Wearable Sensory System for a Motorized Compression Bandage

by

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Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics

or

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Abstract

Disorders associated with excessive swelling of the legs are common. This swelling can be associated with pain, the production of varicose veins, reduced blood pressure (hypotension) when standing and cause light-headedness, fainting and falls. These events can significantly affect quality of life and, in severe cases, lead to death. It is well documented that up to 30% of the elderly have standing hypotension. Swelling is common during pregnancy ranks highly as one of the causes of varicose veins.

Current physical remedies to these disorders include air compression leg massagers, which do not allow for ambulatory use, and compression stockings, which attempt to limit blood pooling and fluid build-up in the legs during walking. However, neither of these devices is able to adapt to the changing physiological conditions of the patient while compression stockings can provide only passive assistance to edema.

One of the developed technology, a motorized bandage, which is wrapped around the lower leg, has recently been prototyped. It uses an actuator and thin cables to apply a fully controlled and desired compression profile on the lower leg. The device is battery operated and is designed to be utilized for ambulatory situations.

The main goal of this MEng project is to develop and test a sensor system for the motorized compression bandage. This sensor system should be able to detect lower leg motion and trigger the compression bandage when a user is inactive.

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Secondly, I would like to thank all my lab mates, especially Ph.D. candidate Shahram Pourazadi who were deeply involved in this research project. Without their passionate participation and input, the project could not have been conducted.

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1. Introduction

1.1 Background

Leg swelling is common during pregnancy and ranks highly as one of the causes of varicose veins. Over seven million people in North America, and approximately 1 in 62 Canadians suffering from leg swelling. Control blood flow and volume in the lower limbs of spinal cord injury is also a health risk for many Canadians living with spinal cord injury [1, 2].

1.2 Current solutions

Current physical remedies to these disorders include air compression leg massagers, which do not allow for ambulatory use. Another solution is compression stocking, which reduce venous hypertension and helps the leg muscle pump, improves filtration, prevents skin breakdown, and results in a reduction of edema and venous pooling [3, 4]. However, compression stockings attempt to limit blood pooling and fluid build-up in the legs during walking. Neither of these devices is able to adapt to the changing physiological conditions of the patient while compression stockings can provide only passive assistance to edema.

In this regard, a motorized bandage, which is wrapped around the lower leg, has recently been prototyped in the Menrva research group. It uses an actuator and thin cables to apply a fully controlled and desired compression profile on the lower leg. The device is designed to be utilized for ambulatory situations.

1.3 Project scope

The focus of this project is to develop a group of wearable sensors which will be able to detect individual's activity and leg swelling condition, in order to trigger the compression bandage at the right time.

The MEng project includes:

- Literature review on sensing technologies with emphasis on e-textiles
- Proposed design approach
- Discussion on the performance of the developed prototype

2. Literature review

2.1 Review of calf volume change behavior

The human calf compresses upon application of pressure. The size of the calf changes considerably with the application of an external compression. One of the mathematical models shows the relationship between changes in volume to changes in external pressure is determined by its compliance (C):

$$C = \frac{\delta \Delta V}{\delta P}$$

Equation 1.

As shown in Equation 1. the compliance is a nonlinear function of external pressure. Different regions of the calf have different values due to the different circumference of the calf region shown in Figure 2.1. There are several works in the literature that studied and measured the calf compliance with different methodologies [5–12]. The common clinical method of calf compliance measurement is to apply external pressure proximal to the knee with congestion cuffs and then monitor the volume changes in the calf area using plethysmography [5–9].

In this method, it is assumed that the volume change in the limb is equivalent to the volume change of the underlying venous vessel. This assumption, however, is argued to be not very accurate [12]. Moreover, this method does not precisely predict the compliance of the calf as the external pressure is applied proximal to the knee and not to the calf itself.

A more sophisticated method was used to accurately measure the calf compliance by monitoring cross sectional changes of the calf under application of an external pressure to the calf area [11, 12]. Specifically, Thirsk et al. [12] proposed a procedure that removed possible artifacts, such as involuntary muscle contractions, from the lower leg. In that work, compliance was measured in six different regions of the leg, from the ankle to the knee shown in Figure 2.1

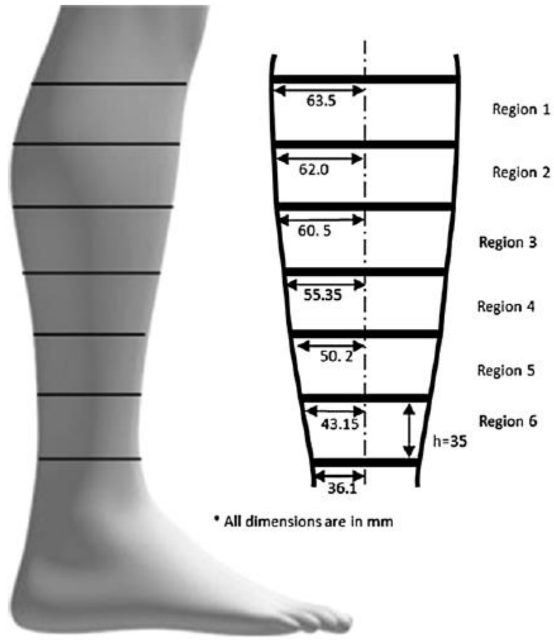


Figure 2.1. Human calf - Geometry of the calf and its six different regions

The values of the percentage change in the cross section area of the calf were different in various calf regions.

According to the data and calculation acquired by Pourazadi et al. [13], the maximum calf volume changes occurs in calf region is around 4.4%. However, the most sophisticated region which removed possible involuntary muscle contractions is in region 4. The calf volume changes occurring in region 4 is up to 4% depends on different scenarios, and the measured circumference change in this region is maximum around 4%. The swelling usually occurs when an individual is inactive, for instance, sitting or standing for a long period of time. The blood accumulates in the leg which is the cause of the swelling. However, leg swelling reduces when individual is moving.

2.2 Review on sensing technologies

2.2.1 Electronic textile

One of the popular sensing technologies is electronic textile, an electronic textile (E-textile) is a type of fabric that contains electronic elements. In general, the development of electronic textiles supports the idea of wearable computing, or electronic devices worked into garment designs. Within the relatively new industry around electronic textiles, projects are pursued based on various different kinds of functionality. Many of these are used to the health care industry, where wearable computing elements can be used to monitor vital signs and otherwise track a person's health in real time.

2.2.1 A) Adafruit's conductive rubber band

Figure 2.2. Adafruit's conductive rubber band [14]

A stretch sensor is sold by Adafruit [14] which consist of a round, conductive rubber band as shown in Figure 2.2. It relies on measuring changes in resistance, which enables it to be interfaced to a micro-controller with a simple voltage divider. It is also very cheap in comparison to other sensors solutions. Costing just around $10 for a full meter of the rubber band, which can be used to make multiple sensors. It is not a perfectly linear sensor, but the behavior can be well estimated with a linear function. The rubber band is also very flexible, which is a necessity for it being used in a wearable technology product.

2.2.1 B) StretchSense's stretch sensor kit

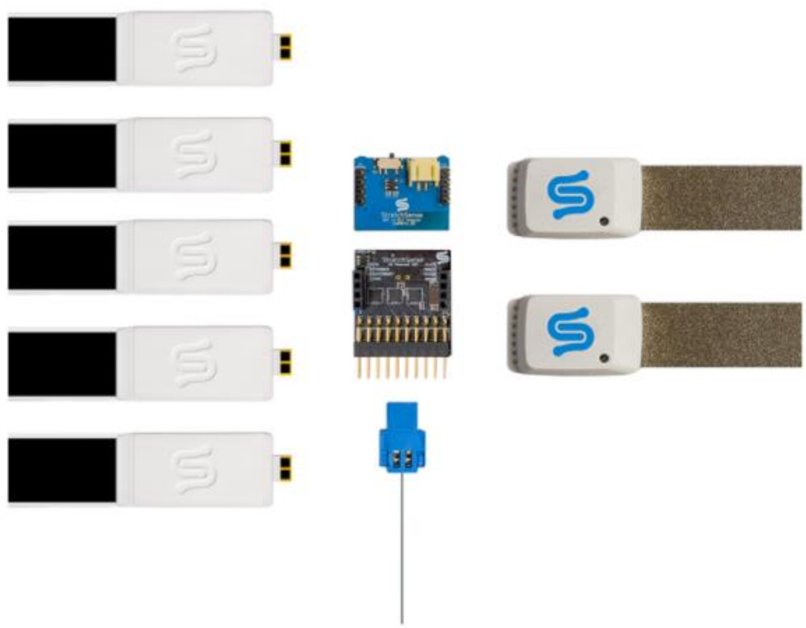


Figure 2.3. StretchSense's stretch sensor [15]

StretchSense's stretch sensor [15] consists of two thin, conductive layers coated with silicone and fabric on both ends for attachment. As shown in Figure 2.3. It uses the capacitance across the two conductive layers to measure the stretch of the sensor, but can also be used to track pressure or strain. The sensor is very soft which is of great for its wearability.

The sensor is quick response and linear with respect to the stretch. However, the sensor also has some serious downfalls. First of all, the price for an evaluation kit is over $1000 excluding taxes, which is very high for this MEng project. By using capacitance as a measuring principle results in the need for additional hardware This reduces the wearability of the sensor. Another downside is that it is not customizable by the designers, only by the manufacturer. So the sensor cannot be cut or sewn in the sensing area, only in the fabric ends. If the size of it needs to be adjusted, this can only be done by ordering new customized sensors from the manufacturer. In conclusion, this sensor works very well, but also has a few disadvantages, especially the price and the need for additional hardware.

2.2.1 C) Stretchable fabrics

Figure 2.4. Eeonyx piezoresistive fabric [16]

Another solution for measuring stretch is made by Eeonyx in the form of a piezo-resistive fabric [16]. When the fabric is fixed on two ends, the resistance over both ends changes alongside with the stretch. The fabric has great the wearability since it is very flexible and does not have any edges like the previously discussed rubber band. Another advantage is a great potential of customizing the sensor according to needs. The fabric can be cut into any desired shape.

However, there are problems with the Eeonyx fabrics as well [17]. The fabrics is the interfacing to the micro-controller. Wires cannot be directly attached to the fabric itself by soldering, so they have to be interfaced in another way. As an example shown in Figure 2.4. This introduces a rigid structure again and can have a negative effect on the wearability.

2.2.2 Motion sensor

With low-cost, low power consumption, and relatively high accuracy, motion sensor have been widely accepted as useful and practical sensors for wearable devices to measure and assess physical activity. The common operation principle of accelerometers is based on a mechanical sensing element which consists of a proof mass attached to a mechanical suspension system with respect to a reference frame. Due to acceleration or gravity, the inertial force will cause the proof mass to deflect. The acceleration can be measured electrically with the physical changes in displacement of the proof mass with respect to the reference frame.

2.2.2 A) activPAL (PAL Technologies Ltd.)

Figure 2.5. activPAL Ambulatory Physical Activity Meter [19]

The activPAL is a motion sensor based on a uniaxial piezoresistive accelerometer. Worn and positioned on the thigh by direct adhesion to the skin, the activPAL classifies sitting, standing and walking among free-living activities. Recorded data is transferred to a PC via USB port. Ryan et al. [18] investigated the validity and reliability of the activPAL, showing that it was a valid and reliable tool in measuring step and cadence of the healthy subjects during walking. The activPAL was also compared with a discrete accelerometer device on the same healthy adults. The study indicated that the activPAL achieved a close match to the proven accelerometric data [19]. For older adults, the activPAL also exhibited accurate step counting and cadence compared with two other pedometers [20]. However, activPAL is a data log sensor, and relatively pricey, it is not the best chose for this project.

2.2.2 B) An affordable IMU: MPU-6050

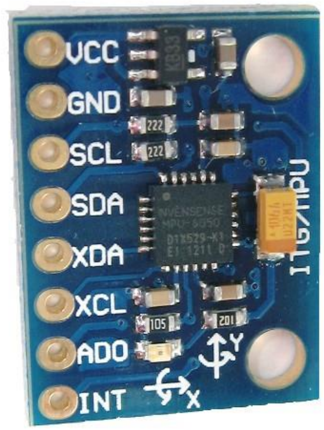


Figure 2.6. MPU-6050 Accelerometer + Gyro [21]

The last few years have seen a revolution in inertial motion sensing technology (Inertial Motion Units or IMUs) that consists of three components: the availability of gyroscope/accelerometer/magnetometer sensors of high precision.

The development of efficient and simple sensor fusion algorithms; and the availability of small, fast, and inexpensive microcontrollers. The combination of these three elements allows the creation of devices that can track orientation with respect to a fixed world frame with high accuracy. The MPU-6050 is made by Invensense[21] is a very small package and for less than $5. The size of MPU-6050 is around 1.5cm * 3cm, it has a great potential use in the wearable device.

3. Context of MEng Project

3.1 Proposed sensor design

As discussed in section 2.1, when an individual is being inactive, as a result, the calf would start to swell, during calf swelling, the corresponding calf circumference change is up to 4%. The proposed design has been a response to individual's activity level and calf circumference. An accelerometer MPU6050 is attached to lower ankle, in order to monitor individual's activity level, shown as Figure 3.1 b) MPU6050 on a leg model.

Figure 3.1a) MPU6050 on bandage

Figure 3.1 b) MPU6050 on leg model

Since there is a relationship between calf swelling and calf circumference. A stretch sensor, Adafruit's conductive rubber band can be used to measure the calf circumference change, and an accelerometer can be used to determine individual's activity level. Combining the reading of leg swelling condition and the individual's activity level, the following 6 cases can be determined:

	SIT	STAND	WALK
NO CALF SWELLING	1	2	3
CALF SWELLING	4	5	6

Table.1 individual's activity cases

In order to test the performance and behavior of each sensor, some test experiments have been done and will be presented in the following section.

3.2 Test of accelerometer MPU6050

Because accelerometer has a great reading frequency, accurate measurement, and it is very inexpensive. It has the potential to determine individual's activity.

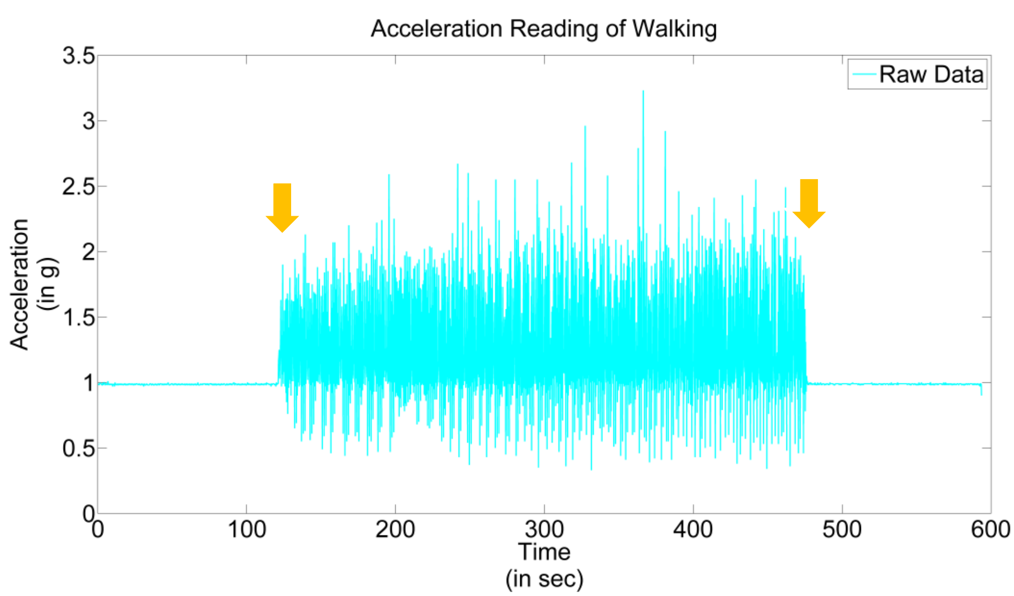


Figure 3.2 Acceleration reading of walking

In order to test the acceleration change between resting (sitting and standing) and walking, an experiment test has been done. The accelerometer was attached to subject’s angle, the subject performed approximately 5min walking on a treadmill with 3km/hour speed. The corresponding acceleration reading is shown in Figure 3.2., where walking starts from 120sec and ends at 480sec (marked with yellow arrows), there is a significant difference between walking and resting. Therefore, the accelerometer would be suitable to justify whether individual is walking or not.

3.3 Test of rubber band

Adafuirt’s conductive rubber band is a stretch sensor, which consists of a round, conductive rubber band. It is not a perfectly linear sensor, but the behavior can be well estimated the change of length and the change of resistance. Since during calf swelling, the calf circumference change can be up to 4%, if rubber band would detect less than 4% length change, it would have a good potential to be the part of the sensory system.

An experiment has been set up to test the reading limit of the rubber band, alligator clips were used to mount the sensor at the center of the linear stage:

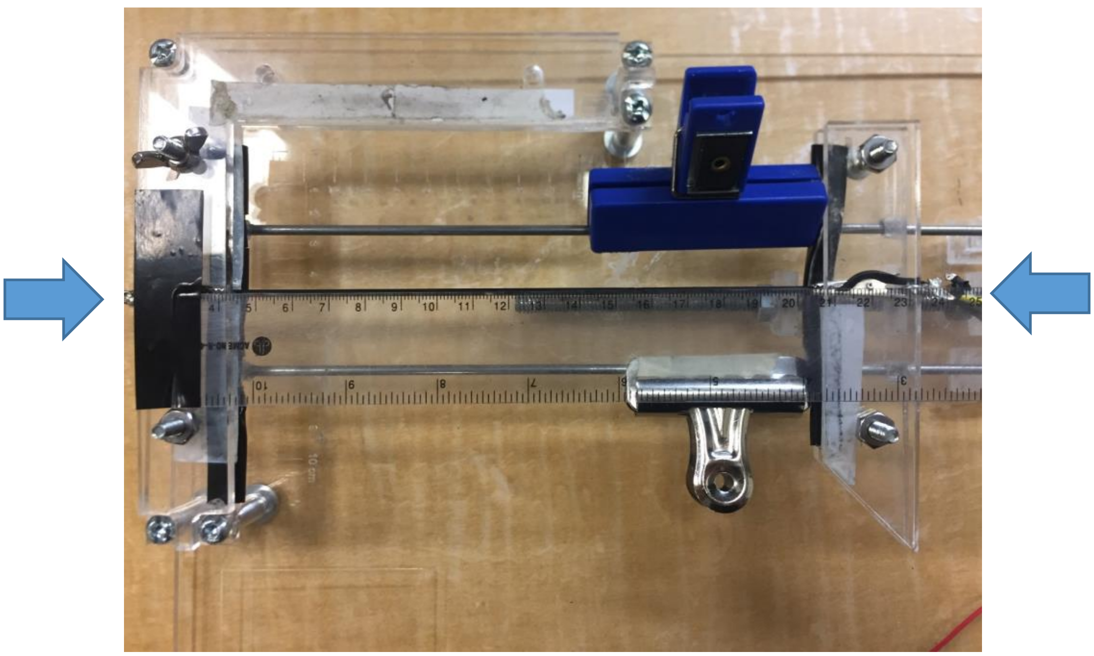


Figure 3.3. Experiment set up on linear stage

As shown in Figure 3.3. An initial length L_0=15cm conductive rubber band is mounted on to a linear stage. The rubber was been stretched 1% of its original length dL=1.5mm at a time, and held for 5 min for each increment. Followed the same process until it reaches 5% of its initial length. Although this stretch test is not same as calf swelling, it can test the detection limit of the sensor (the smallest percentage length change with no voltage reading overlapping) the recorded voltage data shows in Figure 3.4. :

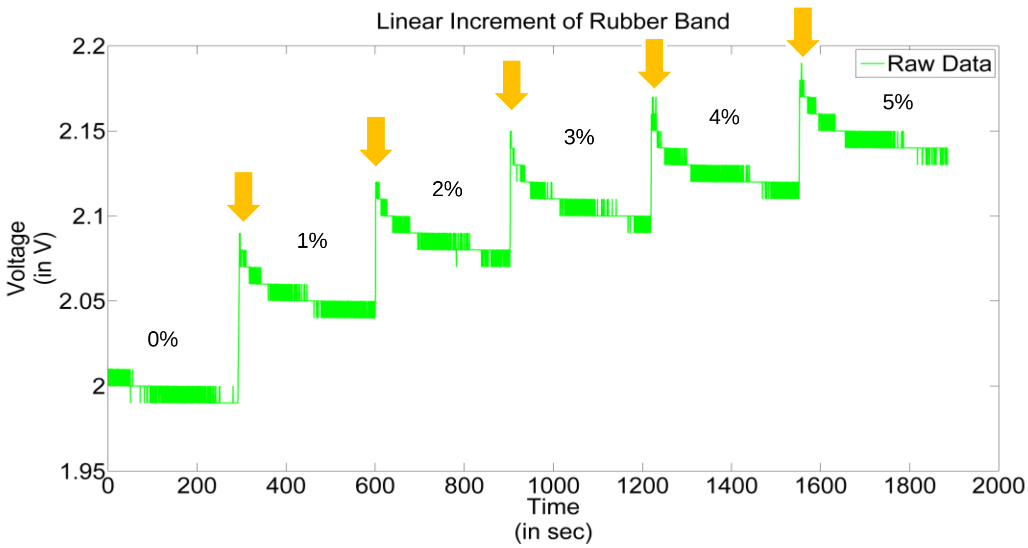


Figure 3.4. Voltage reading of linear increment

From Figure 3.4., every time when stretch(marked with arrows) and hold(marked with percentage) the rubber band, the voltage, however, voltage is keep dropping during each stretch and hold, but we still can justify 3% change from the result since there is no reading overlapping between 0% to 3%, 1% to 4%, and 2% to 5%.

A further experiment on the rubber band has been done: Stretch 1%, 2%, 3%, until reach to 5% its initial lengths, then decrease from 5% to 4%, 3% down to 1%. The voltage was recorded around 5min for each stretch and hold, the time when increment/decrement the rubber band is marked with arrow.

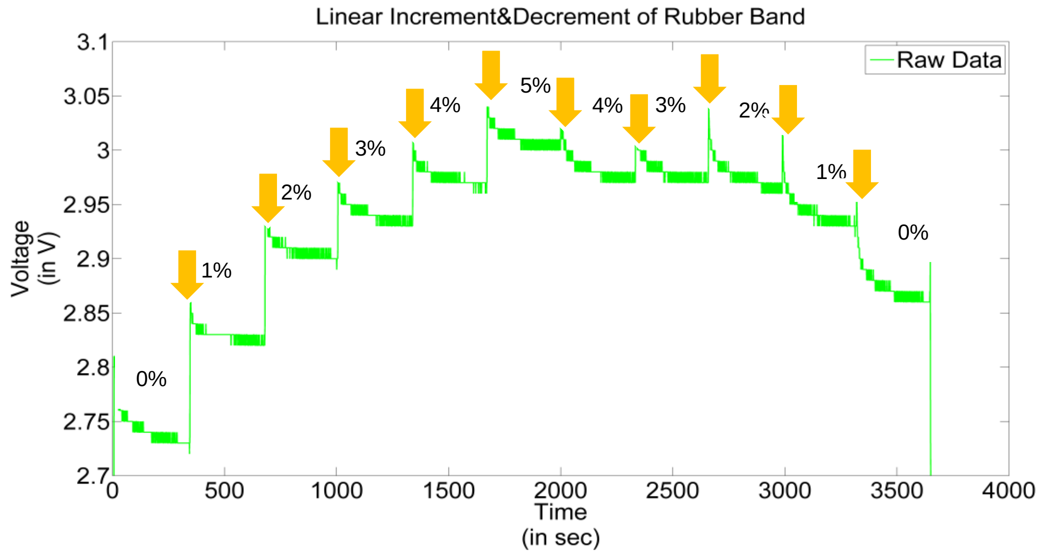


Figure 3.5. Voltage reading of linear increment and decrement

The result shown in Figure 3.5., when decreasingthe length of the rubber band (after 2000 sec), the reading cannot be used to justify even 3% of the length change due to the reading overlapping, for instance, at time 2000sec and 3000sec, the rubber length is different by 3%, but the voltage reading is same, due to this fact, it cannot be justify the length change just based on directly reading the voltage. The sensor is not the best choice for the project.

3.4 Test on medical strain gauge

Since the rubber band is not suitable for detecting small length changes, a medical strain gauge has been introduced to this MEng project. The strain gauge has higher accuracy and commonly used in the medical experiment.

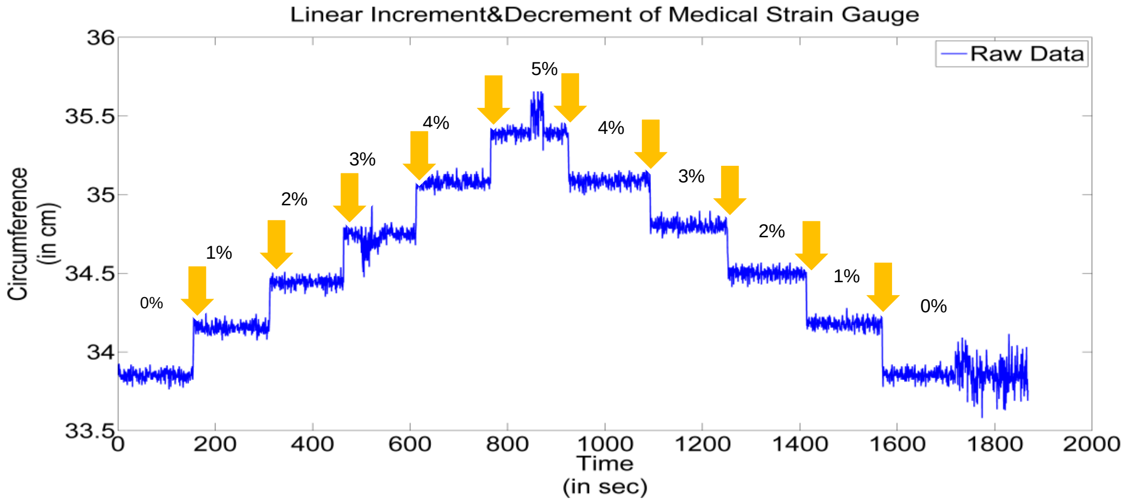


Figure 3.6 Strain gauge increment and decrement on linear stage

A medical strain gauge was tested on linear stage by using the same method as section 3.3. As shown in Figure 3.6. The time when increment/decrement the strain gauge is marked with arrow. Although the signal contained some noise, it can be clearly determined the change in length, and the reading is stable in each increment and decrement. Therefore, this sensor is more suitable for this project compares to the conductive rubber band.

3.5 Experiment design on subject test

Acrroding to Lipp et al.[8] work, by applying pressure on the thigh area can artificially create the calf swelling, as the blood will accumulate in the low leg region. As shown in Figure 3.7a) a pressure cuff was used to create pressure on the thigh area in order to artificially create the calf swelling in short period of time.

Figure 3.7 a) Blood pressure cuff set up

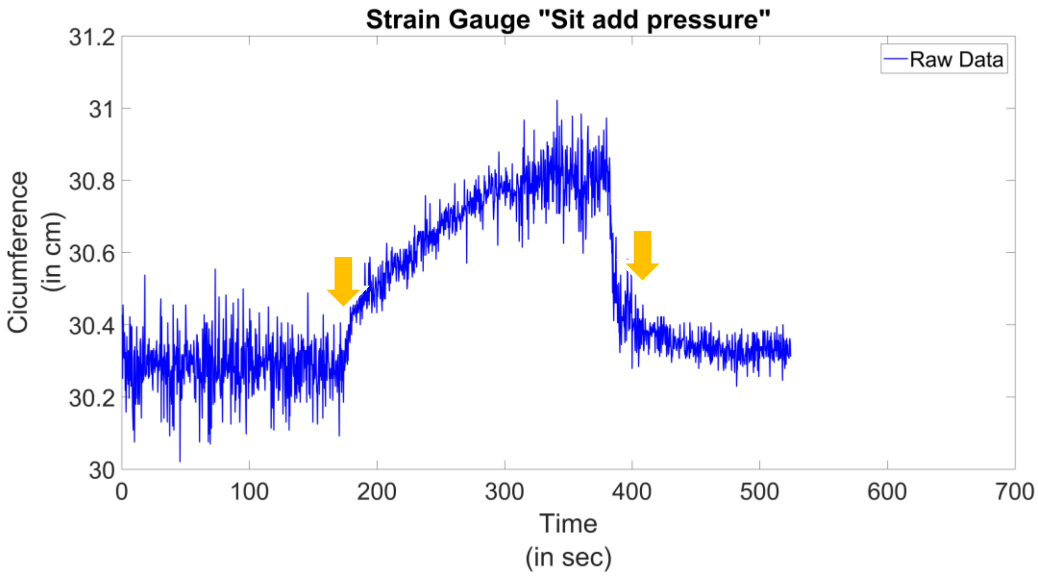


Figure 3.7 b) Strain Gauge reading when applying pressure on the thigh

As shown in Figure 3.7. b), the circumference of the calf region is gradually increasing around 1% of the initial circumference during 180 sec to 400 sec(between the arrows), due to the pressure apllied on the thigh area. By using this method, leg swelling can be artificially created during a short period of time.

In order to cover the six cases in Table 1. discussed in section 3.1, the final subject experimental protocol is proposed as following: (where swelling means artificially create calf swelling by apply pressure on subject's thigh area):

Part A. On treadmill:

- 2min walking on treadmill (No swelling)
- 2min walking on treadmill (swelling)

Part B. Off treadmill:

- 4min standing (2min Swelling+ 2 min No Swelling)
- 4min sitting (2min Swelling+ 2 min No Swelling)
- 2min standing 2min sitting(No Swelling)

Case 1 (sitting) and Case 2 (standing) are covered in 2min standing 2min sitting(No Swelling)

Case 3 (walking) is covered in 2min walking on treadmill (No swelling)

Case 4 (sitting and calf swelling) is covered in 4min sitting (2min Swelling+ 2 min No Swelling)

Case 5 (standing and calf swelling) is covered in 4min standing (2min Swelling+ 2 min No Swelling)

Case 6 (walking and calf swelling) is covered in 2min walking on treadmill (swelling)

As explained above, this particular experiment protocol would cover all 6 different cases, and the experimental data will be selected and classified using classification toolbox later.

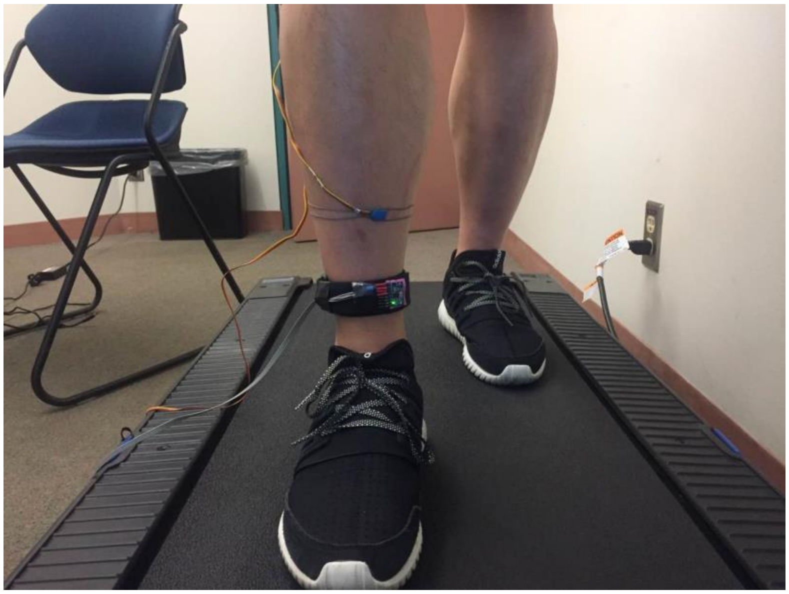


Figure 3.8 a) Experiment setup front view

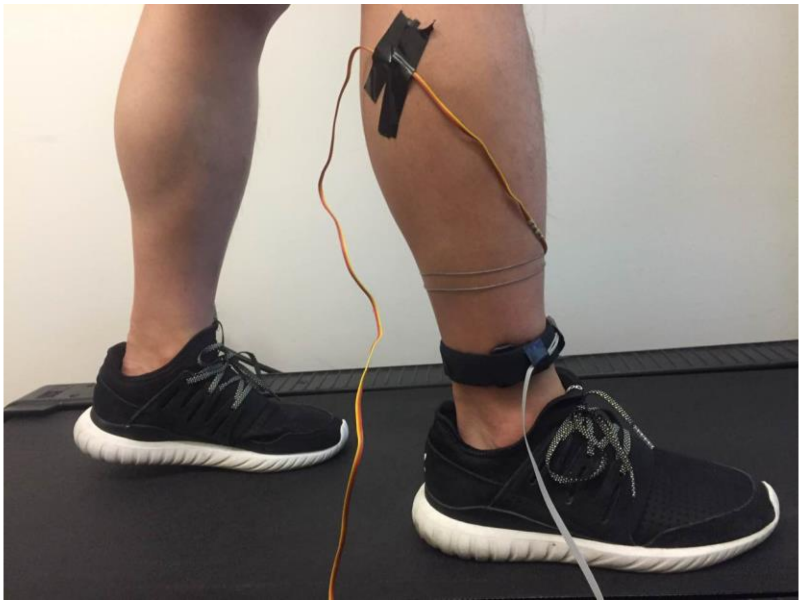


Figure 3.8 b) Experiment setup side view

Figure 3.8 shows the final experiment set up, the accelerometer was attached to the subject's ankle, and the medical strain gauge is around the lower calf region, a blood pressure cuff is attached in subject's thigh area, similar as Figure 3.7.a) in order to artitially create calf swelling for case 4, case 5, and case 6. The two sensors were recording the data simultaneously. Discussion and data analysis is shown in the following section.

4. Data analysis and discussion

4.1 Data gathered from the sensor system

As following the experiment protocol proposed in section 3.5, in order to have sufficient amount of data to be analyzed, each step of the experiment was repeated 10 times (in cycles). All the experiment was done on the same day, to minimize the human error and uncertainty.

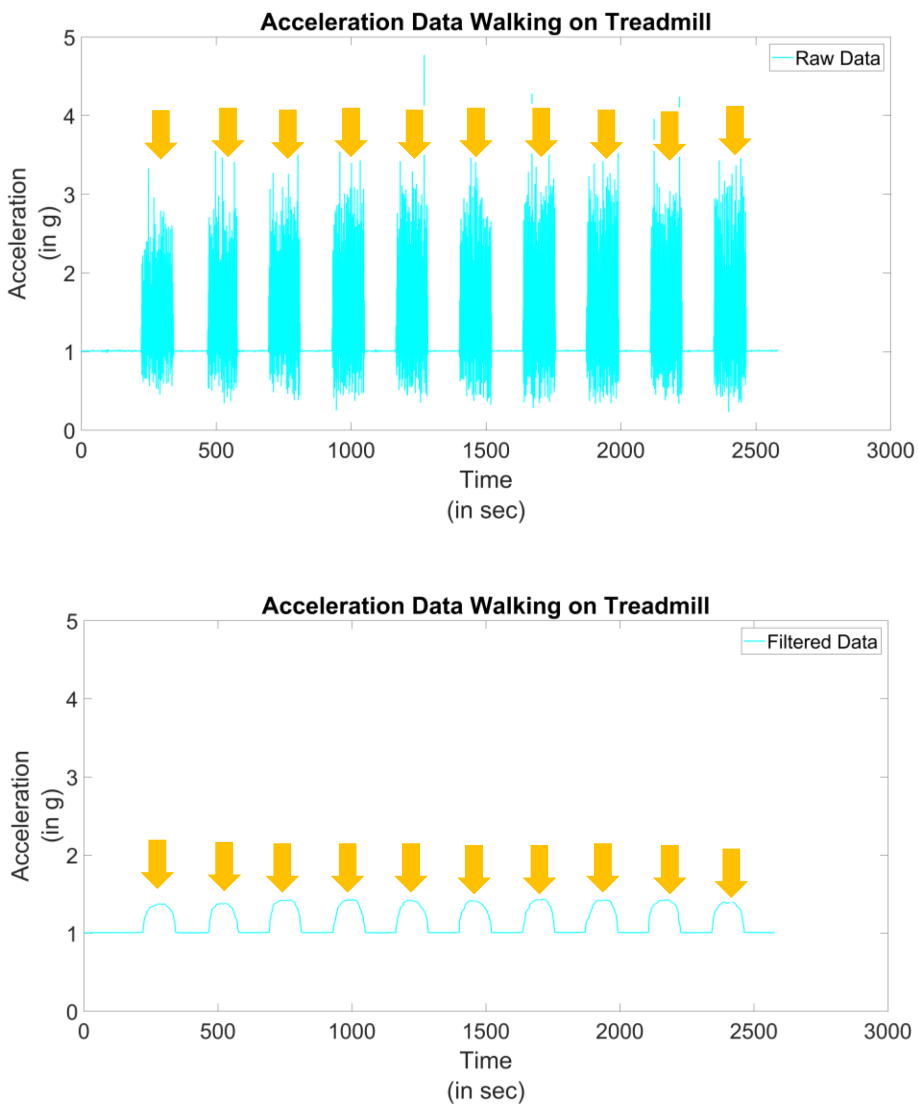


Figure 4.1 Accelerometer reading when walking on treadmill

As shown in Figure 4.1, the raw data (on top) can be used to justify when subject is walking (arrow pointed). To reduce the noise, a median filter with 100 window size was applied (since 100 window size have a good result for this experiment sample size compare to other window size), then an moving average filter with window size 4 was applied, the result in Figure 4.1 (bottom) is more clear compare to raw data.

The accelerometer data will combine with strain gauge data to justify subject is walking or not, so the arrow pointed region will be labelled for case 3(walking) and case 6(walking and calf swelling).

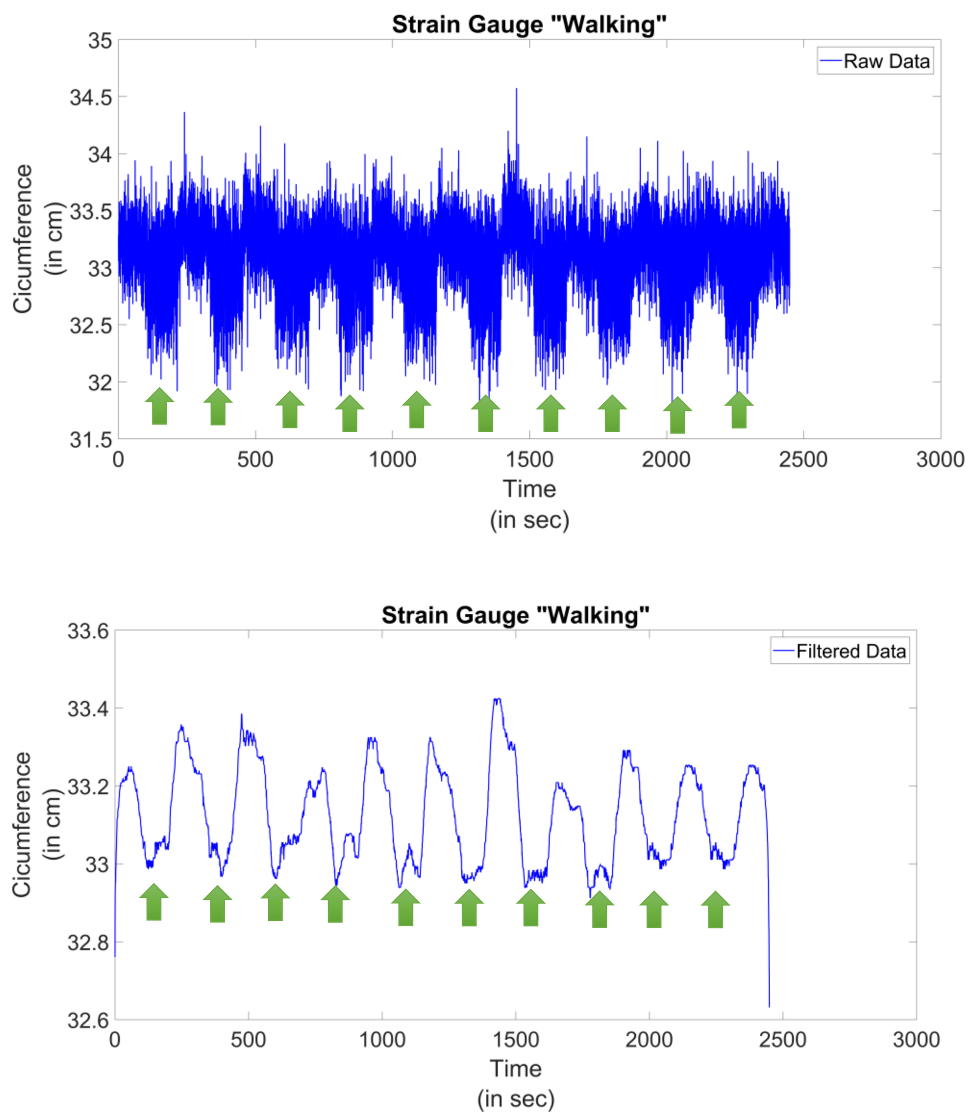
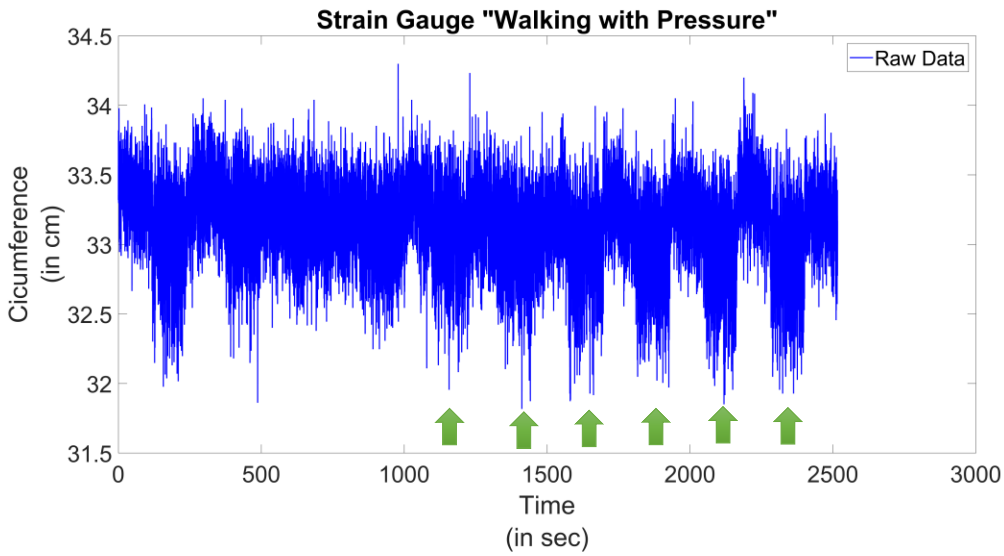


Figure 4.2 Strain Gauge reading when walking on treadmill

In Figure 4.2, the raw data (on top) was filtered with a median filter with 200 window size (since 200 window size have a better result for this experiment sample size compare to 100 window size) the result in Figure 4.2 (bottom) is clearer compare to raw data. During the time region (green arrow pointed) subject was preforming walking, those data is labeled as case 3(walking) combine with accelerometer reading in Figure 4.1.



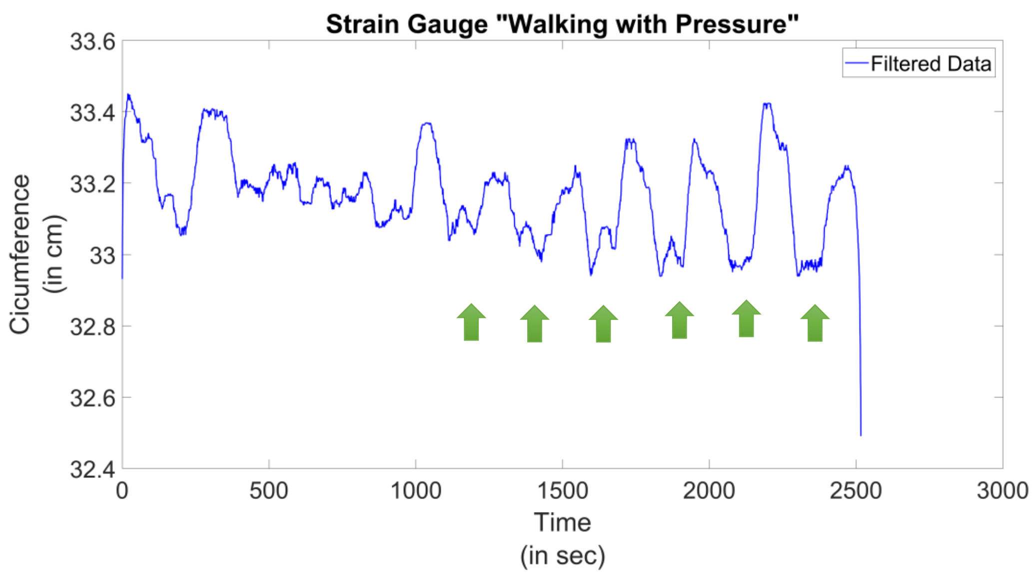


Figure 4.3 Strain Gauge reading walking on treadmill with pressure on thigh area

In Figure 4.3, similarly the raw data (on top) was filtered with a median filter with 200 window size and Figure 4.3 (bottom) is filtered data. In the time region (green arrow pointed) subject was preforming walking with calf swelling, the data combine with accelerometer reading is labeled as case 6(walking and calf swelling), also due the high noise level, some of the data is not clear was dropped (between 0sec to 1000sec)

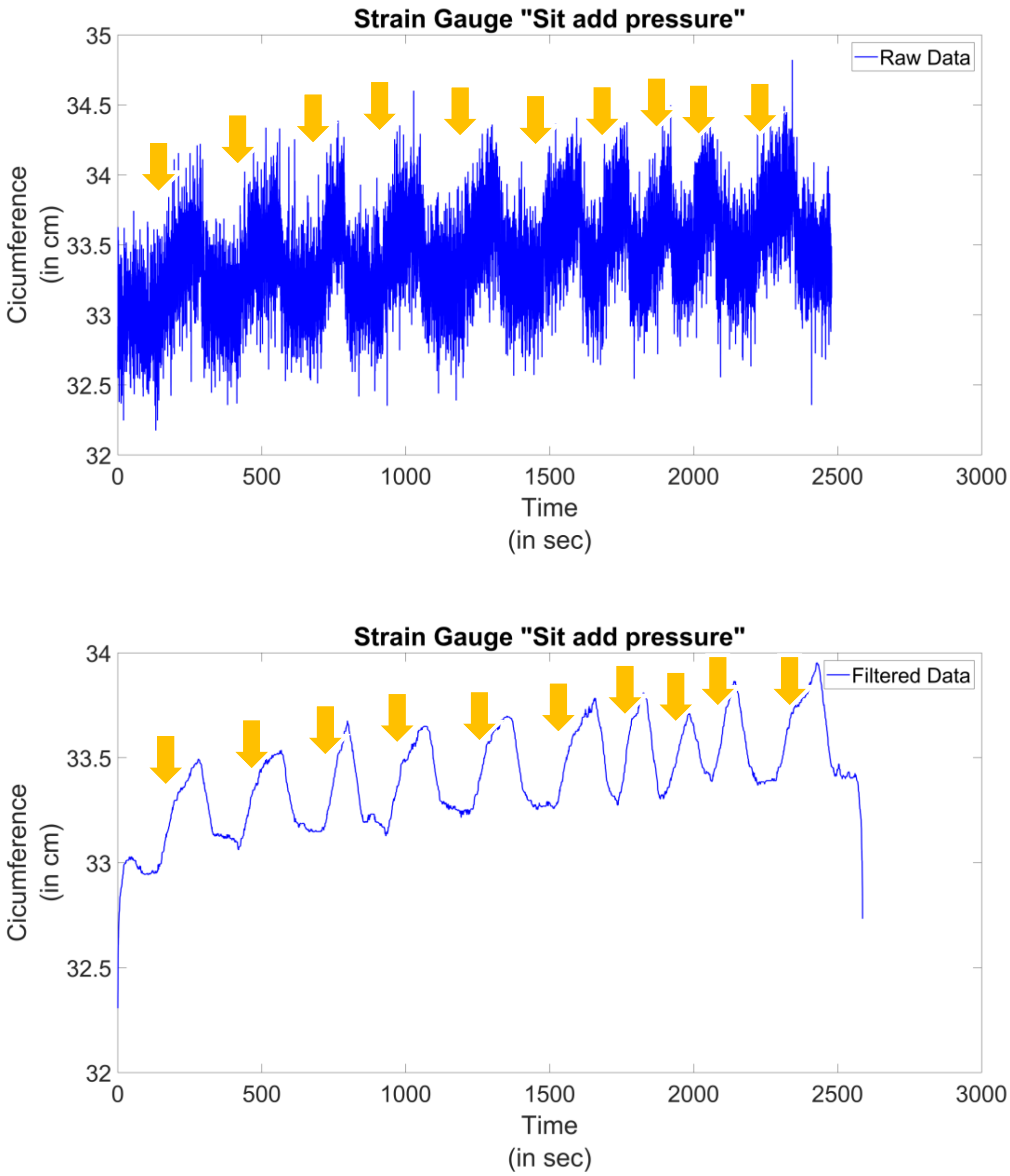


Figure 4.4 Strain Gauge reading when sitting with pressure on thigh area

In Figure 4.4, the raw data (on top) was filtered with same median filter, and Figure 4.4 (bottom) is filtered data. In the time region where circumference is gradually increasing (yellow arrow pointed) the calf is swelling while subject is sitting, those data is labelled as case 4(sitting and calf swelling), since subject is not moving, the accelerometer reading is set as 1 later for the classifier.

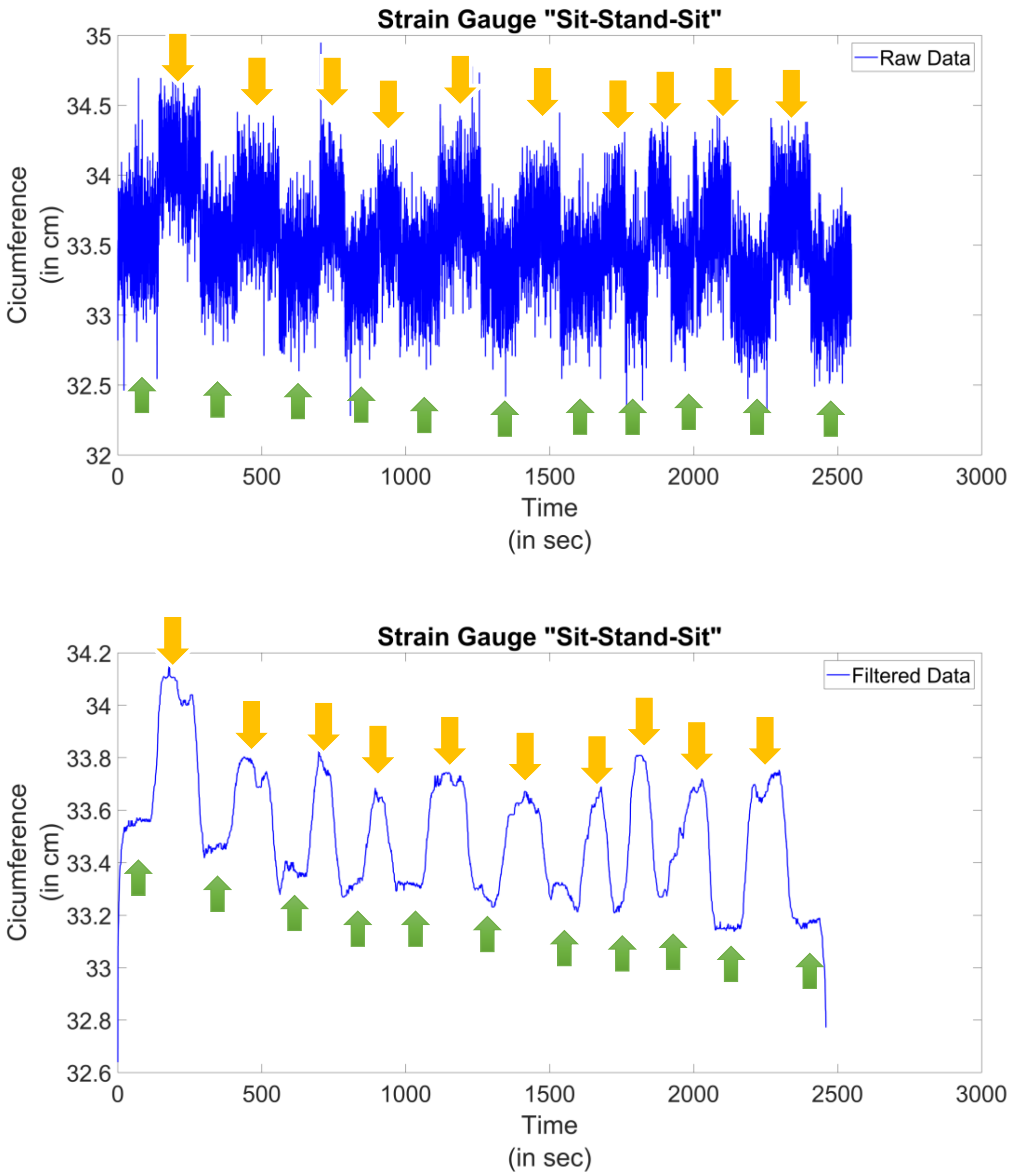


Figure 4.5 Strain Gauge reading during 2min sitting and 2min standing cycle

In Figure 4.5, In the time region (yellow arrow pointed) the while subject is sitting will be labeled as case 1(sitting), and In the time region (green arrow pointed) while subject is standing those data is labelled as case 2(standing), since subject is not moving in case 1 and case 2, the accelerometer reading is set as 1 for the classifier.

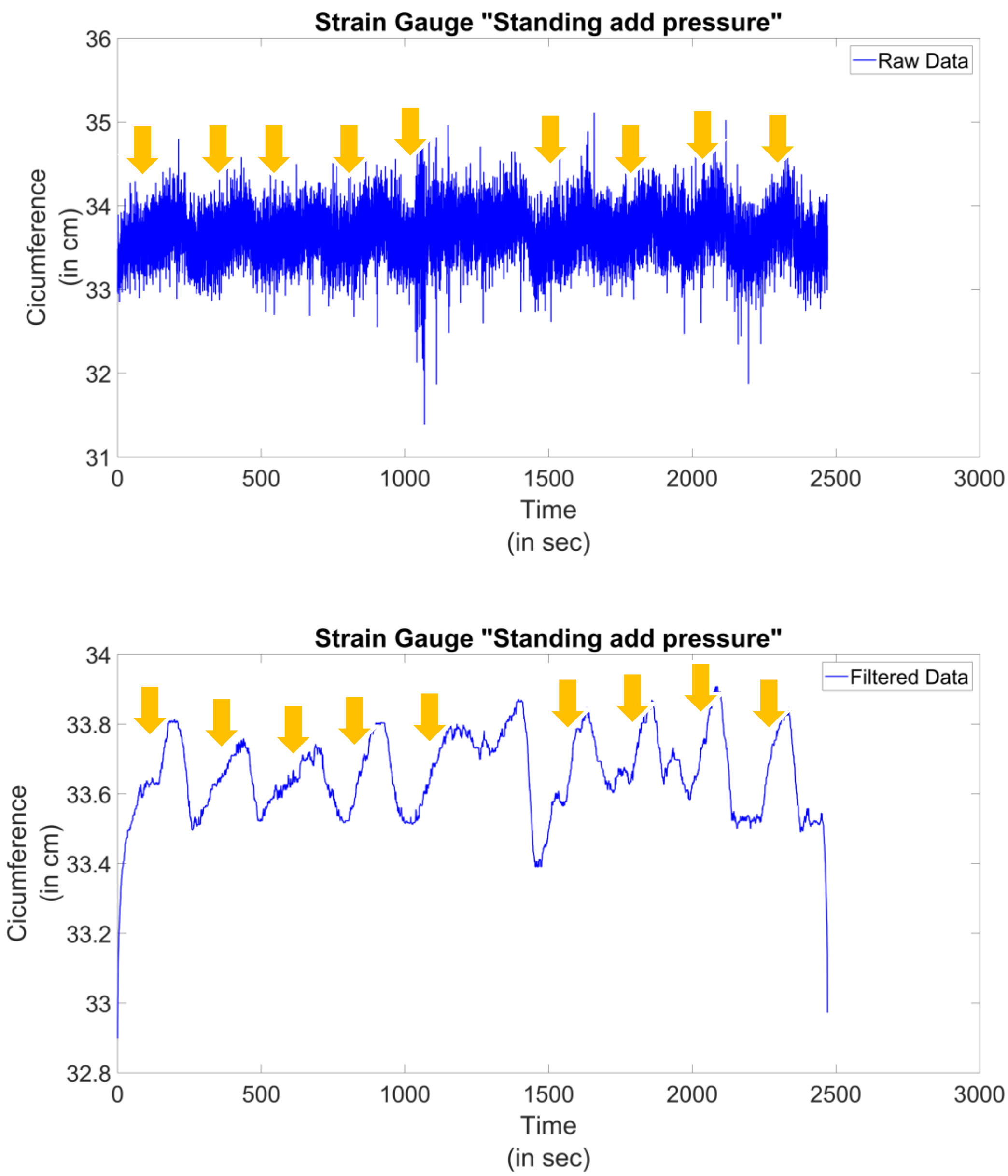


Figure 4.6 Strain Gauge reading when standing with pressure on thigh area

In Figure 4.6, In the time region (where yellow arrow pointed) the calf is swelling while subject is standing, those data is labeled as case 5(standing and calf swelling), the accelerometer reading is set as 1 for the classifier.

As explained, from Figure 4.1 to Figure 4.6, data have been selected and labeled for 6 different cases. In order to justify 6 different cases: sitting, standing, walking, and sitting, standing, walking with calf swelling, Matlab Classification leaner tool box was used to classify 6 different cases. The classification method was used is Linear Discriminant for raw data(Figure 4.1 to Figure 4.6 top) and filtered data (Figure 4.1 to Figure 4.6 bottom).

4.2 Linear Discriminant Analyzer

Linear discriminant analysis (LDA) is a generalization of Fisher's linear discriminant, a method used in statistics, pattern recognition and machine learning to find a linear combination of features that characterizes or separates two or more classes of objects or events [22].

As discussed in the previous section, 6 different cases were classified. Both raw data and filtered data were input to the classifier separately, Figure 4.7 a) and b) are the results for raw data and Figure 4.8 a) and b) are the results for the filtered data. Since the data sets are fairly large, the hold-out validation method was used for both cases, with 75% data training the model and 25% for model validation.

The data input to the classifier are two 12684*3 matrix (raw data input and filtered data input), the 3 column of the matrix from left to right is accelerometer data, strain gauge data, and 6 different Labels. As shown in Table 2. The data is assigned as predictor, and the label is assigned as response

Accelerometer data	Strain gauge data	Label 1 to 6
Predictor	Predictor	Response

Table 2. The classifier option for each group of data

Each row of the input matrix combines the accelerometer reading and strain gauge reading at the same time region with specific label for 6 different cases. For case 1, 2, 4, 5, since subject is not walking, the accelerometer reading is set as 1, for case 3, 6, the accelerometer reading is selected from Figure 4.1(where the arrow marked region).

There are 12684 samples in total, and for each case, the number of sample is shown as following table:

Labeled Case	Number of samples selected for Figure4.1 to Figure4.6）
Case 1. Sitting	2199
Case 2. Standing	2300
Case 3. Walking	2097
Case 4. Sitting(Calf swelling)	1679
Case 5. Standing(Calf swelling)	2099
Case 6. Walking(Calf swelling)	2310

Table 3. Number of samples using for each case

The raw data from Figure 4.1 to 4.6 was input to the classifier. In Figure 4.7, a scatter plot is generated from the classification toolbox

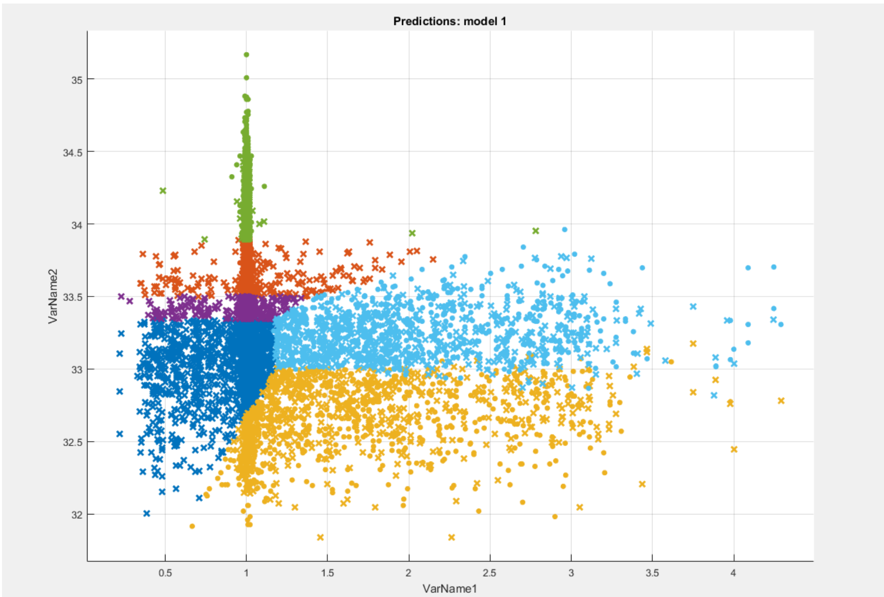


Figure 4.7 a) Scatter plot of raw data

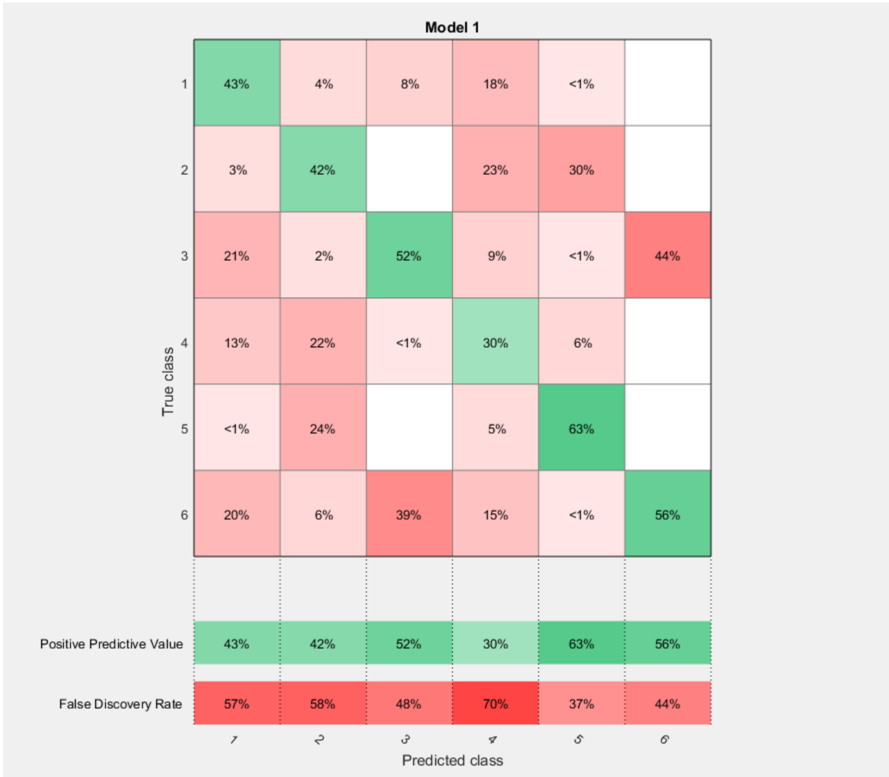


Figure 4.7 b) Confusion Matrix and prediction accuracy of raw data

Figure 4.7 b) is the confusion matrix of the raw data. The overall LDA prediction accuracy of raw data is 48.6%, the 6 cases were poorly been classified, mainly due to the heavy noise level of the reading from the sensors.

The filtered data from Figure 4.1 to 4.6 was input to the classifier. In Figure 4.8, a scatter plot is generated from the classification toolbox, the data is more grouped as compares to raw data plot.

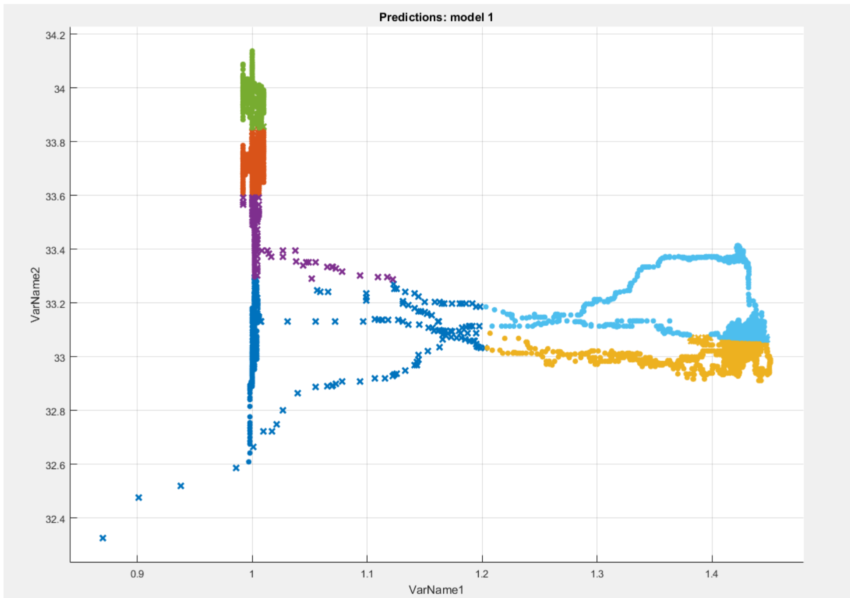


Figure 4.8 a) Scatter plot of filtered data

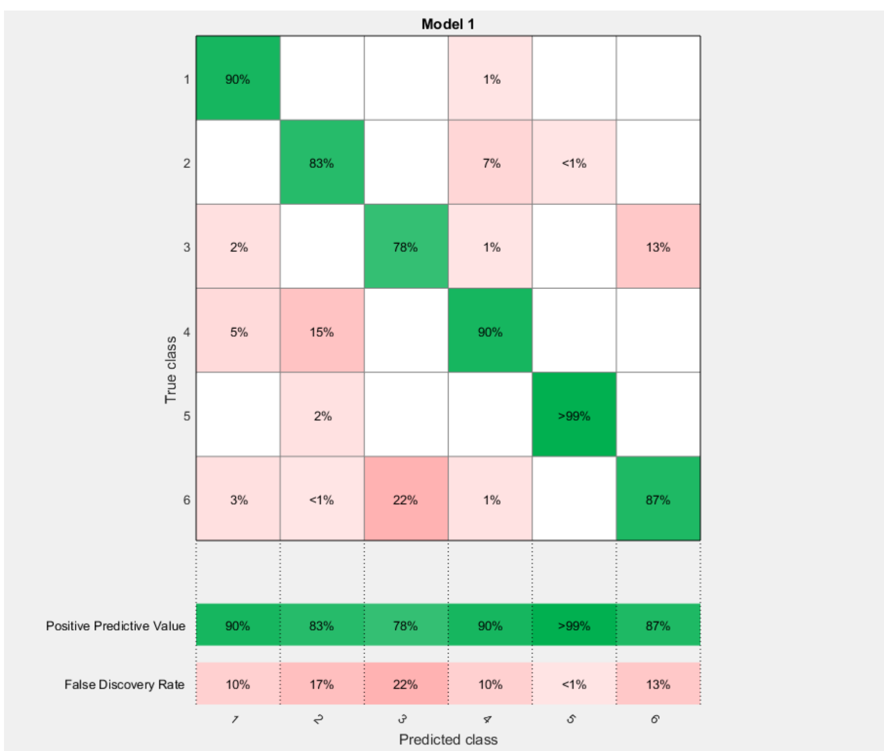


Figure 4.8 b) Confusion Matrix and prediction accuracy of filtered data

For the filtered data, shown in Figure 4.8 b), the overall prediction accuracy is to 87.5%. However, the LDA classifier still failed to justify case3 and case6 by 22%, which are walking, and walking with calf swelling. Because those two cases are both in walking stage, the calf swelling percentage is very small when an individual is active compared to other cases. Since our goal is more focus on detecting the calf swelling when an individual is inactive, the LDA classification result is acceptable.

5. Conclusion and Future work

5.1 Conclusion

In this MEng project, a review of current wearable sensor and technology has been done. Several of sensors have been tested in order to find the suitable sensor of this particular application. Finally, a sensory system combining an accelerometer and strain gauge has been implemented and tested.

The sensory system can be used to detect calf swelling and monitoring individual's activity level, the overall accuracy of LDA classification is over 85%.

5.2 Future work

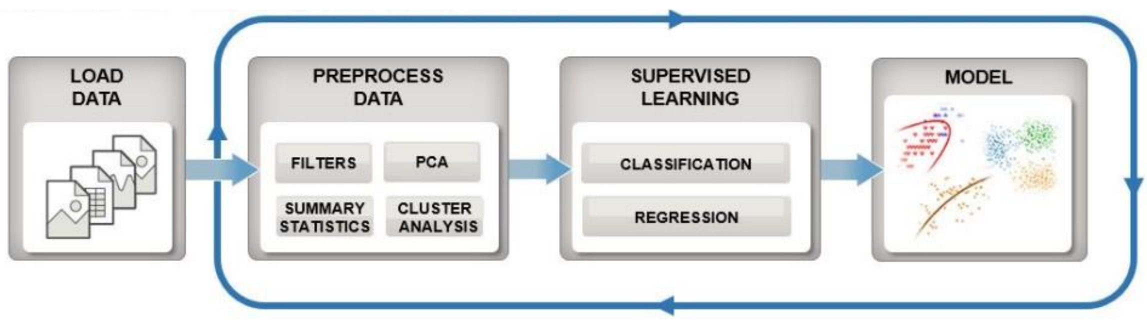


Figure 5.1 Machine Learning work flow [23]

Due to the time constraint, this MEng project is more focused on concept approval of how to use two sensors and Machine Learning classification to justify 6 basic cases. The experiment was done on one healthy subject. In the future, more experiment can be done on different subjects to improve the accuracy of the classification.

Furthermore, a data selection algorithm need be implemented to improve data selection efficiency, in order to have a better classification model.

6. References

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Appendix A. MPU-6050 Reading Sketch

```
// MPU-6050 Short Example Sketch
// Public Domain
#include<Wire.h>
const int MPU_addr=0x68;  // I2C address of the MPU-6050
int16_t AcX,AcY,AcZ,Tmp,GyX,GyY,GyZ;
void setup()
{
  Wire.begin();
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x6B);  // PWR_MGMT_1 register
  Wire.write(0);     // set to zero (wakes up the MPU-6050)
  Wire.endTransmission(true);
  Serial.begin(9600);
}
void loop(){
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x3B);  // starting with register 0x3B (ACCEL_XOUT_H)
  Wire.endTransmission(false);
  Wire.requestFrom(MPU_addr,14,true);  // request a total of 14 registers
  AcX=Wire.read()<<8|Wire.read();  // 0x3B (ACCEL_XOUT_H) & 0x3C (ACCEL_XOUT_L)
  AcY=Wire.read()<<8|Wire.read();  // 0x3D (ACCEL_YOUT_H) & 0x3E (ACCEL_YOUT_L)
  AcZ=Wire.read()<<8|Wire.read();  // 0x3F (ACCEL_ZOUT_H) & 0x40 (ACCEL_ZOUT_L)
  Tmp=Wire.read()<<8|Wire.read();  // 0x41 (TEMP_OUT_H) & 0x42 (TEMP_OUT_L)
  GyX=Wire.read()<<8|Wire.read();  // 0x43 (GYRO_XOUT_H) & 0x44 (GYRO_XOUT_L)
  GyY=Wire.read()<<8|Wire.read();  // 0x45 (GYRO_YOUT_H) & 0x46 (GYRO_YOUT_L)
  GyZ=Wire.read()<<8|Wire.read();  // 0x47 (GYRO_ZOUT_H) & 0x48 (GYRO_ZOUT_L)
  Serial.print("AcX = "); Serial.print(AcX);
  Serial.print(" | AcY = "); Serial.print(AcY);
  Serial.print(" | AcZ = "); Serial.print(AcZ);
  Serial.print(" | Tmp = "); Serial.print(Tmp/340.00+36.53);  //equation for temperature in degrees C
  Serial.print(" | GyX = "); Serial.print(GyX);
  Serial.print(" | GyY = "); Serial.print(GyY);
  Serial.print(" | GyZ = "); Serial.println(GyZ);
  delay(333);
}
```