Mechanical Engineering Thesis Defense

Characterization of Human Postural Balance under Compliance and Deep Learning for Predicting Environmental Conditions during Postural Balance.

School for Engineering of Matter, Transport and Energy

Vu Nguyen Phan

Advisor: Dr. Hyunglae Lee

Abstract

This thesis work presents two separate studies:

The first study expands previous work by assessing standing balance under various vision conditions and 2-dimensional (2D) compliant environments simulated using a dualaxis robotic platform. Directional VTC measures were introduced to better characterize postural balance from both temporal and spatial aspects, and enable prediction of fall-relevant directions. Twenty healthy young adults were recruited to perform quiet standing tasks on the platform. Conventional stability measures, namely center-of-pressure (COP) path length and COP area, were also adopted for further comparisons with the proposed VTC. The results indicated that postural balance was adversely impacted, evidenced by significant decreases in VTC and increases in COP path length/area measures, as the ground compliance increased and/or in the absence of vision ($ps < 0.001$). Interaction effects between environment and vision was observed in VTC and COP path length measures ($ps \leq 0.05$), but not COP area ($p = 0.103$). The estimated likelihood of falls in AP and ML directions converged to nearly 50% (almost independent of the foot setting) as the experimental condition became significantly challenging.

The second study introduces a deep learning approach using convolutional neural network (CNN) for predicting environments based on instant observations of sway during balance tasks. COP data were collected from fourteen subjects while standing on the 2D compliant environments. Different window sizes for data segmentation were examined to identify its minimal length for reliable prediction. Commonly-used machine learning models were also tested to compare their effectiveness with that of the presented CNN model. The CNN achieved above 94.5% in the overall prediction accuracy even with 2.5-second length data, which cannot be achieved by traditional machine learning models ($ps < 0.05$). Increasing data length beyond 2.5 seconds slightly improved the accuracy of CNN but substantially increased training time (60% longer). Importantly, averaged normalized confusion matrices revealed that CNN is much more capable of differentiating the mid-level environmental condition.

These two studies provide new perspectives in human postural balance, which cannot be interpreted by conventional stability analyses. The outcomes contribute to the advancement of human interactive robots/devices for fall prevention and rehabilitation.

November 1, 2021; 10 AM; ERC 490;

Zoom Link: https://asu.zoom.us/j/88160263306