Digital Healthcare Empowering Europeans
R. Cornet et al. (Eds.)

doi:10.3233/978-1-61499-512-8-354

Integrated Wireless Sensor Network for Monitoring Pregnant Women

Adina NIȚULESCU[a,1], Mihaela CRIȘAN-VIDA[a], Lăcrămioara STOICU-TIVADAR[a] and Elena BERNAD[b]
[a] *Faculty of Automation and Computers, University Politehnica Timisoara, Romania*
[b] *Department of Obstetrics and Gynecology/University of Medicine and Pharmacy "Victor Babes", Timisoara, Romania*

Abstract. The paper presents an integrated monitoring system for pregnant women in the third trimester using a mobile cardiotocograph and body sensors. The medical staff has a useful tool to detect abnormalities and prevent unfortunate events in time. The mobile cardiotocograph sends data in real time to a Smartphone that communicates the information in a cloud. The physician accesses the data using the hospital ObgGyn application. The advantage of using this system is that the pregnant woman can follow her pregnancy status evolution from home, and the physician receives alarms from the system if the data is not in normal range and has available information about the health status at any time and location.

Keywords. obstetrics and gynecology department, hospital, pregnant women, cardiotocography, fetal monitoring, remote consultation

Introduction

Information technology is progressively entering in a critical medical domain as pregnancy monitoring and baby delivery. According to World Health Organization, around 287000 women worldwide die due to complications from pregnancy each year, and 20 times that number are injured or contract an infection while giving childbirth [1]. Home monitoring of both future mother and foetus vital signs as well as for the entire evolution during pregnancy may help avoiding complications and prevent early delivery. By listening to the baby's heartbeat, one can identify foetuses who are becoming hypoxic and who may benefit from caesarean section or instrumental vaginal birth. Foetal monitoring may be used in pregnancies from about 26 week's gestation right through labour and delivery by using two methods: Doppler ultrasound or foetal ECG [2]. Typical electronic foetal monitoring equipment used in hospitals is expensive and cannot be used on a daily basis by pregnant women living in remote areas. The sensors in routine use are fixed on the future mother abdomen using belts that can leave visible marks on the patient's skin and can cause irritations. Also, an important problem is that pregnant women are unable to change position or walk while foetal monitoring is performed.

[1] Adina Nitulescu, Faculty of Automation and Computers, University Politehnica Timisoara, Romania, email: nitulescu.adina@gmail.com.

To overcome these problems, our paper presents an integrated solution that comprises all the sensors used by a cardiotocograph (CTG), into a smaller portable version, with Internet connectivity, provided by the user's smart-phone, for sending the data to the remote server which allows real-time monitoring by medical professionals.

This paper describes a wireless network of body-sensors, integrated into a single module together with the processing and transmission unit in order to be worn by the patient. This module captures the vital signs, processes them and transmits wireless directly to the smartphone maximizing the comfort of the patient in terms of mobility and ease of wearing. Thus, the patient module will have higher reliability because all units are incorporated into a single capsule. The solution includes an application for Android operating system with 2 modules: one for receiving the signals from the body-sensors and the second to inform the pregnant woman about her health status and information about the pregnancy.

1. State of the art

The first practical commercially available fetal monitor for clinical use was produced by Hammacher and Hewlett-Packard in 1968 using external tocography and phonocardiography, but since then technological advances have allowed further development of more and more accurate tools of monitoring. According to the American College of Obstetricians and Gynecologists (ACOG), electronic fetal heart rate monitoring is increasing in use, e.g. 62% of pregnant women in 1988, 74% in 1992 and 85% in 2002 [3]. [4] presents the use of electronic fetal monitoring in United States in the 1980s helping to increase the live births.

In our modern world there is an increasing interest for using wireless approaches for data transfer. Budinger's work [5] presents some classical approaches in deploying wireless monitoring for measuring body parameters. As it can be seen in [6], the need for a low-cost wireless and mobile fetal monitoring system is increasing, especially for pregnant mothers living in areas with limited access to healthcare. Using a Bluetooth module attached to the Fetal Heart Rate (FHR) monitoring device provides the advantage of using a smart-phone and set alarms to prevent high-risk situations. For monitoring the uterine contractions there are two major approaches [7]. Of these, the external one requires no insertions into the uterus and thus is preferred in our case. A belt is wrapped around the waist and attached to a machine called a tocodynamometer. To monitor the contractions at home, the pregnant women must sit in a restful position and place the band attached to the tocodynamometer around the abdomen. The machine records the contractions and the data is transmitted via a low poser wireless connection to the smart-phone and further using the data connection to a central monitoring server [8]. More and more aspects of the medical monitoring process are taken by automatics embedded systems comprising of dedicated sensors (lab-on-chip) which are delivering data in near real time to some kind of monitoring and analysis infrastructure/server. In regard to this, there are a few approaches of using the underlying messaging infrastructure provided by HL7 in order to carry time series-like data. In [9], authors present a custom XML schema built on top of HL7, version 3.0 and provide an implementation of a simple C# application for exchanging simulated real time data with a HL7 compatible data store. They don't present actual hardware devices exploiting these new possibilities, but avenues of investigation are left open for various communication protocols and standards.

2. System specification and description

During the initial survey at the County Hospital Timisoara of both the medical professionals in the field of Ob-Gyn care and recipients of the care (future mothers) one of the requirements we identified is the fact mothers are keen to be involved into monitoring their babies, but in the same time need assurance against any dangers for their yet to be born child and prefer using small form-factor devices that allow them to perform other activities and in the same time are not difficult to use while being outdoors[10]. Knowing that their babies are in good health and the labor progress as expected, gives them an inner peace and satisfaction that can further affect positively the development of the fetus. Figure 1 describes the general architecture of the solution presented in this paper. The system consists of 3 modules. The first module is the Obstetrics-Gynecology Department Information System where the physician can add different information about the patient [10]. The second module consists of the mobile application based on Android with two main functions: to monitor the pregnant women based on the data received from the sensors and the second to help the pregnant with general information about the pregnancy. The third module is composed by the smart sensors, and gives the possibility to send the data collected from the sensors.

Communication is realized based on cloud computing. The system monitors an important vital sign, the respiration rate, as it provides early detection of respiratory compromise and patient distress. Pulse oximetry provides a non-invasive and comparatively inexpensive method of continuously monitoring the concentration of oxygenated hemoglobin in blood, based on the differential light absorption properties of oxygenated and deoxygenated hemoglobin. This method provides an accurate measure of both heart rate and oxygen saturation and is widely used in accident and emergency (A&E) departments to monitor patients at risk of hypoxia. Clinicians are familiar with the appearance of the wave form (plethysmogram) produced by the pulse oximeter, but only use it to determine if the oximeter is working correctly. Our solution uses the plethysmogram to further determine the respiration rate by using wavelet signal analysis.

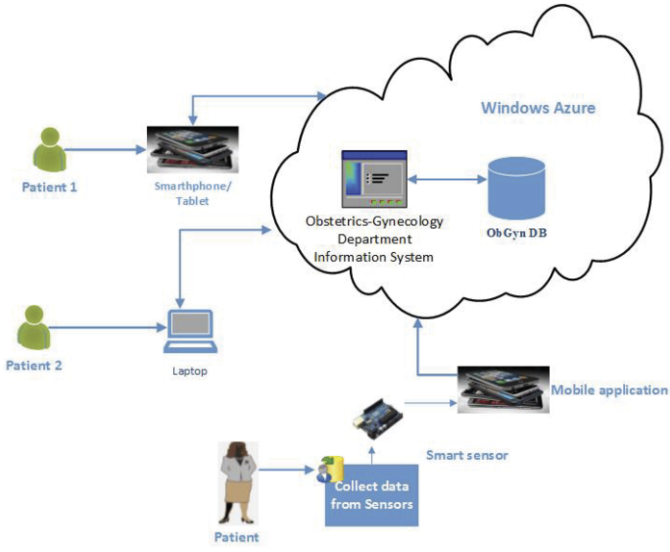

Figure 1. System architecture

The data collected by the sensors is transmitted to the smartphone, and an Arduino based module will support monitoring the data from the sensors. A normal value will be sent to the Smartphone from time to time, and if it is an alarm it will be sent immediately to the Smartphone. The Smartphone will generate an alarm and transmitt it to the ObGyn system. The data will be stored in the Cloud, in our case the Windows Azure cloud. This data can be accessed by the medical staff.

Further on the physician may monitor the data in real time or use the alert triggering facility or the reporting module to get a more general overview of the patient's situation. One of the medical personnel raised issue is that currently this monitoring information isn't kept in an electronic format. It is important for the physician to follow the pregnant woman evolution and status and intervene quickly in risk situations.

Figure 2 presents the process workflow for the whole system based on modeling using Business Model and Notation supported by Bizagy software.

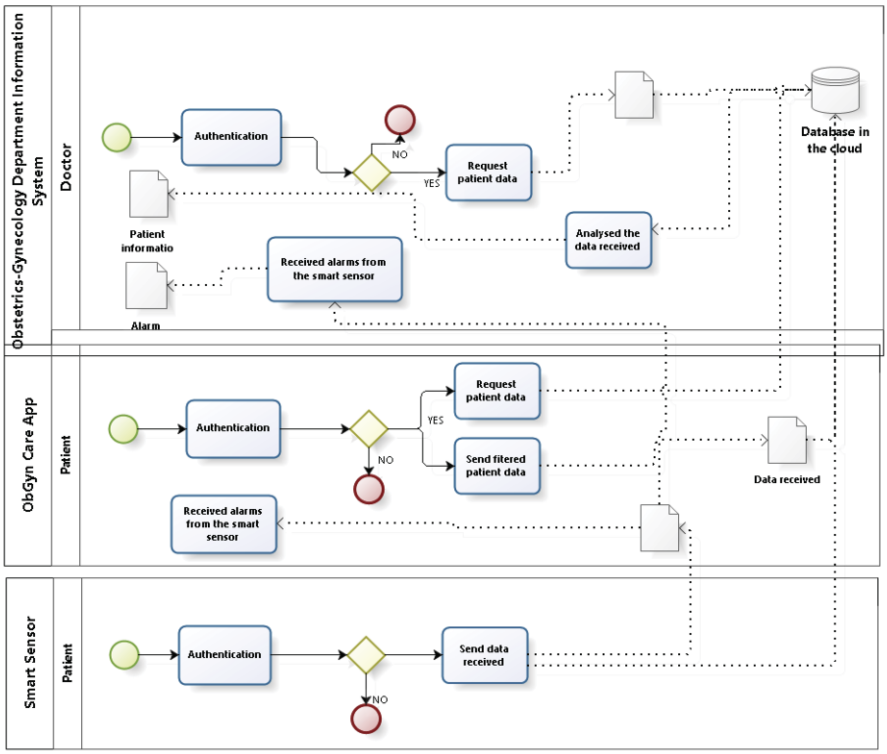

Figure 2. The system workflow

3. System implementation

The Obstetrics-Gynecology Department Information System is an application developed in Visual Studio.NET 2014, using ASP.NET pages and C# language and for

his database is uploaded in Windows Azure cloud, more information regarding this application can be found in [10]. This database is used also by the Android app.

The Android app is developed using Java language in Eclipse and has the possibility to receive data from the Smart sensor component and sent to the cloud and also have the possibility to inform the pregnant women with different information.

The smart sensor uses a Lilypad, which is a microcontroller integrated in materials. All the components are integrated in the materials as wear for the pregnant woman.

Conclusions

This paper presents an opportunity to integrate monitoring systems as well as sending the information into different hospital wards. The network of sensors functions as a wireless cardiotocography device that monitors the fetal heart rate and the uterine contractions but gives the mother mobility and flexibility. This can prevent further complications by receiving alerts on threshold events and informing the doctors in real time about the patient's health. The project is tested on 10 pregnant woman starting November 2014 and the results are monitored by doctors in the Hospital ObGyn application. The advantage of using this system is that the pregnant woman can monitor her baby in real time and also the doctors monitor the pregnant's health status. The system is connecting with already existing systems, is a cheaper and more flexible solution than the one with a classical cardiotocograph, and it integrates and monitors more vital signs. Future research after acceptance test on pregnant women will enhance prevention including a smart alert module.

Acknowledgement

This work was supported by a fellowship of the Romanian Ministry of Education, UEFISCDI, project number 10/01.04.2014.

References

[1] W. H. Organization, World health statistics 2010. *World Health Organization*, 2010.
[2] C. V. Ananth, S. P. Chauhan, H.-Y. Chen, M. E. DŠAlton, and A. M. Vintzileos, Electronic fetal monitoring in the United Sates: temporal trends and adverse perinatal outcomes, *Obstetrics & Gynecology*, vol. 121, no. 5 (2013), 927–933.
[3] L. Coughlin and A. Huntzinger, Practice guidelines briefs*, American Academy of Family Physicians*, vol. 72, no. 3, (2005), 527.
[4] L. Alberts, C.J. Krulewitch, Electronic fetal monitoring in the United States in the 1980s, *Obstetrics&Gynecology 82, (1993), 8 - 10*
[5] T. F. Budinger, Biomonitoring with wireless communications, *Annual Review of Biomedical Engineering*, vol. 5, no. 1 (2003), 383–412.
[6] M. Roham, E. Saldivar, S. Raghavan, M. Zurcher, J. Mack, and M. Mehregany, A mobile wearable wireless fetal heart monitoring system, i*n Medical Information & Communication Technology (ISMICT), 2011 5th International Symposium on. IEEE* (2011), 135–138.
[7] C. Marque and J. Duchene, Human abdominal ehg processing for uterine contraction monitoring." Biotechnology (Reading, Mass.), vol. 11 (1989), 187.
[8] H.-P. Huang and L.-P. Hsu, Development of a wearable biomedical health-care system*, in Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on. IEEE* (2005)1760–1765.
[9] S. Baird, S. Dawson-Haggerty, D. Myung, M. Gaynor, M. Welsh, and S. Moulton, Communicating data from wireless sensor networks using the HL7 v3 standard, *in Wearable and Implantable Body Sensor Networks*, 2006. BSN 2006. International Workshop on. IEEE (2006).
[10] M. Vida, L. Stoicu-Tivadar, O. Lupse, B. Blobel, E. Bernad, Models Supporting Development of Complex Information Systems in Healthcare. Case study: an Obstetrics-Gynecology Department, *EJBI – Volume 9* (2013), Issue 1