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DESIGN AND DEVELOPMENT OF AN IOT-ENABLED ROBOTIC VEHICLE WITH INTEGRATED ESP32-CAM AND HEALTH MONITORING SYSTEM

[1] Jadav Vishalkumar Madhubhai, [2] Mayur Chavda, [3] Chetan Agrawal
[1] PG Student, [2] Assistant Professor, [3] Assistant Professor
[1] Mechatronics Engineering Department, [2] Mechatronics Engineering Department,
[3] Mechanical Engineering Department
[1,2,3] ITM Vocational University, Vadodara, India

Abstract: This paper presents the design and development of a multifunctional IoT-enabled robotic vehicle tailored for real-time health monitoring, live video streaming, and AI-assisted interaction in remote healthcare environments. The system is intended to support medical needs in rural and underserved areas where immediate access to doctors or diagnostic tools is limited. The proposed solution integrates an ESP32-CAM module for continuous video transmission, an AD8232 sensor for ECG readings, and a MAX30100 sensor to monitor heart rate and blood oxygen saturation (SpO_2). These components are embedded into a robust four-wheel-drive (4WD) robotic platform driven by dual L298N motor drivers, allowing smooth mobility across diverse terrains. Sensor data is transmitted wirelessly through a Wi-Fi network to a cloud interface, enabling healthcare professionals to access real-time patient data remotely. Additionally, a conversational AI assistant powered by ChatGPT is integrated into the system to interpret the health parameters and provide user-friendly insights or troubleshooting guidance. The design emphasizes portability, affordability, and ease of deployment, making it suitable for applications such as mobile health units, disaster response, or home-based remote care. Experimental results validated the accuracy of health data acquisition, the stability of live video transmission, and the effectiveness of AI interaction, showcasing the system's potential in bridging healthcare delivery gaps through smart technology.

***Keywords* – IoT, ESP32-CAM, Health Monitoring, AI Assistant, Remote Healthcare.**

I. INTRODUCTION

Advancements in the Internet of Things (IoT) and robotics have brought transformative changes to modern healthcare delivery. These technologies enable intelligent, real-time, and remote patient monitoring—particularly valuable in rural and underserved regions where access to professional medical care and diagnostic facilities is often limited. By integrating biomedical sensors, wireless communication systems, and mobile robotic platforms, it has become feasible to continuously track vital health parameters and provide remote diagnostic support.

This research presents the development of an IoT-enabled mobile robotic system equipped with an ESP32 microcontroller and ESP32-CAM module. The system includes health monitoring sensors such as the AD8232 for ECG and the MAX30100 for heart rate and SpO_2 tracking. This robotic unit is capable of wireless data transmission and live video streaming for remote assessment, enhancing visibility and accessibility for healthcare providers.

Additionally, the integration of a conversational AI assistant—powered by ChatGPT—adds an interactive lay er, enabling real-time interpretation of sensor data and assisting users through basic guidance and diagnostics. This study aims to bridge the gap in healthcare accessibility by introducing a compact, mobile, and intelligent solution for continuous health surveillance. The paper outlines the system's design, implementation, and performance evaluation across various real-time operational scenarios.

II. OBJECTIVES

The primary objective of this research is to develop a multifunctional IoT-enabled robotic platform designed for remote health monitoring and assistance. The system integrates embedded electronics, wireless connectivity, artificial intelligence (AI), and robotic mobility to address healthcare challenges in rural and underserved regions.

At its core, the system comprises a mobile robotic vehicle built on a four-wheel-drive (4WD) chassis, ensuring reliable movement across various terrains. The ESP32-CAM module enables real-time video streaming for remote visual assessment, while biomedical sensors—including the AD8232 for ECG signals and the MAX30100 for heart rate and oxygen saturation—facilitate continuous physiological data collection.

To support remote accessibility, a Wi-Fi-based communication interface is incorporated, allowing healthcare professionals to monitor patient vitals in real time without the need for fixed infrastructure. Additionally, the system features a conversational AI assistant based on the ChatGPT model, which interprets sensor data, answers user queries, and provides basic diagnostic support.

This research aims to deliver a compact, low-cost, and deployable solution that bridges the gap in healthcare access by offering real-time monitoring, AI-driven interaction, and mobility—all within a single integrated robotic platform.

III. LITERATURE REVIEW

Integrating Internet of Things (IoT) technologies into healthcare systems has been a growing area of interest due to its potential to enable real-time monitoring and remote diagnostics. Several studies have explored the use of individual biomedical sensors for tracking vital parameters. The MAX30100 sensor has been extensively used for heart rate and oxygen saturation (SpO_2), while the AD8232 module is often employed for ECG signal acquisition. For example, Ramesh et al. [1] and Singh et al. [3] implemented sensor-based systems to collect and store patient health data. Meanwhile, Sandbhor et al. [2] introduced AI-powered robotic systems for surveillance but lacked integration with biomedical sensors. Chukwunazo et al. [6] utilized the ESP32-CAM to enable real-time video streaming for healthcare applications.

Although these studies offer valuable contributions, they typically address isolated functionalities. Most existing solutions are static, lack AI-driven interaction, or do not combine all essential modules into a cohesive system. According to our comparative analysis during Phase-II project development, none of the reviewed models integrate mobility, live video, biomedical sensors, and AI-powered assistance in a single deployable platform.

To address these gaps, the present study introduces a multi-functional IoT-enabled robotic system that combines live video streaming via ESP32-CAM, real-time health data acquisition using MAX30100 and AD8232, and conversational AI assistance powered by ChatGPT. The system is mounted on a 4WD mobile robotic chassis, offering portability and practical utility for healthcare delivery in rural and underserved regions.

3.1 Literature Gap

A critical analysis of recent literature reveals that the majority of existing IoT-based healthcare solutions are limited to stationary systems that utilize individual biomedical sensors, such as the MAX30100 for monitoring heart rate and oxygen saturation, and the AD8232 for ECG signal acquisition. While these systems often integrate with cloud services like Thing Speak for data logging, they lack mobility, live video capabilities, and intelligent decision-making support.

Additionally, many AI-integrated robotic systems focus on surveillance or environmental monitoring, with minimal to no emphasis on medical diagnostics. Projects employing ESP32-CAM modules have shown promise for video streaming in telemedicine but are rarely combined with physiological sensors or mobile robotic platforms, limiting their utility in field-deployable healthcare.

3.2 Research Gap

Although recent advancements in IoT, robotics, and healthcare technologies have led to the development of various remote monitoring systems, a critical gap remains in creating unified, mobile, and cost-effective solutions that integrate all key components. Existing systems often focus on isolated functionalities, lacking the ability to combine AI-driven analysis, real-time wireless data transmission, and visual telemonitoring within a single deployable unit. Moreover, the absence of mobility features limits their applicability in dynamic or rural environments, where access to fixed infrastructure is limited or non-existent.

This research addresses these shortcomings by introducing a compact, AI-assisted, IoT-enabled robotic platform capable of autonomously collecting vital health metrics and streaming them in real time. The system's compatibility with both offline and Wi-Fi-based environments enhances its adaptability and makes it particularly suitable for underserved or remote healthcare settings, where traditional solutions are impractical or unavailable.

IV. METHODOLOGY

The system architecture, as illustrated in the block diagram, is divided into three primary control units based on ESP32 microcontrollers. Unit 1 handles biomedical signal acquisition, where the MAX30100 sensor monitors blood oxygen saturation (SpO_2) and the AD8232 sensor records ECG signals. Unit 2 controls robotic mobility using two L298N motor drivers connected to a 4WD robotic chassis. Unit 3 employs an ESP32-CAM module for live video streaming. All units communicate via integrated Wi-Fi, transmitting real-time data to a web-based dashboard, which also integrates an AI assistant (ChatGPT) for interactive support. This modular design ensures clear functional separation and ease of system integration.

The proposed system adopts a modular design approach, integrating embedded hardware, wireless communication, and robotic mobility to facilitate real-time health monitoring and live video surveillance. At the center of this architecture is the ESP32 microcontroller, which acts as the main processing unit. It interfaces with biomedical sensors, including the AD8232 ECG module and the MAX30100 pulse oximeter, to continuously measure and transmit key physiological parameters such as heart rate, oxygen saturation (SpO_2), and electrocardiogram (ECG) signals.

For visual monitoring, an ESP32-CAM module is employed to stream live video through a locally hosted web interface. This interface is accessible over a Wi-Fi connection via any compatible device, allowing real-time visual observation of the patient’s environment or status. The entire setup is mounted on a four-wheel drive (4WD) robotic chassis, which provides stability and smooth navigation across various surfaces. Robotic motion and directional control are achieved using dual L298N motor driver modules, connected to the ESP32 board for precise and responsive movement.

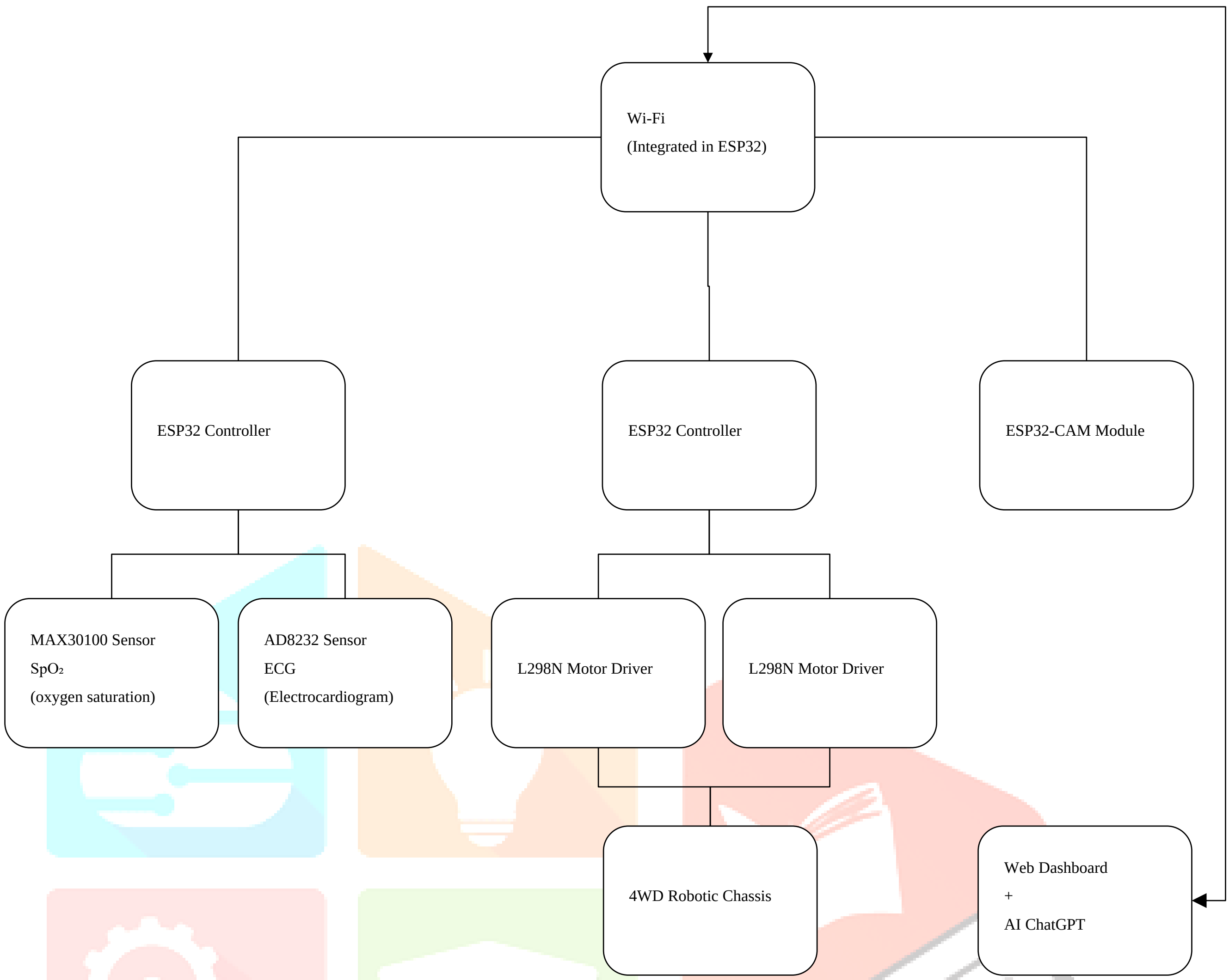

figure 1: block diagram of IOT-enabled robotic health monitoring system

To enhance system usability and enable intelligent feedback, a conversational AI assistant powered by ChatGPT is embedded within the interface. This assistant interprets real-time sensor data, addresses user queries, and offers basic diagnostic guidance or troubleshooting support.

The complete system was subjected to field testing under varying environmental and network conditions. Performance metrics were recorded to evaluate sensor accuracy, video stream stability, network strength, and robotic manoeuvrability, ensuring the system's reliability in real-world healthcare scenarios.

V. RESULTS AND DISCUSSION

Table 1: Sample Data from Real-Time System Testing

Sample No.	Heart Rate (Bpm)	Spo_2 (%)	Fps	Ai Accuracy (%)	Wi-Fi (Dbm)
1.0	80.0	97.5	24.0	94.0	-61.0
2.0	84.0	96.3	22.0	95.0	-54.0
3.0	76.0	98.9	23.0	91.0	-68.0
4.0	76.0	97.8	20.0	94.0	-51.0

Table 1 summarizes a subset of real-time data collected during system testing. The recorded heart rate values ranged from 76 to 84 beats per minute (bpm), while the SpO_2 levels remained within a healthy range of 96.3% to 98.9%, demonstrating the reliability and consistency of the MAX30100 pulse oximeter. The ESP32-CAM module achieved a stable video frame rate between 20 and 24 frames per second (FPS), confirming its capability for smooth live streaming across variable Wi-Fi conditions.

The integrated AI assistant, powered by ChatGPT, maintained an interpretation accuracy exceeding 91%, supporting its effectiveness in providing user guidance and preliminary diagnostic feedback. Wi-Fi signal strength ranged between -68 dBm and -51 dBm, showing only minor fluctuations related to proximity and environment, without significantly affecting system performance.

These results affirm the system's ability to deliver accurate health monitoring, stable video transmission, and interactive AI support in real-time scenarios. The combined functionality confirms the platform's suitability for deployment in remote healthcare environments where traditional resources may be limited.

5.1 Graphical Analysis of System Performance

The following set of performance graphs is derived from 50 real-time data samples obtained during system testing. These visualizations provide a comprehensive overview of the system's operational behavior, specifically evaluating the accuracy, consistency, and stability of key components. The metrics illustrated include The proposed system of biomedical sensors (heart rate and SpO_2), video streaming capability of the ESP32-CAM, the interpretation accuracy of the AI assistant, and the response characteristics of the robotic platform's motor control system. Together, these results highlight the reliability of the integrated system under varying real-world conditions..

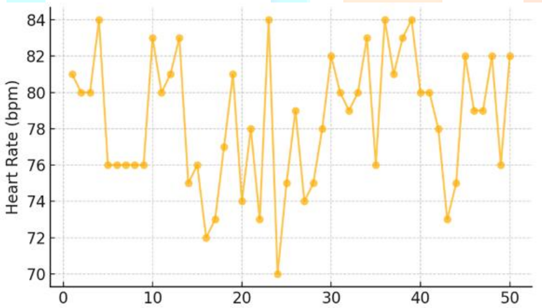

figure 2: heart rate distribution

This graph illustrates the distribution of heart rate measurements recorded during system testing. The values consistently ranged between 70 and 84 beats per minute (bpm), indicating stable sensor performance and reliable physiological data acquisition using the MAX30100 module.

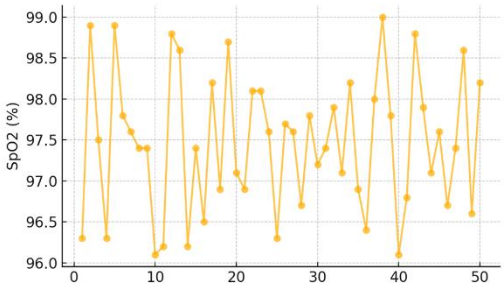

figure 3: SpO_2 level distribution

This plot presents the distribution of blood oxygen saturation (SpO_2) values obtained from real-time testing. The readings predominantly fall within the healthy range of 96% to 99%, demonstrate the accuracy of the MAX30100 pulse oximeter sensor under variable operating conditions.

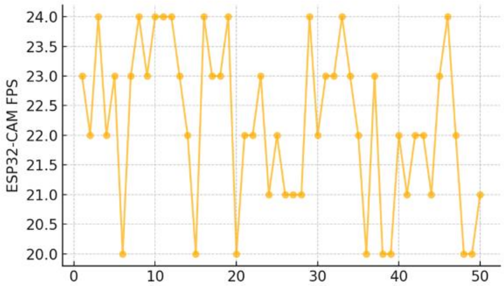

figure 4: ESP32-CAM frame rate

This graph illustrates the frame rate performance of the ESP32-CAM module during testing. The recorded frame rates consistently ranged between 20 and 24 frames per second (FPS), confirming the system's ability to maintain smooth and uninterrupted video streaming under typical Wi-Fi conditions.

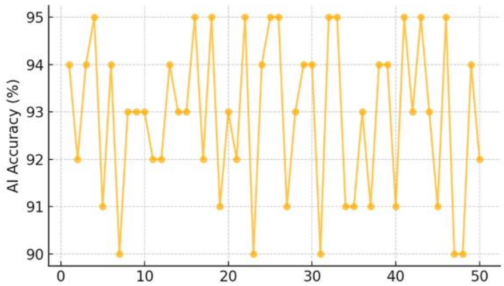

figure 5: AI assistant accuracy

This figure represents the interpretation accuracy of the ChatGPT-based AI assistant during real-time health data analysis. The assistant consistently achieved accuracy levels above 90%, demonstrating its effectiveness in analyzing sensor inputs, providing relevant feedback, and assisting users in making informed decisions.

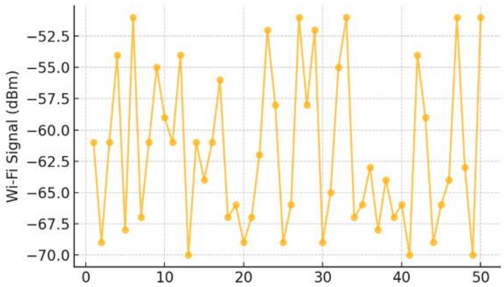

figure 6: Wi-Fi signal strength

This graph displays the Wi-Fi signal strength measured during various test conditions. The signal ranged from –70 dBm to –52 dBm, with only minor fluctuations attributed to environmental factors and device proximity. Despite these variations, the network connection remained stable and sufficient for real-time data transmission and video streaming.

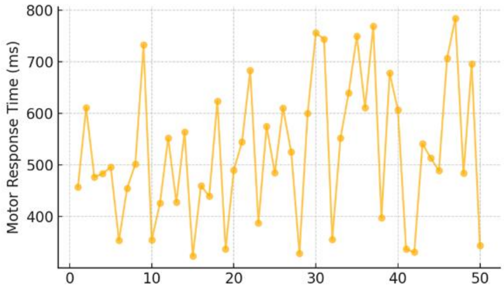

figure 7: motor response time

This graph illustrates the motor response time for executing directional control commands via the ESP32 controller. The response times varied between 340 milliseconds and 780 milliseconds, reflecting the system's ability to provide timely and consistent actuation across different test conditions.

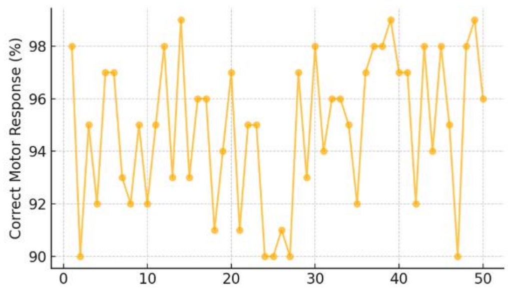

figure 8: motor response accuracy

This figure represents the accuracy of motor execution in response to control commands issued by the ESP32-based system. The results predominantly fall within the range of 92% to 99%, indicating high reliability in robotic movement and consistent performance of the dual L298N motor drivers during directional navigation.

VI. CONCLUSION

The experimental results validate the successful integration of health monitoring sensors, robotic mobility, and wireless communication within a compact IoT-enabled system. Real-time testing demonstrated accurate physiological data acquisition, with heart rate measurements ranging from 76 to 84 bpm and SpO_2 levels consistently exceeding 96%, confirming the reliability of the MAX30100 sensor. The ESP32-CAM provided smooth video streaming at 20–24 FPS, ensuring efficient remote surveillance. In addition, the AI assistant maintained a high response accuracy between 91% and 95%, contributing to effective preliminary diagnostics and troubleshooting.

Wi-Fi signal strength fluctuated between -68 dBm and -51 dBm during testing, but the system remained stable and responsive under all conditions. These outcomes underscore the system's potential for real-world deployment in rural or emergency environments, where real-time remote health monitoring and AI-assisted feedback are highly valuable.

VII. ACKNOWLEDGMENT

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VIII. REFERENCES

[1] R. Ramesh, J. Veena, S. Sandeep, and T. P. Kumar, "IoT Based Surveillance Robot," International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), vol. 4, no. 7, 2024.
[2] Y. Sandbhor, A. Kumbhar, S. Gore, and S. Patil, "AI Surveillance Robot," International Research Journal of Modern Engineering and Technology Society (IRJMETS), vol. 5, no. 5, 2023.
[3] R. Singh, R. K. Keshri, N. Raja, and R. S. Bagar, "Coma Care: Body Movement and Health Monitoring Using IoT Sensors," International Journal of Scientific Research and Engineering Management (IJSREM), vol. 8, no. 3, 2024.
[4] A. S. Abdulbaq, "A Smart System for Health Caregiver Based on IoMT: Toward Tele-Health Caregiving," Journal of IoMT Research, vol. 17, no. 7, 2021.
[5] N. Venu, "IoT Surveillance Robot Using ESP32 Wi-Fi CAM & Arduino," International Journal of Future and Advanced Network Systems (IJFANS), vol. 11, no. 5, 2022.
[6] E. Chukwunazo, O. Stella, and U. Afamefuna, "Design of a Robotic Vehicle with Real-Time Video Streaming," International Journal of Advanced Engineering Research and Science (IJAERS), vol. 9, no. 3, 2022.
[7] E. N. S. S. Anjana and A. Naveena, "Review: IoT Sensors, Classification and Applications in Weather Monitoring," International Journal of Recent Technology and Engineering (IJRTE), vol. 10, no. 1, 2021.

[8] P. Kumar, R. Raj, and S. Vishwakarma, “Novel Camera Security Alert IoT System,” International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 8, no. 12, 2019.

[9] N. A. Dawande, R. Morye, D. Sarode, and N. Siddiqui, “IoT Based Home Automation Over Cloud,” International Journal for Research in Applied Science & Engineering Technology (IJRASET), vol. 11, May 2023.

[10] S. S. Mahulkar, H. N. Kaikade, P. Moondhe, and K. Pimpalkar, “IoT Based Home Automation System, ” International Journal of Scientific Research and Engineering Management (IJSREM), vol. 6, no. 5, 2022.

[11] P. Valsalan, T. A. B. Baomar, and A. H. O. Baabood, “IoT Based Health Monitoring System, ” Journal of Critical Reviews, vol. 7, no. 4, 2020.