Robotics and Autonomous Systems Thesis Defense

A Soft Robotic Hip Exosuit (SR-HExo) for Assistance and Rehabilitation of Human Locomotion

School for Engineering of Matter, Transport and Energy

Lily Baye-Wallace
Advisor: Dr. Hyunglae Lee

Abstract

The Soft Robotic Hip Exosuit (SR-HExo) was designed, fabricated, and tested in treadmill walking experiments with healthy participants to gauge effectivity of the suit in assisting locomotion and in expanding the basin of entrainment as a method of rehabilitation. The SR-HExo consists of modular, compliant materials to move freely with a user's range of motion and is actuated with X-oriented flat fabric pneumatic artificial muscles (X-ff-PAM) that contract when pressurized and can generate 190N of force at 200kPa in a 0.3 sec window. For use in gait assistance experiments, X-ff-PAM actuators were placed anterior and posterior to the right hip joint. Extension assistance and flexion assistance was provided in 10-45\% and 50-90\% of the gait cycle, respectively. Device effectivity was determined through range of motion (ROM) preservation and hip flexor and extensor muscular activity reduction. While the active suit reduced average hip ROM by 4^o from the target 30^o, all monitored muscles experienced significant reductions in electrical activity. The gluteus maximus and biceps femoris experienced electrical activity reduction of 13.1\% and 6.6\% respectively and the iliacus and rectus femoris experienced 10.7\% and 27.7\% respectively. To test suit rehabilitative potential, the actuators were programmed to apply periodic torque perturbations to induce locomotor entrainment. An X-ff-PAM was contracted at the subject's preferred gait frequency and, in randomly ordered increments of 3\%, increased up to 15\% beyond. Perturbations located anterior and posterior to the hip were tested separately to assess impact of location on entrainment characteristics. All 11 healthy participants achieved entrainment in all 12 experimental conditions in both suit orientations. Phase-locking consistently occurred around toe-off phase of the gait cycle (GC). Extension perturbations synchronized earlier in the gait cycle (before 60\% GC where peak hip extension occurs) than flexion perturbations (just after 60\% GC at the transition from full hip extension to hip flexion), across group averaged results. The study demonstrated the suit can significantly extend the basin of entrainment and improve transient response compared to previously reported results and confirms that a single stable attractor exists during gait entrainment to unidirectional hip perturbations.

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