of related literature on patient health monitoring system, till now no work has been described on usage of IoT-based health monitoring system for a patient to monitor overall health statistics and provide timely alerts to patients by predicting patient's health data in real time through deep learning and advanced analytics techniques.

4 Conclusion

In this paper, we presented state-of-the-art research carried out in the field of patient health monitoring with different technologies such as IoT, wearable devices and cloud. The motive of this work is identifying different solutions and frameworks for monitoring patient health status by sensing physiological parameters and other information of patient. It also presents what are the current systems and technologies which give effective and efficient solutions to the patient in the perspective of real-time information/alerts to be communicated to caretakers or other belongings of patient. With this review, we conclude that there is an acute need of patient monitoring system to help or save patient life by giving real-time decisions and actions without delays.

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