TremorCare: A Smart Wearable Glove for AI-Based Tremor Detection and Remote Patient Monitoring

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ABSTRACT

Parkinson's disease (PD) and essential tremor (ET) are two neurological movement disorders that cause an involuntary hand tremor, affecting normal functions. The constant monitoring of the severity of the tremor allows physicians to measure the development of the disorder and provide appropriate treatment to patients. In this paper, an AI-based wearable tremor detection device called TremorCare is designed that provides real-time detection, severity assessment, and remote patient monitoring. The system consists of an ESP32 microcontroller and an MPU6050 IMU which are used to gather the data about hand movement. Then, signal processing and machine learning algorithms are used to recognize the pathological tremor and assess its severity. The acquired data is sent to the Web application and cloud platform, allowing physicians and caretakers to monitor the patient from a distance.

I. INTRODUCTION

Parkinson's Disease (PD) and Essential Tremor (ET) are neurological disorders that affect millions of people world-wide. One of their most noticeable symptoms is involuntary hand tremors, which can make everyday activities such as writing, eating, drinking, and holding objects difficult. The severity of these tremors can also vary over time, making continuous monitoring useful for understanding changes in a patient's condition and supporting appropriate medical care.

At present, tremor assessment is largely based on clinical examinations and standardized scales such as the Unified Parkinson's Disease Rating Scale (UPDRS). While these methods are well established, they depend heavily on clini-cal observation and are generally performed during periodic hospital visits. As a result, they may not fully reflect how a patient's tremors change during normal day-to-day activities. An objective and portable system capable of continuously monitoring tremor activity could therefore provide a more complete picture of a patient's condition.

Recent developments in wearable technology, the Internet of Things (IoT), and Artificial Intelligence (AI) have created new possibilities for continuous health monitoring. Wearable motion sensors can capture hand movements throughout the day, while signal processing and machine learning techniques can be used to identify patterns associated with pathological tremors and distinguish them from intentional movements. This allows tremor activity to be measured quantitatively rather than relying solely on visual assessment.

This paper presents TremorCare, an AI-enabled wearable system designed for real-time tremor detection, severity as-sesment, and remote patient monitoring. The system uses an ESP32 microcontroller and an MPU6050 Inertial Mea-surement Unit (IMU) to continuously capture hand movement data. Signal processing and machine learning techniques are then applied to identify tremor patterns and estimate their severity. The processed information can be transmitted to a Web application and cloud platform, allowing caregivers and healthcare professionals to remotely monitor tremor activity and maintain long-term records of the patient's condition.

The primary contributions of this work are as follows:

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1. Design and development of a wearable glove for real-time hand tremor monitoring.
2. Integration of an ESP32 microcontroller with an MPU6050 IMU for continuous motion data acquisition.
3. Implementation of signal processing and machine learn-ing techniques for tremor detection and severity assess-ment.
4. Development of a cloud-connected Web monitoring plat-form for remote access to patient data.
5. A low-cost and portable architecture suitable for contin-uous monitoring in home and clinical environments.

II. OBJECTIVES

The primary objectives of the proposed TremorCare system are:

1. To develop a wearable glove capable of continuously monitoring hand tremors in patients with Parkinson's Disease and Essential Tremor.
2. To acquire accurate hand motion data using an MPU6050 Inertial Measurement Unit (IMU).
3. To implement signal preprocessing and feature extraction for reliable tremor analysis.
4. To develop an AI-based model for real-time tremor detection and severity assessment.
5. To provide wireless communication between the wearable device and a Web application using the ESP32 microcon-troller.
6. To enable cloud-based storage of patient data for long-term monitoring and analysis.
7. To facilitate remote access to tremor reports for healthcare professionals and caregivers.
8. To design a lightweight, portable, and cost-effective sys-tem suitable for continuous use in home and clinical environments.

III. LITERATURE SURVEY

A comprehensive review of recent research on wearable sensing, machine learning, and remote healthcare systems was conducted to identify current advancements and the limitations of existing tremor monitoring solutions.

A. Real World Parkinson's Disease Tremor and Score Predic-tion using Wearable IMU Sensors

Pope et al. proposed a wearable monitoring framework that utilizes wrist-mounted Inertial Measurement Unit (IMU) sensors to estimate tremor severity in Parkinson's Disease patients during daily activities. The system employs semi-supervised machine learning techniques to predict clinical tremor scores while reducing dependence on frequent hospital visits. Although the framework demonstrates promising accu-racy in real-world monitoring, it primarily focuses on tremor prediction and does not provide an integrated Web application or cloud-based remote healthcare platform.

B. Continuous Tremor Monitoring Using Wearable Sensors

Rodriguez et al.developed a wearable sensor-based system that continuously monitors tremor severity using accelerometer and gyroscope data collected during unconstrained daily activ-ities. Supervised machine learning algorithms were employed to classify tremor intensity with high accuracy. While the proposed approach effectively supports long-term monitoring, it relies primarily on offline data processing and lacks real-time feedback and embedded implementation.

C. Wearable Sensor-Based Gait Analysis to Discriminate Early Parkinson's Disease from Essential Tremor

Lin et al. introduced a wearable sensing framework that combines multiple IMU sensors with machine learning tech-niques to distinguish early Parkinson's Disease from Essential Tremor through gait analysis. The proposed system achieved high diagnostic accuracy by extracting discriminative motion features. However, the

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requirement for multiple wearable sensors increases system complexity and reduces user con-venience for continuous daily monitoring.

D. AI-Driven Precision Diagnosis and Treatment in Parkin-son's Disease

Twala presented a comprehensive review of artificial intelli-gence applications in Parkinson's Disease diagnosis and treat-ment, along with an experimental multimodal AI framework. The study examined different AI-based approaches involving motor symptom analysis, voice pattern recognition, and gait assessment. The proposed framework combines computer vi-sion, deep learning, and wearable sensor-based gait analysis to identify patterns associated with Parkinson's Disease.

E. Wearable Sensors for Healthcare and Rehabilitation

Patel et al. reviewed wearable sensor systems and their applications in rehabilitation and healthcare monitoring. Their work highlights the potential of wearable technologies for monitoring patients in home and community environments. However, the review does not specifically address AI-based tremor detection or integrated tremor-monitoring platforms.

TABLE I COMPARATIVE LITERATURE SURVEY

Reference	Paper Title	Key Advantages	Limitations	Addressed in TremorCare
Pope et al. [1]	Real-World Parkinson's Disease Tremor Score Prediction Using Wearable IMU Sensors	Accurate tremor prediction using wearable IMU sensors.	No integrated cloud-connected mobile application for monitoring.	Provides cloud-connected monitoring through a dedicated mobile application.
Rodriguez et al. [2]	Continuous Tremor Monitoring Using Wearable Sensors	Continuous tremor assessment with machine learning.	Offline processing and lack of real-time feedback.	Implements real-time embedded AI for immediate tremor analysis.
Lin et al. [3]	Wearable Sensor-Based Gait Analysis to Discriminate Early Parkinson's Disease from Essential Tremor	High diagnostic accuracy using wearable sensors.	Requires multiple wearable sensors.	Uses a single wearable glove equipped with an MPU6050 IMU sensor.
Twala et al. [4]	AI-Driven Precision Diagnosis and Treatment in Parkinson's Disease	Multimodal AI-based assessment using motor, voice, and gait analysis.	Requires multiple data modalities and focuses on broader disease diagnosis.	Uses wearable hand-motion sensing for tremor detection, severity assessment, and remote monitoring.
Patel et al. [5]	E-Wearable Sensors for Healthcare and Rehabilitation	Remote patient monitoring through cloud connectivity.	Not specifically designed for neurological tremor assessment.	Integrates tremor detection, severity assessment, and remote monitoring into a single platform.

IV. EXISTING SYSTEMS AND LIMITATIONS

A. Existing Systems

- Wearable devices using accelerometers, gyroscopes, and Inertial Measurement Unit (IMU) sensors are widely used for tremor detection.
- Machine learning algorithms such as Support Vector Machines (), Random Forests, and Neural Networks are employed for tremor classification.
- Cloud-based healthcare systems enable remote monitor-ing by transmitting patient data to caregivers and clini-cians.

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- Smartphone applications provide visualization of tremor data and patient health records.
- Several systems support continuous motion monitoring in home environments.

B. Limitations

- Most existing systems rely on offline data processing, preventing real-time analysis.
- Many solutions require multiple sensors, increasing sys-tem complexity and reducing user comfort.
- High computational requirements make some AI models unsuitable for low-power embedded devices.
- Existing systems often focus only on tremor detection without providing severity assessment.
- Integration of wearable sensing, AI analysis, web appli-cations, and cloud connectivity is limited.
- Commercial solutions are often expensive, reducing ac-cessibility for regular patient use.

V. PROPOSED SYSTEM

The proposed system, TremorCare, is an AI-enabled wear-able glove designed to continuously monitor hand tremors in individuals affected by Parkinson's Disease and Essential Tremor. The system integrates wearable sensing, embedded processing, machine learning, and cloud connectivity to pro-vide objective tremor assessment and remote patient monitor-ing.

The glove is equipped with an MPU6050 Inertial Measure-ment Unit (IMU), which continuously captures acceleration and angular velocity data generated by hand movements. An ESP32 microcontroller acquires the sensor data and performs initial signal preprocessing, including noise filtering and fea-ture extraction. The processed data is then analyzed using a machine learning model to classify tremor patterns and estimate tremor severity.

The results are transmitted via Wi-Fi or Bluetooth to a Web application, where patients and caregivers can view real-time tremor information. The data is also uploaded to a cloud database, enabling healthcare professionals to monitor patient progress remotely and maintain long-term health records. By combining wearable sensing, AI-based analysis, and IoT con-nectivity, TremorCare provides a portable, cost-effective, and user-friendly solution for continuous neurological monitoring outside traditional clinical settings.

A. Features of the Proposed System

- Wearable glove for continuous hand tremor monitoring.
- MPU6050 IMU for real-time motion sensing.
- ESP32 microcontroller for embedded data acquisition and processing.
- Signal preprocessing and feature extraction.
- AI-based tremor detection and severity estimation.
- Wireless communication through Wi-Fi/Bluetooth.
- Web application for real-time visualization.
- Cloud storage for long-term patient records.
- Remote monitoring by healthcare professionals and care-givers.

VI. SYSTEM ARCHITECTURE

The proposed TremorCare system consists of the following functional modules:

- Wearable Glove: Serves as the platform for integrating all sensing and embedded components while ensuring user comfort during continuous monitoring.
- MPU6050 IMU Sensor: Continuously measures three-axis acceleration and angular velocity to capture involun-tary hand movements and tremor characteristics.
- ESP32 Microcontroller: Collects sensor data, performs initial signal preprocessing, feature extraction, and con-trols wireless communication.

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- Signal Processing Module: Filters noise from the ac-quired IMU data and prepares it for feature extraction and machine learning analysis.
- Machine Learning Module: Classifies hand movements as normal or tremor-related and estimates tremor severity using extracted motion features.
- Wireless Communication Module: Transmits processed data to the Web application using Wi-Fi or Bluetooth.
- Web Application: Displays tremor severity, historical trends, and patient information through an intuitive user interface.
- Cloud Database: Stores patient data securely, enabling long-term monitoring and analysis.
- Doctor/Caregiver Dashboard: Allows healthcare pro-fessionals and caregivers to remotely monitor patient conditions, access reports, and track disease progression.

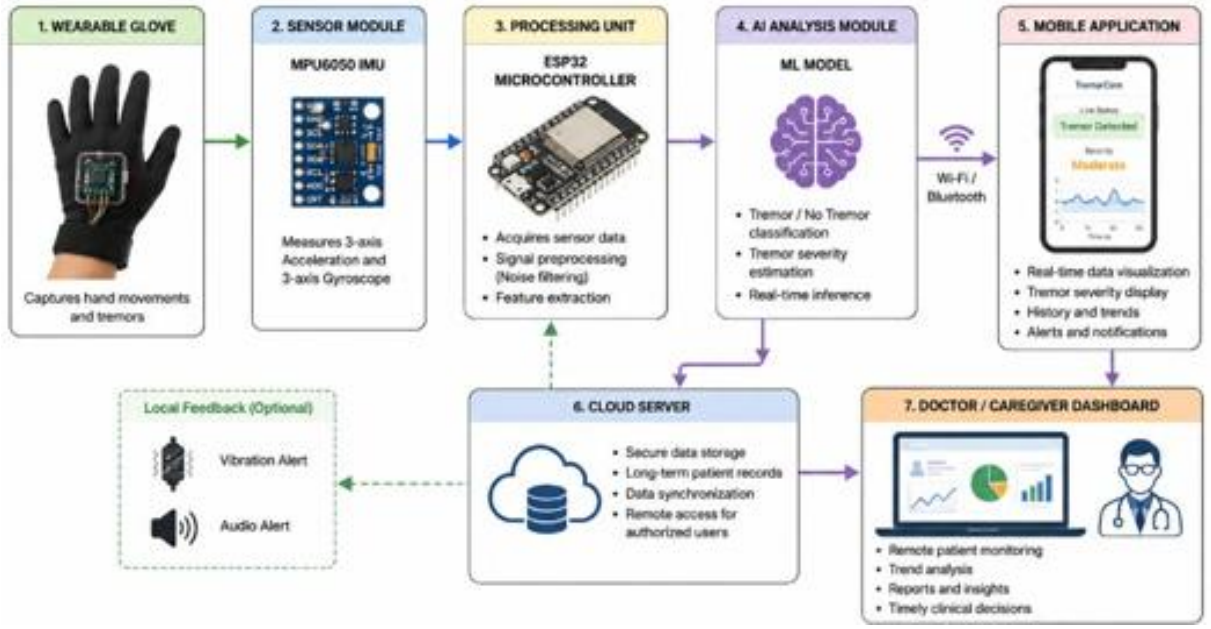

Fig. 1. System Architecture.

VII.METHODOLOGY

The proposed TremorCare system follows a sequential pro-cess for acquiring, processing, and analyzing hand movement data to detect tremors and estimate their severity. The method-ology consists of the following stages.

A. Data Acquisition

The wearable glove is equipped with an MPU6050 Inertial Measurement Unit (IMU), which continuously measures three-axis acceleration and angular velocity generated by hand movements. The sensor data is sampled at regular intervals and transmitted to the ESP32 microcontroller.

B. Signal Preprocessing

The ESP32 performs initial preprocessing to improve signal quality. Noise and unwanted disturbances are reduced using digital filtering techniques, and the processed signals are normalized to ensure consistent feature extraction.

C. Feature Extraction

Relevant features such as tremor frequency, amplitude, mean acceleration, standard deviation, and signal energy are extracted from the filtered sensor data. These features provide meaningful information for distinguishing involuntary tremors from normal hand movements.

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D. AI-Based Tremor Detection

The extracted features are provided as input to a machine learning model trained to classify hand movements as either normal or tremor-related. The model also estimates tremor severity based on the characteristics of the detected motion.

E. Remote Monitoring

The processed results are transmitted through Wi-Fi or Bluetooth to a Web application and synchronized with a cloud database. Patients, caregivers, and healthcare professionals can access real-time tremor information, historical trends, and severity reports for continuous monitoring.

VIII. IMPLEMENTATION

The implementation of the proposed TremorCare system combines wearable hardware, embedded processing, machine learning, and cloud technologies to enable continuous tremor monitoring and remote patient assessment.

A. Hardware Implementation

- The system uses an ESP32 microcontroller as the primary processing and communication unit.
- An MPU6050 Inertial Measurement Unit (IMU) is at-tached to the wearable glove to capture three-axis accel-eration and angular velocity.
- The sensing module is securely mounted on a glove to continuously monitor hand movements during daily activities.
- A rechargeable battery powers the wearable device, en-suring portability and ease of use.

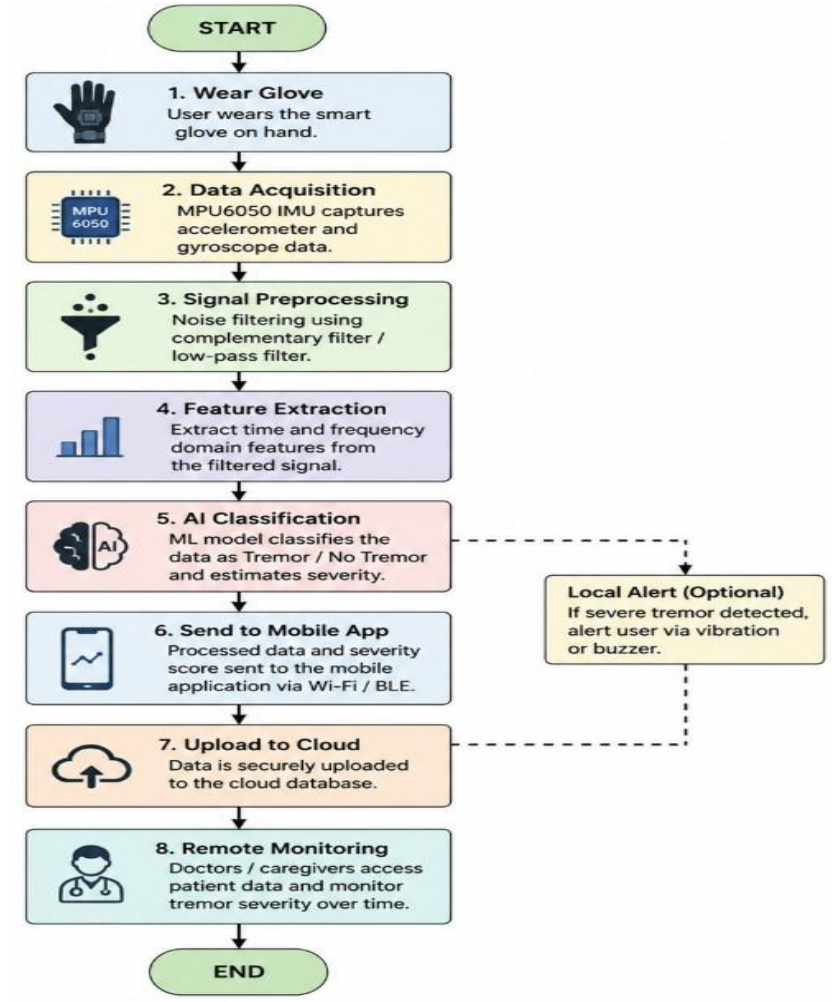

Fig. 2. Workflow of the proposed TremorCare system.

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B. Software Implementation

- The ESP32 is programmed using the Arduino IDE to acquire and preprocess sensor data.
- Signal processing techniques are applied to reduce noise and improve the quality of the collected data.
- Relevant motion features are extracted before being sup-plied to the machine learning model.
- The trained model classifies tremor patterns and estimates tremor severity in real time.

C. Web Application and Cloud Integration

- The processed tremor data is transmitted wirelessly using Wi-Fi/Bluetooth.
- A Web application displays tremor severity, historical records, and patient information.
- Patient data is securely synchronized with a cloud database for long-term storage.
- Healthcare professionals and caregivers can remotely access patient reports and monitor disease progression.

D. System Workflow

1) Capture hand motion using the MPU6050 IMU.
2) Acquire sensor data through the ESP32.
3) Perform signal preprocessing and feature extraction.
4) Detect tremors and estimate severity using the AI model.
5) Transmit processed results to the Web application.
6) Upload data to the cloud for remote monitoring and record maintenance.

IX. SYSTEM REQUIREMENTS

A. Hardware Requirements

- ESP32 Development Board
- MPU6050 IMU
- Wearable Glove
- Rechargeable Li-ion Battery

B. Software Requirements

- Arduino IDE
- Python
- TensorFlow / Scikit-learn
- Firebase
- Flutter
- Windows 10/11

X. RESULTS AND DISCUSSION

The current implementation demonstrates the feasibility of the proposed TremorCare architecture. The ESP32 and MPU6050 enable continuous acquisition of hand motion data, while the proposed signal processing and machine learning pipeline provides a framework for tremor detection and sever-ity assessment.

The system successfully acquires accelerometer and gyro-scope data and supports wireless transmission for remote mon-itoring. However, quantitative evaluation of the machine learn-ing model has not yet been

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performed. Further experiments using a larger and clinically validated dataset are required to evaluate classification accuracy, severity estimation, reliability, and real-time performance.

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