

AI Based Parkinson Disorder Diagnosis System – A Comprehensive Review

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Abstract

Parkinson Disorder (PD) is a progressive neurological disorder. There is no specific and quantitative based PD diagnosis system. Artificial Intelligence (AI) is a tremendously growing technology, which aids in all sectors of healthcare. AI based PD diagnosis provides quantitative assessment more than subjective assessment, thereby providing robustness in diagnosis. This paper presents the review of Artificial Intelligence (AI) based PD diagnosis system. The conceptual framework for AI based PD diagnosis system, the challenges and future prospects in the domain of AI in PD diagnosis have been discussed.

Keywords: Artificial intelligence, Parkinson disorder, feature extraction, pre-processing, data sampling

1. Introduction

Parkinson Disorder (PD) is a neurodegenerative disorder which is characterized by two prominent types of symptoms namely motor symptoms and non-motor symptoms [1]. The early symptoms of PD are slurred speech and handwriting variations. The main causes of PD are genetic, environmental, trauma, and tumors [2]. The examination of subject is purely done on the basis of subjective assessment made by the clinicians and there is no quantitative assessment like the laboratory-based test for PD diagnosis. The solution is to provide a robust objective assessment tool for PD diagnosis which is made possible by the incorporation of AI.

The different ways by which Parkinson Disorder (PD) are detected in clinics are:

- Scans/Imaging Tests: Magnetic Resonance Imaging (MRI), Dopamine Transporter Scan (DATSCAN), Positron Emission Tomography (PET).

- Blood Tests
- Scores: Unified Parkinson Disorder Rating Scales (UPDRS), Hoehn and Yahr Scale

Artificial Intelligence (AI) is the state-of-the-art technology which is by definition is the simulation of the intelligence of human beings at some level. AI system is also known as Intelligent Agents. The term Artificial Intelligence was coined by John McCarthy in the year 1955 [3]. AI systems consist of sensory system which includes sensors that perceives the input from the environment and responds accordingly with the use of actuators [4]. AI is an umbrella term wherein Machine Learning (ML) is a sub part and Deep Learning is an extension of ML. AI has numerous applications widespread from high level to low level.

The main contributions of the review paper are:

- Comprehensive review for AI based PD diagnosis system
- Proposed Conceptual Framework for AI based PD diagnosis system

The remaining organization of the paper are as follows: section 2 provides the terminologies and the working principle with respect to AI, section 3 summarizes the comprehensive review on AI based PD diagnosis system, section 4 describes the proposed conceptual framework, section 5 presents the challenges and future prospects, and section 6 concludes the paper.

2. Artificial Intelligence – Terminologies and Working Principle

AI is a technique which emulates the human intelligence. AI can be defined as the computer machine which has a software embedded system, which performs intelligent tasks like humans at some levels [5]. The prominent algorithms of AI are fuzzy algorithms, and the commonly used AI programming language is LISP, which is procedural and functional language. The vital terminologies of AI are intelligent agents, rules engine, knowledge base, inference engine, various task domains of AI, classification of AI and types of AI based on capabilities and functionalities.

2.1 Terminologies

2.1.1 Intelligent Agents (IA)

- The IA are an autonomously performing robot which consists of sensors and actuators. The sensors perceive the inputs from the user using sensors and performs the outputs using the actuators. The IA are of two types namely Hardware Intelligent

Agent (HIA) and Software Intelligent Agent (SIA). Figure 1 presents the classification of IA.

- There are different architectures of IA, which are broadly classified as layered architectures, reasoning-based system architectures, network architectures and hybrid architectures [6].
- There are many applications of IA integrated with multi agent systems. One of the important case studies is Airborne Mission System [7].

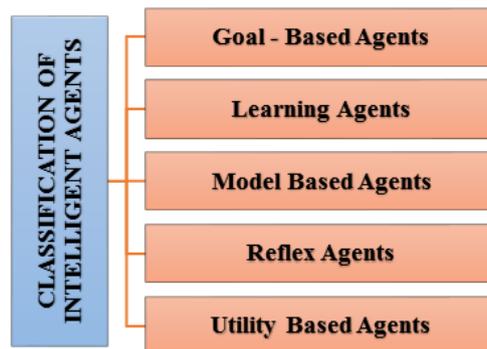


Figure 1. Classification of Intelligent Agents

2.1.2 Rules Engine (RE)

RE of AI consists of pre-defined rules constructed by subject expert and it is one of the core components of AI based Expert System (ES) [8]. The RE is constructed using complex if-then rules. Figure 2 represents the types of RE. Classification based RE and Regression based RE come under the types of single input – single output and multiple input-single output.

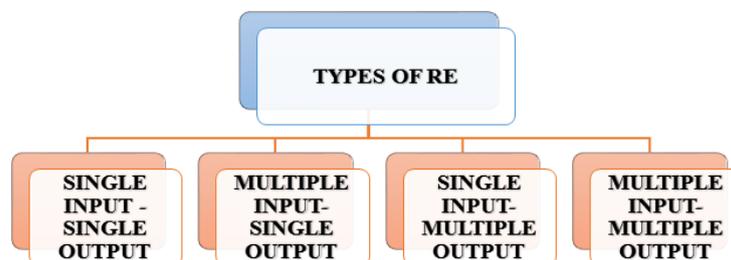


Figure 2. Types of RE

a) Inference Engine (IE)

IE is one of the core components of the AI based ES and the main functionality of IE is to make inferences from the knowledge present in the knowledge base [9]. The IE makes execution based on the satisfaction of some criteria using if and then clauses.

b) Knowledge Base

KB is the core component of AI based ES and it is the assimilation of knowledge with respect to the particular domain. The information in KB is presented as formal specifications with relationships among the information, technically the information in KB is presented as domain ontology [10].

c) Task Domains of AI

There are three main task domains of AI [11]. The task domains are depicted in figure 3. The KB construction for expert tasks is much easier when compared to KB construction for mundane tasks and formal tasks. The mundane task refers to the ordinary task, formal task refers to the evaluation, verification and proving based task, and expert tasks refers to the specialization tasks.

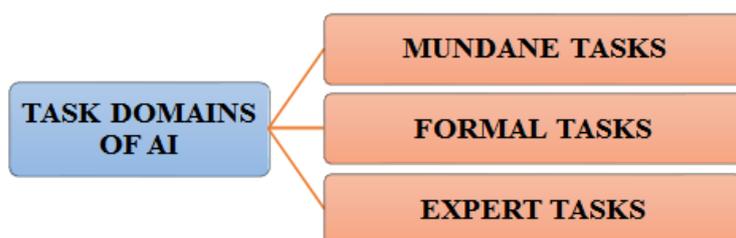


Figure 3. Task Domains of AI

d) Classification of AI

The prominent classification of AI is under these broad categories namely Expert Systems (ES), Machine Learning (ML), Natural Language Processing (NLP), Planning, Scheduling and Optimization, Robotics, Speech and Vision [12,13]. ML category consists of two main types namely deep learning and predictive analytics. NLP includes information extraction, translation, classification and clustering. Speech category of AI deals consists of two main processes such as, speech to text conversion process and text to speech conversion process. Vision category consists of image recognition and machine vision.

e) Types of AI

The two main types of AI are based on capability and functionality. The types of AI under the capability category are Narrow AI or weak AI, General AI or strong AI and Super AI. The types of AI under the functionality category are Reactive Machines, Limited Memory, Theory of Mind and Self-Aware AI.

2.2 Working Principle of AI in Medical Domain

The working of AI in medical domain is possible with the incorporation of algorithms namely Artificial Neural Network (ANN), Hybrid Fuzzy Systems and Evolutionary Computation [14]. The working of AI in medical domain begins with the collection of information from various primary and secondary sources. The primary sources of AI for medical domain are the domain experts namely the doctor, and the information is provided by the domain experts through direct interviews and conversations. The secondary sources are the literature works.

- Information Collection: Raw data and high information from primary and secondary sources
- Feeding to the Knowledge Base: KB is provided with raw data and processed data and stored as domain ontology.
- Inference Engine: The IE which consists of the complex algorithm, process the information and provides the inferences based on the if and else rule or based on intuitive AI algorithms.

3. Comprehensive Review – AI based PD Diagnosis Systems

Yang, Y et al., [15] presented an AI model for PD diagnosis based on breathing signals procured from the breathing belt wore by the individuals during sleeping process. The AI model incorporated in the system is a neural network which consists of attention layer. The advantage of the system is that, it is non-invasive in nature and it supports telediagnosis and telemonitoring process. The disadvantage of the system is that, it is evaluated based on the smaller number of samples and less exploration on the diversity of the dataset with respect to the variations of PD as PD consists of various sub types.

Armando de Jesús Plasencia Salgueiro et al., [16] presented a PD monitoring and diagnosis tool by integrating AI model with Gait based modality procured from smartphone. The AI model used in the system is Deep Reinforcement Learning Algorithm. The main advantage of the system is that the user need not be active in providing data which saves the time of the user. The disadvantage of the system is that the appropriate preprocessing technique is not being incorporated before sending to the AI model.

F. Cavaliere et al., [17] presented a Handwriting modality-based PD diagnosis using Genetic Programming (GP) integrated with Explainable AI. The advantage of the system is

the integration of Genetic Algorithm (GA) with AI system which eventually provided an optimal performance. The limitation of the system is that the creation of more balanced and larger dataset is missing which is needed for improving the AI model performance.

R. Sarankumar et al., [18] demonstrated the use of AI model for PD diagnosis based on voice features. The following methods were demonstrated in the system: signal error drop standardization for signal standardization, wavelet cleft fuzzy algorithm for features grouping, and the classification decision made by the Deep Broke Inception Net Classifier. The advantage of the system is that the data cleaning and pre-processing is performed in a standard way which improves the performance of the classifier. The disadvantage of the system is that, it didn't focus on the optimization of parametric values of classifiers.

U Anusri et al., [19] presented a facial recognition-based PD diagnosis system using AI model namely Convolutional Neural Networks (CNN) for feature extraction and deep transfer learning model namely VGG16 for classification. The advantage of the system is that, it provides robustness in diagnosis as the system integrates CNN and VGG 16 for feature extraction and classification.

Faisal Saeed et al., [20] presented an early prediction of PD based on voice features using a ML model, a subtype of AI model namely K Nearest Neighbor (KNN), which is a best performing model comparatively than other ML models and it is also integrated with feature selection methods for selecting the most important features. The advantage of the system is that there is a diverse set of combinations implemented to identify the best performing combination with respect to the feature selection and ML algorithms. The disadvantage is that the exploration of Deep Learning (DL) algorithms is not focused.

Ramzi M. Sadek et al., [21] presented an Artificial Neural Network (ANN) based on voice features extracted from raw voice signal for PD prediction. The advantage of the system is high accuracy. The disadvantage of the system is that there is no focus on different sampling techniques to prove the high accuracy of the model in different sampling scenarios.

The main issues identified in the existing systems are:

- Samples: The quantity of sample is less and quality of sample is average with respect to the diversity of the samples (age, gender, different levels of PD).
- Optimization: The optimization parameters for AI model is not focused in the experiments.

- Sampling Techniques: Different sampling techniques are not explored or focused in the implementation of the existing systems.

Table 1. Summary of the Literature Review

Authors	Year	Modality Type	Methodologies	Advantages and Disadvantages	Accuracy
Yang, Y et al. [15]	2022	Breathing Signals from Breathing Belt	AI Model: Customized Neural Network with Attention Layer	Advantage: Non-Invasive, Supports Telemonitoring and Telediagnosis. Disadvantage: The system is evaluated based on smaller number of samples and less diversity with respect to the variations of PD.	90%
Armando de Jesús Plasencia Salgueiro et al. [16]	2021	Gait Signals from Smartphone	AI Model: Deep Reinforcement Learning Model	Advantage: Passive data collection, saves time for user. Disadvantage: Appropriate preprocessing technique is not incorporated.	Not Specified
F. Cavaliere et al. [17]	2020	Handwriting Image	AI Model: GA Integrated with Explainable Artificial Intelligence	Advantage: Model provides optimal performance through integration of GA with AI model. Disadvantage: Large and balanced dataset collection is missing.	79%
R. Sarankumar [18]	2022	Voice Features	AI Model: Deep Broke Inception Net Classifier	Advantage: Standard data cleaning and Preprocessing technique is employed. Disadvantage: Optimization of parametric values in classifier is not focused.	99.8%
U Anusri et al. [19]	2021	Face Images	AI Model: CNN, VGG16	Advantage: Robust in nature due to integration of CNN and VGG16 architectures.	96.5%

				Disadvantage: Less focus and exploration towards optimization parameters of AI model.	
Faisal Saeed et al. [20]	2022	Voice Features	AI Model: K Nearest Neighbor (best performing model)	Advantage: Implementation of diverse set of combinations with respect to feature selection algorithms and ML algorithms. Disadvantage: Less exploration of DL algorithms.	88.3%
Ramzi M. Sadek et al. [21]	2019	Voice Features	AI Model: Artificial Neural Network	Advantage: High Accuracy Disadvantage: No focus on the different sampling techniques.	100%

4. Proposed Conceptual Framework

Figure 4 presents the proposed conceptual framework for AI based PD diagnosis system. The proposed conceptual framework consists of two main categories of individuals namely the user (patient and non-patient) and the doctor who is the domain expert of this PD diagnosis system.

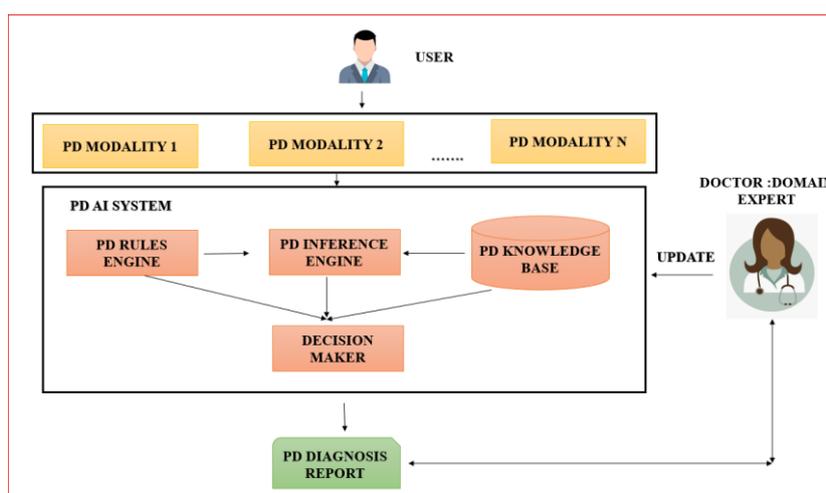


Figure 4. Proposed Conceptual Framework for AI based PD diagnosis System

The modality layer consists of ‘n’ possible modalities, for instance voice-based modality, handwriting based modality, gait-based modality, etc. The PD AI system consists

of four main compartments namely PD rules engine, PD inference engine, PD knowledge base and decision maker. The PD rules engine consists of the set of rules related to PD diagnosis, PD knowledge base consists of complete end-to-end information of PD diagnosis, which is provided by the domain expert, the PD inference engine is the AI algorithm incorporated compartment, which is the complex if and else parts (fuzzy system), and the decision maker consists of the final decision part i.e., prediction. The PD diagnosis report is provided as the output from PD AI system which is cross checked by the domain expert. The AI based PD diagnosis system is not a replacement of the doctor (domain expert), rather aids the decision-making process for the doctor.

5. Challenges and Future prospects

5.1 Challenges

- Challenge 1: Large and balanced dataset collection with respect to age and gender.
- Challenge 2: Identification of specific modality which discriminates the symptoms of PD exclusively when compared to other neurological disorders.

5.2 Future Prospects

- Multimodal AI architecture framework for PD diagnosis system.
- Non- invasive PD telemonitoring and telediagnosis system.

6. Conclusion

Parkinson Disorder (PD) is a neurological based disorder which affects the Substantia Nigra region in the brain that is responsible for dopamine generation. This paper has provided a comprehensive review on AI based PD diagnosis system. This paper clearly covers the AI terminologies and the working principle of AI. The proposed conceptual framework is presented after the knowledge accumulation from the review. The challenges and the future prospects provided in the paper will help the researchers with the directions in the AI based PD diagnosis domain.

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