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Preliminary Control Strategy Design of the Abnormal Gait Pattern and the Developed RGO for the Above Knee Amputees

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Abstract—*Amputation mainly caused due to trauma or surgery or due to industrial accident which can lead to the removal of their body portion. In India the amputation causes mainly due to motor vehicle trauma, and has 7,455,494 amputations in their total population. This paper explains in detail about the Reciprocating gait orthosis which is intended to provide a normal gait pattern for the above knee amputees by mimic the movement of functional leg through wireless. The field of exoskeleton and wearable devices for amputation has advanced considerably over the past few years. This work is mainly focused on the single leg 13cm above knee amputees. The prototype which we have developed could mimic the movement of the functional leg and achieves the normal gait cycle. The system incorporates accelerometer sensor, Wireless transceiver, controller, Dc motor, Rechargeable battery. The x, y, z axis of the functional leg has been detected by the accelerometer sensor and the data sent to the developed leg through wireless transceiver. The received data has further sent to the DC motor which has been controlled by driver circuit would achieve the normal gait cycle for the above knee amputee.*

Keywords*: Above knee amputee, RGO, dc motor control, time limit.*

1. INTRODUCTION

An amputation usually refers to the remove of part of the arm or hand, foot or leg. [4]. It occurs after an injury or during surgery. This type of amputee is caused by loss of blood supply to the body's tissue. The leg amputees suffers major problems like lack of normal gait cycle, as there is natural sensory loss in the muscle due to amputation they suffer from normal extension/flexion of the knee joint function. According to the population of the countries the US estimates the amputation level in each country all over the world. Amputation in Asia region was divided like northern Asia, Sothern Asia, central Asia, and eastern Asia. Northern Asia country like Mongolia has 19,529 amputees in their total population. Central Asian country like Uzbekistan has 184,872 amputations in their total population. Eastern Asia country like china has more amputation than any other countries in Asia. The amputation count in china comes around 9,091,933 among their total population. Southern Asia country like India has 7,455,494 amputations in their total population. Reciprocating gait orthosis (RGO) [4] is a hip knee ankle foot orthosis (HKAFO) that used for lower limb paralysis patients to walk and stand using crutches or walkers. RGOs are often prescribed so that persons with lower limb paralysis may enjoy the physiological benefits of upright ambulation, such as lower incidence of bone fractures and pressure sores. Studies have reported that the difficulty of ambulating with RGOs is a contributing factor to their limited use and high rates of abandonment. Unfortunately, investigating RGO-assisted gait is complicated by the difficulty of recruiting RGO users for research. The population of RGO users is small, which makes recruiting a sizable, homogenous sample population challenging as implied by the small sample sizes of RGO studies.

Fig. 1: Photograph of the LLPS [3]

A mechanical Lower Limb Paralysis Simulator (LLPS) [4] was designed to provide able-bodied persons with a set of paralyzed legs. The purpose of this study was to determine if able-bodied LLPS users exhibit some of the distinguishing patterns of RGO-assisted gait.

The functional neuromuscular based mechanical RGO [5] has been also developed by stimulating the nerve in the muscles. It has a temporal relationship between necessary muscle activation and dynamic state of the joint.

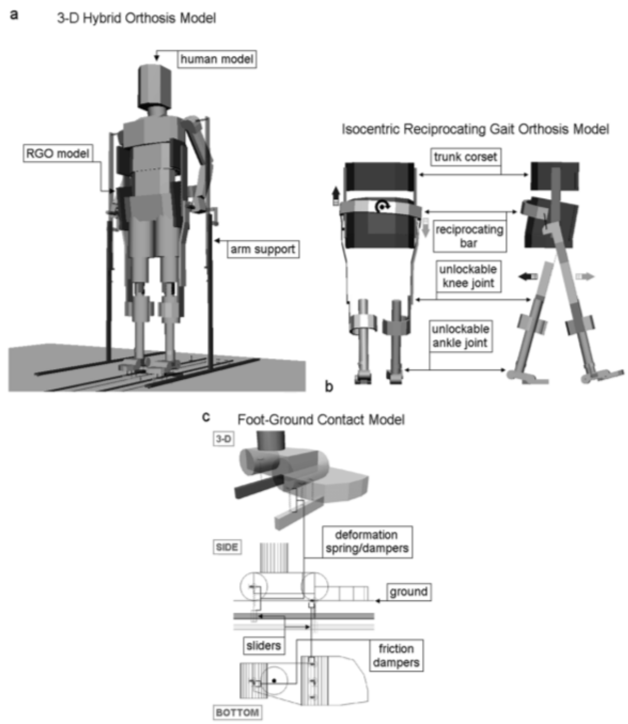

Fig. 2: (a) Three-dimensional hybrid orthosis model [5]

The model was composed of: 1) human model, 2) FNS model (not shown), 3) RGO model, and 4) arm support. The initial posture of the model before the first step is shown. (b) Isocentric reciprocating gait orthosis model. Hip extension drives the ipsilateral side of the reciprocating bar up, which forces the contra lateral side of the bar down to facilitate contra lateral hip flexion. (c) Foot-ground contact model.

This system was developed to examine the walking pattern after the spinal cord injury occurs which coordinates the knee and ankle joints of a RGO, while giving propulsive forces and controlling unlocked joints with functional neuromuscular stimulation.

The existing system was the Otto-Bock C-leg which mimic the knee's functionality during gait, microprocessor controlled knee joints have been developed which controls the flexion and extension of the knee. The Otto bock's C-leg was introduced in 1997, ossur's Rheo knee was released in 2005, whereas the power knee by ossur, introduced in 2006. The idea was originally developed by Kelly James, a Canadian engineer, at the University of Alberta.

The microprocessor receives the signals from the sensors which analyses the knee angle and moment of the leg. And to determine the type of motion being employed by the amputee. Most microprocessor controlled knee joints are powered by a battery housed inside the prosthesis. The sensory signals are computed by the microprocessor are used to control the resistance generated by hydraulic cylinders in the knee joint.

It has some significant drawbacks that impair its use. They can be susceptible to water damage and thus great care must be taken to ensure that the prosthesis remains dry. Another drawback was the time delay between the functional leg and the developed leg.

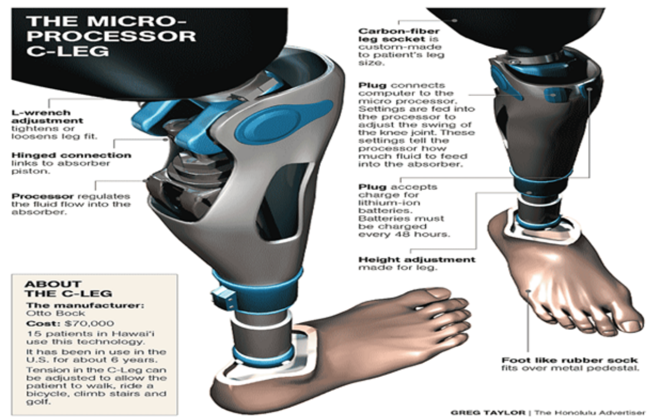

Fig. 3: Otto bock's C-leg

Image courtesy:http://biomed.brown.edu/Courses/BI108/2006-108websites/group07HighTechProsthetics/pages/cleg.htm

Date: 15/03/2015

2. METHODOLOGY

DESIGN

To design the reciprocating gait orthosis for the above knee amputees, the average Asian height and weight is considered. The average Asian height is 165cms and the average Asian weight is 70kgs.

In lower limb the joints are the most important as it bears and provides support to the body weight. There are three types of joints in leg; they are 1) Hip joint 2) Knee joint 3) Ankle joint. But in this project the case is that we are going to design and develop orthosis for above knee amputee, so we have to consider only knee joint and ankle joint. Pressure sensor is placed on the foot in order to overcome the possibilities of falling down.

In knee joint there are two degrees of freedom can be performed that is extension and flexion. The range of motion for the knee joint is from 0° to 130°. During flexion, healthy range of motion for knee joint is 0° to 90°. During extension, healthy range of motion for knee joint is 90° to 130°. The range of motion for this work can be controlled by threshold which can be performed by the microcontroller and analog to digital converter.

This system contains Accelerometer sensor (MMA 7361) which has the special feature of detecting motion and tilting purposes. This system has arduino UNO development board which has an ATMEGA328 microcontroller for control and data analysis purposes. For transferring the data and receiving purposes Zigbee wireless data transfer pair (WLZDP01) were used, where zigbee transmitter placed in the normal leg and zigbee receiver placed in the developed amputee leg. This system contains one motor at the knee joint and fixed the ankle joint, because it's just to support and bear weight, there would not be more rotation or major movement done by ankle joint. The motor used for the amputee leg flexion and extension is DC geared motor which has the specification of 38kgcm torque and 300rpm speed.

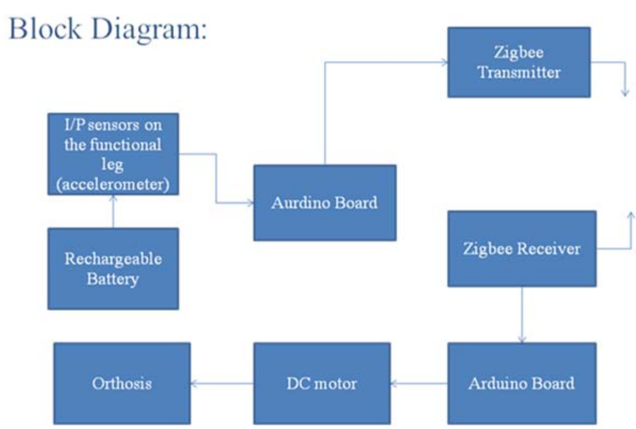

Fig. 4: Working model of RGO for above knee amputees

The input for the accelerometer sensor is given by the 12V rechargeable lithium ion battery. The accelerometer sensor detects the movement of the normal leg XYZ axis and the data's sends to the controller where the data's get calibrated and it transferred to the developed amputee leg through the zigbee transmitter which is placed in the normal leg. The given data is received by the zigbee receiver which is placed in the developed leg and the data's get calibrated using controller and sent to geared DC motor which is controlled by L293D driver circuit would mimic the normal leg function which makes the amputee to achieve their normal gait.

This system is divided into three parts that is hardware module for normal, hardware module for amputee leg and developing of the amputee stump according to the patient's normal leg height and their weight.

The hardware module for normal leg contains accelerometer sensor, controller, and the zigbee transmitter. The hardware module for amputee leg contains zigbee receiver, controller and DC geared motor. The placing of rechargeable battery and controller system has separate belt which can be placed in the waist region. The placement of the various RGO modules on the amputee was drawn and shown in the below diagram.

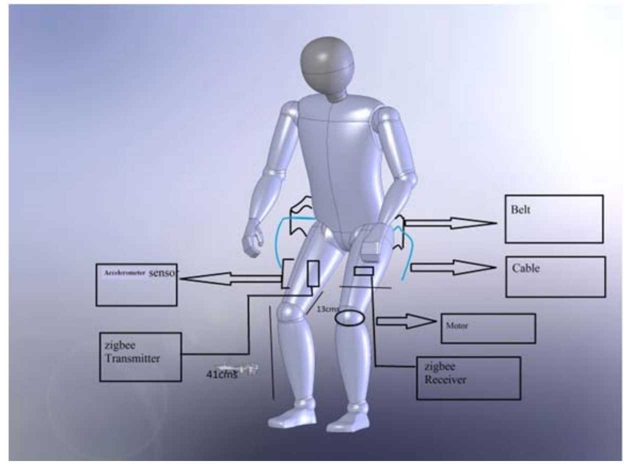

Fig. 5: Placement of the various RGO modules on the body

3. CONTROL STRATEGY

For the height 165cms and weight 70 kgs the mass of the body segment such as thigh, calf, and foot will be 9.85kgs, 2.94kgs and 0.91kgs. In this work the level of injury in the knee was 13cms above the knee. Stature estimation for 40 individuals according to their sex, height, the average femur length and average shank length is estimated. Mass of the body segment for each part is calculated using regressions equations.

Torque of the motor is given by the equation,

Torque (T) =Force (F) x perpendicular distance (D)

In Fig6 it shows the Reciprocating gait orthosis (RGO) for above knee amputees prototype which has one functional leg connects with the proximal (IR) sensor and developed amputee leg connects with the DC motor in the knee joint.

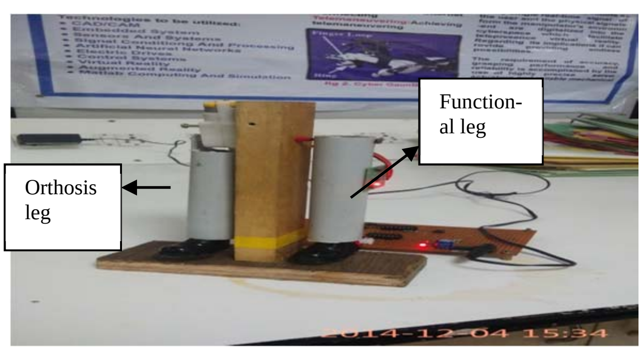

Fig. 6: Prototype of RGO in above knee amputees

When the power supply was given to the sensor in the functional leg, the movement and the speed of the functional leg was recognized by the sensor and given to the amputee leg through microcontroller. In Fig7 it shows that when the functional leg moves backward the amputee leg does the extension up to 20 degrees.

Fig. 7. Prototype During knee extension

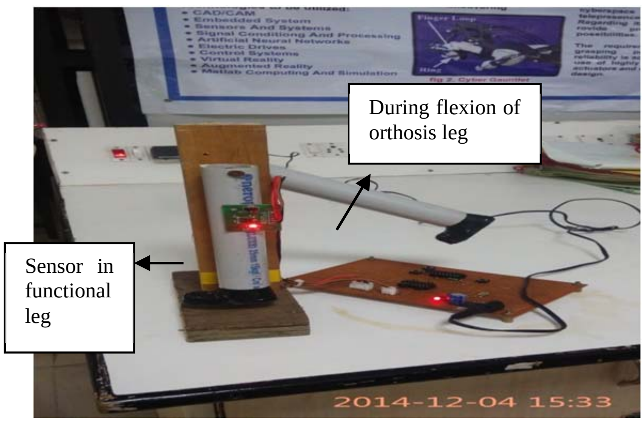

Fig. 8: Prototype during knee flexion

In the above diagram it shows that when the functional leg moves forward the amputee leg does the flexion upto 140 degrees. Comparison between our RGO type and normal standard leg is given in below table.

Table 1: Comparison between normal standard leg and our RGO prototype

Knee Joint	Normal standard leg	Our RGO prototype
Flexion	110-130 degrees	100-140 degrees
Extension	15 degrees	10-20 degrees

4. RESULTS

The reciprocating gait orthosis for above knee amputees has been designed. The testing of the knee joint and their range of motion have done with the prototype. The hardware module for detection of the movement and the transferring of data through wireless has been done. The model of the reciprocating gait orthosis has been made and data like range of motion has been noted.

5. CONCLUSION AND FUTURE WORK

In this paper we have designed and made prototype of reciprocating gait orthosis for the above knee amputees and also have designed the hardware module for detection of movement and transferring of data through wireless has been done. The next stage of this work to make this prototype as real time RGO Module which would be to develop it for the commercial purposes. Using G-sensors the response of the sensor can be improved. The design would be implemented using Medical Standards and using FDA approved materials. The so deigned orthosis would then be studied by using it for clinical trials. The data acquired would be analyzed using statistical analysis and required modifications in the design would be made so that it mimics the standard normal gait.

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