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MONITORING VITAL PARAMETERS OF HUMAN USING NodeMCU PLATFORM

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Abstract: In the recent years, it has become a widespread phenomenon to monitor various medical health parameters of patients outside hospitals. The aim of this paper is to describe the design and possibilities of a system for remote monitoring the patient body vital health parameters at any time using wireless connectivity. The system performs its function as it measures some vital medical parameter of the patient's body, like are temperature, heartbeat, blood pressure, by using appropriate sensors and then sends the recorded information online to a server through Wi–Fi connection and Wi–Fi module. All information about the patient health parameters is stored on the online server. It enables the doctors to remotely monitor and analyse patient's health and also family and friends can access data and see health status of patient using their smart phones. With this design and this system, it can be effectively used Wi–Fi technology to monitor patient health status. Also, the power consumption of used Wi–Fi module can be reduced as much as possible to make it economical. Thus, the designed system provides low complexity, low power consumption and low cost.
Keywords: remote monitoring, patient body, vital health parameter, wireless connectivity, NodeMCU platform

INTRODUCTION

With the recent advances and changes in many fields of science and technology, life becomes quite easier. Technology is always there to help people to perform their jobs and tasks with much less effort, in a more economical and simplified way. The health sector is changing rapidly, allowing digital technology to facilitate doctor–patient interaction, better understand its problems, diagnose and propose appropriate medications and conduct appropriate therapies.

In such applications sensors collect data about patient vital parameters, such as are blood pressure, temperature, heart rate. This data can be stored online on a remote server. Such, health professionals and healthcare professionals (doctors and other staff) can analyse and monitor the patient's condition in real time and perform adequate activities if it is needed.

There are already several technologies that allow the monitoring of patients who have heart disease problems. The great importance and great advantage of the technology for monitoring the patient remotely is the fact that patients spend a critical period, after leaving the hospital, alone at home, without the supervision of professional staff. Such remotely monitoring of that kind of patients, as well as of other type of patients, is of great help for medical staff and for patients.

The advantage of application NodeMCU platform technology is that it does not take interaction between the medical staff and the patient to read the values. It is enough only for the medical staff to use a web application or mobile application to check the patient's current condition and take the necessary steps in case the results are poor and require appropriate intervention.

This paper describes possibilities and the design of a system for remote monitoring vital medical parameter of the patient at any time and any place using wireless connection and mobile phone. The system measures some vital medical parameter of the patient body, temperature and heartbeat, using appropriate sensors. It then sends the recorded information online to the cloud based server via Wi–Fi connection and Internet. All information about the patient monitored body health parameters is stored on the online server. It enables the doctors to remotely monitor and analyze patient health. Also, the patient family and friends can access data and see patient health status using their smart phones. With this system it can be effectively monitored the patient health status. Also, it can be reduced as much as possible the power consumption of used Wi–Fi module to make low energy consumption and economical system. Such, the designed system has low complexity, low power consumption and low cost.

VITAL PARAMETERS OF HUMAN AND THEIR MEASUREMENT

Today's classical methods of treatment of patients are quite slow and, in many cases, diseases are detected in the late stages when treatment cannot be effective. For this reason, there is a need for a system and an algorithm that would automatically detect problems in the human body, as well as for devices and applications that can monitor the state of patient health in real time. Such systems and devices can be very useful, especially in environments where there are not adequate health institutions, that is, in geographical areas that are not easily accessible. Cases like this require an application and system that can be easily tuned and connected to the nearest medical staff who can respond to the needs of the patient. Such systems and applications can be also easily connected with patient family and enable family to monitor and check patient health state in real time. In such situations, there is a need for efficient control of the energy consumption of the system and device and that the system and device is capable of performing self–configuration to eliminate certain interferences. With increased internet availability worldwide, faster communication and less data delay, real–time value readings have become possible. Also, using of mobile phones for such monitoring of human vital health parameters is very simple and is permanently increasing.

— Physiological parameters reflecting the state of human health

Usually, the human health is defined by physiological parameters of person, which are mainly dependent on each other. They are not equally informative, but they are very important. For their measurement, special conditions are usually required, as well as expensive medical materials and treatment apparatus. Therefore, when creating a monitoring system, it is necessary to assess not only the significance of the assumed parameters, but also additional methods of their assessment and the probability of an observation in order to make a useful system. Research related to medicine has shown that the most important vital parameters are those that determine the respiratory system of the human body and the parameters related to the heart. They best show the condition of the human body and its health [1].

Table 1 presents human physiological parameters, of which there are four basic health parameters that should be observed regularly:

- body temperature,
- heart rate,
- breathing rate,
- blood pressure (this is a rare used parameter, but it is often measured in addition to other health parameters).

Table 1. Human physiological parameters

Measured parameter	Physiological parameter examined	Measured value environment
ECG	Heartbeat	Time function, numerical values
Pulse	Heart rate	Mean numeric values
Breathing rate	Breathing rate	Numeric Values
Breathing volume	Respiratory volume	Mean numeric values
Temperature	Temperature	Numeric Values
Blood pressure	Systolic and diastolic blood pressure	Time function, numeric values

These parameters are useful in determining and treating medical complications. The results of these vital parameters can be measured everywhere, at home, at work, in healthcare institutions. Most new smart phones contain health monitoring applications, which mostly have sensors to measure blood pressure, temperature and stress [2].

— Body temperature

The optimal state of body temperature of human beings differs and depends on the gender, what the person did recently and what activities he/she performed, the food and drink consumed, the time consumed, and in women from menstruation and menstrual cycle. Normal body temperature varies from 36.5°C (97.8°F) to 37.2° (99°F) for a healthy person.

Human body temperature can be measured in many ways. Some of them are:

- Oral – body temperature can be measured by placing the thermometer in the mouth, modern digital thermometers available today use electronic probes to measure body temperature,
- Rectally – for rectal temperature measurement, a classical or digital thermometer is used and usually the temperature is 0.6°C to 1.1°C higher than that measured orally,
- Armpit – measurement is done by placing the thermometer under the armpits. The temperature measured this way is generally 0.3°C to 0.4°C lower than that measured orally,
- By ear – there is a special thermometer that can quickly measure the temperature of the eardrum, which is almost equal to the internal temperature of the body (temperature of the internal organs),
- By skin – a special thermometer that is like a strip can quickly measure the temperature of the skin by attaching a strip principle.

Body temperature can also be abnormal due to elevated body temperature (high temperature) or hypothermia (low temperature) [3].

— Heart rate

Heart rate or pulse is a measure of the heart rate or heart beats per minute. As the body pumps blood through the arteries, they expand and narrow with blood flow. Heart rate measurement not only measures heart rate, but can measure heart rate and heart rate strength. The standard heart rate is from 60 to 100 beats per minute. The number can change and increase due to exercise, illness, wound, and emotional states. Women from 12 years of age upwards generally have a faster heart rate rhythm than men. Athletes, such as runners, who complete strenuous cardiovascular training, can have 40 heart beats per minute and have no difficulties [4].

— Breathing rate

The rate of breathing is the number of breaths that a human makes at all times (3–4 seconds). Speed is usually measured when a human is in a calm state and involves measuring only the number of breaths at one time by observing how often the chest rises. The rate of breathing may increase due to increased body temperature, illness and other therapeutic conditions. Checking the rate of breathing is also important to check whether a person feels any difficulty breathing. The rate of breathing for an adult mainly varies from 12 to 16 breaths per minute [5].

— Blood pressure

Blood pressure or the circulatory strain is the power of the blood pushing in the artery walls for the period compression and unwinding of the heart. Each time the heart thumps, it directs blood into the veins, bringing about the most elevated circulatory strain as the heart contracts. At the point when the heart relaxes, the pulse falls. Two numbers are recorded when estimating circulatory strain. The higher number, or systolic pressure, alludes to the pressure inside the corridor when the heart contracts and pumps blood through the body. The lower number, or diastolic pressure, alludes to the pressure inside the supply route when the heart is very still and is loading with blood. Both the systolic and diastolic pressures are measured and recorded as "mmHg" (millimetres of mercury). The chronicle shows that

mercury blood pressure monitors (mercury sphygmomanometer or manometer) are outdated as it raises by the blood pressure. Today, the specialists' offices are equipped with modern digital blood pressure monitors. Normal values of systolic and diastolic pressures for a healthy person are 80 mmHg and 120 mmHg. High body pressure or hypertension, straightforwardly builds the danger of heart attack, heart failure or stroke. Due to the hypertension and in order to maintain a normal blood flow through the vessels the heart has to be stronger [6].

POSSIBILITIES FOR MONITORING HUMAN HEALTH AT A DISTANCE

Monitoring human health from a distance or remote patient monitoring (RPM) is an innovation to enable monitoring of patients outside of traditional clinical settings (e.g., at home), which increases the access to many areas where treatment monitoring and taking result is almost impossible. It also decreases healthcare delivery costs. With the invention of remote monitoring technology, the same monitoring as used in hospitals is available at home. Therapeutic innovation once used exclusively in hospitals and general practices is now available for use at home. Many clinical preliminaries of home distance checking the glucose concentrations by PC demonstrate improved proficiency and much better results in diabetes care. Similarly, measuring the blood pressure using home distance monitoring technology shows improved efficiency. Inability to enhance results of high–risk pregnancies through home distance monitoring shows the challenges in such medical applications. In general, electronic observing of patient health parameters and health state at home guarantees to reduce cost in health services. It also improves involvement of patients in their own care, and another feeling of authenticity in making an analysis of patients.

— Application of technology for remote patient monitoring

A large proportion of older adults suffer from many intense diseases and injuries. Consequently, the administration of chronic diseases, post–acute care administration and health checking are the three most important uses of remote monitoring technology for adults. Remote monitoring technology can encourage moderate improvement of chronic illness and guarantee continued recovery after intensive care. The advancement of patient remote monitoring technology can also alert caregivers and encourage mediation when a disabled adult is injured. After presenting the abnormal condition, each of these examples will be presented with several specific innovations. These opportunities and innovations should be seen as the initial stage of thinking and not as potential outcomes and progress of remote patient monitoring.

Figure 1 shows the remote tracking or monitoring procedure in five phases: collection, transmission, evaluation, notification and intervention. Remote monitoring technologies can efficiently or inactively collect information by connecting to a patient. The information contains vital signs and other physiological information, blood glucose levels, answers to certain health questions and questions about general well–being and additional information about the patient [7].

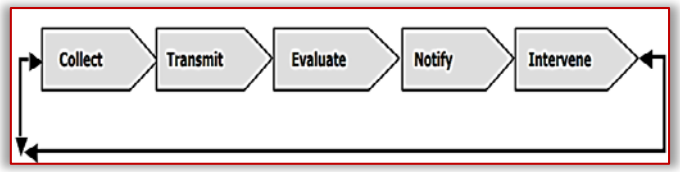

Figure 1. Remote monitoring procedure

MCU PLATFORM WITH WI–FI MODULE

Used NodeMCU platform with Wi–Fi module ESP8266 is an independent SOC (System on chip) with a coordinated TCP/IP protocol, which allows any microcontroller to access a Wi–Fi network. Each separate chip is accompanied by a pre–customized set of AT commands, which takes into account easy use.

— NodeMCU platform technology

NodeMCU platform is a very good starting stage for developers because it provides them with an interactive environment that agrees to run commands not only from those that control ESP8266's remote interface, but additionally GPIO and hardware functionalities such as i2c and PWM. In the case of a default firmware (AT Command Interpreter), the application code should be created using a programming language suitable for a microcontroller or SOC.

— Specification of NodeMCU platform

It consumes small amounts of electricity of 3.3 V and uses small processor on the board, allowing the chip to work completely independently. It is in contrast to the usual chip, which is usually an Arduino chip, and a Wi–Fi module, that costs significantly more. Despite the fact that the NodeMCU platform has only 2MB of memory, as well as a large number of chips in this group, and the amount of GPI0 needles is limited to 8, nevertheless it gives great usability.

NodeMCU platform contains a complete Wi–Fi set. It means that it can be used to host or deactivate the roles of Wi–Fi networks of other processors. For the purpose of facilitating application, it runs especially from external memory, while the coordinated cache improves system execution. It can also be used as a Wi–Fi connector and has the best Wi–Fi chip on the market [8].

— File–system of NodeMCU platform

The file system also alongside the program are put away on a similar chip, in any case, programming another venture won't change the substance of the document system. This implies we can utilize the record framework to store program information, arrangement documents or substance for a Web server. The plan used to make the executions and requirements on the chip is SPIFFS, since it was intended for a small framework, in spite the cost of a few disentanglements. PIFFS does not bolster indexes it just stores records. The good thing is that since it's anything but

a customary document framework it considers the '/' character to be used in names, subsequently permitting the utilization of index posting when using the capacities [9].

PRACTICAL REALIZATION OF SYSTEM FOR MONITORING VITAL PARAMETERS OF HUMAN

For design and implementation of system to remotely monitor a patient's vital signs are used the NodeMCU platform, temperature sensor, ECG and a heart rate sensor, access to cloud based database and smart mobile phones. The system can easily achieve all requirements using NodeMCU platform and send an alert by message or email when the measured parameters are above or below normal value.

— ECG kit

The purpose of ECG electrodes is to record the electrical activity of the heart in a certain period of time. ECG detects tiny changes in the skin that originate from an electrophysiological pattern of the heart muscle depolarization and repolarisation during each heartbeat.

The ECG kit or heart monitor is a block of ECG sensors, which is conditioned by a signal coming from an ECG electrode. It is specifically designed to extract a low–voltage signal, and then delivers and filters it to suppress interference from the signal. The cause of the interference in the ECG signal is the movement of the electrode or remote setup. The advantage of a heart rate monitor is that it requires a small amount of energy to work. It was used ECG or heart monitor AD8232. Figure 2 shows right positions for placing ECG electrodes.

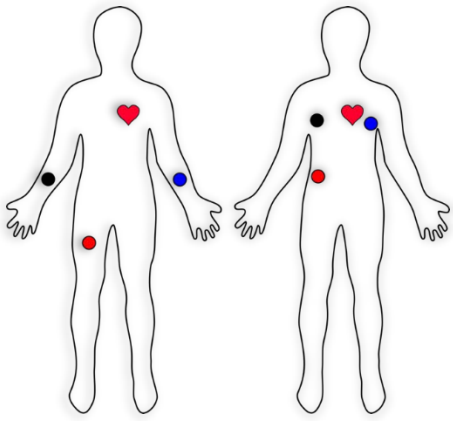

Figure 2. Right positions for placing ECG electrodes

— Temperature sensor

Temperature sensor measures body temperature of the patient. In the system it was used temperature sensor DS18B20. The device is powered by a 1–wire communication line, storing power to the internal capacitor for the time when the signal is high while for the case when the signal is low, it takes stored power from the capacitor. Alternatively, the DS18B20 can also be powered from an external voltage of 3 – 5.5V.

Figure 3 shows used temperature sensor. Sensor from Figure 3 can be used for measuring temperature of air, water and human body. Wires are covered by waterproof material and sensor can be completely drowned in the water.

Figure 3. Temperature sensor

— Schematic view of the solution

Block scheme of the solution is shown in Figure 4. Between NodeMCU platform and temperature senor and ECG kit are used wired connections. NodeMCU platform and mobile devices are connected to the Internet using wireless Wi–Fi technology.

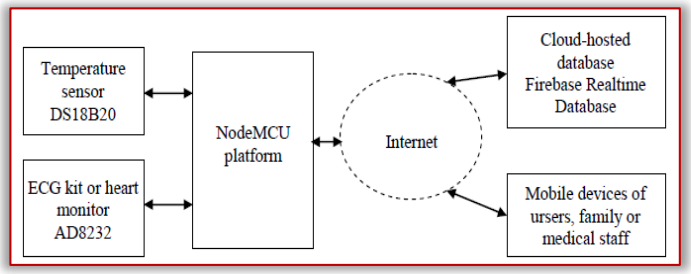

Figure 4. Block scheme of the solution

Figure 5 shows schematic view of the solution.

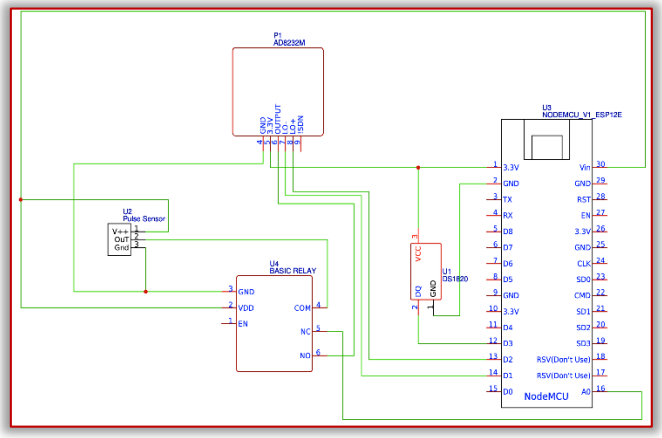

Figure 5. Schematic view of solution

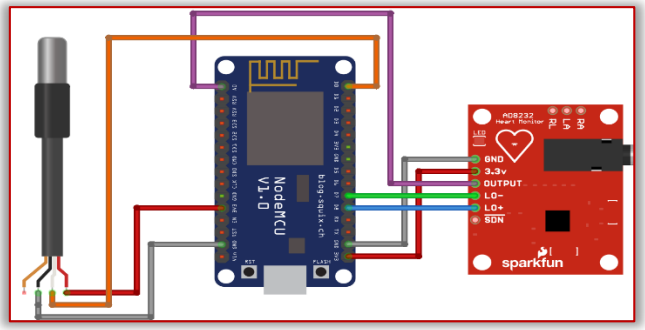

Figure 6. Practical setup of solution

Practical setup of solution that was realized and tested is shown in Figure 6. Figure 6 shows how to connect components to a functional solution that can be used to monitor patient vital health parameters. ECG sensor use two

digital pins D7 and D8, and also for reading data uses analogue pin A0. Temperature sensor required only one digital pin, in this case the pin D1.

— Firebase database

In the system design and implementation it was used Firebase Realtime Database. The Firebase Realtime Database is a cloud–hosted database. Data is stored as JSON and synchronized in real time to every connected client. When you build cross–platform applications, with Apple platforms, Android, and JavaScript SDKs, all of your clients share one real time database instance and automatically receive updates with the newest data.

The Firebase Realtime Database lets you build rich, collaborative applications by allowing secure access to the database directly from client–side code. Data is persisted locally, and even while offline, real time events continue to fire, giving the end user a responsive experience. When the device regains connection, the Realtime Database synchronizes the local data changes with the remote updates that occurred while the client was offline, merging any conflicts automatically. The Realtime Database provides a flexible, expression–based rules language, called Firebase Realtime Database Security Rules, to define how your data should be structured and when data can be read from or written to. When it is integrated with Firebase Authentication, developers can define who has access to what data, and how they can access it [10].

Figure 7. Stored measured values from ECG sensor

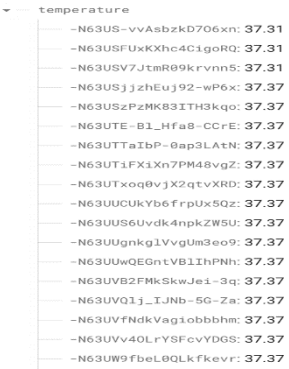

Figure 8. Stored measured values from temperature sensor

Figures 7 and 8 show stored measured data in Firebase Realtime Database. Each sensor has its own node for storing measured data.

— Comparing values and sending notification

After uploading the patient data on Firebase cloud, the data can be tracked and monitored in real–time via mobile phone and mobile application, with ability to compare measured data with normal parameter values of healthy human. Monitored parameter values can be shown to the patient, his family or his doctor by mobile phone and mobile application. Also, if it is detected value of monitored health parameter that is above or under the normal parameter value, it will be generated warning information and sent to the doctor or the family of the patient, by mobile phone or email. If the detected value of monitored health parameter is very significantly above or under the normal parameter value or not existing, it will be generated urgent emergency information and sent to the doctor or the family of the patient, by mobile phone or email.

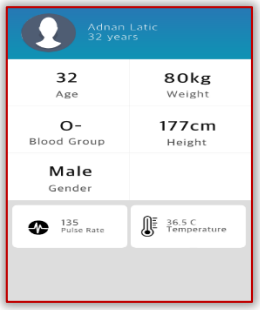

Figure 9. Example of patient monitoring record with real time tracking shown on the patient mobile phone

Figure 9 shows example of results of patient monitoring record with real time parameters tracking shown on the patient mobile phone. It can be seen that the obtained measured patient body temperature is within normal temperature range for healthy patient. But, obtained pulse rate is over normal pulse rate range for healthy patient. The reason is that the measurement was performed after patient exercise. Such was tested system operation also in such situations.

After loading data into mobile application each value fetched from the cloud server is compared with normal parameter value. If application detects sequence of increased or decreased values, it will send by mobile phone or email notification to the patient and person or medical staff responsible for monitored patient.

— Designed and implemented software

It was designed and implemented complete software needed for the system operation. The software consists of code for microcontroller and code for mobile application. Microcontroller was programmed in Arduino IDE using C++ programming language. Arduino IDE is open–source software which gives us great environment for writing code and uploading to microcontroller board. In addition to programming, it can be also used for checking results or debugging via serial monitor. Before triggering function for measuring body parameters, software checks connectivity with dedicated Wi–Fi hotspot. If connection was established successfully, software starts loop functions for collecting data from sensors and uploading results to cloud database, delay between measuring is hardcoded to 2 seconds. For formatting and uploading measured data to cloud database,

software uses open–source library Firebase Arduino. Figure 10 shows program code for collecting and uploading measured data to cloud real–time database.

Mobile app was developed in Android studio using Java programming language. Android Studio is the official integrated development environment for Google's Android operating system software and designed specifically for Android development. For reading data from firebase real–time database, it was necessary to import in project all required plugins and connectors using Firebase Assistant in Android studio. After establishing connection with Firebase, user can start using developed application. Before reading data, user must have required credentials to access patient data. Logged user can track condition of patient in real–time.

```
void loop() {
  measureTemperature(); //function for measuring temperature
  measureHeartbeat();  //function for measuring heartbeat
  delay(200);
}

void measureHeartbeat() {
  digitalWrite(AD2, LOW);
  digitalWrite(AD1, HIGH);
  long now = millis();

  if((digitalRead(LOP) == 1)||(digitalRead(LOM) == 1)){
    Serial.println('!');
  }
  else{
      rythme = analogRead(A0);
  }
  Firebase.pushFloat("sensors/ecg", rythme);
}

void measureHeartbeat() {
  tempS.requestTemperatures();
  temperature = tempS.getTempCByIndex(0);
  Firebase.pushFloat("sensors/temperature", temperature);
}
```

Figure 10. Program code for measuring body parameters and storing on online cloud

CONCLUSIONS

With advances in technology, there are many possibilities to apply them in human life and to make easier many human activities. Wireless communication and mobile devices opened up new possibilities where people can easily communicate with each other. This paper proposes and describes one way of design, one possibility and application of remote monitoring systems for patient vital health parameters in health care systems.

Medical parameters are monitored with the help of sensors. Sensors are connected via a wireless communication network. In this way, doctors can get reports of patient physical health condition when they need it. Also, patient itself and his family or friends can obtain information about his health status. This system could be very effective for monitoring patients who have been left the hospital. In such situations the patients are mostly on their own and undergo a sensitive part of the recovery. Such remote monitoring of patient health parameters could be very useful for doctors, family, friends and patients itself.

With designed system it can be easily and effectively monitored the patient health status. The system is developed and implemented using open source technologies and open source hardware and software platforms. Also, the power consumption has reduced to obtain low energy consumption and to obtain economical system. The designed and implemented system is low complexity, low power consumption and low cost system.

With increased economic migration the described system can be of great benefit. Currently a large number of the elderly population has been left unattended by the family and often in places where medical staff is far from the patient or the person who needs to be supervised. The system can be further improved with using additional sensors, because the current system only uses sensors to measure body temperature and heart pulse rate.

In addition to measuring health parameters for the purpose of treating and monitoring patient chronic illnesses or recovery, this system allows patient family members or patient guardian to check whether the patient is alive or if the vital parameters are very low.

Note: This paper was presented at International Conference on Applied Sciences – ICAS2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA).

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ISSN: 2067–3809