Wearable Micro-Sensor for Continuous Monitoring of Cardiovascular System

Team 13

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Abstract: Cardiovascular diseases are the leading cause of death in the world, and the prevalence is projected to increase in the next decade. The goal of this project is to develop a wearable device to continuously monitor cardiovascular activities over an extended period of time and detect abnormalities in early stage and act accordingly. The following device is a multi-sensor cardiovascular monitor. This device monitors the mechano-acoustic signals and detects and abnormality that leads to cardiovascular diseases (Arrhythmia, etc.). This wearable device will continuously record body motions, heart sounds and breathing patterns. These features make this device stand out among others in the market with the ability to share patient data in real time with doctors without being restricted to a single location. .

Keywords:Heartsound, Mechano-acoustic,Abnormality Detection

I. INTRODUCTION

In the United States, more than 27 million Americans have experienced some form of cardiovascular disease (CVD), whether that was an ischemic heart event, stroke, or hospitalization for myocardial infarction. Also, (CVDs) are the leading cause of death globally, and in 2016, there were an estimated 17.9 million deaths from CVDs globally, which is representing roughly 31% of global deaths that year. From these deaths, about 85% of them were caused by heart attacks and stroke. According to the World Health Organization, people with CVDs or with high cardiovascular risk need early detection and management to either prevent or save their lives as appropriate. This project's goal is to use a wearable detection device to scan the cardiovascular region is needed to identify potential symptoms which then helps improve treatment response and accuracy of diagnosis.

II. DEVICE DESIGN

Here, we present a wearable device that consists of an accelerometer and a temperature sensor, to capture heart rate, body temperature, breathing patterns and cough sounds. The 4×4 mm accelerometer chip can record a wide range of vibrations on human skin, ranging from very low frequency (below 1 Hz) movements associated with the chest wall and body position to high frequency acoustic signals (up to 12 kHz) emanating from the heart and lungs.

This 3-axis accelerometer is highly sensitive with a low power threshold (0.0095W), adjustable BW per axis (0.5Hz-1600Hz for x y-axis and 0.5Hz to 550Hz z-axis), Vin (3-5V), 3Vout (3.3V) @100mA and is suitable for sports and health devices. The lithium ion polymer battery is a good fit for the device because they are thin, light, and powerful. This battery ranges from 4.2V when fully charged to 3.7 V with a capacity of 1200mAh for a total of 4.5Wh. This battery is embedded with protection circuitry to avoid overcharging and overuse by cutting off when completely dead at 3.0V. Below is a block representation of the device:

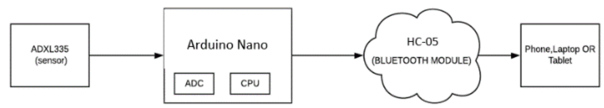

Figure 1: Block representation of electrical system

III. DATA ACQUISITION

The first idea toward designing this device started with acquiring the analog signals needed for study and reference, in other to get the data we used the ADXL335 and analog discovery digital oscilloscope then processed and analyzed the data with origin labs. To get the heart sound the sensor was places on the chest while held with medical tape, the oscilloscope was set to 1.6kHz sample rate. The position of the sensor for the heartbeat was logical to be on the chest allowing the z-axis to pick up the vibrations from the chest wall. This is not the same case for the cough signal, shortness of breath and deep breath, with that in mind the sensor were placed on the neck, chest and stomach which make it easy to analysis the results from these points allowing us to come up with an optimum position for the sensor. The data collected includes 1 cough signal (no cough/cough/no cough) ,2 cough signals, shortness of breath and deep breath from the neck, chest, and stomach then the heart sound from the chest. The processing section which was done in origin labs started with truncating every unwanted signal from the cough and passing a band stop filter to eliminate the 60Hz noise. While processing the data the processing was not intense to avoid losing vital information.

IV. RESULTS

The analog data were processed and analyzed in origin labs; the data analysis is in time domain and frequency domain. In the time domain, the peaks were analyzed while in the frequency domain using Fast Fourier Transform; the power spectrum is used to find unique features of each signal. Time duration of the signals is also vital; each signal despite being almost identical also varies in time duration, which also has its information. The signal from the chest has a duration from 0.25sec, the stomach signal time duration is 0.59sec and the neck signal has a time duration of 0.39sec. Time duration shows that the stomach signal has more information, followed by the neck signal, and the least is the chest signal.

The frequency range for the signals from the neck and stomach are almost identical while the signal from the neck is higher, this justifies the point mentioned above that the neck has more noise (distortion) which might be speech signal or pulse signal. This frequency range is also useful while trying to filter out noise from the neck signal; a lowpass filter can be used to retain the low-frequency component ($f \leq 35$Hz) and reject the high frequency ($f \geq 35$Hz)

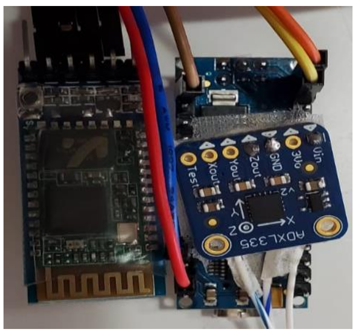

Figure 2: Prototype without packaging

Data for shortness of breath is also from the neck, chest, and stomach. Since shortness of breath is just a pattern, all three locations tend to have identical patterns, which looks like a cosine wave from physical inspection, the data from the chest seems to have more distortion. This distortion is also due to the placement and could be some heart sound. In the frequency domain all the signal from the neck and stomach has a frequency range of 0.1Hz-20Hz. In contrast, the chest signal ranges from 0.1Hz-30Hz, The signal from the neck has a primary peak of 2.2Hz with an amplitude of 0.016, the signal from the stomach has a primary peak of 1.4Hz with an amplitude of 0.012. In contrast, the signal from the stomach has a primary peak at 1.14Hz with an amplitude of 0.0047.

The deep breath pattern is identical to the shortness of breath; they both look like a cosine wave; the most distinctive difference is the distance between the crest in the signals. The distance between the crest in a deep breath is more than the distance in the shortness of breath. The signal from the neck has a frequency range of 0.1Hz-0.4Hz; the signal from the stomach has a frequency range of 0.1Hz-3.4Hz, while the signal from the chest range from 0.1Hz-5Hz. The signal from the neck has a primary peak at 0.4Hz with an amplitude of 0.039; the signal from the stomach has a primary peak at 0.6Hz with an amplitude of 0.033, while the signal from the chest has a primary peak at 0.4Hz at an amplitude of 0.0183.

The frequency range in the deep breath signal is smaller than the frequency in the shortness of breath; this because in the time domain, the deep breath signal is expanded with respect to time, while for shortness of breath, the signal is compressed in respect to time. Which causes higher frequency in the shortness of breath and lower frequency in the deep breath.

The sensor is placed on the chest where is picks up vibration from the chest wall. The signal consists of the s1, s2, s3 and s4. The physical difference between the heart sounds is the magnitude. The signals were processed in origin labs using a low pass filter and a band stop filter to eliminate the 60Hz noise.

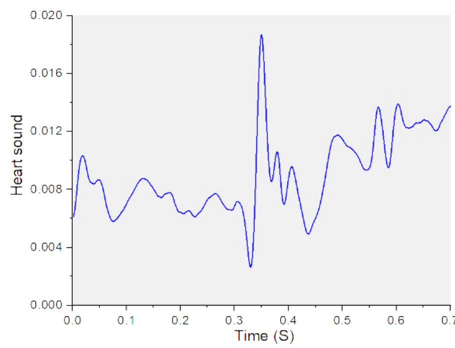

Figure 3: Heart Sound

V. CONCLUSION

This device continuously monitors the heart sound and breathing pattern alongside the user-friendly mobile application that allows the user to track and share vital health information to doctors to aid early CVD detection. This device can also be embedded with AI and machine learning to increase its capability

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