Design and Implementation of a Hospital Assistant Robot for Smart Healthcare Automation using AI Technology

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Abstract - The integration of Artificial Intelligence (AI), IoT, and autonomous robotics enables smart healthcare automation in modern hospitals facing high patient loads and staff shortages. This paper presents a Hospital Assistant Robot (HAR) integrated with a Hospital Management System (HMS) to automate tasks such as medicine delivery, patient interaction, and indoor navigation. The system uses odometry-based localization and PID-controlled navigation for reliable movement, along with a speech-to-text, LLM, and text-to-speech pipeline for voice interaction. MQTT ensures secure, real-time communication between the robot and HMS. Experimental results demonstrate accurate navigation, reduced task time, and improved operational efficiency, validating its suitability for scalable healthcare deployment.

Key Words: optics, photonics, light, lasers, templates, journals

1.   INTRODUCTION

Healthcare systems are undergoing rapid digital transformation driven by advancements in Artificial Intelligence (AI), robotics, and Internet of Things (IoT) technologies. Modern hospitals must manage increasing patient volumes while maintaining high standards of care, operational efficiency, and data security. However, traditional hospital workflows rely heavily on manual processes that are time-consuming, labour-intensive, prone to human error, and difficult to scale in high-demand situations. These challenges highlight the need for intelligent automation within healthcare environments. Autonomous robotic systems present a promising solution by assisting healthcare staff in routine and repetitive tasks such as medicine delivery, patient guidance, material transport, and real-time data reporting. By integrating robotics with centralized Hospital Management Systems (HMS), hospitals can achieve seamless coordination, improved resource utilization, and secure data exchange. Additionally, AI-powered decision

support and voice-based interaction enhance human–robot collaboration, making systems more user-friendly and efficient. Such smart healthcare solutions not only reduce workload on medical staff but also improve response time, operational accuracy, and overall patient experience, paving the way for scalable and sustainable digital healthcare infrastructure.

2. RELATED WORK

Recent research has extensively investigated robotic assistants for hospital logistics, patient monitoring, and service automation. While existing systems have demonstrated improvements in delivery efficiency and patient guidance, many lack seamless integration with hospital management systems and secure communication frameworks. Furthermore, challenges related to navigation reliability, interoperability, and large-scale deployment remain unresolved. Harikrishnan et al. [1] presented a CAD-based hospital/home assistant robot featuring autonomous navigation and distress-response mechanisms using path-planning algorithms. Although the system showed effective modeling and operational efficiency, limitations were identified in security, robustness, and integration with hospital infrastructures. Raj et al. [2] developed AHAMR, an autonomous hospital robot designed for medication delivery, monitoring, and infection control using real-time datasets. While workflow efficiency improved, concerns regarding safety compliance, data privacy, and interoperability persisted. Nambiappan et al. introduced MINA, a nurse-assist robot incorporating augmented reality and barcode detection for navigation and object handling; however, scalability issues, grasp-planning inaccuracies, and security vulnerabilities were observed. Harapanahalli et al. proposed a SLAM- and ROS-based navigation system enhanced with neural networks for complex indoor environments, achieving reliable navigation but lacking advanced AI reasoning and scalability for dynamic hospital settings. In parallel, several studies focused on secure healthcare data management using blockchain technologies. Adeniyi et al. [7] proposed an IPFS-based

blockchain system for tamper-proof medical records, though scalability and regulatory compliance challenges remained. Borade et al. [7] introduced a decentralized EHR framework with fine-grained access control, requiring further optimization for real-world deployment. Sairam et al. [8] implemented smart contract–based EMR/EHR access control, facing integration challenges with existing platforms. Villarreal et al. [9] surveyed blockchain healthcare applications, highlighting architectural trade-offs and scalability limitations. Cruz et al. [10] reviewed hospital robotics across logistics, surgery, and telepresence, emphasizing workflow improvements while noting ethical, safety, and infrastructure concerns.

3. PROPOSED WORK

Manual execution of routine hospital tasks such as medicine distribution, patient guidance, and data retrieval increases staff workload and operational delays. There is a need for an intelligent robotic assistant capable of autonomous operation, secure data exchange, and seamless integration with existing hospital management systems. The proposed system consists of a web-based HMS, a backend server for data processing, an MQTT-based communication layer, a voice interaction module, and an autonomous mobile robot. The HMS manages patient records, task assignments, and robot status, while the robot executes assigned tasks in real time. The design for Hospital Assistant Robot with HMS involves several key considerations: The system must handle diverse hospital conditions including background noise, varying voice tones, and different speech commands from users. Similarly, sensor data such as IMU, ultrasonic, and encoder readings should be consistent and stable. Incoming audio signals and sensor readings require preprocessing steps such as noise cancellation, turn detection, smoothing, and time synchronization to ensure reliable interpretation and navigation. The system must process commands quickly, generate reliable navigation paths, and respond in real time with minimal computational overhead.
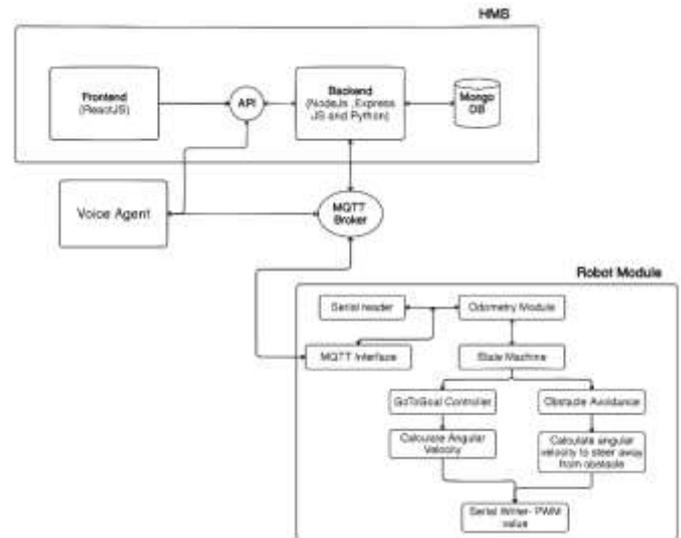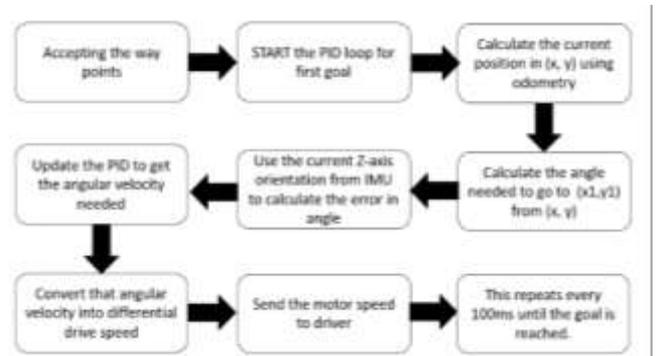

Fig -1: Figure

Fig -2: Figure

Figure 8.6 shows the Hospital Assistant Robot equipped with a mounted voice agent interface featuring expressive animated visuals to enhance user interaction. Figure 8.7 shows the face verification module that authenticates hospital staff using the built-in camera before permitting command execution. Figure 8.8 shows the active voice session screen where the robot listens to spoken commands, processes them through the STT–LLM–TTS pipeline, and responds interactively.

Figure 8.9 shows the rear hardware configuration of the robot, including the Raspberry Pi controller, motor driver circuitry, power unit, and ultrasonic sensors that enable autonomous navigation and real-time communication with the Hospital Management System.
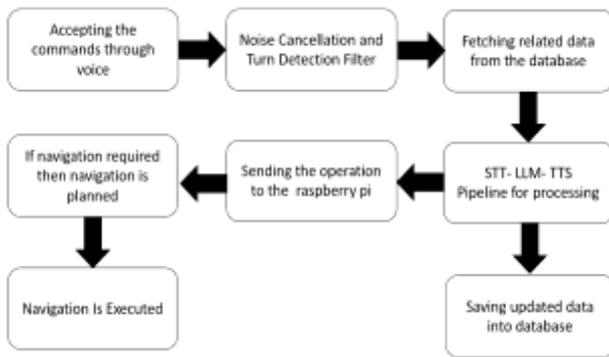
Fig -3: Figure

The navigation process begins by accepting a list of waypoints or destination coordinates from the central HAR system or staff interface, which together define the path the robot must follow. Before movement starts, the PID controller is initialized for the first waypoint to ensure smooth and precise motor control. The robot continuously estimates its current (x, y) position using odometry data from wheel encoders, providing real-time feedback for accurate tracking. The system then calculates the required turning angle from the current position to the target waypoint and determines the orientation error by comparing this target angle with the current Z-axis orientation obtained from the IMU. Based on this angle error, the PID controller computes the necessary angular velocity correction, which is subsequently converted into differential drive commands for the left and right wheels to achieve smooth turning and forward motion. These motor speed commands are transmitted to the motor driver to actuate the wheels. This entire control loop executes every 100 milliseconds, continuously updating position and orientation until the robot reaches the current waypoint, after which it proceeds to the next waypoint until the final goal is successfully achieved.5. Navigation and Control Strategy Autonomous navigation is achieved using odometry-based localization derived from wheel encoders and inertial measurement unit (IMU) data.

A PID-based go-to-goal controller ensures smooth and accurate navigation within hospital corridors and wards. This approach provides reliable performance in structured indoor environments. The system is implemented using Python for robot control, Node.js for backend services, React.js for the Hospital Management System (HMS) frontend, and MongoDB for data storage, while MQTT enables low-latency, real-time communication between the robot and HMS to ensure seamless data exchange and command execution. Experimental evaluation conducted in an indoor hospital-like environment demonstrated that the robot successfully completed assigned tasks with high navigation accuracy and minimal communication delay, validating the robustness of the control and communication architecture. The results showed a noticeable reduction in overall task execution time compared to manual operation, highlighting improved workflow efficiency, faster response handling, and enhanced operational reliability within the healthcare support environment.
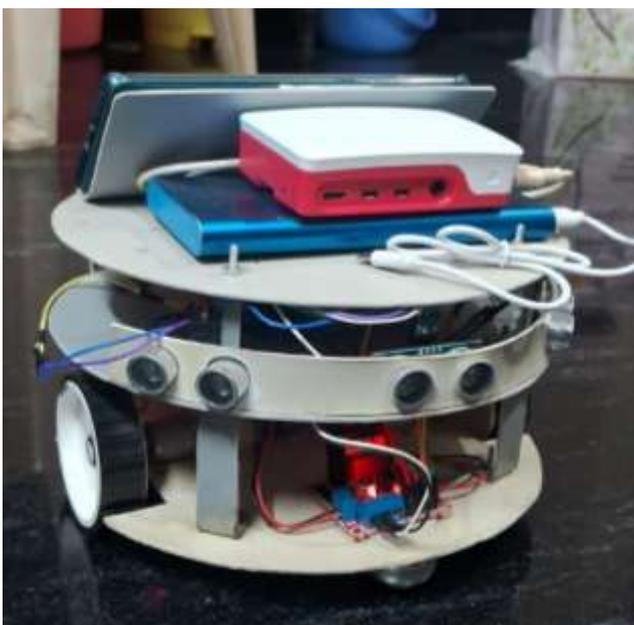
4. APPLICATIONS

The Hospital Management System (HMS) interface includes secure registration and login modules that allow authorized hospital staff to create accounts and access robot-related services. The system dashboard provides functionalities for task assignment, robot status monitoring, patient record management, and navigation tracking through a user-friendly interface. The HMS also supports appointment booking, enabling patients to select doctors and schedule available time slots efficiently. An administrative module allows viewing, managing, and updating appointment details to ensure smooth workflow coordination. The Hospital Assistant Robot is equipped with an interactive voice agent interface that supports secure authentication, conversational command processing, and real-time feedback, enabling seamless communication between hospital staff and the robotic system.
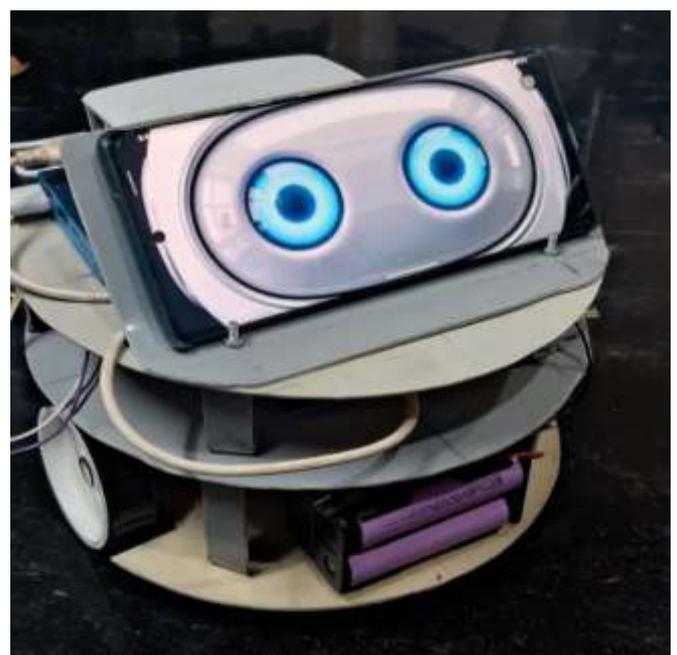
Fig -4: Figure

Fig -5: Figure

convenience and minimizing physical contact within hospital environments. The robot can understand spoken commands, process them intelligently, and provide real-time responses, ensuring smooth human–robot collaboration. Autonomous navigation allows the system to move safely and efficiently through wards, corridors, and departments without human assistance. Its obstacle detection and PID-controlled motion ensure stable and reliable indoor operation. By automating routine tasks such as medicine delivery and report transfer, the robot significantly reduces the workload on healthcare professionals. Integration with the Hospital Management System enables real-time task monitoring, scheduling, and data updates. This coordinated framework enhances operational transparency and workflow management. Overall, the proposed system improves efficiency, patient experience, and supports scalable, intelligent healthcare automation in modern hospitals.

Fig -6: Figure

5. CONCLUSIONS

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