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PH.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy

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Title: Gait Analysis Devices and Methods to Assess Physical Function in Controlled and Free-living Settings

Chairperson: Dr. Damiano Zanotto, Department of Mechanical Engineering, Stevens Institute of Technology

Committee Members:
Dr. Ashwini K. Rao, Department of Rehabilitation & Regenerative Medicine, Columbia University
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ABSTRACT

Gait analysis plays a pivotal role in assessing functional mobility in healthy and clinical populations. Wearable gait analysis technologies have opened a realm of new possibilities for investigators, sparking renewed interest and providing tools to answer open research problems. This work aims to leverage new gait analysis technologies to address two open challenges. First, while gait abnormalities and postural instability have been linked to cognitive decline in older adults, the causal relationship between cognitive capacity and gait remains an open problem. Although new gait analysis tools have been applied to elucidate how cognitive load affects dynamic stability in older adults, most studies to date have focused on standing tasks rather than ambulatory activities. Second, most gait analysis studies have been conducted in controlled environments over limited time periods, which often renders their results unrepresentative of real-world performance. While wearable technologies offer a promising alternative to conventional gait analysis tools for monitoring gait in diverse environments, long-term real-world studies leveraging wearable devices have been largely limited to volume metrics that lack stride-level granularity and cannot evaluate gait quality. How wearable devices can be effectively utilized to capture stride-level gait quality in real-world settings is still an open research question.

This work is articulated in two main research objectives. First, we aimed to develop new gait-analysis tools to study the associations between cognitive function and dynamic stability in older adults. Towards this objective, we combined the well-established dual-task walking paradigm with new and emerging tools leveraging mobile robotics, custom wearable sensors, functional optical brain imaging, and validated gait-analysis equipment. To evaluate these methods, we conducted two studies with community-dwelling older adults. Second, we aimed to introduce new discreet, wearable technology for stride-level gait analysis in real-world environments. Towards this objective, we engineered the first in-shoe system that allows for extended-time real-world spatiotemporal and kinetic gait monitoring and developed a new data-driven delay compensation model (D3CM) that allows precise synchronization between two in-shoe modules and a mobile phone, thereby enabling the accurate evaluation of inter-limb parameters. In addition, within an ongoing collaboration with the U.S. FDA Center for Devices and Radiological Health, we demonstrated the utility of the D3CM as a tool to assist in the verification of off-the-shelf, Bluetooth-enabled wearable devices, extending the model to enable accurate synchronization between two representative commercially available wearables and validated gait-analysis equipment. Concurrently, we further extended our work on in-shoe sensor-informed kinetic parameter estimation by developing subject-agnostic, machine-learning models for the in-shoe system to estimate (i) the biological ankle plantar- and dorsi-flexion moment – a key kinetic parameter to understand gait abnormalities that has also found recent applications in wearable robotics; and (ii) the dynamic center of pressure (COP) during walking tasks, validating the system through a one-month deployment.