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Enhancing Stroke Rehabilitation using Wearable Sensors and ML-Powered Analytics

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ABSTRACT: Every year, strokes result in 5 million motor impairments and 17 million fatalities, underscoring the need for improved rehabilitation. Traditional approaches have drawbacks including exorbitant prices and restricted availability. This study suggests an IoT and machine learning (ML)-based stroke rehabilitation system that uses sensors (ESP32 with ECG, heart rate, and ADXL345) to gather data in real time. The data is then analyzed using ThingSpeak cloud and a Python web application for risk assessment and monitoring. It aims to improve accessibility, save expenses, and improve recovery results by supporting remote care and providing emergency Telegram warnings.

KEYWORDS: Stroke Rehabilitation, IoT, Machine Learning, ESP32, ECG Sensor, ADXL345, Real-Time Monitoring, ThingSpeak, Telemedicine, Emergency Alert System.

I. INTRODUCTION

Stroke is still the second most common cause of mortality and the third most common cause of long-term impairment globally, making it one of the most dangerous neurological disorders. Every year, some 15 million people worldwide have a stroke, which results in 5 million fatalities and 5 million permanent disabilities. Over 1.8 million new stroke cases—one every 40 seconds—and one stroke fatality every four minutes are reported in India annually. Because of clogged arteries, the majority of strokes are ischemic.

Recovery from a stroke depends on post-stroke therapy, but conventional approaches include drawbacks such high expenses, restricted access in remote regions, manual progress tracking, and a lack of real-time, individualized feedback. Slower recuperation and decreased patient participation are the results of these problems. To address these issues, this project suggests a Smart Stroke Rehabilitation System that combines cloud computing, machine learning, and the Internet of Things. Vital signs and motion are tracked using wearable sensors (such as the ECG, heart rate, and ADXL345), which send data in real time to a cloud platform (ThingSpeak) for safe storage and remote access. This data is retrieved and processed by a web application that runs on Python.

Machine learning algorithms assess recovery patterns, forecast the risk of stroke, and modify treatment regimens based on patient requirements. Users can access daily workout schedules, motivational reminders, and immediate feedback using cloud-based mobile applications. For prompt action, a built-in emergency alarm system uses Telegram to notify caregivers.

II. LITERATURE SURVEY

- Despite obstacles such noise and data unpredictability, machine learning (ML) and deep learning (DL) efficiently parse EEG and EMG signals for upper limb rehabilitation, enhancing prosthesis control¹.
- Through IoT-enabled systems with real-time feedback and individualized therapy, wearable sensors and machine learning (ML) offer comprehensive monitoring and predictive analysis of motor functions, supporting automated and remote stroke rehabilitation^{8 9 13}.
- Applications for smartphones, tablets, and the internet that include asynchronous video and educational interventions improve the quality of life, cognitive function, and activities of daily living for stroke survivors while

lessening the strain on caregivers, particularly in settings with limited resources^{2 5 6 10 14}.

- To promote neuroplasticity and functional gains, effective stroke rehabilitation necessitates early needs assessment and the integration of several modalities, including medication, task-specific training, neurostimulation, and assistive technologies^{7 15}.
- Wearable sensors and artificial intelligence (AI) combine in smart home platforms to provide real-time interventions and ongoing monitoring, increasing user pleasure and engagement⁴.
- Despite progress, issues with data quality, interoperability, privacy, and user compliance still exist. These issues are crucial for connected health systems to be successful^{11 12}.
- Clinical instruments such as the Shape Trail Test are reliable in evaluating cognitive recovery, which helps evaluate the results of stroke rehabilitation³.

III. PROBLEM STATEMENT

Present-day stroke rehabilitation depends on recurring clinical evaluations, which are laborious, prone to mistakes, and devoid of real-time tracking and forecasting. An automated system that continuously monitors a variety of health metrics, evaluates recovery, and provides patients and caregivers with useful information is required.

IV. OBJECTIVES

- To develop an IoT-based system that continuously monitors patients' health parameters using wearable sensors like ECG Sensor, Heartbeat Sensor and ADXL345.
- To integrate cloud-based machine learning algorithms for movement classification, progress prediction, and therapy optimization.
- To provide a real-time web application for data retrieval, analysis, and visualization.
- To evaluate the effectiveness of ML-driven rehabilitation compared to traditional therapy in terms of recovery speed and accuracy.

V. PROPOSED SOLUTION

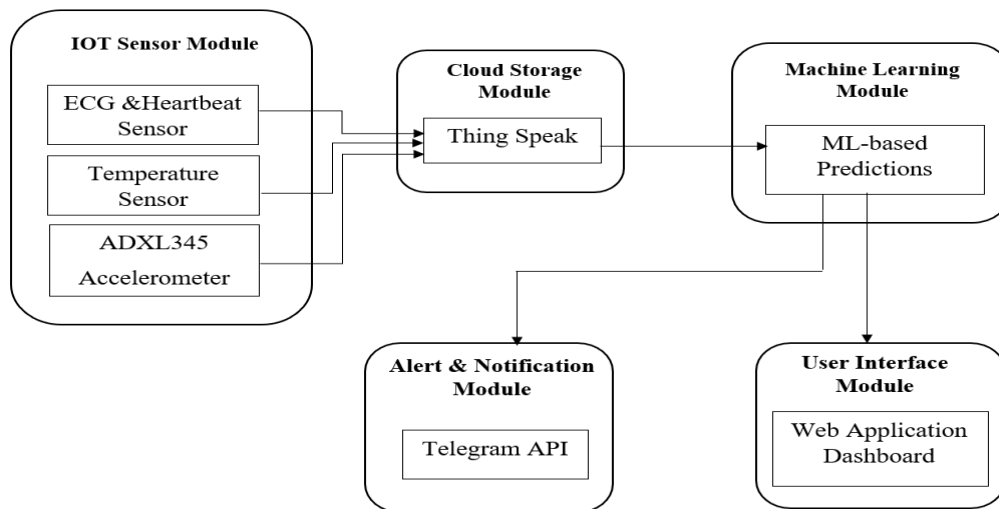
The goal of the technology-driven Smart Stroke Rehabilitation System is to improve and update post-stroke care. By merging cloud computing, machine learning, and IoT-based sensors, the system intends to provide continuous, tailored, and efficient rehabilitation. It solves the fundamental difficulties of conventional therapy, such as delayed assessments, limited access, and lack of individualized treatment regimens, by enabling real-time monitoring and intelligent data analysis.

Key highlights of the system :

- Integrates IoT sensors to acquire important physiological and movement data.
- Utilizes ESP32 microcontroller as the central unit for data processing and wireless transmission.
- Offers automatic analysis to track recovery progress and change therapy options accordingly.
- Ensures 24/7 monitoring to reduce dependency on manual evaluations and eliminate errors.
- Supports cloud-based storage and ML algorithms for predictive analytics and better outcomes.

VI. SYSTEM DESIGN

1. SYSTEM ARCHITECTURE



The system offers ongoing, individualized stroke rehabilitation by combining IoT, cloud computing, and machine learning.

(a) IoT Layer: Instantaneous Data Gathering

Vital health measurements are recorded by sensors that are attached to the ESP32 microcontroller:

- ECG: Tracks cardiac activity.
- Accelerometer (ADXL345): Monitors motor recovery and limb motions.
- Heart rate and oxygen levels are measured via the PPG Sensor (MAX30100).
- A temperature sensor can identify the risk of illness or fever.
- Wi-Fi/Bluetooth data transmission to the cloud is made possible by the ESP32.

(b) Cloud Layer: Processing & Storage of Data

Incoming sensor data is stored, organized, and visualized by the ThingSpeak platform:

- uses MATLAB integration to support real-time dashboards and analytics.
- arranges data according to timestamps, patient IDs, and sensor types.
- provides external apps with access to APIs.

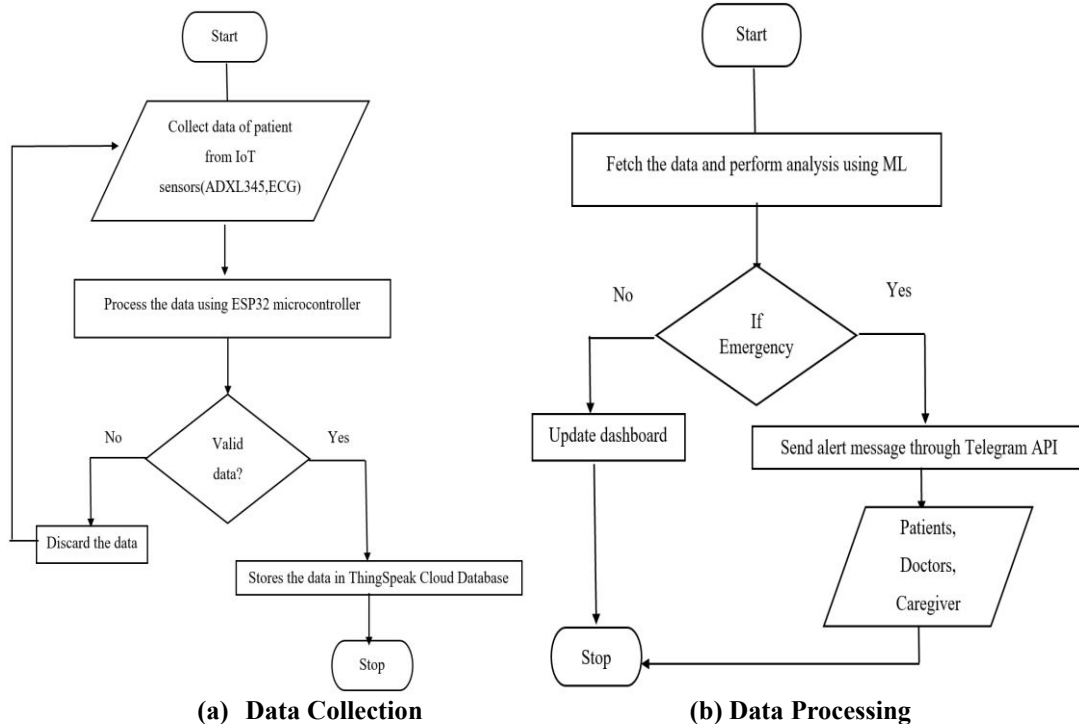
(c) Application Layer: Feedback & Intelligence

Flask, a Python web application, uses machine learning models to analyze cloud data in order to:

- Forecast the course of recovery and identify irregularities (such as an irregular heartbeat).
- Customize treatment according to performance in real time.
- Use the Telegram API to send emergency alerts.
- Present findings with a progress tracking and chart-equipped dynamic dashboard.

With data-driven decision-making, this tiered method improves traditional rehabilitation by enabling automated, accessible, and adaptive stroke care.

2. FLOWCHART



(a) Data Collection :

The following sensors are used by the system to continuously collect movement and physiological data from the patient in real time:

- **ESP32 with MAX30100:** This device measures heart rate and blood oxygen levels.
- **Heartbeat Sensor:** Monitors and identifies anomalies in cardiovascular health.
- **ADXL345 Sensor:** Tracks movement of the body and identifies motor deficits.

1. The patient is fitted with sensors that continuously gather health data in real time.
2. An ESP32 microcontroller receives the gathered data and prepares and processes it.
3. This data is safely transmitted by the ESP32 to the ThingSpeak cloud for additional processing and storage.

(b) Data Preprocessing :

1. **Data Storage & Retrieval:** All sensor data is stored in the ThingSpeak cloud, which also makes it accessible via API endpoints. This data is periodically retrieved by a Python-based web application for machine learning-based analysis, such as recovery pattern analysis, stroke recurrence risk prediction, and abnormality detection.....

2. **Personalized Rehabilitation & Emergency Alerts:** The system creates customized rehabilitation activities for the patient based on the ML analysis. The technology immediately notifies caretakers and medical specialists via Telegram in the event that any critical condition—such as low oxygen levels, an irregular heartbeat, or immobility—is identified.

VII. RESULTS

1. DATA COLLECTION AND STORING



Fig a: Wrist Band

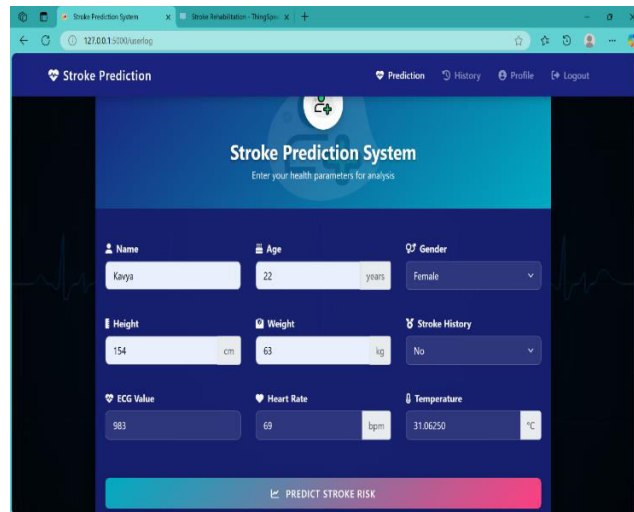


Fig b: Patient's data collection page

Real-time patient health data from Internet of Things sensors (such as the MAX30100, heartbeat sensor, the ADXL345) linked to an ESP32 microcontroller is shown on the Stroke Rehabilitation Web App's Data Collection Page. The app retrieves data from ThingSpeak Cloud for real-time monitoring and analysis.

2. STROKE PREDICTION AND RECOMMENDATION PAGE

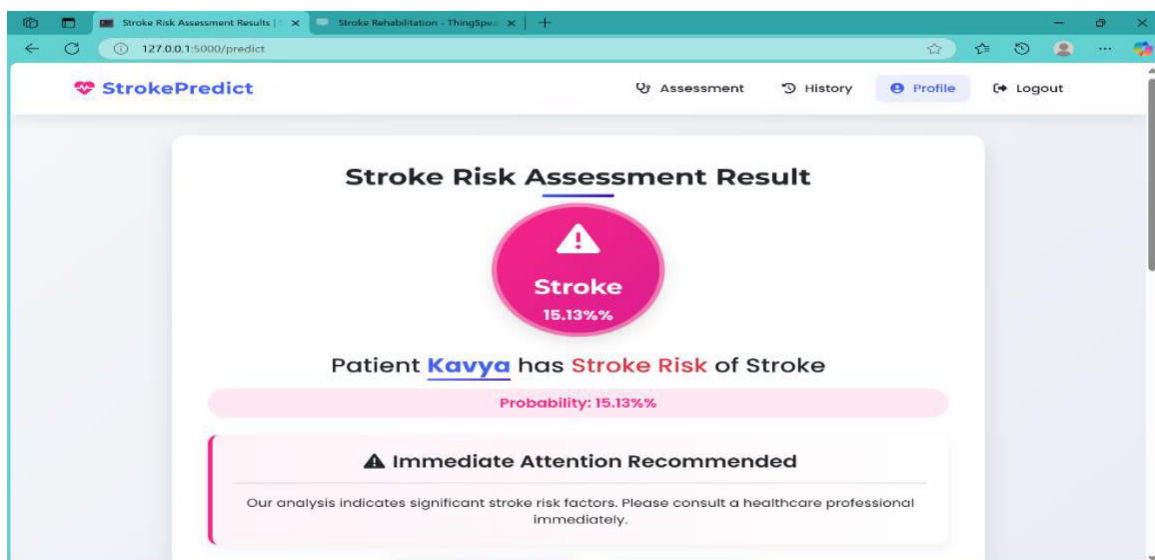


Fig a : Prediction page

ML-based analysis of patient sensor data is displayed on the Prediction Outcome and Recommendation Page in order to monitor recovery and forecast health risks. Additionally, it provides individualized exercise recommendations to improve recovery.

VIII. CONCLUSION

The suggested Stroke Rehabilitation System offers a clever, patient-centered recovery solution by combining IoT and machine learning. Wearable sensors and cloud processing allow for real-time input, ongoing monitoring, and customized treatment. It guarantees prompt treatments and better results by tackling issues including delayed emergency responses, excessive expenses, and restricted access to physiotherapy. Its scalable design allows both home and clinical use, and its automated alarms, ML-driven workout recommendations, and adaptive framework improve safety, engagement, and personalized care.

REFERENCES

- [1] Tala Zaim et al., "Machine Learning- and Deep Learning-Based Myoelectric Control System for Upper Limb Rehabilitation Utilizing EEG and EMG Signals: A Systematic Review", Bioengineering, 2025.
- [2] Sogand Sarmadi et al., "The effect of education based on the seven-step (7E) learning cycle on the quality of life of stroke patients and the care burden of their caregivers: a randomized clinical trial", Taylor & Francis Topics in Stroke Rehabilitation, May 2025.
- [3] Xiuzhen Liu et al., "Test-Retest Reliability and Practice Effects of Shape Trail Test in Stroke Patients", Topics in Stroke Rehabilitation, Volume 32, Issue 1, Published online: March 13, 2025.
- [4] Chenyu Tang et al., "A Unified Platform for At-Home Post-Stroke Rehabilitation Enabled by Wearable Technologies and Artificial Intelligence", arXiv, 2024.
- [5] Roshni G. Kachhadiya et al., "Effectiveness of website-based education program on activities of daily living and fear of falls among sub-acute stroke survivors: a pilot study in South Gujarat Region of India", Bulletin of Faculty of Physical Therapy, 2024.
- [6] Andrew J. Song et al., "EngageHealth: A Mobile Device Application Designed to Deliver Stroke Rehabilitation Exercises Using Asynchronous Video Recordings", Frontiers in Stroke, Stroke Recovery and Rehabilitation, Volume 3, September 2024.
- [7] Li, Xiaohong, "Stroke Rehabilitation: From Diagnosis to Therapy", Frontiers in Neurology, Volume 15, Article 1402729, Published on August 13, 2024.
- [8] Nandini Sengupta et al., "A Survey of Wearable Sensors and Machine Learning Algorithms for Automated Stroke Rehabilitation", IEEE Access, Volume 12, March 2024.
- [9] Jagan P. et al., "XoRehab: IoT Enabled Wheelchair based Lower Limb Rehabilitation System", Annu Int Conf IEEE Eng Med Biol Soc, 2023.
- [10] Mille Nabsen Marwaa et al., "Use of Mobile/Tablet and Web-Based Applications to Support Rehabilitation After Stroke: A Scoping Review", Journal of Rehabilitation Medicine, April 2022.
- [11] Issam Boukhenoufa et al., "Wearable Sensors and Machine Learning in Post-Stroke Rehabilitation Assessment: A Systematic Review", Biomedical Signal Processing and Control, Volume 71, 2022, Article 103197, 2021.
- [12] Vini Vijayan et al., "Review of Wearable Devices and Data Collection Considerations for Connected Health", Sensors, 2021.
- [13] Geng Yang et al., "An IoT-Enabled Stroke Rehabilitation System Based on Smart Wearable Armband and Machine Learning", IEEE Journal of Translational Engineering in Health and Medicine, Volume 6, May 2018.
- [14] K. Sureshkumar et al., "'Care for Stroke': A Web-Based, Smartphone-Enabled Educational Intervention for Management of Physical Disabilities Following Stroke: Feasibility in the Indian Context", BMJ Innovations, January 2015.
- [15] Bruce H. Dobkin et al., "New Evidence for Therapies in Stroke Rehabilitation", Current Atherosclerosis Reports, Volume 15, April 2013.



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