Modelling of exoskeleton robot for walking rehabilitation

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ABSTRACT – A walking rehabilitation exoskeleton robot is used for patient having walking difficulty to undergo walking therapy by wearing it on his lower body. To find out whether such exoskeleton can be used effectively for gait recovery, in the design stage, the robot need to be modelled. This paper present the response of its joints to the inputs replicating human joints behaviour. Given mathematical inputs and actual experiment data, in block diagram form with PID controller, the model shows that the exoskeleton design is able to follow given joint trajectories thus guiding patient wearing it to recover back walking abilities.

1. INTRODUCTION

Exoskeleton robot is a powered wearable robotic suit which is worn on the whole or any parts of the human body in to augment, assist or for rehabilitation therapy. The lower body exoskeleton robot on the other hand is designed to be worn parallelly to the lower part of human body. Some of the widely known exoskeletons are BLEEX [1] for augmentation in load carrying while walking, HAL [2] for walking assistance and Lokomat [3] for walking rehabilitation therapy.

Walking gait impairment mostly happens as a result of damage to the human central nervous system (CNS) which consists of the brain and spinal cord. Any injuries to either the brain or the spinal cord parts which control the nervous system to the lower limb can cause difficulty in walking or gait disorder. In severe injuries the lower limb may become paralyzed and the sufferer cannot walk anymore.

To regain back the walking ability apart from the person with total paralysis, walking therapy as a rehabilitation process is required. With the advancement in robotic technology nowadays, exoskeleton robot has been used alongside the lesser number of therapists required to perform the walking rehabilitation. Over the years, there are interest among the researches around the world in studying on the use of exoskeleton for rehabilitation of walking gait.

However, the cost for developing an exoskeleton is very high from the design stage up to a full working prototype. As such, this work used the exoskeleton design by modelling it directly to form an exoskeleton robot control system that can be simulated to given inputs to see the response behaviour of the design.

2. METHODOLOGY

In the beginning, the lower body exoskeleton is designed using Autodesk Inventor CAD software as shown in Figure 1. The exoskeleton design resembles human lower body part consisting of two legs connected at waist. Each leg has three joints at the hip, knee and ankle. In the design, the joints are not actuated and not geared but in the simulation model later on, actuator is introduced to each joint.

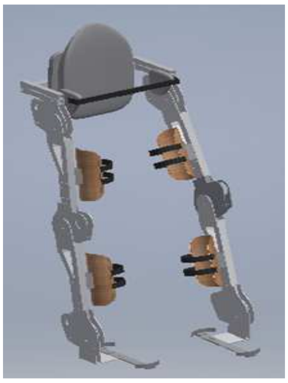

Figure 1 Exoskeleton design

Instead of fabricating the exoskeleton design and develop the hardware, the design is modelled to analyze its response through the use of MATLAB similar to Ali et al. [4] in using MATLAB with PID controller in their work. From Autodesk Inventor, the exoskeleton design is imported into SimMechanics first generation. Based on the exported lower body exoskeleton CAD design, a model is developed in MATLAB SimMechanics to form an exoskeleton control system. The block diagram of the control system after modification by including individual control system with PID controller to each joint as shown in Figure 2 is then simulated.

Simulation is performed on the exoskeleton control system by giving mathematical and numerical inputs of joint angle as reference to each joint.

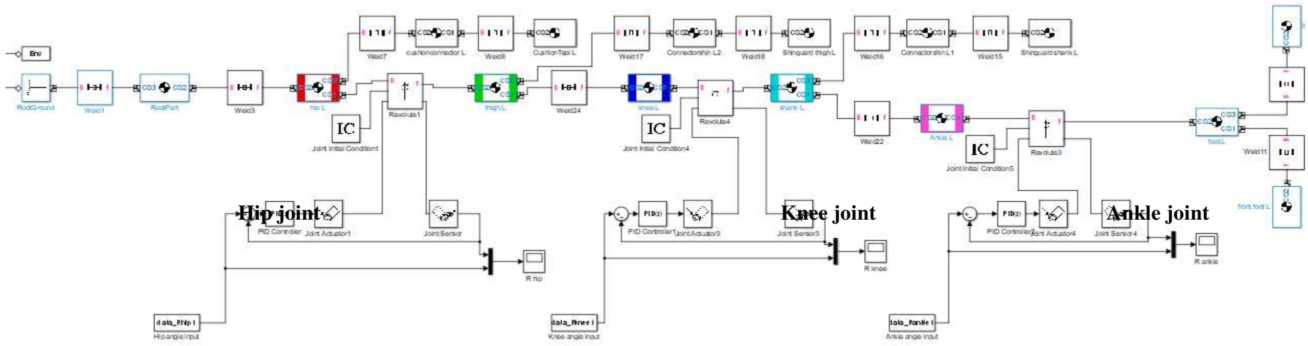

Figure 2 Overview of exoskeleton model in SimMechanics.

3. RESULTS AND DISCUSSION

The following results shown only for the left part of the exoskeleton leg for hip, knee and ankle joint angles over a one second stride time.

$$\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5 \quad (1)$$

In quantic polynomial form as depicted in Equation (1) from Mohammed et. al. [5] input to each joint, with the gait cycle divided into several subphases, the responses are shown in Figure 3.

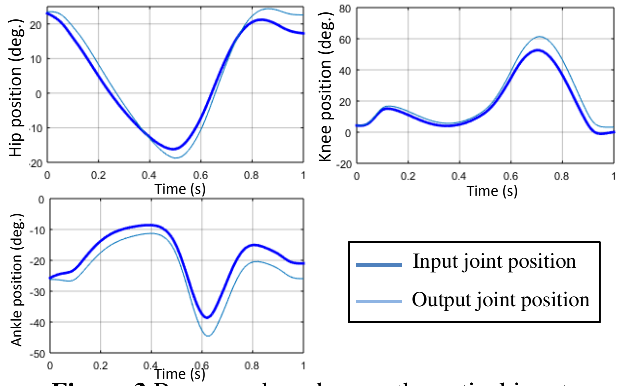

Figure 3 Response based on mathematical input.

When fed with numerical gait data in time and joint positions from Semwal and Nandi [6] as reference trajectories to each joint, Figure 4 shows the response.

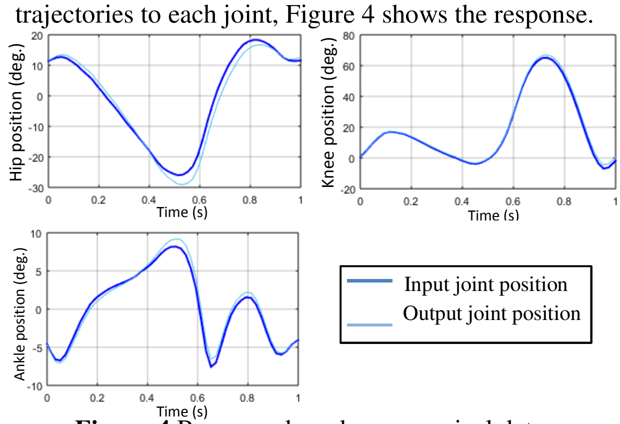

Figure 4 Response based on numerical data.

4. CONCLUSION

The use of MATLAB SimMechanics has helped to speed up to process of modelling and simulation. From the examples, the exoskeleton model is able to tracks the inputs given to its joints and the exoskeleton design is somewhat viable. Further analysis can be made to the output to improve its response. Future improvement to the model is possible by modification of the control system to the joints and giving different type of walking trajectories to the control system.

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