Buletin Teknol. Tanaman, Bil.13, (2016): 10–12

A Critical Review of EMG Based Knee Rehabilitative Exoskeleton Systems

Chor Foon Tan

Abstract
In this literature review the methods of control lower limb exoskeleton with the EMG-based controller is being discussed. The focus of the most references in this chapter is on EMG signals features and how to calibrate them to design motion controller for knee prosthesis and orthosis. In the end non linear-based control design is mentioned to design PID and MRAC controllers.
Keywords: Knee rehabilitation, Lower Limb Exoskeleton, EMG, EMG-Based Orthosis, Prosthetic Knee, EMG Signals.

Introduction

Disability and movement disorder is one of the worst problems that people can have due to some reasons such as accidents, spinal injuries, disturbing brain injuries, brain disorder, and problem in neural commands as a result of stroke [4].

Studies on rehabilitation began from early 1970s seriously in order to construct a helpful device to help people who are physically weak [9], or disable and also amputees to gain the better motion control instead of suffering from the lack of movements of their limbs.

Exoskeleton was the early proposed rehabilitation instrument which is suitable as a patient assistant to correct their movement by the specific motion patterns and also used as army instrument to help soldiers to carry heavy loads by wearing it [10].The exoskeleton has been developed with the aid of lots of studies in different fields. Most of the researches have been done in order to make the motion of the exoskeleton close to natural human's movements and make it able to move in every style like climbing the stairs, sitting and standing, walking etc [5].

In order to recognize the desired motion, the force sensors are used between subject and the exoskeleton to get the signals from the subject to anticipate the movement pattern [10]. In the recent studies the more focus has been on using EMG sensors in order to predict the intended motions and use as more accurate input signal for the controlling parts of the exoskeleton [1], [2].

Electromyography (EMG) is a technique to detect electrical potential or neurological activation of the muscles. This technique opened an important gate in rehabilitations studies. With the aid of EMG signals the intended motions can be predicted and send to the processors in order to movement compensation. Limb can move by the received brace from the computer [2]. There are two ways for getting EMG signals from the muscles, needle electrode and surface EMG, but the problem is the activity of each muscle is varying among different people and some conditions like heat of skin and blood circulation can make the EMG signals untrustable [2], so the calibration of EMG signals must be done before the process to have clear data in order to design the best controller for prosthetic knee.

This study is about rehabilitation of lower limbs that plays an important role to move the body. Leg orthosis is a device that can be controlled with EMG signals to help disable people to walk. The most important part of foot is knee that control of the movement and actually control of the body must be done with it. Lots of methods have been experienced in different movement phases and terrain slopes to get the better signals, and different leg muscles have been experienced to find the best motion detection with EMG signals and design better controllers in order to guide the orthesis.

Accomplished Methods

In the accomplished methods that have been done in this study the prior instrumentation is for EMG part [8]. This is very important to get the signal from which part of lower limb and also which muscles depends on the expected operations of orthosis or prosthesis . EMG signals have the specific calibration for each part of the body [4], and they need to be amplified and also rectified in a signal conditioning unit in order to be acceptable for the controller part. The controller part depends on the number of the motions can be any of the microcontrollers [15], in order to getting the amplified signal and make the desired force power for the actuator. The actuator can make the expected movement sent by the controller and compensate the intended motions which are determined by EMG signals and specific algorithms.

Calibration Approaches

The calibration process must be done experimentally with the patient, for example in [12] six healthy subjects were considered for data acquisitions. In order to get appropriate data for knee exoskeleton, EMG signals must be taken from specific muscles and reachable by EMG surfaces (some of the related muscles are placed close to the bone and unreachable by the surface electrodes [2],) depending on the type and the direction of the desired movement. [13] considered rectus femoris, vastus medialis, vastus intermedius and biceps of thigh muscle for extension and flexion ranges. In order to parameter calibration [2] used EMG-to-muscle activation and individual muscle force algorithm for EMG-to-force conversion for six muscles with mounted sensors on the exoskeleton. In this method the EMG signal calibrated with the sensors on the orthosis alone as a result of easy application of exoskeleton, since EMG parameters are different and depends on the subject's skin condition, blood circulation etc. In this method the EMG surfaces were placed on thigh muscles in order to estimate the knee torque that was the input for torque controller part of orthosis. in the first step of the calibration procedure, subject was in sitting style in which thigh muscle was supported by a chair and the leg was hang without attaching on the ground ,since in this situation of thigh muscle the measured force was orthesis gravity force. After that for getting reference value of different angle, the subject started to extend and flex the knee several times [2].
in first step the calibration procedure, subject was in sitting style in which thigh muscle was supported by a. the EMG sensors measured the flexibility and extension of the knee that converted to the muscle force with EMG-to-force function. The measured force transmitted to the mechanical model in order to calculate the knee torque which is sent to the motion controller to move the orthosis. The EMG signals are taken from hamstring and quadriceps muscles. The method applies a combination of quadratic insulator analysis to row the subject animus to flex or extend the knee joint with the measured EMG pattern. The authors utilized a quadratic discriminate analysis (QDA) to classify flexing and extending. eventually with employing volitional impedance controller the joint torque command can be sent to the prosthesis.
The discussion on whole phase does not have better performance, since the EMG signals are variable in time and the interval of each phase was different, so applying EMG segments of before and after of each phase alternation to speed recognition can recognize the walking pace with better
efficiency than employing whole gait EMG cycle and drive the electric machine to regulate the parameters of knee prosthesis to follow the measured walking speed.

Controlling Approaches

The EMG signals are taken from the quadriceps and the hamstrings muscles as an input data for the controller. In this study the fuzzy logic is used since getting sEMG signals from same person with same position is difficult. For measure the sEMG signal two volunteer are used in sitting position because in this position the knee can move in full range of extension. For designed controller the low pass filter is considered in order to attenuate the components noises [1]-[3]. In sitting style with an impedance utilization in which EMG signals can send firmness and damping data to the controller .

The examined Prosthesis has a three degrees of freedom (DOF) . One degree is from knee joint to support gait and the two rest of degrees come from ankle-foot set to support stability .a predictive model was considered to generate prosthesis trajectory. The test was performed without any patient, force and load that used in swing phase of walking. In this method non-linear model considered based on two types of controllers for the knee opening angle. PID and model reference adaptive controller (MRAC) .in the system modeling a DC motor was considered as joint actuators in order to provide higher knee torques .

Other Approaches

The application of the combined knee angle and sEMG signal is important to distinguish the speed of walking with using the speed pattern recognition in order to knee prosthesis control . The one gait cycle was considered and divided into five phases. the discussion on whole phase does not have better performance since the EMG signals are variable in time and the interval of each phase was different, so applying EMG segments of before and after of each phase alternation to speed recognition can recognize the walking pace with better efficiency than employing whole gait EMG cycle and drive the electric machine to regulate the parameters of knee prosthesis to follow the measured walking speed. Examination a model of human body has been done with two sensors (pose and EMG) to detect the intended motions, transform data to desired muscle force In this study the EMG sensors measured the flexibility and extension of the knee that converted to the muscle force with EMG-to-force function. The measured force transmitted to the mechanical model in order to calculate the knee torque which is sent to the motion controller to move the orthosis.

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C.F Tan, Department of Department of Electrical and Electronic, University of Malaya,
50603 Kuala Lumpur, Malaysia