Android Based Tocodynamometer and Fetal Heart Rate Monitor

Whitney Aaronson, Dale Best, Arnob Mallick, Sara Saheb Kashaf, Matt Sarett, Eric Wise

42-402 Biomedical Engineering Design

Introduction

A tocodynamometer is a medical device used to measure the frequency and duration of uterine contractions [1]. A fetal heart rate monitor is a medical device used to monitor the heart rate of the fetus [2]. Both are used in hospitals to monitor the condition of a woman's pregnancy.

Both tocodynamometers and the fetal heart rate monitors suffer from usability issues. The devices are bulky (~1' x 1' x 0.5'), expensive (~$10,000), and difficult to use, meaning that they are confined to specialized hospitals [3]. Many low resource hospitals do not have tocos, and, in general, the toco device is not portable or convenient.

Our solution is an Android application and small embedded system that will take the place of both of these devices. It is a low cost, portable, easy to use alternative to typical tocos and fetal heart rate monitors. We believe that it will fill a need for low resource hospitals and provide an opportunity for in-home care [4].

Patient Portal

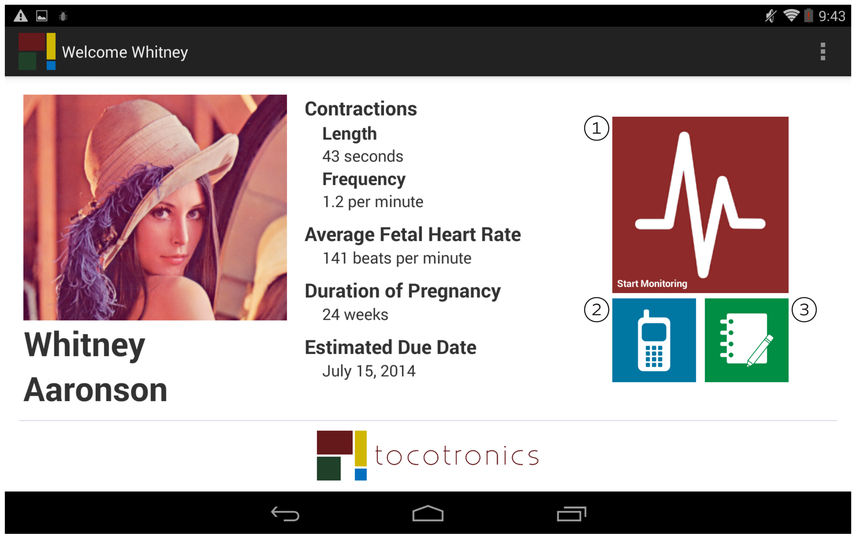

FIGURE 1. APPLICATION SCREENSHOT OF HOME PAGE ALSO CALLED "PATIENT PORTAL"

① Start Monitoring: Allows the patient to monitor her uterine contractions and her fetus' fetal heart rate graphically while viewing useful metrics.
② Contact Doctor: Allows the patient to send an email to her doctor with an editable, prescripted message.
③ Schedule Appointment: Allows the patient to make an appointment with her physician.

Our Solution

APPLICATION ARCHITECTURE

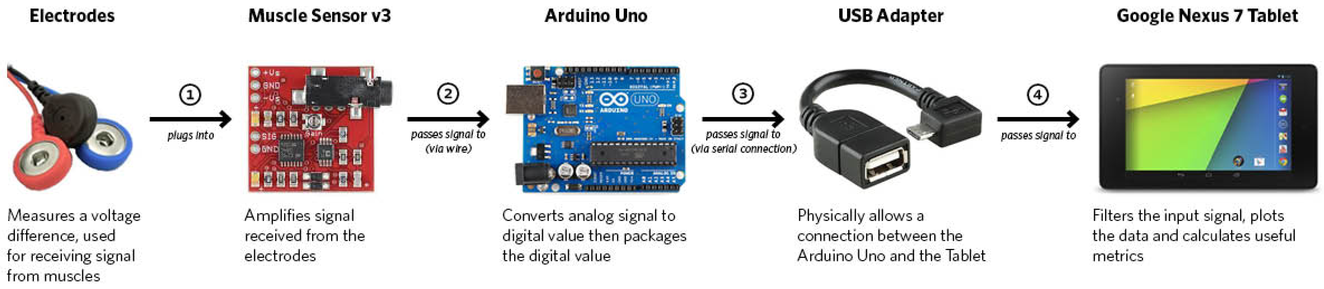

FIGURE 2. APPLICATION ARCHITECTURE FOR TOCOTRONICS TOCODYNAMOMETER AND FETAL HEART RATE MONITOR

① Electrodes plug directly into the Muscle Sensor v3.
② The Muscle Sensor v3 takes in an analog value (voltage), amplifies it, and passes it (via a wire) to the Arduino Uno.
③ The Arduino Uno converts the analog signal to a digital value, packages it, and sends it over a serial connection to the Google Nexus 7 tablet via a USB Adapter.
④ The Tocotronics Android application filters the input signals (ECG and EMG), plots the data, and calculates useful metrics.

SIGNAL FILTERING

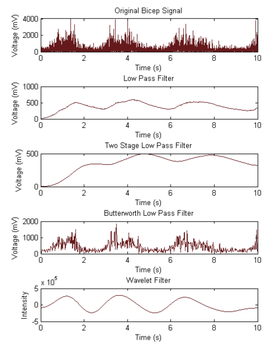

FIGURE 3. DEMONSTRATION OF DIFFERENT FILTERS APPLIED TO EMG DATA

Demonstration of Different Filters Applied to EMG Data *(Figure 3)*. In choosing the most appropriate filter for uterine contractions, sample data was collected from the bicep *(Figure 3)*, quadricep, and abdominal muscles, all at 960 Hz. Because the uterus is a muscle, we expect that the data from uterine contractions would closely mimic this sample data. *Figure 3* shows the results of applying these various filters to EMG data. The wavelet filter creates a strong representation of the input signal and was our initial choice to interpret EMG data. However, the wavelet filter does not perform well on dynamic data, so we have chosen to use a closely calibrated low pass filter.

Demonstration of Adaptive Noise Cancelling Filter on the Fetal ECG Signal *(Figure 4)*. The fetal heart signal is distinct from the maternal signal in two ways: the amplitude of the wave is smaller and the frequency of the heart beats is faster. In extracting the fetal signal from the combined signal, we chose an adaptive filtering technique called adaptive noise cancelling. In this approach, the filter utilizes a primary input (the combined signal), and a reference input (the maternal signal). The filter tries to match the primary and reference inputs, while storing any discrepancies as an error signal. In this application, the error that is being removed from the primary input is actually the signal of interest; it represents the fetal heart rate.

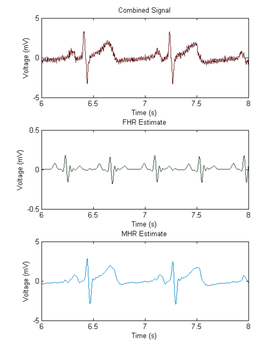

FIGURE 4. DEMONSTRATION OF ADAPTIVE NOISE CANCELLING FILTER ON THE FETAL ECG SIGNAL

APPLICATION IN ACTION

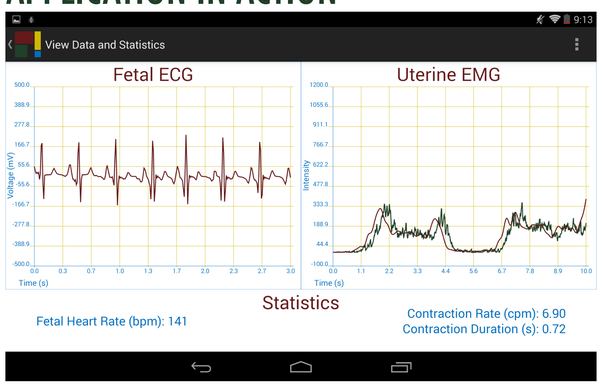

FIGURE 5. APPLICATION SCREENSHOT OF MONITORING PAGE

Figure 5 shows the monitoring page of the application.

The graph on the left shows a visual representation of the fetal heart signal.

The graph on the right shows the uterine muscle signal.

Below the plots, the fetal heart rate, contraction frequency, and contraction duration are calculated and displayed.

BIOMEDICAL ENGINEERING

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References

[1] "Children's Hospital of Wisconsin." Fetal Monitoring. 7 Dec 2013. <http://www.chw.org/display/PPF/DocID/23192/router.asp>.

[2] "Fetal Monitoring: External & Internal Monitoring." Healthlines RSS News. 7 Dec 2013. <http://www.healthline.com/health pregnancy/external-internal-fetal-monitoring>.

[3] "Fetal Heart Monitoring During Labor." ACOG. 22 Nov 2013. <http://www.acog.org/-/media/For%20Patients/faq015.pdf?dmc=1&ts=20131120T0420345865>.

[4] "Pregnancy Complications." Centers for Disease Control and Prevention. Centers for Disease Control and Prevention, 5 Feb 2013. 22 Nov 2013. <http://www.cdc.gov/reproductivehealth/maternalinfanthealth/pregcomplications.htm>.

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