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NeuroSense: Early Detection for Parkinson's Diseases

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Abstract - Parkinson's Disease (PD) is a progressive neurological disease that affects movement, coordination, and motor control. Early detection of Parkinson's disease is critical for better patient management and slowing the progress of the disease. According to various global health reports, Parkinson's disease affects millions of people worldwide and the prevalence of Parkinson's disease increases with age [2][3]. In this paper, the authors propose a multimodal Parkinson's disease detection system using Electromyography (EMG) and Inertial Measurement Unit (IMU) sensors. The proposed system collects physiological and movement information from the patients using the sensors and detects the early symptoms of Parkinson's disease. The proposed system uses the classification of the sensor information using the machine learning algorithm for the detection of Parkinson's disease. The proposed system uses the combination of the sensors for the detection of Parkinson's disease. The experimental analysis proves the effectiveness of the proposed system for the detection of Parkinson's disease using the sensors. The proposed system is useful for the doctors in the detection of Parkinson's disease patients, which is the contribution of the proposed system.

Key Words: Parkinson's Disease, EMG Sensor, IMU Sensor, Machine Learning, Tremor Detection, Healthcare Monitoring.

1.INTRODUCTION

Parkinson's Disease (PD) is a progressive neurological disease that affects movement and motor control. Parkinson's disease is caused by the degeneration of dopamine-producing cells in the brain, resulting in the symptoms of Parkinson's disease, which include tremors, muscle stiffness, slow movement, and balance difficulties [1]. According to the World Health Organization, the prevalence of Parkinson's disease has increased significantly in the past few decades, making Parkinson's disease one of the most common neurological disorders in the world [2][3].

The conventional techniques of diagnosis include clinical observation and neurological tests by experts. These techniques may not detect the disease in its early stage.

Early diagnosis is also important for the improvement of treatment and slowing down the progression of the disease [4][5].

The latest developments in sensor devices, wearable technology, and AI have enabled the development of an automated system for monitoring symptoms and detecting Parkinson's diseases more accurately [6]. Machine learning techniques can also be applied for the analysis of complex biological signals and for identifying patterns that may not be easily identified using conventional techniques.

Fig.1: PARKINSON's SYMPTOMS

In this project, a multimodal detection system is proposed using Electromyography (EMG) sensors and Inertial Measurement Unit (IMU) sensors. EMG sensors measure muscle activity, while IMU sensors detect motion, tremors, and body movement patterns. The collected data is processed and analyzed using machine learning algorithms to identify patterns associated with Parkinson's disease.

The goal of this research is to develop a reliable and cost-effective system that assists healthcare professionals in early detection and monitoring of Parkinson's disease.

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2. LITERATURE REVIEW

Previous studies have shown the effectiveness of handwriting analysis in detecting Parkinson's Disease because of its sensitivity to fine motor impairments [8]. Spiral and drawing tests have been widely employed to measure the severity of tremors and irregular motor control, with convolutional neural networks and transfer learning models having been shown to have high classification accuracy [9].

Speech-based Parkinson's Disease diagnosis has also been explored in depth, given that speech disorders are prevalent among patients with Parkinson's. Jitter, shimmer, pitch variation, and Mel Frequency Cepstral Coefficients have been employed effectively to train machine learning and deep learning models, resulting in high accuracy rates for diagnosis [10], [11].

Medical Imaging Techniques

Medical imaging techniques make use of MRI scans to detect structural changes in the brain that are caused by Parkinson's Disease. Deep learning models like CNNs and Efficient Net have shown great potential in the extraction of discriminative features from MRI images [12]. Wearable sensors like EMG electrodes and inertial measurement units have also received great attention for tremor and muscle activity analysis [13].

However, despite the promising outcomes, most of the existing work relies on a single diagnostic modality. This affects the robustness and reliability of the results. Multimodal diagnostic systems have been proven to enhance accuracy by combining complementary information from multiple data sources [7], [14]. This research gap is what the proposed multimodal AI-based Parkinson's Disease detection system aims to fill.

3. SYSTEM ARCHITECTURE

The proposed Parkinson's detection system consists of multiple components that work together to collect, process, and analyze physiological data.

The system includes:

1. **Sensor Module**
   - EMG Sensor for detecting muscle activity.
   - IMU Sensor for capturing movement and tremor data.
2. **Data Acquisition Module**
   - Microcontroller collects real-time signals from sensors.
3. **Data Processing Module**
   - Sensor data is filtered and pre-processed to remove noise.
4. **Machine Learning Model**
   - Extracted features are used to train a classification model.
   - The model predicts whether Parkinson's symptoms are present.
5. **User Interface**
   - Displays the prediction results and sensor readings.

This architecture enables continuous monitoring and accurate detection of Parkinson's symptoms.

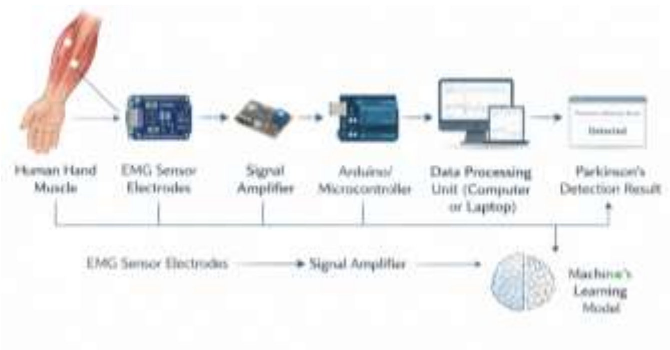

Fig.2: HARDWARE SYSTEM ARCHITECTURE

3.1 Sensor Technology Used

EMG Sensor

Electromyography (EMG) sensors measure electrical signals generated by muscle activity. Parkinson's patients often exhibit abnormal muscle activation patterns, which can be detected using EMG signals.

IMU Sensor

The Inertial Measurement Unit (IMU) sensor contains accelerometers and gyroscopes that measure motion and orientation. These sensors help detect tremors, gait disturbances, and abnormal movements associated with Parkinson's disease.

3.2 Machine Learning Model

Machine learning algorithms are used to analyze the collected sensor data. The process involves:

1. Data collection from EMG and IMU sensors.
2. Feature extraction from sensor signals.
3. Training the model using labeled datasets.
4. Testing the model for prediction accuracy.

Common machine learning algorithms used for Parkinson's detection include:

- Support Vector Machine (SVM)
- Random Forest
- Neural Networks

These algorithms help classify patients based on movement and muscle activity patterns.

3.3 Machine Learning Analysis

The proposed system, **NeuroSense**, is an AI-powered web application designed for early detection of Parkinson's disease using multiple medical indicators. The system analyzes diagnostic inputs such as **MRI scans, voice recordings, spiral drawing tests, and a symptom-based questionnaire**.

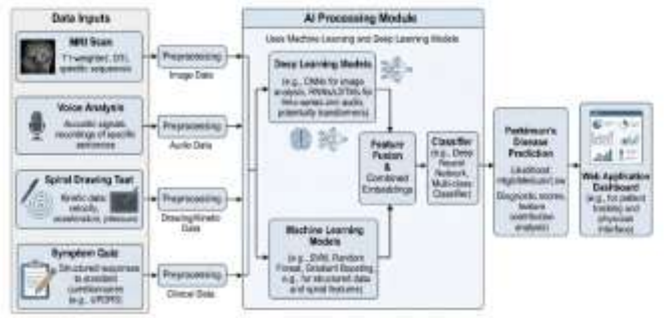

Fig.3: SYSTEM ARCHITECTURE DIAGRAM FOR AI-BASED PARKINSON's DETECTION SYSTEM

The MRI scan is analyzed by deep learning algorithms to identify any abnormal changes in areas of the brain that control motor functions [12]. The voice recordings are analyzed to identify any changes in speech patterns, such as pitch and frequency, which are commonly seen in Parkinson's patients [10][11].The spiral drawing test is used to assess the level of tremors by analyzing the smoothness and deviation of the drawn spiral. The dynamic patterns seen in handwriting have been commonly used to identify Parkinson's patients [8][9].The symptom-based quiz will ask questions regarding various Parkinson's disease-related symptoms, such as tremors, rigidity, and difficulty with balance.The machine learning algorithm will then analyze all these inputs and determine patterns related to Parkinson's disease. This will increase the accuracy and reliability of the system in detecting early stages of Parkinson's disease.

AI-Based Analysis

Different analytical models are applied for each modality:

• VGG-16 models for handwriting and EfficientNet-B0 MRI image analysis [12]

• Feature-based machine learning classifiers for voice signal processing [10]

• Signal processing and classification algorithms for EMG and motion sensor data [13]

4. METHODOLOGY

The system methodology involves data preprocessing, feature extraction, model training, and fusion-based decision-making. Handwriting and MRI images are resized, normalized, and augmented to enhance the generalization capability of the models [8], [12]. Speech signals are filtered for noise, silence is removed, and MFCC features are extracted before being processed by a Deep Neural Network [10], [11]. EMG and motion sensor signals are filtered and segmented to remove artifacts and extract relevant features for motor symptom analysis [13].

A Deep Neural Network is used for speech classification because of its capacity to learn complex non-linear patterns in speech. VGG-16 is used for spiral analysis using handwriting because of its strong capability to extract spatial features [9]. EfficientNet-B0 is used for MRI classification because of its high accuracy and efficiency [12]. Random Forest classifiers are used for tabular data obtained from questionnaires and sensors because of their strong performance on structured biomedical data [14]. The predictions are combined using a decision-level fusion technique to obtain the final diagnosis.

5. RESULTS AND DISCUSSION

The proposed system has been tested by integrating sensor data collected from subjects who performed various actions. The EMG and IMU sensors have been successful in collecting data regarding levels of tremors, muscle activity, and motion patterns. The machine learning algorithm has analyzed the data and classified it as normal or Parkinson's-affected. The results show that by integrating both EMG and IMU sensors, the accuracy level is higher than by integrating any single sensor.

Multimodal machine learning has been proven to improve the accuracy level significantly for Parkinson's disease detection by integrating multiple physiological parameters [7].

The system also shows its capability in the early detection of Parkinson's disease, as well as real-time patient monitoring. It may help doctors in quicker and more precise diagnostic decisions.

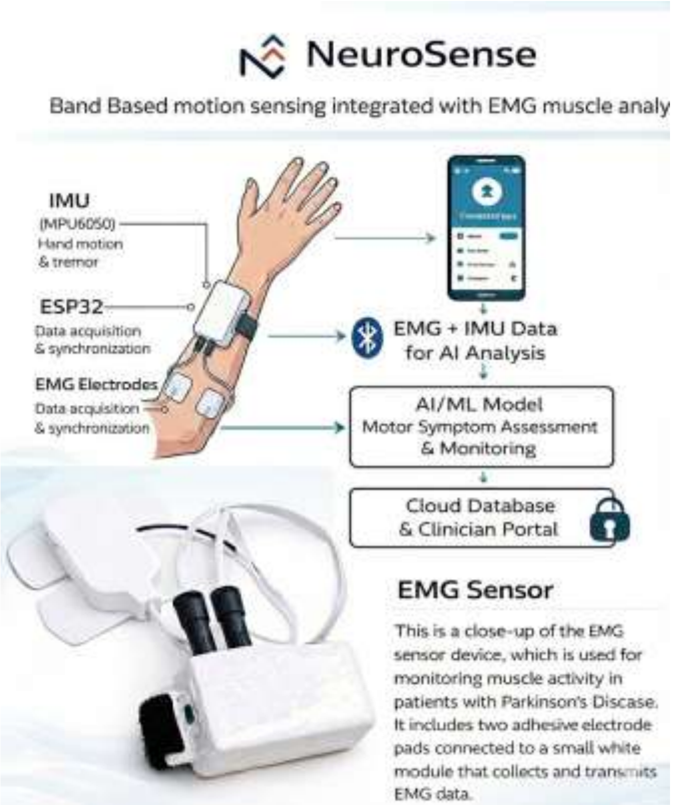

Fig. 4: Proposed EMG and IMU Based NeuroSense System

6. BENIFITS OF THE PROPOSED SYSTEM

The proposed system allows for the early and accurate diagnosis of Parkinson's Disease through non-invasive methods. The system combines artificial intelligence and biomedical sensors for objective and data-driven diagnosis and also allows for remote monitoring through web and mobile services. The proposed system lowers the cost of diagnosis and improves the accuracy of clinical decision-making [6], [13].

7. APPLICATIONS

- Early screening and monitoring of Parkinson's Disease
- Clinical decision support for neurologists
- Remote patient health monitoring
- Academic and medical research in healthcare engineering
- Intelligent assistive healthcare system development

8. CONCLUSIONS

The detection of Parkinson's disease using sensor technology and machine learning is a promising approach for early diagnosis and monitoring of the disease. The proposed system utilizes EMG and IMU sensor technology for data collection from the patients affected by Parkinson's disease. The proposed system uses machine learning algorithms for effective detection of Parkinson's symptoms using the data collected by the sensor technology. The results of the proposed approach show effective detection of Parkinson's symptoms using sensor technology and machine learning algorithms. The proposed system is useful for the diagnosis of Parkinson's disease and monitoring of the health of the patients affected by the disease.

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