An Intelligent Decision Support System for Enhancing an M-Health Application

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***Abstract*—In most of the developing countries, the rural population is denied of the efficient and effective health care facilities. This increases the mortality of people in very young age due to several unknown and untreated diseases. This situation can be improved by adopting the usage of wearable sensors that are capable of continuously monitoring the patients and issue warnings to specialized experienced doctors in hospitals or to the care takers. This approach will bring in better healthcare facility to the people living in the rural world or to the people who are unnecessarily staying in the hospitals just for the purpose of monitoring. This can also help those people who do not want to stay in hospitals. However the efficiency of such a system will depend on the capability of the decision support system integrated with it. Hence this research work aims at the development of a decision support system architecture that can support data collection and processing from multiple wearable wireless sensors. The real-time data received from multiple wearable sensors will be analyzed for a variety of diseases. The results will be stored and send to the required persons via SMS. As an initial step towards the development of decision support system, a prototype system is developed that can be used for the monitoring of cardiac disease such as Ischemia, Myocardial Infarction, Cardiomyopathy, Hypokalaemia, Hyperkalaemia, First degree AV Block and Wolff Parkinson White Syndrome. This work has also developed a new risk based scheduling algorithm to handle the data processing so that the patients with the highest risk are processed first. The work also includes the implementation of several techniques such as decision trees for taking better decisions and for proper classification of diseases.**

Keywords*—e-health, data mining, wearable sensor, ECG, decision support system.*

I. INTRODUCTION

In developing countries, there is an immense shortage of health care professionals. The situation is even worse in rural areas due to the lack of diagnostic tools. As a result the people living in these rural areas are not able to get proper care. However, one way to address these issues is to introduce and make use of computer assisted diagnostic systems, also known as decision support systems [1].These decision support systems have been successfully implemented in many of the developing countries. In this research work, we are developing a decision support system that can be used to detect any type of disease which will be useful to the people living in the rural areas.

The idea of decision support system has been widely accepted in health care. The development of clinical decision support system have drawn much attention [2]. Decision Support Systems can be defined as ”any software designed to directly aid in clinical decision making in which characteristics of individual patients are analyzed for the purpose of generating patient specific assessments that are then presented to clinicians for consideration”[3].These systems have been used to improve the quality of health care by supporting clinical decision making. In most of the decision support systems, the patient data are stored in a patient database and are available for computer-assisted decision making. If the computer detects any abnormality, the physician is immediately notified via a message on the computer screen explaining the reasons.

Even if it is a difficult task to develop a decision support system that can be used for detecting almost all major types of diseases, we are planning to develop a system that is capable of detecting any type of disease. But in the current research work, we are proposing a decision support system that can detect some of the major types of cardiac diseases such as Ischemia, Cardiomyopathy, Hypokalaemia, Hyperkalaemia, First Degree AV Block, Myocardial Infarction and Wolff Parkinson White Syndrome. The system analyses and processes the patient’s data depending on the type and nature of the disease and come up with recommended diagnosis.

II. RELATED WORK

The development of computerized applications for supporting physicians is an old but still alive quest. A number of systems have evolved for supporting medical decision by supplying a variety of services from information retrieval and communications to cost-effectiveness, error prevention, safety, and improvement of health care quality.

A Mobile Intelligent Medical System is developed in the paper proposed by Charles V et.al [4] that supports mobile nursing applications and clinical decision support. A Java-based expert system integrated with an RFID-enabled patient data collection module and a rule base is used to issue warnings and send diagnostic messages. This system does not take into account the health risk of the patients and hence it will not be able to consider the high risk patients immediately. But this can be overcome in our system by means of prioritizing the patient’s data and scheduling these patients in a more efficient manner.

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The paper [5] describes the development of a remote monitoring system for ECG signals. Here, the patients will be wearing a wireless sensor and a server computer is used to analyze ECG signals and detect serious heart anomalies in time. The ECG signals are then wirelessly transmitted from the patient to the server located in the hospital where the signals are analyzed by the doctor. The system uses only wearable ECG sensors. But the proposed decision support system is capable of collecting the readings from multiple patients wearing multiple wearable sensors such as ECG sensors, pressure sensors and so on which will be capable of detecting multiple types of diseases in addition to cardiac disease. The concept of providing early warning messages to the doctors, patients and care takers which is used in the system can be incorporated into our system to improve the efficiency of the system.

A low cost, real-time patient monitoring platform is designed in [6] to improve the current medical services. The data gathered by the sensor unit is transmitted to the server through a medical hub and the data is then stored in the server and displayed in the Medical Assistant's system. The doctors analyze the data with available functions and make the preliminary diagnosis. The main disadvantage of this system is that, for retrieving and analyzing the data, presence of doctor is a must. Hence, doctor is the ultimate person who has to take the decision. While in our system, the data is automatically retrieved and analyzed by the decision support system and produces the necessary decisions which can then be conveyed to the physicians through messages to take the final decision regarding the condition of the patient. Another decision support system that is built by the Stanford University to assist physicians in the diagnosis of infectious diseases is MYCIN. The system is capable of asking a series of questions and from the responses to these questions it produces a list of possible diagnoses. One of the main problems associated with the implementation of MYCIN is that it has never been actually used to diagnose and prescribe treatment for a patient.

III. PROPOSED SYSTEM

A. Overview

Decision support system can play a vital role in providing basic health services to the remote village population. This system can enable expert doctors to monitor patients in remote areas. As a result, the patients no longer need to travel long distances to reach the basic health units. Presently, care is being provided by a person who takes readings of patient's physiological data using instruments which are difficult to handle. These data are then recorded into printed forms manually. Finally, the collected forms are sent to a doctor who goes through all of them looking for any symptoms of abnormality. If any abnormality is detected, the doctor prescribes the medicine depending on the nature of the disease. Here we propose to develop an automated system that will replace all this hectic activity. The proposed system consists of multiple wearable sensors that are capable of sensing the vital parameters. The sensed data are then wirelessly transmitted to the decision support system server to detect any abnormality. The data and the results are then conveyed to the doctors and the care takers by means of messages. This can assist the doctor in the decision making process.

The mode of monitoring of patient is determined by the nature and seriousness of disease. A normal patient under observation may need to be monitored only at periodic intervals; whereas a critical patient must be under constant monitoring. The patients will be equipped with wearable wireless sensors which will be capable of taking continuous measurements. The use of these wearable sensors will help in the continuous monitoring of the patients. Here, we are considering the case of cardiac patients who needs immediate care and hence the system can be considered as a time critical system. So we need to develop certain methods in order to reduce the delay of processing.

The patients were continuously monitored and the medical signals are transferred anonymously. Each of the patients is assigned an identification number which can be uniquely used to identify the patient. The signals can be continuously acquired from the patients while they are performing their activities. The data were collected by means of several wearable wireless sensors and they are transferred wirelessly to the server which acts as the decision support system. All the processing will be done at the server.

The Figure 1 shows an overview of the proposed system. The main component of the system is a remote server providing Clinical Decision Support System. The module consisting of medical sensors senses the patient's data and when all the readings have been taken, the data is transferred to the server through internet. The server processes the data and then invokes the Clinical Decision Support System to perform analysis of data. The decision support system will provide automated analysis of data and assist the doctor in decision making process.

The database will contain the stored information about the patient in addition to the sensed medical data that are received. Depending on the priority of the patient, this data is then retrieved from the database for further analysis. Here priority can be assigned to the patients depending on various risk factors such as Hypertension, Hypercholesterolemia, Diabetes Mellitus and Previous heart attack or stroke. This is because of the fact that there is a high risk for cardiac diseases in patients

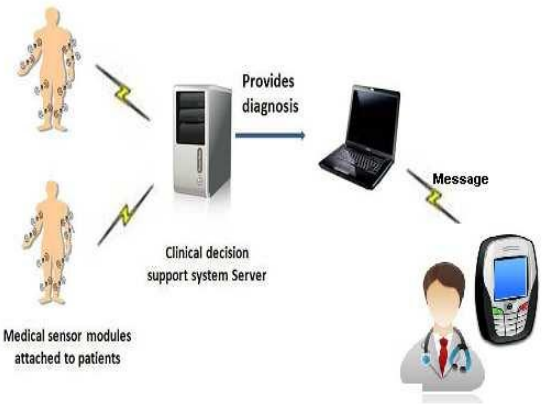

Figure 1. Proposed System Overview

who are suffering from these diseases. Hence they are given a high priority. Thus, depending on the priority of the patient, the data is processed and then it is analyzed to detect the presence of abnormalities. If any abnormality is detected then the disease is identified and the warning messages can be sent to the doctor or to the care takers to take the necessary precautions. The working principle of the decision support system architecture is discussed in section 4.

B. Research Challenges

The main challenges which should be solved for the successful realization of this system are:

- Prioritizing the data: Since the bandwidth is limited and we are receiving the data from multiple sensors the reception of data should be prioritized so that the critical data is analyzed first.
- Scheduling: Since we are receiving data from multiple patients, these data's must be processed in a scheduled manner so that the critical patient's data is analyzed first.
- Association rule development: There are various types of cardiac diseases and we need to identify how these diseases are related to each other.
- Evaluation: The evaluation of the decision support system is important because it is important to check at frequent intervals whether the system is producing the correct decisions or not.

In the current research work, we aimed at solving the main research challenges such as prioritization of data and scheduling of the patients.

IV. DECISION SUPPORT SYSTEM ARCHITECTURE

The sensed information from the patients wearable sensors are transmitted to the decision support system server. The server will receive different patient's data and upon receiving the data, it will record the data into the patient's database. The data is then scheduled according to their priority by means of a scheduling algorithm. The data of the patient with highest priority is taken from the database and are given immediately to a signal processing module where they are processed by means of several signal processing algorithms depending on the type of the medical signal that are received. If the received signal is an ECG signal, then the corresponding signal processing algorithm will be invoked to extract the various segments of the signal. The result of this signal analysis is then conveyed to the doctor via SMS for further clarification. The decision support system proposed here should be capable to handle the reception of multiple signals that are transmitted from multiple patients at the same time, store the signals and schedule them for processing. Our design has considered all these characteristics that are necessary for the decision support system and developed a new design as shown in Figure 2. It consists of various modules such as Data Acquisition module, Database module, Signal processing module, Decision module and report generation.

A. Data Acquisition Module

The patient data is acquired at frequent intervals based on the priority of the patient. The data is received through wireless medium over the network to a database server where it can be analyzed and stored in a database for further processing. The real time data so collected is stored into a patient database in the server. The medical data of a high risk patient will be received more frequently than a low risk patient. The data can then be analyzed on the basis of the priority of the patient and nature of the disease.

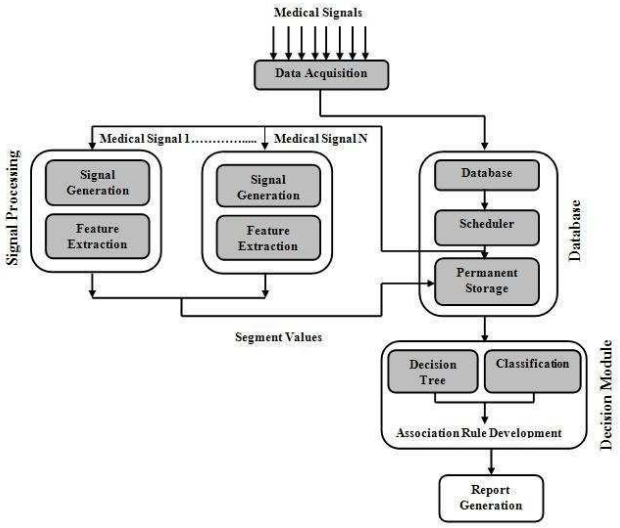

Figure 2. Decision Support System Architecture

B. Data base Module

The database module consists of patient database (MySQL), scheduler and a permanent storage. The sensed patient data that are wirelessly transmitted are stored into the patient database. The stored information are then scheduled by the scheduler and are given to the signal processing module for further processing. The results that are obtained after the application of advanced signal processing techniques also gets stored into the database for future purposes.

C. Scheduler

The medical data that are coming from multiple patients needs to be processed on the basis of the risk level of the patient and the nature and type of the disease. The incoming medical signals may include ECG, EEG and other types of signals. The scheduler must be able to decide which signal should be processed first. Therefore, scheduling is central to decision support system design. There exist many scheduling algorithms [7] for scheduling. In FCFS scheduling the signals are processed in the order in which they arrive, without any preferences. If we schedule the signals according to the order of their arrival, the signals of the high risk patients will not get processed first. Hence we cannot use FCFS scheduling in our system. In the case of Round Robin scheduling, time slices are assigned to each of the signals for processing in a circular order but without considering the priority. So here we propose a new scheduling algorithm that schedules the incoming medical signals for processing on the basis of the health risk of the patient which will be discussed in section 5.

D. Signal Processing Module

The signal processing module can assist the physician to come up with more accurate and reliable diagnosis at early stages. The medical data that are stored in the database is given to the signal processing module on the basis of the new scheduling algorithm. These data are then processed in signal processing module [9] before a final diagnosis can be made. The module consists of various signal processing algorithms which are invoked depending on the type of the medical signals (ECG, EEG) that are coming to the signal processing block. For example, if the incoming signal is an ECG signal, then the corresponding ECG signal processing algorithms will be invoked. The processing includes regeneration of the signal and feature extraction. In the case of ECG signal, feature extraction involves detection of various segments of ECG such as P,QRS,QT,T,PR and ST segment which are useful in the detection of cardiac diseases. The extracted values are then stored into the database for future use.

E. Decision Module

The ECG segment values that are stored in the database are then retrieved from the database and are used as input to the classification algorithms. Classifications of medical signals are very important in the diagnosis of various types of diseases. By means of the classification techniques we can classify the medical signals as normal and abnormal one. A simpler autoregressive modeling technique is proposed in [10] to classify normal sinus rhythm and various cardiac arrhythmias. Various classification techniques have been performed to classify cardiac arrhythmias in [11]. Here we have used the decision trees and support vector machine for classification. Decision trees are powerful classification algorithms in which mathematical algorithms are used to identify a variable and corresponding threshold for the variable that splits the input observation into two or more subgroups. Several algorithms such as ID3,J48,LAD Tree are available of which we have used the J48 algorithm for the development of decision tree. In the case of ECG signals, we used the decision trees to classify the signals into one of the several classes of cardiac disorders which will be discussed later in other sections.

V. ALGORITHMS USED IN THE SYSTEM

A. Scheduling Algorithm

The decision support system proposed here will work effectively if and only if proper scheduling is done for multiple signals that are received. The scheduling is performed with respect to the health risk of the patients. When there are numerous patient data in the global ready queue, the scheduling algorithm can be used to decide the order of execution of those data. Here we propose a new scheduling algorithm which is an improvement of the prioritized scheduling algorithm. The working of the algorithm is shown in Figure 3. The algorithm schedules the data on the basis of their increasing order of the health risk and the time duration that they are in the queue. The incoming data is categorized as high priority data and low priority data. This is done by taking the RR interval of the ECG. Those patients with a high value of RR interval are moved to the high priority queue and all others are given to

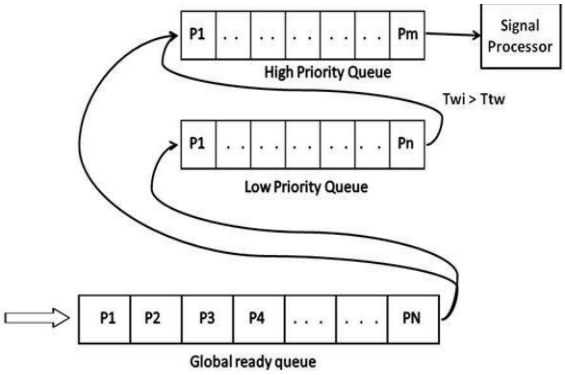

Figure 3. Scheduling Algorithm

the low priority queue. The high priority queue is scheduled using prioritized Round Robin algorithm. All the other data have to wait in the low priority queue for a particular time frame. The waiting time Tw is decided by the Little's theorem,

$$Tw=n/\lambda \quad (1)$$

Where n is the number of patients in the low priority queue and λ is the arrival rate. When this waiting time is crossed the data will be moved to the high priority queue for processing.

B. Signal processing Algorithm

The incoming patient data is scheduled using the proposed scheduling algorithm and then the data of the patient with the highest risk is given to the signal processing block. In the signal processing phase, first the ECG signals are retrieved from the database and then they are regenerated to extract the various segments of the signal such as P waves, Q waves, QRS waves, ST segment and PR segment. Using the amplitude and duration of each of these segments, the ECG signal is analyzed to check whether it is normal or not. If the ECG is not normal, then the amplitude and duration of each of the segments are compared with the normal values to check it for the presence of various cardiac diseases such as Hyperkalaemia, Hypokalaemia,Wolff Parkinson White Syndrome, FirstdegreeAVblock, Ischemia, Cardiomyopathy and Myocardial Infarction. ECG is an important and central tool used to establish the diagnosis of Cardiac diseases. One cardiac cycle in an ECG signal consists of the PQRST waves. Most of the clinically useful information in the ECG is found in the intervals and amplitudes defined by its features [12]. In the proposed system we are considering various cardiac diseases which are the leading causes of death all over the world. Myocardial Ischemia and Infarction results from the insufficient blood supply to the heart muscles. Cardiomyopathy can be detected by inverted T waves, low QRS and short PR interval. Abnormal wide QRS waves with short PR interval leads to the disease, Wolff-Parkinson-White Syndrome and abnormalities in the ST segment and T waves represent Myocardial Ischemia[13].One of the ways to identify Ischemia is to compare the level of ST segment with the isoelectric line level. ST segment depression leads to the

Myocardial infarction [14]. In this way we are able to detect the abnormalities.

VI. ADVANTAGES OF THE SYSTEM

The use of decision support systems offers many potential benefits. The proposed decision support system has the potential to improve health care quality, and it also increases the efficiency and reduces health care costs. The system can also be used to warn the patients about the upcoming diseases. It can provide early warnings that have an impact on both cost and quality of care. The patient's data can be analyzed on the basis of their health risk so that the data of the patient with the highest risk is processed first. Importantly, decision support system can also reduce unnecessary variation in clinical practices. Compared to the previous systems where the data is just stored and retrieved later, the proposed decision support system can automatically retrieve the data from the database, provides diagnosis and it can immediately send warning messages to the doctors or to the care takers via GSM modem. This decision support systems can also assist doctors in taking decisions, reduce their mental workload, and improve clinical workflows.

VII. IMPLEMENTATION AND RESULTS

MySQL is used as the database server for the storage of the patient data. The data stored in the database is scheduled by means of the scheduling algorithm that we have proposed. The scheduling is done on the basis of the risk level of the patient. The higher risk patients are scheduled first. When patients with the same priority arrives, they are scheduled in the order in which they arrive and if multiple patients with the same priority arrives at the same time then they are scheduled by assigning a probability. For testing, we used the ECG signals from the PhysioNet library. PhysioNet offers free web access to large collections of recorded physiologic signals including ECG signals. The ECG waveforms are regenerated from the ECG Databases and the features are extracted. The amplitude and duration of each of these segments are compared to detect the presence of various cardiac diseases such as Ischemia, Myocardial Infarction, Hypokalaemia, Hyperkalaemia, First degree AV Block, Cardiomyopathy and Wolff Parkinson White Syndrome.If any abnormality is detected, the system automatically send messages to the doctors via GSM modem. The message sent includes the patient ID and the name of the disease. By means of decision trees we are successfully able to classify the signal into one of the several classes such as normal ECG or ECG of a patient with any of the above mentioned cardiac diseases. We tested the system by taking 250 samples and the results shows that the waiting time of high risk patients are very less when scheduled using the proposed scheduling algorithm. Classification technique such as Support vector machine has also implemented and the accuracy of classification was found to be 94.36%.

VIII. CONCLUSION AND FUTURE WORK

The use of wearable sensors and decision support systems are capable of continuously monitoring the patients and issue warnings to specialized experienced doctors. Decision Support Systems are effective to some degree in preventing medical errors and in improving patient safety. The systems can improve the clinical diagnosis process by improving ongoing care of patients with chronic diseases. Here, we proposed a decision support system design that would be easy to use, provide instantaneous abnormality detection on the basis of their risk factors. The scheduling and signal processing algorithms have been implemented for the detection of various cardiac diseases. The proposed system is expected to improve the efficiency and quality of service. The decision support system that we have proposed can be used for the early detection of the cardiac diseases. In the future, we can also extend this system to detect any type of disease other than the cardiac disease. Also, as a part of association rule development, we can identify the relationship between various types of diseases and we can also determine how the presence of one type of disease can lead to other serious diseases. Thus we will be able to find out the chance of one disease leading to another type of disease.

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