

Title: Design and Development of Powered Ankle Prosthetic and Knee Orthotic Devices and Associated Algorithms for Autonomous Control

Abstract:

In this study, a novel compliance mechanism, namely a four-bar controlled compliance actuator (FCCA), is designed to develop ankle prosthetic and knee orthotic devices. In FCCA, a four-bar mechanism with an extended rocker arm modulates the stiffness of a series spring that adjusts the joint impedance. FCCA amplifies the input motor torque to reduce power consumption. The design parameters are optimized (using genetic algorithm and particle swarm optimization) to improve energy efficiency further. The performances of the ankle prosthetic and knee orthotic devices are tested through computer simulations and bench-top testing. Moreover, various strategies are developed for autonomous control of prosthetic and orthotic devices. At first, a gait event detection strategy is developed for walking on level-ground and ramp. It uses inertial measurement units (IMUs) attached to the shank and foot of the subject. The proposed gait event detection algorithm can detect both the starting, inner and terminal stance events as well as starting and inner-swing events. Additionally, early detection of gait events is also explored in this study. It is hypothesized that the detection of gait events at the earlier stage can minimize the response delay of prostheses and orthoses. In another study, a locomotion mode adaptive gait event detection strategy is developed for level-ground walking, staircase ascending and staircase descending. Due to the locomotion mode adaptive nature, the accuracy of the detected gait events is found to be better than the existing studies. Secondly, a step length prediction algorithm is developed utilizing thigh kinematics. An adaptive neuro-fuzzy inference system (ANFIS) has been utilized for prediction. At last, a locomotion mode recognition strategy is developed that can also detect some environmental features, i.e., stair height, stair width, slope of the ramp, and lead distance. It uses a combination of IMU and laser range sensors to generate a cloud of points in the sagittal plane. The cloud of points helps to reconstruct a 2D structure of terrains. The environmental features are predicted from the 2D structure.

Keywords: Ankle prosthesis; knee orthotic device; locomotion mode recognition; gait event detection; finite state control.