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Fetal Kicking Monitoring Device for Intrauterine Death Prevention

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Abstract

Background: The fetal health is possible to fluctuate and deteriorate and lead to unexpected loss of the pregnancy. Time is crucial for heart life and any decrease in oxygen to the heart muscle is crucial and means death. Therefore, it is substantial to do an obstetric tracing, in order to spot the sudden changes in the fetus health. **Problem Statement:** Away from all the methods that could measure heart health, fetus movements monitoring is one way to identify the fetal wellbeing. One very popular movement that is used to gauge fetal health is a fetal kick, in which a frequency of perceived and/or registered fetal kicks by a healthy fetus is higher as compared to the frequency of perceived and/or registered fetal kicks a by an unhealthy fetus. However, the conventional methods such as ultrasound and manual measurement endure some errors. **Objective:** The aim of this study is to develop a portable belt that can be used to measure the fetal movement accurately by setting the appropriate threshold. **Methods:** A total of 9 Force Sensitive Resistors (FSR) were used to detect a simulated force exerted by fetus on the abdomen of pregnant women in order to count the fetal movements. **Finding:** Based on the overall result the sensor detects 90% of the kicks given. **Conclusion:** We believe that this device could help the pregnant women to measure the fetal movement with less attention and can reduce the error.

Keywords: Fetal Health and Technology, Kicks, Monitoring, Sensor

1. Introduction

Monitoring fetal movements is not just about counting the kicks. It's about getting to know the typical pattern of the fetal movements so the awareness of any changes can be monitored as quickly as possible if something's not right. It is very important to identify prompt changes in the fetus health by *"monitoring the fetus movements and the Fetal Heart Rate (FHR)"*[1]. Fetal movement counting is one of the methods to assess the condition of the baby and to obtain an obstetric tracing. Detecting the risk of fetal heart hypoxia early could lead to alerting practitioners for fast response and baby lifesaving. Evidence shows that clinicians consider fetal movement counting a good method as it allows the clinician to make appropriate interventions in good time[2]. There are two main categories of kick counting method exists either using fixed time or fixed number approach[3].

Technology is promising a lot in diagnosis: Ultrasound imaging was used to determine type, volume of the movement, FHR and the uterus contractions in the clinical setting. Sensors are devices that detect measure and

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records different types of signals such as ‘physical, chemical, and biological signals’. Several fetal behavioral and physiologic characteristics can be assessed by using ultrasound. However availability of this medical procedure is limited, due to a high cost of equipment and requirement of medical staff to carry out the test for a quite long time. Some other studies reported ‘false positives’ as the movements which detected by the woman and not by the ultrasound[4,5]. It is possible some of these ‘false-positive’ movements are actual movements that have occurred outside the ultrasound beam. Besides, some concern amongst clinicians about the safety of the fetus under prolonged exposure to ultrasound radiation[6]. Signal processing techniques has been praised by many such as in[7], were he show the ability of signal process for ultrasonic system to extract the desired information from the received signal when a sample medium is being questioned. Whether it is for material characterization or sensor accuracy, prediction and reliability, signal processing is a requirement.

Prediction of fetal at risk was sought by fetal echo too to identify and trace maternal medical disorders (cardiac defects)[8,9]. Therefore changes in the pattern of movement could be related very well indication for poor oxygen supply. Sridevi et al., 2015 in their work describes the sequential application of several techniques such as motion estimation, speckle suppression, image enhancement, image alignment and edge detection to delineate the edge structures of the fetal heart from clinical ultrasound images[10].

Technology of sensing has been applied to many prospect for pathophysiological identification such as kidney detection[11], heart detection[10] detecting distances[12]. Ultrasonic sensor investigated and proved it is a viable concept[10]. Based on Sathishkumar et al., 2011, the development of MEMS (microelectromechanical system) transducer is investigated and proved it is a viable concept[13].

A microsize ultrasonic transducer for marine applications, piezoelectric, pressure and capacitive transducer is presented. In addition there is limitation in the transducer due to the large acoustic impedance mismatch between the ceramic and a fluid such as water or air according to. In spite of that, MEMS are cost advantageous due to their mass fabrication techniques[14]which is expected to offer many advantages over conventional transducers. In this work, we investigate pMUTs through novel design and fabrication methods. A finite element (FE. Meanwhile Kumaran and Rani, 2014 placing the un focused ultrasonic transducer at the top of hollow cylinder, kept in the water bath[8]. Two hollow cylinder, 3mm and 5mm have been used. As proposed by Mitra and Ravi, 2015, they create a centralized monitoring environment one can able to integrate all the headend devices where the operator can identify and rectify errors based on their priority that occured through network[15]. Technology of Force Sensing (FSRs) has been evolving. FSRs are sensors that allow us to detect physical pressure, squeezing and weight. Force-sensing resistors consist and react to the application of force to its surface. When there is no pressure, the sensor looks like an infinite resistor (open circuit), as the pressure increases, the resistance goes down. In Vichy et al., 2000, performance of Flexi force sensor shows a better performance in term of dynamic accuracy than the FSR sensors. However it shows limited robustness due to detachment of the two layers of the sensorsr[16]the models and estimation methods for continuous (i.e., interval or ratio scale.

Maternal perception of fetal movement is an inexpensive and non-invasive method of assessing fetal well-being at home[17], counting the fetus movements (the pregnant feels 80% of the movements), which should be registered in a form for posterior analysis of the medic.

Winje B. A., et al., 2012, reported that maternal perception of fetal movement’s plateau around 28 weeks and then reduce slightly at term and mostly the fetal movement occurs in the evening[18]. However, maternal perception of fetal movement counts may vary statistically due to subjective thresholds. Besides, the short duration or weak movements tend not to be recorded by the mother[19]. Furthermore, kick counting based on mother’s perception is difficult to accomplish due to anxiety and concentration of mother, thus, lead to error in counting.

To address these limitations, this paper proposed a sensor based device that could be used to examine the fetal health and well-being for pregnant women. The aim of this research was to develop a portable belt that could be used to measure the fetal movement accurately by setting the appropriate threshold. Besides, this device is safe for prolong use since there is no ultrasound radiation. The coming sections explain in details about the development of the device and testing.

2. System Overview

A total of 9 Force Sensitive Resistors (FSR) were used to detect force exerted by fetus on the abdomen of pregnant women in order to count the fetal movements. The sensors were placed on the 9 different regions of abdomen which are Right Hypochondriac (RH), Right Lumber (RL), Right Iliac (RI), Epigastria (E), Umbilical (U), Hypo Gastric (HG), Left Iliac (LI), Left Lumber (LL) and Left Hypochondriac (LH) regions. Figure 1 (a) shows the overall system overview and Figure 1 (b) shows the sensor placement in the abdominal regions and Figure 1 (c) shows the prototype of the sensor based belt. The sensors are connected to microprocessor to receive and convert the analogue data from FSR to digital signals. Liquid crystal display (LCD) 16x2 was used for display the data received from Arduino Mega 2560.

3. Sensor Calibration

Calibration was done in order to find the relationship between the values of the output voltage with the value of the force applied. A Mass from 40 gram to 300 gram with increasing of 40 gram was placed on top of the sensor and the output voltage was recorded. The calibration process was repeated 3 times and the results were analyzed using Mat lab. Figure 2 shows the graph of voltage against force for the calibration process. Equation (1) shows the respective model equation from the calibration process.

$$Voltage = 0.7403 \times Force + 0.0137 \quad (1)$$

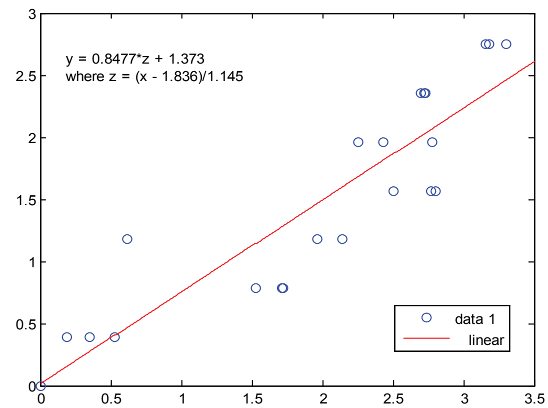

Figure 2. Graph of voltage against the force for calibration process.

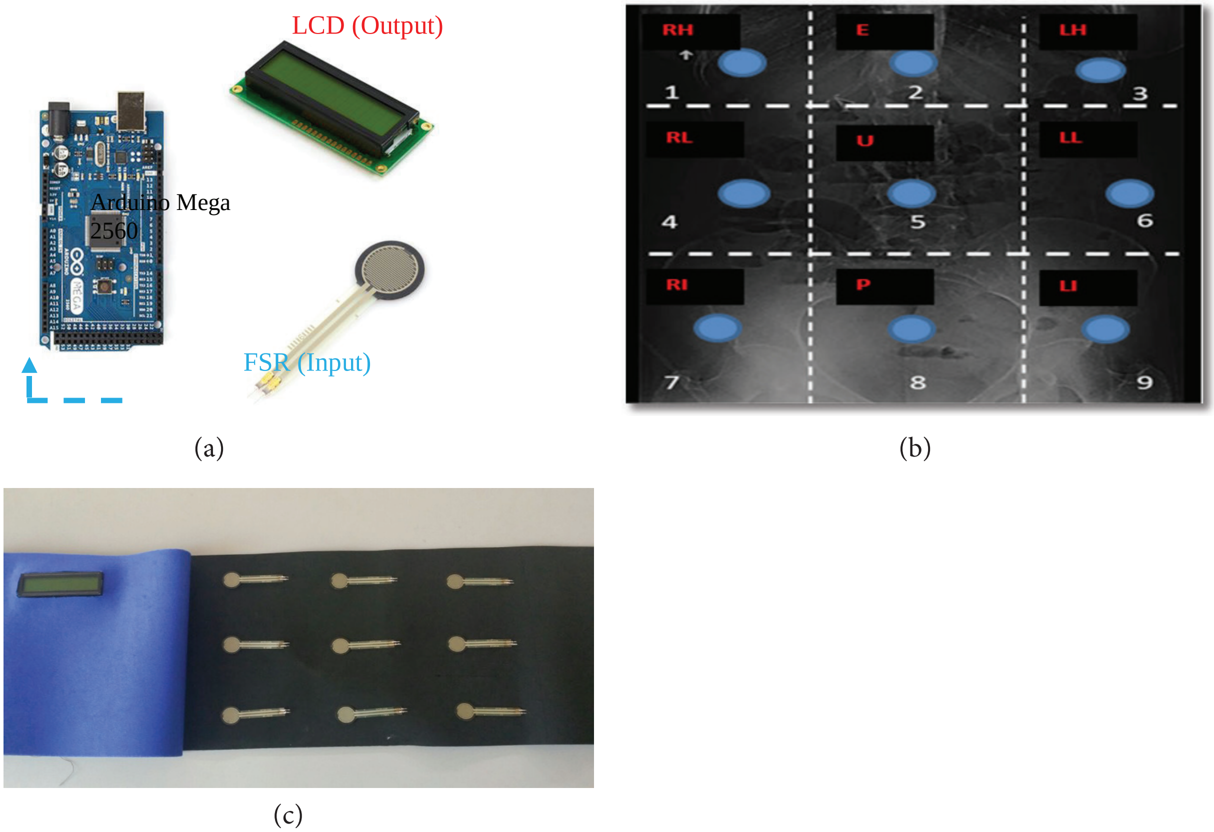

Figure 1. (a) System overview and (b) Sensor placement in the abdominal regions and (c) sensor based belt prototype.

Where,

$$Force = ma$$

$$a = 9.81m^2$$

The variable m is weight in unit of kilogram and 'a' is the acceleration due to gravity. However, this system need to measure the fetal movement by using the FSR sensor, therefore, this system require an equation of Force in term of voltage. Equation (2) shows the respective equation model.

$$Force = 1.3508 \times Voltage + 0.0185 \qquad (2)$$

4. Performance

We have observed the function of 9 FSR sensors with a fetal simulator. Figure 3 shows the fetal simulator been designed for testing purpose. The objective was to evaluate the performance of this device. Figure 4 shows the display on LCD of the kicking from the fetal simulator. The kicking will be counted as a kick when the force applied increase to bigger than the threshold value until the force applied decrease to less than the threshold value. The threshold was at 0.70N. This algorithm applied to each sensor where each sensor works independently. Hence, this system can measure a total of 9 movements at a time from the 9 sensors.

The experiment was repeated fourteen times with each time specified number of kicks given. Firstly four kicks were given to check how many kicks sensor detects, and after that it was increased by two kicks. The expected outcome from the device is to get equivalent number of kicks as given. Based on overall result the sensor detects 90% of the kicks given. Figure 5 shows the number of detected kick using the fetal simulator.

After the initial test, the belts need to be tested in a clinical setting (pregnant woman), in order to detect its sensitivity and specificity and to determine the suitable threshold wither individually or in total.

5. Conclusion

This paper presents the development of the sensor based belt, which aim at baby kicking counting. It detects the fetal movement based on the force applied on the top surface of the sensors. Besides, this device shows the location

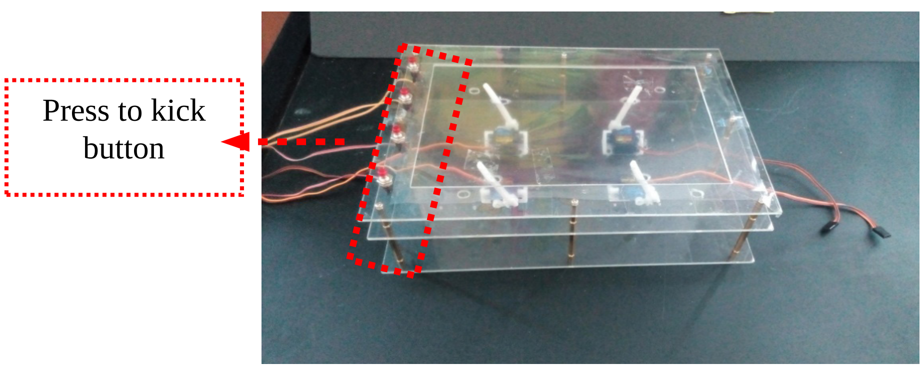

Figure 3. Fetal simulator.

Figure 4. The output displays on the LCD.

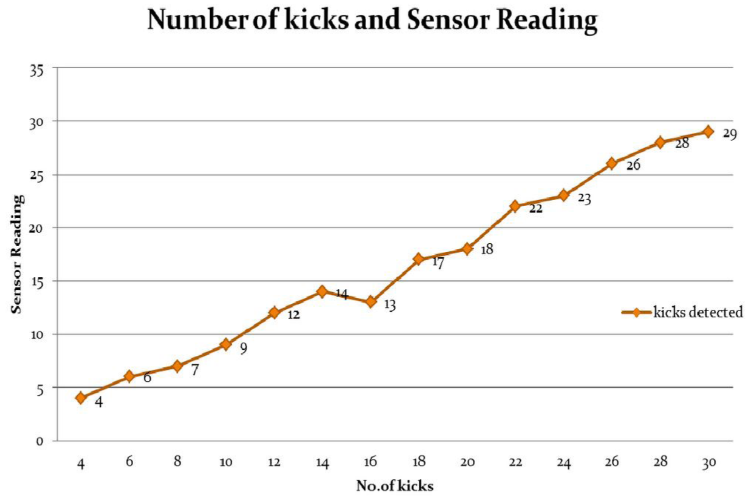

Figure 5. The number of detected kick using the fetal simulator.

of the detected kick. Further study needs to be conducted in order to determine the suitable threshold and accuracy of the fetal movement's detection.

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