Smart Glove to Monitor and Suppress Parkinson Disease

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Abstract—Parkinson's disease is a progressive, long-term condition that affects patients for many years, necessitating continuous management. In this study, we introduce an innovative smart glove designed to predict, monitor, and assist in the treatment of Parkinson's Disease. This intelligent system effectively tracks the severity and frequency of tremors experienced by patients, utilizing embedded accelerometers to capture and analyze movement data, thereby estimating the primary motor symptoms associated with Parkinson's disease. The smart glove utilizes machine learning algorithms, including XGBoost and SVM, to process the collected data and accurately estimate the severity of the motor symptoms. The data-driven insights generated by these algorithms are used to inform and adjust the patient's treatment plan, ensuring that therapeutic interventions, such as medication, are optimized daily. In addition to monitoring capabilities, the glove incorporates a tremor suppression mechanism powered by Transcutaneous Electrical Nerve Stimulation (TENS). This system delivers low-frequency electrical impulses to targeted muscle groups in the hand, helping to reduce involuntary movements and stabilize muscle activity. By stimulating nerves and improving neuromuscular control, the TENS-based suppression method provides non-invasive, drug-free relief for tremors, allowing for improved motor function in daily activities. By integrating both monitoring and suppression functions into a single wearable device, the smart glove reduces the necessity for frequent clinical visits, offering a more comfortable and continuous management solution for Parkinson's patients.

Keywords: Parkinson Disease, Smart Glove, Tremor Suppression Mechanism, Machine Learning Algorithms, ADXL345 Accelerometer.

I. INTRODUCTION

A. Objective

Parkinson's disease is a neurological disorder that primarily affects motor function due to a deficiency of dopamine in the brain. This deficiency leads to motor impairments, including tremors, which are a common symptom in Parkinson's patients. These tremors typically range between 3-8 Hertz in frequency. Regular monitoring of symptoms is crucial for managing the disease, yet traditional check-ups, typically scheduled biannually, may not capture the daily fluctuations in symptom severity.

This project aims to develop a user-friendly, wearable device that monitors and analyzes tremors in Parkinson's patients. The glove uses the ADXL345 accelerometer, placed on the thumb and index finger, to capture tremor data, which is transmitted to a smartphone via an ESP32 Microcontroller. This enables continuous monitoring and allows neurologists to adjust treatment plans accordingly.

Additionally, the glove features a TENS-based tremor suppression mechanism, reducing tremors by up to 90% and significantly improving the patient's ability to perform daily tasks. Unlike existing models, the device offers a lightweight, compact, and efficient solution for managing Parkinson's symptoms.

B. Motivation

Parkinson's disease, primarily affecting individuals over 47, impacts approximately 10 million people worldwide. This progressive disorder severely hampers motor functions and daily activities, imposing significant economic burdens through healthcare costs, lost productivity, and caregiver support. Traditional monitoring methods often fall short, requiring frequent clinical visits and providing limited real-time insight into symptom fluctuations.

We are motivated to develop a smart glove utilizing IoT and Machine Learning technologies to address these challenges. By continuously monitoring tremor levels and analyzing data in real-time, this innovative device aims to enhance patient care and reduce the need for frequent hospital visits. The integration of advanced technology in a wearable form seeks to improve the management of Parkinson's disease, making daily life easier for patients and alleviating caregiver stress.

C. Relevance of the project

Our smart glove project addresses a critical need amidst the growing global prevalence of Parkinson's disease, which affects millions of individuals, particularly those over 47. As the population ages and Parkinson's cases increase, the challenge of managing this progressive disorder becomes more pressing. Traditional methods of monitoring and managing Parkinson's symptoms are often inadequate, leading to frequent clinical visits and less precise treatment adjustments.

The relevance of our project lies in its potential to transform Parkinson's disease management through advanced technology. By offering real-time tremor monitoring and suppression via a wearable device, we provide patients and healthcare providers with actionable insights that enhance daily symptom management. This approach not only improves immediate quality of life by reducing tremors but also supports long-term health planning. With continuous data collection and analysis, the smart glove enables more precise treatment, reduces the need for frequent hospital visits, and contributes to a more efficient and personalized care strategy, ultimately fostering greater patient independence and resilience.

D. Design Methodology

Tremor Signal Acquisition:

The system starts with the acquisition of tremor signals from the patient using sensors embedded in the smart glove. These sensors detect the frequency and amplitude of the tremors.

Signal Analysis:

The collected tremor data is then analyzed using a processing unit in the glove. The analysis focuses on determining the tremor frequency, typically within the range of 3-8 Hz, to classify the severity of the tremor.

Classification of Tremor Severity:

Based on the frequency analysis:

Low Level (3-4.5 Hz): Indicates mild tremors.

Medium Level (4.6-6 Hz): Indicates moderate tremors.

High Level (6.1-8 Hz): Indicates severe tremors.

Depending on the classification, appropriate actions are taken, such as alerting medical professionals or adjusting medication dosage.

Data Monitoring:

Continuous monitoring of the tremor data allows for real-time adjustments in the treatment plan. The data is transmitted to a central system where it is analyzed over time.

Doctor's Intervention:

The system can suggest medical interventions based on the analyzed data. This could involve adjustments in medication, physical therapy recommendations, or other medical advice.

Tremor Suppression:

Finally, the glove can activate mechanisms to suppress tremors. This could involve vibration feedback, muscle stimulation, or other forms of therapeutic intervention to reduce the severity of tremors.

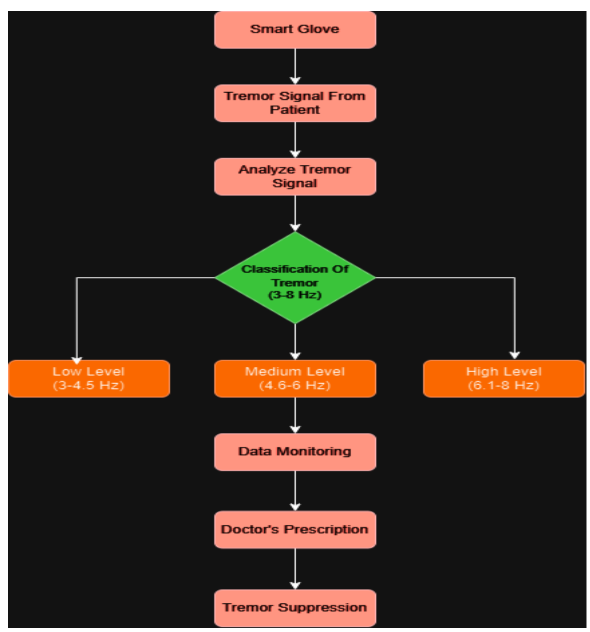

Figure 1. Design Methodology

E. Abridgement

Effective management of Parkinson's disease hinges on accurate and continuous monitoring of symptoms, particularly tremors. By leveraging advanced sensor technology and real-time data analysis, our smart glove offers precise detection and suppression of tremors in Parkinson's patients. This innovative device empowers both patients and healthcare providers by enabling timely adjustments to treatment plans, thereby enhancing patient autonomy and reducing the need for frequent clinical visits. The integration of this technology not only improves daily symptom management but also contributes to a more personalized and effective long-term care strategy.

II. RELATED WORKS

[1] This study presents a prototype designed to monitor and quantify tremor signals in Parkinson's Disease patients, a disorder characterized by symptoms such as tremors, stiffness, and difficulty walking, affecting nearly 80% of those diagnosed. The prototype employs an Arduino Uno microcontroller interfaced with an ADXL335 tri-axial accelerometer to capture acceleration data from the patient’s fingertip, wrist, and forearm. This data is processed by the Arduino and then analyzed in MATLAB to assess the amplitude and spectral density of the tremor signals. Observations indicated that the amplitude of the acceleration ranged between 40 dB/Hz and 80 dB/Hz across the three measured locations. The findings suggest that this wearable device, which could be integrated into a glove, provides a valuable foundation for further development, potentially offering a practical tool for assisting in the management of Parkinson’s Disease symptoms.

[2] This research investigates the use of wearable sensor technology to improve the treatment of Parkinson's Disease (PD) by providing objective, continuous analysis of motor symptoms, which are often difficult to distinguish from normal activities in everyday life. The study focuses on the detection of PD tremors by comparing several feature sets and classification algorithms. Data was collected using wrist-worn accelerometers from six PD patients performing tasks that mimic daily activities. The researchers explored both traditional and novel feature sets, including Mel frequency cepstral coefficients (MFCCs) and features derived from Convolutional Neural Networks (CNNs). They also introduced a method to separate tremor signals from voluntary movements, enhancing the accuracy of tremor detection. Two classifiers, Random Forest (RF) and Multilayer Perceptron (MLP), were used to evaluate the feature sets. Results showed that CNN-derived features, particularly when applied to decomposed tremor and activity spectra, yielded the best performance, outperforming the baseline and traditional feature sets. The study demonstrates the potential of combining advanced feature extraction techniques with machine learning algorithms to improve the accuracy of PD symptom detection, thereby offering a more reliable tool for monitoring and managing the disease.

[3] This paper discusses the use of various sensor-based instruments and hardware for detecting and measuring the key motor symptoms of Parkinson’s Disease (PD), including resting tremor, bradykinesia, postural instability, and rigidity. Accelerometers are commonly used for tremor detection, with the first tremor measurement device being developed in 1979. This device involved amplifying the tremor signal, converting it to digital form, and processing it with a microprocessor to determine tremor frequency. Beyond accelerometers, other sensors such as piezo sensors, gyroscopes, magnetometers, and goniometers have been employed to provide more accurate measurements of tremor characteristics, including amplitude, direction, and angular velocity. Wearable devices equipped with these sensors can transmit data wirelessly, allowing for continuous monitoring of patients. In recent years, Inertial Measurement Units (IMUs) have gained popularity for tremor measurement due to their compact and integrated design, offering highly accurate results.

[4] This paper presents an initial effort towards developing a cost-effective and scalable clinical device for monitoring Parkinson's disease (PD) progression through magnetic measurements. The project aims to create an Internet-connected device that allows patients to perform standardized tests and share the results with specialized medical centers. The current system focuses on two key parameters: tremor frequency and hand trajectory. The setup includes a fixed receiver coil system and a mobile transmitting coil, with preliminary tests conducted using a robotic arm as a reference. The results demonstrate the system's ability to accurately estimate tremor frequency and hand trajectory, even under high

tremor conditions. The paper discusses the growing need for such devices due to the aging global population, which is leading to an increase in neurodegenerative diseases like PD. Traditional diagnostic methods, while effective, are subjective and may lead to incorrect diagnoses. The proposed system offers a more objective and precise alternative, with the potential for integration into general practice and home environments.

[5] This paper introduces a non-invasive, cost-effective method for predicting Parkinson's disease (PD) by analyzing hand tremors using an accelerometer sensor. Parkinson's is a progressive neurological disorder characterized by tremors, muscle rigidity, and slow movement, predominantly affecting older individuals. The study focuses on detecting tremor frequencies, which typically range between 3-8 Hertz in PD patients.

The system employs a 3-axis accelerometer (ADXL335) to measure hand tremors, capturing tilt and motion data. This data is then processed using MATLAB, where the time-domain signals are converted to the frequency domain via Fast Fourier Transform (FFT) to identify the dominant tremor frequency. The study collected data from seven subjects, three of whom had Parkinson's disease, while four were healthy. The results confirmed that tremor frequencies in Parkinson's patients consistently fall within the 3-8 Hertz range, while those in healthy subjects are below 3 Hertz or nearly zero.

The findings suggest that this accelerometer-based system could serve as a reliable tool for general physicians to predict Parkinson's disease without relying on traditional, expensive diagnostic methods. The study also highlights the consistency of tremor readings across different axes and hands, indicating that data from any one axis or hand could suffice for analysis.

[6] This paper addresses the challenge of managing tremors in individuals with Parkinson's disease (PD), particularly focusing on the often-overlooked tremors in the fingers. Approximately 25% of PD patients do not respond effectively to traditional treatments, leading to the development of alternative approaches like Wearable Tremor Suppression Devices (WTSD). The study's objective was to design a glove capable of independently suppressing tremors in multiple hand joints—specifically, the index finger metacarpophalangeal (MCP) joint, the thumb MCP joint, and the wrist—while preserving the user's ability to perform voluntary movements.

The WTSD developed in this study utilizes a distributed cable transmission system to remotely locate the actuation mechanism, ensuring that the device remains compliant and does not restrict the forearm or hand's natural movements. This design approach also minimizes the bulk and weight of the device, making it more suitable for daily use.

[7] This study investigates the application of machine learning techniques, particularly Support Vector Machine (SVM) and Extreme Gradient Boosting (XGBoost), to improve the accuracy of Parkinson's Disease (PD) prediction. PD is a neurological disorder that impairs movement, causing symptoms such as tremors, muscle stiffness, and slowed mobility. While there is currently no cure, early diagnosis and intervention can significantly reduce symptoms and enhance quality of life. The research demonstrates that XGBoost, with an accuracy rate of 92%, and SVM, with 87% accuracy, are highly effective in classifying and predicting PD. XGBoost is especially adept at handling large datasets and missing values, while SVM excels in efficiently classifying complex data. Early and accurate detection of PD allows for timely medical intervention, including physical therapy, surgery, or medication, which can slow disease progression. The study also highlights that PD typically develops around the age of 60 and progresses slowly, with symptoms varying widely among patients, underscoring the need for personalized treatment strategies.

III. EXISTING AND PROPOSED SYSTEM

A. Existing system:

Parkinson's disease, a progressive neurodegenerative disorder, profoundly impacts motor function, manifesting in symptoms such as tremors, rigidity, and impaired mobility. Tremors, a predominant symptom affecting approximately 80% of patients, are currently monitored using accelerometer-based wearable devices, specifically gloves. These gloves are equipped with accelerometers to capture tremor signals across all five fingers, providing a cost-effective solution for continuous monitoring. The primary advantage of this system is its ability to be worn for extended periods, thereby enabling prolonged observation of tremor activity. However, the current system is limited in its ability to analyze tremor patterns in detail, as it primarily measures tremor intensity without offering in-depth insights into specific tremor characteristics or potential triggers. Consequently, while the accelerometer-based gloves facilitate consistent tremor monitoring, there is a need for enhanced analytical capabilities and additional features to improve the comprehensiveness and effectiveness of tremor management. Future improvements could include the integration of advanced data analysis techniques, real-time feedback mechanisms, and the incorporation of supplementary sensors to provide a more holistic view of motor symptoms and treatment efficacy.

B. Proposed system:

This paper proposes a wearable device in the form of a smart glove designed to monitor and mitigate tremors in Parkinson's patients. The glove uses ADXL345 accelerometers on the thumb and index finger to capture precise tremor data, which is wirelessly transmitted to a smartphone via an ESP32 Wi-Fi module for continuous monitoring. Additionally, the glove features a TENS (Transcutaneous Electrical Nerve Stimulation) system that delivers controlled electrical impulses to stabilize hand muscles, effectively reducing tremors and enhancing the patient's ability to perform daily tasks. This lightweight, compact solution addresses the limitations of existing models, offering an efficient approach to managing Parkinson's symptoms.

1. Tremor Monitoring:

The proposed prototype integrates an ADXL345 accelerometer with an ESP32 microcontroller to create a comprehensive system for monitoring hand tremors in patients with Parkinson's disease. The accelerometer is strategically positioned on two critical parts of the hand: the thumb and index finger, ensuring precise tremor data collection from the most affected areas during daily tasks. The accelerometer records movement along three axes: X, Y, and Z, capturing the three-dimensional motion of the hand. By analyzing variations across these axes, the system can detect even subtle tremors. The collected data is then processed to identify the axis with the greatest variation, which typically corresponds to the most significant tremor activity. This axis-specific analysis enables more accurate monitoring and a deeper understanding of tremor dynamics.

Once processed, the tremor data is wirelessly transmitted via the ESP32's Wi-Fi and Bluetooth capabilities to a smartphone for real-time monitoring and analysis. This wireless integration allows healthcare professionals to track tremor patterns over time and adjust treatment strategies accordingly. Additionally, the smartphone interface provides an intuitive platform for patients and caregivers to view and manage the data, ensuring that the system remains practical, accessible, and effective in everyday use.

Figure 2. Block diagram of the Proposed System

2. Predictive Analytics:

By continuously monitoring hand tremors using smart gloves, healthcare providers can apply predictive analytics to develop highly personalized treatment plans for Parkinson's patients. The tremor data, captured in real-time by the gloves, is processed using advanced machine learning algorithms like XGBoost and Support Vector Machines (SVM). These algorithms are adept at handling complex data, allowing for accurate predictions of tremor patterns and symptom progression.

XG Boost Algorithm:

XGBoost (Extreme Gradient Boosting) is a powerful algorithm used in predictive analytics to enhance the accuracy and effectiveness of tremor analysis in Parkinson's patients. By applying XGBoost, the project can create sophisticated models that predict future tremor patterns based on historical data. This algorithm excels at identifying important features from the data, such as tremor amplitude and frequency, and understanding their relationships with disease progression. XGBoost handles complex, non-linear data interactions and scales efficiently with large datasets, which is essential for continuously monitoring tremors. Its predictive capabilities allow healthcare providers to anticipate changes in tremor severity and adjust treatment plans proactively, improving patient management and outcomes.

SVM Algorithm:

Support Vector Machine (SVM) is a robust algorithm for predictive analytics, particularly useful for classifying tremor data into different severity levels and predicting disease progression. SVM works by finding the optimal hyperplane that separates different classes of tremor data, ensuring accurate classification even when data is not linearly separable. By applying the kernel trick, SVM can handle complex, non-linear relationships within the tremor data, which helps in understanding and predicting the nuances of tremor patterns. This capability is crucial for creating models that forecast how tremors will evolve under various conditions and for making real-time adjustments to treatment strategies based on the predicted outcomes. SVM's precision in classification and outlier detection supports personalized treatment plans, enhancing the overall management of Parkinson's disease.

3.Tremor Suppression:

In a tremor suppression system, Transcutaneous Electrical Nerve Stimulation (TENS) plays a crucial role in providing precise and effective tremor management. The TENS electrodes are embedded within the glove to deliver controlled electrical impulses to the hand muscles, stabilizing involuntary movements. The system continuously monitors tremor patterns using sensors like the ADXL345 accelerometer. This data is processed by an ESP32-based control system, which dynamically adjusts the TENS stimulation intensity based on tremor severity. By applying targeted electrical pulses, the system modulates neuromuscular activity, reducing tremor amplitude and improving hand stability. TENS is particularly suitable for this application due to its non-invasive nature, adjustable intensity levels, and compact integration within wearable technology. Unlike mechanical suppression methods, TENS offers a lightweight and energy-efficient solution that enhances user comfort while effectively managing tremors, allowing for better control and improved daily functionality.

IV. HARDWARE REQUIREMENTS

A. ADXL345 Accelerometer:

The ADXL345 is a high-precision, low-power, 3-axis accelerometer designed for motion tracking and tremor detection in wearable applications. It operates on a voltage range of 2.0V – 3.6V and communicates using I2C or SPI protocols. The sensor provides acceleration measurements across the X, Y, and Z axes, with a selectable sensitivity range of ±2g, ±4g, ±8g, or ±16g, making it highly suitable for detecting even minor tremor movements in Parkinson's patients. With a resolution of 256 LSB/g at the ±2g setting, it ensures precise motion analysis. The compact size of 3mm × 5mm × 1mm and lightweight design of approximately 0.5 grams make it ideal for seamless integration into a smart glove without adding significant bulk. The accelerometer continuously monitors tremors, and the collected data is analyzed to classify tremor severity for further processing.

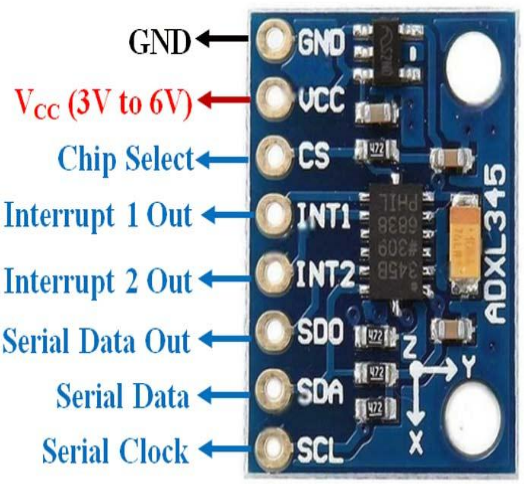

Figure 3. ADXL345 Accelerometer

B. ESP32 Microcontroller:

The ESP32 is a dual-core microcontroller that serves as the primary processing unit for the smart glove, handling sensor data acquisition, wireless communication, and real-time processing. It features a 240 MHz Xtensa LX6 processor, 34 GPIO pins, and supports multiple communication protocols such as SPI, I2C, UART, PWM, ADC, and DAC. A key advantage of the ESP32 is its built-in Wi-Fi (802.11 b/g/n) and Bluetooth (Classic & BLE 4.2) connectivity, allowing seamless data transmission to a mobile application for remote monitoring. The device operates on 3.3V, has a 520KB SRAM, and supports external flash memory, ensuring efficient data processing and storage. With a compact footprint of 25.5mm × 18mm × 3mm and weighing approximately 5 grams, the ESP32 is well-suited for wearable healthcare applications, enabling real-time tremor analysis and patient monitoring.

Figure 4. ESP32 Microcontroller

C. TENS (Transcutaneous Electrical Nerve Stimulation) Module:

The TENS module is integrated into the smart glove to provide tremor suppression by delivering mild electrical impulses to the affected muscles. This technique helps in reducing involuntary movements by stimulating nerves and promoting muscle stabilization. The TENS module operates on 5V – 12V DC with an adjustable current output of up to 80mA. It generates electrical pulses with a frequency range of 1Hz – 120Hz and a pulse duration of 50µs – 250µs, allowing for fine-tuned stimulation. The module typically connects to two or four electrodes, which are strategically placed on the hand to target key muscle groups. With a size of 30mm × 20mm × 5mm and a weight of approximately 3 grams, the TENS system remains compact and lightweight, ensuring user comfort while effectively managing tremors.

Figure 5. TENS (Transcutaneous Electrical Nerve Stimulation) Module

V. CONCLUSION

The development of our smart glove marks a transformative step forward in the management of Parkinson's disease. By integrating real-time tremor monitoring, data analysis, and tremor suppression into a single wearable device, we offer a comprehensive solution that significantly improves the daily lives of patients. This innovation not only facilitates precise and personalized treatment adjustments but also empowers patients to manage their symptoms autonomously, reducing the reliance on frequent clinical visits and easing the burden on healthcare providers.

Moreover, the continuous data collection and real-time feedback provided by the glove enable more informed decision-making by both patients and healthcare professionals, leading to better long-term outcomes. The device's ability to suppress tremors in real-time enhances the patient's ability to perform everyday tasks, thus improving their overall quality of life. By combining advanced technology with user-friendly design, our smart glove addresses the critical needs of Parkinson's patients, offering a more efficient, effective, and patient-centered approach to managing this complex condition. The success of this project underscores the potential for further innovations in wearable healthcare technology, paving the way for improved disease management and enhanced patient care.

VI. FUTURE ENHANCEMENT

To further advance the smart glove's capabilities, several strategic enhancements are proposed. Incorporating additional sensors to track vital signs like heart rate, blood pressure, and oxygen levels would offer a multi-dimensional health monitoring tool, enhancing the device's ability to provide a holistic view of the patient's condition. Exploring the expansion of this technology to address other neurological or chronic conditions could significantly broaden its utility, offering a versatile solution for comprehensive health management.

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