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An Intensive Review on The Symptoms and Advancements In Diagnosis System Of Parkinson Disorder (PD)

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ABSTRACT

Parkinson Disease (PD) is a neurodegenerative disorder, progressive in nature which has no cure. The delay of PD progression is possible by incorporation of early diagnosis system. Early diagnosis can be made effective and accurate by the usage of Artificial Intelligence (AI) techniques. AI is prevalent in almost all the fields due to its intuitiveness and accuracy which covers the small applications in education sectors to the large applications in healthcare diagnosis system. This paper aims to provide an intensive review in the advancements of PD diagnosis by providing taxonomy, classification of PD diagnosis system and mapping the symptoms with its modalities. This paper also focuses on presenting the advancements of PD Clinical Decision Support System (CDSS) along with telemonitoring and telediagnosis in chronological order. A generic framework is presented for early PD diagnosis with the state-of-the-art technique. The paper is concluded with challenges and future prospects in the field of early diagnosis of PD.

Keywords : Parkinson Disease (PD), Clinical Decision Support System (CDSS), Artificial Intelligence

I. INTRODUCTION

Parkinson Disease (PD) is the common neurodegenerative disorder next to Alzheimer. The main symptoms of PD are motor symptoms and the secondary symptoms of PD are non-motor symptoms. The cardinal symptoms of PD are resting tremor, bradykinesia which specifies the slowness in movement and the rigidity of muscles [1]. The non-motor symptoms include sleep disorder, mental illness namely depression, speech problems, vision issues and loss of smell. The PD projection study done in [2] states that there is a prevalence of PD patients over 50 years of age ranging from 4.1 million and 4.6 million in the year 2005 and there is a possibility of doubling the patients in 2030.

The nature of PD is progressive and chronic, and it has no treatment of cure. The early diagnosis system of PD can aid the delay of progression which can

improve the livelihood of PD patients. Therefore, there is a need of effective early diagnosis system which is possible through the incorporation of Artificial Intelligence (AI), a state-of-the-art technology. AI is a technology which tries to mimics the certain aspects of human intelligence. The applications of AI are prevalent in almost every field, the two main subfields of AI are Machine Learning (ML) and Deep Learning (DL). There are various systems incorporated with AI for the PD diagnosis with non-invasive data modalities, which are included as part of CDSS, telemonitoring and telediagnosis. CDSS is a system which helps healthcare professionals to make effective decision as it provides results based on the integration of various data namely personal and clinical data. Telemonitoring and telediagnosis are two effective ways of monitoring and providing clinical support without the patient's physical presence at the clinic.

The paper is organized as follows, section 2 covers the taxonomy associated with PD, section 3 presents the classification of PD diagnosis system in consolidated manner, section 4 focuses on mapping the symptoms with various data modalities, section 5 presents the review on advancements of PD diagnosis which includes Clinical Decision Support System (CDSS), telemonitoring and telediagnosis systems, section 6 provides the proposed generic framework for early diagnosis of PD and section 7 presents the challenges and future prospects in the field of PD diagnosis for further research explorations.

II. TAXONOMY

PD affects the nerve cells of the most prominent part of the brain known as Substania nigra which is responsible mainly for motor movements. The taxonomy related to PD which provides the consolidated causes and symptoms in the figure 1. The various causes of PD are genetic factors, environmental factors, medication factors, other progressive brain condition, cerebrovascular disease. The symptoms of PD are categorized into two parts, they are cardinal symptoms and non-cardinal symptoms. The cardinal symptoms are associated with motor movements and non-cardinal symptoms are associated with non-motor movements.

The primary causes of PD are:

i. Genetic Factors: The study in [3] which states that PD is caused by genetic factors. There is a report of PD patients wherein 10% of patients are associated with PD positive family history, therefore the majority of PD cases are known as sporadic.
ii. Environmental Factors:
iii. Other Progressive brain conditions: The other progressive brain conditions namely Corticobasal degeneration, multiple systems atrophy and progressive supranuclear palsy are the causes of PD.
iv. Cerebrovascular Disease: It is a condition wherein the blood flow and blood vessels associated with the brain are affected.

The cardinal symptoms of PD are:

i. Resting Tremor: This condition refers to the shaking of limbs, usually arms when it is at rest.
ii. Muscles Rigidity: This symptom refers to the stiffness in the muscle which leads to state of dystonia (muscle cramps).
iii. Bradykinesia: The symptom "Bradykinesia" refers to slowness of movement which affects daily physical movements resulting in collapsed walk with tiny steps.
iv. Posture instability: The patient doesn't have the ability to maintain the steady posture for long time.
v. Walking and Gait problems: This symptom arises due to the integration of bradykinesia and posture instability. The patient experiences freezing of limbs, propulsion and also there is lack of natural swing of limbs.

vi. Dystonia: It is a symptom which exhibits repetitive muscle movement of any body part which is involuntary in nature.

vii. Speech problems: About 89% of PD patients exhibit speech disorders [6]. The speech disorder refers to the problems in any inter related activities of speech production. The speech production involves various coordination activities namely respiration, phonation, articulation, resonance and prosody. The problems associated with these coordination activities are decrease in speech volume, fluctuation in pitch, roughness in voice quality and articulation inconsistencies. These PD speech problems are called as Parkinsonian dysarthria or hypokinetic dysarthria.

The non-cardinal symptoms of PD are:

i. Sleep disorder: sleep disorder namely insomnia which can lead to lack of sleep during night and excessive sleepiness state during day.

ii. Depression: It is a psychiatric problem which shows symptoms such as extreme sadness and suicidal thoughts.

iii. Vision problems: PD patients exhibit vision problems such as alterations in vision contrast, visual processing speed becomes slower, colour vision problems, eye movement problems and vision hallucinations [7].

iv. Loss of smell: It is stated that more that 90% of PD patients show olfactory impairment [8].

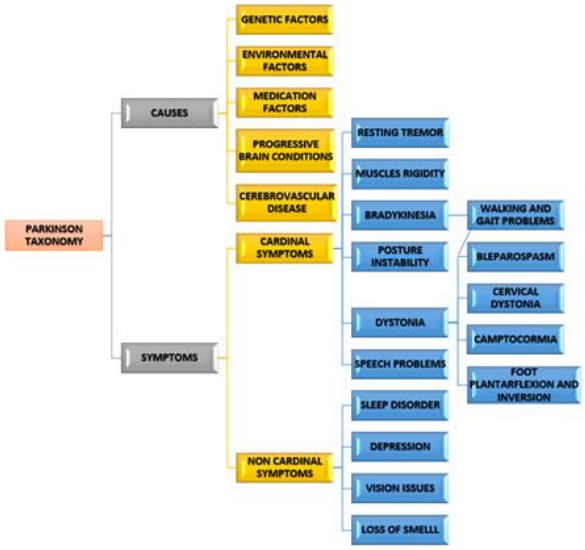

Figure 1- Taxonomy of PD- Causes and Symptoms

III. CLASSIFICATION OF PD DIAGNOSIS SYSTEM

The classification of Parkinson's Disease (PD) diagnosis system is done based on two criteria, namely method of acquisition which specifies the way in which the data is acquired from the patient and method of monitoring and access which specifies the way in which the patient's data is stored, diagnosed and accessed. Figure 2 represents the mind map of classification of PD diagnosis system.

- Method of acquisition:
  - Invasive and Non-Invasive
- Method of monitoring and access:
  - Clinical Decision Support System (CDSS)
  - Telemonitoring
  - Tele diagnosis

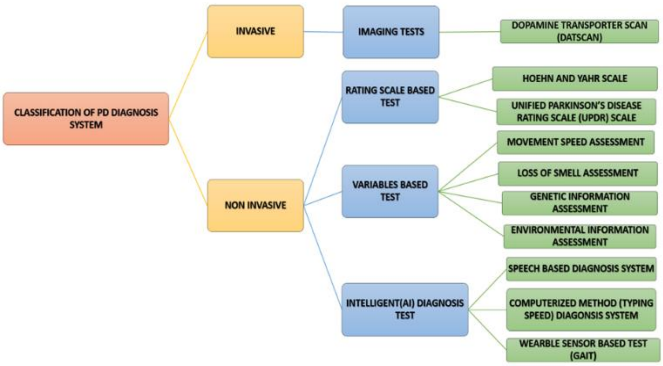

Figure 2 – Classification of PD Diagnosis System

3.1 METHOD OF ACQUISITION

The method of acquisition refers the way in which the patient's data is procured. The two main ways of acquiring patient data are invasive and non-invasive.

3.1.1 INVASIVE

The most popular invasive method to diagnose PD is an imaging-based test known as Dopamine Transporter Scan (DATSCAN).

3.1.2 NON-INVASIVE

The non-invasive methods to diagnose PD is categorized into rating scale-based test, variables-based test and intelligent (AI)diagnosis test.\

3.1.2.1 RATING SCALE BASED TEST

The two main rating scale which is broadly used in PD diagnosis are Hoehn and Yahr scale and Unified Parkinson's Disease Rating Scale (UPDR) scale.

i. Hoehn and Yahr Scale: It is the scale which is used to capture the progression of PD by mapping the symptoms to the five stages (1-5), the modified version includes intermediate stages namely 1.5 and 2.5.
ii. Unified Parkinson's Disease Rating Scale (UPDR) Scale: This scale covers five segments which is used to determine the PD progression, it consists of 199 points. The score of 199 indicates total disability and the score of 0 indicates no disability.

3.1.2.2 VARIABLES BASED TEST

The variables which are considered for PD diagnosis are olfactory (smell) assessment, genetic information assessment and environment information assessment.

3.1.2.3 INTELLIGENT (AI) DIAGNOSIS TEST

The prominent Artificial Intelligence (AI) based diagnosis test are based on speech, typing speed and wearable sensor-based test.

3.2 METHOD OF MONITORING AND ACCESS

3.2.1 Clinical Decision Support System (CDSS)

The CDSS is a system which aids effective decision making for clinicians based on the patient's data which includes personal information, information from sensors and wearables, subjective data (questionnaire based on variables). There are advancements in CDSS which includes mHealth based CDSS (mobile based CDSS) [9]. The mHealth CDSS integrates various modalities of patient's data which is provided to the healthcare professionals to make decisions based on frequent monitoring and analysis of data. The decision making of CDSS are improved using AI predictions.

3.2.2 Telemonitoring

The remote monitoring of patients after diagnosis and treatment is known as telemonitoring. The wearables (sensor)data at patient's end is send through the mobile applications to the severs of the medical device vendors which is captured at the CDSS at the hospital end [10]. The CDSS at the hospital will make decisions (outputs) and provide to the healthcare professionals.

3.2.3 Telediagnosis

The remote diagnosis is known as telediagnosis. The most prominent telediagnosis system of PD is based on dysphonia symptom-based (speech modality), since speech-based symptoms occurs for around 90% of PD patients [11].

IV. MAPPING SYMPTOMS WITH MODALITIES

The two main modalities are subjective and objective data. The subjective data mainly involves the data procured from the patients based on a questionnaire. The subjective data mostly covers the symptoms

experienced and the psychological factors. The objective data are the raw data obtained from the patient using some medical devices which are invasive and non-invasive in nature. The objective data covers the physiological and clinical data of the patient. Figure 3 presents the mapping of PD symptoms with appropriate modalities which can be used for diagnosis.

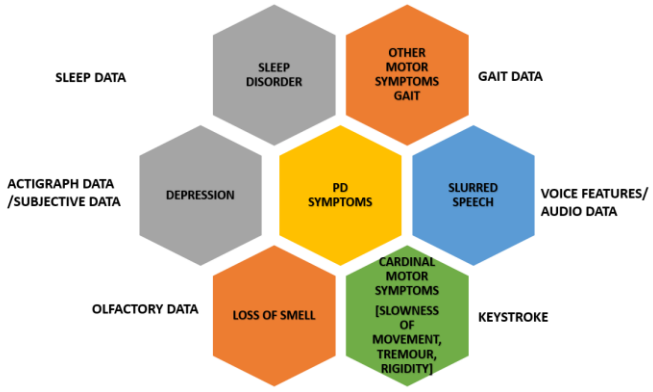

Figure 3- Mapping of PD Symptoms with Modalities

V. REVIEW ON ADVACEMENTS OF PD DIAGNOSIS SYSTEM

The review on advancements of PD diagnosis system is provided based on the classification of PD diagnosis system which covers two main categories, namely advancements in method of acquisition and advancements in method of monitoring and access. Table 1 presents the summary of the review.

4.1 REVIEW ON ADVANCEMENTS IN METHOD OF ACQUISITION

Jonathan R. Isaacson et al [12] presents the impact of the invasive technique for PD diagnosis known as DaTscan which is an imaging-based dopamine transporter scan. The specification of various clinical scenarios and the results analysis of DaTscan test is done. The problem of diagnostic uncertainty is solved using DaTscan which provides the evaluation of Nigrostriatal Dopaminergic Degeneration (NSDD).

Muntasir Hoq et al [13] presents an AI model for PD prediction based on voice extracted features which is a non-invasive approach. The AI model presented in the system consists of two hybrid models with Support Vector Machine (SVM) as the primary model which is integrated with Principal Component Analysis (PCA) and Sparse Autoencoders (SAE).

Warwick R. Adams [14] focuses on the PD diagnosis system which provides effective early detection by using the typing speed as the modality which captures the status of finger movement. The ensemble-based Machine Learning (ML) model is build based on the keystroke information.

Rafael Anicet Zanini [15] provides validation model for PD treatment approaches by presenting the simulations of PD patients tremor patterns using Electromyography (EMG) signals data. The data augmentation methods used are Deep Convolutional Generative Adversarial Networks (DCGANs) and style transfer.

4.2 REVIEW ON ADVANCEMENTS IN METHOD OF MONITORING AND ACCESS

Tamara.T. Muller et al [16] presents a “PECLIDES Neuro” which is a personalized Clinical Decision Support System (CDSS) for neurological disorders especially for Alzheimer’s and Parkinson’s Disease (PD). It provides insights with clarity for effective decision making which is built using Random Forest algorithm. This CDSS prevents the fault detection in diagnosis as it is formulated with an Algorithmic approach.

A remote monitoring system for PD diagnosis based on speech features is presented in [17]. The framework is a cloud-based framework which focuses on the dysphonia symptom and the diagnosis method is non-invasive nature. The methodology which is highlighted is the patients upload the speech samples

using the mobile phone which is retrieved by the doctor through the cloud manager after sample receiving at the doctor end , the voice is denoised and stored in the hospital database, further the Feed Forward (FF) Backpropagation Artificial Neural Network (ANN) algorithm is used to classify the speech sample as PD or healthy , based on the classification result the doctor is alerted for the diagnosis report generation which is send to the patient's end and further frequent monitoring is done by alert messages if the patient is classified as PD.

TABLE I – SUMMARY OF REVIEW

PAPER	CATEGORY	SUB CATEGORY	MODALITY	METHODOLOGY
[12]	METHOD OF ACQUISITION	INVASIVE	Imaging - based	DaTscan- Dopamine Transmitter
[13]	METHOD OF ACQUISITION	NON-INVASIVE	Voice Extracted Features	Machine Learning Algorithms • Support Vector Machine (SVM) • Principal Component Analysis (PCS) • Sparse Autoencoders (SAE)
[14]	METHOD OF ACQUISITION	NON-INVASIVE	Keystroke information	Ensemble based Machine Learning (ML) algorithm
[15]	METHOD OF ACQUISITION	NON-INVASIVE	Electromyography signal (EMG)	Deep Convolutional Adversarial Networks (DCGANS) and style transfer.
[16]	METHOD OF MONITORING	CLINICAL DECISION SUPPORT SYSTEM (CDSS)	• MRI data • Clinical data • Genetic data • Blood samples	Random Forest Algorithm
[17]	METHOD OF MONITORING	TELEMONITORING	Speech features	Feed Forward (FF) backpropagation algorithm.

VI. GENERIC FRAMEWORK OF PD EARLY DIAGNOSIS – CLINICAL DECISION SUPPORT SYSTEM (CDSS)

Figure 4 presents the proposed basic generic framework of PD early diagnosis. It is a non-invasive and AI based Clinical Decision Support System (CDSS).

The main modules of the CDSS are:

User Module

The user module consists of the data given by the user to the CDSS central component. The data modalities incorporated in the user module are based on the symptoms which is shown higher in patients namely speech and tremor. The dysphonia symptom can be identified by the voice recording sample and the tremor symptom can be identified by the typing information i.e., keystroke information. Further the other two data modalities are subjective in nature which covers the genetic and questionnaire test which cover the psychological and symptoms experienced by the user.

CDSS Central components

The CDSS central components are PD knowledge base, Inference Engine (AI model), Decisions – classification (PD/Non-PD) and recommendations (Alert messages to doctor if PD). This middleware is connected to the user module and doctor, it is a two-way communication. The Inference Engine is the most vital part of the CDSS. The inference engine can be effective and robust, if it is incorporated with the Artificial Intelligence (AI) technology. AI is the state-of-the-art technology which mimics the human intelligence. It has numerous applications which covers high end systems (Industrial applications and healthcare) and low-end systems (recommendations systems in e-commerce). The main subparts of AI algorithms are Machine Learning (ML) and Deep Learning (DL). The AI based inference engine reduce the misdiagnosis rate and provides robust automatic diagnosis for PD.

Doctor Module

The doctor module consists of CDSS report generation and validation. wherein the doctor verifies the generated reported from CDSS central component system. The updating of PD knowledge base is done by the doctor whenever new terminologies are framed.

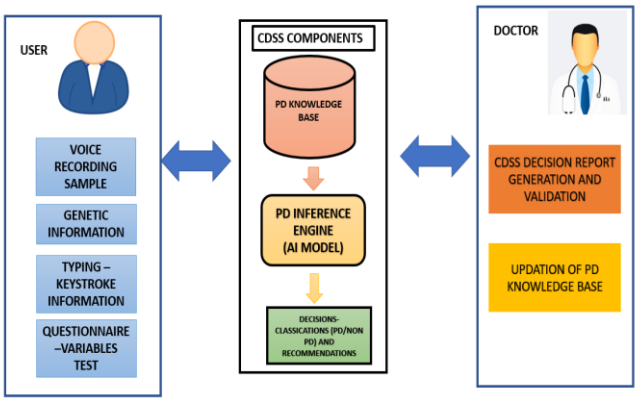

Figure 4 – Generic Framework of Early PD diagnosis system

VII. CHALLENGES AND FUTURE PROSPECTS

CHALLENGES

The main challenges of PD diagnosis are

- Identification of effective biomarker/ modality for PD diagnosis.
- The development of accurate and robust Clinical Decision Support System (CDSS) is challenging because the modality has to be free from processing errors and the best modality to be fed to CDSS has to be found which is a tedious trial and error task.

VIII. FUTURE PROSPECTS

The future prospects of PD diagnosis

- The incorporation of the state-of-the-art technology namely Artificial Intelligence (AI) in CDSS aids the patients and healthcare professionals for faster and easier diagnosis process and decision making.
- The robust telemonitoring system can prevent the patients from the invasive approaches and also encourages many people to use the system to test for PD diagnosis at an early stage as it is a remote and non-invasive approach.

IX. CONCLUSION

Parkinson Disease (PD) is progressive in nature and does not have cure. The only solution to the PD patients is to delay the progression by effective early diagnosis system. The PD diagnosis can be made effective by incorporating Artificial Intelligence (AI) diagnostic tools into the Clinical Decision Support System (CDSS) or telemonitoring systems which replaces the manual neurological examination and

also reduces misdiagnosis rate. This paper presents the complete review which covers the taxonomy, classification of diagnosis system, mapping of PD modalities and the recent research advancements in PD diagnosis system. A generic framework for PD diagnosis is proposed and presented in this paper based on the knowledge extraction obtained from the literature review, which would be useful as a foundation for further research in the PD diagnosis field.

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