Fusing Digital Biomarkers: A Multimodal AI Framework for Parkinson's Disease Detection Using Gait, Voice, and Handwriting

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Parkinson's disease is a progressive neurodegenerative disorder requiring early intervention, yet screening is often delayed due to a dependency on expensive, in-person clinical assessments. AI models using digital biomarkers offer a low-cost alternative, but their utility is limited by a single-modality focus. As a result, these models evaluate only a portion of the disease's characteristics, which reduces predictive reliability and hinders the development of accessible, real-world screening tools. This project developed a multimodal AI framework that integrates gait, voice, and handwriting data to screen for Parkinson's disease. The implementation consisted of a four-stage architecture. First, modality-specific encoders extracted disease-relevant features from gait, voice, and handwriting data. Second, Domain-Adversarial Neural Networks reduced data biases, improving performance across varying data-collection environments. Third, Contrastive Learning maps embeddings into a single latent space and clusters disease representations by disease label. Finally, an attention-gated fusion stage combined these signals to produce a classification output. The results indicate that the fusion framework integrated gait, voice, and handwriting signals, achieving an F1 Score of 0.93 and an ROC-AUC of 0.94. These results suggest that a multimodal framework improves the robustness of Parkinson's screening compared to single-modality methods. This project demonstrates the feasibility of a multimodal AI system as an accessible tool for Parkinson's screening for underserved or rural populations via telehealth platforms.

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