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An Innovative Study for the Development of a Wearable AI Device to Monitor Parkinson's Disease Using Generative AI and LLM Techniques

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Abstract— Parkinson's Disease is a neurodegenerative disorder in the central nervous system that causes significant damage to the nerve cells. Patients with PD experience symptoms such as slow movement, loss of balance, tremors, and stiffness. This paper aimed to develop a new AI device that will be efficient and convenient for PD patients' home monitoring. The assessment of Parkinson's disease is usually difficult because it is a disorder that is characterized by damage of the motor symptoms especially dyskinesia [1]. My AI device is designed to monitor Parkinson's disease by generating a dyskinesia severity score. This device will leverage both AI and LLM AI techniques to collect multimodal data like tremors, movement, and posture. This multimodal data is collected using non-invasive sensors that are installed in the device. The AI algorithms will be significant in this device in analyzing and interpreting the patient-specific patterns from the data collected over some time [1]. It will adapt and refine assessment to ensure there is a comprehensive and personalized pattern of dyskinesia assessment. This device is significant due to its effectiveness in transforming the care management of Parkinson Disease's patients. This device will have the potential to help patients in continuous and unobtrusive home monitoring of Parkinson's Disease which will eventually improve their care and management of the disorder. It will also be significant to the research field in collecting valuable data on the disorder to allow for real-time interventions and improvement of personalized treatment plans. This device is made of cost-effective tools hence it provides a practical solution to PD care and reduces the burden on health facilities.

Keywords— Artificial Intelligence, Parkinson's Disease, Dyskinesia, Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS), Unified Dyskinesia Rating Scale (UDysRS), Large language models (LLMs)

I. Introduction

Parkinson's Disease is a disorder that mostly affects elderly people from the age of 60. The impact of this progressive neurodegenerative disease has seen 1% of the global aging demographics affected, causing a burden now and in the future [1]. is one of the most common motor complications in PD patients. Findings show that 50-80% of PD patients experience motor complications from dyskinesia such as involuntary and abnormal movements [2]. This complication is characterized by slow movements, tremors, and loss of posture which affects their general quality of life. There is a need for accurate and timely management of dyskinesia to guide health practitioners in making the right interventions and improving the quality of care for PD patients. There have been various interventions especially the application of clinical methods like the Unified Dyskinesia Rating Scale (UDysRS) which has been deemed to be traditional and subjective in making observations [2,3]. This method may also not capture any fluctuations of the disorder during periodic visits and therefore there is a need for home monitoring to make objective and continuous assessments of the severity of dyskinesia. This proposal looks at developing a novel-based wearable technology that will utilize AI and LLM AI techniques.

Artificial intelligence has revolutionized many technological systems, especially in the medical field. AI approaches have the potential to transform the techniques applied to a wide range of healthcare problems. This is expected to expand in the future as more innovative and powerful techniques are developed to solve ever-evolving problems. Large Language Models are emerging as one of the most transformative AI techniques. LLM is trained to generate human-like responses from massive resources and input that are converted to natural language queries. LLM works by utilizing supervised and unsupervised learning to analyze the collected data. This model produces its output by predicting the next word and phrases from the information fed to its systems from different resources [4]. The advancement of technology, especially AI has increased the current ways of solving problems by pushing boundaries that would otherwise be unimagined. A good example of such technologies is the Large Language Models (LLMs) which help in developing intelligent and sophisticated applications and technologies [5]. The use of LLM in the medical field is diverse with a major focus on facilitating operations such as clinical documentation, diagnosing conditions, suggesting treatment options, keeping medical records, and assessment of data, symptoms, and concerns. The LLM technique's potential benefits are expected to increase especially in research, medical education, streamlining workflows, and cost saving. Considering its effectiveness in healthcare, this proposal will look at how this technology can be implemented in medical devices to solve major problems affecting patients. The main aim of this paper is to develop an AI device that utilizes LLM techniques to collect and analyze dyskinesia data and measure its severity in patients with Parkinson's disease [6]. This AI device will be a novel and practical technology that will be wearable by PD patients as a solution to addressing some of the challenges faced by health practitioners in collecting data and assessing dyskinesia severity. This tool will assess the condition using a scoring index on data such as posture, movement, and tremors. This is significant in providing periodic evaluations of the disease hence offering timely and personalized treatment plans. The paper will be structured into different sections including the research problem, literature review, how the device works, its significance, its future in the U.S., and conclusion of the research findings.

II. RESEARCH PROBLEM

The main problem that this innovative study will solve is to develop a device that will address Parkinson's Disease care and management through the evaluation of dyskinesia severity. The medical field has experienced many challenges in PD care and management due to subjective methods of evaluating dyskinesia severity. Current methods have only been applied in clinical observations of PD and frequent assessments in controlled environments which has resulted in the collection of limited data and a potential for inaccuracies. Various scholars and researchers have noted that the biomarkers for testing the progression of PD are inadequate in the current medical environment which makes it difficult to assess the severity of the disease over time. What is currently available is a method called the Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS) which has been determined to be a semi-subjective or qualitative rating by nurses [7]. Researchers have also found this technique to be less sensitive to any small changes in a patient's status. This means that tests must be done for several years to report any changes in a patient's condition using the MDS-UPDRS for sufficient statistical reference . As a result, the costs and delays will be common making the technique inadequate to give insights and interventions on the severity of PD [8,9].

III. LITERATURE REVIEW

Recent research studies have shown that AI and LLM have been rapidly adopted in many areas to improve the efficiency of analysis and operations. One major area is in the medical field where tools like robots are currently under a lot of research to improve their efficiency in undertaking various tasks. Landers et al. (2021) explored how Artificial intelligence is adopted by clinicians and researchers in the diagnosis and management of various diseases [10]. The researchers state that there is a lot of health data collected in the clinical settings that would be beneficial to gaining better insights into disease severity and patient status. Such data are collected using inexpensive tools and sensors and assessed using sophisticated technologies like AI which makes it easy to analyze large volumes of healthcare data. An analysis of clinical datasets advances the field of medicine by ensuring there is timely monitoring of patients and collection of real-time data to help in assessing their status and guiding health practitioners in developing timely clinical interventions. While these global epidemiological techniques are advancing, there are still some challenges in examining and analyzing strategies as diseases evolve [10]. The researchers believe that the application of AI in medicine has been promising but more novel methods need to be developed to assist in future interventions of the diseases. One example of the use of AI is in monitoring the molecular subtypes of Parkinson's disease. The researchers noted that AI will be highly necessary for matching PD patients to molecular therapies hence advancing the field of precision medicine. The potential of AI needs to be explored to push the boundaries in precision medicine instead of traditional and individualized monitoring. If fully explored, AI will help health practitioners in monitoring and treating Parkinson's disease.

Another study by Yang et al.(2022) developed an AI model to track the progression of Parkinson's disease using nocturnal breathing signals. The researchers identified a gap which is the lack of biomarkers in the diagnosis of PD [11]. Their model included a dataset of 7671 participants approached in hospitals and multiple public datasets across the U.S.This AI model was developed to detect PD severity and progression with the target area under the curve(0.90 and 0.85) and its progression using the Movement Disorder Society Unified Parkinson's Disease Rating Scale ($R = 0.94$, $P = 3.6 \times 10{-}25$) [11]. The researchers also note that this model has an attention layer that interprets and predicts aspects such as sleep and electroencephalogram. The benefits of the model were attributed to its efficiency in-home monitoring in a touchless manner and its ability to use radio waves to extract the breathing patterns of a patient when sleeping. The findings from this model show that AI is an effective noninvasive technology that can be applied in a home setting to collect firsthand information for risk assessment of PD patients before a clinical diagnosis [11].

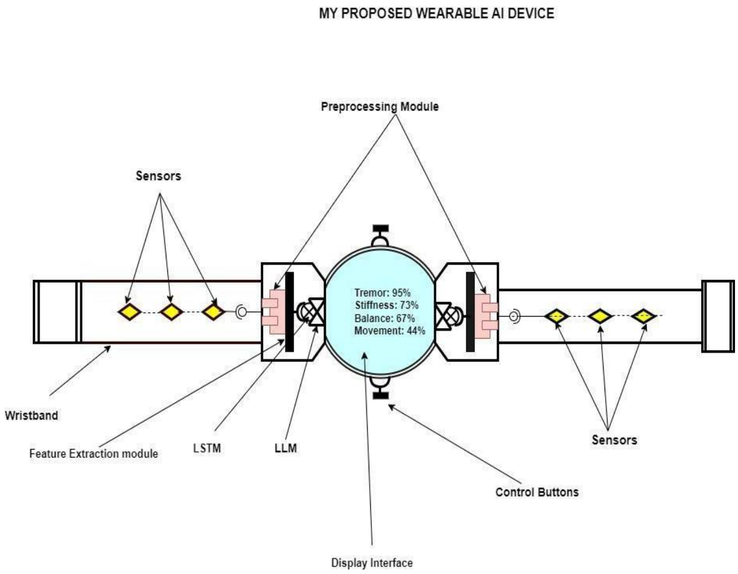
Some of the biomarkers that have been tested and found to have good accuracy include neuroimaging, blood biochemical, and cerebrospinal fluid. However, they are invasive, and costly and are only found in specialized health centers. This makes these biomarkers unsuitable when conducting frequent analyses and tracking PD's progression and severity in a patient.

A study by Karabacak & Margetis (2023) sought to explore the significance of Large language models (LLMs) as an AI tool that is expected to revolutionize the medical field [12]. One important thing to note about their study is the potential of LLMs in medical practice especially in the diagnosis of diseases, predicting their progression, and in making clinical decisions. The researchers mention that some of the medical departments poised to benefit from the use of LLMs include pathology, radiology, and oncology. This is a technology that will analyze large volumes of medical data and is expected to facilitate health practitioners with medical knowledge and expertise on various diseases. One challenge with the current use of LLM is the complexity and diversity of medical language and contexts which makes it difficult to accurately assess the nuances in medical practice [12]. Additionally, there are issues with data privacy and the difficulty in avoiding unbiased models. The researchers recommend they collaborate with medical practice stakeholders such as health practitioners, policymakers, and data scientists to develop a comprehensive LLM deployment. This will ensure that there is a robust approach toward the leveraging of the technology in pre-trained models and its adaptation to medical domains. Furthermore, there should be an increased fine-tuning of medicine-specific data from pre-trained LLMS to ensure that up-to-date and relevant medical knowledge is captured from the medical field [12]. These recommendations will ensure that medical practice relies on specialized knowledge and information that will provide solutions to the unique needs across diverse healthcare settings.

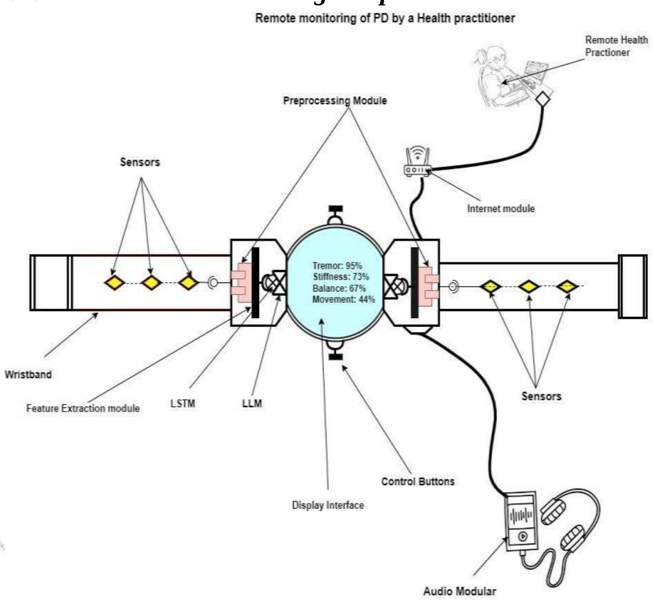
Sibley et al. (2021) note that assessing the severity of PD is an important medical intervention for clinical follow-ups of patients and how they respond to drug changes [13]. The researchers also believe that this is a major priority for clinicians in their evaluation of clinical trials. PD patients were considered to be a risk group during the COVID-19 pandemic after the in-person assessment became impractical and undesirable. This is why many health centers preferred remote/video consultations to assess the severity of their condition to avoid the need to travel or in the absence of their dopaminergic medication [13]. Many medical researchers also tried to develop automated rating mechanisms to assess PD severity by applying AI and video recordings. Sibley et al.(2021) note that some of the clinical tools that have been widely used in assessing PD are the Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS UPDRS) [13]. However, there are some challenges with video evaluations especially on agreement of items like tremors and bradykinesia. There are also issues in rating multiple elements adding more complexity to the system when assessing a patient's aspects like gait and balance [14,15]. There are also greater challenges to the system due to unstable motion blurs, time lags, and internet connections. This creates increased difficulty in getting an accurate scoring of PD severity [16].

IV. ORIGINAL CONTRIBUTIONS

V. *Initial design of the device*



VI. *Remote monitoring components*



VII. *How it works*

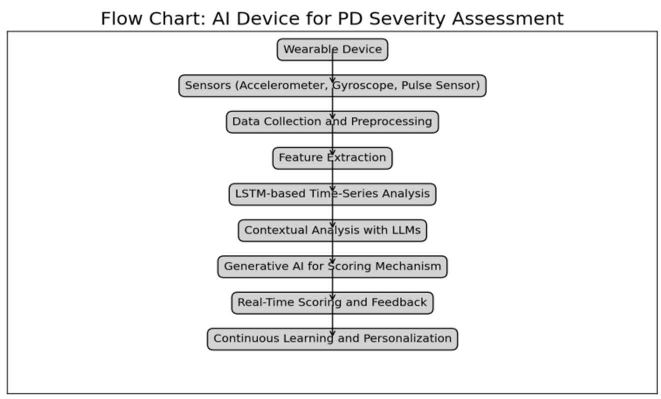


Fig i: A flow chart showing the working mechanism of the proposed AI device

My proposed device will be worn by the PD patients on the palm of their hands in the form of a wristband near the pulse nerves. The main objective of the device is to apply LLMs and AI in assessing the severity of PD using a scoring mechanism. The main data that will be captured are the general movement of the body, tremors, stiffness, and balance.

The device will work by first collecting data using the sensors installed in the device. The sensors that will best work in this case are the accelerometers, gyroscopes, and pulse sensors. Accelerometers will be vital in monitoring and measuring data concerning the movement and acceleration of the body. The main aim of measuring these data is to detect the severity of symptoms of Parkinson's Disease such as tremors and movement of the body. The gyroscope sensors will be integrated with the device to record data on the movement patterns and balance fluctuations in a patient's body. Pulse sensors will detect any changes in pulse waveform to evaluate the patient's stiffness and pulse rate.

TABLE I

	Severity Scoring			
Patient ID	Tremors	Stiffness	Balance	Movement
46321	87	55	88	77
46782	90	77	94	56
34355	44	55	55	39
44565	55	77	57	56
55646	88	55	96	78
56655	33	88	33	86

Table 1: PD severity scoring from the device

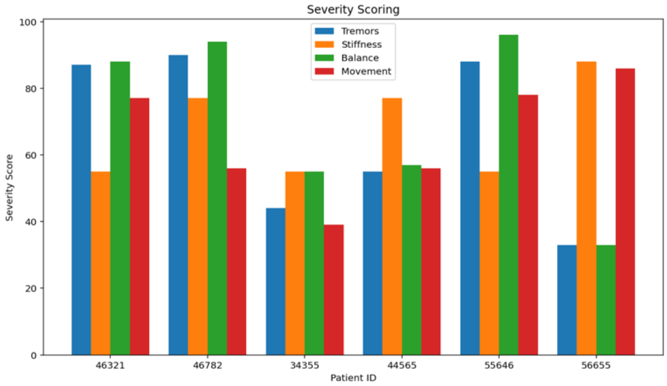


Fig ii: PD severity scoring from the device

The above table and the bar graph show some of the collected data using the device to record the main symptoms of PD. Once the data is collected, it will be sent to preprocessing and feature extraction chambers. This is where noise and artifacts will be removed from the raw sensor data. Next step is to extract the identifiable patterns in the data for the data collected on balance, tremors, stiffness, and related features of Parkinson's Disease. The feature extraction algorithms will be used in this step to process data into an input that will be analyzed by the AI model.

The next step is to apply the LLMs techniques to analyze the input data. One technique that will be applied is the LSTM-based Time series which will capture the temporal dependencies in the input data. This simply means the identification of the severity patterns of the disease through changes in their stiffness variations, balance fluctuations, tremor intensity, and movement patterns. The device will then perform contextual analysis using LLMs where the patient will be required to provide natural language prompts in the form of verbal or textual information. They can be asked to describe how they feel, their activities, emotional changes, their response to medication, and related factors that can cause changes in dyskinesia severity.

Generative AI algorithms in the form of Variational Autoencoders will be used to generate the scoring for PD severity. The Variational Autoencoders/AI algorithms will work by reconstructing the features from the input data and comparing them with the control samples to generate the score [17,18]. The continuous contextual input data from the severity scores will then be sent to the patient's user-friendly interface or display to provide them with real-time feedback about their PD severity. This information can also be sent to the supervising health practitioners in charge of monitoring the health status of the patient remotely.

This device will employ continuous learning and personalization to improve its working mechanism. This means that the device will be updated with contextual inputs to learn from each patient's severity patterns and responses. This will give the device the ability to adapt to severity assessments from different unique features that will eventually improve its working mechanism.

VIII. SIGNIFICANCE

My proposed device is not only significant to the patients but also to the medical especially in the management of PD severity. With the implementation of this device, there will be increased objectivity and continuous monitoring of Parkinson's Disease in real-time. This will allow medical practitioners a better and more advanced technology to make better assessments and subsequent health interventions on the dynamic symptoms associated with Parkinson's disease. The device will also be significant in early detection and making personalized treatment of Parkinson's Disease. This is expected to improve the overall management of Parkinson's Disease. The device will also be a good empowerment mechanism for patients. They will be able to get instant feedback about their condition and therefore they can actively participate in its management, increase their engagement and adhere to treatment routines. This device will also be significant to telemedicine in terms of remote monitoring. Since the health practitioners can track the patient's condition in a remote location, it will boost the progress made in telemedicine, especially a reduction in clinic visits and improving patient care.

IX. FUTURE

The future of this AI device will be promising to the U.S. considering the advancement of telemedicine and healthcare systems. The country will expect to experience enhanced patient care through accurate and personalized assessment of patients' diseases, especially Parkinson's Disease. There will be a general improvement in the quality of care across the country for PD patients. Additionally, the U.S. will expect a reduction in the cost of healthcare especially for managing Parkinson's Disease. The implementation of this device in the future will also enhance remote healthcare access. This will reduce the costs for the patients and healthcare practitioners. The device will also advance the use of AI technology in the medical field. This will set a precedent in the U.S. healthcare sector for the integration of AI-powered devices in disease management. The device will also improve U.S. economic growth and innovation, especially with the expansion of research and development.

X. CONCLUSION

This innovative study looked at developing a wearable AI device that utilizes LLM techniques to analyze dyskinesia data. This device is a good innovative breakthrough to data-driven studies. This will be valuable because it will contribute to a better understanding of Parkinson's Disease and dyskinesia assessment. It will also change the medical field by improving the treatment outcomes for patients and improving the strategies for dealing with disease progression. The device needs a large volume of data that will be collected using sensors integrated into the device. The main sensors that will be integrated into the device include accelerometers, gyroscopes, and pulse sensors. Accelerometers will be vital in monitoring and measuring data with movement and acceleration of the body. The main aim of measuring these data is to detect the severity of symptoms of Parkinson's Disease such as tremors and movement of the body. The gyroscope sensors will be integrated into the device to record data on the movement patterns and balance fluctuations in a patient's body. Pulse sensors will detect any changes in pulse waveform to evaluate the patient's stiffness and pulse rate. The main objective of developing this device is to assess the severity of Parkinson's Disease to help patients and healthcare practitioners to manage the disease on time. This study will expand future research on Parkinson's disease management by guiding on the efficient technologies to home monitor the disease. This innovation underscores the significance of AI and LLM techniques in developing a technology that can detect the severity of PD for early interventions and management of the disease.

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