Femone Health Monitoring System

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Abstract*: *As per the medical reports, each year 4 million newborns die within 28 days of birth and more suffer from disabilities, diseases, infections, and injuries. According to 2017 death rate, about 8,02,000 neonatal deaths are reported in India. The inability to detect any discomforts/criticalness that the babies can go through in the initial stages of life can lead to permanent disabilities/disorders and even death. The absolutely imperative approach to shrunken the mortality rate is to detect neonatal criticalness and give timely attention. Enabling an environment for newborn safety depends on the availability of adequate health-care facilities, equipment's, medicines and emergency care when needed. Femone Health Monitoring System is developed with an aim to detect the difficulties faced by the babies and make it available to the user as well as doctors for easy diagnosis and treatment. The proposed technique is a wireless noninvasive system which monitors the vital physiological parameters of neonates including heart rate, oxygen level, body temperature, and wetness. Heart rate, oxygen level and body temperature are measured using the principle of photoplethysmography (PPG). The measured parameters are sent to an MQTT server and are published through the Femone app in real-time. The system also records the neonatal conditions in a day to day manner for future reference. A number of clinical trials were conducted in order to check the performance and for validation.

Keywords: **PPG, MQTT, wetness, oximeter.**

I. INTRODUCTION

The neonatal period (i.e. below 28 days old) is the most crucial phase in a baby's lifetime since they will be subjected to a wide variety of diseases which can even cause their death. This problem can be avoided if the baby is given immediate care by monitoring and determining the neonatal struggle at the right time thereby the death cause is avertable. Therefore, providing a 24/7 full-time care for the baby at the home itself can relatively reduce the death rate of neonates. Some of the reasons for neonatal death are complications due to preterm birth, infections and also due to oxygen deprivation during birth. Preterm babies will also suffer from respiratory problems. Substantial neonatal care can reduce the mortality rate of babies due to oxygen deprivation. The critical medical conditions due to heart rate variations in a neonate includes arrhythmia (heart rate rises above 180 beats per minute or it decreases below 100 beats per minute), heart failure (heart
fails to pump blood), hydrops fetalis (neonate will be anaemic and hence its circulatory system must pump more blood to balance the amount of hemoglobin and thereby resulting in an increased heart rate, etc. Oxygen deprivation can cause several conditions such as cerebral palsy (the cerebrum of the brain is affected and the baby loses its ability of movement), autism (where the baby is incapable of interacting), Attention deficit hyperactivity disorder (here the baby is not able to be attentive and it will be hyperactive), etc. As per the neonatal mortality survey of UNICEF, an average of 18 out of 1000 neonates died in the year 2017. Therefore globally 2.5 million babies died i.e. approximately 7000 babies died each day. Similarly, according to WHO 2.6 million deaths were recorded in the year 2016. There are many neonatal health monitoring systems that are prevailing in the market. But they are not assured to provide a 100% health care for the baby. It is necessary to estimate some of the vital parameters within a neonate simultaneously in order to determine the health of the baby. The important parameters that are to be calculated periodically consists of body temperature, pulse rate (heart rate), respiration rate, blood pressure, and oxygen level. There are not many health monitoring systems which are able to quantify all these parameters concurrently. In Femone health monitoring system three of the vital parameters are being computed namely body temperature, heart rate, and oxygen level altogether and apart from these, an extra parameter is also determined i.e. the wetness surrounding the baby (if any). Unnoticed prolonged exposure of baby's tender skin to urine or any other dampness surrounding can cause rashes and other problems related to cold. The system is relatively low cost and easy to operate since very portable and wearable sensors are used for the designing. The four parameters are being monitored in real-time and any abnormal variations from the normal threshold values will give an alert to the caretaker[5],[8]as soon as Femone application detects any variation. These measurements are even stored in the form of a text file which is easily accessible. Therefore, any future consultations with the doctor along with these recordings will be very useful for earlier diagnosis. Depending on the pattern of the variations of the vital parameters the doctors will be able to predict or determine the cause for the abnormalities in the baby thereby suitable treatments and medications can be provided before the situation gets worsened.

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II. RELATED WORKS

There is a wide range of neonatal health monitoring systems prevailing. The following section gives an outlook on some of these systems.

The paper [1] describes a smart jacket which is subtle and monitor continuously. It can also enable neonatal care and interaction between the baby and mother. A new solution for the dangers posed by the textile electrodes is also being explored. It is mainly used to monitor ECG, body temperature, respiration, and blood oxygen saturation. Observation of ECG and respiration is mainly done using smart textiles and wireless communication. Forehead type reflectance pulse oximeters are also being developed. Textile embedded optical fibers are used. They allow freedom to move, is aesthetic, allows stress less dressing and the jacket even provides means for eye protection.

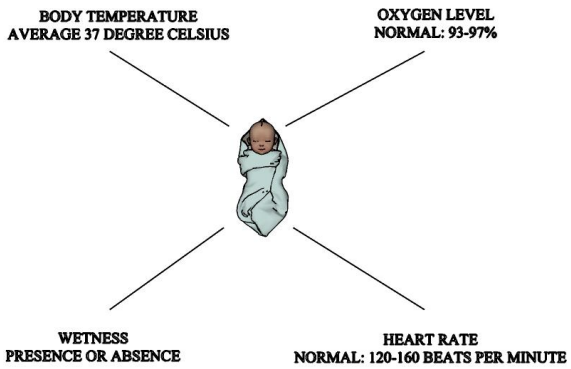
The paper [2] describes a neonatal health monitoring system which is mainly based on the principle of sensor mobile cloud computing (SMCC). It is an automated system in order to monitor critical hypothermia conditions. SMCC is a collaboration of mobile cloud computing (MCC) as well as wireless sensor network (WSN). The system puts together some of the sensors such as acceleration sensor, heart rate variation sensor and temperature sensor in order to measure the body temperature, acceleration caused by the neonate's body movement and also the heart rate of the baby. The data from the sensors are stocked up in the cloud. The caretaker can continuously access and monitor these data using an android application. In abnormal cases, an alert is generated in the device of the caretaker.

The paper [3] describes a neonatal health monitoring system which is primarily wearable. The temperature is continuously monitored in order to predict the outbreak of hypothermia in babies. Temperature is measured using a medically graded thermistor that is directly connected to a microcontroller which consists of an integrated Bluetooth facility. An inertial sensor is used for measuring the breathing rate. The data are sent to a database for enabling real-time monitoring. It provides an extended battery life. The device is packed in such a way that, it is neonatal friendly, waterproof, can be decontaminated easily and can also be used again.

By comparing with the above systems, Femone health monitoring system is capable of measuring an extra parameter such as wetness apart from determining just the vital parameters. Wetness detection is useful in cases where the babies are subjected to prolonged exposure of urine or any other sort of dampness which can affect the delicate skin of babies and can result in other health problems.

III. FEMONE HEALTH MONITORING SYSTEM

As shown in Fig. 1, Femone health monitoring system primarily obtains four parameters from the baby i.e. babies body temperature, heart rate, oxygen level and wetness (presence or absence). The crucial parameter to track is heartbeat rhythms and oxygen saturation levels of babies owing to the fact that Cardiac arrhythmia and diseases due to oxygen level variations can cause sudden death of babies [5], [6], [7], [11], [12], therefore regular monitoring of the baby's heartbeat and oxygen level is essential. Another important vital parameter tracked in this health monitoring system is body temperature, i.e. neonatal fever. Variation in body temperature of neonates plays a key role in the diagnosis and treatment of diseases. In particular, rapid feverishness can cause a major health problem in neonates so the body temperature should be continuously monitored. It is also important to monitor bed wetting of babies. When the parents are too late to intervene with bed wetted babies, chafing problems may emerge. In such cases, the baby will be disturbed, sleeping disorders can be caused and fever may occur. Excessive perspiration may cause the dehydration of babies, which results in illness or aggravation of the existing disease. All this can be surveyed by using a set of units like sensors, Arduino Uno, Wi-Fi module, power regulator and android based smartphone (for evaluating the received data and also for creating an alert when emergency conditions pop up.



IV. METHODOLOGY

As illustrated in block diagram there are mainly 3 sensors used namely MAX30100 (a sensor based on the principle of photoplethysmography [4] for determining the heart rate and oxygen level) [9], LM35 (a temperature sensor for detecting the body temperature) and LM393 (a moisture sensor for monitoring the presence of any wetness around the baby) [10]. Arduino Uno microcontroller receives inputs from the sensors. The data from the microcontroller is transmitted using a Wi-Fi module (ESP8266 WEMOS) to the MQTT server (MQTT Broker-Eclipse).

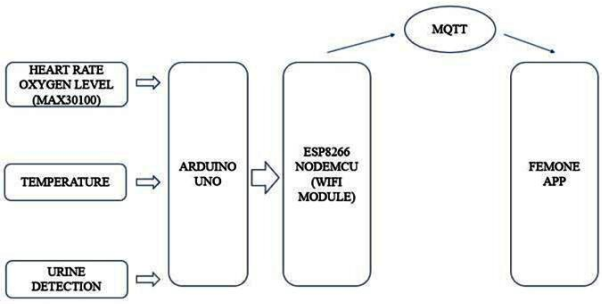


Fig. 2. Block diagram of Femone Health Monitoring System

The circuitry unit in Fig -3 incorporates all the aforementioned modules. MQTT server is used for publishing the data to the Femone application. The data can be viewed in real-time through the Femone App. There are predefined normal values for all of the above-mentioned parameters hence, abnormal variations in any of the values can be inferred as the cause of a serious underlying problem especially in neonates. In order to view these vital parameters, the user can log in at any time through the App. The system is also programmed in such a way that in critical situations that is if the key parameters exceed certain values or go below the predefined values then an alert will be given

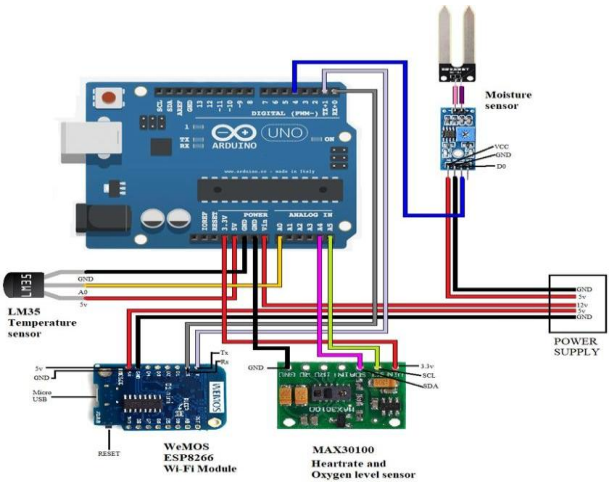


Fig. 4. Circuit diagram of Femone system

to the user through the Femone App.

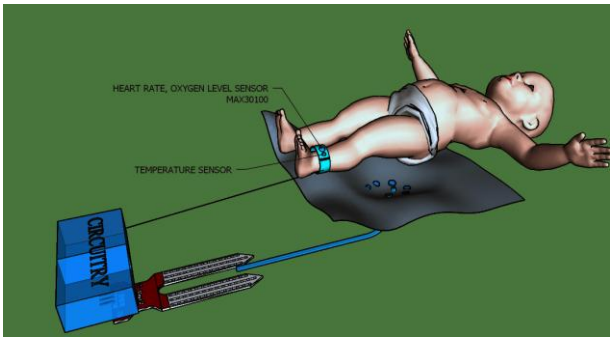


Fig. 3. Representative model of Femone Health Monitoring System

V. FEMONE CIRCUITY

As in Fig. 4, the circuit diagram consists of, Atmega328p of Arduino UNO is used as the controller. The MAX30100 sensor has an I2C communication, so it is connected to the SDA and SCL communication pins of the Arduino Uno (A4 and A5) with respect to the SDA and SCL pins of the MAX30100 sensor. I2C stands for inter-integrated-circuit. It is a serial communication protocol specially designed for microcontrollers. The MAX30100 sensor should be provided with 3.3V for stable performance. 5V can damage the board. Using the principle of photoplethysmography the sensor reads the heart rate and oxygen level.

For measuring temperature, a temperature sensor LM35 is added to A0 pin of the Arduino. LM35 uses SPI communication (Serial Peripheral Interface communication). SPI is a different form of serial-communication protocol specially designed for microcontrollers to talk to each other. The temperature sensor provides analog data according to the respective temperature. This data is fed into the A0 pin of Arduino. The analog value is converted to readable degree Celsius value with decimal points.

For wetness detection, a moisture sensor (LM393) is used which can detect the water content. LM393 also uses SPI communication. The output of this sensor is provided to the digital pin of the controller in order to get either 1 or 0 depending upon the absence or presence of water respectively.

The data obtained from the sensors can be viewed in the Femone App using a Wi-Fi module which can send the data from Arduino to the app via a host server with MQTT. This is done by Wemos, an ESP8266 Wi-Fi module that is programmed to connect to any Wi-Fi network in order to access the internet which in effect can connect to the host server. Here eclipse server is used to upload the data. The data is uploaded as a single string of message in which heart rate, oxygen level, temperature, and wetness are separated with a symbol "@". In the Femone app, this string message is decoded to receive the four values and it is displayed accordingly.

VI. FEMONE ANDROID APPLICATION

Femone health monitoring system is also provided with an android application which acts as an interface between the Femone circuit and the user. The android application is known as FHMS application. The application is designed in

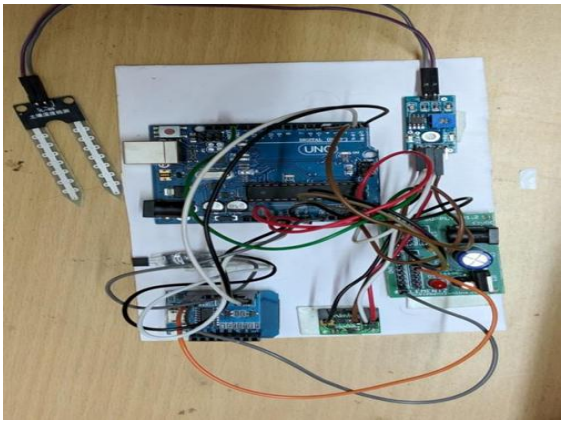


Fig. 5. Illustration of Prototype

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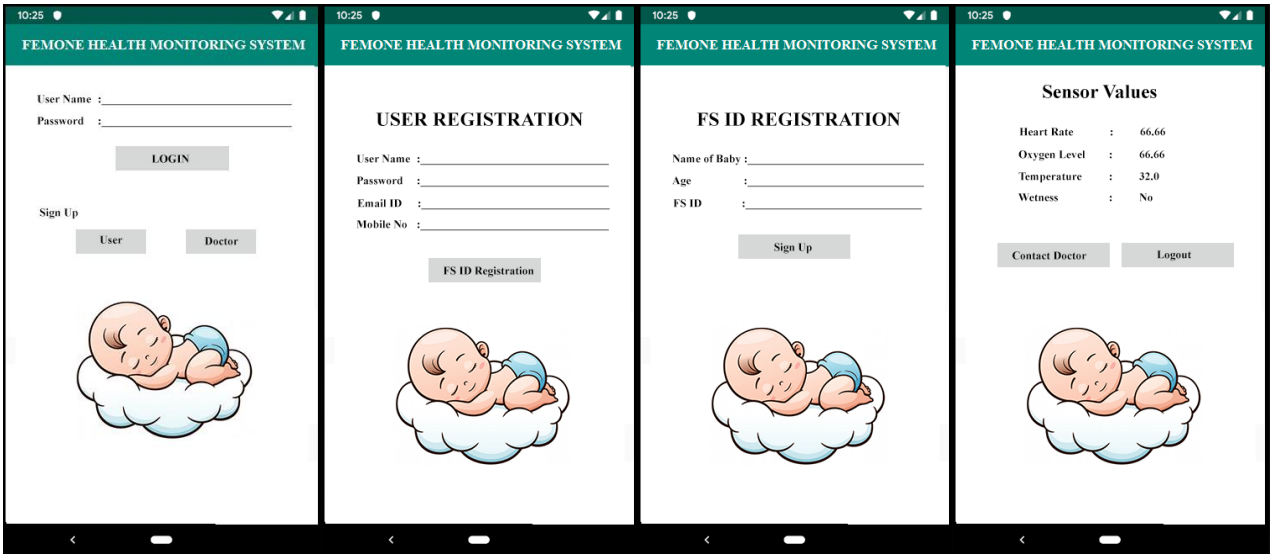

(a) (b) (c) (d)

Fig. 6. Femone Health Monitoring System Android Application. (a) Startup Screen, (b) User Registration Screen, (c) FS ID Registration Screen, (d) Monitoring Screen.

such a way that even a layman can operate with ease.

The application consists of a user registration form which the user has to first create before any functionality of the Femone Health Monitoring system can be utilized. Two modes of registration are possible one for the customer and another for the Doctor. As far as the registration process of customer is concerned, it requires details such as Username, Password, Email Id and Mobile Number. Once the details are entered the registration process is complete and on the next

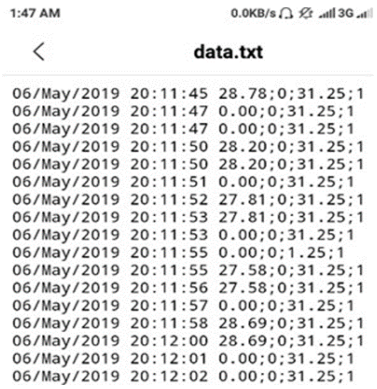

Fig. 7. Text file format which is decode by FHMS app.

screen, customer is requested to enter name of baby, age of the baby (in days) and FS ID (Femone System Identification Number) of the particular equipment after that the FHMS application registers itself with the Femone System via MQTT server. The customer also has the option of entering the details of Doctor such as Name of Doctor, Email Id, Phone Number & Hospital Details. This detail will be utilized if at some point in time the customer wants to send the sensed parameter to the doctor for further diagnosis.

After registration the user can log in into the application by entering the username and password. Once logged in the user can view the sensed values such as Heart rate, Oxygen level, temperature, and wetness respectively. As soon as the user logins the FS ID will be used to connect to the MQTT Server and the parameter values will be fetched for monitoring purpose. The detected values will be compared with a predetermined value depending upon the age of the baby. If there is any variation beyond the predetermined values a Femone Alert Mechanism kicks into action which will be sent alert messages to the customer via message/email/ mobile notification. The customer has also a provision to send the sensed data to the registered doctor (During Registration Process) via text files (can be also seen in user mobile storage) as shown in Fig. 8. The system is designed and programmed in such a way that the data values will be updated online without any delay, thereby enabling early detection of any misfortunes. Fig. 6 shows various screen of the FHMS application including registration screen, login screen, Sensor Values, etc. Apart from the customer, Doctor can also register into the application by entering their corresponding details like a username. Password, email id, phone number, and hospital details. Once the Doctor completes the registration process, the Doctor can log in to the application, where he/she can see the details of all the Femone Health Monitoring systems who have a registered with that particular Doctor. In order to make the life of Doctors easy, the details will be seen from only those customers who have send the sensed values as mentioned earlier.

Once the Doctor selects a particular FS ID, details such as baby name, age, and the sensed values (Real-Time) will be displayed in the Doctor application menu. Thus, it will help the Doctor to easily identify the problems and suitable precautions can be communicated to the customer either via email or message. In case of emergency, the Doctor can request the customer to bring the baby to the hospital for further treatment thereby avoiding a vital catastrophe. The details of the sensed values will be sent to the Doctor as a text file as shown in Fig. 7 and the FHMS application will decode this text file and make it in a presentable form for the Doctor for easy Diagnosis.

VII. RESULTS & DISCUSSIONS

The validation of the system is of at most importance especially when it comes to systems implemented in the field of health. The performance and accuracy of Femone Health Monitoring System was evaluated by conducting a number of clinical trials and verifying the result with the authorized personal. Table 1 shows the values obtained by conducting clinical trials on babies under 2 months of age. All three babies are examined during their active state (awake). As expected, the acquired values show similar performance to those obtained from clinical thermometers and oximeters.

Table- I: Clinical Trials done using Femone Health Monitoring System

Vital Signs	Neonate 1	Neonate 2	Neonate 2
Heartrate (beats/min)	135	140	130
SPO2 (%)	95	93	96
Temperature (°C)	39.0	36.5	37.1

No critical effects are noticed in all the three babies, however neonate 1 shows symptoms of fever and neonate 2 is diagnosed with bronchiolitis which is reflected in the lower value of 93% oxygen level.

VIII. CONCLUSION

Noninvasive methods to detect discomforts/criticalness in babies due to up normal variation in body temperature, heart rate, and oxygen level is very important for neonatal caring and health development. An absolute solution for monitoring all the aforementioned neonatal difficulties is presented in this paper. A new system known as Femone Health Monitoring System was implemented using Arduino Uno board to monitor and alert the user and doctor regarding the various vital physiological parameters of neonates including heart rate, oxygen level, body temperature, and wetness. Finally, the implemented system was tested for performance and validation using a number of clinical trials.

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