DESIGN AND DEVELOPMENT OF A MULTI-UTILITY INDOOR SERVICE ROBOT FOR HOSPITALS

Project Reference No.: *49S_MTECH_0068*

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Keywords:

Indoor Service Robot, Autonomous Navigation, Robotic Operation System, Slam and Localization, Four-Wheel Drive Mobile Platform.

Introduction:

The increasing demand for efficient healthcare services has created a need for technological solutions that can support hospital staff in performing routine tasks. In many hospitals, the transportation of medicines, medical supplies, reports, and other essential items between departments is still carried out manually. These repetitive tasks can increase the workload of healthcare workers and reduce the time available for patient care. With the advancement of robotics and automation technologies, autonomous mobile robots are being explored as effective solutions for improving hospital logistics and service efficiency.

The proposed project focuses on the design and development of a multi-utility indoor service robot specifically intended for hospital environments. The robot is designed as a four-wheel mobile platform capable of carrying multiple items using a multi-shelf payload structure. It incorporates technologies such as LiDAR-based navigation for obstacle detection and mapping, RFID-based identification for shelf and a touchscreen interface for user interaction.

Objectives:

1. To model and develop a autonomous indoor service robot which is integrated with a multi-shelf payload structure capable of transporting various items safely and reliably during delivery tasks.
2. To integrate and develop a touchscreen display for user interface that enables users to assign destinations and interact with the robot.
3. To incorporate a camera module for vision-based interaction enhancing the robot's perception and user engagement.
4. To enable autonomous navigation using ROS.

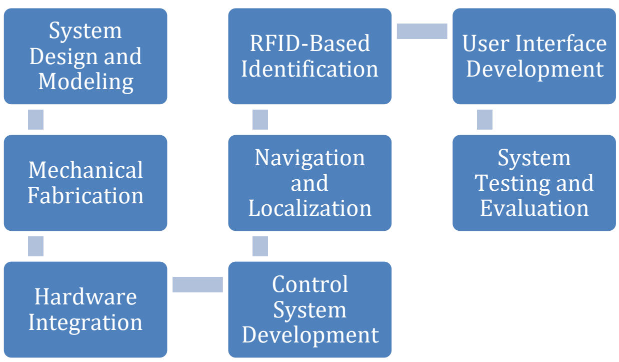
Methodology:

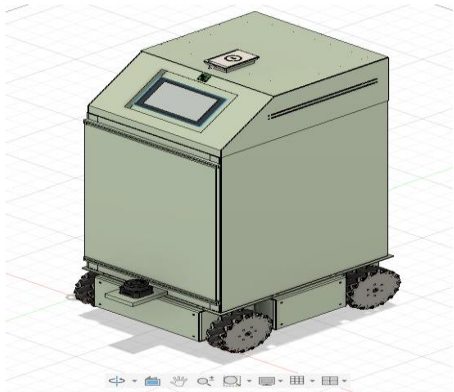
1. The proposed project will be developed through a systematic design and implementation process. The mechanical structure of the indoor service robot is designed using Fusion 360. The robot chassis will be fabricated as a four-wheel mobile platform with a multi-shelf payload structure to enable transportation of

multiple items within hospital environments. Aluminium will be used as the primary fabrication material for the chassis and structural frame due to its lightweight properties, strength and durability which helps improve the robot’s mobility and energy efficiency.

2. The hardware components including ST3215 Series Serial Bus Servo motors, motor drivers, battery system, LiDAR, camera module, touchscreen display and a UHF RFID reader will be integrated with the robot platform. A Waveshare Serial Bus Servo Driver Board will be used to control the motor and handle low-level motion control while a single-board computer (Raspberry pi 5 - 4GB) will manage higher-level processing such as navigation, user interface and sensor data processing.
3. For autonomous navigation LiDAR-based mapping and localization techniques will be implemented using the Robot Operating System. Obstacle detection and avoidance algorithms will be implemented to ensure safe movement in dynamic hospital environments.
4. A UHF RFID system will be integrated to detect RFID tags placed on shelves or specific locations. This enables the robot to verify delivery points and identify designated storage areas automatically. A touchscreen-based user interface will allow users to assign destinations and interact with the robot easily.
5. **5.** The integrated system will be tested in an indoor environment to evaluate navigation accuracy, object detection, RFID-based identification and overall operational efficiency. The performance of the robot will be analysed to ensure reliable operation in real-world hospital settings.

Figure 1: Service Robot for Hospitals





Hardware Components:

(1) Raspberry Pi 5 (4GB)
(2) Waveshare Serial Bus Servo Driver Board
(3) ST3215 Series Serial Bus Servo Motors
(4) LiDAR Sensor – RPLiDAR C1M1-R2
(5) UHF RFID Reader Module
(6) Camera Module – Logitech c270
(7) Waveshare 7-inch Capacitive Touchscreen Display
(8) 3S Lithium-ion Battery Pack – 11.1~12.6 V 10 Ah
(9) Emergency Stop Button

Control System Architecture:

The control system follows a hierarchical two-layer architecture designed to separate high-level intelligence from low-level real-time control. The upper layer runs on the Raspberry Pi 5 and executes all ROS nodes: the navigation stack, SLAM module, sensor drivers for LiDAR and camera, the RFID processing node and the touchscreen GUI application. It publishes velocity commands over a ROS topic to the lower layer. The lower layer is implemented on the waveshare driver module which has inbuilt ESP32 microcontroller and a 9 axis imu sensor which subscribes to velocity commands via a serial ROS bridge, performs PID-based closed-loop speed control on each wheel motor using encoder feedback and sends odometry data back to the Raspberry Pi. This layered design ensures that computationally intensive tasks such as map building and path planning do not interfere with the low-latency requirements of motor control. The Robot Operating System humble running on Ubuntu 22.04 on the Raspberry Pi provides the middleware framework for inter-process communication, sensor data fusion and seamless integration of the navigation, perception and user interface subsystems. Obstacle avoidance is handled by the ROS Navigation Stack using the Dynamic Window Approach (DWA) local planner, combined with global path planning using the A* or Dijkstra algorithm on the costmap generated by SLAM.

Result and Conclusion:

1. This project presents the design and development of a multi-utility indoor service robot for hospital environments. The robot integrates a four-wheel drive mobile platform with a multi-shelf payload structure, enabling efficient and reliable transportation of medicines and essential supplies across hospital departments. By combining LiDAR-based autonomous navigation, ROS-based SLAM and localization, RFID-based delivery verification, a camera module for vision-based interaction and an intuitive touchscreen user interface the system addresses the critical need to reduce the workload of healthcare workers and improve operational efficiency. The dual-layer computing architecture handling real-time motor control and a Raspberry Pi 5 managing high-level navigation.
2. The robot is expected to navigate hospital corridors reliably, detect and avoid dynamic obstacles, identify delivery points via RFID tags and interact with hospital staff through its touchscreen interface. This work demonstrates that autonomous mobile robots can play a transformative role in hospital logistics paving the way for smarter and more efficient healthcare facilities.

Future Scope:

1. Integration of artificial intelligence and machine learning algorithms for improved path planning, dynamic obstacle prediction, and context-aware navigation in complex, crowded hospital environments.
2. Development of a multi-robot coordination system enabling a fleet of service robots to operate collaboratively, share map data, manage task queues and avoid inter-robot collisions across hospital floors.
3. Incorporation of voice command capabilities, natural language processing and remote monitoring via a hospital management dashboard to enhance human-robot interaction and operational oversight.