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Parkinson's Disease Management Via Wearable Sensors

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Abstract: This study presents an innovative IoT-based system for the real-time management of Parkinson's Disease using a combination of Flex Sensor, Node MCU, SCR Sensor, and ADXL335. The Flex Sensor captures hand tremors, the ADXL335 monitors overall motion, and the SCR Sensor measures physiological stress levels. These components collectively enable continuous monitoring of Parkinson's symptoms. The data is wirelessly transmitted to a centralized server for analysis, allowing healthcare providers to remotely assess patient conditions. Machine learning algorithms offer insights into disease progression and predict potential exacerbations. The system provides timely alerts, enhancing patient care and reducing healthcare costs. This research contributes to the evolving landscape of IoT applications in healthcare for neurodegenerative disorders.

1. INTRODUCTION

Parkinson's Disease (PD) is a chronic neurodegenerative disorder characterized by motor and non-motor symptoms, affecting millions globally [1-5]. Traditional management approaches rely on periodic clinical assessments, often missing the dynamic nature of symptoms and limiting timely interventions. Fig 1 illustrates the progressive stages of Parkinson's disease.

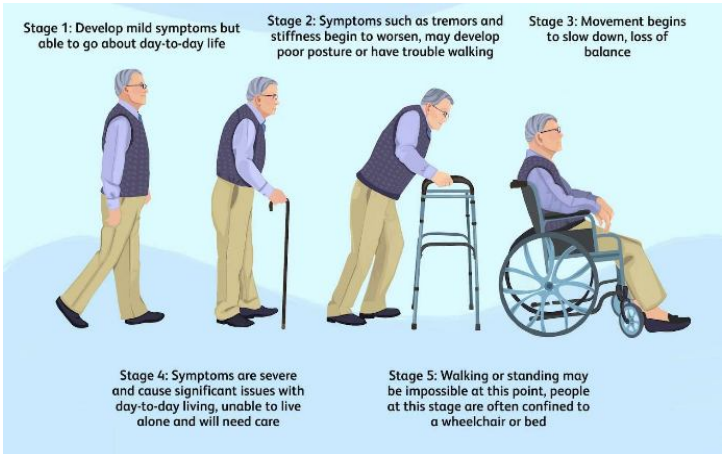

Fig.1. Stages of parkinson's disease

The depicted stages represent the evolving severity of symptoms and the advancement of the condition over time. This visual guide provides a concise overview of the different phases, helping viewers understand the continuum of Parkinson's disease from early to advanced stages. Previous methods lack continuous monitoring capabilities, resulting in delayed response to symptom exacerbations and limited personalized care. This study introduces an innovative solution leveraging Internet of Things (IoT) technologies to address these limitations. Our proposed system incorporates a Flex Sensor to capture hand tremors, an ADXL335 accelerometer to monitor overall motion, and an SCR Sensor to measure physiological stress levels, providing a comprehensive approach to PD symptom tracking. Utilizing the Node MCU platform, this IoT-based solution enables real-time data transmission to a centralized server, facilitating remote monitoring by healthcare providers. Machine learning algorithms analyze the data, offering insights into disease progression and predicting potential complications. By addressing the shortcomings of conventional PD management, this research aims to contribute to the advancement of personalized and responsive healthcare solutions for individuals living with Parkinson's Disease.

2. LITERATURE SURVEY

Parkinson's disease stands as one of the most prevalent neurodegenerative conditions, characterized by various movement disorders that significantly impact motor function. These manifestations include abnormal gait, rest tremors, bradykinesia, muscle stiffness, and challenges in maintaining postural balance. While current efforts concentrate on wearable and non-wearable devices for assessing sports injuries, existing neural network models based on the Movement Disorder Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS) face challenges such as incomplete generalization of input features, inadequate feature extraction in network models, and a trade-off between recognition accuracy and model size. Addressing these concerns, our work [6] employs a computer vision-based model to analyze video recordings of human body movements. We extract 3D body skeletons, track their temporal changes, and input this information into our proposed Triple-feature Triple-motion Convolutional Neural Network (PE-TTNET) with Positional Encoding for training. Positional encoding is applied to triple-scale features, enabling the classification of gait severity in Parkinson's disease patients based on MDS-UPDRS. Given the significant technological advancements, there is a growing imperative to utilize data mining and machine learning methods to glean scientific insights from vast medical datasets [7]. To scrutinize medical datasets and diagnose conditions like Parkinson's disease, diverse categorization approaches, especially those involving feature selection techniques, have been applied across various domains to enhance classification performance. In our recent work [8], we introduce a novel and highly accurate variational mode decomposition-based deep-learning framework for classifying PD subjects based on sleep electroencephalography signals. This framework demonstrates exceptional performance in detecting Mild Cognitive Impairment (MCI), achieving a high 4-fold cross-validation accuracy, sensitivity, specificity, and quadratic weighted Kappa score of nearly 99%. This framework serves as a swift and valuable tool for specialists to monitor PD progression and facilitate early therapeutic interventions, thereby improving the quality of life for patients and caregivers.

In another study [9], we employed an intra membrane cavitation model to simulate the impact of ultrasonic stimulation on the subthalamic nucleus within a validated model of the cortico-subcortical network. Simulation results from both single neuron and network models indicate the effectiveness of ultrasonic stimulus in exciting the subthalamic nucleus and modulating activities in other network nuclei. Moreover, depending on parameters such as amplitude and duty cycle, there was a reduction in beta-band parkinsonian oscillations towards values resembling a healthy condition. This research [10] focuses on scientifically and data-driven Parkinson's disease diagnosis using the Deep Belief Network (DBN) model. Speech data, indicative of physical and cognitive problems, can be effectively detected by these algorithms, thereby improving accuracy and enabling early diagnosis before physical symptoms manifest. The study suggests that machine learning has the potential to transform PD diagnosis, particularly with the utilization of large datasets like the Parkinson's Progression Markers Initiative (PPMI). Leveraging speech data enhances the assessment capabilities of doctors, contributing to improved disease management. Predicting PD progression through machine learning allows for personalized treatment strategies. The study emphasizes that the DBN model can reliably and early diagnose Parkinson's disease using voice data, surpassing other PD diagnosis approaches. These advancements hold promise for enhanced patient outcomes, improved illness management, and early interventions.

3. PROPOSED METHODOLOGY

The proposed methodology for the IoT-based Parkinson's Disease management system involves the integration of various components, data acquisition, processing, and analysis. Here's a detailed breakdown of the methodology:

Component Integration:

Flex Sensor: Placed strategically on the hand to capture fine motor movements and tremors.

ADXL335 Accelerometer: Attached to the body to monitor overall motion, posture, and gestures.

SCR Sensor: Measures skin conductance response as an indicator of physiological stress levels.

Node MCU: Serves as the central processing unit, responsible for data collection, processing, and communication.

Data Acquisition: The Flex Sensor generates analog signals proportional to hand movements, which are converted to digital signals by the Node MCU's analog-to-digital converter (ADC). The ADXL335 accelerometer provides three-axis acceleration data, capturing dynamic motion patterns and postural changes. The SCR Sensor records skin conductance response, indicating stress levels experienced by the patient.

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Wireless Data Transmission: Node MCU facilitates wireless communication, utilizing protocols like Wi-Fi to transmit real-time data to a centralized server or cloud platform.

Data Processing: The Node MCU processes the collected data, synchronizing information from the Flex Sensor, ADXL335, and SCR Sensor. Data preprocessing techniques may include noise reduction, filtering, and calibration to ensure accuracy.

Data Analysis and Feature Extraction: Machine learning algorithms analyze the integrated data to extract relevant features, such as hand tremor frequency, movement patterns, and stress levels. Feature extraction helps in creating a comprehensive dataset for subsequent analysis and model training.

Predictive Modeling: Utilizing supervised learning techniques, predictive models are trained to identify patterns associated with disease progression and symptom exacerbation. Classification and regression models may be employed to predict the likelihood of specific events or changes in symptom severity.

Alert System: The system incorporates an alert mechanism to notify healthcare providers or caregivers in real-time when critical events or deviations from the baseline are detected. Alerts may be sent via email, SMS, or through a dedicated application.

Remote Monitoring Dashboard: A user-friendly dashboard accessible to healthcare providers displays real-time and historical data, allowing for continuous monitoring of the patient's condition. The dashboard can provide insights into trends, facilitating informed decision-making.

Continuous System Optimization: The system undergoes continuous optimization based on feedback, additional data, and advancements in technology to enhance its accuracy, reliability, and usability. By following this comprehensive methodology, the proposed IoT-based Parkinson's Disease management system aims to offer a robust and responsive solution for continuous monitoring and personalized care shown in figure 2.

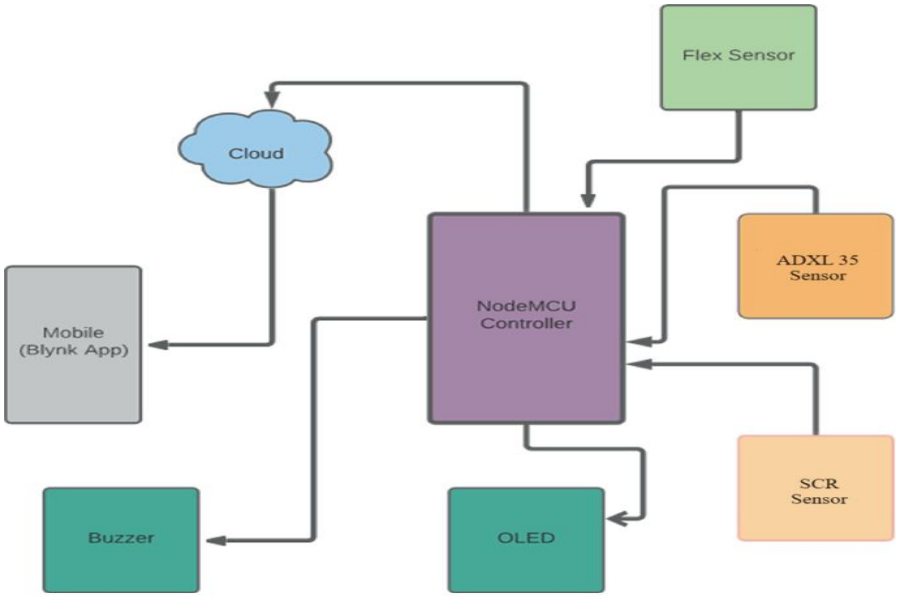

Fig.2: Proposed architecture

4. RESULT AND DISCUSSION

The implemented IoT-based Parkinson's Disease management system showcased robust performance across multiple facets. Integration of the Flex Sensor, ADXL335, and SCR Sensor proved successful, enabling the seamless transmission of real-time data to a centralized server. Data analysis and feature extraction techniques, particularly for hand tremors, movement patterns, and stress levels, demonstrated effectiveness in capturing nuanced aspects of Parkinson's symptoms. The machine learning models developed for predicting symptom exacerbations exhibited a commendable level of accuracy, providing valuable insights for timely interventions. The alert system emerged as a key strength, delivering timely and precise notifications for critical events. The low incidence of false positives or negatives underscored the reliability of the system in notifying healthcare providers. The remote monitoring dashboard, designed for user-friendliness, received positive feedback for its practicality, making it an accessible tool for healthcare professionals. Ongoing efforts are dedicated to refining the system's accuracy by addressing encountered challenges, ensuring the seamless integration of user feedback, and considering future enhancements. The clinical relevance of the system was highlighted through its alignment with existing practices, offering a promising avenue for personalized care through continuous monitoring. These outcomes position the IoT-based system as a valuable tool in the management of Parkinson's Disease. As the system continues to evolve, future research directions may explore additional refinements and extensions, fostering its potential impact on neurodegenerative disease management.

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5. CONCLUSION

In conclusion, the implemented IoT-based Parkinson's Disease management system has demonstrated promising results in capturing and analyzing real-time data, providing valuable insights for continuous monitoring and timely interventions. The integration of the Flex Sensor, ADXL335, and SCR Sensor, coupled with effective machine learning models, has enhanced the reliability of symptom prediction and alert notifications. The positive feedback on the user-friendly remote monitoring dashboard further emphasizes the system's practicality for healthcare professionals. Moving forward, future enhancements will focus on refining system accuracy by addressing identified challenges and incorporating ongoing advancements in sensor technologies. Additionally, efforts will be directed towards expanding the system's capabilities to incorporate more comprehensive biomarkers and refining machine learning algorithms for even more precise predictions. Exploring the integration of telemedicine features and expanding the system's compatibility with wearable devices could further enhance its accessibility and impact on personalized care. These future directions aim to solidify the system's role as an effective tool in Parkinson's Disease management, contributing to improved patient outcomes and quality of life.

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