Volume 64, Issue 2, 2020

Journal of Scientific Research

Institute of Science,

Banaras Hindu University, Varanasi, India.

Wearable Fetus Monitoring: An IoMT Approach

Soumitra Das*

Dept. of Computer Engineering, Dr. D Y Patil Institute of Technology, Pimpri, Pune, Maharashtra.
soumitra_das@yahoo.com*

Abstract: **The Internet of Things in healthcare is one of the novel applications. With growing innovations in other sectors, pressure is now on the healthcare industry to embrace digital change. Under the Internet of Things approach, a wearable fetus monitoring system was designed to be used by pregnant women. Currently, the interpretations of available fetus monitoring systems require expensive equipment operated by a trained midwife. This limits use of such systems by women from resource-poor locations. The proposed solution comprises of a smart mobile phone enabled software application. This new method monitors Fetal Heart Rate using Internet of Things where system can be connected with small Doppler device by smart mobile phone for observing abdominal area fetal parameters e.g. heart rate remotely. The software transforms the received data by calculating the mother fetal heart rate, stores the earlier readings, monitors fetal movement and provides this data to the remotely located midwife in a structured format as needed by the hospital system. Along with mother fetal heart rate, two other parameters of mother as heartbeat and body temperature is also measured. The goal of the Wearable Fetus Monitoring System is to empower mothers in remote locations with an opportunity to regularly screen fetal well-being and calculate fetus risk. This will help decrease maternal and fetal complications and deaths.**

Index Terms: **Fetal Heart Rate Monitoring, Doppler Device, Fetus Monitoring, Wearable Wireless Sensor, Internet of Things**

I. INTRODUCTION

The Internet of Things (IoT) is a combined system of electronic devices and applications with an ability to link the healthcare IT systems using online computer networks and smart mobile devices. The basic principle of IoT allows electronic devices which are Wi-Fi enabled to facilitate machine-to-machine communication. IoT devices have the functionality to connect with cloud infrastructures such as Amazon Web Services wherein the captured data are warehoused and analyzed as required.

Historically, the healthcare industry lagged behind other industries to adopt the IoT technologies. However, in the recent times, the IoT has transformed the healthcare system by providing cost-effective solutions to keep people safe and healthy. The IoT can ensure availability of actual data for healthcare providers to identify issues before they become critical through remote access and allow for earlier invention in addition to routine monitoring by the care-givers.

Fetal death is a common problem in resource-poor settings (Ayres-de-Campos et al. 2000). Routine monitoring of fetal heart rate is an important method to assess fetal well-being. Any abnormality in fetal heart rate gives an indication of fetal distress. Similarly monitoring of maternal heart rate is also important especially during third trimester of pregnancy.

Heart rate of the unborn baby (fetus) can be monitored from as early as 6.5 weeks of pregnancy until delivery of the baby (Dieffenderfer, J. P. et al. 2015). Fetal heart rate is a good indicator of monitoring fetal well-being and detecting abnormalities. Increased fetal heart rate indicates if contractions of your uterus are affecting your baby.

Fetal cardiotocography is generally conducted at a center with appropriate facilities including equipment and staff. Devices currently available 'in the field' provide limited information, which includes either just the sound of the fetal heartbeat or displays an instantaneous heart rate on a Liquid Crystal Display screen. However, fetal well-being assessment requires continuous monitoring of heart rate over time to determine what was the baseline value, any variability, and response to fetal movements. A smart e-health system gives the ability to track, document and report current fetal condition during the entire monitoring period. Such a system is able to define and raise an alert if there is any change compared to previous status of the fetus and mother too; this helps the physician and nursing staff to take appropriate measures.

This paper introduces a new approach to monitor the fetus heart rate with maternal parameters such as temperature and heart rate. It is an end-to-end and a low cost Doppler device to monitor healthy gestation. For regular screening of fetus, the Doppler system needs to be placed on mother's abdominal wall.

* Corresponding Author

Depending upon the analog signals sensed by the sensors, it computes sensed value and then it interprets the result. If the Fetal Heart Rate goes beyond the normal baseline (increases or decreases), a yellow signal is depicted on Doppler. For the installation of the software solution, the existing mobile phone hardware is been used. The mobile phone screen is used as portable fetal monitors, thereby reducing the cost significantly so as to make inexpensive device.

II. Literature Review

The clinical practice of examine a patient by listening to sounds from the heart, lungs, or other organs, using a stethoscope began in 1818. In the 1970s, the examination of fetal heart rate and uterine activity turned out to be broadly utilized in obstetric care. The Electronic Fetal Checking (EFM) is essential procedure for screening fetal prosperity during labour. The extensive literature survey related to EFM is listed below

The authors (Ertugrul, D. Ç et. al. 2016) has presented a concept in which a "Toco Probe" is attached with a Doppler device for gathering Uterus Contraction signals is proposed. FHRMS can assess the FHR values of an unborn baby at frequent intervals, by considering instant baseline FHR, baseline FHR variability, and any periodic and/or non-periodic FHR changes, including accelerations, and decelerations.

In paper (Roham, M., et al. 2011), A Mobile Wearable Wireless Fetal Heart Monitoring System, presented the uses of both wireless and mobile systems. The proposed system is located near the mother and the measured data can be viewed from any web browser-based device including smart phones, tablets, or laptops.

In paper (Fanelli, A., et al. 2010), Prototype of a wearable system for remote fetal monitoring during pregnancy, presented by authors, allows a pregnant woman to monitor fetal well-being in a remote location without visiting the hospital care. The treating doctor(s) can receive the recorded signals to give expert advice about the fetal condition.

In paper (Ionescu, V., et al. 2015), Fetal Heart Rate Detection and Monitoring from Noninvasive Abdominal ECG Recordings, presented by authors, in which FHR can be successively estimated from an extraction of fetal ECG signals. This is done from a collection of an ECG recordings using Fast ICA algorithms and a post-processing stage with wavelet transform and an FFT/IFFT pair.

In paper (Dawes, G. S., et al. 1981), Numerical analysis of the human fetus heart rate: the quality of ultrasound records, presented by authors, described the method for the computerized numerical analysis of fetus heart periods (pulse intervals). To separate the records of Low and High frequency components this method uses digital filter and the Doppler ultrasound from the last 10 weeks of gestation. The difference between direct ECG and ultrasound records gives the problem of signal loss. Therefore system gives a particularly useful adjunct to the analysis of antenatal fetal heart rate records.

In paper (Dawes, G. S., et al. 1985), Improvements in the analysis and registration of fetus heart rate hears at the bedside, in which for the purpose of online analysis of fetus heart rate a microprocessor system is described using conventional Doppler systems. The system has been tested by analyzing abnormal and normal antenatal fetal heart rate records.

In paper (Lätt Nyboe, E. 2011), an algorithm based on the Dawes/Redman criteria for automated fetal heart rate analysis, in which the equipment based on Dawes/Redman criteria as a product in STAN S31 is used for fetus heart rate measuring produced by Neoventa Medical AB in M lndal. This involves concern around valid patents which protects the algorithms and other applicability problems like if related publications provide enough details to implement a version with claims on similarity.

III. System Architecture

The management of any system requires hardware and software usage and technique for measuring the performance and efficiency of achieved result based on the sensed data. The recommended hardware and software components needed for the development are:

Hardware Components: Controller ATmega328P, Firmware Node Microcontroller, Sensors, HB 100 (Doppler), LM35 (Temperature), Pulse Sensor and Buzzer.

Software Components: Android Studio IDE and Think speak API.

The high level design of the architecture of fetus heart rate monitoring system is shown in the fig 1, where all the main components of the system are shown. The architecture shown in the fig.1 has three areas as the first area is the users which is the pregnant woman, the second area is the backend Internet of Things system coupled with information management, information processing and information analysis and the third area is handled by the midwife, medical specialist and paramedics.

In the user side the device "fetus heart rate monitoring system" is a portable medical device which is easy to use. The device has three sensors attached to it as a Doppler, a Pulse Sensor and a Temp Sensor which are used by the pregnant women for measuring the fetus parameters like baby's heart rate, length and weight of the fetus, and mother's temperature and heart rate. These sensors are attached with a probe which can be placed in the investigation area of the users. The sensed information of the user is collected, processed by the microcontroller and the information is stored in the cloud.

The midwife, medical specialist and paramedics are provided with mobile device or computer systems to access the information from anywhere at any time to make decisions.

IV. The Development & Working of the System

The development of the system needs the following to be done as

- Data acquisition which can be done through the sensors
- Input processing which is done by the microcontroller's which are attached to the system
- Display of the desired output in the form of graphs

and buzzers.

For the development of the Fetal Heart Rate Monitoring System the following components such as sensors, actuators and controllers are needed which are responsible for the Data acquisition. For data uploading, processing and displaying of analyzed results can be achieved through a Smartphone or computer system or laptops.

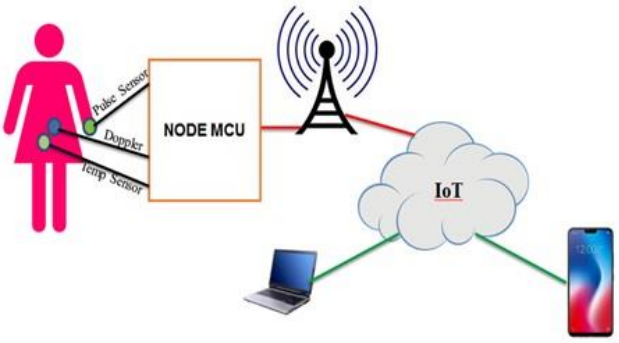

Fig. 1. The Architecture of Fetal Heart Rate Monitoring System

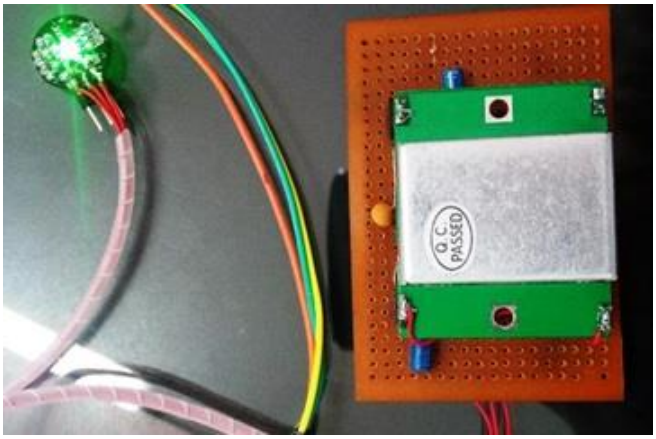

Fig. 2. The Doppler and Pulse Sensor Interfacing

All the basic devices such as Doppler ultrasound (HB100), Pulse Sensor, LM 35 temperature sensor, Node MCU, Controller ATmega328P and Buzzer are all assembled in integrated on the motherboard as shown in the Fig.2. & Fig.3.

From Fig 3 it can be seen that there are sensors which are connected to the pregnant women's desired area, and these sensors in turn are connected to the Node Microcontroller Unit. The data which is sensed and collected are transmitted through Wi-Fi to the internet and then to the cloud which then can be accessed to the users through smart mobile phones or laptops for further actions and decision can be made based on these by the experts.

In fetus if any abnormal activity is occurred then the buzzer or vibration is triggered out by sending SMS or e-mail notification to the user and finally the result is shown in the form of graph.

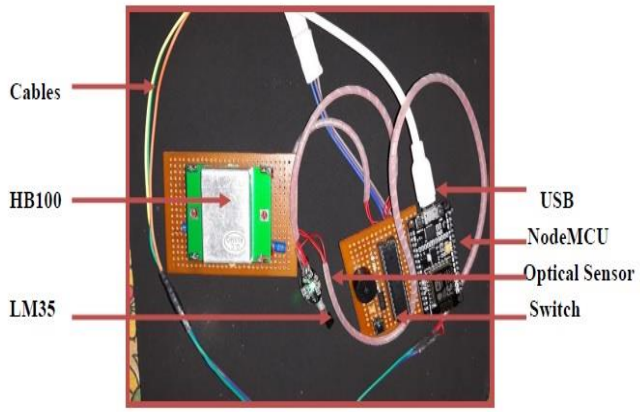

Fig. 3. The hardware experimental setup of Fetus Monitoring System

For better understanding of the system the flow diagram is shown in Fig.4. Initially the equipment is attached to the user's body on the desired location.

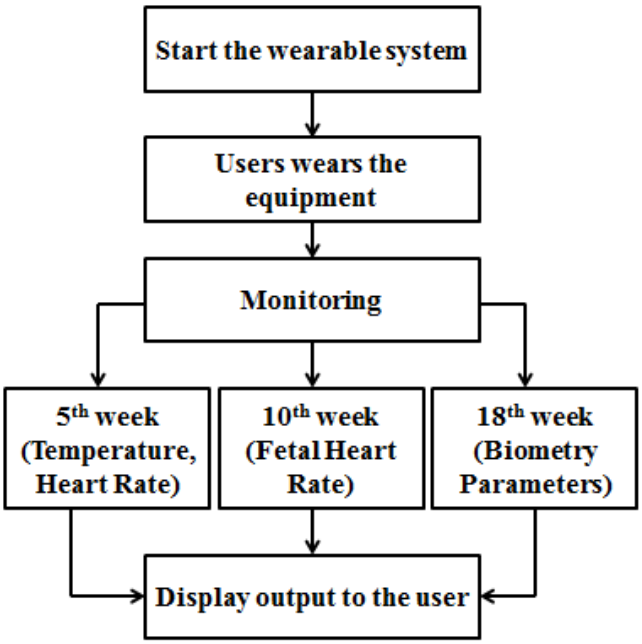

Fig. 4.The process flow of the wearable system

The system presents a Fetal Heart Rate Monitoring System which is operated using software application which can installed on a mobile phone. At about 5th week of gestation, baby's heart begins to beat. At this point Fetal Heart Rate is similar ro mother's Heart Rate which is about 80-85 beats per minute (bpm). System consists of hardware components out of which optical finger-based heart rate module is used to monitor the mother's heart rate. At the beginning of 9th week of pregnancy Fetal Heart Rate can be heard by using Doppler. The software on the phone analyses the sound of fetal heart rate using network module connected to controller to calculate heart rate. Along with Fetal Heart Rate the system also monitor the Fetus

biometry parameters (weight and length) as well as mother's parameters

V. Experimental Results

In this case study the pregnant woman's fetal heart rate signals are recorded from 9th week to 10th week of gestation. One of the records is taken as an example to depict how the results can be displayed for the end users.

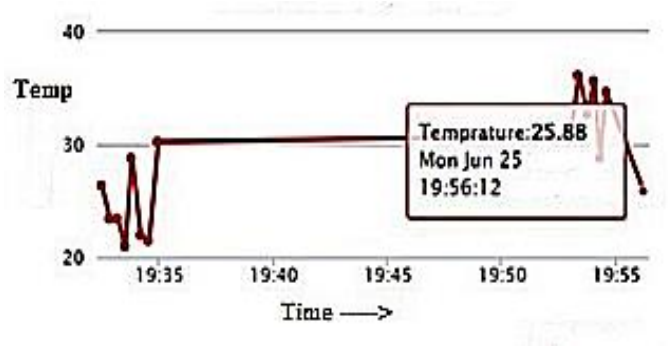

Fig.5. The pregnant women's temperature versus time

The temperature and heart rate of mother is captured and analyzed and plotted in terms of graphs which are shown in Fig.5. & Fig.6. The fetus heart rate is captured and analyzed and plotted in terms of graphs which are shown in Fig.7. If any abnormality is observed then it can be immediately observed in the graphs and also the buzzer will ring at the mother side.

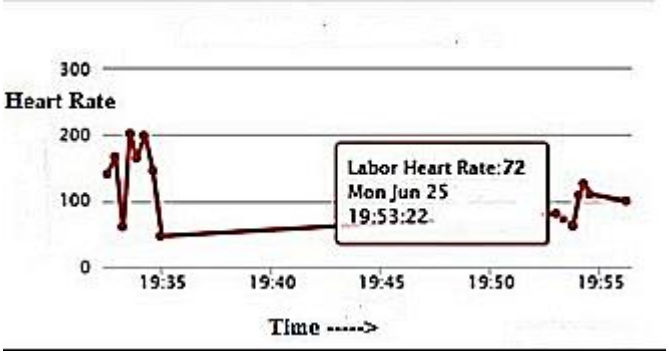

Fig.6. The pregnant women's heart rate versus time

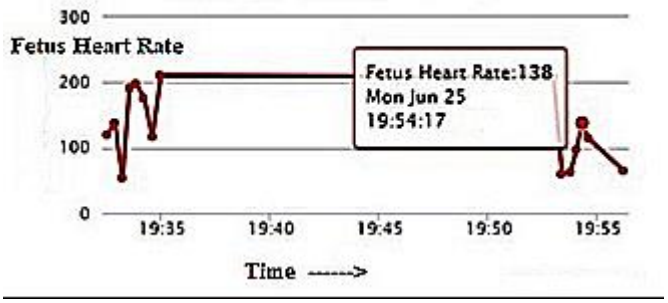

Fig. 7. The fetal heart rate

Based the comparison as shown in Fig. 8, it is concluded that the proposed system is better than the existing systems in term of Price, Features, Convenience to use (Portability) and Availability.

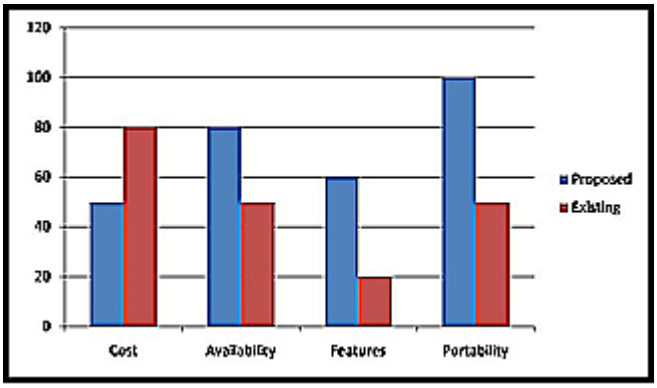

Fig.8. Comparison with other existing systems

Conclusion

The prototype for monitoring the heart beats of fetus were presented in this paper. The system as wrist band worn by mother has the capability for measuring parameters like temperature and heart rate. By using different types of sensors the desired analog data is captured and then the analog data is converted to digital data so that an appropriate data value of sensed data is generated. The system works on real time object i.e. mother can also access the previous results of her healthy fetus at any time and any location on mobile phone. As every coin has two sides it also has some drawbacks. Accuracy could be an issue for remote FHR monitoring. The result obtained from clinic-based equipment is comparative and may not be100% similar. Thus to obtain accuracy, we need to enhance our hardware, so that it can give better performance result as compare to the previous one.

References

Ayres-de-Campos, D., Bernardes, J., Garrido, A., Marques-de-Sa, J., & Pereira-Leite, L. (2000). SisPorto 2.0: a program for automated analysis of cardiotocograms. *Journal of Maternal-Fetal Medicine*, *9*(5), 311-318.

Dieffenderfer, J. P., Goodell, H., Bent, B., Beppler, E., Jayakumar, R., Yokus, M., ... & Peden, D. (2015, June). Wearable wireless sensors for chronic respiratory disease monitoring. In *2015 IEEE 12th International Conference on Wearable and Implantable Body Sensor Networks (BSN)* (pp. 1-6). IEEE.

Ertugrul, D. Ç., Kanmaz, H., Yüksel, M. U., Elçi, A., & Ertugrul, M. (2016, June). Fetal Heart Rate Monitoring System (FHRMS). In *2016 IEEE 40th Annual Computer Software and Applications Conference (COMPSAC)* (Vol. 2, pp. 65-70). IEEE.

Roham, M., Saldivar, E., Raghavan, S., Zurcher, M., Mack, J., & Mehregany, M. (2011, March). A mobile wearable wireless fetal heart monitoring system. In *2011 5th International Symposium on Medical Information and Communication Technology* (pp. 135-138). IEEE.

Fanelli, A., Ferrario, M., Piccini, L., Andreoni, G., Matrone, G., Magenes, G., & Signorini, M. G. (2010, September). Prototype of a wearable system for remote fetal monitoring during pregnancy. In *2010 Annual International Conference of the IEEE Engineering in Medicine and Biology* (pp. 5815-5818). IEEE.

Ionescu, V., & Hnatiuc, M. (2015, November). Fetal heart rate detection and monitoring from noninvasive abdominal ECG recordings. In *2015 E-Health and Bioengineering Conference (EHB)* (pp. 1-4). IEEE.

Dawes, G. S., Visser, G. H. A., Goodman, J. D. S., & Redman, C. W. G. (1981). Numerical analysis of the human fetal heart rate: the quality of ultrasound records. *American journal of obstetrics and gynecology*, *141*(1), 43-52.

Dawes, G. S., Redman, C. W. G., & Smith, J. H. (1985). Improvements in the registration and analysis of fetal heart rate records at the bedside. *BJOG: An International Journal of Obstetrics & Gynaecology*, *92*(4), 317-325.

Lätt Nyboe, E. (2011). An algorithm based on the Dawes/Redman criteria for automated fetal heart rate analysis.

***