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Ph.D. DISSERTATION DEFENSE

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Date:	August 21st, 2023
Time/Location:	1:30PM EDT via Zoom < https://stevens.zoom.us/j/4182298666 >
Title:	Toward Real-life Gait Analysis Using Wearable Sensors
Chairperson:	Dr. Damiano Zanotto, Department of Mechanical Engineering, SES
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ABSTRACT

Walking-related mobility measures such as kinematic and kinetic gait parameters may be used as indicators of neurological conditions affecting the motor function, fall risk, or overuse musculoskeletal injuries. Traditional gait analysis is carried out in controlled environments using laboratory equipment that is expensive and requires trained operators and dedicated infrastructure. Moreover, due to constraints in data collection environments, duration, and personal factors, laboratory-based gait assessments may not accurately reflect daily function/performance. Wearable sensors have the potential to become an affordable alternative to gait laboratory equipment for capturing ambulatory function in real-life environments. However, moderate accuracy and validity have been major challenges to the widespread use of these sensors in clinical and behavioral research.

This work focuses on the development and validation of novel wearable sensor systems and data processing techniques that can significantly improve the validity and reliability of wearable-based gait analysis in controlled and real-life environments. Firstly, to mitigate the drift and sensor-to-body-segment misalignment in measuring kinematic parameters in human locomotion with wearable motion capture sensors, a novel two-step functional calibration algorithm is developed and validated with a custom-engineered instrumented belt that measures 3D hip joint angles during walking. The use of wearable sensors in capturing kinetic gait parameters is also investigated. To this end, a novel outsole-embedded optoelectronic force sensor is developed to measure 3D ground reaction forces. Secondly, to examine the correlation between the wearables-derived metrics and established clinical measures, learning-based inference models are proposed for a novel pediatric instrumented insole system. Significant associations are unveiled between the gait parameters extracted using the inference models and a clinical scale of motor function in a group of children with neurodevelopmental disorders, indicating convergent validity of the technology. New probabilistic regression models and deep recurrent neural networks to estimate foot center of pressure trajectories using multi-modal instrumented insoles are also established and validated in healthy and pathological gait. Lastly, to facilitate the transition from in-lab to free-living gait analysis/monitoring, we propose a multi-stage validation procedure. The method includes high-level ambulatory activity classification and low-level gait analysis algorithms, and is validated under structured, unstructured, and free-living environments.

The outcomes of this dissertation contribute to the ongoing efforts by the research community to improve the validity of wearable sensors for human motion analysis and bridge the gap between in-lab and real-life gait assessments.