SAARTHI : Real-Time Monitoring of Patients by Wearable Device

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***Abstract*— The proposal comprises using cutting edge technology of Internet of Things (IoT), Cloud and AI-based analytics to monitor and provide timely and proactive alerts to not only patients but also healthcare workers such as doctors, nursing homes and even remotely located family members about patient's critical health parameters. The measured raw data will record live location and calculate heart rate, pulse, temperature and detect fall through wireless devices and connect to cloud servers. Also, this data will then be merged with the patient's historical medical data and analyzed using machine learning techniques for disease prediction at an early stage. It helps the family members and health workers to monitor and manage the health parameters of patients in an efficient way.**

Keywords*— *SAARTHI, Real-time Monitoring of Patients, IoT, Cloud, Artificial Intelligence

1 Introduction

As per the World Health Organization [11], few chronic diseases such as heart diseases, stroke, chronic obstructive lung diseases and lower respiratory infections have remained the top killers during the past few decades. Chronic diseases cause an increasing number of deaths worldwide. In the year 2015, diabetes caused 1.6 million (2.8%) deaths as compared to the year 2000, where there were 1.0 million (1.8%) deaths. The death rate caused by dementia more than doubled between 2000 and 2015 and thus made it the 7th leading cause of global deaths in 2015.

Despite these deadly statistics given by the WHO, most of the existing devices are fitness based rather than being healthcare based. They include all the wearables which record parameters like running time, sleeping time, etc. However, this equipment neither predicts potential health risks nor do they provide any real-time assistance in case of any emergencies.

To overcome the flaws of the existing system, the system proposes a smart wearable device, "SAARTHI" which aims to build a complete health care system in real-time to provide better human care. The system consists of a wearable device to record health data continuously and give real-time updates related to the health risks of the patients. Additionally, emergency alerts will be issued in case the need arises. It ensures that the patient is safe and allows the rest of the family members to work peacefully.

The paper discusses the merits and demerits of a few existing systems in section 2. The section 3 describes the proposed methodology and the implementation details of SAARTHI is discussed in section 4. The section 5 clearly states the results and inference drawn from the machine learning model by comparing its various performance measures.

2 Literature Review

Several promising technologies such as cloud/fog computing, IoT, big data have significant potential in providing real-time monitoring of the patients. Here, we discuss a few existing technologies based on our survey.

A. IOT BASED REAL TIME HEALTH MONITORING SYSTEM

The purpose of the invention [7] is to reduce the burden of patients visiting the doctor every time a patient needs to check his blood pressure, heartbeat rate, temperature, Glucose and Body Fat. However, this device does not predict any potential health risks for the user in the near future.

B. HEALTH MONITORING DEVICE FOR PREGNANT WOMEN AND FETAL

The device [2] presents a complete health monitoring device for a pregnant woman. The device is designed to

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capture blood pressure; pulse rate, fetal movement and heart rate based on WIFI in-built microcontroller CC3200. Also, the device has been designed to measure and monitor the haemoglobin content, blood sugar rate, thyroid level, calcium content, vitamin D3 for a pregnant woman and fetal. But it fails to provide the real-time location of the woman in case of an emergency.

C. PATIENT HEALTH MONITORING SYSTEM

The health monitoring system [8] comprises a wearable device that monitors the heart condition of a subject. It also monitors physiological data, movement and fall of the subject. If a patient is distressed or faces a heart attack, the system notifies and sends a message to the caretaker. It also sends the location of the subject in the case of emergency. However, in this system the user does not have the provision to ask for help on his own.

D. SYSTEM FOR ONLINE HEALTH MONITORING USING IOT BASED WEARABLE DEVICE

The device is designed to monitor patients [6], which comprises a wearable health monitoring device, a plurality of the internet of things, a computing device, a cloud server and a graphical user interface. The objective is to overcome the inadequacies in the health monitoring system. But this device is limited to provide emergency services like an Ambulance when such a necessity arrives.

E. IOT HEALTH CARE SYSTEM FOR A INDOOR AND OUTDOOR PATIENTS USING PDR

The advanced sensored devices can be either worn or embedded into the patient's body or clothes so that we can monitor the health conditions of the patients. The information collected is analysed and aggregated to detect the early prediction of the diseases. The proposed algorithm [5] helps the doctors to treat the patients and make health care more economic to the patient. But this device does not provide the real-time location of the user to help in case of an emergency.

F. HEALTH PARAMETER MONITORING APPAREL

The apparel [3] comprises a sensor including temperature, heart rate sensor, oxygen level meter, and blood pressure measurement module to detect the physiological parameters of the human body and send the signal to an external device and set an alarm or indicator to transfer the information. But this device does not allow the user to ask for help in case of an emergency.

G. HEALTH MANAGEMENT SYSTEM

The system is developed [4] to fit with a user's body, having a heartbeat sensor, an oxygen level sensor, a blood sugar sensor, a controller, a data signal, a communication module, a pacemaker, a display, a battery and a motorized injection for injecting drug during heart attack in case of failure of the pacemaker. But it lacks access to the real-time location of the user.

3 Proposed System

The proposed system aims to design and develop an IoT based wristband device and storage of this health data into a cloud server. This data would be further analysed using an artificial intelligence-based analytics system. The wristband is designed to send emergency alerts to a mobile phone of a caregiver/ family member.

Fig 1 depicts the conceptual architecture of the proposed system, SAARTHI. The various modules involved in the system are as follows:

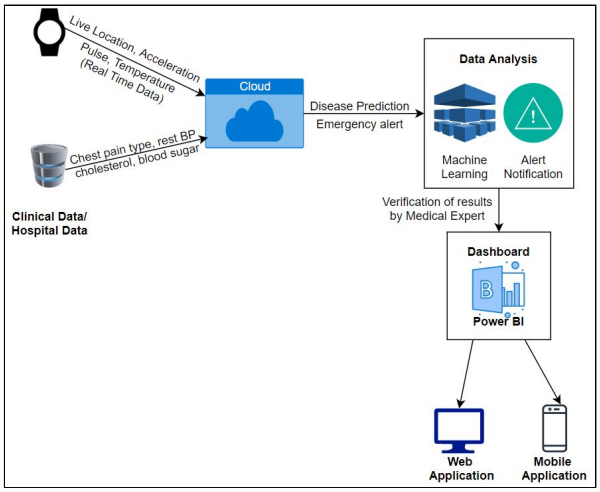

Fig. 1. System architecture - SAARTHI

A. *IoT Wrist Band*

Internet of Things (IoT) offers a platform for sensors and devices to communicate seamlessly and enables information sharing across platforms conveniently.

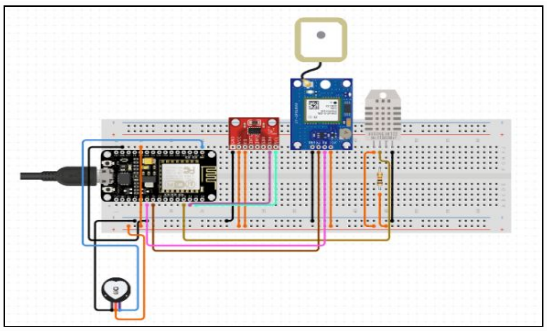

Fig. 2. IoT Circuit Diagram

The circuit diagram of IoT devices as depicted in fig. 2 comprises of the following specified hardware components used in the development of a wrist band are:

i) Sensors

Acceleration Sensor: As shown in Fig 3, it is the sensor that measures acceleration in x, y and z directions. If this value exceeds a predefined threshold, there may be a possibility that a sudden event like a fall or accident has occurred.

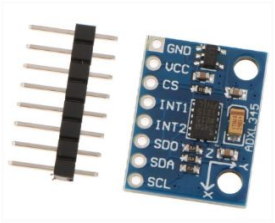

Fig. 3. Acceleration Sensor [17]

Temperature and Humidity Sensor: The sensor is DHT11 as shown in Fig. 4. It provides highly accurate and highly frequent results that require no complex circuitry. It does not need a lookup table or calibration, while its low-power operations minimize self-heating.

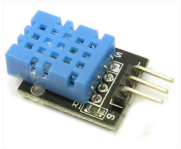

Fig. 4. Temperature and Humidity Sensor [16]

Heart Beat Sensor: As shown in Fig 5, it is designed to provide an analog output of heartbeat, when a finger is placed on it. When the Heart detector starts working, the topmost LED will start flashing with every heartbeat. The output pin of this sensor can be connected to the microcontroller directly to measure the heartbeat.

Fig. 5. Heartbeat Sensor [13]

ii) GPS Module: As shown in Fig 6, it is responsible to track the live location. The sensor gives the output as the Latitude and Longitude of the location. It is sufficient to find the real-time position of the user.

Fig. 6. GPS Module [14]

iii) Wireless Fidelity module: Wi-Fi is famous for low cost, low power consumption and flexible network topology. As shown in Fig 7, Wi-Fi allows local area networks (LANs) to operate without cable and wiring. It can be used to provide wireless broadband internet access for many modern devices such as smartphones, laptops, tablets and computers with authentication.

Fig. 7. Wi-Fi Module [15]

iii) Push Button: As shown in Fig. 8, it is a component that connects two points in a circuit when you press it. When the pushbutton is unpressed, there is no connection between the two legs, the pin is connected to 5 volts and it reads the output as HIGH.

Fig. 8. Push Button [12]

When the button is closed (pressed), it makes a connection between its two legs, connecting the pin to ground, so that it reads as LOW.

B. *Cloud Analytics*

ThingSpeak cloud server is a powerful physical or virtual infrastructure that performs application and information processing storage. A cloud is a logical server that is developed, hosted and delivered through a cloud computing platform over the Internet. Cloud servers have similar capabilities and functionality like a typical server but additionally. They can be accessed remotely from a cloud service provider.

C. *Analysis System*

Sensors, devices, social media, health care applications, temperature sensors, and various other software applications and digital devices generate large amounts of structured, unstructured, or semi-structured data. Real-time analysis can be typically performed on data collected from sensors.

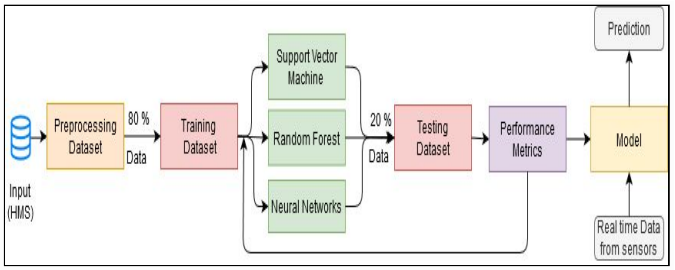

Fig. 9. Analysis System

As the real-time data changes constantly, and rapid data analytics techniques are required to obtain an analytical result within a short period. The health data received by the analysis system through the cloud server would be published on the dashboard after the verification of the medical expert. As shown in Fig 9, the analysis system would detect and recognize any variation in the health parameter. When the alert manager compares the incoming data with the critical data condition, it sends alerts (SMS/fax) to a healthcare provider or a family member.

D. *Web and Mobile Application*

The web and mobile applications will receive sensor data through the cloud server. The data will be stored on the cloud server and can be used for routine monitoring and consultation. Information related to the health condition including preventative and curative care would be provided through the application.

E. *HMIS / HIS / Telemedicine*

The health management and information system or hospital information system or telemedicine system are used for providing healthcare services to the patients or citizens.

The EHR and EMR of the citizens as per the health standards notified by the Ministry of Health and Family Welfare, Government of India has been adopted for developing such healthcare systems. Saarthi system is a wearable Wristband device integrated with existing hospital database systems aimed at extending health services to the patients using Cloud analytics-based AI solutions. The dashboard will be synchronized with SAARTHI web or mobile-based applications.

4 Implementation

The proposed system gathered the data from 52 patients to read real-time data using the sensors of wearable devices and combined it with data from the UCI Machine Learning repository to predict Heart Disease. Such processes are generalised for predicting other diseases.

The features considered in the input dataset are as expressed in the Statlog (Heart) Data Set [18]. In the data set, Class 2 indicates the presence of heart disease and Class 1 indicates absence.

The patient dataset is divided into 80-20% as training and test dataset respectively. The prediction model is trained using Support Vector Machine, Random Forest and Artificial Neural Networks (ANN) algorithms. Later it was compared to choosing the best algorithm. The model was evaluated using performance measures such as accuracy, precision, recall and f-score.

Support Vector Machine:

A support vector machine (SVM) is an example of a large margin classifier. It, being a supervised machine learning model, uses classification algorithms for two-group classification problems. The labelled training dataset is trained in each category and can categorize new text. SVM with sigmoid kernel gave about accuracy of 90.32%. The Precision is 91.89% and Recall is 91.89% with an F1 score of 0.918. Confusion matrix for the same is as depicted in Table 1.

True \ Predicted	Class 2	Class 1	All
Class 2	16	9	25
Class 1	1	36	37
All	17	45	62

Table 1: Confusion Matrix obtained using SVM

Random Forest:

Random forests are a learning method for classification that operates by constructing a multitude of decision trees at the time of training and predicting the class that was predicted by the highest number of trees.

The model was also trained and gave about 91.5% accuracy. The Precision is 89.4% and Recall is also 89.4% with an F1 score of 0.894. The confusion matrix is as shown in Table 2.

True \ Predicted	Class 2	Class 1	All
Class 2 (presence of heart disease)	17	2	19
Class 1 (absence of heart disease)	2	41	43
All	19	43	62

Table 2: Confusion Matrix obtained using RF

Artificial Neural Network:

Artificial Neural Networks is a supervised learning algorithm, works very similar to biological nervous systems such as the brain processes information. It is one of the widely used prediction models in healthcare systems.

The model was trained and achieved better accuracy of 91.93%. Table 3 indicates the confusion matrix obtained from ANN model.

True \ Predicted	Class 2	Class 1	All
Class 2	17	2	19
Class 1	3	40	43
All	20	42	62

Table 3: Confusion Matrix obtained using NN

5 Results and Discussion

Using the above-stated modules, the device first fetches real-time health data and GPS location of the patient. The health data is transferred via the cloud Server to the family and doctor of the patient. Similarly, the GPS location is shared with the family. As shown in Fig 10, this measured health data of the patient is shown to the relative.

Fig. 10. Relative's Dashboard

Simultaneously, this real-time data is analysed to implement disease prediction. The results of the prediction model is viewed and approved by the doctor expert and finally these results are then possibly visible to the patient dashboard as shown in Fig 11.

Fig. 11. Patient's Dashboard

If there is any chance of risk to the wellbeing of the patient, the medical expert first verifies the results and immediately alerts are sent to the family. The doctor can view all his patient's health analysis as shown in Fig 12.

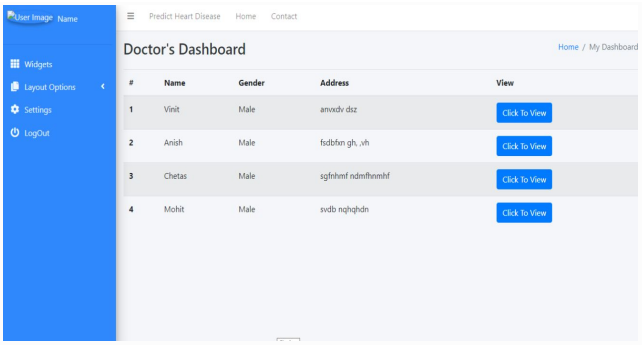

Fig 12. Doctor's Dashboard

Additionally, the system also ensures the safety of elderly patients by monitoring their stay within the home region. To support this, the GPS module is used to alert the family once the patient has crossed the safe region as shown in Fig. 13.

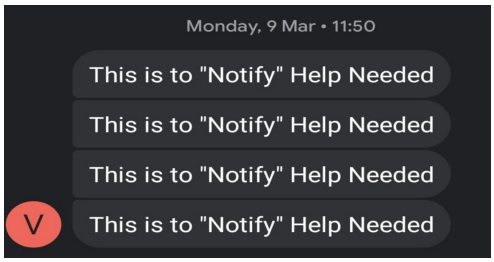

Fig 13. Emergency Alert Notification

The comparison plot of various performance measures of ML models like Random Forest, SVM and Neural Network algorithms are as shown in the table. 4.

Evaluation metrics	Random Forest	SVM	Neural Network
Accuracy	91.5%	90.32%	91.93%
Precision	89.4%	91.89%	85%
Recall	89.4%	91.89%	89.47%
F1 Score	89.4%	91.89%	87.17%

Table 4. Comparison of Performance Measures

The prediction model was evaluated using various performance measures such as:

Accuracy:
It is used to determine which model is best at identifying relationships and patterns between variables in a dataset based on the input, or training, data.

Precision:
It refers to the fraction of relevant instances among the total retrieved instances.

Recall:
It refers to the fraction of relevant instances retrieved over the total amount of relevant instances.

F1 Score:
It combines precision and recall relative to a specific positive class. It is a weighted average of the precision and recall, where it reaches its best value at 1 and worst value at 0.

The Artificial Neural Network performed best on accuracy metric with random forest following closely. But, in the case of Precision and Recall measures, SVM outperformed both of them with higher F1 score.

6 Conclusion

SAARTHI comprises using cutting edge technology of IoT, Cloud and AI-based analytics to monitor, alert and provide timely and predictive alerts to not only patients but also various health professionals and even remotely located family members to monitor critical parameters. The measured raw data will calculate heart rate, pulse, temperature, humidity, and detect a fall like situation through wireless devices and connect to the cloud.

The predictive analytical tools integrated with the cloud along with the alert system mobile app are the heart of the problem in hand. This ensures the timely deliverables to the various beneficiaries of the system to increase average life expectancy and also adding life to years and aid in making a huge social impact to ensure inclusive growth.

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