Jurnal 35

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Journal of Physics: Conference Series

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To cite this article: Chrismis Novalinda Ginting *et al* 2019 *J. Phys.: Conf. Ser.* **1230** 012037

Fetal heart detection based wide area network technology with wireless sensor transmission

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Abstract. Fetal heart detection technology, especially in remote areas, has so far been manual and lacks facilities for monitoring fetal safety. This results in many pregnant women at risk of labor, so early detection of fetal heart conditions becomes important. Development of fetal heart detector technology based on wide area network technology that is able to provide real-time monitoring results and is connected to the proposed wireless sensor network transmission. Its integration with smartphones makes it easy to use in rural and remote areas. The design of this monitoring system called detector of fetal abnormalities technology has the advantage of sending medical data for pregnant women and fetal heart conditions to families and to health care centers for pregnant women in large cities or obstetricians. Visualization of data in image, graphic and text, can be used as a digital-based maternal and fetal health detector tool. In the initial trial, fetal heart rate data from 4 pregnant subject were evaluated and obtained results with an average curation of 94%.

1. Introduction

Remote areas in most parts of Indonesia are still lacking with equipment that can detect a baby's heart and the condition of a pre-natal pregnant woman which results in many labor processes being at risk. In addition, communication facilities to health centers and hospitals in the city are not yet available, including professional birth attendants. The infant mortality rate in Indonesia is still high from other ASEAN countries, when compared to the target of the Millennium Development Goals, which is 23 per 1000 live births [1]. In accordance with health theory, fetal heart anomalies can be congenital heart disease or congenital heart malformations. The incidence of heart disease anomalies is around 8 per 1,000 births. The congenital heart disease is one of the causes of infant death. Since the late 1970s, ultrasound has begun to describe the fetal heart. Since that time, detection of fetal heart abnormalities began to be actively worked on. The biggest disadvantage of echocardiographic examination in the first trimester of pregnancy is the occurrence of congenital heart disease during intrauterine life [2, 3]. Physiological or biosignal signals are signals produced that are often measured and monitored to

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measure and analyze a person's health. Biosignals that are often measured include electrocephalogram (EEG), electrocardiogram (ECG), electromyogram (EMG), and electrooculography (EOG). These topics have become popular research areas in the field of instrumentation, specifically in the field of medical instrumentation. There are many studies conducted in this field, such as EEG [4-7], ECG [8-11], EOG [12-14], and EMG [14]. Among other electricbiosignals, ECGs are one of the most popular fields in research due to the importance of these signals. The ECG is closely related to cardiovascular diseases.

An electrocardiograph or ECG can be used to monitor biopotential signals caused by the heart [15]. Unfortunately, the electrocardiograph is generally only available in hospitals because the costs are quite expensive. Because the availability is also limited, patients are required to rent this tool, and should consult a doctor regularly. High tariffs, complicated processes, and distances that may be far away make patients reluctant to check the condition of their pregnant if they do not feel significant complaints. Development of portable electrocardiograph technology that is integrated with intelligent communication devices that can be used for cardiac detection and the condition of pretrial pregnant women needed.

By utilizing mobile technology, fetal heart detection based on wireless sensor wide area networks called detector of fetal abnormalities technology (DOFAT) are developed. The DOFAT is able to monitor the health of fetuses and pregnant women based on cheap and effective information and communication technology services for people in remote areas. Using a fetal heart rate monitor can provide a kind of early detection system whether the fetus is experiencing stress or other problems and the effects of its development that might arise. Although it is not definitive or guaranteed, an abnormal heartbeat is generally a strong indicator that something is wrong. With the technology built it does not mean a substitute for a doctor, hospital, or proper prenatal care. The fetal heartbeat that is very fast or very slow is a sure sign that pregnant women should at least visit a doctor to ensure that there is a problem. Reference to the frequency of the fetal heart rate ranges from 12-20 Hz, while the mother ranges from 40-50 Hz. The heartbeat sound that has been filtered is then processed by the ADC on a microcontroller and then sent to the processor for classification. The classification results in the form of abnormal data will be sent to the server to be stored in the form of a database and translated in graphical form.

2. Experiment and Method

In this study an Android-based electrolytic diographic monitoring system was built. This tool is a portable electrocardiogram that is integrated with a smartphone device. This tool works by capturing heart signals through electrodes, then amplifying and filtering, and is processed in the microcontroller to obtain heart rhythm parameters as a sign of heart fatigue. The signal is then sent via Bluetooth communication to an android device. From there you can get a specific heart rate and heart rate zone. From these data, when detected fatigue from the heart rhythm a warning will appear on the user's device application. The Hamilton segmenter is used for the detection of QRS segments and RR intervals for heart rate, in an android application, if the heart rate exceeds 80% of the maximum heart rate a warning will emerge in the hope that users can take a break to avoid the risk of a heart attack. The long-term goal of this tool is to increase the alertness of its users to heart health and reduce the mortality rate caused by heart disease. Figure 1 shows the steps and diagrams of the proposed DOFAT research system for monitoring fetal heart activity in the womb. Data recorded with the sensor is then sent to rassberry pi for processing before being sent to the cloud server via the wireless network. Here are provided two forms of sending messages to the family via an automatic message that is set on rassbarry pi. If the application provided in the monitoring tool has problems, the message can be sent manually directly from the main server sent to the medical party and family.

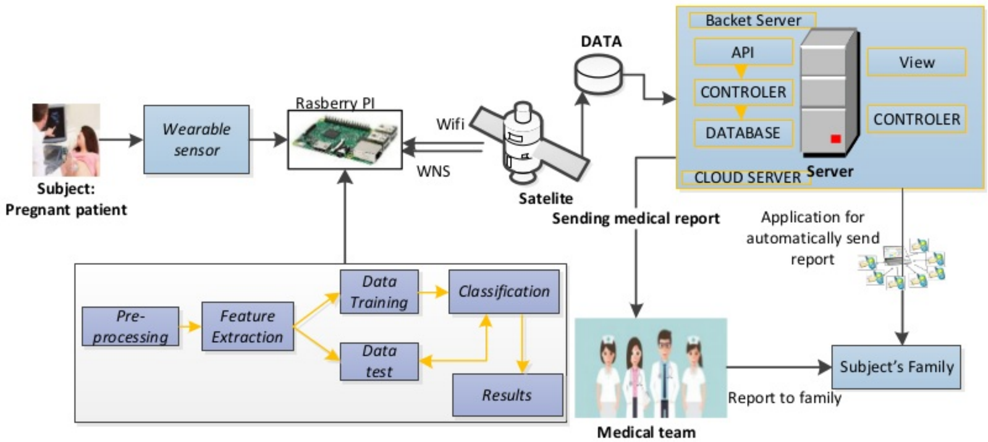

Figure 1. Research Diagram of the DOFAT for monitoring fetal hearth actifities.

2.1. Experiment
To test the performance and accuracy of the developed DOFAT (such as filtering, extraction, QRS detection, and classification), the experiment was carried out with four pregnant subject approximately about 28 ± 7 years old and were healthy both physically and mentally. The gestational age of each subjects are 7 months, 8 months, 28 weeks, and 37 weeks, respectively. In the experiment, each subject was installed with 3 electrodes in a position (depend on the fetal position) as shown in Figure 2 to measure information on their fetal heartbeat in the womb. In its installation, each electrode covered with an electrolyte gel is intended to increase the conductivity of the recording signal. Electronic circuits will strengthen this data and filter it to increase the signal / noise ratio. The ECG data obtained from three Ag / AgCl electrodes are stored and processed before being sent to the monitoring system through a developed wireless ECG system. The information is temporary stored in the memory and the data is then processed and sent via blootooth communication to the anroid smartphone, where the data is analyzed: if any abnormalities are found, the message will be stored in the coud and accessed to the family or doctor. At the end of the experiment, all participants receive IDR 150,000 remuneration for transport fees.

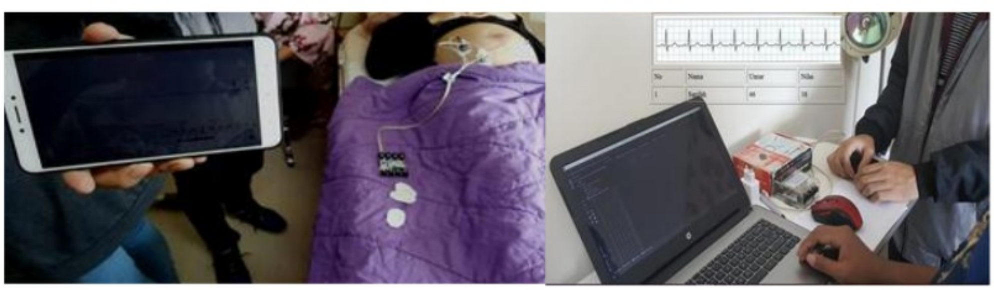

Figure2. Experiment Schema of the fetal heartbeat detection in the womb with wireless ECG connected to Anroid Smartphone.

2.2. Fetal Wave Detections
For monitoring used of the ECG signal information, the required frequency must be correct so as not to lose the actual information signal. The ECG signals have very small amplitude so that they are

susceptible to interference from other signals or noise such as muscle signals, sensor movement and interference from electrical grid voltage. To reduce the noise, a filter circuit is used to get a good ECG signal. Filter is a circuit used to pass signals with the desired frequency and reduce signals outside the frequency limit of the ECG signal. Reference to the frequency of the fetal heart rate ranges from 12-20 Hz, while the mother ranges from 40-50 Hz. In the feature extraction programming stage, the ECG recording signals are first filtered using a band pass filter (BPF) consisting of a low-pass filter and a high-pass high-pass filter. This aims to minimize the effect of muscle movement, baseline wander, P- and T-wave interference, and other disorders with high frequency. The cut-off frequencies are evaluated for three ranges (based on the fetal heart rate ranges) which 8 Hz and 24 Hz; 10 Hz and 22 Hz; and 3 Hz and 25 Hz.

As per the conditions for determining one wave, the peak point is P, Q, R, S and T. Every wave one wave graph starts to appear slightly increased because the sensor heart rate receives a heartbeat signal. PQ interval is a signal slowdown. This slowdown gives the atrium time to empty the blood inside it into the ventricles. This signal to the Q point through the atrium causes the two atiums to contract and push blood to the ventricles below. The R wave is the peak of the heartbeat contracting and pumping blood to the lungs. After the heart rate contracts, there is an interval to the next heart rate to point S. The peak point T is the process when the ventricles undergo repolarization. Point R shows a high graph, due to the moment of emotion of the heart's speed to pump blood to the lungs and the whole body very quickly compared to the R point when the condition relaxes.

3. Results and Discussions

The ECG has been made to display the PQRST heart complex signal on the laptop display for the installation of three different leads. Calculation of P, Q, S, T waves cannot be done maximally because the signal is too small and mixes with noise as shown in Figure 3. The ECG signal on the final display is not clear of noise so that the PQRST wave is not clearly visible. The next study can be used Fast Fourier Transform to find out the frequency value that causes noise. This step is the basis for designing filters to obtain a low noise ECG. Developed software that can work in real time that can display heart conditions. From Figure 4, it is clear that the PQRST wave has not been detected perfectly but R-peak detection can be obtained with an average accuracy of around 94%. Figure 5 show the web interfacing design when the user would like to show the abonormal classified ECG signals.

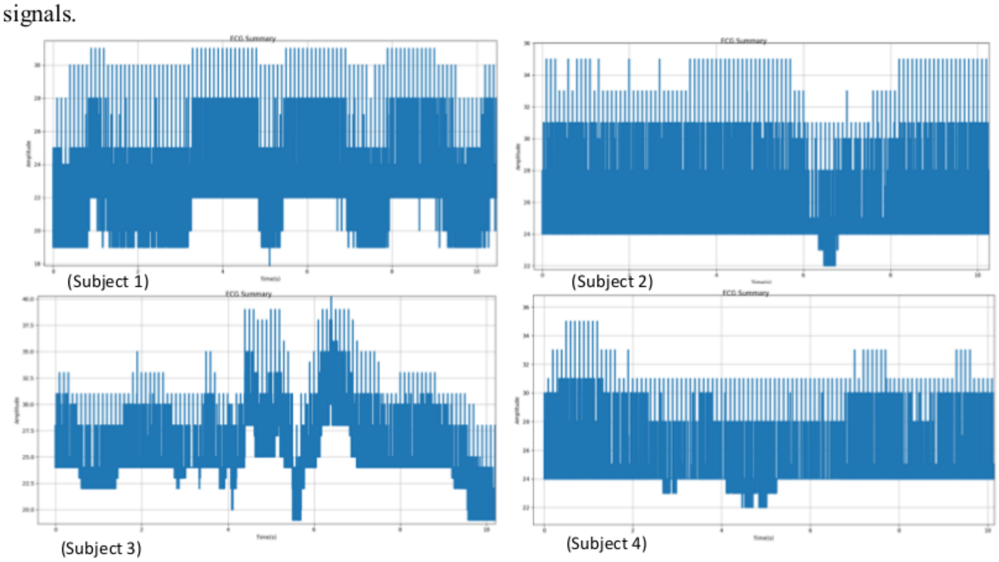

Figure 3. The filtered ECG signals of each subject.

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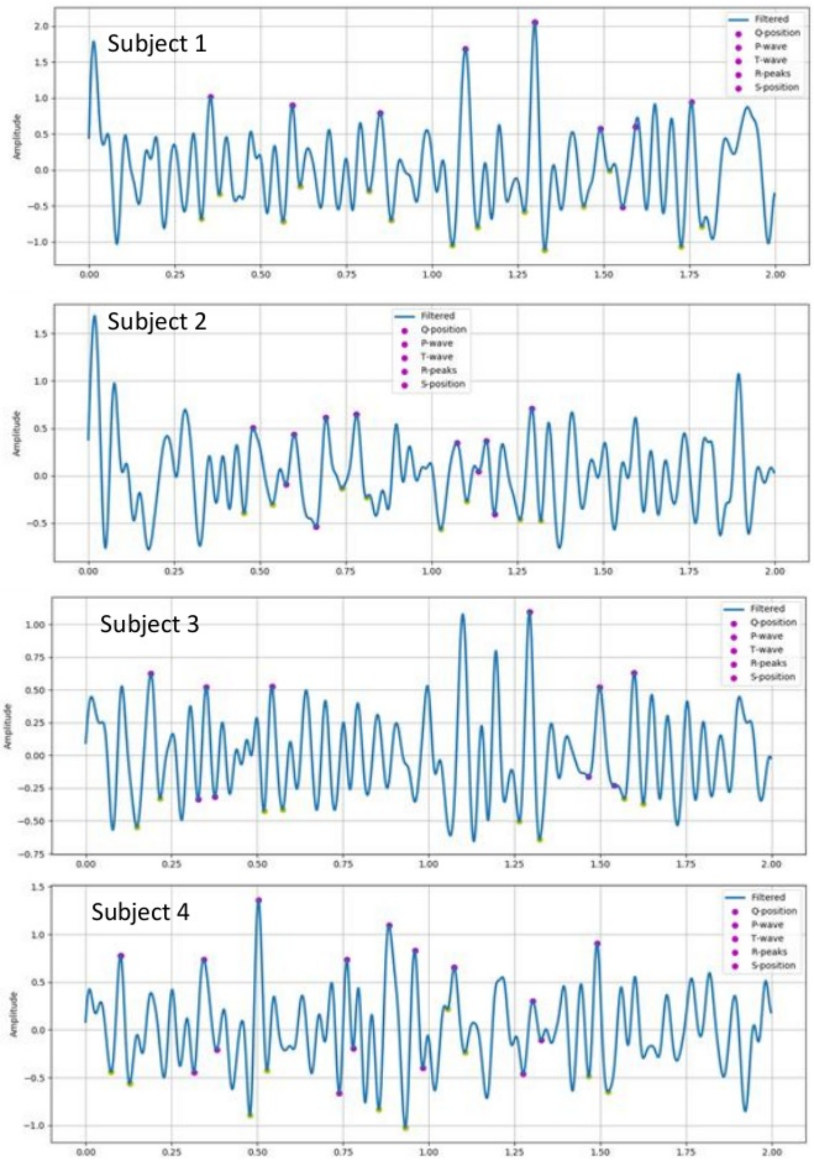

Figure 4. P, Q, R, S, T wave detection of each subject.

Noises and artifacts play a vital role in the processing of ECG signal. They make the physicians difficult to diagnose the diseases if the artifacts are present in the ECG signal. In this work, the noises often corrupted the ECG signal are modeled and simulated. Then, design and implementation of digital filters for each type of noise are considered and applied. Finally ECG signal contaminated by the composited noise passed through the band-pass filters because of the combination of different frequency contents. The performance of filters for removing the composite noise is enough for basic signal analysis, the critical R-peak is distinct enough for further

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processing. Tabel 1 shows the accuracy of the developed tecnology from the doppler echocardiography for different cut off frequency range of the bandpass filter. The higher average accuracy is obtained when the cut off frequency about 3 to 25 Hz. According to the reference that the fetal heart rate ranges from 12-20 Hz, the selection of the frequency range for filter design is very important. The nerro of frequency range, the higher of the removig noise but the higher of the losing desired informations. To improve the quality of extraction, a filter combination design is needed so that the filter trade off can be overcome. By reducing the frequency range, it will ensure that the fetal mother's heart rate can be removed.

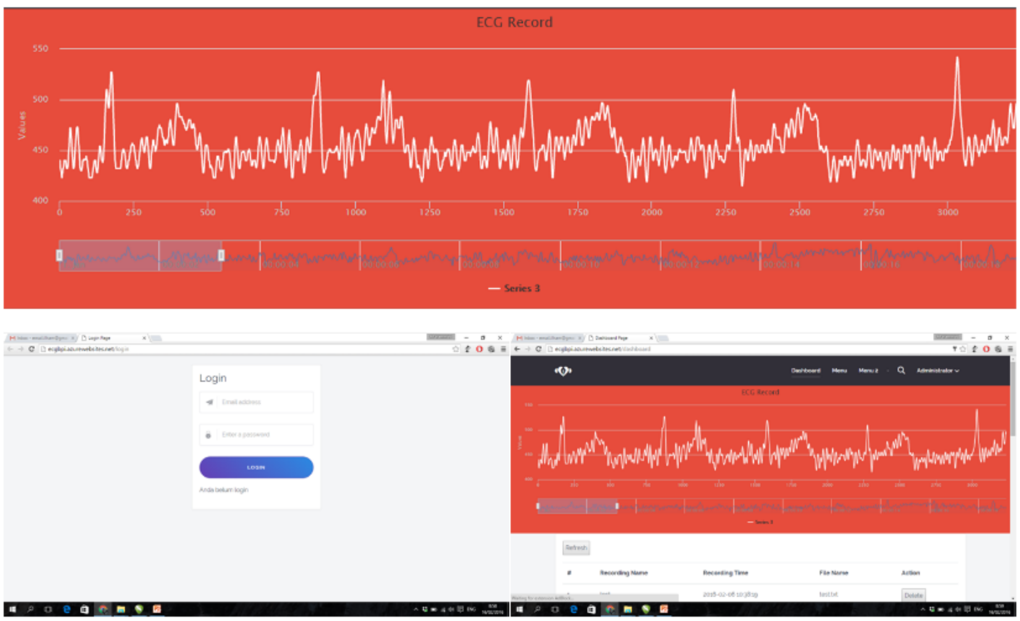

Figure 5. The ECG cloud interfacing.

Table 1. Accuracy of the R-peak detection using the developed DOFAT from the doppler echocardiography

Subject	Doppler Echocardiography	DOFAT					
		3-25 Hz		8-24 Hz		10-22 Hz	
	BPM	BPM	Accuracy	BPM	Accuracy	BPM	Accuracy
S1	150	156	96	148	98.7	149	99.3
S2	141	144	98	121	85.8	120	85.1
S3	160	146	91.2	145	90.6	145	90.6
S4	153	144	94	148	96.7	141	92.2
	Average		94.8		92.95		91.81

4. Conclusions

The cutoff frequencies for all filters are changed to [3 30] Hz. In this time, the filters could better attenuate almost all noises, but the signal was distorted. But, the critical information, such as R-peak is not lost. The performance of filters for removing the composite noise is enough for basic signal analysis, the critical R-peak is distinct enough for further processing. The PQRST wave has not been detected perfectly but R-peak detection can be obtained with an average accuracy of around 94%.

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