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Real-time controller for foot-drop correction by using surface electromyography sensor

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Abstract

Foot drop is a disease caused mainly by muscle paralysis, which incapacitates the nerves generating the impulses that control feet in a heel strike. The incapacity may stem from lesions that affect the brain, the spinal cord, or peripheral nerves. The foot becomes dorsiflexed, affecting normal walking. A design and analysis of a controller for such legs is the subject of this article. Surface electromyography electrodes are connected to the skin surface of the human muscle and work on the mechanics of human muscle contraction. The design uses real surface electromyography signals for estimation of the joint angles. Various-speed flexions and extensions of the leg were analyzed. The two phases of the design began with surface electromyography of real human leg electromyography signal, which was subsequently filtered, amplified, and normalized to the maximum amplitude. Parameters extracted from the surface electromyography signal were then used to train an artificial neural network for prediction of the joint angle. The artificial neural network design included various-speed identification of the electromyography signal and estimation of the angles of the knee and ankle joints by a recognition process that depended on the parameters of the real surface electromyography signal measured through real movements. The second phase used artificial neural network estimation of the control signal, for calculation of the electromyography signal to be stimulated for the leg muscle to move the ankle joint. Satisfactory simulation (MATLAB/Simulink version 2012a) and implementation results verified the design feasibility.

Keywords

Surface electromyography, artificial neural network, foot-drop correction

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Introduction

Surface electromyography (SEMG) allows non-invasive investigation of skeletal muscle properties. It records low-amplitude (50 μV–5 mV) potentials within a relatively narrow bandwidth (50–500 Hz). It has been instrumental in monitoring muscle behavior in rehabilitation programs and in the mechanical control of prostheses. It has served as an effective alternative to methods based on numerical simulations, such as the work of Andreaus and Colloca,[1] who employed the finite element method to analyze the structural behavior of hip joint prostheses.

Correct prediction of the user-intended movement is important; so, other than being non-invasive and simple to use, SEMG suits such applications because it relates intrinsically to user intention. There are, however, other useful variables relating especially to proprioception—joint angle, limb position, and force exerted being some examples.[2–6]

Active leg prosthesis with ankle and foot axes needs information other than SEMG signals to be developed. To improve reliability in closed-loop control systems, variables relating to proprioception use myoelectric signals (see Figure 1 for typical main components of general myoelectric pattern recognition). Surface electrodes on the user's muscle skin acquire SEMG signals that are preamplified to isolate small signals of interest before being amplified, filtered, digitized, and then transferred to a myoelectric controller.[7–11]

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