Robotics and Autonomous Systems Thesis Defense

Identification of Autogenic Force Feedback Responses In Elbow Flexor Muscle Group

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Abstract

Proprioception, the awareness of limb kinematics and kinetics, stands as a fundamental aspect of human movement, playing a pivotal role in subconscious movement planning and balance maintenance. Embedded within muscle-tendon complexes (MTC), Muscle spindles (MS) and Golgi tendon organs (GTO) encode crucial information about limb position and muscle forces. Proprioceptive signals are continually utilized by the neuromuscular control system for feedback control, correcting discrepancies between sensed and commanded movements. Although previous studies have elucidated the role of position feedback, the specific contribution of GTO in force feedback, especially in stabilizing voluntary limb movements, has remained theoretical due to limitations in experimental techniques. This research aims to establish force feedback regulation mediated by GTO afferent signals. Using a neuromusculoskeletal model of the monoarticular elbow flexor (MEF) muscle group, simulation studies were conducted to assess the impact of force feedback in maintaining steady state interaction forces against variable environmental stiffness. The results revealed significant force deviations in open loop configurations, while closed loop models showed no deviations, thus underscoring the essential role of force feedback in achieving precise force regulation. Subsequently, human subjects were engaged in experiments utilizing an instrumented elbow exoskeleton that applied loads to the MEF muscle group according to predefined stiffness policies. Responses obtained from these experiments mirrored the outcomes observed in closed-loop force feedback models. This alignment between experimental results and model predictions conclusively establishes the presence of force feedback mechanisms mediated by GTO within the human neuromuscular system. This study not only unveils the critical involvement of GTO in force feedback but also emphasizes the importance of understanding these mechanisms for developing advanced neuroprosthetics and rehabilitation strategies, shedding light on the intricate interplay between sensory inputs and motor responses in human proprioception.

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