Intelligent Healthcare

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1 Introduction

Remote Intelligent Healthcare, also known as telemedicine, requires diligent care and effort and is the largest growing area of study and expertise with growing applications in Biomedical Engineering and Medical Sciences using the latest technology – the Internet of Things (IoT). The basic definition of telemedicine is an exchange of clinical/medical-related information from one destination to another destination using information and communication technology (ICT). Population analysis indicates the percentage of people over the age of 65 will increase by approximately 38% in Japan, almost 29% in Western Europe and 22% in the U.S. by 2050. There will be an increase in health care needs related to the aging population in society. This chapter predicts the development of intelligent health care will increase in proportion with the increase in the aging population. Some important areas where telemedicine can be proficiently used are:

- Tele Support
- Tele Monitoring
- Tele Diagnostics
- Tele Treatment
- Tele Consultation
- Tele Education
- Tele Training

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Fig. 1a A powerful & friendly Bluetooth blood pressure monitor module

Tele monitoring enables medical experts to remotely examine the patients and their needs within the comfort zone of the patient as well as medical expert. With the help of tele monitoring, transportation charges, transportation time and waiting time will be reduced to zero; in most cases, the transportation charges are more than the doctor fees. This new method of investigation has exploded over the past two decades because of the increasing doctor to patient ration, aging populations and, in countries such as India, because of the inaccessibility of hospital centres. Most of the research indicated that tele monitoring, telemedicine, tele diagnostics, tele support, tele consultation, tele education and tele training are more cost effective than hospitalization. Tele monitoring is based on the broadcast and reading of medical indicators. The broadcast reading analysis may lead to the judgment that the patient should be hospitalized or that only advice is required.

Tele monitoring supports continuous monitoring for urgent situations and serious care patients, and it includes tele care for elderly people, continuous monitoring, examination of chronic diseases, such as for people with cardiac diabetes or dysfunction, while the continuous medical care of pregnant women sometimes requires their hospitalization, or they need to visit hospital every day in order to use cardiotocography (CTG) and pulse oximeters. The tele monitoring system uses physiological sensors to measure blood pressure, weight, temperature, blood oxygen saturation, etc. Some of the I Health Care System Modules are shown in Figs. 1a and 1b [1].

In the 1990s, basic tele monitoring used standard telephone lines, and it relied on a very limited set of vital signs. At the beginning of this century, it moved to the internet and now is incorporated into various services, especially for chronic patient

Fig. 1b Gluco-monitoring system with Android application

follow-up. In the era where everything is available with a single click, this system is available on wireless and mobile technologies and is also called the portable and home-based system. The next update in this system is the use of wearable sensors in which sensors can provide the reading in an easily readable form. Presently, the overall research focus is on emergent implantable and wearable sensors, which will play a crucial role in achieving continuous measurement of vital sign parameters throughout the entire day without limiting the mobility of patients.

Tele monitoring will help to address the increasing patient to doctor ratio that is expected to reach 12.9 million in the next 10 years, as suggested by the World Health Organization (WHO) in 2013 [1]. The above condition is owing to the rapid population increase, and when the total population increases, the aging and disabled population also increases. In addition, if a country has a good healthcare system, then it is possible to reduce the number of hospital visits and hospitalizations with the help of Information and Communication Technology (ICT). The UK has had excellent results after implementing intelligent healthcare according to the UK National Health Service (NHS), and by using intelligent healthcare, they have saved seven billion pounds per year [2].

In a similar way, to better analyse how patients could avoid needless admissions to the Intensive Care Unit (ICU) because of chronic conditions, Veterans Health Administration (VHA) conducted a Care Coordination/Home treatment (CCHT) survey from 2003 to 2007. Further, they analysed medical-related data regarding the stage of schedule and pre-eminence from a cohort of 17,025 CCHT patients who participated in the survey and found there was a 25% decrease in the number of ICU bed days and a 19% decrease in hospital admissions. Veterans Health

Administration (VHA) received a very good response to achieve the technological change in the medical field, and the survey concluded that home tele-health accomplishes providing an extremely caring and reasonable approach for assisting chronic care patients (CCP) in rural and urban areas [3].

Now, the upcoming technology is wireless, and the new tele monitoring research is based on a wireless patient monitoring system (WPMS). In the medical field, contactless treatment should always be a secure treatment and this system plays a vital role in early diagnosis of diseases and physical conditions by relating information to the healthcare experts [4]. The main function of WPMS is to competently: (1) gather medical-related clinical data using predefined medical sensor devices; (2) recognize the medical-related clinical data in consideration mode; (3) obtain the early warning score (EWS) from medical professionals who have access to the data; (4) carry out appropriate action through medical experts or professionals [5, 6]. This is the way to shift from the traditional method and adopt the smart method, and it will include calculating EWS, which helps to predict early detection of chronic diseases [7]. It has been found that ambulatory blood pressure monitoring (ABPM) offers nonstop measurement of blood pressure at a predefined time gap for 24-h periods or longer. Mainly, this system helps to identify white-coat hypertension, which shows unusual systolic and diastolic averages in those who are not taking antihypertensive medications. This system gives measurement readings in any window size frame, which will be very helpful for the medical professionals; it will also help clinical supervisors to categorize and identify chronic diseases such as hypertension and boost the correctness of diagnosis [8]. The proposed intelligent healthcare is a very cost effective IoT-based system. The main function of this system is to easily connect with digital medical sensor devices and send the measurements to the cloud. Most of the time patient essential parameter readings such as body temperature, pulse rate, diastolic and systolic pressure will be sent to medical professionals through a global cloud server.

Figure 1c shows the workflow of an intelligent healthcare system for remote patient monitoring; the smart home consists of IoT devices and medical sensors. Digital medical sensors sense the patient readings and, for the purpose of analysis, send it to the cloud server through the intelligent healthcare system, and this clinical data is received at, for example, a hospital where medical authorized professionals analyse and compare the patient parameter readings with the data that are already available in the hospital data base and convey to the patient to visit hospital or not. If the patient readings are normal or nearest to normal, then there is no need to visit hospital; for the condition of nearest to normal, medical professionals could remotely prescribed medicine to the patient.

2 Research Method

Many researchers have published papers on intelligent healthcare and many more are working on it; this segment presents some of the significant works on intelligent healthcare. Digital medical devices use Bluetooth (BT) and USB from the intelligent

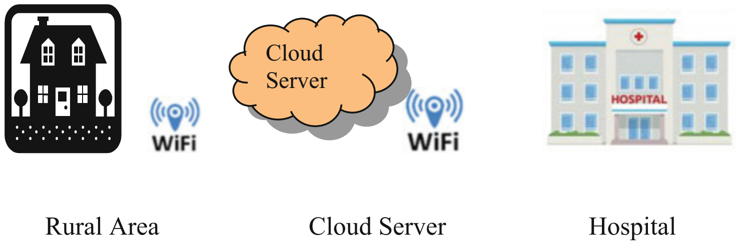

Fig. 1c Workflow of an intelligent healthcare system for remote patient monitoring

healthcare domain, and the limitations include the number of devices connected, range and power [9, 10]. Today's researchers are focused on the need for wireless technology. For example, the Zig-Bee device has a good transmission and reception range, allows connectivity for a good number of devices, has low power consumption and supports intelligent healthcare domains on a solo wireless technology [11]. Alesanco [12] worked on electrocardiogram (ECG) signals and using 3G cell phone network simulations and analyses. The author developed a transmission procedure and transmission algorithm to fulfil the medical trial condition regarding ECG signals, and as per the medical trial's criterion, 4 s is the maximum common delay in ECG signal. Trigo et al. [13] obtained a trial object implementation of concurrent ECG transmits through the IEEE 11073 standard family, where synchronization on behalf of the ECG device branch of learning continues. The same practice formation was not clinically evaluated, but put into practice in standard feasibility [14, 15].

3 Labelling or Classification of Vital-Sign Data

Data classification is a very important aspect of vital-sign detection, and accurate labelling of normal and abnormal data is required for the data used to calculate the early warning score (EWS). There are two types of data classification: one is one-class classification, where only the abnormal label is used for demonstration. When we consider one-class classification, the total calculation depends upon abnormal data only, but for the analysis of patient data, normal data must also be in the data set. On the other hand, in two-class classification (TCC), if we have an ample sample of abnormal data, joint normal and abnormal sample data are used, and the abnormal bunch is evidently modelled. To accurately calculate or predict the EWS, data labelling is a very important aspect when we compare the patient data sets with the available clinical data sets. A huge quantity of data is collected from uninterrupted patient monitoring, and thus realistically managing clinical data sets for every patient in the hospital is monotonous work for any medical professional. Therefore, to conquer this task, it is better for medical clinicians to mark only those patients for whom known abnormalities occurred [16], occasionally only those patients having simple univariate alerting criteria, for example, heart rate (HR) $\geq$ 120 beats per minute, were renowned or accepted for the period of retroactive trying [17, 18]. Many authors want to predict the early warning score (EWS) from the vital signs; for the detection of chronic diseases, there is always a possibility of over-scoring as well as under-scoring. Here, under-scoring creates delay in the detection of worsening patient health and over-scoring leads to gratuitous calling of medical personnel [19]. It is not totally dependent on the exercise of stiff patient results; conceivably, on discharge, collection labels may be offered because many times it happens that patients have negative results such as unanticipated cardiac arrest or urgent situation admission to ICU; there can be periods of normal physical processes, believably prior to their deterioration in the patient health, and in a similar way with the periods of abnormal physiology prior to complete renewal.

Many review papers discuss the 4-D dataset investigation involving breathing rate (BR), oxygen saturation (SpO2) and heart rate (HR); the systolic–diastolic average (SDA) is the arithmetic mean of the two blood pressures. Three successive run-throughs conducted between November 2006 and August 2007 at the Presbyterian Hospital, University of Pittsburgh Medical Centre (UPMC), collected a dataset involving over 18,000 h of 4-D vital-sign data samples from 332 patients that were admitted into the ICU because of various diagnoses [20]. The main aim of this study was to obtain all basic vital-sign measurement parameters, including oxygen saturation (SpO2), heart rate (HR), diastolic and systolic blood pressure (BP) that were generated by their proposed remote system with a sampling rate of 20 s. Most of the time blood pressure is also measured noninvasively with a hot-air balloon pump attached to the bedside screen, and diastolic and systolic blood pressures are simultaneously measured by it. The conclusions of this survey were determined after consulting with medical experts or professionals and rejection criteria included rejecting sample data outside the following ranges: SDA 20–180 mmHg, HR 30–300 bpm, SpO2 60% and higher was acceptable [20].

Existing One-Class Classification (OCC) Methods

Existing one-class classification (OCC) is used to outline a model of normal data, and afterwards detect deviations from that model and document them as being abnormal according to previous works. A regular approach is emerging which involves using vital-sign sample data [21–23].

Existing Two-Class Classification (TCC) Methods

The conclusions regarding TCC approaches of labelled patient's data are insufficient because there are very few examples of TCC approaches to the problem of patient vital-sign monitoring (PVSM). Parati G et al. concluded that a huge set of data is needed to allow the abnormal class to be correctly modelled. It has been noted that at the boundary level, TCC is achieved in which all types of abnormalities are explicitly modelled. To create such modelled requisite, adequate sample data that would also not group up to data sets of higher dimensionality requires connotation, summing together a unique vital sign would start on further modes of abnormality due to further vital signs; hopefully, covariance can be decided by modes of abnormality starting from other vital signs [24].

4 Results

The major aim of this chapter is to comprehend telemedicine programs in the framework of chronic diseases that are accurately linked with the existing medical or clinical settings. This chapter discusses the implementation of a basic model, at a very low cost, for telemedicine by using the latest technology – the Internet of Things (IoT) and ThingSpeak. ThingSpeak is a widely accepted and open source IoT platform where medical professionals can remotely obtain basic parameter readings to observe and analyse patient vital signs. This platform also allows users to collectively analyse and visualize live data streams in the cloud. This IoT module helps in continuous measurement of basic parameters involved with chronic diseases and the basic parameters such as blood pressure (BP), which includes diastolic and systolic, pulse rate and body temperature throughout the entire day without limiting the patient mobility or removing them from their comfort zone. Figure 2 shows the basic module for an intelligent healthcare system. This cost effective system consists of ESP32. Figure 3 shows the detailed pin diagram of ESP32, which is a very popular controller because of its small size, low cost and having microcontroller as well as Wi-Fi module capability in the same package. ESP32 was invented by Espressif Systems, a Shanghai-based Chinese company, and manufactured using TSM Cusing, which is their 40 nm process [25, 26].

A demonstration of a low-cost IoT module for a smart healthcare system with blood pressure sensor module is shown in Fig. 4.

Graphical Analysis of Measurement of Systolic, Diastolic and Pulse Rate Parameters

Blood Pressure (BP) is the force of blood against the walls of arteries. Blood is pumped in through a patient's arteries every time their heart beats. There are two types of BP: systolic and diastolic. The systolic pressure is a measure of when a patient's heart pumps blood, and a patient's BP is highest; the diastolic pressure is a measure of when the patient's heart relaxes between beats, and the patient's BP

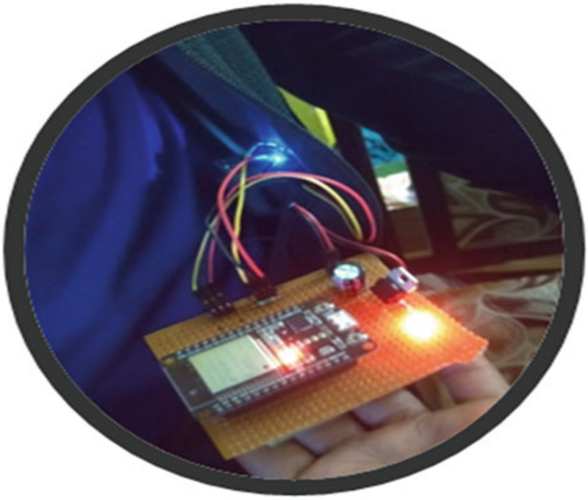

Fig. 2 Assembly of low-cost IoT module for a smart healthcare system

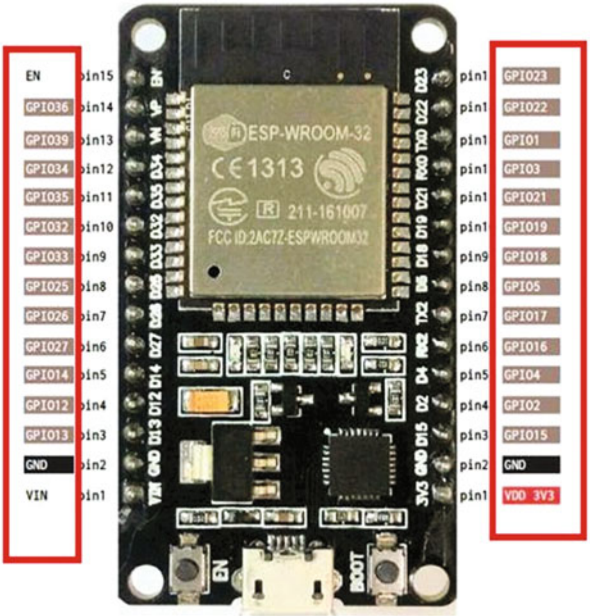

Fig. 3 Standard pin diagram of ESP32

Fig. 4 Demonstration of a smart healthcare system with low-cost IoT module

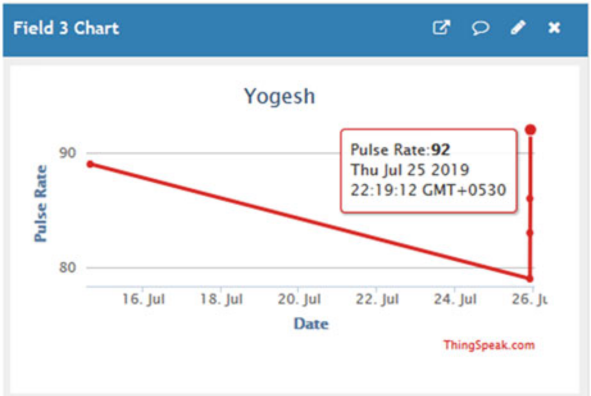

Fig. 5a Graph of pulse rate parameter from ThingSpeak platform

falls [27]. Figures 5a, 5b, and 5c show graphs of pulse rate, systolic and diastolic parameters from ThingSpeak platform.

Tables 1a, 1b, and 1c show the excel sheet of systolic, diastolic and pulse rate readings with date and time, directly from ThingSpeak, and it is very easy to evaluate the clinical data.

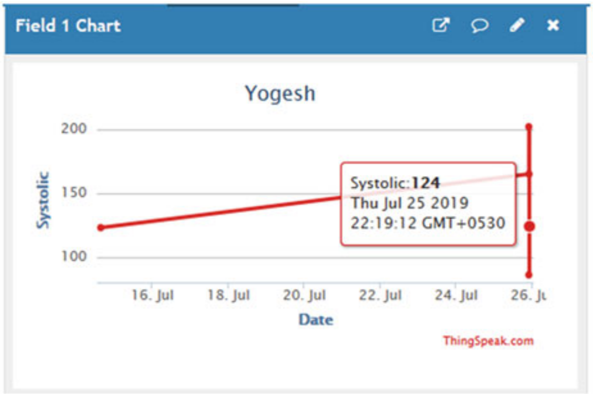

Fig. 5b Graph of systolic parameter from ThingSpeak platform

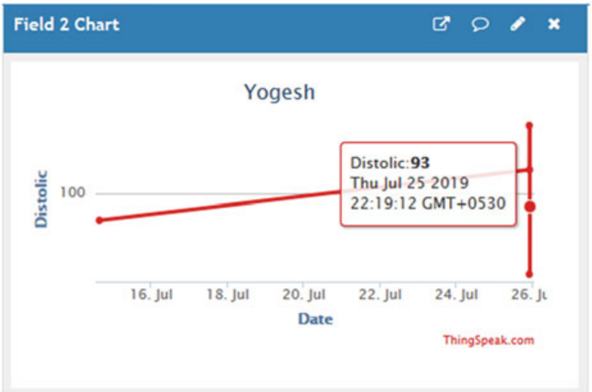

Fig. 5c Graph of diastolic parameter from ThingSpeak platform

Table 1a Excel sheet of systolic parameter from ThingSpeak platform

Sheet for systolic reading		
Date and time	Yogesh	Field1 (Systolic)
2019-07-25 22:19:12 GMT + 0530	1	124

5 Discussion

Often times the transportation charges related to a hospital visit are more than the doctor's consultation fees, and it is time consuming to personally visit the doctor at hospital. Using Information and Communication Technology (ICT) and the IoT, this proposed system will help to overcome this cost and the geographical distance between rural people and the doctor. Typically, the system easily connects with

Table 1b Excel sheet of diastolic parameter from ThingSpeak platform

Sheet for diastolic reading		
Date and time	Yogesh	Field2 (Diastolic)
2019-07-25 22:19:12 GMT + 0530	1	93

Table 1c Excel sheet of pulse rate parameter from ThingSpeak platform

Sheet for pulse rate reading		
Date and time	Yogesh	Field3 (Pulse Rate)
2019-07-25 22:19:12 GMT + 0530	1	92

digital medical sensors, and the measured parameter readings are made available to medical professionals globally by sending the readings over the cloud server.

6 Conclusion

This chapter presented telehealth monitoring systems with different wireless technologies and related their physiognomies. This chapter also indicated that the two-class method is always better than the one-class method. We designed a low-cost IoT module which mends the classification performance, compared it with the existing Ambulatory Blood Pressure Monitoring system (ABPM) and demonstrated that our proposed system is more useful than the existing one.

The main advantages of this system are it is very cost effective, easily interfaced with BP sensors and body sensors, the measured reading can be easily accessed globally and it has user-friendly operation. The only limitation is the availability of the internet. This system can be easily used for better coordination between doctors and patients not only in urban areas but also in rural areas. It can help to overcome the geographical barriers between rural patients and medical specialist by enabling remote patient monitoring that is totally contactless. The results proposed in this chapter require external validation and clinical trials.

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