BE 352 - Final Project

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Background

Recent applications, such as the Fitbit or the WakeMate, have seen a sudden surge in growth as the demand for consumer health electronics increases. The aim of all these devices is to prove helpful to athletes, fitness pros and ordinary folks alike, looking to better themselves mentally and physically. In recent years a device called the “aXbo” used information about movement and established communication between an alarm clock and a bracelet (containing the sensor). With the use of some proprietary algorithms, the stage of sleep could be extracted and the alarm clock would wake up the user as comfortably as possible. There are a number of criticisms levied against sensors that exclusively use accelerometers and the most significant concern is the algorithm's effectiveness. Due to the proprietary nature of algorithms and the dubious claims made by certain companies, we intend on implementing a similar device using a 3-axis accelerometer and an Arduino UNO to learn more about the complexities of sleep and verify company claims. In addition, the intended goal of this project is to use information from the sensor and use statistical techniques to gain greater insights into an individual’s sleep pattern. From this point, it may be possible for an alarm clock to dynamically determine the optimal time for an individual to wake up.

Device Information

It is our intention to implement a technique called actigraphy, that will allow the monitoring of the gross motor activity of an individual, such as their rest and activity cycles. The actigraph device interacts with the body in a non-invasive manner by gathering information, in real time, about bodily movement that occurs during sleep. We intend on placing the sensor either on the wrist or the trunk of the body and measuring sleep activity on both of these locations to determine the optimal location. It may be possible for the sensor to be placed off the body, though it may be more difficult for the sensor to obtain data about movement. The use of the technique also has many advantages over traditional techniques like polysomnography. For example, unlike polysomnography, a user is able to have their sleep cycle data recorded in the comforts of their own home. By staying in their own home, a user’s data may be more representative of their actual sleep patterns. Furthermore, actigraphy provides a more affordable alternative to polysomnography while still offering reliable results in comparison (accuracy above 90%). Actigraphy can also be used to help diagnose conditions like insomnia, excessive sleepiness, restless legs syndrome, and other circadian rhythm sleep disorders.

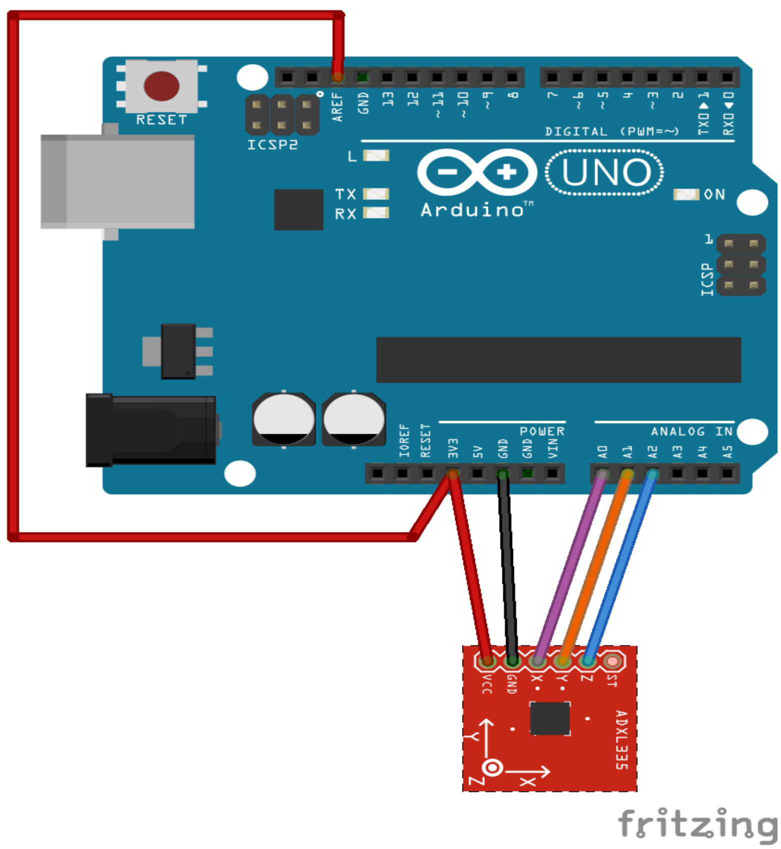
An actigraph sensor is comprised of a piezoelectric sensor or accelerometer, a low-pass filter, memory, and an interface that can start or stop the device, as well as download the data from memory. Our actigraph sensor will use a three axis accelerometer to transduce the motor activity of a user to an electrical signal that will be recorded and transmitted by an A/D converter, in this case the Arduino UNO. But first, a low-pass filter is used to condition the signal from the accelerometer by removing any noise above 2-3 Hz. As a result high frequency external vibrations and 60Hz noise will be ignored. Finally, the electrical signal will be converted by the Arduino and transmitted over a serial bus to a computer where the data can be stored and later processed. The data will be processed in R using various statistical techniques in order to ascertain any patterns or correlations that may exist within the data. It is our hope that the device will ultimately provide us information about an individual's circadian rhythms and sleep patterns.

Objective

Given the background information for this project, our original goals were to extract biological signals and perform statistical comparisons between our experimental conditions: normal breathing, deep breathing, holding breath, and jumping. After obtaining the raw signal, heart rate and respiration rate will be extracted using the Discrete Fast Fourier Transform. A spectrogram will display any band of energy corresponding to the features of interest.

Methods

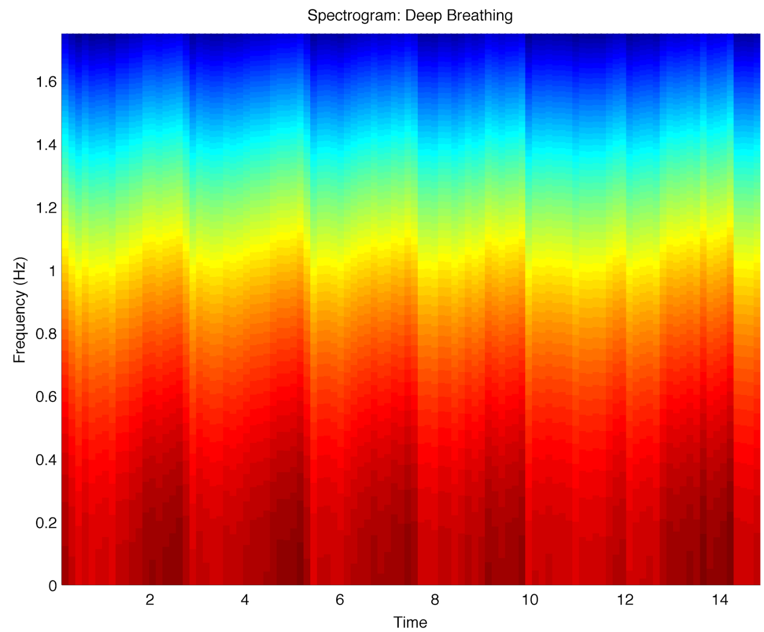
Data collection was performed using an Arduino UNO microcontroller and an ADXL335 accelerometer. The Arduino sampled the signal from the accelerometer at approximately 900Hz. A diagram of our experimental setup is shown below:



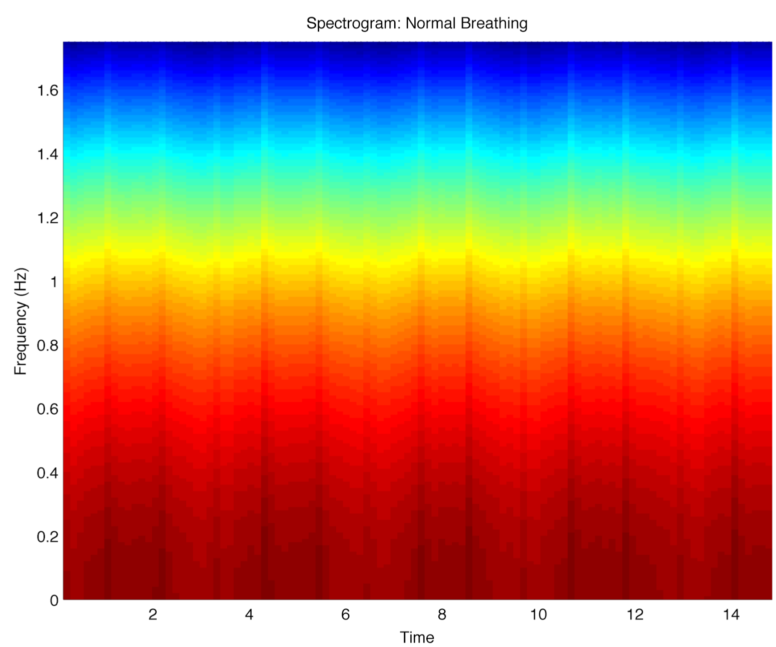
The data from the x, y, and z axes were stored and later processed in R.

Results

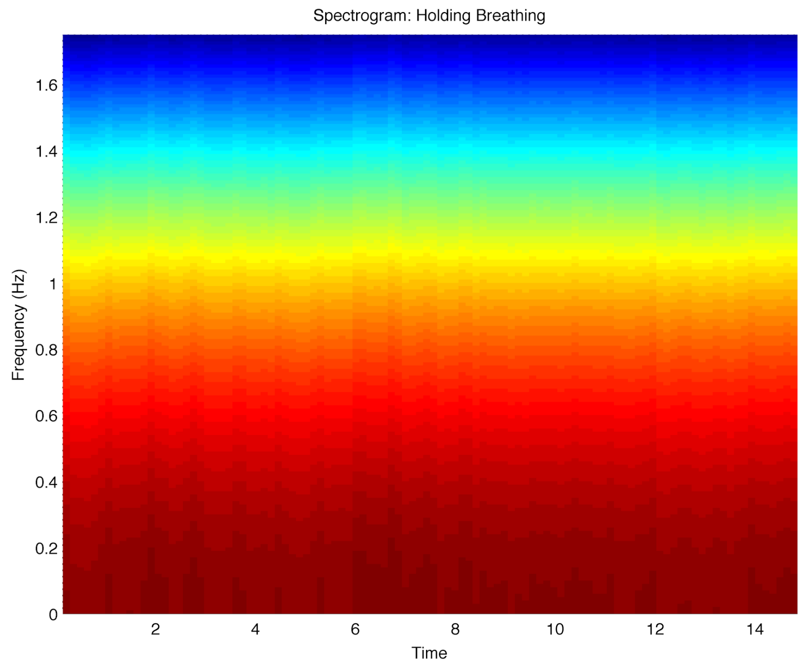
Deep breathing : *X Axis*



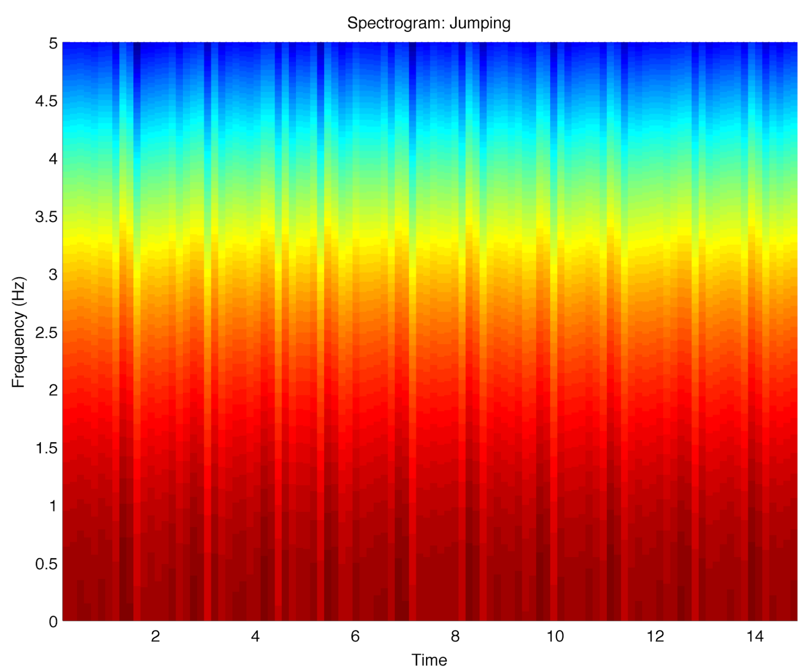
Normal Breathing : *Z Axis*



Holding Breath : *Z Axis*

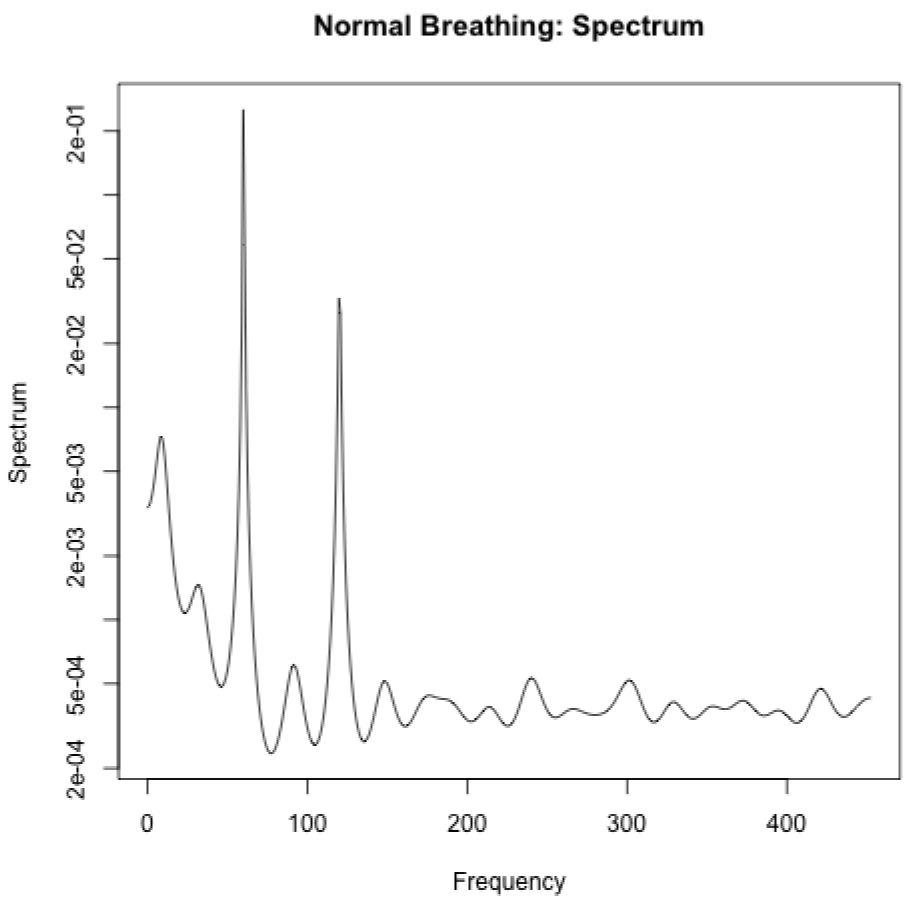


Jumping : *X Axis*



Discussion

Biological signals are inherently difficult to extract because of their low signal to noise ratio. Heart rate and respiration rate fall around ~ 0.4 Hz and ~ 1 Hz respectively, distinguishing them from the background proved to be difficult. In certain axes these features were more distinct. As an example, for normal breathing in the z - axis, the vertical bands occurring every one second correspond to the heart rate, while the 'semi-circle' like patterns occurring every three seconds correspond to the respiration rate. For deep breathing in the x - axis the characteristic cycle of slow inspiration and forced expiration were recognizable. In addition, 60 Hz noise and harmonics were found in the FFT plots for all conditions. The figure below shows the characteristic findings of the FFT for normal breathing.



In addition to noise from the environment, the duration of data collection and the number of trials were not sufficient for scientific accuracy. The former is an issue because we were only recording for 15 seconds. Many of the accelerometers on the market are recording for at least 8 hours and provide information about the motor activity of an individual. On a larger time scale it would be possible to distinguish between periods of REM and non REM sleep. Furthermore, by including more trials any conclusions drawn will be more valid.

Conclusion

We were able to construct a device that provided insight into the challenges of acquiring and analyzing biological signals. We were moderately successful in distinguishing heart rate and respiration rate in some of the conditions. Within this project, we were able to qualitatively determine heart rate and respiration rate, but a further investigation would require some type of quantitative analysis to measure these features . Gross motor movement is a trivial task but finding the finer movements associated with heart rate and respiration proved to be a challenging one.