Human Activity Monitoring and Assistance System with Digital Twin

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Abstract— Human activity monitoring plays a vital role in ensuring the safety, health, and well-being of individuals, especially elderly people and patients who require continuous supervision. This project proposes a real-time human activity monitoring and assistance system designed to detect and analyze human activities using sensor-based technology and IoT communication. The system utilizes a wearable BNO055 sensor to capture real-time motion and orientation data, which is processed using an ESP32 microcontroller for efficient activity recognition. Activities such as walking, sitting, running, and falling are identified using predefined algorithms and data processing techniques. Additionally, an IoT-based communication module enables real-time data transmission and remote monitoring through a web dashboard. In case of abnormal activities like fall detection, the system triggers instant alerts via notifications or email, ensuring timely assistance. The proposed system is cost-effective, reliable, and suitable for real-world healthcare applications. By integrating embedded systems, sensor technology, and IoT, the system enhances safety, enables continuous monitoring, and provides immediate response during critical situations.

Indexed Terms— Human Activity Monitoring, Activity Recognition, ESP32 Microcontroller, BNO055 Sensor, IoT-Based System, Real-Time Monitoring, Fall Detection, Embedded Systems, Sensor Data Processing, Wireless Communication, Smart Healthcare System, Emergency Alert System

I. INTRODUCTION

Human activity monitoring plays a significant role in ensuring the safety and well-being of individuals, especially elderly people and patients who require continuous supervision. Daily activities such as walking, sitting, and performing routine tasks can become risky without proper monitoring, particularly in cases of sudden falls or health-related emergencies. In recent years, the need for intelligent monitoring systems has increased due to the growing demand for safety, healthcare support, and independent living. Real-time monitoring plays a crucial role in detecting abnormal activities and providing immediate assistance to prevent serious consequences. Traditional methods such as manual supervision by caregivers provide basic support but have limitations in continuous monitoring and immediate response. These methods lack real-time tracking capabilities and cannot ensure constant observation of individuals. Existing electronic monitoring systems also have limitations in accuracy, cost, and usability, making them less effective in practical applications. A reliable monitoring system is essential to ensure continuous tracking of human activities and provide instant alerts without human intervention. The use of advanced technologies such as embedded systems, sensor-based monitoring, and Internet of Things (IoT) can significantly improve activity detection accuracy and response time. By integrating these technologies, the system can enhance safety, improve monitoring efficiency, and support independent living for individuals requiring assistance.

II. LITERATURE REVIEW

Human activity monitoring systems have gained significant importance due to the need for continuous supervision and safety, especially for elderly individuals and patients. Various technologies have been developed to monitor human activities and ensure timely assistance in case of emergencies. Traditional monitoring methods include manual supervision by caregivers and basic wearable devices. Although these methods are simple and widely used, they provide limited support and are not effective in continuous real-time monitoring. As a result, critical situations such as falls may go unnoticed, leading to serious consequences. With advancements in technology, sensor-based systems have been introduced for activity detection. These systems use accelerometers and motion sensors to capture human movement and provide alerts. While they improve monitoring capabilities, they are limited by noise in sensor data and may produce inaccurate or false detections. This reduces their effectiveness in real-world scenarios. Camera-based systems using computer vision techniques have further improved activity monitoring by enabling visual recognition of human actions. These systems capture images and process them to identify activities, but their performance may be affected by lighting conditions, privacy concerns, and high computational requirements. Recent developments focus on integrating embedded systems with Internet of Things (IoT) to enhance real-time monitoring and alert generation. Despite these advancements, existing systems still face challenges such as accuracy issues, communication delays, and high implementation cost. Therefore, there is a need for a more efficient system that combines sensor-based activity detection with IoT communication for real-time monitoring and alert generation. The proposed system aims to provide a reliable, cost-effective, and user-friendly solution for continuous human activity monitoring and assistance.

III. FEATURES EXTRACTION

1. *Activity Detection using Sensor:*

The wearable BNO055 sensor captures real-time motion and orientation data such as acceleration and angular movement to identify human activities.
Rule: If Motion Pattern Detected → Classify Activity
If No Significant Movement → Continue Monitoring

2. *Fall Detection using Sensor Data:*

The system analyzes sudden changes in acceleration and orientation to detect fall events accurately.
Rule: If Sudden Change ≥ Threshold → Fall Detected
If Normal Movement → No Fall

3. *Data Preprocessing:*

The collected sensor data is filtered and processed to remove noise and improve accuracy for activity recognition.
Rule: If Noise Present → Apply Filtering
If Clean Data → Proceed to Processing

4. *Activity Classification:*

The system classifies activities such as walking, sitting, running, and falling using predefined algorithms.
Rule: If Pattern Matches → Assign Activity Label
If No Match → Unknown Activity

5. *Threshold-Based Analysis:*

Threshold values are defined for different activities to improve detection accuracy and reduce false positives.
Rule: If Value ≥ Threshold → Activity Detected
If Value < Threshold → Ignore.

6. *IoT-Based Data Transmission:*

The processed data is transmitted to a remote system using IoT communication modules like Wi-Fi or GSM.
Rule: If Data Ready → Send to Server
Otherwise → Store Locally

7. *Emergency Alert Generation:*

The system generates alerts when abnormal activities such as falls are detected.
Rule: If Alert Triggered → Send Notification
If No Alert → No Action

8. *Real-Time Monitoring:*

The system continuously monitors and processes sensor data to track human activities and update status in real time without delay.
Rule: If System Active → Continue Monitoring
If System Inactive → Stop Process.

9. *Notification Delivery:*

The system sends alerts to caregivers or users through mobile notifications or email to ensure timely awareness during abnormal conditions. **Rule:** If Alert Triggered → Send Notification
If No Alert → No Action.

IV. METHODOLOGY

1. *Data Collection and Preparation:* The proposed system collects real-time motion and orientation data using a wearable BNO055 sensor. The sensor

continuously captures parameters such as acceleration and angular movement, which are essential for identifying human activities. The collected data is processed using an ESP32 microcontroller, where preprocessing techniques such as noise filtering and data smoothing are applied to improve data quality. This ensures accurate and reliable input for further analysis and real-time activity detection.

2. *Feature Extraction and Selection:* The system extracts key features such as acceleration, orientation, and motion patterns from sensor data to identify activities. These features are processed in real time to classify activities like walking, sitting, and falling.
3. *Algorithm Implementation and Training:*

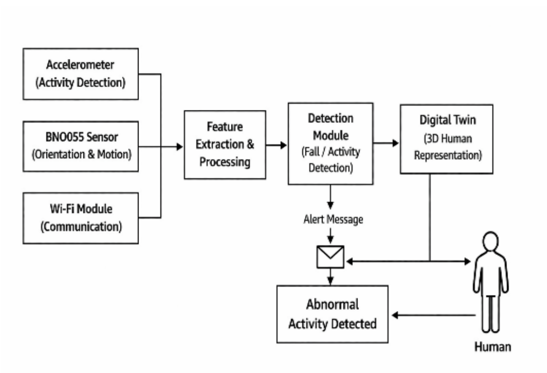

Fig 1: Block Diagram

Fig. 1 Illustrates the overall workflow of the system, including sensor-based activity detection, data transmission, feature extraction, activity recognition, and digital twin visualization. The system continuously processes real-time data and provides immediate alerts.

4. *Model Evaluation and Optimization:* The performance of the system is evaluated using metrics such as accuracy, response time, and detection reliability. The activity recognition algorithm ensures efficient performance for real-time monitoring. Optimization techniques are applied to reduce processing time and improve overall system efficiency.

5. *Real-time Application and User Interface Development:* The developed system is implemented as a wearable monitoring device with real-time alert support. A simple and user-friendly interface is designed to ensure easy monitoring of human activities. The system provides real-time notifications, enabling quick response during abnormal situations. Future enhancements may include mobile application integration and advanced alert features.

V. FUTURE WORK

Future enhancements of the proposed system include the integration of advanced sensors to improve activity detection accuracy and reliability. Machine learning techniques can be incorporated to enhance activity recognition under different user conditions. Additionally, mobile application support and cloud-based data storage can be implemented to improve accessibility and remote monitoring. Further improvements may focus on optimizing power consumption and enabling advanced alert mechanisms for better user assistance.

VI. RESULTS

This section presents the outcomes obtained from the implementation and testing of the proposed Real-Time Human Activity Monitoring and Assistance System. The system performance is evaluated in terms of activity detection accuracy, response time, and reliability in real-time monitoring. The results demonstrate the effectiveness of the system in accurately identifying human activities and generating timely alerts for user safety. The system achieved an overall detection accuracy of approximately 90 percent in recognizing activities such as walking, sitting, running, and falling. It successfully monitored user activities in real time .The BNO055 sensor provided accurate and consistent motion and orientation data, contributing to reliable system performance. However, minor variations in detection were observed due to sensor noise, sudden movements, and overlapping activity patterns.

Model	Accuracy
Activity Recognition	90.00%
Threshold-Based Method	87.50%
Basic Sensor Analysis	85.20%

VII. CONCLUSION

In this project, a Real-Time Human Activity Monitoring and Assistance System was developed to ensure the safety and well-being of individuals. The system utilizes a BNO055 sensor for motion detection along with an ESP32 microcontroller for activity recognition, providing accurate and real-time monitoring. From the analysis, it was observed that the system achieved good detection accuracy and reliable performance in identifying activities such as walking, sitting, and falling. The integration of alert mechanisms further enhances real-time response and user safety. Overall, the results demonstrate that sensor-based monitoring systems improve safety, support independent living, and enhance the quality of life.

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