

## **Adaptive Neuro-Fuzzy Inference System (ANFIS) in Parkinson's Disease (PD) Diagnosis**

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### **Abstract**

Parkinson's Disease (PD) is a progressive neurodegenerative disorder characterized by motor impairments such as tremors, rigidity, and bradykinesia, along with a wide range of non-motor symptoms. Conventional diagnostic methods rely primarily on clinical evaluation, often leading to delayed or inaccurate diagnoses due to overlapping symptoms with other movement disorders. The integration of Artificial Intelligence (AI) in medical practice has opened new pathways for improving diagnostic accuracy and early detection of PD. Among these approaches, the Adaptive Neuro-Fuzzy Inference System (ANFIS) has gained attention for its ability to combine the adaptive learning power of neural networks with the uncertainty-handling capacity of fuzzy logic. ANFIS models have been applied to diverse patient data sources, including speech analysis, gait dynamics, handwriting patterns, and biomedical signals, to differentiate PD from healthy controls and assess disease severity. This paper reviews the role of ANFIS in PD diagnosis, highlighting its advantages over conventional machine learning models, its medical implications, challenges, and future research opportunities.

**Keywords:** Parkinson's Disease, ANFIS, Fuzzy Logic, Machine Learning, Inference System

### **1. Introduction**

Parkinson's Disease (PD) is recognized as the second most prevalent neurodegenerative disorder after Alzheimer's disease, imposing a profound medical, social, and economic burden on patients, families, and healthcare systems [1, 2]. It is characterized by the progressive degeneration of dopaminergic neurons in the substantia nigra pars compacta, which leads to impaired dopamine production and results in motor dysfunctions such as tremor, rigidity, bradykinesia, and postural instability [3, 4]. Alongside these motor symptoms, PD also manifests with a wide range of non-motor complications including sleep disturbances, depression, cognitive decline, and autonomic dysfunction, which significantly affect patients' quality of life [5]. Early manifestations may be subtle, for instance, micrographia or mild tremors, and often remain unnoticed until the disease reaches more advanced stages. Globally, and particularly in developing countries, delayed diagnosis and limited access to advanced neuroimaging facilities exacerbate the challenge of early detection [6].

The absence of a definitive laboratory biomarker for PD makes diagnosis highly dependent on clinical expertise, neurological examinations [7], and observation of patient response to dopaminergic therapy. While imaging modalities such as PET and SPECT scans can assist in diagnosis [8], they remain costly, technically demanding, and largely inaccessible to many healthcare institutions, especially in resource-constrained regions. Moreover, clinical diagnosis is subject to inter-observer variability, and its sensitivity for identifying early or atypical PD cases remains insufficient. These limitations have motivated researchers and clinicians to explore advanced computational tools capable of augmenting traditional diagnostic approaches with greater accuracy, consistency, and affordability.

In recent years, Artificial Intelligence (AI) has emerged as a transformative field in medical diagnostics [9-11], offering innovative solutions for pattern recognition, predictive modeling, and clinical decision support [12-23]. Within this domain, hybrid models that combine the strengths of multiple computational paradigms have gained particular attention. Among these, the Adaptive Neuro-Fuzzy Inference System (ANFIS) [24] has demonstrated considerable potential for PD diagnosis and monitoring. ANFIS uniquely integrates the adaptive learning capabilities of neural networks with the interpretability of fuzzy logic systems [15, 16, 20, 25-46], allowing it to effectively manage uncertainty, non-linearity, and heterogeneity in clinical data. By leveraging features extracted from speech signals, gait analysis, handwriting patterns, or physiological markers, ANFIS provides a robust platform for distinguishing between PD and non-PD individuals while simultaneously offering interpretable rules that can support clinical reasoning.