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Review of Patient Monitoring System: Design and improvements.

Aman Kumar, Anurag Kumar, Ashish Verma, Aadesh singh,

[1]1721610015, B tech C.S.E , IIMT College of Engineering,

[2]1721610020, B tech C.S.E , IIMT College of Engineering,

[3]1721610023, B tech C.S.E , IIMT College of Engineering,

[4]1721610002, B tech C.S.E , IIMT College of Engineering

Abstract:

Technological advancements have brought many life-changing innovations to the forefront. Over the past couple of decades, we have witnessed major breakthroughs in the fields of medical science. A lot of new ways of medication and treatment are being discovered. Human health has been thoroughly examined, and its results are expressed in terms of generic parameters that shape the treatment and medication. Computer science, and especially machine learning, can be utilized to solve complex medical science problems in the examination, determination, operation, and post-care treatment. An important aspect of today's healthcare relies on the Patient Monitoring System. It is evident developing countries lack proper healthcare infrastructure requirements to deal with a deadly pandemic, as has been the case with SARS Corona Virus. The current situation brought to public notice that the healthcare force isn't sufficiently available to cater to the contagious nature of this communicable virus. And therefore there is a substantial gap between the needs and availability. This paper will cover the proposal and implementation of a patient monitoring system to deal with inevitable emergencies.

2. Introduction:

Health is wealth! Health is the greatest wealth a human can possess. With the ever-increasing population, the spread of chronic diseases and health issues have escalated multi-fold. Health care and precisely patient monitoring system refer to a system established to detect, monitor, and regulate various health parameters with the help of sensors and actuators. These patient monitoring systems serve as a technique to mimic the knowledge of doctors through well-learned machines. It detects symptoms and monitors the detected threats. And real-time monitoring helps to locate abnormalities in the patient. Over time mankind has witnessed great technological shifts like remote assistance and machine learning. Machine learning not only predicts unforeseen conditions by analyzing the input health data but can also be used to further enhance the quality of service that can be offered. The current system should have a few amendments and improvements to serve better.

3. System Design of Patient Monitoring System:

The patient Monitoring system is a multi-dimensional system with its focus on providing the best possible healthcare solution working on the system constraints it is assigned with. A patient monitoring system usually consists of various biosensors, processing units (embedded microcontrollers), communication channels for data transmission, and cloud storage along with a cloud processing system. Advancement in technology has brought further addition of resources to the system. A modern approach to the Patient monitoring system has brought remote assistance and monitoring a very feasible task. Remote assistance not only came as a result of better communication channels but also because of the need of the hour is multi-user monitoring simultaneously. Personalized benefits can be used by adding technologies like machine learning and Artificial intelligence as a part of it. Machine Learning provides better detection and monitoring by learning the symptoms and data analytic provide for a better understanding of the current situation of the patient under consideration. At the other significant node, it is connected via a cross-platform app to transmit data to end-user and medical personnel in a well-presented form. Keeping in view the requirements and significance of the system, the design of each component has to be really accurate and sensitive to capture the details and offer better detection and thus prove to be valuable to human life.

These days Patient Monitoring System consists of various modules of software and hardware components and is powered by technologies like machine learning and artificial intelligence.

The system design can be broadly classified into three major categories namely hardware, software, and assisting technologies.

3.1 Biosensors:

Biosensors: Biosensors are those devices that are capable of generating pulses or signals upon contact with biological molecules and thus quantify various parameters of biological significance. It comes with a transducer that converts the impulses or signal into an understandable form. Usually, these biosensors communicate with the enzymes of the body or the cell, and the interaction generates signals or responses. But these responses are sometimes so minute that it is practically impossible to determine the quantified version of it. Therefore it comes supplemented with amplifiers to maximize its strength and filters to control the noise in the signal. These days Biosensors are widely used in medical applications because of their high prospects in diagnosis and detection. Majorly it is used in wearable and monitoring systems. With the rapid advancement in research, conventional transducers-based sensors are replaced by better Aptasensors that not only increase their sensitivity but also the area of application like virus detection. A Patient Monitoring system may comprise many of these sensors but a few are basic necessities of the system. A few of the sensors are being mentioned here:

a. Temperature Sensor:

The temperature sensor is one of the essential sensors installed on the Microcontroller unit, The characteristic that is kept in mind while designing and selecting temperature sensors are their size and sensitivity. Also, the operational range of the sensor should be according to the human body. For the minimum requirements, it should have precision up to 0.1 degree Celsius and has an operational range of -55 to 150 degree Celsius. Also the power source and working potential are prior criteria for the selection of sensor. The other important point to be kept in mind while selection is output(form either analog or digital). After being installed on the microcontroller unit it senses body temperature upon contact. Body temperature is to be periodically sensed whenever triggered by the Microcontroller. The output readings are subject to analysis and are stored on the cloud.

b. Heart Rate Sensor:

Heart rate is one of the key health parameters as far as patient monitoring is concerned. It helps to detect heart-related diseases and works by sensing the volume of blood that the heart pumps. The deviation or changes in the volume of blood is tracked by an optical sensor responsible for capturing the pulse waves. By integrating better optical filters at the sensor nodes, a major gain in the quality of signals can be observed. Booster circuit or amplifier can also be implied as other alternatives to enhance the quality and sensitivity of the sensor. Commercially heart rate sensors are put together with pulse Oximeter sensors to reduce the size as well as boost the operational value of a single sensor.

c. Blood Pressure Sensor

The other key health parameter is the blood pressure of the patient. Blood pressure is monitored regularly for heart-related diseases.

The Pressure Sensor is to measure the blood pressure of the human body. It is viewed when the energy full of air from the body is blown out through the nozzle pipe in the pressure sensor. It measures the amount of pressure inside the human. It is checked for the humans who have reached the abnormality condition
when they not in a normal one. The normal range of pressure for each human is 120/80mm/Hg. the 120 is called the high pressure and the 80 is called the low pressure. The pressure above 160 is called Hypertension.

d. Pulse Oximeter Sensor:

The Pulse Oximeter Sensor senses the oxygen saturation in the blood. Pulse Oximetry is a technique that is non-invasive in nature and therefore highly recommended. The sensor is selected based upon

the operational value, and sensitivity towards human skin. A sensitive Oximeter yields better results but the constraints are its size and sensitivity. The Pulse Oximeter sensor is mounted on the panel and installed on the microcontroller unit and programmed using the embedded system for triggered instances for oxygen level checks. The Output usually is received in the form of an analog signal which is later converted into digital by using an A2D converter at the microcontroller end. Cost is one of the key parameters for the selection of Pulse Oximeter sensor.

e. ECG sensor vs Pulse Oximeter sensor:

Many of patient monitoring system usually comes with ECG sensor instead of Pulse Oximeter sensor. ECG or electrocardiogram is also a non-invasive method for heart monitoring that records the electrical signals in the heart. ECG is majorly done at hospitals and clinics with great accuracy. But the comparative study of ECG vs Pulse Oximeter by as mentioned in the research study of B. Iglesias, it had been observed that in the case of infants or old age people Pulse Oximeter yields better results.

Other Sensors: A generic Patient monitoring system may also comprise of various other sensors apart from the above-mentioned one. It may include sensors for measuring glucose level, infection level, weight, etc. It may be supplemented with pathogen detecting sensors and air filters for lungs disorder.

3.2 Processor:

The Processor is the connecting bridge among all the resources. Therefore, its selection should be done very carefully. We have certain basic constraints that need to be met when choosing a processor for this purpose. These parameters help us in selecting a processor based on its performance, peripheral set, power consumption, and cost.

Performance: Since reliability needs to assured, the performance index should be of high quality. It should accept multi instruction sets simultaneously. Specialized processing can also be seen as an alternative to processing prowess.

Power Consumption: Every processor needs certain power input but using a relatively power-efficient processor can help the sustainable cause. It also involves the cost factor.

Peripherals: The peripheral requirement of the system is one of the major selection criteria to be met for processor selection. These peripherals(including biosensors, communication channels, and other input and output devices) are specific in nature and essentially required to be installed on the processor. The varied nature of peripherals limits the selection criteria to the needs of the monitoring system. Essentially ESP WIFI module needs to be installed for data transmission to the cloud server.

Cost: Cost is the defining feature in the selection of processors, it can vary largely depending on the quality assessment and design strategy.

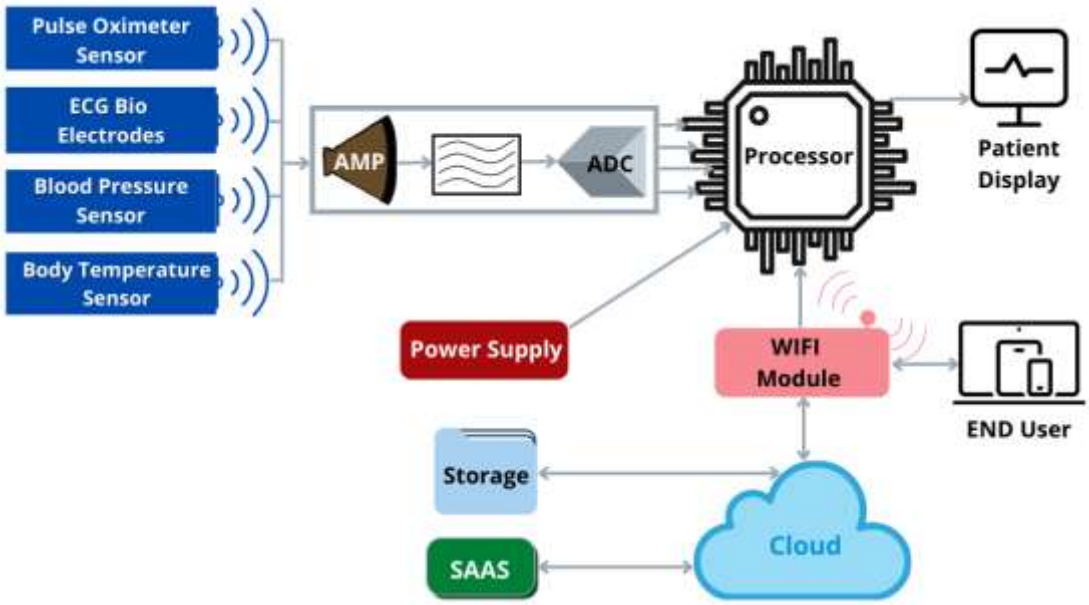
3.2 Communication Channel: After data acquisition, medical data is transmitted from one node to the other via various communication channels. These days the observed standards suggest WSN or Wireless Sensor Network.

Our wireless network may consist of various nodes or observation centers for the data as well as the terminal node where the acquired data will be stored for processing. These communication channels may be either wired or wireless or a combination of both. The communication channel may be divided into further subcategories for a better understanding of the system design.

Level 1: This involves data transmission from the sensors to the processor. It may be pre-processed before reaching the processor either through filters or an A2D converter.

Level 2: The acquired data after digital signal processing go through this level of a communication channel to reach cloud storage. Cloud storage is external to the system and requires vital application Integration with the subsystem. This has been further discussed in the software and cloud section [3.2]. The processor forwards these data in the form of data streams to the cloud through a WIFI module attached to the processor.

Level 3: This communication channel connects major input and output devices including various actuators. Actuators are those parts of the system that manage or control various mechanical or signaled tasks. These actuators are then controlled by the processor. It also connects the display unit to present various health parameters and real-time analysis of the patient.



3.3 Security analysis of communication channels using Wireless Sensor Network.

As Wireless Sensor Network is very prone to interception and noises, the security aspect of its application in Patient monitoring system is usually under the scanner. Wireless technology has brought about various changes in the kind of service it can provide with. These services comprise remote Monitoring and multi-patient monitoring simultaneously. But threats to the security of confidential medical data is an enormous drawback to it. Thankfully, Several layered approaches with refinement in security algorithms as well as terminal extraction of data, cloud security, and planting physical storage nodes in between WSN nodes help restricting data impedance and restrict interception. It should follow the DICOM Standard(DICOM 2008) which is a standard norm for retrieving and exporting in case of medical data.

3.4Power: Power source is as necessary as anything else in the system design. Keeping in view the system requirements constant power availability should be 24 hours every single day in the year. This is achieved by using both rechargeable batteries and a direct power supply. It may consist of AC to DC converter for AC plugins.

3.5 Display Unit: The Display unit is installed on the patient monitoring end. The processor is responsible for sending out outputs to the display and maintaining a constant synchronization between observed data and processed data to be presented at the patient's end. The display unit also presents real-time monitoring of various health parameters like temperature and Oxygen level that suggest the health condition of the patients. It can have touch screen controls for navigating through various sections of the interface.

4. Software Design:

Software design of patient monitoring systems is an important aspect of the design process. The essential components of the software modules are cloud technology, data analysis, machine learning, neural language processing, and user interface.Software design involves various procedural needs that should be met beforehand. For the patient monitoring system, the software requirement documentation is written specifically with clean manuals and a friendly user interface for the presentation of data.

Broadly software design paradigm is described in three phases:

a. Interface design: This design process includes the layout and description of each possible activity required by the system. It involves various events and responses the system provides. For constant workflow there should be a stream of data in and out of the system, interface design lays out the basics of the design process.

b. Architecture design: This involves an exhaustive breakdown of the system into major components. The architecture design deals with the structural portion and data flow through the components.

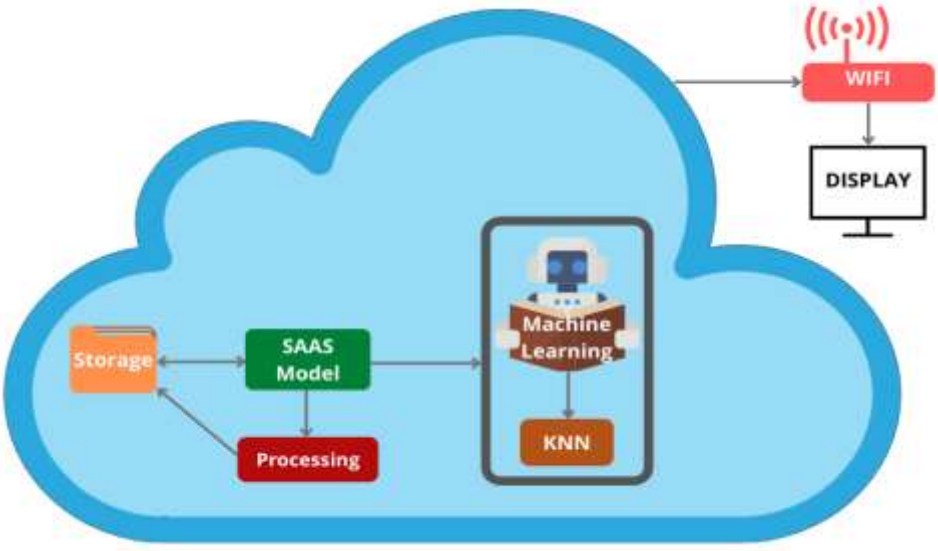
It draws scaling, resource management, and communication among components.

c. Elaborate design: This stage of designing involves elementary breakdowns and detailed emphasis is laid on the programming of units, These units refer to elementary components that collectively form system components. Interaction between all the states and data transmission is the highlight of this stage. It involves implementing data structure and algorithms.

4.1 User Interface: User Interface or UI refers to the graphical user interface available to the end-user or clients as well as medical personnel for access to health data. It presents real-time analysis and monitoring of various health variables. This should have a simple and user understandable form. User Interface is composed of various activities or states that present information and features of the system. It should have an activity for emergency medical assistance, remote access configuration, and also remedies and suggestion panels for patients with daily assessment.

4.2 Cloud Services: Cloud services have immensely shaped the way patient monitoring and healthcare services have evolved. With the advent of cloud storage and processing, the major computing power has become virtual in nature. Cloud service providers extend their storage service as well as offer significant SAAS implementation of the model. Data acquired by the sensors is transmitted through the processor and aided with the ESP WIFI module, it communicates and transmits data and information to the cloud. Cloud Services include the SAAS model for operation on various streams of data.

4.3 SAAS implementation: SAAS implementation of the model includes predefined methods and algorithms for the processing of data and its transmission to and from the processor. It implies various co-existing technologies like Exploratory data analysis and Predictive data analysis for a better understanding of the monitored data. It also comes with machine learning algorithms for better analysis and prediction of threats associated with the acquired data.



4.4 Machine Learning Model: Monitoring and Prediction of health state go hand in hand. And Machine learning brings about one of the most promising features to this proposal. For long machine learning have been inducted into healthcare industry for data analysis and learning market trends but recently a lot of manufacturers have shifted their attention towards building co-existing technologies and bring machine learning as a part of the patient monitoring system. It tends to imitate how doctors and medical personnel tries to detect and predict diseases by the means of data mining.

Machine learning offers various approaches to analyze and predict healthcare data, but we propose a classifier over others. Classification approach forms classification models using provided data set. It provides an algorithm to build and identify that model which describes the relationship among the attribute set and class label of the given data.

The Classifier proposed here is the K-Nearest neighbor classifier approach. The process involves initialization and definition of K (subject to training set) which is followed by computing distance among test instance and train instance of the data set. This Distance is euclidean distance and is thereafter sorted. After the sorting of data, the class labels are produced upon medical data as normal or abnormal classes. And later apply the simple majority to form the classes. Selection of K's value is tough as the smaller the value of K will be the larger will be the impact of noise on the result. i.e. P[OF] tends to reach 1. while a larger selection value of K is expensive because of the computational resources and disqualifies as a better classifier method. We suggest taking K as

$K= n^{0.5}$

Optimization is done by using the cross-validation technique, which further ensures better accuracy and makes it an ideal solution. Accuracy is stated as the calculated ratio of right detection to the total number of detection.

The algorithm is immensely dependent on the nature and accuracy of the training data set. The mean value is used to replace the omission and incorrect values in the training set. To achieve better accuracy, the mean value has to be kept low. Compared to Naive Bayes and support vector machines, decision trees have better accuracy.

Conclusion: We have tried to present system design, improvements, and adaptation for the patient monitoring system. For better diagnosis and treatment healthcare facilities are relying on technologies. Remote Patient monitoring replicates the idea of medical care remotely. In the current pandemic situation where healthcare facility has collapsed, the Patient monitoring system provides a glimpse of hope to those who need medical attention. The successful integration of all the above-stated technologies make for great advancement in terms of prediction and treatment of a patient. Constant Medical attention is provided remotely and routine interaction is also an option. The need for security of medical data and accuracy of prediction is emphasized upon.

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