To Develop, Test and Record a 3 Lead EMG Electrode and Flex Sensor on a 3D Prosthetic Limb with Different Gait Patterns using Arduino Microcontroller.

Eric Nkansah Boateng, Nitin Kumar, Anuj Jain

Electronics and Communication Department, Lovely Professional University, Phagwara, Punjab

Abstract

Electromyograph is very vital in prosthetics and orthosis to monitor the activities of the muscles during gaiting. In this paper we designing, testing and recording the surface Electromyogram electrodes and flex sensors on the 3D above knee prosthetic limb and normal adult limb. Here we use 2 flex sensors placed on the limb and 3 lead EMG electrodes on same limb as per connections.

To test the system performance the above-named sensors are applied to an amputee and a healthy subject during gaiting, thereby measuring the values and graph. This set up and system has suggested that this proposed system is suitable for other applications in biomechanics and robotics.

In this paper, we use surface electromyograph electrode and flex sensor data sets were collected and analyzed for different gait patterns such as flexing of 45 degree of the limb and normal walking gait. Accurate values and graphical representation of both sensors were evaluated and shown.

Keywords 1

Amputation, Electromyography, Gait, Muscle activity, Rehabilitation,

1. Introduction

"The concise design, testing and recording of gaiting activities of an amputee and humans is very essential step in rehabilitations and robotics. In recent times, a lot of different and diverse projects have been built to accurately measure and record human gaiting and muscle activities using EMG signals. But in this paper, we including flex sensors and Arduino microcontroller" [1].

"Electromyography is grouping of electronic signals from muscles by the nervous system during contraction of muscles signals are applied to produce control commands for rehabilitation equipment and robotics, prosthetics and ergonomics especially medical applications" [2]. The measurement and recording of Electromyographic signals are very tedious procedure affected by external factors and other noisodal factors such as system noise, electromagnetic noise and other harmonic interrupts.

A 3-lead surface EMG electrode and flex sensor are attached to the prosthetic and human limb through the EMG sensor and the Arduino controller and software which the gaiting and muscle reactions will be recorded on the screen/monitor. These electrodes have high gain level and impedance input.

WCES-2021: Workshop on Control and Embedded Systems, May 01, 2021, Chennai, India.
EMAIL: knb.bme24@gmail.com (Eric Nkansah Boateng)
ORCID: 0000-0002-1803-7616 (Eric Nkansah Boateng)

The electrodes are made of Ag/AgCl which permits electrons conductivity from the skin to the electromyography. The electrodes have 3 conductor sensors with pads, also here we use electrolytic gel between the skin and electrode so as to reduce electrode impedance.

Even though gait patterns has helped in the field of rehabilitation, it has certain drawbacks. There are other gait analysis in rehabilitation which will be talked about in subsequent projects. Each gait analysis depends on the kind and level of rehabilitation needed. Gait patterns of patients are assessed using different variable and technical procedures [3].

In the "development of an EMG-based muscle health model for elbow trauma patients' sensors was used to identify patterns in EMG data that shows the injury levels of patients with MSK elbow joints. It involves classification models based on EMG data being implemented into the control system of a robotic device to identify the level of muscle health in patients with MSK elbow injury and to respond accordingly" [4].

Furthermore, in the design of "EMG position-controlled system for an active ankle-foot prosthesis, an EMG-controller was used to estimate the intended ankle movement of an amputee according to the measured EMG signals" [5]. It included two EMG controllers that are based on biomimetic and neutral network approach.

"Gaiting cycle has two components, namely the swing phase and stance phase.

Stance phase: That is the phase which the foot is in contact with the ground.

Swing phase: That is the phase which the foot is in the air for limb advancement" [6].

There a number of gait analysis processes used during rehabilitation assessments that is used to strengthen the limbs of the amputee. Examples of such analysis methods includes but not limited to gait event detector which uses functional electrical stimulation. Some also uses cameras to determine the gait patterns not excluding wearable sensors and other imaging processes which are used to monitor gaiting patterns pf amputees.[7]

Gait analysis is very important because it improves the amputee walking and also to decide a specific kind of treatment that should be given to the patient. Again, gait analysis helps to improve comfort of the patient.[8].

During gaiting curves of patients, the area under curve determines the distance covered by the patient. Also, the peak positive and peak negative of the curve can be determined. The same way the times of the peaks can be calculated in the time domain [9]. "A vital problem in the study of a mechanical robot manipulation is the forward kinematics which is the static geometrical problem of computing the position of the robot if a rotation of joints occurred" [10].

Notwithstanding, the velocity and kinematics of the gaiting cannot be overemphasized, The velocity of the gaiting affects the movement and the pressure or force exerted on the limb either natural or artificial limb. The quantity or magnitude of the velocity and pressure all affects the gaiting patterns for automated or mechanized limbs.[11]. In all patients are sometimes trained on how to walk around using specific models.

2. Methodology

The main purpose of this paper is to design, measure and record the numerical and graphical functions of the electromyograph and flex sensors on an active limb and a 3D lower limb using a direct method while classifying and reviewing the analysis.

2.1. Parts and quantity used for the design.

Table 1: Component parts and quantity.

Part	Quantity
EMG sensor	1
Flex sensor	2
Arduino uno controller	1
Software	2

The above component parts are purchased, checked and accepted. Connections are made per diagram below. Arduino uno software must first be installed before any simulation is done. The EMG electrode is connected to the Arduino uno via the EMG sensor. Also, the flex sensors 1&2 are connected to the Arduino uno controller. The output of the controller is then fed to the display computer.

EMG electrodes and flex sensors are attached to specific muscle lower limb muscles namely knee, ankle and gastrocnemius muscles.

The set up is run/start per a specific gait pattern while recording values and graphical readings of same gait pattern.

2.2. Factors affecting the workability of the prosthetic limb

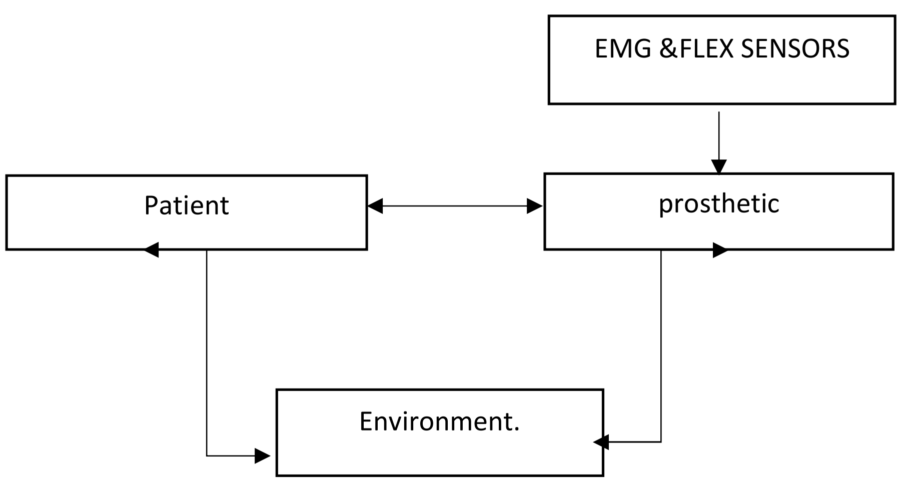


Figure 1: Factors affecting workability of prosthetic limb.

The above diagram describes the factors which affects the workability of a prosthetic limb, namely the patient, the prosthetic itself and the environment at which the system will be used. One portion of the system depends on the other for the overall functionality of the artificial limb.

2.3. Block diagram of the Proposed System

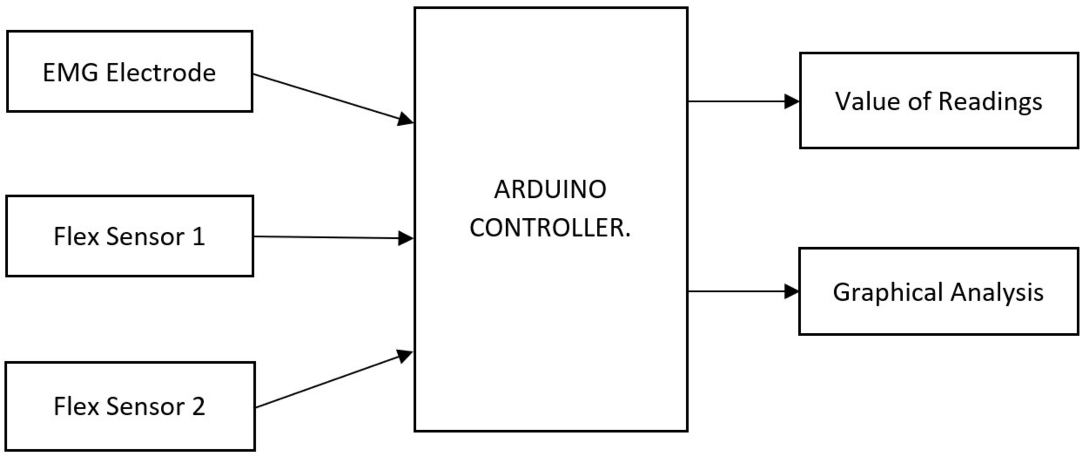


Figure 2: Block diagram of the Proposed System

Description of Hardware Implementation

The 3 sensors are connected to the human lower limb and the 3D prosthetic limb, then the output is then connected to the input of the Arduino microcontroller from which the output is connected to the display show values and graphical representations. Two flex sensors are used with one EMG sensor and 3 lead electrodes.

Figure 3 shows the Myoware EMG sensor detects bioelectrical signals or electric potentials produced by the muscles and feeds them into the Arduino controller for processing.

Figure 4 also shows the Arduino micro controller is an open-source controller with input and output pins which is interfaced with other boards powered by 5 volts dc voltage producing 3.3 volts by the on-board voltage regulator.

2.4. Control System used to Control the Simulation

Figure 3: Myoware EMG Sensor

Figure 4: Arduino Uno Controller

2.5 Flowchart of the system

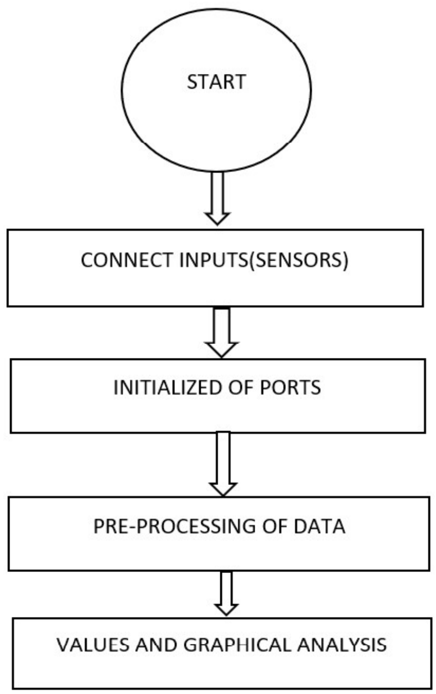


Figure 5: Flowchart of the system

The above flow chart represents the stepwise technical procedure or process which was systematically followed to install, recoding and display of readings. First of all, the Arduino uno software should be installed on the computer.EMG sensors and flex sensors are connected to the lower limb for different gaiting patterns. The electrodes and sensors are attached to the joints of the lower limb of a particular gait pattern. All sensors are connected to the input of the Arduino uno controller which is then connected to the computer via a D-connector.

Simulation is then done per the gaiting patterns while recording of the EMG and flex sensor is taken with regards to the real values and graphical analysis per the gait patterns.

2.6. EMG Control System

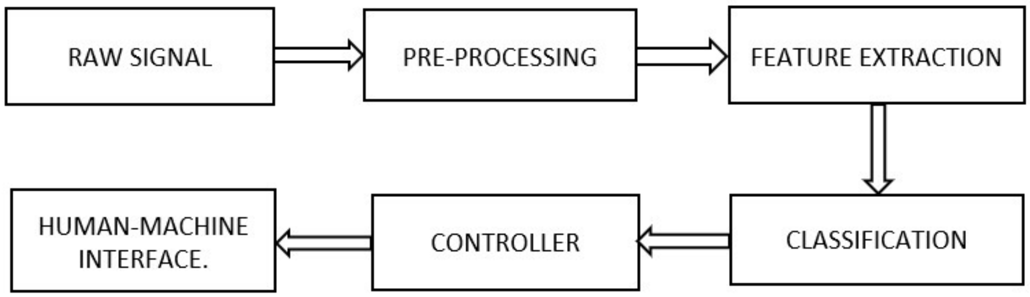


Figure 6: Electromyogram control and feedback system

The above figure depicts the control system of the electromyograph recordings. Raw signals are acquired through data acquisition process from the patient. The signals are then processed, whereby filtering and amplification takes place. The third stage is feature extraction where noise and other irrelevance elements are removed.

The signals are then classified and categorized by the Arduino uno controller. Commands are sent to the system to read real value and graphical representations of each gaiting pattern which is displayed on the screen for recording.

2.7. Placement of electrodes and sensors on the lower limb.

Table 2: Electrodes and site of placement on lower limb

SENSORS	POSITION
EMG 1 (RED)	ANKLE JOINT
EMG 2 (YELLOW)	KNEE JOINT
EMG 3(GREEN)	GASTROCNEMIUS (muscle at back of lower limb)
FLEX 1	ANKLE JOINT
FLEX 2	KNEE JOINT

3. Results

This study describes the electrical behavior of EMG and Flex sensor patterns on natural lower limb and prosthetic limb during swing and stance phase during gaiting. Gaiting patterns have become very important in recent experiments with different outcomes. However, electromyography has become paramount in the rehabilitation sector with its results being used to diagnose and treat patients and amputees.

The gaiting methods below were used in this paper to record the values of the sensors.

a. Lifting one leg off the ground.
b. Using the leg in contact with the ground, push your body forward.

3.1. Gait A. lifting one leg off the ground

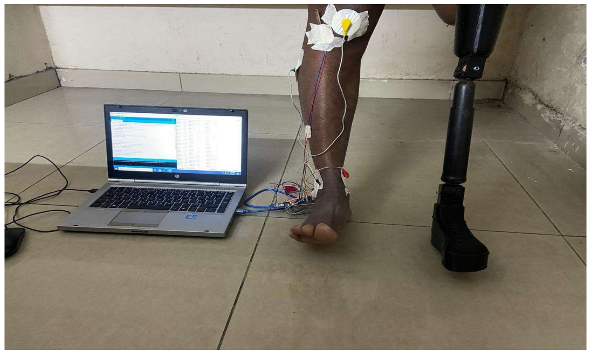


Figure 7: Lifting of one leg off the ground

Graphical analysis of the Gait A above showing the values of the EMG electrode and 2 flex sensors.

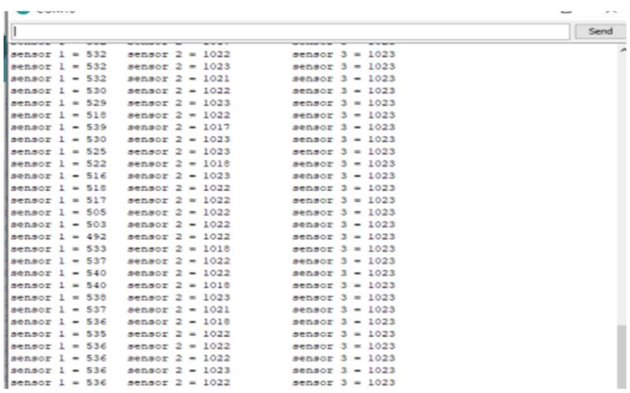


Figure 8: Values of the EMG electrode and 2 flex sensors of Gait 1

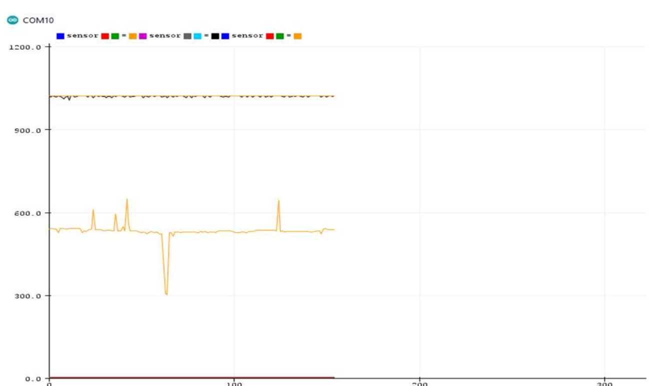


Figure 9: Graphical representation of EMG electrode and 2 Flex Sensors

3.2. Gait B Using the leg in contact with the ground, push your body forward

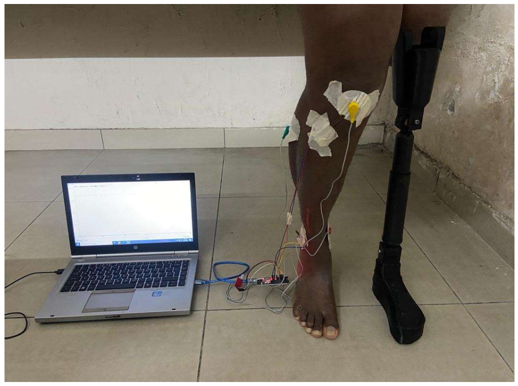


Figure 8: Using the leg in contact with the ground, push your body forward

The figures below represent the values of the EMG sensor and flex sensors during simulations as per the coding. It shows the values and graphical representations. The electrode and flex sensors were attached to the surface skin of the vital joints of the lower limb thereby recording the corresponding signals and readings.

The table and graphical analysis below are for the Gaiting pattern above showing the values and graph of the EMG and 2 flex sensors.

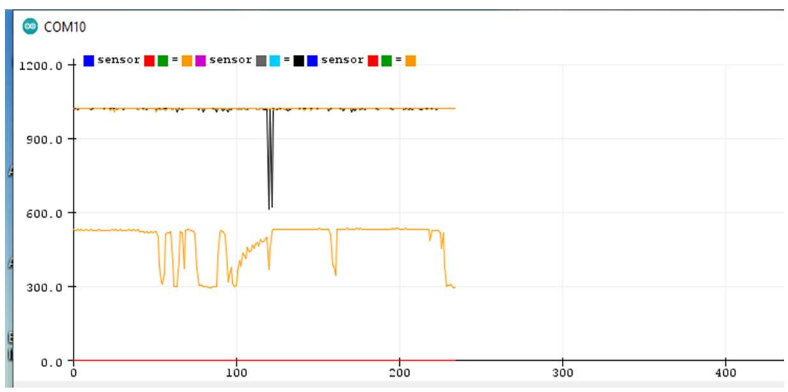
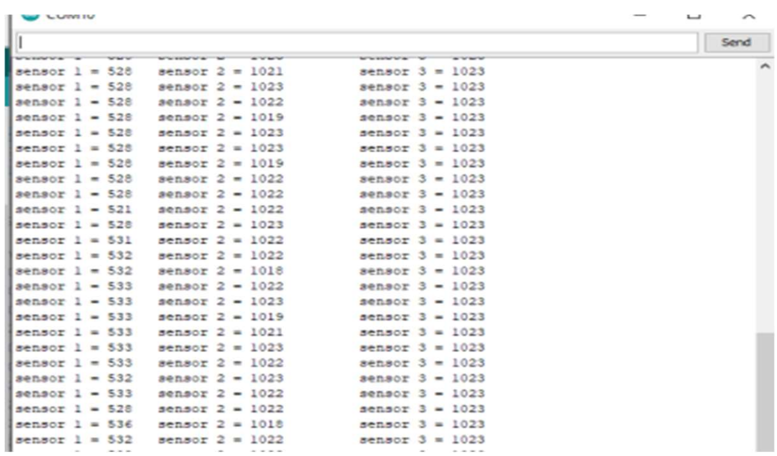


Figure 10: Graphical representation of Gait B of EMG electrode and Flex Sensor



```
sensor 1 = 528   sensor 2 = 1021       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1023       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1019       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1023       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1023       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1019       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 521   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1023       sensor 3 = 1023
sensor 1 = 531   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 532   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 532   sensor 2 = 1018       sensor 3 = 1023
sensor 1 = 533   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 533   sensor 2 = 1023       sensor 3 = 1023
sensor 1 = 533   sensor 2 = 1019       sensor 3 = 1023
sensor 1 = 533   sensor 2 = 1021       sensor 3 = 1023
sensor 1 = 533   sensor 2 = 1023       sensor 3 = 1023
sensor 1 = 533   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 532   sensor 2 = 1023       sensor 3 = 1023
sensor 1 = 533   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 528   sensor 2 = 1022       sensor 3 = 1023
sensor 1 = 536   sensor 2 = 1018       sensor 3 = 1023
sensor 1 = 532   sensor 2 = 1022       sensor 3 = 1023
```

Figure 11: Values of EMG electrode and two flex sensors of Gait pattern B.

Interpretation of the graph and values of the gaiting patterns.

The values of the EMG indicate the electrical activity of the area muscles during gaiting. Again, the real values of the flex sensor indicates the bending nature of the sensor during that specific gaiting. One flex sensor is attached to the knee joint whiles the other is attached to the ankle joint.

Again, the graphical representation indicate the displacement of the muscle fibers at each node of the electrodes. They are able to pick up the mechanical energy during gaiting to electrical signals which is being analyzed.

The flex sensors gave similar values and graphical analysis even at different positions because of their bending properties at instance gaiting. Some gait patterns require a specific coding. It also depends on the gait recognition system and rehabilitation process. It may be python, java or even MATLAB to code the gaiting process.

4. Conclusion

The developed system can be attached to the lower limb of an amputee or on normal limb (unamputated limb). The entire system is an embedded system with input and output signals. The system has its limitation: It cannot be used for running and climbing. It is comfortable for normal gaiting(walking).

In this paper, proper care was taken on specific areas of muscle movements of the lower limb. Force exerted on the muscle could affect the values and graphs of the gait patterns as this could be a factor of misinterpretation and abnormal graphs. Electromyograph and flex sensor values and their corresponding graphical representations were displayed and recorded on the prosthetic limb at different gaiting.

The swing and stance phase of the patient gaiting was simulated and values recorded seemingly. Electromyograph is normally used in medical situations to check limb activities and strength of stumb and muscles of the amputees during rehabilitation. There is difference when taking recording of a natural limb to a prosthetic limb as the later shorts of natural muscles.

At the braking part of the stance phase of gaiting the knee muscles was aiding in the braking which also had effect on the sequence of the signals and again during the propulsion portion of the stance phase care was taken in measurement as the ankle had the most effect of the gaiting.

4.1. Software/ Coding

There is so many software that has been used to monitor gaiting patterns of amputees and to record Electromyography of patents. However, in this paper we using the Arduino uno software which was installed in the PC with windows setup. This setup is used alongside Arduino Uno controller with the Python coding to enable smooth running of the program.

```
const int analogInPin1 = A0; // Analog input pin that the potentiometer is attached to
const int analogOutPin = 9; // Analog output pin that the LED is attached to
const int analogInPin2 = A1;
const int analogInPin3 = A2;
```

```
int sensorValue1 = 0; // value read from the pot
int sensorValue2 = 0;
int sensorValue3 = 0;
void setup() {
// initialize serial communications at 9600 bps:
Serial.begin(9600);
```

4.2. Future Development

In our future scope of work, we wish to include force sensor which will measure the force exerted on the lower limb during specific gait pattern at swing and stance. Again, in future works we want to make it more automated by including a motor to make the prosthetic limb more automated. Also, we wish to include more gait patterns and subjects during data recording. In this work the importance of three kinds of muscles were investigated on how they react during stance and swing phase of gaiting in which knee extension and ankle plantar which help in locomotion thereby supporting the limb. There are two kinds of lower limb muscles, that's the monoarticular and biarticular muscles. Simulations showed that there are irregular patterns of EMG when the subject displaces himself due to shift of muscles.

5. Acknowledgement

I would like to thank the Almighty God for the strength He has bestowed on me throughout my studies. Again, would like to give a special gratitude to my supervisor Mr. Nitin Kumar for his continuous support, coaching and advice putting up this paper.

Funding: The paper was written and funded by the author.
Conflict of Interest: The author declare no conflict of interest.

6. References

[1] Castro J.L, Medina-Carnicer,Design and Evaluation of a new three dimensional motion capture system based on video, Gait posture,2006.

[2] Moeslund T.B, Granum E.A Survey of computer vision-based human motion capture. Computer vision-based human motion capture. Computer vision Image Understanding,2001.

[3] Javier Marin, Jose.JMarin,Teresa Blanco, Is My Patient improving?Individualised Gait Analysis in Rehabilitation.

[4] Emma Farago.The university of western Ontario,' Development of An EMG-based muscle Health Model for elbow Trauma Patients",August,2018.

[5] Samuel K. Au, Paolo Bonato,Hugh Herr.An EMG-position Controlled system for an active Ankle-foot prosthetics.An initial experimental study".9th International Conference on Rehabilitation Robotics.July,2005,IL USA.

[6] Y.Kalyan Chakravarthy,R.Harish Kumar, A.Srinath," Automatic Control using Haptics for prosthetic leg" Mechanical Engineering, KL University, Guntur.

[7] Ngan-Calvin,"Design and Evaluation of a Prosthetic knee Joint based on Automation Stance-phase lock.(ASPL) Technology for children with Transfemoral Amputation., Institute of Biomedical Engineering, University of Toronto,2018.

[8] Rami Alkhatib," Human Locomotion Analysis Classification and modelling of normal and Pathological vertical ground reaction force signal in elderly".2016, Lyon University.

[9] Yazan Ahmad Manna,"A gait Generation mechanism for leg Rehabilitation Therapy"August,2015 New Jersey Institute of Technology.

[10] Samuel K. Au,Paolo Bonato,Hugh Herr.An EMG-position Controlled system for an active Ankle-foot prosthetics.An initial experimental study".9th International Conference on Rehabilitation Robotics.July,2005,IL USA.

[11] academic.oup.com/icb/article/48.