Fetal Movement Detection Based on MEMS Accelerometer

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ABSTRACT

Fetal movement is a significant indication of fetal well-being. The monitoring of fetal movement is an important measure taken against the fetal death. Standard clinical fetal monitoring technologies include ultrasound imaging and cardiotocography. Both have limited prognostic value and require many health resources. We have recently developed a low-cost, passive, non-invasive and portable system based on tri-axial MEMS accelerometer to monitor fetal activity, and therefore fetal health. Using this system, we aim at developing signal processing methods to automatically detect and quantitatively characterize fetal movements. This work is a preliminary study to test the performance of the accelerometer in detecting fetal movement and our test results indicate the suitability and the efficacy of using MEMS accelerometer to detect the fetal movement.

Keywords: fetal movement, MEMS accelerometer, signal acquisiting and processing, wavelet transform

1 INTRODUCTION

The monitoring technology during the 28 weeks after the woman was pregnant is of great significance to the safety of the mother and the fetus. The monitoring of fetal movement (FM) is an important measure taken against the fetal death. Monitoring of the fetus during pregnancy is one of the most important and challenging problems in modern obstetris and it is widely accepted that fetal conditions during pregnancy significantly affect outcomes after birth [1].

Mothers can feel fetal movements. Absence of maternal perception of fetal movements is one symptom of fetal death, and a reduction in fetal movement is an alarming sign of fetal compromise[2]. Maternal perception, however, does not appear to be a sufficient surveillance tool. The average sensitivity of maternal perception of gross movements is only 30%. In addition, pregnant women are likely to detect long term movements while missing the short term movements [3].

Currently, there are two general methods for measuring FM: passive and active. Passive methods, such as accelerometry, phonography and tocodynamometry, measure the fetal vibration incident on the maternal abdomen [1], [3-5]. Active methods, such as ultrasond, use the echoes from high frequency sound waves directred at the fetus to generate a signal displayed as a sequence of images [6]. Ultrasound techniques are accurate in identifying FM but there are a number of objections to their routine use in long-term fetal monitoring. Ultrasonic techniques are expensive and require a skilled operator to periodically reposition the transducer at the fetus to identify movements. There is, however, some concern amongst clinicians as to the safety of the fetus under prolonged exposure to ultrasound radiation [7]. Passive techniques of fetal monitoring, such as accelerometry, lack the imaging capability and therefore the ability to locate anatomical structure compared to ultrasound; but are safe, inexpensive, and simple to implement. Recent advances in solid state technology have allowed the production of new accelerometers that are small, low powered, sensitive, and robust; thus making them ideal for long-term monitoring [1].

We have recently developed a low-cost, passive, non-invasive and portable system based on tri-axis MEMS acceleromete, placed on the maternal abdomen, to monitor FM. The first stage in developing a system capable of diagnosis and prognosis of clinical outcome is to construct a method to automatically detect FM from the recorded accelerometer signal. In section 2, the data acquisition system is descrbed. Then, the detailed processing methods of the acceleration information of fetal movement are presented in section 3. The test results are given and discussed in section 4. At last, we draw some conclusions and outline directions for future work.

2 DATA ACQUISITION SYSTEM

The block diagram of the MEMS accelerometer-based FM monitor system is shown in figure 1, in which the tri-axial MEMS accelerometer is designed and developed by ourselves in our group. The National Instruments (NI) USB6211 data acquistion module is chosen as the data acquistion tools and the data reading is achieved through LabVIEW software program in the laptop computer.

2.1 Tri-axial MEMS accelerometer

Three single axial capacitive MEMS sensors With orthogonal direction installed constitute the tri-axial MEMS accelerometer, in which the force-rebalanced is used to implement the closed-loop system.

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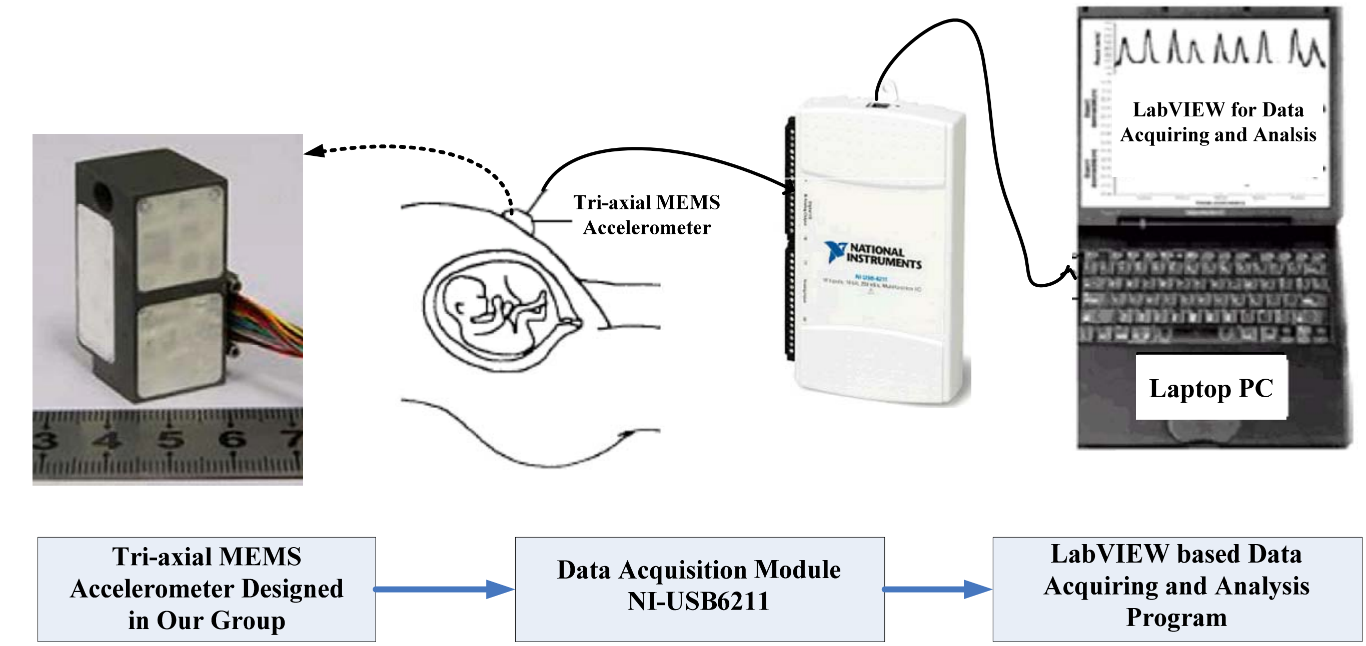

Figure 1: Block diagram of the MEMS accelerometer-based fetal movement monitor

The main perfomance of the tri-axial MEMS accelerometer is listed in table 1.

Item	Value
Full scale	±30g
Resolution	0.1mg
Scale factor	130mV/g
Bandwith	400Hz
Bias stability	0.2mg @1hour

Table 1: the main perfomance of the tri-axial MEMS accelerometer

2.2 Data Acquisition module

The National Instruments USB-6211 is a bus-powered USB M Series multifunction data acquisition (DAQ) module optimized for superior accuracy at fast sampling rates. It offers 16 analog inputs; 250 kS/s single-channel sampling rate; two analog outputs; four digital input lines; four digital output lines; four programmable input ranges (±0.2 to ±10 V) per channel; digital triggering; and two counter/timers. The NI USB-6211 is designed specifically for mobile or space-constrained applications. Plug-and-play installation minimizes configuration and setup time, while direct screw-terminal connectivity keeps costs down and simplifies signal connections. This product does not require external power.

When the USB6211 is used to implement the data acquisiton, three channels are connected to the X, Y, Z axial MEMS accelerometr output, respectively. The sampling rate for each channel is 100Hz/s. A special channels is connected to the switch signal controlled by the pregant woman, through which the mother's perpception is recorded.

2.3 LabVIEW software program

LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) is a system design platform and development environment for a visual programming language from National Instruments.

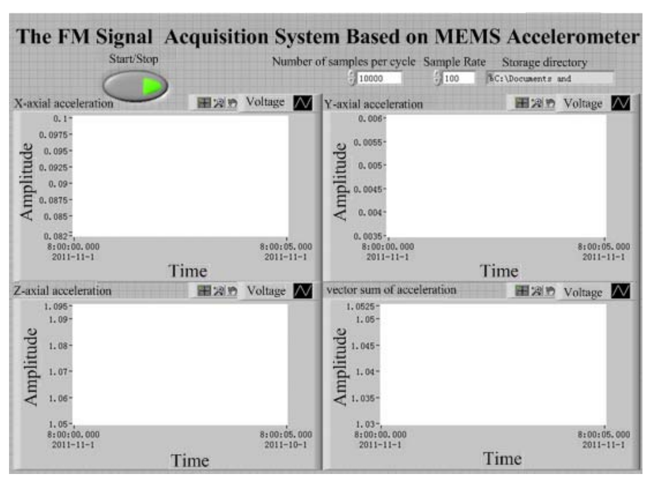

Figure 2: Front-panel of the FM signal acquisition system

Based on the virtual instrument (VI) LabVIEW, the FM signal data acquisition and analysis software is independently designed and the front-panel of the FM signal acquisition system is shown in figure 2.

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3 SIGNAL PROCESSING STEPS

The original data measured by the tri-axial MEMS accelerometer is very complex and need relevant signal processing through the following steps:

1.) Transform of coefficients and calibration of the original data. The acceleration for X, Y, Z axial can be calculated by taking off the the zero bias from the accelerometer output before being divided by the scale fator, respectively. Taking off the booting time of the accelerometer, the tri-axial accelerometer vector sum output is shown in the figure 3.

2.) Elimination of tendency item. The baseline will drift with time because of the bias drift of accelerometer due to the change of temperature and other factors in the test [8]. Using Matlab, the tendency item can be eliminiated by the polynomial least -squares fitting method.

3.) Low -pass filtering. The FM sigal is low-frequence, weak physiological signa, whose frequence is between 0.1Hz and 10Hz. Furthermore, the power-line interference and other high frequence noise may be collected during the test, so it is important to filte the noise by designing low-pass filter.

4.) Wavelet-based denoising. The wavelet transform has emerged over recent years as a powerful time–frequency analysis and signal coding tool favoured for the interrogation of complex nonstationary signals. So it can effectively extract information from the signal and carry outmultiscaled detailed analysis through dilation and shift operations, then removing the signal componets corresponding noise, to get the effective signal by taking inverse wavelet transform.

5.) Sigal smoothing. The smoothing of data will enhence the smoothness of curve and eliminate rregular tendency item.

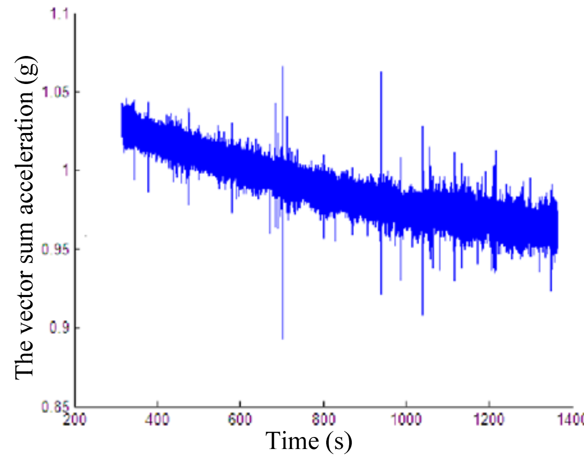

Figure 3: The original output of the tri-axial accelerometer vector sum

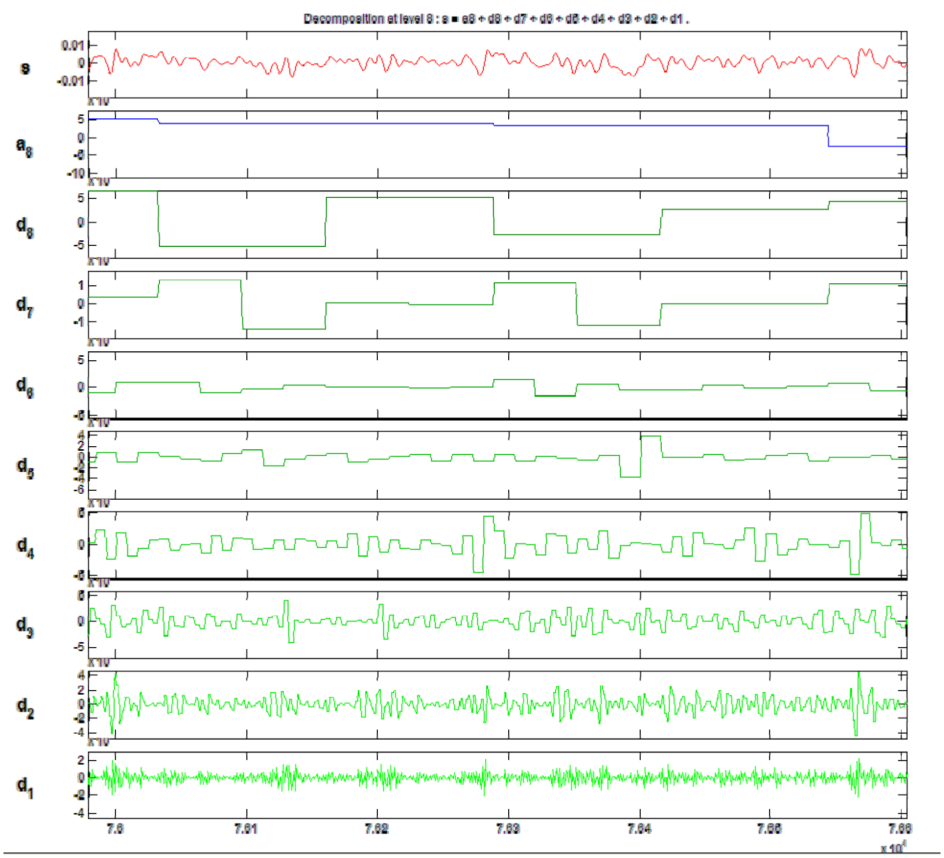

Figure 4: The details of the signal decomposed by the wavelet transform

4 TEST AND RESULTS

The tri-axial MEMS accelerometer based FM detection system was tested in the hospital with several 28~35 weeks pregnant women and the data was collected through the data acquisiton module introduced in section 2.

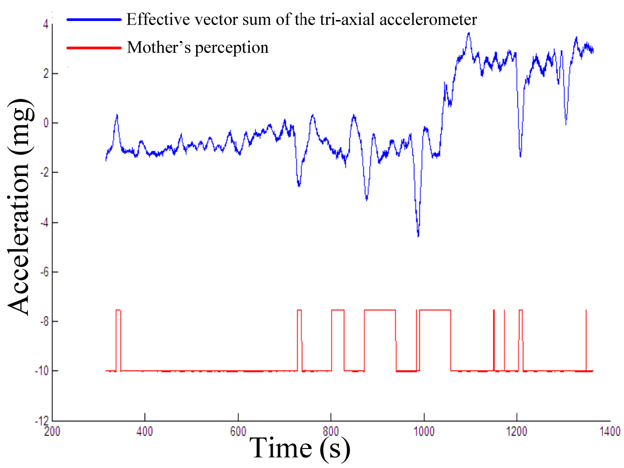

Figure 5: Effectve vector sum of the tri-axial accelerometer versus mother's perception

Taking the 28 weeks pregnant woman as example, the collected data is processed using the steps presented in section3. The gravity acceleration is subtracted to normalize the original data and the low-pass filter is used to eliminate the high frequency noise at first; then the signal is decomposed by the Wavelet transform at eight levels to get the details of the signal content, which is shown as the figure 4. From the figure, some content is periodic signal corresponding to the movements such as the breath, heartbeat of the mother and can be removed from the signal, with data smoothing method to get the effective signal and compared to mother's perception shown in the figure 5, from which the suitability and the efficacy of using MEMS accelerometer to detect the fetal movement is proved.

5 CONCLUSION

In this paper, a low-cost, passive, non-invasive and portable system based on tri-axial MEMS accelerometer to monitor fetal activity, and therefore fetal health is reported. Using this system, we aim at developing signal processing methods to automatically detect and quantitatively characterize fetal movements. This work is a preliminary study to test the performance of the accelerometer in detecting fetal movement and our test results indicate the suitability and the efficacy of using MEMS accelerometer to detect the fetal movement. The method mentioned in this paper implements the MEMS inertial sensors to the biomedical areas, and it could be developed as a portable long-term home monitoring device, also as monitoring workstation in hospitals.

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