ECE4081: Gait Lab

Preliminary Questions

1. The two major calf muscles are the gastrocnemius (GA) and the soleus (SO).

2. The Gastrocnemius is responsible for plantar flexion at the ankle joint as it comprises half of the calf muscle and therefore is responsible for any fast-twitch movements (running, jumping, etc).

   The soleus on the other hand, although responsible for plantar flexion at the ankle joint, mainly stabilizes the tibia limiting forward sway and hence is the most active when walking.

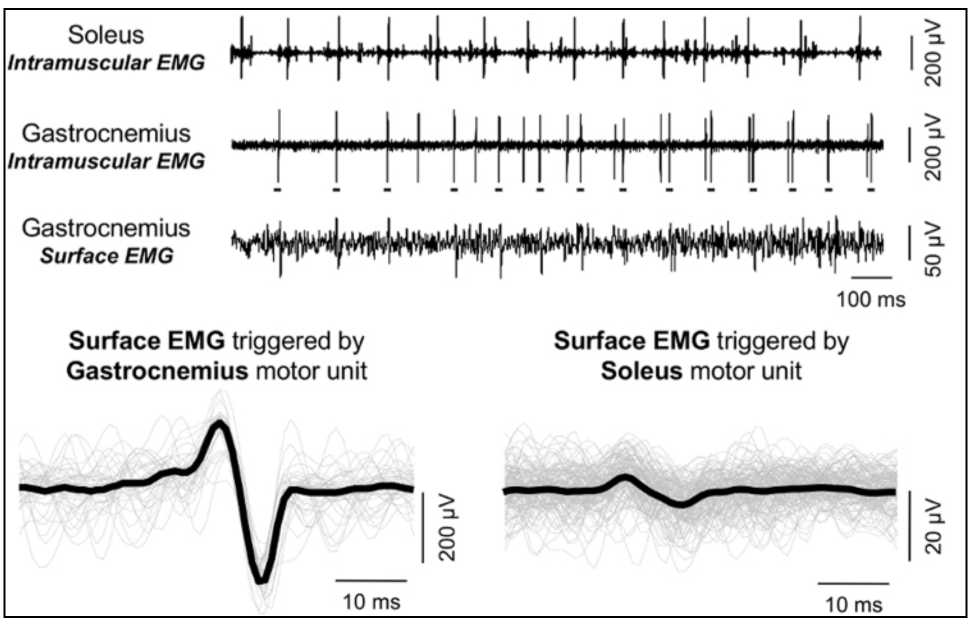


Fig 1. EMG from Soleus and Gastrocnemius. [1]

   When looking at surface EMG data signals produced by the GA is almost 10x the magnitude of the Soleus, and intramuscularly, the SO produces more burst activity while the GA produces a single impulse [1].

3. We can place an accelerometer right above the hip, because:
   a. As it is stiff, it minimizes the effects of the rotation of the body.
   b. It also reduces height deviations while walking which could help us calculate the step length accurately.

4. The following is a diagram showing idiopathic toe walking, it's a condition that involves abnormal gait due to toe strikes:

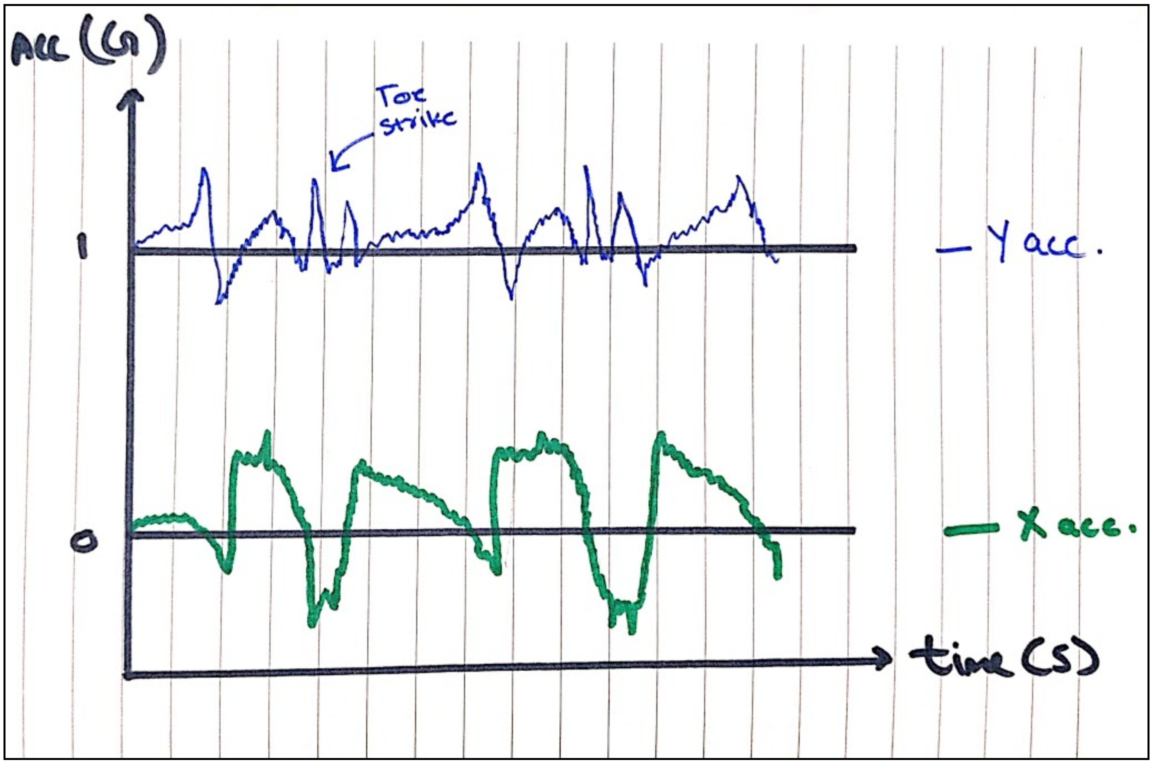


Fig 2. Idiopathic toe walking

Analysing EMG Data

1.

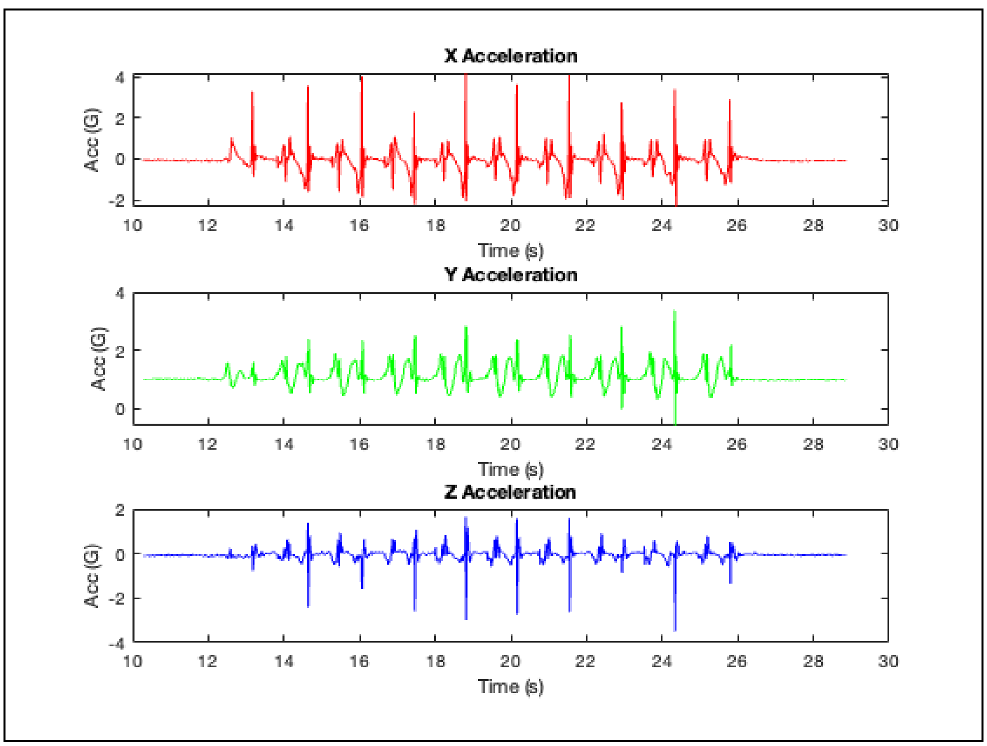
```
%% import raw sensor data
data =  xlsread("raw data including emg.xlsx");

time = data(1, :)/70;
AccX = data(2, :);
AccY = data(3, :);
AccZ = data(4, :);
EMG  = data(5, :);

%% ploting data
figure;
subplot(3, 1, 1);
plot(time, AccX, 'r')
title("X Acceleration");
ylabel("Acc (G)")
xlabel("Time (s)")
subplot(3, 1, 2);
plot(time, AccY, 'g')
title("Y Acceleration");
ylabel("Acc (G)")
xlabel("Time (s)")
subplot(3, 1, 3);
plot(time, AccZ, 'b')
title("Z Acceleration");
ylabel("Acc (G)")
xlabel("Time (s)")

```

2.



3.

a. **Average peak acceleration during heel strike (Y-axis)**

The average peak acceleration is 2.58 G.

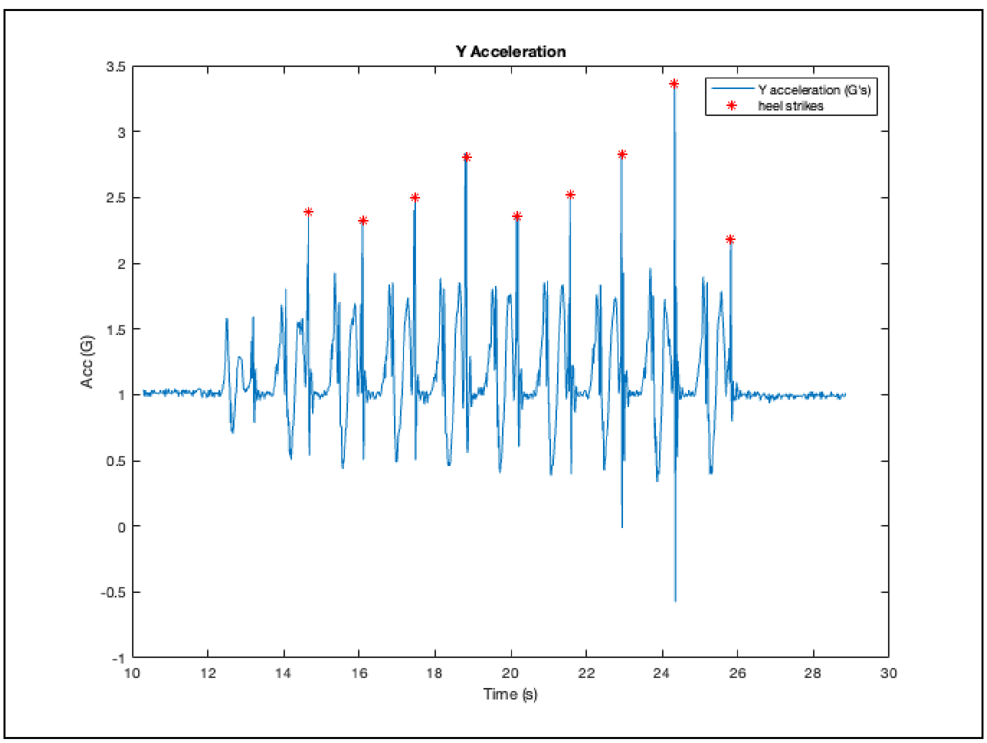
```matlab
%% Average peak acceleration during heal strikes (y-axis)
acc_peaks  = islocalmax(AccY) & (AccY > 2);
peak_times = time(acc_peaks);
peak_vals  = AccY(acc_peaks);

% find errored readings
outlier_ind = [];
for i  = 2:length(peak_times)
    if peak_times(i) - peak_times(i-1) < 0.5
        outlier_ind(end + 1) = i-1;
    end
end

% remove outliers
peak_times(outlier_ind) = [];
peak_vals(outlier_ind)  = [];

avg_peak_acc = mean(peak_vals); % m/s^2

figure;
plot(time, AccY);
hold on;
plot(peak_times, peak_vals, 'r*');
legend("Y acceleration (G's)", "heel strikes");
title("Y Acceleration");
ylabel("Acc (G)")
xlabel("Time (s)")
```



b. Stride length (time and meters)

After [filtering/cleaning the data](), we can find the stride length as :
Time - 1.4s
Meters - 1.19m

```
%% Stride length (time and meters)
% time -> 2.58s (from above)
% length -> 1.2m

% trim to take stride section (x acceleration peak-peak) only
peak_ind  = find(acc_peaks == 1);
AccX_trim = f_AccX(peak_ind(1) - 5:peak_ind(2)); % -5 for shifting  few samples back
time_trim = time(peak_ind(1) - 5:peak_ind(2));

% integrate to find velocity
vel_x  = detrend(cumtrapz(time_trim, AccX_trim)); % detrend sensor shift
vel_x = vel_x + (-1*min(vel_x)); % remove negative values
dist_x = cumtrapz(time_trim, vel_x); % integrate again to find distance

stride_length = dist_x(end);

```

c. Step length (time)

The step length in seconds is 0.7s.

```
%% Step Length
% The step length should be approximately half the stride length.
step_length = stride_length/2;

% step time calculation
step_times = [];
for i  = 2:length(peak_times)
    step_times(end+1) = peak_times(i) - peak_times(i-1);
end
gait_cycle = mean(step_times);
step_length = gait_cycle/2;

```

d. Time period during the gait cycle

The time period is the mean of all the differences between all adjacent peak times, which is 1.39s.

e. Gait frequency

The gait frequency is $\frac{1}{gait\ cycle\ period}$, which is 0.7Hz.

Discussion Questions

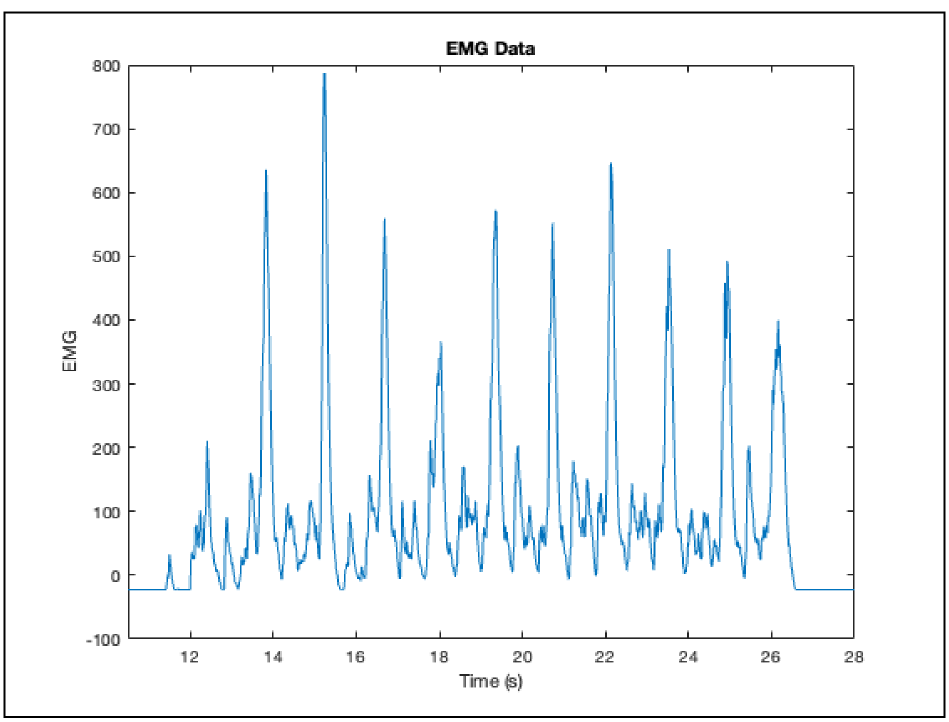
1. Surface EMG signals range from 20-200 µV [1]. Yes, amplification of the signal is required for ease of processing. Some muscles (like the biceps) may need less amplification compared to other muscles (like the muscles in our fingers) may require a higher gain [2].

2. The three sources of noise are:
    a. High-Frequency Electromagnetic Radiation induced noise: This type of noise is inherent in all electronic devices, these are caused due to stray electromagnetic waves in the environment and power-line interference. We can remove such disturbances by filtering out high-frequency components (low pass filter) of the signal.

    b. Low-Frequency patent artifacts: These include patient movement and other action potentials introduced into the measuring signal due to bodily functions. We can eliminate these by using a high pass filter.

    c. Sensor noise: This noise is caused by the material property of the electrodes themselves, this includes Johnson–Nyquist noise (thermal noise), shot noise, and flicker noise. We can reduce such noise by using materials that produce a high signal-to-noise ratio like Ag/AgCl electrodes.

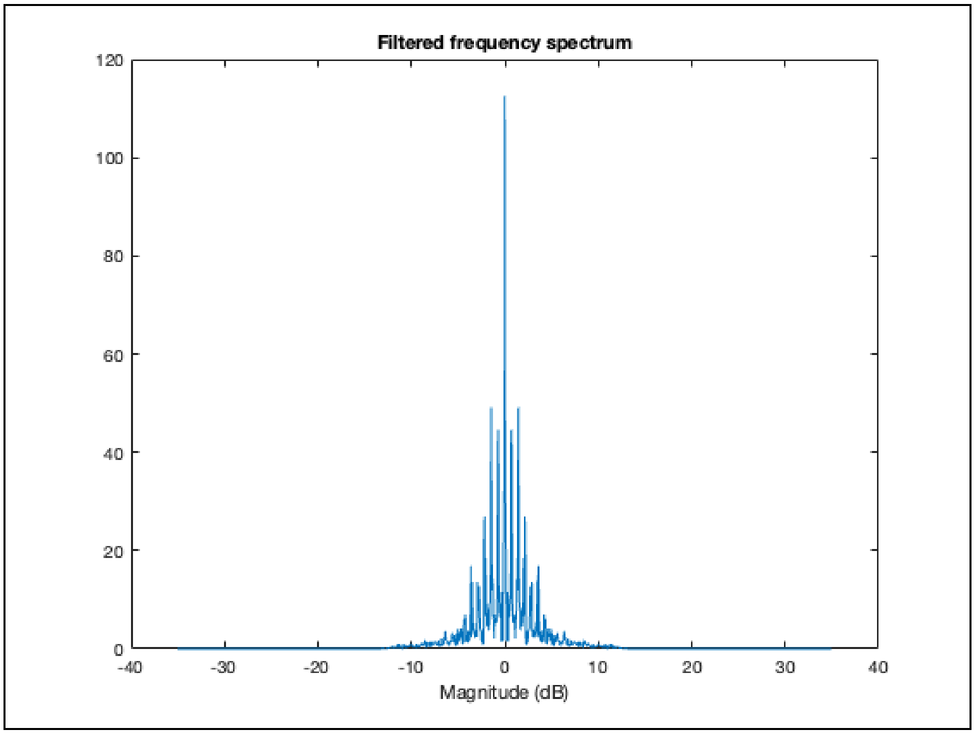
3.



The EMG data provided is the calf EMG only. Therefore only two muscles, the gastrocnemius (GA) and the soleus (SO) EMG magnitude should be in the plot. These are the muscles involving forward motion.

Although not shown in the EMG, the Quadriceps femoris, the Rectus Femoris, the ILiopsoas, and the gluteus maximus are also responsible for forward motion.

4.



(Not considering the current sample frequency of 70 Hz) Looking at the frequency plot, the maximum frequency is around 10Hz, therefore we can sample from THIS SIGNAL at 20 samples/sec.

Else, we have to sample at double the Nyquist frequency, which is 140 samples/sec.

5. We can use a three-axis accelerometer in many medical health care monitoring conditions, but specifically, we can use them in fall detection and sleep monitoring.

   Fall detection: We can use sudden accelerations to detect falls in either elderly or critical state patients (Parkinson's, Alzheimer's, etc).

   Sleep monitoring: We can use movement data to measure the quality of sleep in patients. This can be a vital measurement in aiding chronic insomniacs.

6. Pressure sensors: Pressure sensors can allow medical staff to monitor the patient's ground reactive force and calculate the weight distribution for stability study.

   Accuracy: Using multiple cameras increases the accuracy of gait measurements in 3D space when compared to accelerometer-only measurements.

7. The average stride length in humans is about 0.762m. In general, $\frac{Step\ Length}{Height} \approx 0.42 \pm 0.3$ [3].

8. We know that,

   $$\frac{Step\ Length}{Height} \approx 0.42 \pm 0.3$$

   Therefore,

   $$\frac{0.66}{0.42} = 1.57m$$

   The Height of the individual is about 1.57m.

9. The three factors are:
   a. Accuracy of the accelerometer.
   b. Induced noise.
   c. Sampling frequency.

Note: You can find the full code here.

References

[1] T. Vieira, A. Botter, S. Miceli, and D. Farina, "Specificity of surface EMG recordings for gastrocnemius during upright standing", Scientific Reports, vol. 7, no. 1, 2017. Available: 10.1038/s41598-017-13369-1.

[2] M. Z. Jamal, "Signal Acquisition Using Surface EMG and Circuit Design Considerations for Robotic Prosthesis".

[3] S. Buddies, "Stepping Science: Estimating Someone's Height from Their Walk", Scientific American, 2021. [Online]. Available: https://www.scientificamerican.com/article/bring-science-home-estimating-height-walk/#:~:text=On%20average%2C%20adults%20have%20a,from%20about%200.41%20to%200.45). [Accessed: 16- Apr- 2021].