GaitGuardian: Real-Time IMU Processing and Visual Monitoring Using Machine Learning (ML) for Advanced Parkinson's Disease Patients (II)

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Over 10 million people live with Parkinson's Disease (PD), an incurable movement disorder that disrupts daily life. Freezing of Gait (FoG) affects 80% of advanced patients, causing sudden immobility and falls. Accordingly, PD patients often look down while walking, needing navigation assistance. Additionally, over 75% of patients undergo rest tremors (uncontrolled shaking), disrupting motor tasks. Hence, this work proposes GaitGuardian — a holistic machine learning (ML) solution for advanced PD patients, including FoG prediction, fall and tremor detection, and visual monitoring. First, the FoG prediction algorithm uses accelerometer data to flag a “pre-FoG” state (2s before FoG). A hybrid CNN + biLSTM model enhanced with dual-attention captures spatial and temporal features, achieving high sensitivity and specificity. Fall detection runs an ML ensemble on IMU data, nearing perfect accuracy. Tremor detection uses a lightweight 1D CNN trained on wrist-worn IMU data. Finally, visual monitoring pairs an object + depth detection backbone using transformer and convolutional modules (cloud-based) with a multimodal large language model for text output. ML techniques like oversampling, feature extraction, low-pass filtering, and tuning are applied to optimize accuracy and computation. For physical construction, a 6-DoF IMU connected to an ESP32-S3 is cased in PLA, using USB-C for power and data. The device mounts on the trunk while walking, or on the wrist for tremor remediation via haptics. Finally, a 2 MP Arducam is placed on the user’s forehead, using BLE-5 for data transmission (via ESP32). Overall, GaitGuardian can predict FoG, detect falls, remediate tremors, and monitor surroundings while outperforming existing models, demonstrating its beneficial impact on PD patients.

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