

# Patient Monitoring System with Miniaturization of Sensors

S.Geetha, Shilpa Pande, P.Deepalakshmi, Sheetal R

**Abstract:** *The quality of human life has improved with the technological advancement and miniaturization of sensors. Healthcare sector has adopted the new technology with the results of related research. Still, healthcare services are not easily affordable in developing countries. This paper aims to reduce the expenses of healthcare system through designing a remote healthcare system comprising of three modules. The first module deals with detection of patient's vitals using sensors. Second module is to collect and analyze the data and can be sent back to the doctor or guardian through Email and/or SMS alerts in case of any emergencies using Arduino. Third module implemented by K nearest neighbor classification algorithm is used to make runtime decisions if the alert message is not answered by doctors. By implementing these three modules, we achieved a better results in prediction and accuracy than the Attribute based credential and Amrita IoT-based Medical.*

**Keywords:** *Wireless Sensor Networks; Remote Monitoring; Arduino; GSM, KNN, PMSMS;*

## I. INTRODUCTION

In India, significant percentage of people lose their lives die to improper health monitoring systems. If the patient is unwell, patient has to be monitored continuously. During emergency, patient details need to be conveyed as a message to the concerned doctor. If the patients are in the remote areas, doctors are not available all the time and in such cases getting doctor is very difficult too. Even in emergency cases also, getting doctor is really a tough task. Apart from this, in few cases, patient has to be monitored continuously and patient's health parameters like blood pressure, body temperature, heart rate need to be continuously measured and kept. In certain cases, if the blood pressure of a patient shoots up suddenly, then patient needs immediate help from doctor as well as family members.

Sometimes, if a person gets heart attack and if pulse rate becomes low, then concerned doctor should be alerted with a message so doctor can rush and provide the necessary aid. Along with the message alert, if additional information of

patient's location is sent, the required help can reach there easily [1]. Road accidents are very common in India and during this situation, a person may not be able to call for help. Hence, there is a huge demand for patient monitoring system which satisfy all the requirements. Using this, patients can be continuously monitored as well as doctors can check more than one patient at a time. Doctors can get continuous reports about patient's health conditions.

The Internet of Things (IoT) plays an important role in health care sector. The IoT revolution is reshaping the modern health care with wide ranges of aspects like economical, technological and social. Data exchange and automation using IoT is a rapidly growing technology. It includes sensors and data streams. The advances in Internet innovation have made possible techniques for conveyance in health care.

Usually, the body temperature indicates the normal condition of a person. For a normal person, body temperature ranges from  $98^{\circ}\text{F} \pm 0.7^{\circ}\text{F}$ . If the body temperature is extremely hot then doctor has to receive the report. Heart beats show soundness of person's heart. Normal heart rate in case of adult males is 70bpm and in case of adult females, it is 75bpm. In case of cardiac arrest, heart rate becomes low. This information should reach the doctor. If something goes wrong with the patient, he screams or makes a loud sound, which will be caught by sound sensor and an emergency message will reach the doctor [3]. So an emergency alert system is needed without compromising of locations and absence of doctors. In our proposed work, we incorporated these ideas for saving the patient's life.

The proposed Patient Monitoring System with Miniaturization of Sensors (PMSMS) provides solution to all specified problems. The patient is continuously monitored with the help of IoT. The sensor data is collected and checked against the threshold values and the data is uploaded on the cloud. The cloud will monitor health parameters and provide assistance in case of emergency.

In PMSMS, if the observed reading of sensors is crossing the threshold values then immediately alert message is sent to the doctor and the care taker. Immediately his location will be shared to doctor and nearby hospital for ambulance emergency. For the first aid, patient's data will be checked for doctor's prescription and immediately first aid will be provided to the patient. In case of road accidents, the nearby hospital's ambulance can reach to the patient's location with required aid. Care takers are given with language option too. So our health monitoring can enhance the quality of life especially for elderly people.

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## II. LITERATURE SURVEY

The authors of [4] analyzed and planned for patient's wellness as a theme based on Attribute Based Credentials (ABC) and the necessities, actions and conditions advised by caretakers, doctors and the patient. Wireless Sensor Network (WSN) and their needed and necessary information transferred over the web helped to achieve the patient monitoring system. But emergency alert system is not discussed in the absence of doctors. In our PMSMS, we incorporated the ideas for saving the patient's life. From this, all the health connected information and knowledge of the patients are simply accessed via doctor's smartphone. This eliminates the need for doctor to go to every section of the hospital. Instead, the doctor's guidance over a message to the medic leads to faster treatment associated with the patient's condition.

It has been clinically shown in [5] that Personalized Health Motifs (PHMs) are nearly as good as raw sensing element information in prognosis and diagnosing of illness conditions as given by preciseness, recall and F1-score numerous 0.87, 0.83 and 0.85. Amrita IoT Medical Smart-edge system analyses the performance and the results have been displayed. It clearly specifies that the results collected from sensors are moved to cloud based storage. It has been shown an outstanding enhancements in information measure as 98% and accuracy of sensors as 90% within the Amrita IoT Medical (AIM) Smart-edge by means of PHMs. AIM Smart-edge will significantly cut back the information load within the network.

There is a significant distinction between Global System for Mobile Communications (GSM) based patient health observance system and IoT based patient monitoring system as discussed in [6]. In IoT based system, details about the patient's health is seen by several users. The rationale behind this is, often the information has to be monitored by visiting a website or uniform resource locator. Whereas in GSM based patient observance system, the health parameters are sent by means of GSM via SMS which is not retrieved by multiple users at a time.

The authors in [7-9] proposes a framework to uncover the knowledge in a database and brings into the notice the patterns which help for critical decision making. They provide a predictive system for diseases such as heart disease, breast cancer, diabetes, spect\_heart, thyroid, dermatology, liver disorder using many input attributes related to a specific disease.

Usage of machine learning algorithms such as KNN, support vector, Machine Trees, Random Forest and MLP improve interactivity between patient and doctor as stated in [10]. They analyzed and concluded that Random Forest provides good accuracy among all other algorithms. The accuracy can be further increased by using larger data sets.

This authors in [11] implemented an ambulatory health care, a remote patient monitoring system which allows a medical caretaker to use medical device in ambulance to perform a routine test and test data will be sent to a health care professional in real time. If the patient suddenly falls sick and he is being carried to the hospital, the cause of illness is known only when the patient reaches the hospital. When the

patient is in the ambulance, he can't be monitored much. The authors at [12] provide a solution to this problem by providing online system for monitoring. The system is implemented using an Android Application. The doctor sees the health parameters on his smart phone and even he can suggest a quick medical help as suggested in [13].

Authors in [14] present a design of a real time health monitoring system which can store a patient's basic health parameters. This work enhances overall healthcare delivery by facilitating multiple modes of connectivity between patients and clinicians. In [15], the three modes of communication are BLE (Mobile App), Wi-Fi, GSM. The multiple modes of communication help in reducing the risk of losing track of patient if one of the three modes of communication fail. The data is received from multiple sensors in various formats as in [16]. This data is multiplexed by the software program. The sensor data multiplexed and framed into a custom payload packet. This packet is passed on all three modes of communication [17].

## III. SYSTEM ARCHITECTURE

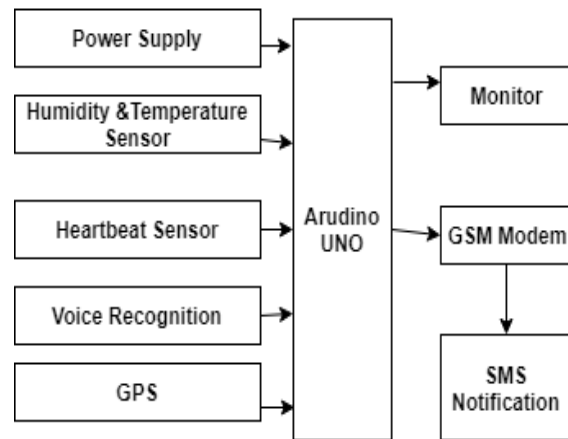


Fig. 1. Architecture of ARDUINO UNO for Patient Monitoring System

In Fig.1, the architecture of ARDUINO UNO for Patient Monitoring System is illustrated. In IoT-based patient monitoring system, the real-time parameters of patient's health are directed to cloud. This is done with the help of ARDUINO UNO kits.

## IV. PROPOSED SYSTEM

We provide solutions to certain problems by proposing smart patient monitoring system which means constantly monitoring the patient. Nowadays, smart phones are everywhere and easily accessible too. Using this, we propose an Android-based wireless patient monitoring system. With the help of this, we can continuously monitor few parameters like body temperature & humidity, heart rate, sound of a patient and patient's location [2].

Data pre-processing is the integral part of data mining. It is used to convert raw data into meaningful and useful data. It is an integral step in data processing as the useful information can be extracted from it which affects our results. The data in

the real world is not clean. It can be incomplete, noisy or inconsistent and our results are crucially dependent on quality of input data. Data travels through multiple of steps during pre-processing like data cleaning, data integration, data transformation, data reduction and data discretization. Numerous issues need to be addressed when the data is collected. Sensor data by default is noisy and uncertain, and may either have missing values or duplicate readings depending upon the application domain. In our proposed system, we continuously get the values from various sensors like temperature, heart beat and sound. All the values might not be useful, so depending on the threshold values, other values are neglected.

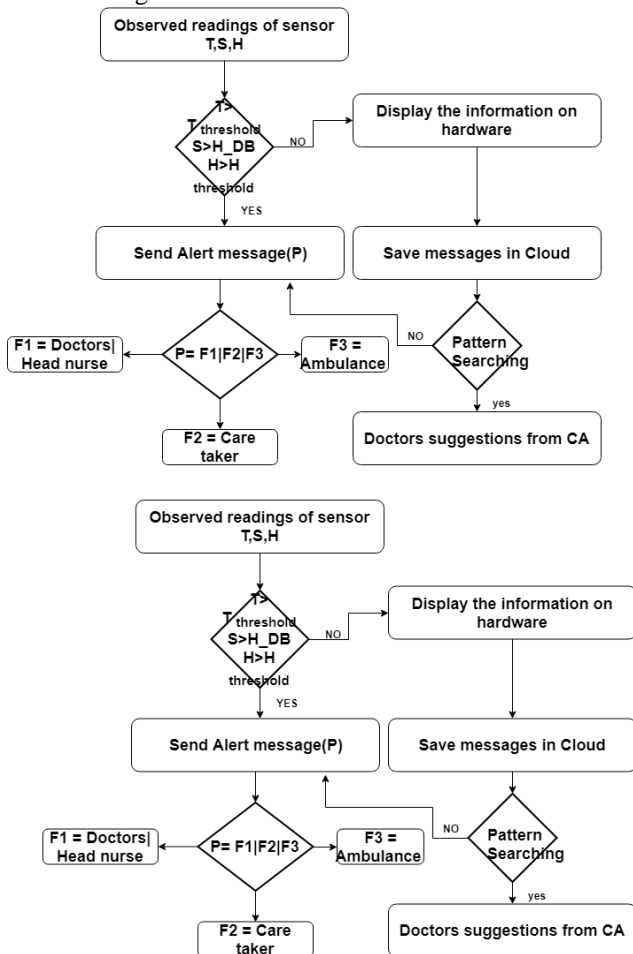


Fig. 2. Flow Chart for Patient Monitoring System

Body temperature is one of the important parameter which is checked for patient when he goes to the hospital. The body temperature varies from person to person and keeps changing throughout the day. We cannot define the exact value of body temperature as it totally depends on the age, day timing and the state in which the person is like running / playing / sitting. The normal body temperature ranges from 98oF ± 0.7oF.

We are using DHT11 sensor, a digital temperature and humidity sensor. It is less expensive digital temperature and humidity sensor. It generates digital output. It gives long term stability and reliability. This sensor will be connected to Arduino Uno for temperature monitoring. We can get updated data from it in every 2 seconds. If the body temperature goes above 100oC, the SMS will be sent to the concerned doctor along with the patient location information.

### A. Algorithm for Temperature Sensor

#### Algorithm 1 : For Temperature Sensor

```

For i=0 to n
    temperaturei = Read_sensor(data, Ti)
    Di = Store_data(temperaturei, Ti)
For i=0 to n
    tempi = Read_document (Di)
    if (tempi > 104°F) then
        counti++
    if (counti > 5) then
        Send_AlertMessage()
        SaveMessage_PatternSearch()
    
```

In Algorithm 1, we are discussing for Temperature Sensor. The number of nodes in the IoT is referred as n. D = {D1,D2...Dn} represents the set of collected documents which is stored with data of sensors. It is recorded with respect to the time stamp T<sub>i</sub>. If the patient body temperature exceeds the threshold for 5 times with different period then alert message is triggered and sent to others. The same message is saved on cloud.

### B. Algorithm for Sound Sensor

The sound sensor module detects the sound and its intensity. We can adjust the accuracy according to the convenient usage. It has microphone which gives the input to an amplifier, peak detector and buffer. When the sensor finds a sound, it processes an output signal voltage. Sound sensors are trained to differentiate the sound frequencies. The output signal is sent to a microcontroller to perform necessary processing. When the sensor detects the sound, it transmits the voice through GSM module and location of person is sent to the specified number that may be doctor or guardian of the patient through GPS module.

#### Algorithm 2 : For Sound Sensor

```

For i=0 to n
    Si = Read_sensor(data, Ti)
    Di = Store_data(Si, Ti)
For i=0 to n
    soundi = Read_document (Di)
    if (soundi > 90 db) then
        Send_AlertMessage()
        SaveMessage_PatternSearch()
    
```

In Algorithm 2, we are discussing for sound sensor. The number of nodes in the IoT is referred as n. As stated earlier, D represents the number of collected documents which is stored with sound data of sensors. It is recorded with respect to the time stamp T<sub>i</sub>. If the patient body voice threshold is greater than 90 db then alert message is triggered and sent to others. The same message is saved on cloud. Messages are saved on cloud and further it is analyzed with pattern search.

**C. Algorithm for Pattern Searching**

The unique contribution of this paper, a set of first aid commands are delivered to the caretakers when the alert message is not answered by the doctors. K-nearest neighbor classification algorithm (KNN) is implemented to attempt saving of the patients during emergency conditions, in the absence of doctor. If the doctor is not available even after the alert, then PMSMS system itself runs the KNN algorithm and finds a solution like prescription or first aid act for the patient. It will be given as a message to the caretakers for the necessary actions like first aid. The saved messages are analyzed to get a decision as a result from the previous result set by using K-nearest neighbor classification algorithm.

KNN is simple to implement and works faster on data sets. It also performs asymptotical comparison which isn't available in Bayes Classifier. Prior knowledge about the structure of data in the training set is not required. The new training pattern gets added to the existing training set.

Here the training set is extracted from the patients' database with class labels of prescription/first aid and it is mentioned as  $(X_i, C_i)$  where  $i = 1, 2, \dots, n$  be data nodes.  $X_i$  denotes attribute values &  $C_i$  denotes labels for  $X_i$  for each  $i$ . Let us assume the number of classes as 'c'  $C_i \in \{1, 2, 3, \dots, c\}$  for all values of  $i$ . Let  $X$ (Hypothesis) be patient details which is given to caretaker in the absence of doctor. If label for the patient is not known then we would like to find the label class using k-nearest neighbor algorithms.

**Algorithm 3 : Pattern Search**

```

For i=0 to n
  For j=0 to n
    L [i] = Extract_TrainedData()
    K= Find_DISTANCE(L, X)
    Sort(L,k)
    If (ki > kj ∀ i ≠ j) then
      a. X= {I}
    
```

After the alert message, if there is no response from doctor and the waiting time threshold is greater, then pattern search algorithm is called. In Algorithm 3, we discuss for pattern search with the Hypothesis of  $X$ . The number of stored messages on cloud is referred as  $L$ .  $K$  represents the distance between given new patient record and the stored messages. After sorting, we can derive the closed result from the trained patient record for the unknown record. We have to provide a result with the type of first aid or prescription ( $I$ ) for the given Hypothesis  $X$ .

TABLE 1: Hardware Description

Sensor / Device	Description	Threshold value	Information
Temperature Sensor	displays digital output of temperature	Temperature >99	Temperature 99 to 100 observed per minute
Heart beat sensor	displays digital output of heart beat	Pulse rate becomes zero or goes above 100 bpm	Pulse Rate as 60 to 100 beats per minute
GSM module	It connects the board to the internet for	NA	NA

	sending & receiving SMS		
Voice Recognition Module	Speaker-dependent voice recognition module.	Max 7 voice commands work at the same time	80 voice commands recognition
Arduino Uno	Microcontroller based kit	7-12V	Tmega328 with 28 pins
GSM Modem	GSM modem through which messages will be sent to the concerned doctor	AT commands as high status	FT232 USB to serial converter
GPS module	small Electronic circuit	Altitude, speed, date and time as per on UTC	ZigBee module

The label class of unknown data record is classified with the use of trained data sets in K-nearest neighbor algorithms. Here patient details which is given to caretaker in the absence of doctor is  $X$ . KNN Algorithm finds the match for patient details using attributes like temperature, heartbeat and sound with the existing stored and trained data set. The output of the KNN Algorithm is a first step solution for the patient.

The pulse oximeter for heart beat sensor has two designs for pulse detection. The first design has Arduino to process the incoming data. In this method, peaks are detected and based on peak values, pulse will be estimated. The second design detects pulse on the main computer. This method didn't cause data skew. The same way we used the hardware for readings with temperature sensor and sound sensor.

Table 2 shows the inputs for KNN algorithm with the samples of patient details. Class label is specified with Prescription/First aid attribute. This is the message details provided for the care takers in the absence of Doctors. Column 1 of table 2 is mentioned with the assignment of patient with doctors.

TABLE 2: Classification Table

Patient/ Doctor	Temperature	Heart beat	Voice	Prescription / First aid
P1 / D1	102	108	Low	Crocin/ Paracetamol tablet should be given, sponging to be done
P7 / D3	102	105	Low	Crocin/ Paracetamol tablet should be given, sponging to be done
P9 / D6	99	91	Low	Lots of fluids / electrolyte should be given
P5 / D2	101	103	Low	Crocin / Paracetamol tablet should be given, sponging to be done
P13/ D5	99	89	Low	Lots of fluids / electrolyte should be given
P17/D5	99	78	Medium	Normal Condition
P22/D4	104	108	Low	Crocin / Paracetamol tablet should be given, sponging to be done
P10/D3	98	82	High	Normal condition





## V. RESULTS

Caretakers of patients and the doctors are initially registered with a system on PMSMS. Later based on the patients' health status, alerts are initiated and delivered to doctors.

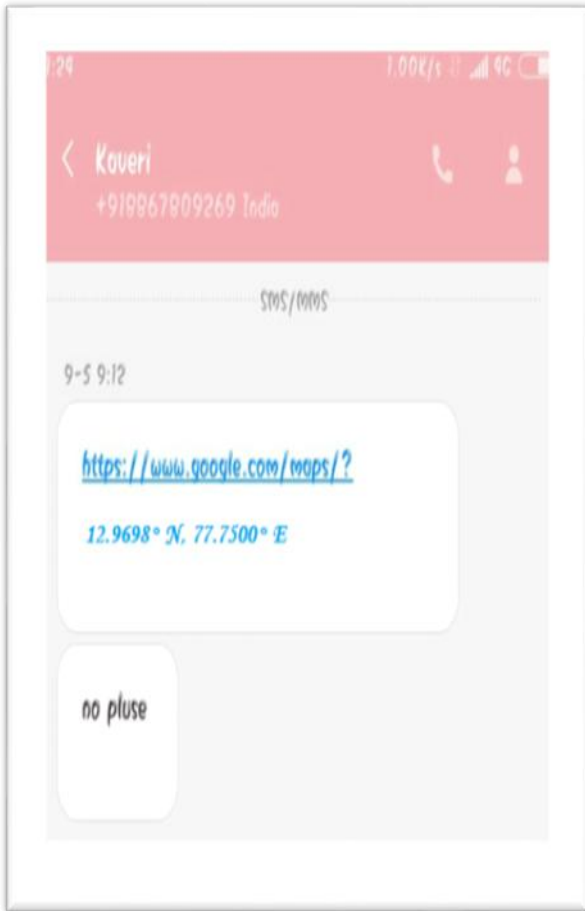


Fig 3: Alert messages from PMSMS system.

Fig.3 shows the status of the patient as no pulse in the body and this message is immediately dispatched to the caretaker of patient and doctor respectively. It is a worst case scenario. It displays the patient live location with altitude data.

Fig.4 shows the result of KNN as an adaptive method from PMSMS system. The alert message to the doctor is sent and if the doctor is not available then PMSMS system runs the KNN algorithm and discovers a prescription or first aid steps for the patient. It is a display message for the caretaker to take prior actions before the doctors reach the patients.

Here again we are supposed to prove how much accuracy we have obtained for proposed PMSMS. Table.3 shows the metrics of PMSMS compared to other algorithms.



Fig 4: Result of KNN as an adaptive method from PMSMS system.

Fig 5. Illustrates the language selection module for caretakers. It is also enabled with options in text using English and voice options too. After the selection of options, remaining modules will be displayed based on their previous options. This module helps the care taker to act fast towards the patient's health improvement. Most of the care takers may not be educated or expertized in technical modules. So, care takers need a support with their own language system with self employed voice system.

After successful testing of PMSMS, we derived the results of Table 3. It shows the different metrics of KNN classification with respect to the data set generated by the Arduino. PMSMS data is improved with performance compared to ABC and AIM. ABC method and Amrita IoT System explained only the attributes of handling with patients' health. But the alert message for the doctors' absence is presented in proposed PMSMS system.

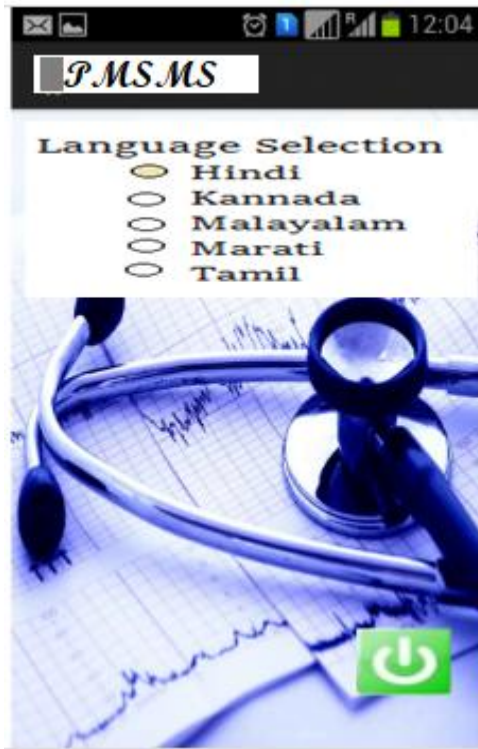


Fig 5. Language Selection

Parameters	PMSMS	Attribute based credential (ABC)	Amrita IoT-based Medical (AIM)
Accuracy Of Single	0.5	0.4	0.3
Error Of single	0.3	0.4	0.3
Sensitivity	0.5	1	1
Specificity	1	0.9	0.8
Precision	1	0.9	0.75
FalsePositiveRate	0	0.1	0.2
AccuracyInTotal	0.125	0.115	0.105
ErrorInTotal	0	0.1	0.125

TABLE 3: Metrics from PMSMS

Fig.6 shows the analytical data of accuracy comparison with single sensor reading. It indicates how much PMSMS is correct without error data on message for care takers and it is deciding from the different class labels (first aid) of table 2 which as a message need to be sent for the caretaker in the absence of doctor. ABC method and Amrita IoT System explained only the single sensor attribute data of handling with patient’s health whereas the error accuracy calculation and total error estimation in PMSMS is comparatively better than other system.

Fig.7 shows the analytical data of accuracy comparison with more sensor reading. After successful testing of PMSMS, we derived the results of PMSMS and again it is seen that performance is improve, compared to ABC and AIM.

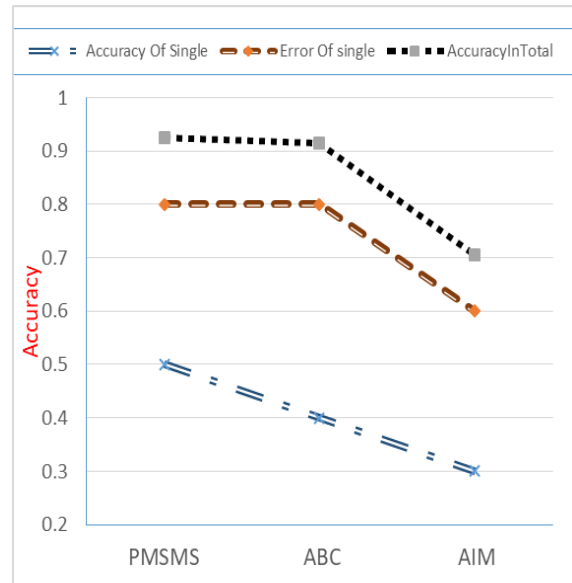


Fig 6. Metrics Comparison for Single Sensor Attribute Data

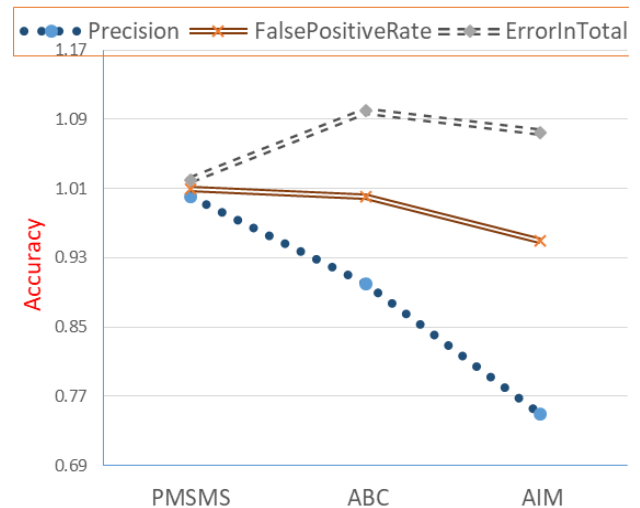


Fig 7. Metrics Comparison for Multiple Sensor Data

ABC method and Amrita IoT System is explained with more number of sensor attributes of handling patient’s health. But the precise and false positive rate estimation in PMSMS is comparatively better than other system. A message need to be sent for the caretaker in the absence of doctor. In Fig 7, we shows how much PMSMS message is having accuracy than the others methods.

## VI. CONCLUSION AND FUTURE SCOPE

In this paper, we have proposed a smart patient monitoring system which is very useful in biomedical applications. Using this system, doctors can continuously monitor patient’s health from anywhere and anytime so that proper and timely care can be taken. In emergency cases, concerned doctor will get an SMS about patient’s critical condition so he can take fast aid actions to save the patient. This reduces number of fatalities because of delay in providing timely help. The unique contribution of this paper is that



if the doctor is not available then system itself runs the KNN algorithm and finds a solution, prescription for the patient. It will be given as a message for the caretakers for the preliminary actions like first aid. In the future, the message can be delivered to the care takers with minimal delay. After the first aid was given by the care takers to the patient a report can be generated and delivered to the doctor for future monitoring.

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**S. Geetha**, completed her schooling in 2001. She obtained her undergraduate, B.Tech (Information Technology) degree from Francis Xavier Engineering College (affiliated to Anna University, Chennai), Tirunelveli by means of a First Class with Distinction in 2005. She had completed her postgraduate, M.Tech (Information Technology) from Satyabama University, Chennai again by means of First Class with Distinction in 2009, and distinguished herself in the Toppers list too. She worked as a faculty in different engineering colleges affiliated under Anna University, Tamilnadu as well as Visvesvaraya Technological University, Karnataka. Thereafter, she joined as a research scholar in the Department of Computer Science and Engineering at Kalasalingam Academy of Research and Education in 2014. She is currently working as an Associate Professor in Department of Information Science and Engineering at CMR Institute of Technology, Bangalore. Her research interest includes Wireless sensor networks, Data Mining and Warehousing and Sensor cloud. She has published her research in many Journals and conferences. Mrs. S. Geetha is currently specializing in Wireless Sensor Networks with a focus on void free routing mechanisms for sensor and cloud storage and retrieval systems. She has submitted 4 proposals and she has published 25 papers in international journals and conferences during this period. She is the active member in ISTE and INC.



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