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Integrated Embedded System for Pre-Natal Health Care

Rajesh Kannan Megalingam, Goutham Pocklassery, Athul Asokan Thulasi, Vivek Jayakrishnan, Galla Mourya, Manoj Sajeev Nair

Amrita School of Engineering, Amrita Vishwa Vidyapeetham University, Kollam 690525, India

Abstract

Adequate health care facilities are not available for people of low resource settings in India. It is even worse when it comes to the monitoring of the health of pregnant women in villages. In this paper we discuss about the integrated healthcare system which has both vital parameter monitoring and ultrasound scanning, particularly for pregnant women in rural areas. We present in depth about the significance of vital parameter measurements in pregnant women and the system we designed for this purpose and the experimental setup. The measured parameters are stored in SD card by the healthcare workers who carry the portable system to villages. This SD card is taken to the nearest primary health care center for diagnosis of any pre-natal disorders by medical experts. The same is reported back to the pregnant women in case of any treatment is required. The measured parameter values are also provided in this paper. Such a system would help in global effort for reduction in child and mother mortality rates in low resource settings, identification of prenatal disorders and treatment at right time.

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Keywords: vital parameter, pre-natal, healthcare, rural areas, low resource settings

1. Introduction

Prenatal care is very important in that it helps reduce the pregnancy complications and infant risks for complications. Unfortunately, only people who can afford to such care due to economic, social and societal factors can afford to it. While majority of population in India is rural based, many pregnant women in rural areas do not care or know about prenatal care. Even today many pregnant women in rural areas prefer giving birth at their homes rather than at proper heath care centers or hospitals. According to the article in the Deccan Herald dated Jan 18, 2014, over 400,000 newborns in India die within first 24 hours of their birth every year which is the highest anywhere in the world.

Proper pre-natal care helps to ensure that the newborn is healthy. It also reduces the chances of early delivery and other serious problems related to pregnancy. Pre-natal health care check-ups have to be done regularly or at least at the right time when it is required. In the Indian rural scenario, regular check-ups are neither practical nor feasible due to lack of infrastructure, doctors or due to poor financial background of the

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pregnant women's family. In this case, where going to hospitals or health centers are not feasible, the hospitals or the government health departments can appoint health workers who can carry portable medical monitoring equipment and record the medical conditions of the pregnant women. Relevant parameters like heart rate, temperature, blood pressure, ultrasound scan can be collected and stored in a memory device. The data thus obtained, can be taken to doctors and they can analyze the data to provide pre-natal health care to the pregnant women through the medical care worker. Since the workers take care of many pregnant women in a locality this becomes much more economically feasible. This system is effective solution to the problem because pre-natal care is not required as an emergency care in most of the cases but must be regular care.

2. Problem definition

Majority of India's population live in rural areas and most of them live on less than a dollar per day. Unlike in cities where people have access to adequate health care facilities; there are only few health care centers which are not at accessible distance for the rural people. They have to travel long distances to consult doctors for any health problems. With less than dollar per day to lead their life, many pregnant women do not even care to visit health care centers. If any problem related to pregnancy is identified at right time, then mortality rates are sure to come down. Pregnant women need more attention and care to ensure healthy growth of the baby. Prenatal health care can identify the position of the baby in the womb, miscarriage; assess the baby's size and growth [5], estimate delivery date, to check if there is single baby or twins, abnormal growth rate, tumors of pregnancy etc. It can also identify variations in vital parameters like body temperature, blood pressure, heart rate [7], oxygen saturation level etc., which can indicate cardiac diseases, pneumonia, asthma etc. in a pregnant woman. With timely treatment given to pregnant women, many problems can be taken care at early stage.

3. Related works

There are wide ranges of ultrasound scan devices available in the market. A detailed study was conducted among the currently available ultrasound scan products in the market. As per the study, Ultrasound products are classified into mainly three classes such as stationery, portable and handheld devices. At present, most of doctors prefer to go for portable and handheld devices because they are more likely easy to handle. The companies named GE, Sonosite, Terason are some of the leading manufacturers in portable and handheld ultrasound products. Major Image Modes produced in all products are B-Mode, M-Mode, color Doppler and Power Doppler. In the case of handheld devices, GE Healthcare has developed a complete solution for ultrasound scan. Similarly, Mobisante system integrating Smartphone to it. Though ultrasound devices provides the information regarding B-scan, M-scan and Doppler Mode scan, they lack the ability to identify some of the vital parameter measurements which are very crucial in pregnant women such as Electrocardiogram(ECG) , Body temperature etc. For example, echocardiography is an ultrasound evaluation of heart which can be done through these particular ultrasound devices. In fact, it helps to determine structural issues of the heart. However, electrical disturbances of the heart usually do not produce anatomically detectable changes as it is possible detect only from ECG. Moreover, rhythm disturbances are difficult to diagnose solely by ultrasound devices.

We have also done the front end analysis of different companies which manufacture the chips for ultrasound scan. Analog front end designs of companies like Texas Instruments (TI) [11], Maxim Integrated Circuits and Analog Devices were compared. From the analysis, we concluded that TI offers a complete solution with minimal hardware.

We also came across several research papers who are working on portable ultrasound devices. Mobile medical device for point of care applications was one among them which can provide combined diagnostic information of ultrasound B-mode and color mode images with help of smart probe; using Extended

aperture(EA) technique[1]. Similarly another paper titled "An embedded ultrasound signal system" which has the capability to process ultrasound signals of B mode, color flow and spectrum Doppler in real time also came into out notice [2]. It uses four high performance digital signal processors, TMS320VC6416, and other peripherals such as FIFOs and SDRAMs

4. Relation between health parameters and pregnancy

4.1. ECG Electro Cardio Graph

1-4 % of pregnancies in women get complicated due to cardiac diseases. High risk of maternal mortality is associated with many heart disorders like severe left heart obstruction, depressed systemic ventricular function and pulmonary hypertension. It has become extremely important to familiarize with the treatment of commonly encountered cardiac diseases during pregnancy. In our proposed system, we are trying to identify the issues related to heart so that if treated in time would be a great advantage to pregnant women.

4.2. Oxygen Saturation

Pneumonia during pregnancy could cause the baby at the risk of premature birth and low birth weight. Compared to non-pregnant women, the mortality and morbidity rate due to pneumonia is higher in pregnant ladies. Other diseases like asthma and anemia also increase the risk of pneumonia in pregnancy. Pneumonia affected patients are suffered from a condition where the oxygen saturation level is less than 92% which is a serious concern in pregnant women.

4.3. Heart Rate

Heart rate also has a slight increase in woman during pregnancy; as the blood flow from the heart increases. The normal heart rate of a woman is 70 beats per minute. However, it varies to 85-90 beats per minute during pregnancy. In the last trimester of pregnancy, there is the chance of 10-20 beats increase than the normal heart rate in order to fulfill the additional supplements to the fetus. So, it is considered that heart rate is another important vital health parameter to be monitored during pregnancy.

4.4. Body Temperature

During pregnancy, woman's body produce added heat due to increased metabolic rate, increased work stress due to extra weight during the growth of fetus and raised levels of hormones like progesterone. However, it is understood that normal range of body temperature should not go beyond 100.4 Fahrenheit. In fact, an increase in temperature beyond 100.4F can risk the health of both the pregnant and baby. Hence, Body temperature is another vital parameter that should be monitored during pregnancy.

4.5. Blood Pressure

During Pregnancy period, high blood pressure can make it hard for blood to reach placenta, which provides nutrients and oxygen to the fetus. The decrease in blood flow can slow the growth of the fetus and can place the mother at greater risk of preeclampsia and preterm labour. High blood pressure that develops during pregnancy is called gestational hypertension. Women who have high blood pressure before they are pregnant should continue to monitor and control it with medications throughout the pregnancy.

5. System architecture

In the proposed system Fig.1, we are building a low cost, medical diagnostic device. This system is used mainly to perform obstetric ultrasound scanning. It also measures heart rate, blood oxygen level, ECG and

blood pressure and requires very less training for those who use it. In low resource setting areas, it is the community health workers who manage the healthcare needs of the population as there are hardly any physicians, clinics, or hospitals nearby. A community health care worker by means of the diagnostic device provides proper healthcare to those who otherwise would not have gotten proper medical care. Accordingly, the health care worker takes this device to the rural areas scans the baby in the womb and measures various health parameters of the pregnant woman. The measured parameters are then transferred to an SD card and taken to the gynaecologist for comprehensive diagnosis by the healthcare worker, who is located in the nearest Primary Health Care center. The results are then conveyed to the pregnant women during the next visit of the health care worker. Unlike cases like heart attack, which requires immediate attention to the patient, any issues associated with pregnancy need not treated immediately.

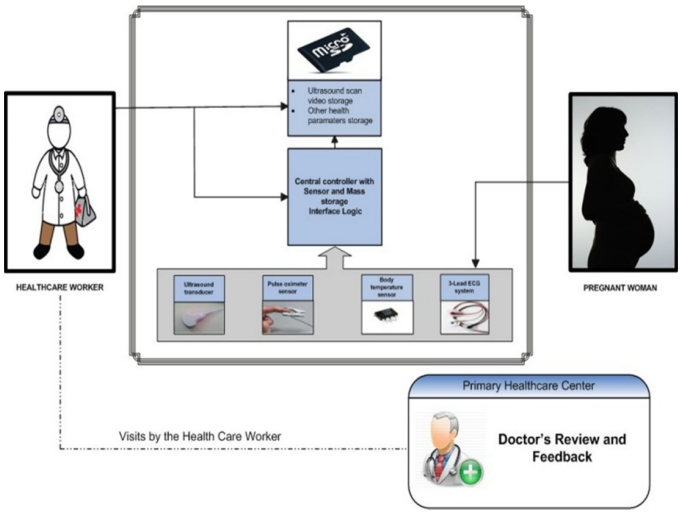

Fig. 1. Prenatal Health Care - The System Architecture

6. System design

6.1. Pulse Oximeter

Pulse oximeter works on the principle of Beer-Lambert law: the amount of light absorbed is proportional to the concentration of the substance through which the light is passing. In fact, it is determining the relation between amount of red and Infra-red light that is absorbed by deoxygenated and oxygenated blood. Red light has the wavelength of 600-750 nm and Infrared light has the wavelength of 850-1000 nm. When both the lights are passed through finger, oxygenated haemoglobin absorbs more infrared light whereas deoxygenated haemoglobin absorbsmore red light. The absorption of light is done using a photodiode. According to that, when Red(R) and Infrared (IR) light are transmitted, the output of transmitted lights is acquired; the R/IR ratio is calibrated. The ratio of R/IRis used to estimate the percentage of SpO2 content present in the human blood.

The pulse oximeter circuit consists of a sensor module and a signal conditioning circuit as in Fig 2. The sensor module is made up of an IR LED (910nm), a RED LED (660nm) and a photodiode which is sensitive to both these wavelengths. The LEDs act as sources of light and photodiode the receiver. A finger of the person whose oxygen saturation is to be measured is placed between the LEDs and the photodiode. The module has to be covered properly to avoid interference from ambient light sources. The RED and IR LEDs are pulsed with non-overlapping pulses of 5% duty cycle and 1millisecond period [6]. The signal obtained from the photodiode

is filtered and amplified by the signal conditioning circuit. The signal conditioning circuit consists of a pre-amplifier, a sample and hold circuit, a high pass filter, a low pass filter, a post amplifier and a clamper circuit for processing each LEDs output. The preamplifier is shared by both LED outputs. Two sample and hold circuits are used to divide the paths for the output from the two LEDs [9][8][12]. The preamplifier is required because the photodiode output that we obtain is in the order of few mill volts, hence cannot be fed into a filter for proper filtering. A band pass filter with cut off frequencies 0.5Hz and 5Hz is implemented by a series high pass filter and low pass filter. The circuit implementation of the pulse Oximetry along with the temperature measurement is shown in Fig.2

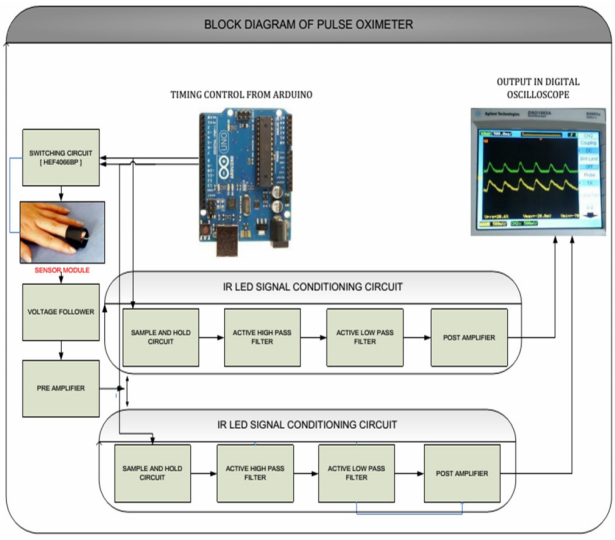

Fig.2. Pulse Oximeter- Block Diagram

6.2. Body Temperature Measurement

The body temperature is measured using DS 1620 IC from Maxim Industries. It is a digital thermometer and thermostat. It supports two modes: Stand-alone mode and 3-Wire Interface mode. The latter is used when the DS 1620[10] is used in combination with a micro-controller or micro-processor to allow synchronous serial data transfer whereas the former is used in absence of any such component and when it acts as a thermostat. Here the temperature is read as 9-bit values through the 3-wire serial interface.

6.3. BP Measurement

Blood pressure (BP) is a main concern for any human being. For a pregnant woman the blood pressure will keep varying slightly throughout the 10 months [13]. This is what makes them feel woozy during the pregnancy period. Monitoring Blood Pressure measurement is vital as the discrepancy in blood Pressure can affect the baby's supply of oxygen and nutrients. In this design, the blood pressure can be measured using Pulse Transit Time (PTT) method. PTT is the amount of time a particular volume of blood inside the artery takes to shift from one arterial site to another. Photoplethysmography (PPG) and Electrocardiogram (ECG) are the two main non-invasive technologies used for measuring Pulse Transit time. In this method, PTT is calculated by an ECG-PPG combination. The PQRS waveform obtained by the ECG is compared with the Photoplethysmography waveform which is obtained by the apparatus fixed at the fore-fingertip. The time interval between the R-peak of the ECG waveform and the peak ofphotoplethysmography waveform gives the pulse transit time. Pulse wave velocity (PWV) is calculated by measuring distance from heart to location of PPG module, and then divides the

distance by the PTT. At the end, Blood pressure is estimated through linear regression analysis. An increase in Blood Pressure makes an increase in PWV as a result of which blood takes very less time to move from one arterial location to another. A low blood pressure gives a high PTT value [3].

7. Implementation

The experiment was conducted among ten healthy adult subjects, six males and four females of the age group twenty to twenty three; labeled test case one to ten in the tabular results. The SPO2, Temperature and Heart rate measurements were taken simultaneously using our experimental setup. At the same time the temperature reading were recorded using the commercially available Omron MC-246 digital thermometer. The temperature readings were taken under the left armpit using both setups. Table 1 shows these readings and Fig 4 shows the plot. The pulse oximeter probes were placed on the right index finger. The heart rate was and SPO2 was calculated inside the microcontroller. The heart beats were counted for one minute to get the manual observations. The PPG wave forms were observed through the DSO to ensure that correct signal are fed into controller. Choicemmed MD300C2D Pulse Oximeter was used to check the accuracy of the PPG values obtained. Table 2 gives the readings and Fig 5 shows the plot.

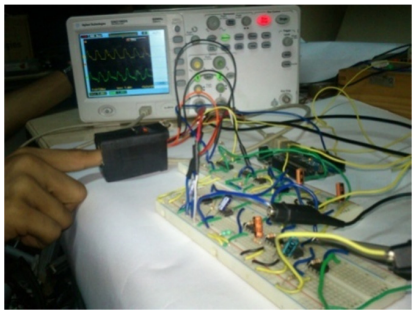

Fig.3.Experimental Setup

The analysis of the temperature, oxygen saturation (SPO2), heart rate was done in ten healthy subjects. It shows that all their readings fall under the normal range of values 80 -100 % in case of blood oxygen saturation the maximum error was just 2% as shown in Table 3. Fig 6 shows the plot. The heart rate was also in the normal range of 70 -92 beats per minute and the experimental results were fairly accurate with the maximum error percentage being 5.70% as in Table 1. The normal range of temperature in the axilla (armpit) is 96.4–99.3 F.The maximum error percentage that was obtained was 0.31%. The normal range of all the values for healthy subjects indicates the correctness of the circuit implementation. Further testing with commercially available equipment could be done after successfully integrating the system with blood pressure and ultrasound scan units.

Table 1.Temperature measurement of ten subjects.

Test case	Temperature sensor: DS-1620 Reading (F)	Omron MC-246 digital Thermometer	Error Percentage (%)

		Reading (F)	
1	97.4	97.5	0.10
2	96.5	96.5	0.00
3	96.5	96.5	0.00
4	96.6	96.5	0.10
5	96.5	96.5	0.00
6	96.7	97.0	0.31
7	96.6	96.6	0.00
8	96.5	96.5	0.00
9	96.7	96.5	0.20
10	96.5	96.6	0.10

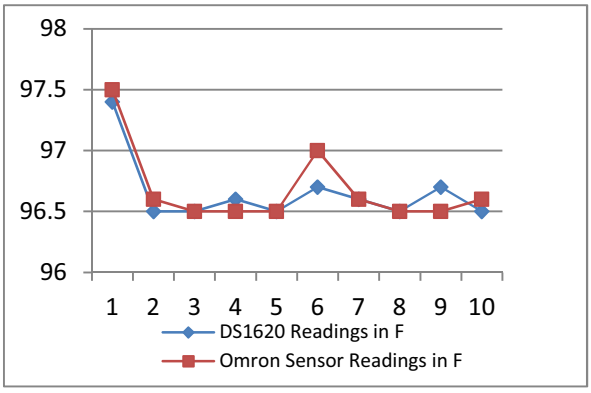

Fig. 4. Experimental Circuit Readings VS Omron Readings

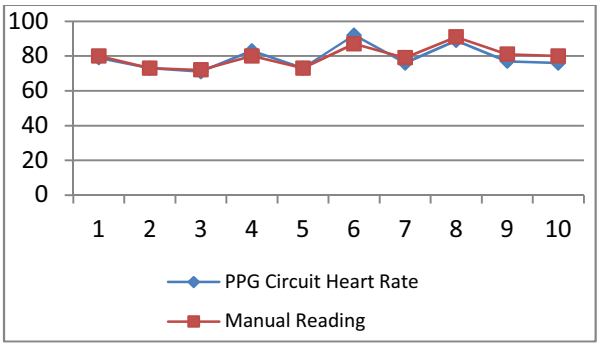

Fig. 5. Experimental Circuit Readings VS Manual Readings

Table 2.Heart rate using PPG circuit(Fig. 2) of ten subjects.

Test	Circuit	Manual	Error (%)

case	Reading(BPM)	Reading(BPM)	
1	79	80	1.25
2	73	73	0.00
3	71	72	1.38
4	83	80	3.75
5	73	73	0.00
6	92	87	5.74
7	76	79	3.79
8	89	91	2.19
9	77	81	4.90
10	76	80	5.00

Table 3.SPO2 measurement of ten subjects

Test case	Circuit Reading (%)	Choicemmed MD300C2D Reading (%)	Error (%)
1	100	100	0.00
2	98	99	1.01
3	98	100	2.00
4	99	99	0.00
5	100	100	0.00
6	96	97	1.03
7	99	99	0.00
8	98	100	2.00
9	98	100	2.00
10	99	98	1.02

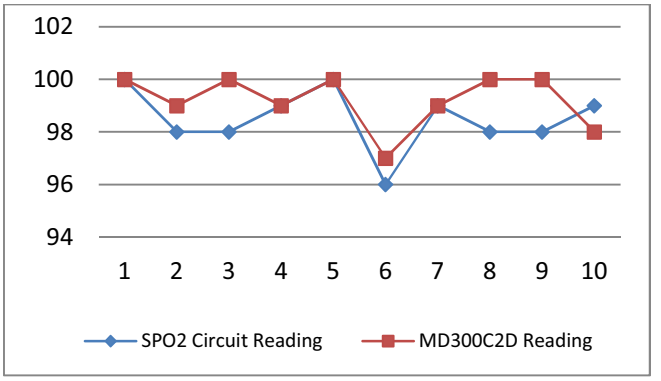

Fig. 6. Experimental Circuit Readings VS MD300C2D Readings

8. Future works

The system has to be completely developed incorporating blood pressure measurements and ultrasound scan system. Then all the modules in the system have to be integrated and tested with considerable number of test subjects. Further development if required: the storage of the data can be done in clouds to improve the access time and hence the response time of the doctors. The medical works can collect the data in a single visit and the doctors can analyze the data from their hospitals and give a report instantaneously to the pregnant women. This avoids two visits from a medical care worker to obtain data and to give the results; both of this could be completed in a single visit. This improvement however requires wireless data connectivity in rural areas which is highly unlikely

9. Conclusion

Pregnancy related problems are common in low resource setting areas mostly for the people live in underdeveloped and developing nations with very little or no access to proper health care. High costs, power scarcity, lack of healthcare centers to access are menacing issues facing by present rural world. The proposed system performs obstetric ultrasonography with high reliability as well as other vital parameters which are essential for prenatal healthcare. The device integrates Ultrasound transducer, Electrocardiogram (ECG), a Pulse oximeter and temperature sensor [16]. The ECG and the Pulse oximeter are used to monitor the heart rate, blood oxygen content and the Blood Pressure whereas the ultrasound transducer is used to detect the anomalies in the fetus of pregnant women. It can be easily carried by the healthcare workers to the homes of pregnant woman living in low resource setting areas. The scan output is stored as video in the SD card with other measured parameter values. The healthcare worker carries the storage device to the nearest Primary Health Care center where a medical professional analyses the contents and gives expert opinion. The healthcare worker conveys doctor's report to the concerned woman during the next visit to the low resource setting areas. The device uses a rechargeable battery source that can be charged with more than one external source, i.e. using a portable solar suitcase, car battery, or a/c mains. As electric power from the grid may not be available, the three options of recharging the device's battery will be advantageous.

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