

Automatic Control Using Haptics for Prosthetic Leg

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Abstract

Robotic prosthetic leg supports the individuals with above or below knee amputations. It mimics the action of normal human leg, reflecting typical movements involved during stance and swing phases of human walking cycle. This paper presents the detailed analysis on change of proper acceleration during walking and running at different speeds. Precise movements of this robotic leg are achieved using haptic technology. Sensors are placed on the un-amputated leg that traces its continuous motion and the same is replicated for the movement of prosthetic leg. These sensors capture the movements of un-amputated leg and foot to the microprocessors. Using this data, corresponding actuators are actuated with required angle and speed to reciprocate the leg movement.

Keywords: Prosthetic, amputations, Haptics, mimics, Articulation, Gait cycle.

1. Introduction

In orthopedic medicine, prosthesis, prosthetic or prosthetic limb is an artificial device extension that replaces a missing body part. It is part of the field of bio-mechatronics, the science of using mechanical devices with human muscle, skeleton, and nervous systems to assist or enhance motor control lost by trauma, disease, or defect. Prostheses are typically used to replace parts lost by injury (traumatic) or missing from birth (congenital) or to supplement defective body parts. Inside the body, artificial heart valves are in common use but lungs are less common and under active

technology development. Other medical devices and aids that can be considered prosthetics include artificial eyes.

This paper provides solution that helps the people with above or below knee amputation to walk normally without any support. This is developed on the phenomenon that, during locomotion both the legs perform similar action but at different point of time. So in brief, reproducing the movements of the un-amputated leg in the robotic leg can make the person walk.

2. Principle

2.1 Analysis of gait cycle

The gait cycle has two basic components, the *swing phase* and the *stance phase*.

- Stance: phase in which the limb is in contact with the ground
- Swing: phase in which the foot is in the air for limb advancement.

Considering this gait cycle, both legs undergo same phases at certain interval of time. When the movement is even then it both the legs undergo these phases one after other at equal intervals of time.

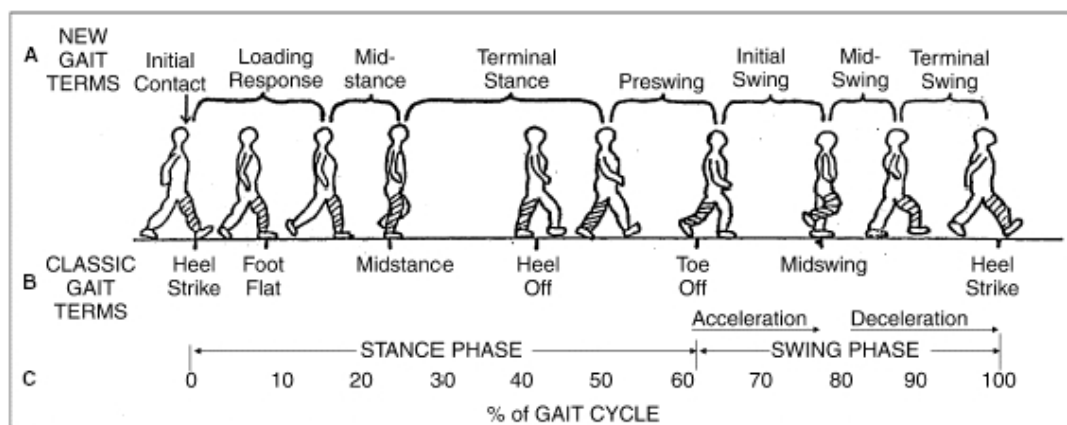


Fig. 1: Gait analysis. Source National Center for Biotechnology Information.

2.2 Approach

There are two approaches to implement this mechanism. Feedback from the un-amputated leg results in the difference between these two methods. First type of approach is without feedback and can be called as open loop method where second approach is with feedback and called as closed loop method.

2.2.1 Open loop approach

In this method time intervals between the knee movements are generalized and those intervals are programmed into the robotic limb. But the main drawback is un-amputated leg has to adapt to the speed and timing of the robotic leg. Second approach overcomes this problem.

2.2.2 Closed loop approach

Here robotic limb adapts to the speed and timings of the un-amputated leg, making them more comfortable. This adaptability is reached by taking continuous feedback from the un-amputated leg. Sensors placed on un-amputated leg notify the position to the central control system.

3. Walking Analysis

To make such a robust and adaptable system, thorough analysis is required. In order to estimate the threshold of forward and backward swing of the leg, general walking and running states should be analyzed. Different subjects of distinct age, weight and gender were chosen for the analysis as these parameters are dependent of gait cycle [1]

Position sensors were placed on the leg and readings were observed on the oscilloscope. Parameters observed are the position variables, time and speed at which subject is walking or running.

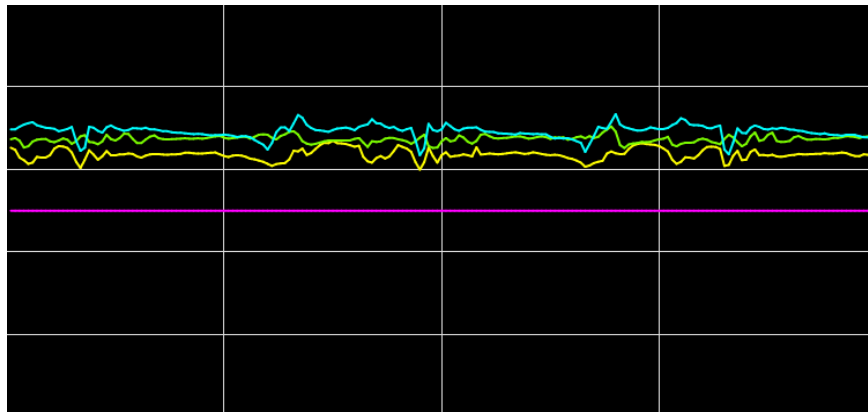


Fig. 2: Male Subject 1 walking at 4Kmph.

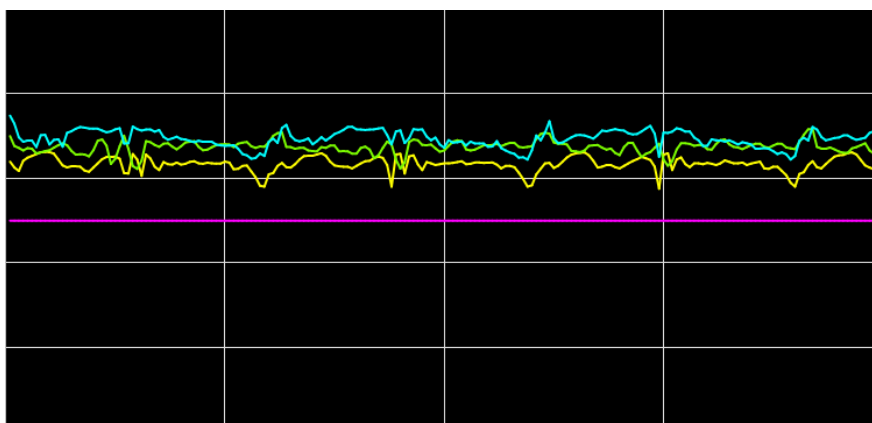


Fig. 3: Male Subject 1 running at 6Kmph.

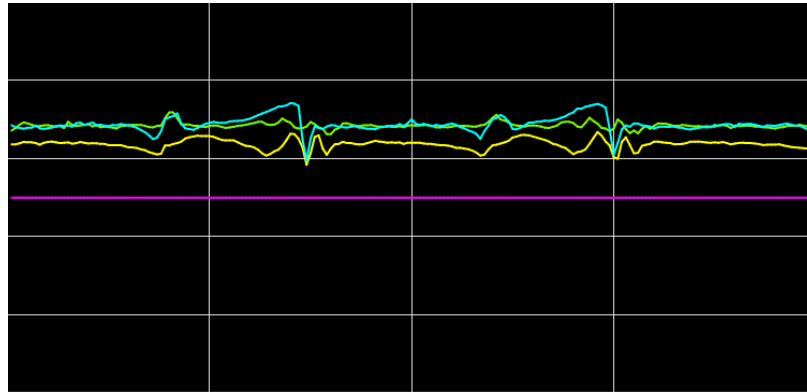


Fig. 4: Male Subject 2 walking at 4Kmph.

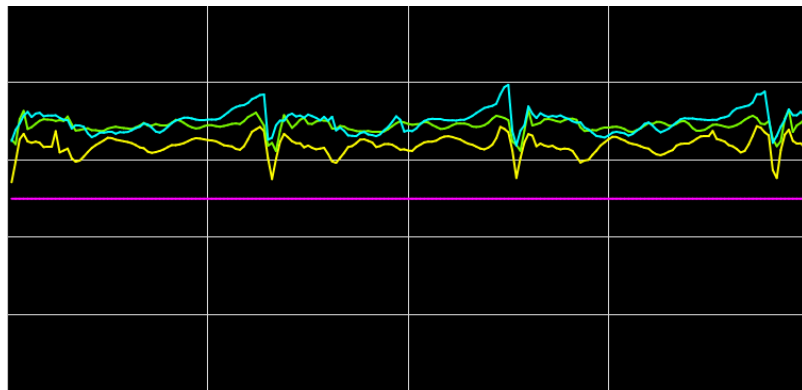


Fig. 5: Male Subject 2 running at 6Kmph.

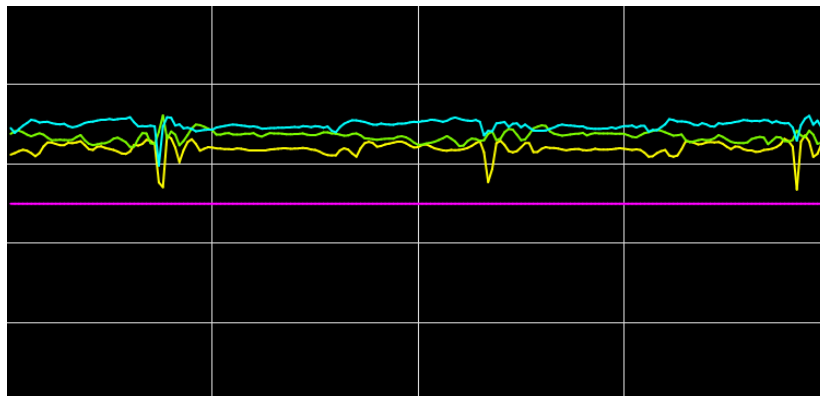


Fig. 6: Female Subject 3 walking at 4Kmph.

Above oscilloscope readings represent recognizable patterns of individual subjects while walking or running. Everyone has their own pattern, even the gender parameter has a slight impact on the style of walking. This proves that parameters like age, gender, weight and height has their impact on the way of walking.

On plotting these values we can find the maximum and minimum values for each subject at particular speed. Using these values we can program the controller to trigger the movement. Angular position of the leg with respect to thigh can be found using combination of two accelerometers [2].

4. Program

4.1 Algorithm

1. Processor reads the data from position sensors.
2. Forward swing or backward swing is detected when the calculated threshold of respective movements are crossed.
3. Present movement is stored.
4. Program checks if the present movement is different from past movement.
5. If yes, step 6 executes, if no, program executes from step 1
6. Movement is stored and program checks if timer is running or not.
7. If yes, timer value is stored and timer reset occurs and program continues from step 1
8. If no, timer is initiated and program continues from step 1.

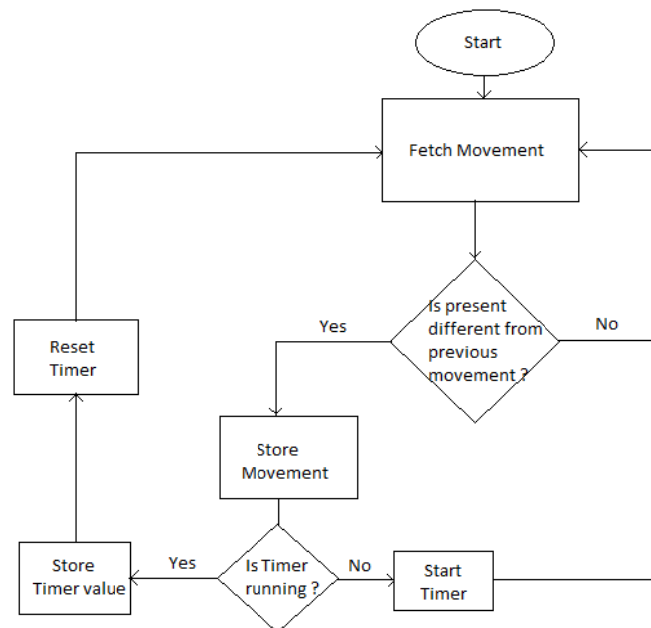


Fig. 7: Movement recorder program flowchart.

4.2 Movement replication

It is fine recording the movements and time intervals between every movement. But it is meant to be replicated by the robotic limb to achieve the natural movement. A triggering sensor placed on the thigh of amputated leg notifies the processor to reproduce the stored movements in the robotic leg by activating corresponding actuators for certain time.

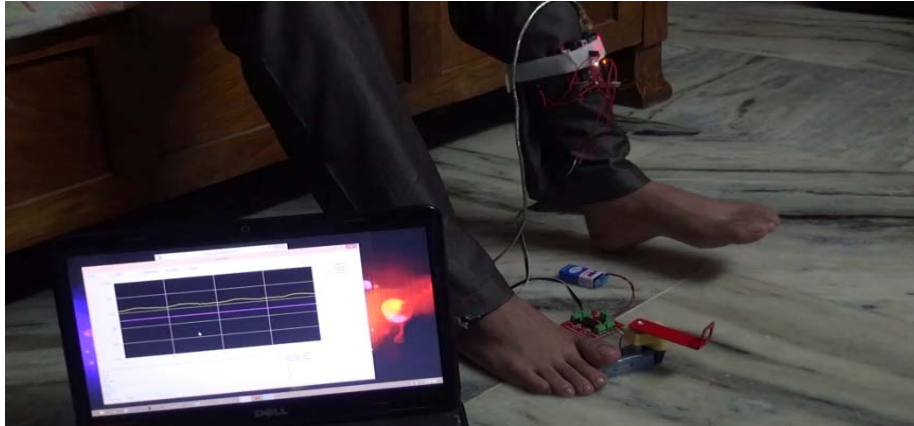


Fig. 8: Author's Prototype.

5. Conclusions

Thus developed prosthetic leg can be attached to the thigh part of the amputated leg in such a way that it is firm. Sensors are placed on the thigh of amputated leg and on un-amputated leg. Entire system is embedded inside the prosthetic leg. This model has its limitations while walking on rocky terrains and climbing a mountain. But it makes the person comfortable while walking, taking stairs.

6. Future Scope

This model can be further developed through neural interface or using Electromyography Sensors (EMG) on the thigh muscles. It further increases the precision and timing of the robotic leg. As of now person should wear the sensors on his leg, they can be embedded in his leg and can be send data over wireless protocol.

7. Acknowledgements

References

- [1] http://en.wikipedia.org/wiki/Gait_analysis#Factors_and_parameters
- [2] Thesis on Design, Modeling, and Control of an Active Prosthetic Knee by Roozbeh Borjjan Pg-61