A Modular Approach for Modeling, Detecting, and Tracking Freezing of Gait in Parkinson Disease Using Inertial Sensors

PhD Dissertation Defense

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Abstract: Parkinson disease, the second most common neurodegenerative disorder, is caused by the loss of dopaminergic subcortical neurons. Approximately 50% of people with Parkinson disease experience freezing of gait (FOG), a brief, episodic absence or marked reduction of forward progression of the feet despite the intention to walk. FOG causes falls and is resistant to medication in more than 50% of cases. FOG episodes can often be interrupted by mechanical interventions (e.g., a verbal reminder to march), but it is often not practical to apply these interventions on demand (e.g., there is not usually another person to detect an FOG episode and provide the reminder).

To address this issue, we develop a modular approach to model, detect, and track freezing of gait (FOG) in Parkinson disease, using four modules, namely the detection, navigation, validation, and filtering modules. To capture the gait motion, we use an inertial measurement unit (IMU) consisting of a three-axis accelerometer and a three-axis gyroscope. We first build physically-based signal models that describe “no movement” and “trembling motion” during FOG events, and develop a two-stage detector for determining the zero-velocity event intervals (ZVEI) and trembling event intervals (TREI) in the detection module. However, not all the detected TREI are associated with FOG. To filter out the TREI not associated with FOG, we consider the fact that the trembling motion in FOG are associated with low foot speeds and small pitch angles. We use the ZVEI to extract gait parameters in the navigation module and identify valid gait cycles in the validation module. Finally, to detect the onset and duration of FOG, we develop a point-process filter that computes the probability of FOG (pFOG) in the filtering module. We model the edges of the TREI as a point-process, then assign weights to the edges, which depend on an autotuned participant-specific tunable parameter and the average value of the gait parameters observed in the bin containing the edge. Our central hypothesis is that regions in the space of sensor data with high values of pFOG indicate FOG with high likelihood. We validate the performance of the modular system design using real data obtained from people with Parkinson disease who performed a battery of gait tasks known to trigger FOG. The results indicate improved performance, with an average accuracy greater than 85% and an average false positive rate of less than 14%. Altogether, we not only improve the accuracy of FOG detection but also open new avenues towards the development of low-cost remote health monitoring systems, which will help provide insights into the frequency and patterns of FOG that affect the quality of daily life in people with Parkinson disease.

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