### MEDICAL ASSISTIVE WEB ROBOT

##### PROJECT REPORT

###### Submitted by

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**BONAFIDE CERTIFICATE**

This is to certify that the thesis entitled “**Medical Assistive Web Robot**” submitted by **KS Venkatram(CB.SC.U4AIE23236), Sanggit Saaran KCS(CB.SC.U4AIE23247), Vishal Seshadri B (CB.SC.U4AIE23260), Surya HA (CB.SC.U4AIE23267)** is a Bonafide record of work carried out under my guidance and supervision at **Amrita School of Artificial Intelligence**, Coimbatore, as part of the **IV Semester**, **Second Year** B.Tech curriculum in the course **“Mathematics for Computing 4”**(**22MAT230**) and **“Introduction to AI Robotics”**(**22AIE214**).

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#### DECLARATION

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**Contents**

Acknowledgement v

[List of Abbreviations vi](#_TOC_250011)

[Abstract vii](#_TOC_250010)

1. Introduction viii
   1. [Problem Statement . . . . . . . . . . . . . . . . . . . . . . . . . . . . . x](#_TOC_250009)
   2. [Objectives . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . x](#_TOC_250008)
   3. [Organization of the Report . . . . . . . . . . . . . . . . . . . . . . . . . xi](#_TOC_250007)
2. Background xii
   1. [Introduction xii](#_TOC_250006)
3. Proposed Work xiii
   1. [Overview xiii](#_TOC_250005)
   2. [Sensing xiii](#_TOC_250004)
4. Results and Discussion xiv
5. Conclusion xv

[References xvi](#_TOC_250001)

[List of Publications based on this research work xviii](#_TOC_250000)

**List of Figures**

**List of Tables**

1.1 Literature Review Summary . . . . . . . . . . . . . . . . . . . . . . . . ix

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# List of Abbreviations

SLAM Simultaneous Localization and Mapping

RViz ROS Visualization Tool

DWA Dynamic Window Approach

LiDAR Light Detection and Ranging

RGB Red Green Blue GUI Graphical User Interface

GPU Graphics Processing Unit

CPU Central Processing Unit

ROS Robot Operating System

RTAB-Map Real-Time Appearance-Based Mapping

IMU Inertial Measurement Unit

# Abstract

We are building a **Medical assistive web-controlled robot** that can autonomously navigate hospital environments. Using the Hiwonder JetHexa hexapod robot with ROS1, our system performs SLAM to map and localize itself in real-time. The main goal is to enable the robot to move between hospital rooms by selecting start and destination points through a custom web interface, rather than using RViz. We are also working on a voice control system as an add-on feature to allow basic directional commands like “forward” and “left,” making the robot even easier to use without needing a screen.

**Chapter 1 Introduction**

The field of autonomous robotics has seen rapid advancements, with modern robots expected not only to navigate but also to interpret their environments in real time. As automation increasingly enters domains such as healthcare, education, and home services, the role of intelligent indoor mobile robots has become more crucial. In hospital environments specifically, healthcare professionals are often burdened with repetitive tasks such as monitoring patients and moving between rooms to collect data. These challenges become more pronounced with increasing patient loads and limited staff availability.

Table 1.1: Literature Review Summary

|  |  |  |
| --- | --- | --- |
| **Paper Title and**  **Year** | **Key Contributions** | **Limitations** |
| Development of a Service Robot for Hospital Environments in Rehabilitation Medicine with LiDAR-Based SLAM (2024) | Medical service robot using 3D LiDAR and SLAM with NDT Matching for mapping | High computational demand for real-time processing and needs further testing in dynamic hospital settings. |
| Agile mobile robotic platform for contactless vital signs monitoring (2023) | AI-powered mobile robot for autonomous navigation and biometric data collection | Limited by ambient temperature variations, impacting IR accuracy and Motion artifacts |
| CMS-Robot: A Cloud Medical Service Robot Merging SLAM and IoT (2024) | SLAM and IoT for autonomous navigation, remote monitoring, and patient care | Navigation accuracy may be affected in highly dynamic environments, and obstacle avoidance in crowded spaces |
| Mobile Robotic Platform for Contactless Vital Sign Monitoring (2022) | Dr. Spot, a teleoperated quadruped robot, enables accurate, contactless monitoring of vital signs | system relies on external control rather than full autonomy. long-term usability remain untested |
| Augmentation of Mapping and Autonomous Navigation for Hexapod Robots by using a Visual Inertial System(2021) | VIS-enhanced hexapod navigation with VINS-Mono cuts drift by 91% | VINS-Mono requires 10Hz updates (vs 100Hz gait odometry), creating latency. |
| Gap Traversing Motion via a Hexapod Tracked Mobile Robot (2021) | Autonomous hybrid robot uses IR sensing to traverse extended terrain gaps. | 0.5° servo resolution causes up to 9.7% gap width error |

**LiDAR-Based SLAM for Hospital Robots** (Sayat Ibrayev et al., 2024) introduced a service robot designed for hospital environments using 3D LiDAR and SLAM. The robot used NDT Matching for localization and obstacle avoidance, but it required high computational power and lacked extensive testing in dynamic medical settings.

**Vital Signs Monitoring via Mobile Robots** (Hen-Wei Huang et al., 2023) developed a mobile robotic platform capable of autonomous navigation and biometric data collection using InsightFace for facial detection and IR sensors for vitals estimation. While accurate in controlled scenarios, its real-time performance was limited by ambient temperature effects and motion artifacts.

**CMS-Robot with SLAM and IoT** (Yubin Huang et al., 2024) combined SLAM and cloud IoT for autonomous hospital navigation and remote healthcare services. It addressed integration but struggled with navigation accuracy in dynamic or crowded spaces.

**Dr. Spot - A Quadruped Monitoring Robot** (Hen-Wei Huang et al., 2022) proposed a teleoperated robotic platform to maintain social distancing and perform contactless vital sign monitoring. However, the system’s reliance on human control limited full autonomy and long-term deployment efficiency.

**Home-Care Robot with Vital Signal Sensors** (Caridad Mireles et al., 2022) utilized 3D-printed components and embedded health sensors for assisting patients at home. Though innovative, the platform was only tested on a small scale.

**Gap-Traversing Hexapod Robot** (Taiga Sasaki & Toyomi Fujita, 2021) explored a hybrid hexapod-tracked robot equipped with infrared and servo-based sensing for rugged terrain traversal. The system enabled cost-effective gap detection and autonomous crossing, contributing insights into terrain adaptability in hexapod locomotion.

## Problem Statement

In hospital environments, healthcare workers are often overwhelmed by routine tasks such as collecting patient information, delivering medications, and frequently moving between rooms. While robotic systems have been introduced to assist in these areas, many existing solutions are expensive, hardware-intensive, or require complex software interactions that are unsuitable for non-technical medical staff. Most rely heavily on predefined paths or command-line tools like RViz for navigation, making them impractical for real-time hospital use. Furthermore, these systems typically lack accessible user interfaces and adaptable control options, limiting their usability in fast-paced clinical settings. To address these limitations, there is a need for an affordable, autonomous robotic system that can map hospital layouts, navigate accurately, and be controlled through a user-friendly web interface.

## Objectives

* + - To implement a real-time, LiDAR-based SLAM system using RTAB-Map for autonomous navigation within indoor hospital environments.
    - To integrate the system on a hexapod robot powered by Jetson Nano for efficient SLAM and obstacle avoidance.
    - To develop a web-based interface for visualizing the map and remotely setting navigation goals without relying on RViz.

## Organization of the Report

The structure of this report is outlined below:

* + - Chapter 1: Introduction

Provides the background, literature survey, problem statement, and objectives of the project.

* + - Chapter 2: Background

Explores the fundamental concepts used in the project, including LiDAR-based SLAM (RTAB-Map), ROS1 Melodic, RViz for visualization and web technologies.

* + - Chapter 3: Proposed Work

Details the system design, architecture, hardware integration, SLAM, autonomous navigation using map goals, and implementation of web-based control.

* + - Chapter 4: Results and Discussion

Describes the mapping results, navigation performance, robot control through the web interface, and challenges during implementation.

* + - Chapter 5: Conclusion and Future Work

Summarizes the key outcomes of the project, lessons learned, and proposes enhancements.

**Chapter 2 Background**

## Introduction

Autonomous robots that operate in real-world indoor environments need two core abilities — the power to navigate safely and the intelligence to understand their surroundings. For our robot to function reliably in a hospital setting, it must build an accurate map, locate itself within it, and move while avoiding obstacles. At the same time, it should be flexible enough to adapt in real-time without relying on heavy computing infrastructure.

To support this, we use a LiDAR-based SLAM system called RTAB-Map. It allows the robot to create a 2D map of its environment using laser scans and wheel-based odometry data. This map helps in real-time localization and path planning, even as the environment changes. All the sensing and control logic runs on ROS1 Melodic, a widely adopted framework in robotics. ROS helps us structure our software using nodes and topics, making communication between sensors, motors, and algorithms smooth and modular.

We use Jetson Nano due to its high GPU-based architecture, which handles tasks like mapping and visualization more efficiently. Jetson Nano provides enough processing power while still being compact and power-efficient.

To see what the robot is doing, we use RViz, a 3D visualization tool that lets us monitor sensor data, maps, and navigation goals during testing. However, since RViz is not user-friendly for hospital staff, we introduced a web interface. This web interface simplifies interaction with the robot, letting users set navigation goals or track the robot visually without needing technical knowledge.

**Chapter 3 Proposed Work**

## Overview

The proposed system focuses on building an autonomous medical assistant robot capable of navigating indoor hospital environments while being controlled through a user-friendly web interface. The system is modular in nature and separates the core functions of **perception**, **navigation**, and **control**, enabling better performance, maintainability, and scalability.

We began by selecting a **Jetson Nano-based hexapod robot** for its processing power and mobility. The robot is equipped with a **2D LiDAR (RPLIDAR S2L)** and onboard odometry to support real-time mapping and localization. To handle SLAM and navigation tasks, we employed **ROS1 Melodic**, which allowed integration of multiple components using a publisher-subscriber architecture.

The mapping process utilizes **RTAB-Map**, a graph-based SLAM package. This tool allows the robot to construct and update a 2D occupancy grid map of the hospital environment using laser scans and odometry data. Once the map is created, the robot can localize itself within this map and autonomously move toward user-defined goal positions.

Navigation is handled using the ROS **move\_base** package, which includes both global and local planners. We used the **Dijkstra algorithm** for global path planning and the **DWA (Dynamic Window Approach)** for local path adjustments and obstacle avoidance. These planners work together to ensure safe and efficient movement even in dynamic environments.

The robot is designed to be controlled using a **custom-built web interface**. Through this interface, healthcare staff can view the live map, track the robot's current position, and set navigation goals with a simple click. This interface communicates with the ROS backend via **ROSBridge**, which converts ROS messages into web-friendly formats (such as JSON over WebSocket).

## Sensing

Sensing is a fundamental part of our system, as it enables both environment understanding and safe movement. The primary sensors integrated into the robot include:

* **LiDAR (RPLIDAR S2L):** Used for 2D mapping and obstacle detection. The LiDAR provides high-frequency scan data that is fused with odometry for SLAM.
* **Odometry:** Although not fully accurate on its own, it complements LiDAR by providing relative motion data for localization.
* **IMU (Inertial Measurement Unit):** Used for estimating orientation and aiding in motion stability, especially during turns or uneven movement.
* **Camera (AstraPro Plus):** Though not currently used for SLAM, it is intended for future integration with object recognition or patient interaction modules.

All sensor data is published to relevant ROS topics and visualized in **RViz** during testing. The robot is capable of performing real-time localization using **Adaptive Monte Carlo Localization (AMCL)** on the pre-built map, ensuring accurate positioning throughout navigation.

**Chapter 4**

**Results and Discussion**

The initial phase of the project involved developing a **custom wheeled robot** using DC motors, a Raspberry Pi, and a basic chassis. This stage aimed to implement autonomous navigation, but technical challenges such as unbalanced motor speeds, absence of odometry data, and lack of LiDAR functionality impacted the feasibility of the setup. Subsequently, efforts to optimize the system using Raspberry Pi 4 were undertaken; however, hardware limitations prevented effective SLAM implementation and led to system instability.

As part of an iterative development process, the project transitioned to utilizing a lab-grade **hexapod robot**ic platform (**Hiwonder JetHexa** equipped with Jetson Nano) that provided the necessary SLAM capabilities. Building on its existing SLAM codebase, the team successfully deployed and adapted the RTAB-Map SLAM to the laboratory environment. A detailed map of the space was generated, and localization features were validated using RViz visualization tools.

To enhance user accessibility, the project focused on developing **a web-based interface** for intuitive robot control. While the backend connection to ROS was established successfully, efforts to enable real-time goal publishing via the web interface are ongoing and remain a key objective.

This exploration yielded significant insights into robotics systems integration. Comprehensive work with the ROS framework enabled deeper understanding of SLAM tuning parameters, navigation systems, and interface design. Rather than constructing a system from scratch, the project aimed to adapt complex robotics technologies to enhance usability for non-technical users—a critical aspect of practical robotics deployment.

**Chapter 5 Conclusion**

This project explores the practical implementation of autonomous navigation and user-friendly control in a hospital-inspired indoor environment using a hexapod robot. Although our initial attempt using a self-built wheeled robot faced critical hardware and odometry limitations, these early challenges helped refine our understanding of robot requirements and guided the decision to adopt a more capable platform.

By switching to the Jetson Nano-based Hiwonder JetHexa robot, we successfully deployed real-time SLAM using the RTAB-Map and generated consistent indoor maps for localization. Leveraging ROS1 Melodic, we validated autonomous navigation using goal-publishing tools in RViz, and further aimed to create a web-based interface. While the complete integration of the web interface with ROS navigation is still under progress. The experience also deepened our practical understanding of robotics middleware, perception systems, and real-world system debugging.

For future work, our focus will be on completing the web interface for seamless goal-setting. Enhancements may also include implementing basic voice control, visual feedback for navigation status, and improving the robot’s interaction layer for real-world hospital use cases. Expanding this system to support multi-robot task distribution and more advanced object detection will make the framework more scalable and robust for real-world deployment.

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# List of Publications based on this research work