**PhD Preliminary Qualifier**

Primary assistive devices to help rehabilitation of people with neurological disorders can be categorized into: a wearable robotic system and a neuroprosthetic system. These devices usually operate in closed-loop require a systematic understanding of modeling physical human robot or neuroprosthetic interaction, estimation of sensory feedback from the human physiological, neural or musculoskeletal state, and designing control algorithms that guarantee human safety and desired rehabilitation outcomes. The latter algorithms may need learning or adaptability due to uncertain physical human robot interaction or changing human strength and behavior.

This PhD qualifier exam wants to test your ability to understand and apply these concepts in the field of rehabilitation engineering. The test will have two parts: a written component and a simulation and report component. You will be 48 hours to complete the exam. The scope of testing include:

1. Musculoskeletal model: one should be able to derive toques (inverse dynamics) from a musculoskeletal model, a Hill model of muscle force generation, applying Newton-Euler method or Lagrangian formulation to derive 2-3 degree of freedom dynamic model,
2. Forward and inverse kinematics
3. Control schemes such as admittance control/ impedance control
4. Control techniques such as LQR, feedback linearization, sliding mode control, Learning and adaptation

**Reference Textbooks:**

Robot Modeling and Control- Mark W. Spong, M. Vidyasagar, and Seth Hutchison

Biomechanics and Motor Control of Human Movement- David Winter

Feedback Systems- An Introduction for Scientists and Engineers- Karl Johan Astrom and Richard M. Murray

Applied Nonlinear Control- Jean Jacques Slotine and Weiping Li

Modern Robotics: Mechanics, Planning, and Control- Kevin M. Lynch and Frank C. Park

**Journal Papers:**

E. T. Wolbrecht, V. Chan, D. J. Reinkensmeyer and J. E. Bobrow, "Optimizing Compliant, Model-Based Robotic Assistance to Promote Neurorehabilitation," in *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 16, no. 3, pp. 286-297, June 2008.

Freeman, Chris T., et al. "Iterative learning control in health care: Electrical stimulation and robotic-assisted upper-limb stroke rehabilitation." IEEE Control Systems Magazine 32.1 (2012): 18-43.

J. Rosen, M. Brand, M. B. Fuchs and M. Arcan, "A myosignal-based powered exoskeleton system," in *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, vol. 31, no. 3, pp. 210-222, May 2001, doi: 10.1109/3468.925661.

T. Hayashi, H. Kawamoto and Y. Sankai, "Control method of robot suit HAL working as operator's muscle using biological and dynamical information," *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2005, pp. 3063-3068, doi: 10.1109/IROS.2005.1545505.

Aguirre-Ollinger, Gabriel, et al. "Active-impedance control of a lower-limb assistive exoskeleton." *2007 IEEE 10th international conference on rehabilitation robotics*. IEEE, 2007.

Ficuciello, Fanny, Luigi Villani, and Bruno Siciliano. "Variable impedance control of redundant manipulators for intuitive human–robot physical interaction." *IEEE Transactions on Robotics* 31.4 (2015): 850-863.

Ajoudani, Arash, and Abbas Erfanian. "A neuro-sliding-mode control with adaptive modeling of uncertainty for control of movement in paralyzed limbs using functional electrical stimulation." *IEEE Transactions on Biomedical Engineering* 56.7 (2009): 1771-1780.

N. Dunkelberger, S. A. Carlson, J. Berning, E. M. Schearer and M. K. O’Malley, "Multi Degree of Freedom Hybrid FES and Robotic Control of the Upper Limb," in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 32, pp. 956-966, 2024,

Dunkelberger, N., Berning, J., Schearer, E. M., & O'Malley, M. K. (2023). Hybrid FES-exoskeleton control: Using MPC to distribute actuation for elbow and wrist movements. *Frontiers in Neurorobotics*, *17*, 1127783.