ECE4144 Embedded Systems

The Embedded Challenge
Parkinson’s Disease Tremor Detector
Project Proposal

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Background

Parkinson's disease affects millions of people globally. The cause of the sickness is mostly unknown, but is believed to be heavily influenced by genetic and environmental factors. The most prominent feature for people who carry this disease is the Parkinsonian tremor. These tremors, mostly affecting hands and wrists, occur when the parts of the body are at rest and diminish when in use. Typically, there is a dominant side of the body for the tremor.

The challenge of treating Parkinson is highly dependent on precise and early detection of such symptoms, which is crucial for future therapy. Current methods for monitoring tremors may involve complex equipment or may not involve detection. The tremor challenge aims to develop a wearable tremor detector. This device will utilize the Adafruit Playground Classic board with its embedded accelerometer to capture and analyze the real time tremor data. This will allow the wearer to receive real time feedback in the form of visual and audio indicators when tremors are detected.

Problem Statement

Transformation of 2D usable data from the embedded accelerometer on the adafruit playground in XY direction. The calibration and the conversion of the raw data requires massive practice.

CAD and 3D printing. Design and produce a wearable holder for the Adafruit Playground Classic for the use of tremor detection requires professional experience. Otherwise could cause inaccurate data or damage the device.

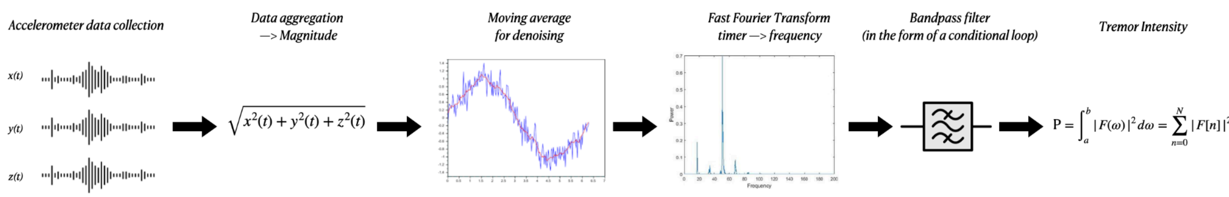
Sampling rate derivation

Nyquist Rate $$f_n = \frac{1}{T_n} \approx 10 \text{ Hz}$$

Sampling Rate $$f_s \geq 2f_n = 20 \text{ Hz} = 20 \text{ samples/s}$$

Proposed Solution

The project aims to build a wearable Parkinsonian tremor detector by programming an Adafruit Playground Classic board. The accelerometer on the board is used to collect three-dimensional accelerations that are processed into the frequency domain. By using the frequency domain data, the project aims to be able to detect the common resting tremor frequencies between 3 and 6 Hz and provide a visual indication of detection. Additionally, support for providing information on the intensity of the tremor using additional LEDs and/or speakers is considered.



Our aim is to offer an effective method for displaying the results of tremor analysis. Additionally, we intend to create a custom holder for the LIPO battery and the PCB, ensuring secure placement without causing any additional noise from movement. Furthermore, we plan to conduct unique tests on the board once the microcontroller is configured.

Timeline

Week of 4/29-5/5

- Finish conducting research on using ArduinoFFT
- Implement FFT, moving average filter, and ISR for timer sampling
- Implement band pass filter in the form of a conditional loop
- Start designing a PCB CAD model for a wrist strap to hold battery and board
- Have a semi-functioning prototype by the end of the week
- Plan video

Week of 5/6-5/13

- Start debugging functionality
- Implement additional functionality, such as speaker and neopixels for intensity
- 3D print out the wrist strap
- Put everything together
- Finish debugging
- Edit video

Design Choices

The Adafruit Circuit Playground library is chosen for interfacing with the Accelerometer data input and the NeoPixel. To collect the acceleration value in each of the x, y, and z axis, the functions motionX, motionY, and motionZ can be invoked through the CircuitPlayground object. The NeoPixels can be configured through either RGB or Hex format using the setPixelColor function. Since both the color and the intensity of the NeoPixels could be configured, more visual indications can be done to signify the presence as well as the intensity of the tremor.

Since the interested frequency range is between 3 and 6 Hz, the sampling frequency has to be fast enough to meet the minimum required fidelity. According to the Nyquist theorem, the sampling frequency has to be, at the minimum, twice the interested frequency. Therefore, with a max desired frequency of 6 hertz, the sampling rate has to be equal or greater than 12 hertz. Because the Adafruit maximum rate of sampling on the ATMEGA32u4 is 8 MHz, the sampling rate can be set to a value a few magnitude higher than the required minimum one to ensure accuracy and precision. For this project, the 8 bit timer 0 is used with a clock prescaler of 64 and a MAX count of 125 for ease of calculation.

Because there is inherent noise in the signal from the accelerometer, a moving average filter can be used to clean the data. A basic algorithm for the moving average filter is shown below:

```
float calculateNpointMovingAVG(float* avg_vals)
{
 float sum = 0;
 for (int i = 0; i < N; i++)
 {
   sum += avg_vals[i];
 }
 return sum / N;
}
```

The ArduinoFFT library will be used for implementing the Finite Fourier Transformation on the inbound accelerometer data. To use the FFT in the Arduino library, an ArduinoFFT object has to be instantiated which takes four parameters: the real component of the signal array, the imaginary component of the signal array, the number of samples, and the sampling frequency. The arrays can be populated with the incoming signal. Since the signal is real, the imaginary component can be set to zeros. The three functions needed to perform the transformation are: windowing, computer, and complexToMaginitude.

To analyze the signal in the frequency domain, a band pass filter can be incorporated. This can be implemented using a simple conditional statement to check if there is a presence of signal between the 3Hz and 6Hz frequency range.
The **intensity** of the tremors will be evaluated after the filtering process: in the frequency domain, the power of the peaks should be calculated, the values of those power values will be mapped out onto a normalized scale (percentage scale). The power will be calculated using Parseval's theorem, which is the integral of the square of the magnitude of the transformed domain. This can be approximated by summing the square of the magnitude of the transformed frequency values across the frequency range of interest.

$$\mathrm{P} = \int_a^b |F(\omega)|^2 d\omega = \sum_{n=0}^{N} |F[n]|^2$$

<u>Output expectations:</u>

We should expect peaks anywhere across the frequency spectrum, but the relevant ones are the following:

$\delta(0)$, or at 0 Hz, there will be a peak for gravity (which we do not have to worry about as it will not be taken into consideration)

3 Hz $\leq f \leq$ 6 Hz is the range where we consider a peak to indicate a potential tremor[1].

1: the range 3 to 6 Hz is only one of the conditions for the signal to be considered to be a Parkinsonian tremor. The duration and intensity are also parameters that we should take into account.