Sensorless control system for assistive robotic ankle-foot

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Abstract
This article presents a novel sensorless control system of assistive robotic ankle-foot prosthesis, two estimation algorithms were developed and an analogy between them has been made. The system actuator’s motor is a permanent magnet synchronous motor, unlike other powered ankle-foot, where the brushless DC motor and DC motor were used. Utilizing the permanent magnet synchronous motor will reduce the torque ripples and increase system ability to be overloaded compared to systems which utilize the brushless DC motor. Moreover, the ability of the machine to operate in all speed range makes this machine more suitable for the application. Both estimation algorithms are built using C-code and assessed in MATLAB Simulink. The estimation algorithms are used to provide motor and powered ankle-foot’s angular speed and position. Two-level control system is used to evaluate the estimation algorithms; the control system role is to mimic biological ankle-foot performance during normal ground level walking speed. Based on the result of this article the unscented Kalman filter (UKF) is applicable for the application, as a result of the observer ability to estimate the motor load and angular position. On the other hand, extended Kalman filter (EKF) accuracy is affected by the load applied to the motor. Furthermore, the angular position is evaluated by integration of the angular speed which means integration of angular speed estimation error.

Keywords
Below-knee powered prosthesis, EKF, powered ankle-foot, powered prosthetic ankle-foot, robotic ankle-foot, sensorless control, UKF

Date received: 11 January 2018; accepted: 16 April 2018

Introduction
It is believed that ankle plantar flexion (PF) has an important role during the gait cycle.1 Ankle PF muscles are responsible for generating approximately 80% of the torque required by the gait cycle, which has an important distribution to regulate the whole-body angular momentum (H).2 As a result, transtibial amputees suffer from higher falling risk compared to non-amputees and the risk vary in different walking speed and/or terrains.2,3 The use of passive prosthetic foot is the cause of many short-term gait problems (asymmetric gait, higher metabolic consumption, and so on.) and long-term health problems (osteoarthritis, backache, and so on.).4

Recently, the robotic lower limb prosthesis has been developed to restore ankle PF roles, in 2007 MIT’s powered ankle-foot was the first prototype able to generate...