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I-CARES: advancing health diagnosis and medication through IoT

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Abstract

Internet of Things (IoT) is changing the way many sectors operate and special attention is paid to promoting healthy living by employing IoT based technologies. In this paper, a novel approach is developed with IoT prototype of Wireless Sensor Network and Cloud based system to provide continuous monitoring of a patient's health status, ensuring timely scheduled and unscheduled medicinal dosage based on real-time patient vitals measurement, life-saving emergency prediction and communication. The designed integrated prototype consists of a wearable expandable health monitoring system, Smart Medicine Dispensing System, Cloud-based Big Data analytical diagnostic and Artificial Intelligence (AI) based reporting tool. A working prototype was developed and tested on few persons to ensure that it is working according to expected standards. Based on the initial experiments, the system fulfilled intended objectives including continuous health monitoring, scheduled timely medication, unscheduled emergency medication, life-saving emergency reporting, life-saving emergency prediction and early stage diagnosis. In addition, based on the analysis reports, physicians can diagnose/decide, view medication side effects, medication errors and prescribe medication accordingly. The proposed system exhibited the ability to achieve objectives it was designed using IoT to alleviate the pressure on hospitals due to crowdedness in hospital care and to reduce the healthcare service delays.

Keywords Healthcare systems · IoT in healthcare · Wireless sensor networks · Big data analysis · Drug diverse effects · Medication errors reduction · Enhancing drugs adherence

1 Introduction

Timely and effective healthcare is important to all the human beings. It has been observed that the rise in elderly population is causing crowdedness in hospitals and increasing the workload of physicians. The rise of healthcare services cost is also creating stress on national budgets and household budgets. The increase number of people needing healthcare services can be accommodated either with more doctors, hospitals, laboratories, and drug companies or by devising an efficient mechanism to accommodate all the healthcare needs in an effective manner. The correct diagnosis and drug prescription is an important task in healthcare sector. The diagnosis process is dependent on patient symptoms, physiological signals measurements and patient demographics. Patient demographics includes age, gender, previous medical history and geographical location.

Physiological signals may include Pulse Rate, Body Temperature, Blood Pressure, Stress, Sweating, ECG and SpO_2, which can be measured manually or through automated machines. There are many factors that might lead to erroneous diagnosis. These factors include symptom assessment techniques, physiological signals measurement devices, patient condition at the time when diagnosis was done and sometimes doctor's personal knowledge also

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effects the patient's assessment. Even based on the correct diagnosis of the patient's health, sometimes prescribed drugs are also not as effective as they need to be based on the patient demographic details and medical history which leads to the diverse drug side effects. Medicine timings and completion of the prescribed medicine course plays an important role for complete treatment of the disease, however usually patients miss or take the doses lately.

The advent of small sized, interconnectable, powerful and economic computing devices allow computer science and information technology to be immersed in healthcare systems advancement. Nowadays, technology is playing an important role to improve our lives in every domain. In 2010, healthcare reforms were announced in United States with an amendment bill [1]. One of the major aim was to use Electronic Health Record (EHR) systems for everyone in the United Sates to store and manage health information so it can be used to improve healthcare. Many other countries have also adopted similar policies to improve the healthcare services. The developed EHR systems still lack techniques for the proper use of stored big data for analysis and risk identification. Furthermore, the developed systems do not have integration with medical devices to capture real-time data and store them in the EHR systems. Healthcare sector is yet to realize the major role that information technology can play in redefining healthcare services management.

Thus, the motivation of this paper is to develop a cost effective method for at home patient monitoring and medicine dispensing system. Through the use of the proposed system, patient of all ages including elderly can be monitored around the clock, reminded of their medicine time, and provide medical providers with periodic reports. In addition, the system is able to predict emergency cases and automatically call emergency personnel in cases that warrant the call.

In this paper, we propose a novel system that allows real-time health monitoring for the purpose of short-term and long-term analysis and diagnosis. A SMART medicine dispensing box integrated with monitoring system is also proposed to ensure medicine adherence with advanced features. The complete system is also equipped with SMART life saving features such as reporting an emergency health situation directly to medical personnel and automated calling for an ambulance.

The rest of the paper will be organized as follows: Sect. 2 will identify the objectives of the system, Sect. 3 will introduce the background and current studies. Section 4 will show the methods used in this study in detail, and finally Sect. 5 is for results and conclusion.

2 Background and current studies

2.1 Medication errors and non-adherence

Medication errors, drugs non-adherence and improper monitoring are major factors that lead to diverse health issues and in severe cases may lead to death. There are five major types of medication errors including prescription (39%), transcription (12%), monitoring (38%) and dispensing (11%) [2]. As per reports, 9.5% of all deaths every year are due to medical errors in US [3]. Table 1 shows comparison of medication errors caused by using barcode reader and computer based prescriptions. Table 2 describes the medication errors and their adverse effects. Research studies also show that effective use of technology can help reduce the medication errors massively.

Table 3 shows the drugs non-adherence statistics. As indicated in previous literature, the risk of missed doses, wrong medicine and dose intake is extremely high and may in some situations lead to tragic circumstances including death. Therefore, the concentration on developing smart applications and devices to ensure proper dosage and proper medicine intake is on top of the priority list for IoT-based healthcare.

2.2 Internet of Things

Internet of Things (IoT) is changing the world as we know it. It is affecting and changing the way we work, live, drive, communicate, purchase, sell, remember, etc. Medical field will also receive the same impact, evolving to remote electronic surgery (e-surgery), electronic diagnosis (e-diagnosis), etc. In [21], the author explores the use of a wearable device for medicine reminders by designing an android application for android watches in order to remind the patient of the time and dosage of medicine. Missing a dose of certain medicine is a problem that even happens in hospital with inpatients as indicated in [22]. The study indicated that pharmacy assistants need to accompany nurses on rounds in order to reduce the number of times medication is missed. In [23], a smart medication adherence system is proposed that utilizes RFID for medication type, sensors, and notification to smart phones. The system will ensure that patients take the right medicine at the right time. Communication with physicians in case wrong medicine is taken is also an added feature in this system. In [24], a review paper is presented that provides a summary and comparison of available IoT-based healthcare systems. Most of these systems are set for elderly patients especially those suffering from dementia. In [25], the authors utilize IoT in healthcare by proposing a Smart water bottle for the

Table 1 Impact of technology to reduce medication errors

	Source	Sample size	Errors	Error rate (%)
With barcode	Poon et al. [13]	7318 medications	495	6.8
Without barcode		6723 medications	776	11.5
Computer system	Fontan et al. [14]	4532 prescriptions	419 drugs	10.6
Hand written		4532 prescriptions	937 drugs	20.7
Technology errors	Samaranayake et al. [7]	1538 medication errors	263 technology errors	17.1

Table 2 Medication errors

Type	Source	# of Sample	Total errors	Error rate
Prescribing	Rainu et al. [4]	10,778 medications	616	5.7%
Dispensing	Perez-Moreno [5]	571 hospital beds over 2 years	1049 dispensing errors	NA
Administration	Frydenberg et al. [6]	250 drugs by 30 patients, 5 weeks stay	50 medication errors	NA
	Samaranayake et al. [7]	6723 medications	776 errors	11.5%
	Bond et al. [8]	1116 hospitals	430,586 errors	NA
Errors by nurses	Barker et al. [9]	3216 doses, 36 Institutions	605 does	19%
	Treiber et al. [10]	202 Nurses Survey	158 Nurses	78%
	Cheragi et al. [11]	237 Nurses Survey	153 Nurses	64.5%
Transcribing/documenting	Callen et al. [12]	13,566 medication	1723 medications	12.7%

Table 3 Drugs non-adherence statistics

Source	Disease	Sample size	Non-Adh. %
Khdour et al. [15]	COPD	173 patients	29.5%
Marcum et al. [16]	Heart, diabetes, hypertension	897 patients	40.7%
Fallis et al. [17]	Coronary artery disease, heart failure, diabetes	232 patients	28%
Gadkari et al. [18]	Asthma, hypertension, diabetes, osteoporosis, or depression	24,017 patients	62% forgot
Tomaszewski et al. [19]	Hypertensive patients	208 patients	25%
Ahmad et al. [20]	Diabetics	557 patients	53%

elderly. The bottle functions to remind the elderly of their daily intake of water.

2.3 Cloud computing and big data analysis

The cloud computing came into existence and provided a paradigm shift in the area of computing and application which influenced the different industry sectors. In [26], the authors analyze cloud-based solutions for electronic health records (EHRs) systems. Different solutions and scenarios are analyzed to reach an optimized solution for large hospitals or a network of hospitals. In [27], the authors propose emergency healthcare process automation utilizing mobile computing and cloud services. Their goal is to create a cloud-based solution that allows cross-linking institutional healthcare systems. If properly developed these algorithms can facilitate an evolution in the field of medicine, enable personalization of treatment and help reduce the cost of healthcare. Big data mining and analytics on the cloud could serve and pave the way for preventive medicine and lifesaving intervention. In [28], the iCarMa; an inexpensive cardiac arrhythmia management and analytics solution is proposed. It facilitates the early detection of fatal cardiac conditions like asystole. In [29], the authors show the capability of big data mining, analysis and decision making assisting process. Their proposed system is able to process measurements from millions of body area network sensors and perform real time response in case of emergencies.

2.4 Health data compliances

Information security is of the utmost importance when providing electronic data of patient's health records. Privacy laws and rules give patients the right to keep their health information confidential and patients will have to consent in order for their information to be shared with others. This is why secure communication and secure storage of electronic health records is of paramount importance in the health sector. In [30], the authors propose a secure Electronic health record (EHR) system based on hybrid clouds. This proposed system utilizes both the private cloud in a hospital and the public cloud. It also utilizes encryptions techniques and gives the patient the right to authorize viewing of electronic medical records. In [31], the authors propose a three factor based user authentication for telecare medical information systems. The method utilizes smartphone capability over a dynamic cloud computing environment.

3 Objectives: IoT-based cloud-application Rx expert system (I-CARES)

As mentioned in the literature review in previous section, some healthcare systems have already been proposed based on IoT and cloud computing. However, the system proposed in this paper is unique and novel and below are some functions that sets IoT-Based Cloud-Application Rx Expert System (I-CARES) apart.

Contributions of this work and how the proposed system is different than those proposed in literature.

1. Previous work put forth some theoretical framework for parts of IoT-Healthcare, however, I-CARES is the first Comprehensive practical extendable prototype.
2. Previously proposed systems allow data to be sent from patient to cloud and then to physician/doctor. I-CARE is the only system that allows closing the feedback loop. Communication from patient to doctor and from doctor to patient.
3. Previous work proposes smart medicine boxes that ensure patients to take their medicine on time. I-CARES proposes a SMART Medicine box able to take decision to give doses out of schedule (within medical guidelines) medication.
4. I-CARES is the first comprehensively communication-enabled system. WIFI-Enabled, Personal Area Network (PAL) enabled, cell communication enabled, and GPS-enabled.
5. Previous systems don't allow patients to interact with the system, I-CARES is the first Patient centered system. Patient have the capability to immediately provide feedback when medication produces negative side effects so that the doctor can change medication immediately.
6. I-CARES is the first expandable system by the patient that can utilize wireless and wired sensors. Whenever a new sensor is introduced in the market, plug-and-play capability allows the patient to add new sensors to the system.
7. In addition, I-CARES has a subset of capabilities that exist in other systems even though in previous systems only the theoretical framework was proposed and I-CARES is a practical prototype, these functions are:
    a. I-CARES detects emergency situation and immediately informs Caregivers and Emergency Personnel via communication channels and send patients' exact location via GPS.
    b. I-CARES reminds patients of their medication schedules.
    c. I-CARES utilizes QR barcode for medication identification.
    d. I-CARES sends all readings to the cloud to a Health Medical Information System (HMIS).
    e. I-CARES Processes Big Data and provides reports for medical doctors with suggested decisions.
8. I-CARES being a critical system that contains life saving features should also contain redundancy to ensure that the system is not susceptible to errors. For example, two methods for contacting emergency personal are integrate one with Internet communication and other through text incase internet is not available or fails at that critical emergency moment. Other parts of the system also contain redundancy to ensure that the system is operational at all times.

4 Method

4.1 System architecture

The proposed system consists of a wearable health monitoring device and a SMART automated medicine dispensing system. Both devices can communicate with each other by establishing a personal area network by a handshake protocol for the verification of device. An interface to access and update the medicine dispensing details and physiological signal recording settings is also designed. The doctor can access the interface by using the touch screen of medicine dispensing system as well as the web interface to change the settings. The recorded data from monitoring device is transferred to the dispensing system. Afterwards, the dispensing system transfers encrypted recorded data including physiological signals, patient demographics and medicine adherence to a secure cloud system. The cloud system is designed for patient privacy and security and therefore uploaded data is saved in patient's file and cannot be accessed nor altered except by authorized personnel. Two analysis algorithms are proposed to classify, aggregate and analyze health data for an individual or all individuals on the cloud in order to assist in short-term and long-term decision making respectively. The recorded data can be synchronized with the EHR to maintain patient history. The proposed system also provides an interface for accessing generated reports and further analysis for decision making. Figure 1 shows the I-CARES architecture.

4.2 I-CARES embedded monitoring system

As discussed above, the I-CARES system consists of a health monitoring system with sensors that can measure vital signs including but not limited to Electrocardiography (ECG), pulse rate, blood pressure, body temperature, stress level, sweating, and peripheral capillary oxygen saturation (SpO_2). However, this system is expandable and a controller program (setup program) after login enables patients to add new sensors and configure sensor settings such as sensor type, reading frequency, threshold levels, etc. This makes I-CARES a plug-and-play system easily configurable by the patient. The monitoring system sends the readings to the Smart Medicine dispenser, which in turn sends these readings to the cloud. The Smart medicine dispensing system also communicates with monitoring system to send alarms to the patient to remind him/her of the scheduled and out of schedule medicine dosages.

Figure 2 shows the prototype design of portable health monitoring system and typical connections of sensors to the Arduino microcontroller [32]. The technical description of used hardware components is described in Table 4. The portable health monitor is embedded with an Arduino chip which controls the sensors, sensors readings, and makes necessary decisions (Call emergency personnel and send patient location whenever an emergency occurs). The monitoring system is Wi-Fi equipped in order to send the readings to the medicine dispenser, which in turn sends the readings to the cloud and emergency case reporting. The threshold levels are indicated in program to indicate the regular range of readings for each sensor. The ranges of

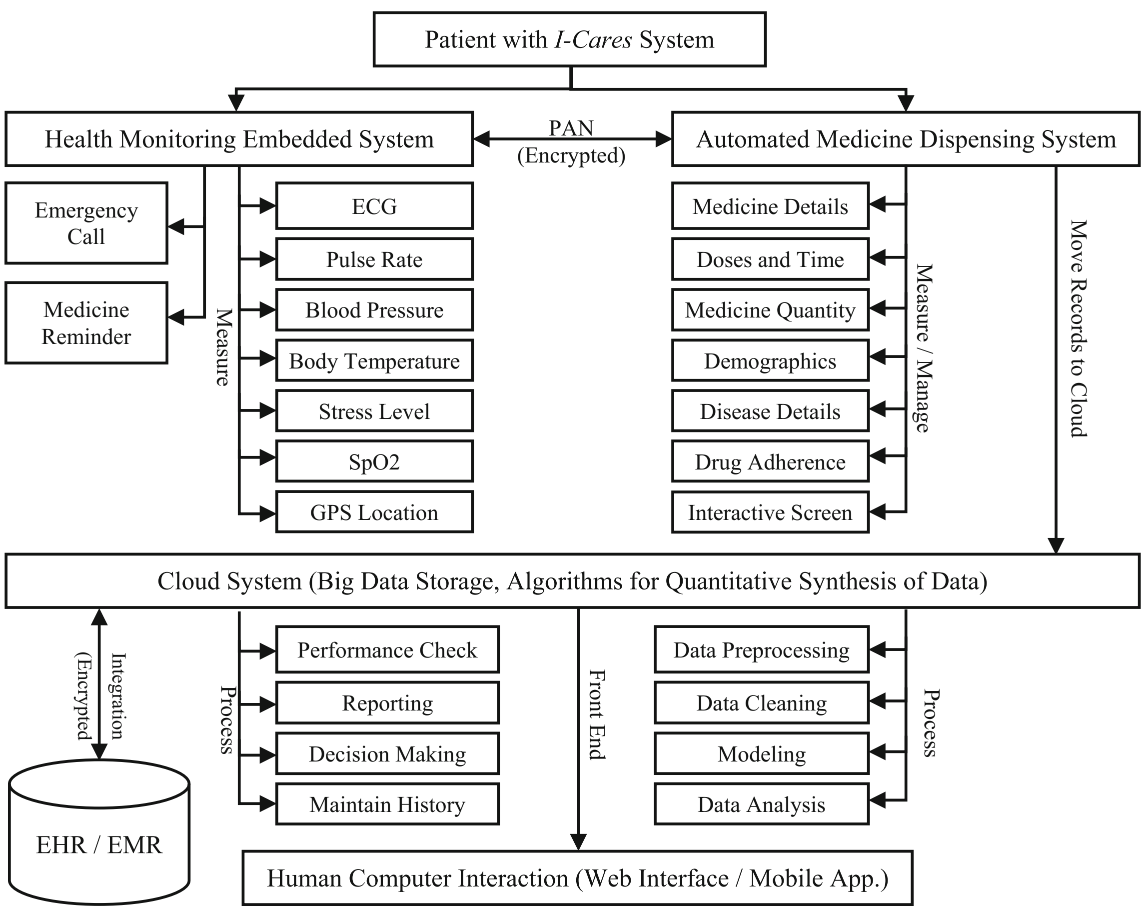

Fig. 1 Proposed architecture of the I-CARES system

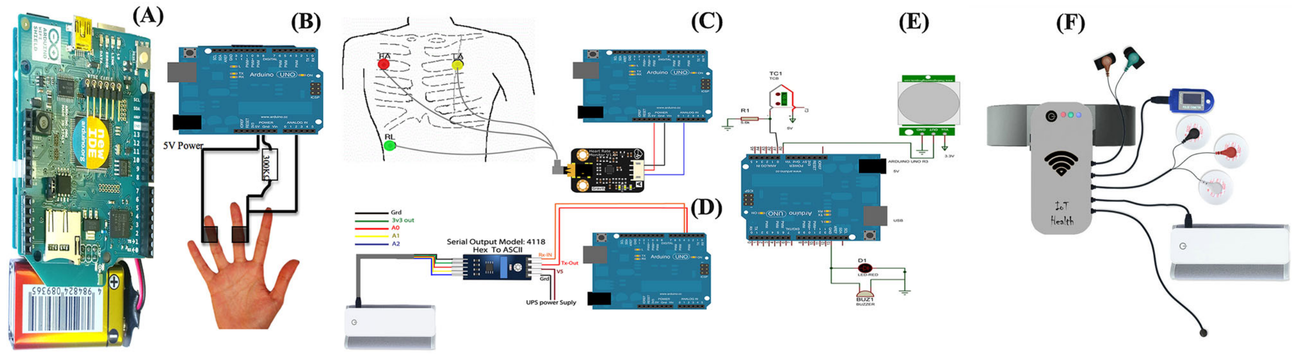

Fig. 2 Internal components used for I-CARES monitoring system Prototype (on left). **a** Arduino UNO, Wi-Fi shield and power battery, **b** GSR sensor connectivity with UNO, **c** ECG sensor connectivity, **d** blood pressure sensor connectivity, **f** temperature and SpO_2 sensor connectivity, **e** final prototype of I-CARES wearable monitoring system

Table 4 Technical details of I-CARES monitoring system

Technical hardware	Description
Microcontroller	Board: Arduino UNO, CPU: 16 MHz, flash memory: 32kB
Communication	Board: Arduino Wi-Fi shield, Protocol: 802.11b/g, encryption: WEP and WPA2
Battery	Product: energizer lithium battery, input: 240 V, output: 9 V
GSR sensor	Grove GSR skin sensor SEN01400P module
SpO_2/pulse sensor	e-Health pulse and oxygen in blood sensor (SPO_2) V2.0
ECG sensor	Heart rate monitor sensor SKU SEN0213
Blood pressure sensor	e-Health blood pressure sensor V2.0
Temperature sensor	e-Health body temperature sensor V2.0
GPS sensor	PAM-7Q GPS Module
Other options	Reset/power button, system status lights, charging/USB port, emergency call, buzzer/vibrator

high or low readings are also indicated. Critical ranges of readings in which an Emergency status flag is raised is also indicated. Based on these ranges, the Arduino is able to decide whether an emergent case that requires immediate attention by medical personnel is in progress or not.

4.3 I-CARES smart medicine dispensing system

The I-CARES system also consists of a SMART Medicine dispensing System which utilizes QR barcode for medicine identification. The medicine dispensing system makes SMART decision within the medically allowed parameters and allows out-of-schedule doses based on medical readings to take care of low priority emergency cases. Figure 3 shows the internal components used for the prototype and the prototype itself.

Both the Health monitoring system and the Smart Medicine dispensing system are connected via a personal area network. The Smart Medical dispenser consists of an interactive LCD screen for users to provide detailed feedback on negative side effects of medication, configure sensors of the monitoring device (deciding frequency of readings and other attributes), medication doses setup and communicating with the doctor. However, this LCD screen also has an Interactive display interface that receives the doctor's prescription indicating type and frequency of dosage. The technical description of all the used components is given in Table 5. A Raspberry Pi 3 is used as the controller for this system [33]. It is also Wi-Fi enabled to communicate with the health monitor and cloud server. The automatic medicine dispenser is SMART in the sense that it can interact with both the patient and the doctor. The healthcare provider can communicate remotely with the dispenser in order prescribe medicine and frequency and the patient can interact physically with the device in order to ensure that he/she receives the necessary reminders and dosage.

4.4 Cloud storage and analysis

Cloud systems is the best solution for applications which have large number of users located in geographically different locations. We utilized the Amazon Web Services GovCloud as part of the initial prototype [34]. The

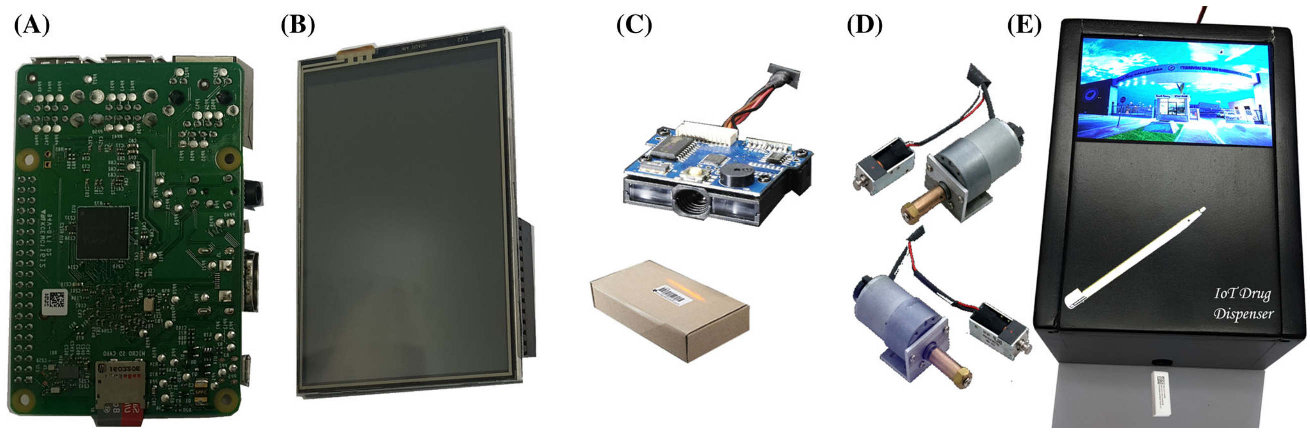

Fig. 3 Internal components used for I-CARES medicine dispensing system. **a** Raspberry Pi 3.0, **b** TFT LCD touch screen, **c** Barcode Reader for Pi, **d** motor to control the movement of barcode reader and drugs, **e** final prototype of I-CARES medicine dispensing system

Table 5 Technical details of I-CARES medicine dispenser

Technical hardware	Description
Microcontroller	Board: Raspberry Pi 3B, CPU: 1.2 GHz quad-core, Memory: 1 GB, Network: 802.11n Wireless LAN, OS: Raspbian (Linux based)
Communication	Model: LCD Touch Screen, Size: 3.2 in., Resolution: 320 × 240 Pixel
Drug verification	Model: Barcode Reader CSD Module, Light Source: Visible 632 nm RED LED
Drugs dispensing	Product: Adafruit DC and Stepper Motor HAT
Power	5 V Micro USB Power Adopter

measurements from both I-CARES monitoring and SMART Medicine dispensing system are sent to the cloud.

Long term medical assessment is an important feature of the proposed system. It can be scheduled as per patient's needs e.g. weekly, monthly, quarterly or yearly to predict possible chance of any disease in future. The long term analysis algorithm is designed to predict probable future diseases based on the measured attributes by using the I-CARES monitoring system. As a classification problem to measure the rank of possibility of a particular disease based on the different attributes. The system uses ranking instances by maximizing the area under ROC curve (RIMARC) algorithm which trains itself based on the ranking function [35]. In RIMARC, all the attribute features are discretized into categorical ones and computation of the scoring function requires a single pass over the training dataset. In training step of the RIMARC algorithm, continuous features of attributes are discretized by using MAD2C which is the combination of ROC and convex hull [36]. For checking disease d, the RIMARC ranking function $rf()$ returns value $rf(d)$ ranging in between 0 and 1. In the algorithm, attribute features are represented by af and the values of features are represented by vf. The weight of the attribute feature is measured by using area under the ROC curve (AUC) as shown in algorithm 2. The ranking function of RIMARC is shown in Algorithm 1 and its training process is shown in Algorithm

Algorithm 1: RIMARC Ranking Function

Input: $d, score[AF][VF], weight[AF]$

// *score for each feature value* vf *of each attribute feature* af

//*weight*$[AF]$ *is the weight for each attribute feature*

Output: $rf(d)$: *the measured ranking function value of disease* d

```
SumScore ← 0 ;
SumWeight ← 0 ;
for i ← 1 to AF do
    if d_i is known then
        SumScore ← SumScore + weight[i] × score[i][d_i];
        SumWeight ← SumWeight + weight[i];
end
return SumScore / SumWeight;
```

Algorithm 2: RIMARC Training Function

Input: $TrainAttribute[AF][C]$

// AF *is attribute features and* C *is number of cases for training*

Output: $score[AF][VF]$

// *score for each feature value* VF *of each attribute feature* AF

```
for i ← 1 to AF do
    if numerical(i) is true then
        cutPoints[i] ← MAD2C(TrainAttribute[i]);
        ConvexValuesTocutPoints(cutPoints[i], TrainAttributes[i]);
    end
    // V is the set of categorical values of AF
    for j ← 1 to V do
        score[i][j] ← Pr[ p | p_i = j ] ; // p ∈ TrainAttributes
    end
    // sort the values of V based on ascending order of score[i]
    Sort(V, score[i]);
    AUC[i] ← ComputeAUC(score[i]);
    Weight[i] ← 2 × (AUC[i] − 0.5);
end
```

Short term critical health prediction based on the measurements of person's body signals is particularly an important and challenging task. Based on the lower and upper bounds, confidence in the prediction is required for emergency call to the doctor or caregiver. The workflow of the proposed approach for short term prediction is shown in Fig. 4. In the first step the regression algorithm is trained to generalize the patterns in the training data of different health related attributes captured by the I-CARES system [37]. After the training, classification algorithm is applied to perform the prediction based on training data and

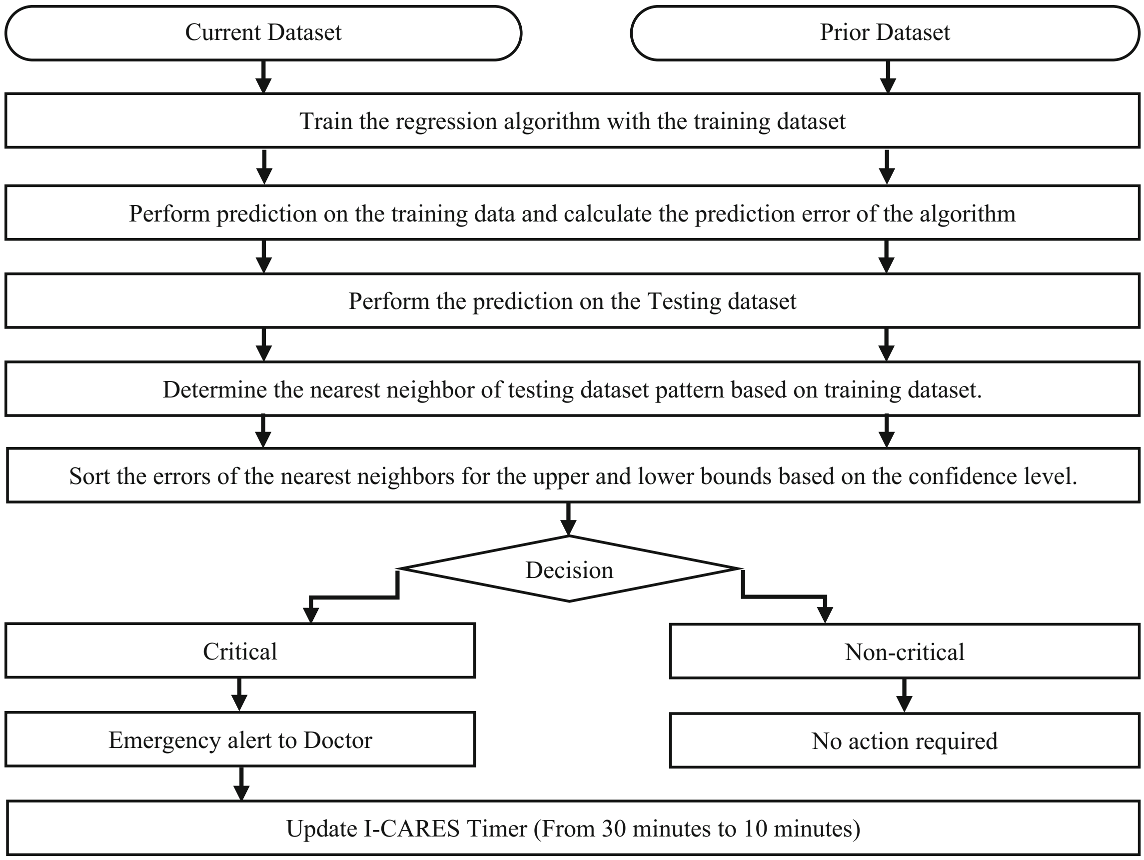

Fig. 4 Workflow process of short-term analysis and emergency alert system

prediction errors are calculated based on the target values of prediction. In next step, patterns are identified by applying the nearest neighbor based regression algorithm and sorted the patterns to compare with defined upper and lower bounds.

4.5 Human computer interaction

The medicine dispensing machine is equipped with a touch screen interface that allow patients (users) to interact with the system providing information such as immediate feedback on negative side-effects from certain medication, adding a new sensor to the system, and communicating with the doctor. The cloud system contains a user friendly interface mainly designed for the doctors to prescribe medicine, view measurements, reports, recommended decisions and diagnosis recommended by the system which can be accessed by patients and any authorized person as well. Figure 5 shows the I-CARES graphical interface for human computer interaction.

4.6 Data security

In healthcare sector, information security is of the utmost importance. Privacy laws and rules give patients the right to keep their health information confidential. The proposed system enables a variety of security features for both electronic healthcare data in rest and in moving state. Table 6 describes the complete list of 11 security features applied to ensure the security and confidentiality of data and to meet all the requirements as per HIPPA compliance.

5 Results and discussions

The real potential of this proposed system can only be realized after it is adopted and put to the test for a large population of persons (patients) and over a long period of time so that enough data can be captured to realize all the functionalities of this proposed system including early prediction of emergency situations. However, our system has been tested on a small group of individuals to ensure that that all functionalities proposed in this prototype work to the fullest. During testing, emergency situation had to be simulated as all test subject were healthy individuals

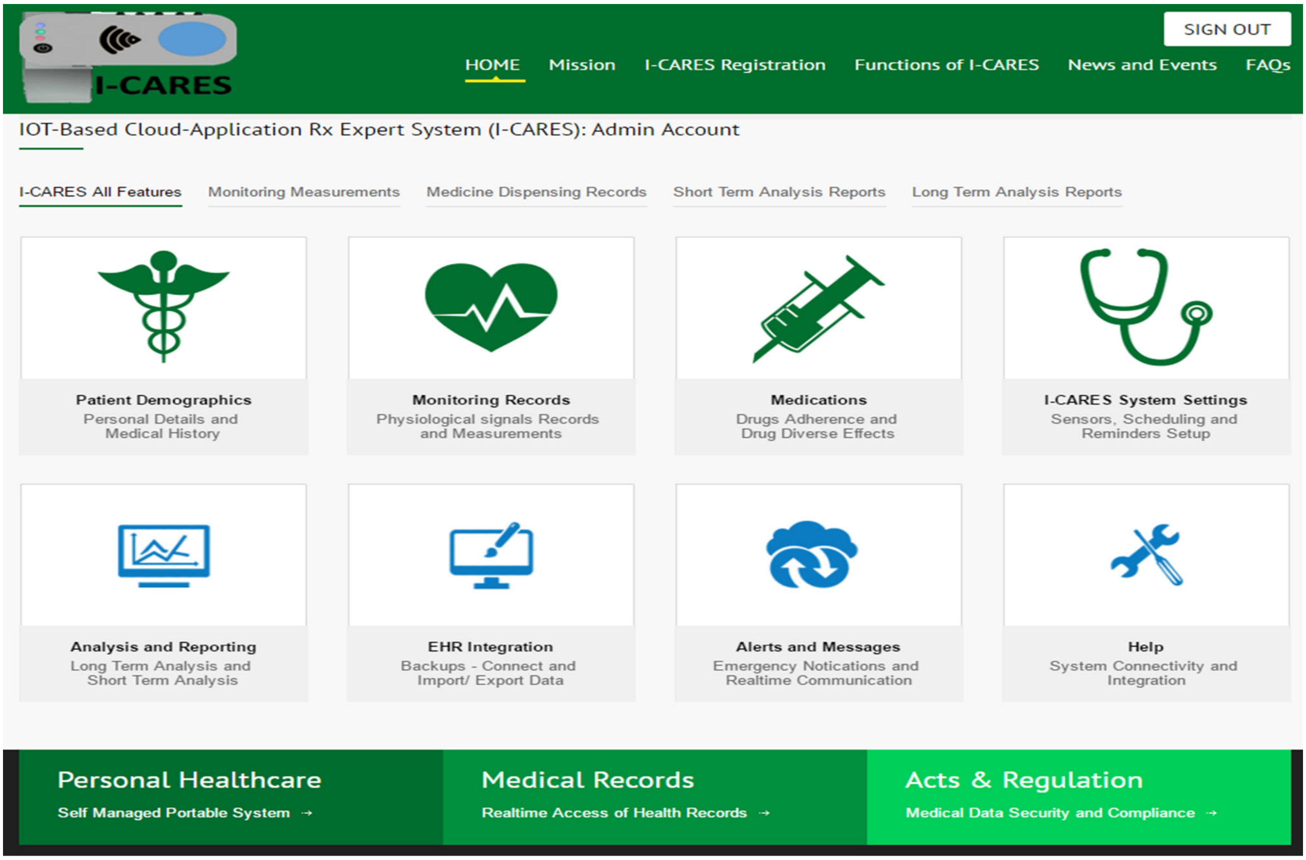

Fig. 5 I-CARES admin control GUI for human computer interaction

between 20 and 29 years of age. The system was able to capture the measurements from the individuals and transmit the measurement to the SMART medicine box and from there to the cloud based medical record system. Other functionalities were also simulated as well such as reporting negative side effects from a certain medication. Even though the proposed system is unique in so many ways as indicated in the description of the system, yet the machine learning Artificial Intelligence that will be able to extract feature from long term measurement of persons who have been diagnosed with chronic disease and other health issues will be a mile stone the medical research community. The proof of concept through a prototype has been established and the authors of this paper urge the medical industry to adopt and test such device for the benefit providing affordable healthcare for the public. Proposed system will provide first step towards the advancement of healthcare and medication sector.

Figure 6 shows a sample of body temperature captured by the I-CARES Rx Expert System for medication taken at 12:10 also showing the body temperature before and after medication. As shown in this result the real-time body temperature is measured using the sensors of the system. Based on a smart set of rules, fever medication is specified for the subject and set with a specific time. The sensors continue to measure the temperature even after the medication is taken to ensure that the temperature has reduced to an acceptable leve1. Figure 7 shows a sample of a real-time measurement of blood pressure (Systolic and Diastolic) along with warnings in case value exceed a normal threshold. These warning are further classified in order to alert patients for medication intake or even alert/call medical assistance for serious cases. Figure 8 shows a sample I-Care's measurement of ECG. The system is equipped to measure ECG as well as take the necessary measure in case of emergencies as well as web interface for both patients and medical personnel.

The economic value of the system is beneficial to all stakeholders as it reduces the health cost from hospital perspective as the patients no longer need to stay in the hospital, this means savings for the insurance companies. This also entails that there are no more hospital expenses and less insurance fees for patients. In addition, using the system on middle age groups ensures that they stay healthier and thus decreasing health cost for the nation through decrease of diseases and declining health conditions. All in all, all stakeholders benefit from keeping individuals healthy in their own homes.

Table 6 Security features of the I-CARES

#	Security feature	Description
1	SSL Certificate	Secure Socket Layer (SSL) certificate is used to make the data secure in moving state from I-CARES device to cloud
2	Device registration	Access device are registered for each doctor/patient/caregiver and after verification, only that device are able to access cloud interface
3	CloudWatch alarms	Setup of different CloudWatch alarms is done to monitor and control the resources usage like memory, CPU, network-in, network-out, etc.
4	GPO settings	Users are managed with different group policies with minimum access permission of cloud resources
5	Firewall settings	Firewall settings are applied to save the cloud server from external threats to the cloud server
6	MFA	Multifactor Authentication (MFA) process is adopted to entree the cloud services portal to strengthen the cloud infrastructure security
7	SNS	Simple notification service (SNS) is enabled on the Cloud servers to send mobile SMS and email notifications based on the enabled alarms
8	Inbound-outbound access rules	TCP/IP port based Inbound-Outbound rules are applied and only specific ports (e.g. HTTPS, HTTP) are opened for specific ip addresses while rest of all the ports are blocked
9	Data encryption	Hardware based encryption method is used to encrypt all the medical data stored on physical drive over the cloud server using bit locket
10	IAM users setup	Based on the requirement, multiple Identity and access management (IAM) users are created and only minimum required access to the particular service is granted in order to make the cloud setup more secure
11	Private key with password	To make the Cloud Server access more secure, private keys with passwords are used
12	Virtual GovCloud	Virtual AWS GovCloud is used to deploy the application which is HIPPA compliance and server access is opened only for particular machine

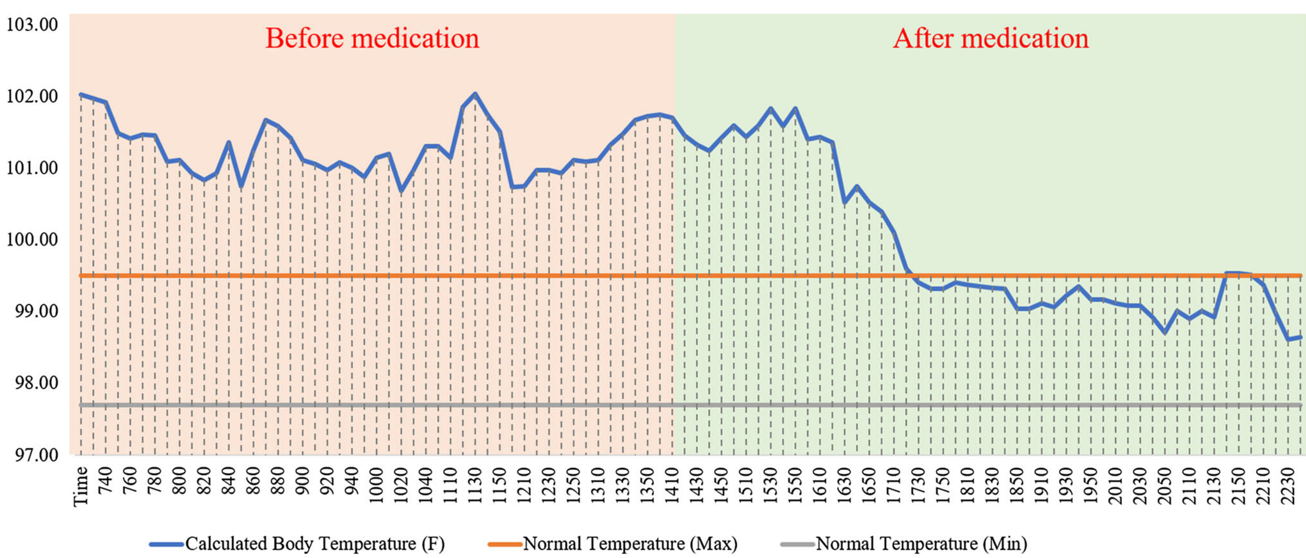

Fig. 6 Body temperature measured by I-CARES Rx expert system for a sample with medication alarm to take medicine at 12:10 and post results of fever medication

The proposed system is ideal for elderly patients needing constant monitoring. However, the system can be used for patients of all ages with chronic illness. For example, a person with diabetes or hypertension and is at high risk of developing a serious medical condition can use the system to keep constant monitoring to control the diabetes levels and hypertension levels in his/her body. It can also be used for healthy individuals who want to keep constant monitoring on themselves to ensure that they stay healthy and not develop any sickness especially chronic illness. Early detection of any sickness or disease plays a major role in the effective treatment methods. Thus, this system will assist in early detection as well.

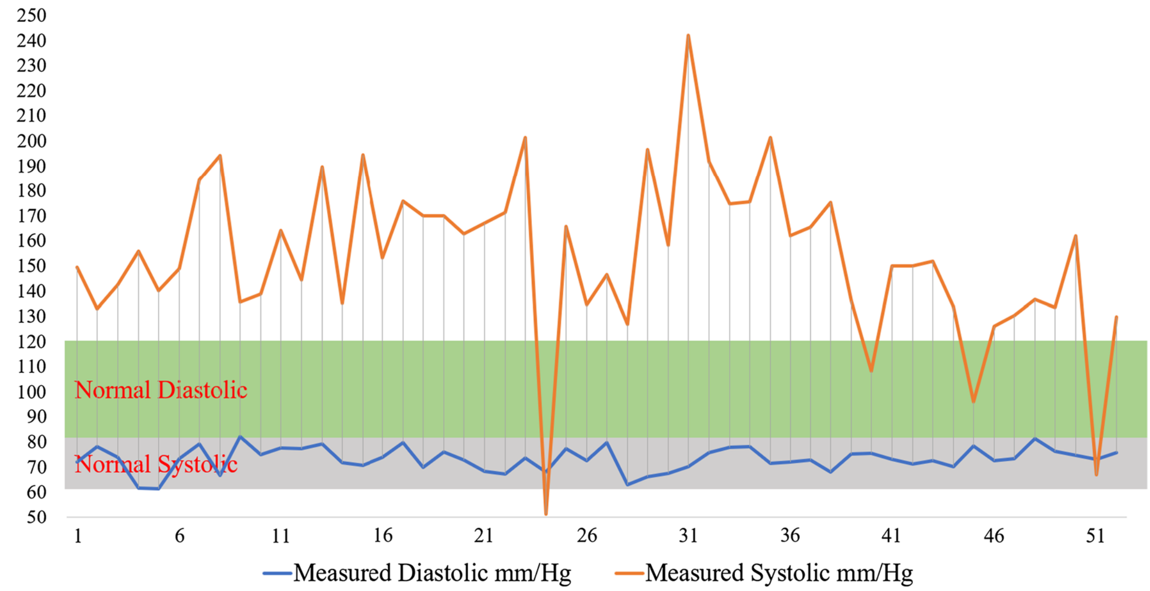

Fig. 7 I-Cares measurement of blood pressure for Diastolic and Systolic with alarms for upper and lower normal and abnormal blood pressure observations

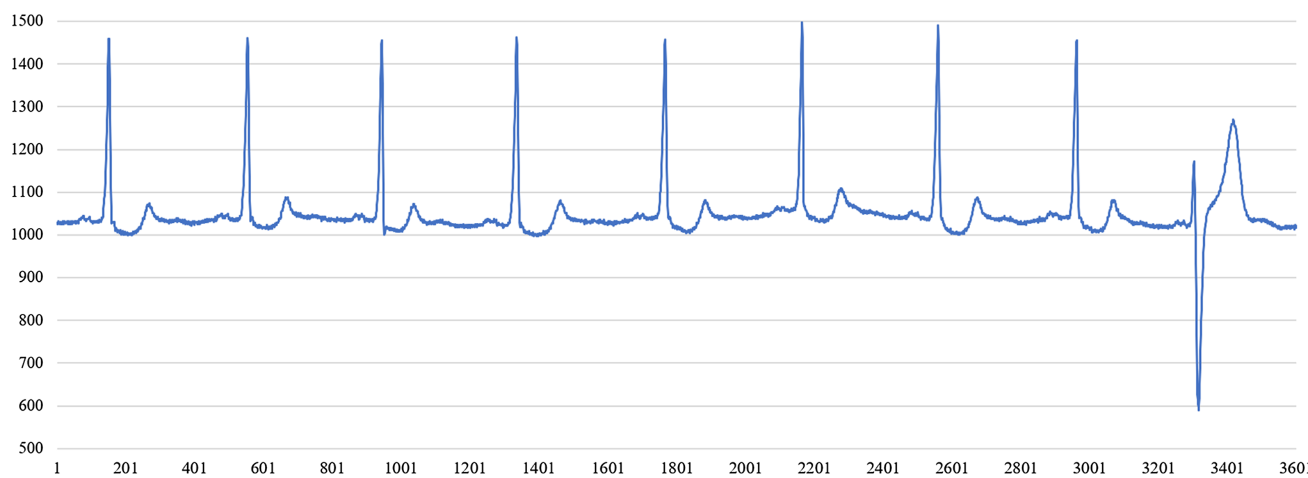

Fig. 8 I-Cares measurement of ECG 3600 signals waveform for a sample case

6 Conclusion

A novel approach is presented and an IoT based prototype has been developed in this paper. This comprehensive theoretical framework was then materialized into an innovative prototype that proves the practical functionalities of the I-CARES system. The system provides continuous monitoring and analysis of the patient's health status, medication effects, side effects, and automatic real-time emergency intervention that could eventually save lives. The system contains a portable wearable prototype device with sensors to measure vitals of patients. This device is connected via personal area network to a Smart Medication dispenser. Both measurements from the patient, medication dosage and frequency are sent to a cloud based Health Information System. The system is able to present reports and dates including recommended decisions to the doctor for deciding the medicine dosages, frequency, etc. I-CARES is also able to communicate with immediate relatives, neighbors, and emergency contacts to attend to the patient immediately. The system works according to the expected standards and in future, the system can be introduced to a large population in order to scientifically view the full potential of the designed system.

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