ECE4081 Medical Instrumentation

Laboratory 2 (10%)

Sensor Signal Processing using Matlab

Aim

The aim of this lab is to give you exposure to signal processing techniques used for processing and analysing sensor data in the health care sector.

Marking

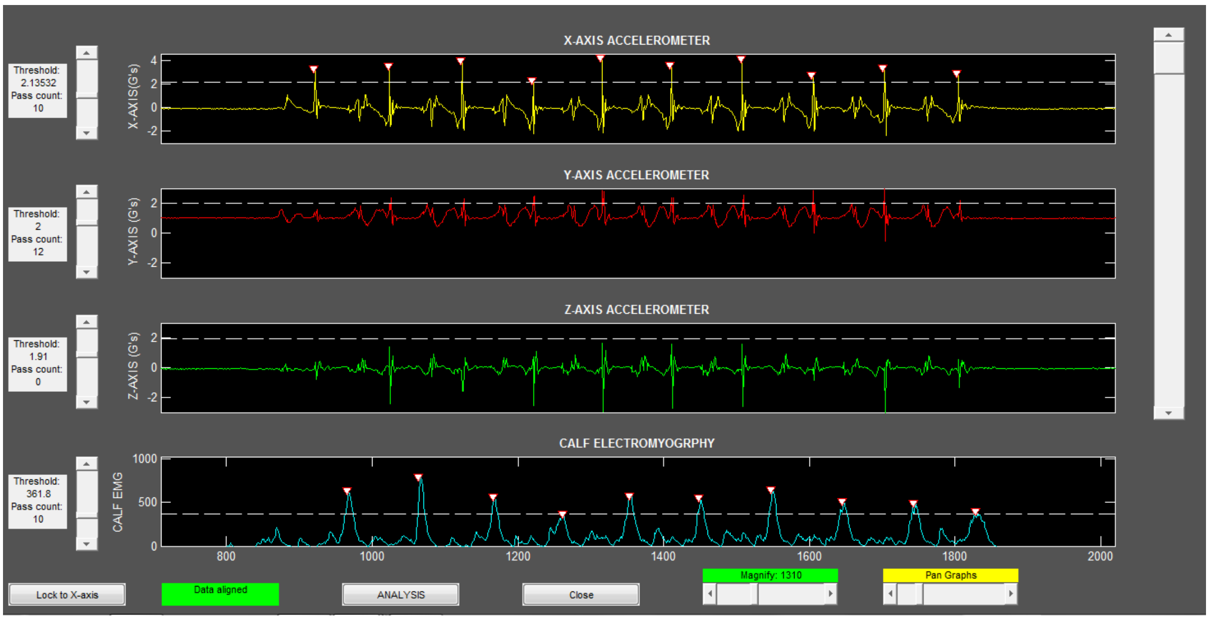
Total: 10 (Preliminary Questions) + 10 (Lab) + 30 (Discussion) = 50 marks

***Preliminary Questions* (10 marks total)**

1. What are the two major calf muscles involved in gait? (2 marks)
2. How might you distinguish between the two major calf muscles in an EMG recording? List two distinguishing features. (2 marks)
3. Where would you place an accelerometer for gait measurement? Give two reasons supporting your selection. (2 marks)
4. Select a condition that might involve abnormal gait. With reference to the below image of accelerometer and EMG data, draw a simple waveform (2 cycles is sufficient) corresponding to your selected abnormal gait. (4 marks)

***Analysing EMG Data* (10 marks total)**

You will be analysing gait accelerometer data obtained using the system described in the lab notes (below) when a person was asked to walk normally. You do not have to conduct an experiment. The below figure shows the three acceleration signals (yellow, red, green) and an EMG signal (blue) when plotted with respect to time. The sample rate of the data is 70 Hz. The accelerometer data is in G's (9.8 m/s^2).



You will have to do the following:

1. Export the raw sensor data provided (from excel sheet) to Matlab.
2. Using Matlab, plot the graphs of the acceleration signals with respect to time and show the various gait phases in the gait cycle. (4 marks)
3. Determine the following parameters using signal processing techniques. (6 marks)
    a. Average peak acceleration during heel strike (Y axis)
    b. Stride length (time and meters)
    c. Step length (time)
    d. Time period for a gait cycle
    e. Gait frequency during walking

***Discussion Questions* (30 marks total)**

1. What are the output voltage levels of an EMG electrode? Do you need to amplify the signal from an EMG electrode? (4 marks)
2. List three sources of noise in the EMG signal, and briefly describe how might you address each. (6 marks)
3. Based on the EMG data, which muscles appear to generate the forward movement of the foot while walking? (4 marks
4. From your plotted data, derive an estimate of the minimum sampling frequency required to identify prominent features of the gait cycle. Provide a brief explanation of how you arrived at this number (2-3 sentences). (6 marks)
5. A three-axis accelerometer senses acceleration in three dimensions. How could accelerometers be useful in health care monitoring? (Describe two scenarios) (2 marks)
6. High-tech gait measurements involve 3D motion capture cameras and pressure sensors underfoot, in addition to extensive EMG and accelerometer readings. What do these two systems add that is not captured in the above EMG and accelerometer data? List two features. (2 marks)
7. What is the average stride length (meters) for a normal human? How does this measurement relate to height? (2 marks)
8. Using your previous answer, derive an estimate of the height of the subject in the above data. (2 marks)
9. Name three factors that might change your height estimate if known. (2 marks)

Submit an individual report (via Moodle) by end of week 6.

EMG Lab Notes
The primary muscles that are utilized in walking include, but are not limited to the quadriceps and hamstrings in the thighs, the calf muscles in the lower legs, the hip adductors and the gluteal and abdominal muscles in forward motion. The lower leg muscles also provide balancing force to maintain an upright stature.

Calf muscle
The calf muscle, is also known as the triceps surae, and consists of the soleus, medial gastrocnemius and lateral gastrocnemius. The bipennate (two muscles) gastrocnemius **is** mainly responsible for plantar flexion during walking. The second muscle is the soleus, which is a uni-pennate (one muscle) muscle located under the gastrocnemius. It is a much larger muscle and is also responsible for plantar flexion, however it only spans one joint (as opposed to the gastrocnemius) thus is used when plantar flexing with a bent knee. It is also greatly utilized in balancing during a standing posture.

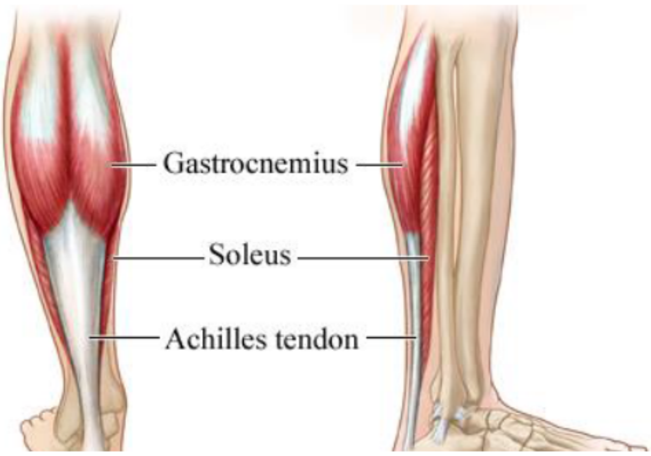


Figure 1

Accelerometers
Accelerometers measure the acceleration of a particular object. Gyroscopes on the other hand measure orientation displacement. A combination of the two can be used to form an Inertial Measurement Unit (IMU) allowing measurement of specific force, and angular rates. In 3D space, there are 6 possible axis; left/right, up/down, fore/aft (XYZ translations), Pitch, Yaw and Roll (XYZ rotations).

Standing and walking encompasses all 6 axis (with an acceleration point measure from the ankle), however for the scope of the lab, a simple 3-axis accelerometer was used.

It is important to note that whilst walking, two different types of acceleration are present in any given axis:

1. Static acceleration: Acceleration due to gravity (caused by angular movements of the foot)
2. Dynamic acceleration: Acceleration due to movement

It is near impossible to differentiate between the two without the use of a video feed, however, careful positioning of the accelerometer can help negate the interference of static acceleration.

Acceleration can be measured in G's, which is a force per unit mass, in relation to the earth's gravity. Gait analysis using accelerometers has shown that normal walking acceleration values (taken from the metacarpals near the ankle) are roughly +/-2G in the X and Y axis.

Electromyography (EMG)

Electromyography is a technique employed in physiology to measure the electrical activity produced by skeletal muscles. These electrical potentials can range from as low as 50uV to 30mV depending on the muscle and the number of motor neurons activated. The differential between a 1 inch apart EMG surface electrodes on the calf during contraction is roughly 3mV in a normal human being. As the force of contraction increases, more motor units are employed causing this differential voltage to increases.

EMG can provide good qualitative results, but weak quantitative results due to many external factors that can influence it. The incorporation of the accelerometer can help improve this.

EMG caveats: Load sharing, multi-jointed muscles output, cross talk, changing muscle length contraction, noise from power source.

Due to these caveats, it is important to measure and note down the location of the EMG placement to allow for comparative analysis.

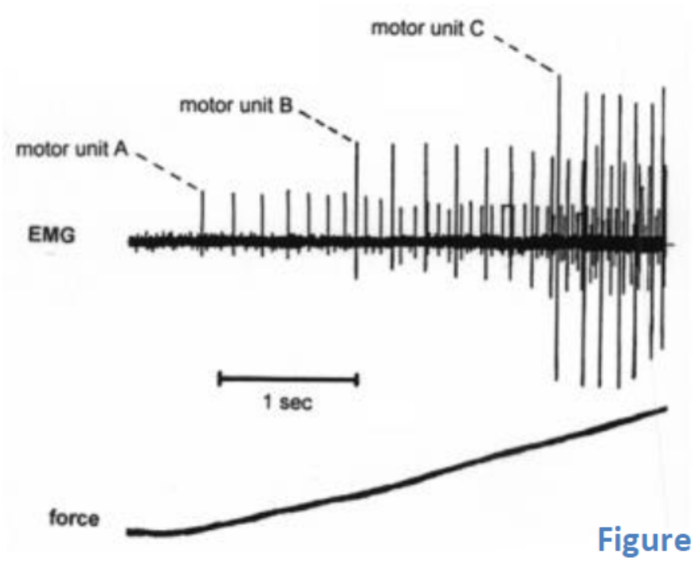


Figure 2

Normal walking cycle

The walking cycle constitutes of two main phases; the stance phase and the swing phase. Knowing the distribution between these two can identify a limp or in severe cases structural abnormalities. Particular attention can be paid to the toe off and the landing point of the swing phase. The force and acceleration at both can indicate how much relative energy is being provided or not being provided in relation to the movement. Further distributions between the acceleration in all 3 axes can give an indication of stability. Deviations from normal gait can be due to range of skeletal, muscular and neuronal issues. Some common diseases related to gait instability are:

- Parkinsons disease — a nervous system related muscular rigidity
- Multiple sclerosis — a disease associated with sheath damage in nerve cells
- Celerbral palsy — a disease marked with uncoordinated muscle control
- Alzheimers — nervous tissue degradation
- Arthiritis — bone structural defects
- Peripheral neuropathy —the breakdown of the peripheral nervous tissue cells

Other factors which can affect normal gait are:

- Post fracture
- Chemotherapy
- Shortness of limbs
- Posture and stance
- Habit
- Muscle weakness
- Balancing issues

All these conditions have their own gait signatures. If they can be visualized on a computer, there is a better chance to diagnose the correct condition.