Topic: Predictive Simulations of Gait with Exoskeletons that Alter Energetics

Master's thesis

Recent advances in hardware and software have allowed for the design of exoskeletons for many applications, such as restoring bipedal locomotion for persons with paraplegia or persons post-stroke, enhancing the locomotor capabilities of emergency personal during load-carriage, reducing fatigue in unimpaired individuals, and providing robot-mediated physical therapy in a clinical setting [1].

A main objective of exoskeleton design is to reduce metabolic cost, since humans minimize metabolic cost during gait. However, this objective is not easily achieved due to the complex interactions between a user and the exoskeleton. Often lengthy design procedures are required to optimize the controller of the exoskeleton, e.g. through parameter sweeping [2], or human-in-the-loop optimization [3], which require hours of walking by the user.

Therefore, we aim to save time by including gait simulations in the design process. When doing so, it is important to include interactions between the user and the exoskeleton, which can be done using forward simulations. We have recently shown that we can use simulations to predict a user's response to a knee worn exoskeleton under different controller conditions [4].

In this thesis, the goal is to use a forward simulation approach to predict the effect of an ankle worn exoskeleton under a series of controller conditions. These may include controllers that shift optimal gaits: i. to higher and lower net energy expenditures, ii. to increased and decreased step rate, iii. and from symmetric to asymmetric step lengths. All simulation predictions will be validated with experimental tests performed by our collaborators, with ample opportunity for cross-disciplinary exchange.

The proposed work consists of the following parts

- Literature review and patent search
- Design of exoskeleton controller in simulations framework
- Predictive simulations study into effect of controller conditions
- Data analysis and prediction of experimental outcome.

The thesis must contain a detailed description of all developed and used algorithms as well as a profound result evaluation and discussion. The implemented code has to be documented and provided.

Advisors: Prof. Dr. Anne Koelewijn, Prof. Dr. Jessica Selinger (Queen's University, Canada), Megan Mcallister , MSc. (Queen's University, Canada), if necessary medical supervisor

Student:

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References

[1] A. M. Dollar and H. Herr, "Lower Extremity Exoskeletons and Active Orthoses: Challenges and State-of-the-Art," *IEEE Trans. Robot.*, 24.1, 144–158, 2008.

[2] P. Malcolm, et al., "A Simple Exoskeleton That Assists Plantarflexion Can Reduce the Metabolic Cost of Human Walking," *PLoS ONE*, 8.2, e56137–7, 2013.

[3] J. Zhang, et al., “Human-in-the-loop optimization of exoskeleton assistance during walking.,” *Science*, 356.6344, 1280–1284, 2017.

[4] A. D. Koelewijn and J. C. Selinger, “Predictions of step frequency adaptations with altered energy landscapes.,” *IEEE Trans. Rob.*, in preparation, 2021.