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A Smart Remote Monitoring System for Prenatal Care in Rural Areas

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Abstract— The complications in maternity especially the women lives in rural sector can be reduced through regular monitoring of their vitals like blood pressure, SpO2 and fetal growth. The internet of things (IoT) is the modern technology bridges the gap between the traditional clinical setting with its consumers as well promotes the telemedicine industry into great levels of accessing proactive healthcare facilities. The predominant aim of this work is to bring a remote monitoring device which assesses the significant health indicators of the pregnant women and their fetus status cost effectively. In order to build such kit, the biosensors like heart rate, SpO2, pressure, temperature and load cell which gives the weight of the fetus are integrated into Arudino board. The sensor readings are processed through ThingSpeak. The timely medical attention is proposed upon observing abnormal physiological vitals of the women which is implemented through a buzzer system in this device. Like such devices in realism help to predict the pregnancy risk and decrease the mortality rate.

Keywords- biosensors; cloud computing; health management; internet of things (IoT); maternal monitoring; telemedicine.

I. INTRODUCTION

Maternal care is considered as a crucial component of any nation's growth in terms of improving fairness & lowering poverty. The mother's livability with good health after delivery is one of the key factors that determine social and economic growth. One of the key metrics for assessing the effectiveness of the nation's healthcare system is the maternal mortality ratio. In the past two decades, India has achieved incredible strides toward lowering maternal fatalities. With 600 women dying during childbirth for every 100,000 live births in 1990, India had a relatively high Maternal Mortality Ratio (MMR). This amounted to almost 1.5 lakh women dying per year.

Improving maternal health is one of World Health Organization (WHO)'s top priorities, and it is linked to initiatives aimed at achieving universal health care and is centered on a human rights viewpoint. In order to estimate maternal health, WHO investigated and then listed health indicators pertained to different stages in and after pregnancy of women [1].

The essence for quality care to prenatal women is deeply elaborated by Estephania et al. in his article [2]. K. S. Vora et al. discussed the facilities utilized in the pursuit of maternal health in India [3]. The poor infrastructure encountered in rural areas challenges, in fact delays the appropriate medical treatment to the people lives over there. Further it persuades the problem of facilitating maternal care. Compared to mothers in large cities, women in rural communities are more likely to encounter life-threatening problems during or after childbirth. It is concerning that a growing number of women in rural regions with limited access to obstetrics care experience extreme maternal death and morbidity during childbirth. The status and implications of maternal health of the specific region was investigated aligned with health indicators of WHO in greater interest [4&5]. A study by Beata Mostafavi revealed the fact that the likelihood of risky delivery scenarios is 9% higher

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in rural areas than in metropolitan areas [6]. The special health requirements and difficulties faced by rural women must be taken into account in policies and initiatives aimed at increasing maternal health and lessen adverse events related to delivery.

The rest of the paper is organized as follows: In section 2 the significant past efforts made are analyzed and the objective of the proposed work is derived. The section 3 discusses the design elements of smart prenatal vital monitor in high interest. Section 4 discloses the results obtained out of the device and section 5 is intended to conclude the work.

II. LITERATURE REVIEW

The past efforts by various researchers in attaining a smart vital monitor for ensuring the quality of prenatal care is summarized below. The research objectives of proposed work is also identified.

A. Related Work

During pregnancy, labour, and childbirth, monitoring of the mother's and the baby's vital signs is essential to ensure their health and safety. This monitoring frequently serves as the first line of defense in the early identification of pregnancy disorders, allowing for timely and efficient management to reduce deaths and morbidity among both the mother and the unborn child. The blood oxygenation level (SpO2), blood pressure, heart rate of mother as well fetal, uterine contractility and temperature are found as predominant vitals to monitor. The significance for quality of care towards prenatal and state of the assessment tools in practice according to WHO guidelines are elaborated [7]. The essence of postnatal maternal care, indicators and tools availability are greatly discussed [8]. In added with key performance indicators to be focused by hospitals in the process of improving quality of postnatal care are discussed by Ann E. Sprague et al. [9] and most common indicators for both prenatal and postnatal is best captured upon a deep systematic review [2].

Christoph Lees et al. [10] conducted a study to discover the feasibility of remote vital monitoring for pregnant women. In their study they observed 24 women in the regular interval of their first trimester to postpartum. Among 24 participant’s, 30% strongly recommended the system. Similarly the adoption of smart wearable electrocardiography (ECG) technique to assess the healthiness of pregnant lady and fetal was investigated among 507 participants, 91% of participants appreciated and accepted, whereas 24% exhibited their readiness to use by purchasing like devices costs up to 200$ [11].

Sachin et al. [12] designed a wearable IoT prototype for prenatal monitoring which observes the mother’s blood pressure, temperature and heart rate along with unborn baby’s kicks through accelerometer. This device is built with the intension of ensuring pregnant women’s health in rural area who often finds difficulty in taking treatments in city especially during pandemic situations.

John A. Rogers et al. [13] built a comprehensive vital monitoring system for prenatal care which facilitates continuous service for the period from antepartum to postpartum. The authors came up with three wearable which are positioned over chest, limb and abdomen. The chest sensor is intended to capture the pregnant women heart rate, respiratory rate and temperature. The limb sensor is used to track SpO2 whereas the abdominal sensor tracks fetal health by examining the uterine contraction and fetal heart rate. Further a noninvasive method for blood pressure estimation is applied by deriving pulse transit time (PAT). Revathi et al. [14] explored the interdependence exists among ECG and photoplethysmography (PPG) signals and usage of the same in obtaining noninvasive methods for blood pressure assessment. A cost effective pulse oximeter is proposed and its efficacy is evaluated across volunteers by Revathi et al. [15]. The scope for complete vital monitor design with reduced circuitry is also discussed.

Fatemeh Sarhaddi et al. [16] contributed a long term solution towards maternal monitoring. The authors used wearable like smart watches to track heart rate of mother. The sleeping and stress patterns are analyzed with the help of smart phones. In order to obtain the vitals like weight, BP and blood glucose, portable devices in practice is ascertained. The mother’s lifestyle, weight before pregnancy and heredity issues are also used as a supportive data in predicting the complications well accurately. Samah A. Z. Hassan et al. [17] presented context aware smart home solutions compatible with android mobile devices in their work. The context awareness which is self-operating characteristic aligned with circumstantial condition is achieved using rule based reasoning. Veena and Aravindhar [18] implemented a remote pregnancy risk monitoring system by formulating a wireless sensor network using heart rate, blood glucose, temperature and uterine contraction sensor in place. Further support vector machine (SVM) which is machine learning algorithm is exercised for attain better prediction accuracy. Shiny Amala and Mythili [19] designed an IoT prototype for maternal monitoring using heart rate, BP, temperature and accelerometer. Instead of ultra sound scan which is costlier practice to examine baby movement, accelerometer is deployed to derive baby movements in name of “kicks”. Ansari and Sainya Ansari [20] worked together and brought an IoT based system to track healthiness of pregnant ladies. For evaluating the state of patient, the mandatory sensors used are heart rate, weight, BP and temperature. The obtained data are processed in cloud layer. ThingSpeak is a renowned cloud platform for IoT

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applications and the same is utilized for processing and visualizing the vitals of interest.

Ahmad O. Alokaily et al. [21] developed an in-house transcranial direct current stimulation (tDCS) kit which is a therapy suggested for brain injuries. Nowadays customers are much interested in home based solutions to avoid clinical visits for simpler causes and practices like vital monitoring. The authors investigated the user interest and presented a cost effective IoT solution towards it. ThingSpeak which is a cloud platform predominantly used to process the sensor data and visualizing the result out of sensory tDCS prototype. Using the same technologies, crop health can be maintained by ensuring greenhouse conditions with help of IoT sensors and processing the output over ThingSpeak platform [22].

B. Research Objectives

To monitor the vital associated with prenatal care, in current clinical settings, it requires a minimum of four to five devices with appropriate user interfaces. In low-resource settings, where maternal morbidity and death are highest, current monitoring systems are found to be expensive, complex, and difficult to implement. The research objectives are as follows:

- To decide significant parameters in assessing pregnancy risk
- To identify technologies of interest in realizing vital monitor for pregnant women
- To facilitate low cost solutions by incorporating appropriate sensors

III. SMART MATERNAL MONITORING DEVICE: STRUCTURE AND COMPONENTS

With an interest to predict pregnancy risk and complications early, the vitals like temperature, hear rate, BP SpO2 and weight of fetal are considered as mandatory data to determine the healthiness. The architectural model for maternity monitoring is composed of four layers, device, communication, processing and application layer namely. The appropriate sensors contributing mother and fetal well-being are integrated into Arduino board to build device layer.

In order to transmit the data from IoT sensory unit to processing, a communication layer is established through a global system for mobile communication (GSM) module compatible to Arduino. For processing the data and predicting the risk, a cloud platform is utilized as processing layer. Mobile applications through which the results are displayed takes role of an application layer. The medical professionals are enabled to view the result and communicate the same to the patients. The maternal monitoring system is captured in Figure 1.

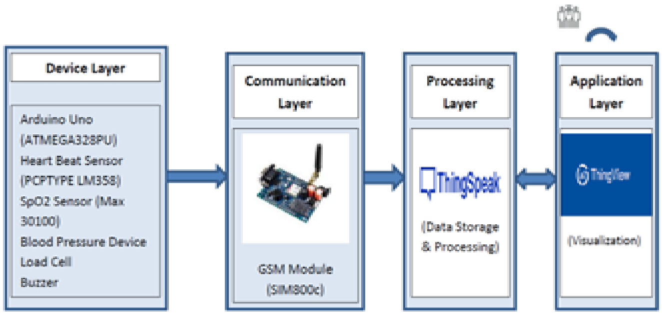

Figure 1. Architecture of Smart Maternal Monitoring Device..

In the device layer, a buzzer is integrated to make an alert upon abnormal readings of mother. The components of device layer are elaborated as follows.

A. Arduino Uno

One type of single-chip microcontroller created by Atmel and included in the mega Automatic-Voltage-Regulator (AVR) family is the ATmega328. The Arduino Uno's architecture is a modified version of the Harvard architecture with an 8-bit RISC processing core. The detailed pin diagram of Arduino Uno is captured in Figure 2.

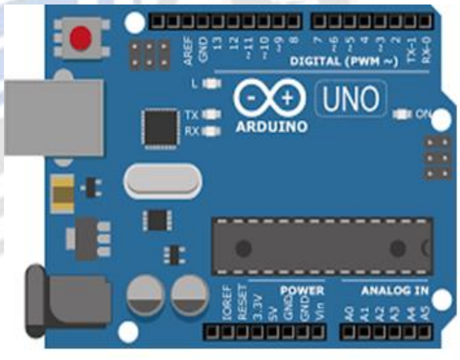

Figure 2. Pin Configuration of Arduino Uno.

An external power source or USB cable can be used to power the Arduino Uno. The majority of external power supplies are batteries or AC to DC adapters. By inserting the adapter into the Arduino Uno's power jack, the Arduino board can be linked. The Vin pin and the GND pin of the POWER connection can both be linked to the battery leads in a similar manner. The recommended voltage range is 7 to 12 volts. A poly fuse that can be moved on the Arduino Uno board protects the PC's USB port from over-voltage. Even though the majority of computers have internal safeguards, the fuse adds an extra layer of security. The fuse will typically break the link if more than 500mA is applied towards the USB port again until excess voltage is reduced.

B. Communication Module

We can expand connectivity to a wide area by integrating GSM technology with a microcontroller. To show whether the

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network is available, the modem has two indicator LEDs: green and red. Red denotes network inaccessibility, whereas green denotes network availability. The universal synchronous / asynchronous receiver / transmitter (USART) protocol is used for communication between the AVR and the modem. Since the GSM Modem SIM900 operates at the time-to-live (TTL) level, we can connect it directly to the Arduino's TXD and RXD pins. Voltage or level converters are not required to be used across them.

C. Heart Beat Sensor

Heartbeats will be detected in this circuitry by two Infrared photodiodes. The receiver detects how much light is emitted or consumed as the transmitter flashes lighting onto either via the finger as given in Figure 3. The heart's rate and the variation in the blood's levels of oxygen have an impact on the measured intensity of the reflected rays.

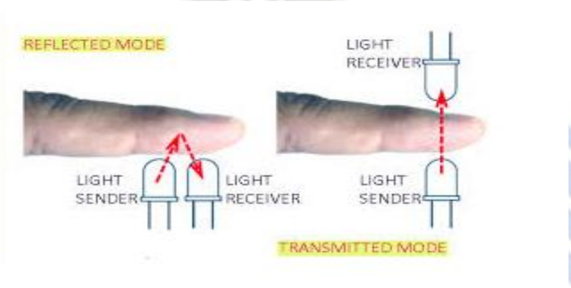

Figure 3. Operation Modes of Infrared Photodiodes.

This circuit uses the IC LM358 which contains two on-chip op-amps. Through a capacitor that mutes the signal's DC components, the output of the photodiode is connected to the first op-non-inverting amp's input. The second op-amp, which functions as a comparator, receives the output of the first op-amp by applying it to one of its inputs. The second op-output, amp's which is accessible at pin 7, is connected to the LED. Our heart rate is displayed by the frequency of LED flashes.

D. Load Cell

An electro-mechanical sensor called a load cell is used to gauge weight. Its straightforward but efficient construction depends on the transference among a force applied, material displacement, and electrical flow, which is a well-known phenomenon. When using load cells, one end is often fastened to a frame, leaving the other end free to fasten the weight or weight-bearing component. The load cell's body flexes a little bit when pressure is applied to it. This occurs similarly to how a fishing rod reacts after a fisherman hooks one.

E. SpO2 Sensor

The MAX30100 Pulse Oximeter Sensor is interfaced with an Arduino board to measure the blood oxygen concentration, or SpO2. In the real world, a tiny clamp-like device is applied to a fingertip, ear or toe during a pulse oximetry reading. The amount of oxygen is measured using tiny light beams that go through the blood in the finger. It does this by tracking variations in light absorption in blood that has been oxygenated or not. Two LEDs are present on the gadget, one of which emits red light and the other infrared light. Oxygen levels in the blood are determined using both red and infrared light.

F. Temperature Sensor

A temperature sensor called the LM35 produces an analogue signal that is proportional to the current temperature. It is simple to interpret the output voltage in order to determine the temperature in Celsius. LM35 has the benefit of not requiring any external calibration over thermistor. Additionally, the covering prevents it from overheating. Further it is cost effective too.

G. Blood Pressure Sensor

To obtain a reliable BP value, still relying on portable devices in practice. Moreover the noninvasive methods for detecting BP still in experimental stage, the system employed a pressure sensor which works based on oscillometric method that detects the pressure in the cuff utilizing air as a pressure transmission medium.

H. Buzzer

In essence, a buzzer is a beeper. When an electric current is sent through the buzzer in the maternal monitoring device when abnormal vital signs are seen in the mother, the buzzer will sound. The buzzer may be connected directly to the Arduino and given various rate electric pulses to make various tones.

IV. RESULTS AND DIXCUSSION

The IoT based maternal monitor built is presented here. Also the outputs i.e. the physiological measures of pregnant women observed out of this device is provided in graphical as well tabular form.

A. Smart Maternal Monitor

The smart maternal monitor is built by integrating all the sensors mentioned above, GSM module and others mentioned above which is presented in Figure 4. The proposed device gets operated upon switching the external power supply.

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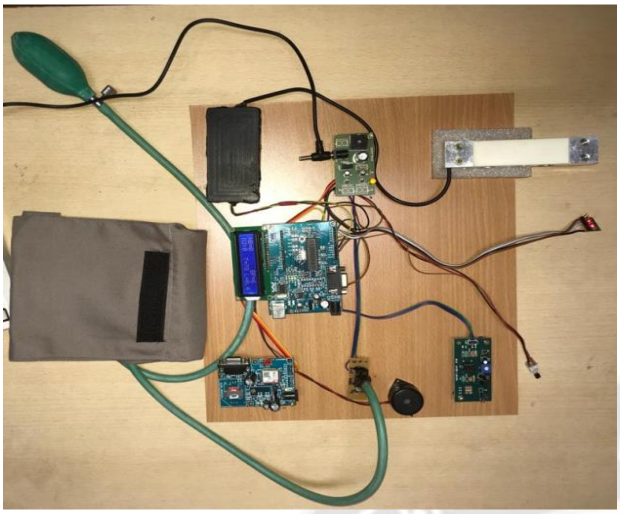


Figure 4. Smart Maternal Monitor – The Proposed Device.

B. Evaluation Strategy

Upon receiving the consent, the interesting participants in different age group ranges from 25 to 40 exercised the device to know their condition.

C. Visualization of Maternal Vital Signs

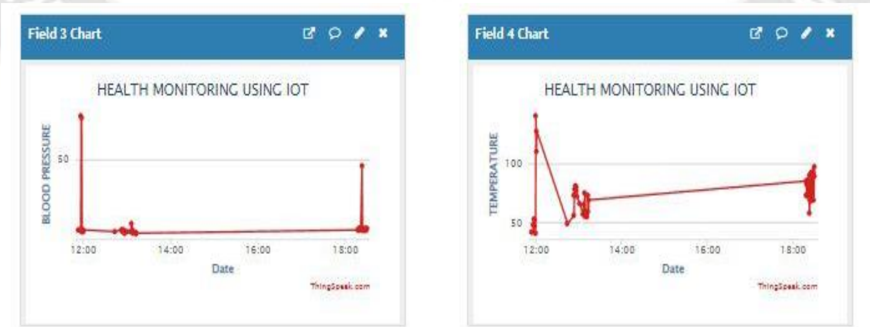
Assembling, visualizing, and analyzing real-time data streams in the cloud is possible with the help of the IoT analytics platform service named as ThingSpeak. Thus the values generated out of proposed device are collected and processed in ThingSpeak platform. Also Data sent by the devices to ThingSpeak is instantly visualized too by ThingSpeak and it is provided in Figure 5.

In aligned with medical professional handbook, he significant vitals and its permissible values which acts an indicator of healthiness of pregnant women is given as Table I.

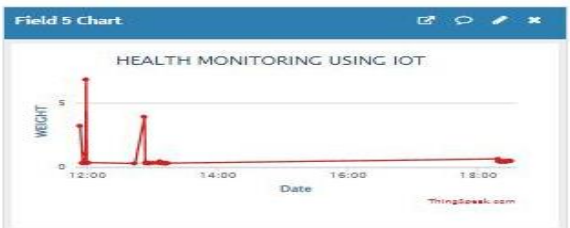
TABLE I. SIGNIFICANT MATERENAL VITAL SIGNS

Vital Sign	**Permissible Range**
Maternal Heart Rate	80-110 beats per minute (BPM)
Blood Pressure	90/60 mmHg - 140/90 mmHg
SpO2	< 97%
Temperature	37.5 ºC - 38.4ºC

(a)



(b)



(c)

Figure 5. Screenshots of Vitals through Smart Maternal Monitor presenting a)Heart rate & SpO2 b) BP &Temperature and c)Weight.

TABLE II. OBSERVED VITAL SIGNS OF PARTICIPANT'S

Participant's	Vital's				
	Heart Rate (bpm)	*BP (mmHg)*	*SpO2 (%)*	*Temperature (°C)*	*Weight (Kg)*
S1	90	110/80	98%	37.6	70
S2	120	145/90	92%	38.6	85
S3	85	100/80	99%	37.9	65
S4	107	130/90	94%	38.0	75
S5	97	110/90	99%	37.8	70

The readings obtained by the proposed device amongst interested participants are captured in Table II. The graphical insight of the readings obtained from participants is captured in Figure 6. If the values of maternal vitals falls within the permissible range, the participant is treat as healthier one. The participants whose vitals out of the range are considered as non-healthier ones and alarm is initiated through the buzzer in the device in order to giving an alert to the care givers.

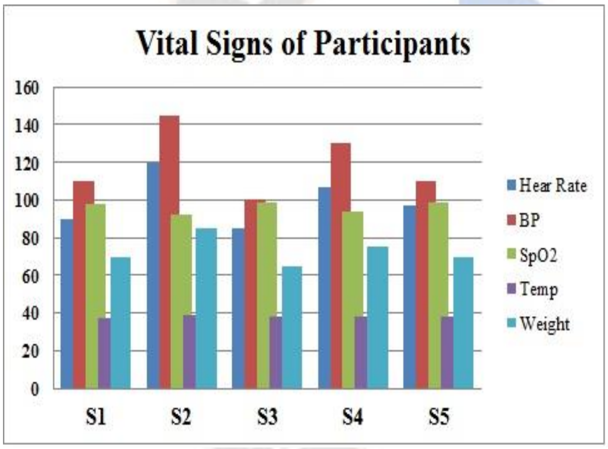


Figure 6. Vital Signs of Participants Observed through Proposed Device.

Thing View is a mobile application available on Google Play that enables us to view the output of any service handled by ThingSpeak from any location at any time, as long as the device is online. Through registering with a specified channel, one can view the resultant on their device end. Upon every 15 seconds, the data gets refreshed.

V. CONCLUSION

It is mandatory to monitor the vitals of mother during their pregnancy at regular interval. They have to visit the clinic, lab or primary health center for examining the vitals. In order to enhance the quality of access to maternal monitoring in rural areas, by incorporating mandatory vital signals for predicting pregnancy complications, a smart maternal monitor is developed. Here the unborn child health is ascertained with weight. It is designed as a cost effective device as it replaces traditional practices like magnetic resonance imaging (MRI) which are high in cost. Using the proposed maternal monitor, one can examine their vitals continuously being in their place and it highly reduces the cost of transportation and time.

In future along with baby weight, uterine contraction can be examined with the help of accelerometer. Moreover reduced circuitry design in deciding heart rate, respiratory rate, temperature, SpO2 and BP can be achieved.

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AUTHORS CONTRIBUTION

Author 1 implemented the concept specified by the author 2 under the supervision of authors 3 & 4. The authors 3 & 4 drafted the article under the guidance of author 2.

CONFLICT OF INTEREST

The authors declare that have no competing interest.

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