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New Control and Sensing Approaches to Integrate Functional Electrical Stimulation in a Wearable Exoskeleton

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Functional electrical stimulation (FES) can be used by people with paraplegia to achieve standing and walking functions. FES uses external electrical currents to artificially activate paralyzed muscles. Gait and standing exercises using FES have been shown to improve quality of life. However, FES-induced muscle fatigue rapidly degrades limb forces. This prevents long-term user acceptability of FES and its usage in activities of daily living. To address this limitation, FES can also be incorporated into a wearable exoskeleton, where they can potentially work in tandem to offset the effects of FES-induced fatigue. To incorporate FES into a wearable exoskeleton, sophisticated automatic controllers are needed.

In this talk, I will be presenting new nonlinear control algorithms that use Lyapunov-based nonlinear control design and dynamic optimization to coordinate FES and a wearable exoskeleton. Further, I will present our recent results on using ultrasound (US) imaging to detect FES-induced muscle fatigue in the quadriceps muscle. These recent results are our initial steps towards realizing US imaging as a sensing modality to detect muscle fatigue and improve coordination between FES and the wearable exoskeleton. Lastly, I will propose that US imaging can also be used to sense intent of an exoskeleton user. Recently, we characterized ankle muscle activity with a US imaging-derived signal in order to predict volitional ankle torque. These results hold promise to develop US imaging-based musculoskeletal models that predict intent of a user in the exoskeleton.

ABSTRACT  Functional electrical stimulation (FES) can be used by people with paraplegia to achieve standing and walking functions. FES uses external electrical currents to artificially activate paralyzed muscles. Gait and standing exercises using FES have been shown to improve quality of life. However, FES-induced muscle fatigue rapidly degrades limb forces. This prevents long-term user acceptability of FES and its usage in activities of daily living. To address this limitation, FES can also be incorporated into a wearable exoskeleton, where they can potentially work in tandem to offset the effects of FES-induced fatigue. To incorporate FES into a wearable exoskeleton, sophisticated automatic controllers are needed.

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