UNIVERSITI TEKNOLOGI MARA

MODELING OF FUNCTIONAL ELECTRICAL STIMULATION (FES) – POWERED KNEE ORTHOSIS (PKO) ASSISTED GAIT EXERCISE IN POST-STROKE REHABILITATION

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ABSTRACT

Hemiplegics can recover or at least regain some function. However, if the patient is not appropriately treated, the consequences of the chronic stage will be long-lasting. Rehabilitation exercise has been deemed one of the most promising methods for hemiplegic regain function. Researchers have recently utilized various exercise techniques in conjunction with Functional Electrical Stimulation (FES). Rehabilitation exercise using a Powered Knee Orthosis (PKO) has been extensively studied, particularly concerning the practical adaption of the users and control technique for FES. In the various mechanism of actuating the PKO, such as rotary series elastics actuators, dc motor actuators, and brushless dc motor actuators, researchers continue to make control strategies to get better actuating of PKO. However, there are still shortcomings in modeling the rehabilitation system involving FES and PKO. Having FES and PKO modeling for the rehabilitation system is critical for controlling PKO and FES. The current technique uses statistical models, but the dynamic properties of human physiology limit the current approach. This research aimed to propose modeling FES – PKO-assisted gait exercise in post-stroke rehabilitation through sub-modeling parts, which are the human gait model and the FES and PKO model. In the human gait model, three Machine Learning algorithms were used: Gaussian Process Regression, Support Vector Machine, and Decision Tree. The improvement of the model was implemented by incorporating different sliding windows on the model's input parameters. The best gait model was a Decision Tree with sliding window data (t-3), which had a root mean square error of 3.3018 and an R-squared value of 0.97. The human gait model was then integrated with the quadriceps muscle model developed by the previous researcher. The quadriceps muscle model is one of the selected muscle groups. In this physiologically based muscle model, the major properties of the human muscle are described in three components: muscle activation, muscle contraction, and, body segmental dynamic. The next sub-model consists of the PKO model. The dynamic model of PKO is developed by developing mathematical equations that connect the torques exerted by the actuator of PKO. The Lagrange formula is employed here to build the PKO's inverse dynamic model equations. The complete modeling of the system was validated with our developed prototype of PKO via experimental work. The developed FES-PKO assisted gait exercise using the approach that combines human gait, muscle, and PKO model shows that FES and PKO generated joint moment and joint angle can simulate movement during gait. These developed models contribute to FES as the primary source in generating joint movement while PKO assists as needed.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Hemiplegia is a condition in which half of the body is paralyzed due to a neurological problem. Hemiplegia is caused by various factors, one of which is stroke. After heart disease and cancer, stroke is Malaysia's third leading cause of death. According to the National Stroke Association Malaysia (NASAM), 40,000 instances of stroke occurs in Malaysia each year. The number of cases is predicted to rise yearly as the population grows and people become more conscious of the need to live a healthy lifestyle. Data from Malaysia Statistics Department (2010 to 2014) [1] shows that from 7668 patients diagnosed with stroke upon hospital admission, ischemic stroke accounts for 79.4% of the cohort, with a slightly higher proportion of male patients. Hence, the study believed that ischemic stroke is expected to rise by 29.5% yearly, whereas hemorrhagic stroke is expected to rise by 18.7% [1]. The most frequent symptom of a stroke is hemiparesis or hemiplegia, weakness or paralysis on one side of the body. Hemiparesis is a partial incapacity to move, whereas hemiplegia is a whole inability to move. It can affect the face, arm, leg or all three, with symptoms ranging from slight weakness to complete paralysis. As a result, this disease will limit the patient's activity, affecting the patient’s regular life.

Hemiplegics can recover or at least regain some function. However, if the patient is not appropriately treated, the consequences of the chronic stage will be long-lasting. As a result, recovery must begin as soon as feasible. The subject would have already had a chronic stroke at the time of starting the rehabilitation process (acute stroke is defined as a stroke that occurs within one week, mild stroke is defined as a stroke that occurs between one week and one month, and chronic stroke is defined as a stroke that occurs longer than a month). The rehabilitation process aids patients in resuming their regular lives by assisting them in obtaining the highest level of independence possible. Physical exercise training, often known as rehabilitation exercise, is one of the most promising ways to recover instead of medicine. It entails either passive or aggressive muscular activation in the affected body part. Several studies have found that physical exercise training can help patients restore their function and avoid repeat strokes [2].