Mechanical Engineering Doctoral Defense

A musculoskeletal model of the human hand to improve human-device interaction

School for Engineering of Matter, Transport and Energy

Jong Hwa Lee

Advisors: Dr. Devin Jindrich &
Dr. Panagiotis Artemiadis

abstract

Multi-touch tablets and smart phones are now widely used in both workplace and consumer settings. Interacting with these devices requires hand and arm movements that are potentially complex and poorly understood. Experimental studies have revealed differences in performance that could potentially be associated with injury risk. However, underlying causes for performance differences are often difficult to identify. For example, many patterns of muscle activity can potentially result in similar behavioral output. Muscle activity is one factor contributing to forces in tissues that could contribute to injury. However, experimental measurements of muscle activity and force for humans are extremely challenging. Models of the musculoskeletal system can be used to make specific estimates of neuromuscular coordination and musculoskeletal forces. However, existing models cannot easily be used to describe complex, multi-finger gestures such as those used for multi-touch human computer interaction (HCI) tasks. We therefore seek to develop a dynamic musculoskeletal simulation capable of estimating internal musculoskeletal loading during multi-touch tasks involving multi-digit fingers, and use the simulation to better understand complex multi-touch and gestural movements, and potentially guide the design of technologies the reduce injury risk. To accomplish these, we focused on three specific tasks. First, we aimed at determining the optimal index finger muscle attachment points within the context of the established, validated OpenSim arm model using measured moment arm data taken from the literature. Second, we aimed at deriving moment arm values from experimentally-measured muscle attachments and using these values to determine muscle-tendon paths for both extrinsic and intrinsic muscles of middle, ring and little fingers. Finally, we aimed at determining the effect of upper extremity postures associated with holding tablets in different positions on index finger motor performance and muscle activity. Towards this end, our musculoskeletal hand model will help better address the neuromuscular coordination, safe gesture performance and internal loadings for multi-touch applications.

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