Autonomous Medicine Dispensing and Distribution Robot (Navigation)

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Introduction

Problem Statement: Healthcare facilities face increasing demands on medical staff, time and resources. Autonomous medical delivery robots present a solution to optimize healthcare logistics and reduce staff workload. This research focuses on developing robust navigation algorithms for an autonomous robot capable of safely and efficiently delivering medicine in hospital environments.

Aim: The primary goal is to develop and validate an autonomous navigation system for medical delivery robot using ROS2.

Research Objectives:

- **Autonomous Navigation:** Implement and optimize SLAM and path planning algorithms for obstacle avoidance and navigation
- **Simulation Validation:** Validate system performance in simulated environments using ROS2
- **User Interface:** Design user interface for medical staff and patients including medication delivery confirmation
- **Performance Evaluation:** Assess navigation accuracy, path efficiency, and real-time capabilities

Research Hypothesis

The autonomous medicine dispensing robot will:

- Reduce nursing staff workload through automation
- Minimize medication administration errors compared to manual processes
- Enable more efficient resource allocation in hospital environments

Research Questions

1. How can an autonomous robot effectively navigate hospital wards with precise localization and obstacle avoidance?
2. What interface design best enables medical staff to monitor operations and medication delivery?
3. How can navigation accuracy, and user satisfaction be measured and validated?
4. What are the key challenges in hospital deployment and their mitigation strategies?

Literature Review

Navigation in robotics consists of four key components: Perception, Localization, Cognition, and Motion Control.

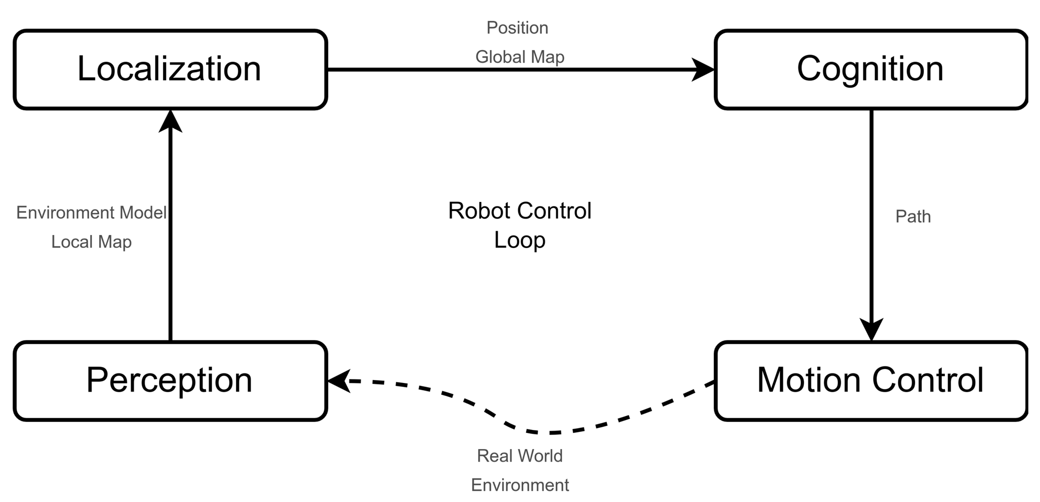

Figure 1. Overview of Robot Navigation System Architecture

Related Works

- **Hospital Navigation System** [7]: Implementation of ROS-based medical robot using Gmapping and AMCL for patient assistance
- **RGB-D Based Navigation** [6]: Enhanced feature extraction using RGB-D cameras for improved environmental mapping and navigation accuracy
- **Tartu University Hospital Study** [4]: Deployment of autonomous robots for medical sample transportation using ROS2 and RMF

Framework	Dimension	Sensors	Level
Nav2	2D	LIDAR, Odometry	M
ARC Nav	3D	Depth Cameras	H
RTAB-Map	3D	RGB-D, LIDAR	H
Cartographer	2D/3D	LIDAR, IMU	H
Hector SLAM	2D	LIDAR	H
Gmapping	2D	LIDAR, Odometry	M
Micro-ROS	2D	embedded sensors	L
Autoware-Based	3D	IMU, Camera	H

Table 1. Comparison of ROS2 Navigation Frameworks

Methodology

- **Hardware Architecture:**
  - Differential drive system
  - Sensor integration: LiDAR, IMU, encoders
  - Raspberry Pi 4B for high-level control
  - ESP32/Arduino for low-level control

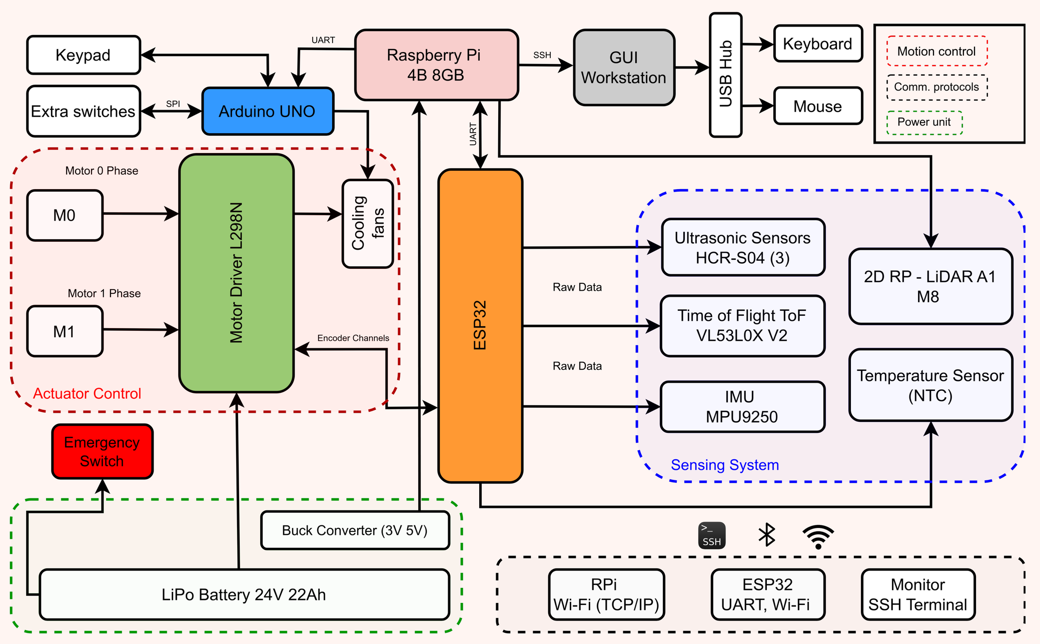

Figure 2. System Architecture Overview

- **Navigation Strategy:**
  - Adaptive Monte Carlo Localization (AMCL) for localization
    - Has less computational load compared to fixed-particle approaches
    - Crucial for real-time performance on resource-limited hardware
  - Gmapping for occupancy grid mapping
  - A* for global path planning
    - Optimal path generation with heuristic efficiency
    - 466ms faster than traditional Dijkstra's algorithm
  - Dynamic Window Approach (DWA) for local obstacle avoidance
    - Real-time obstacle avoidance considering robot dynamics
    - Velocity space optimization for smooth navigation

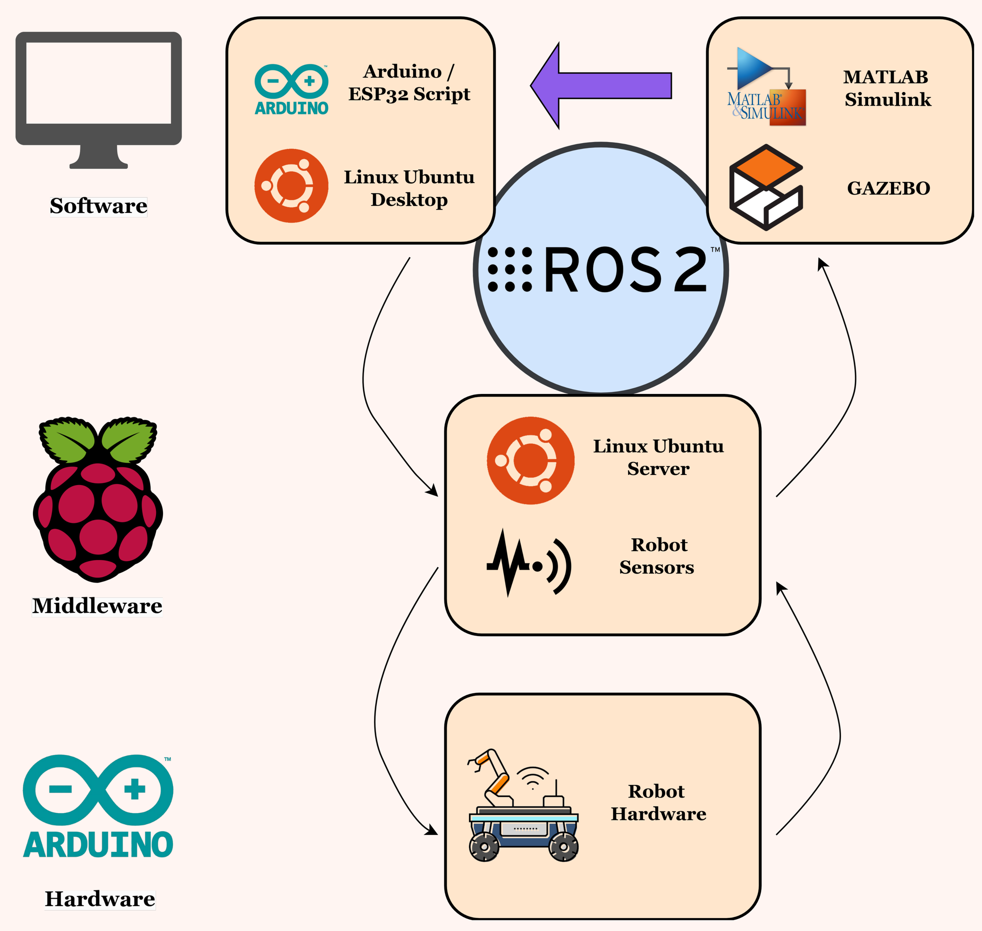

Figure 3. Illustration of the proposed system

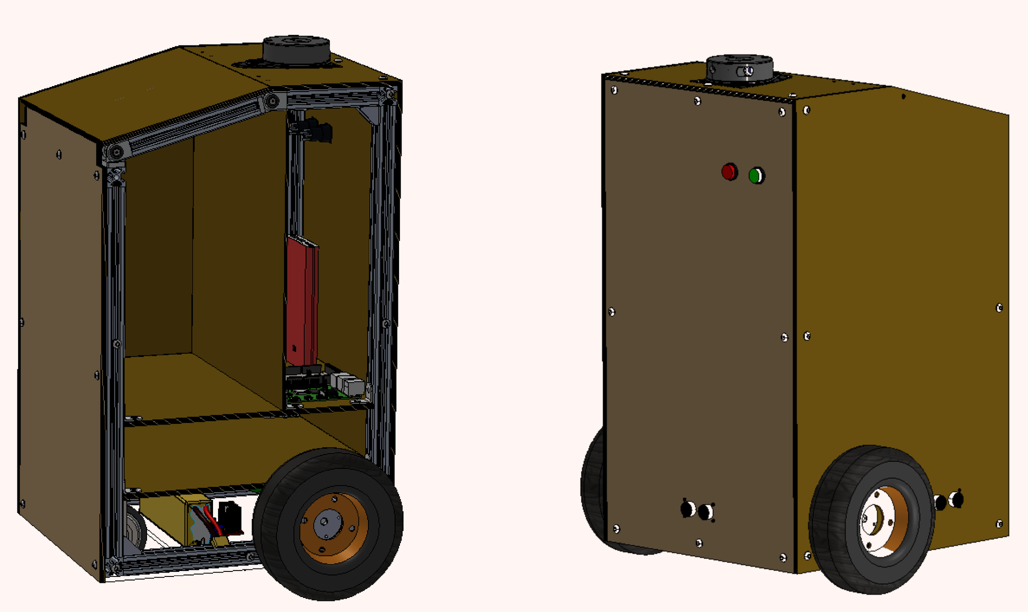

Figure 4. Front and back views of the proposed robot CAD design

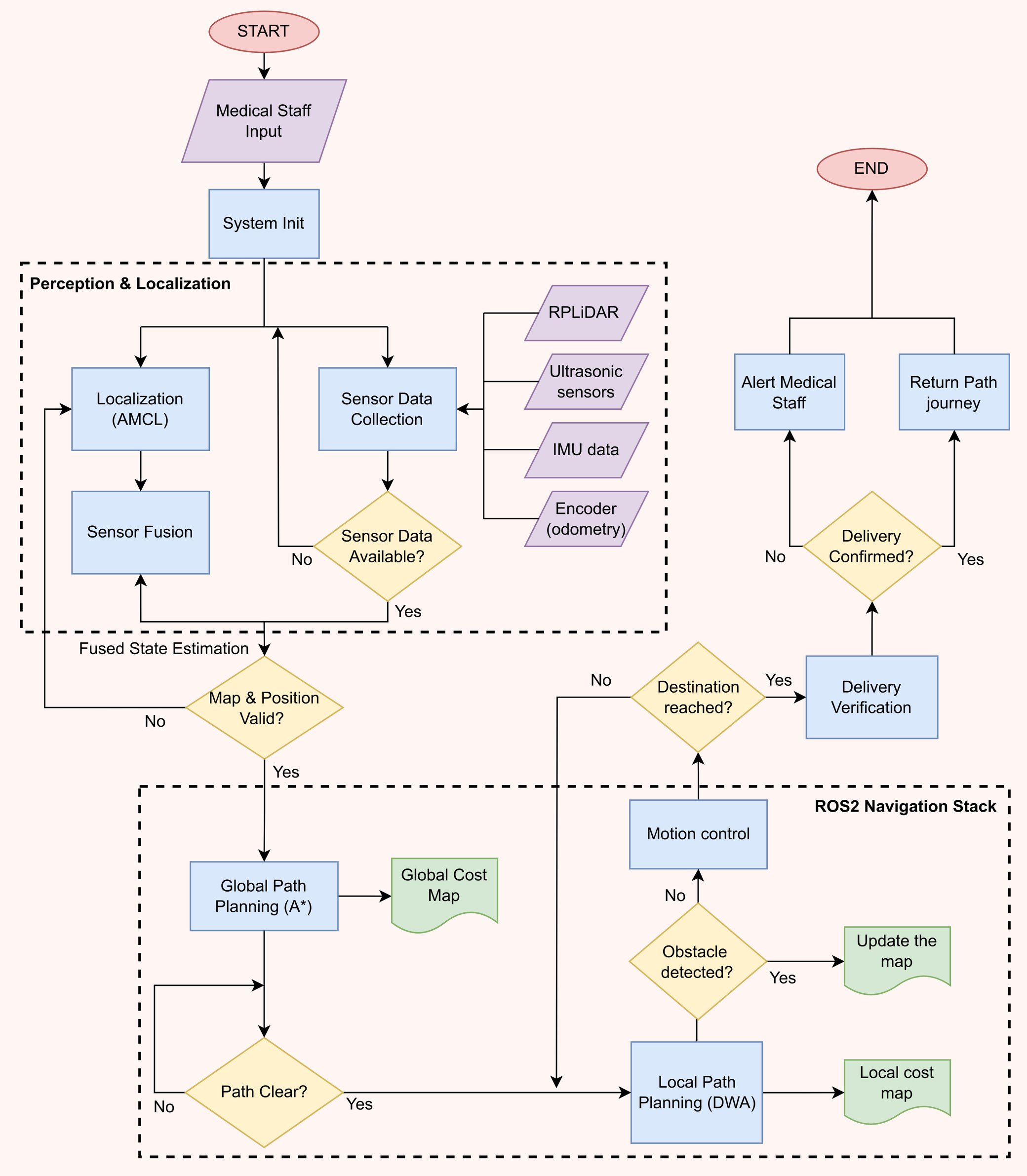

Figure 5. Flowchart of the proposed system

Preliminary Result

GAZEBO SIMULATION

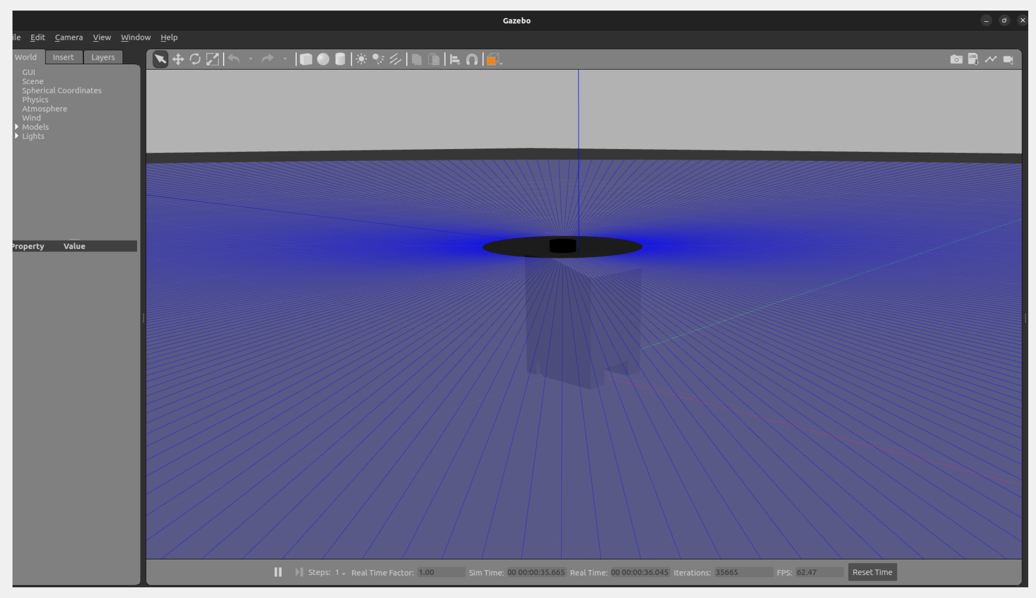

Figure 6. Gazebo simulation

Conclusion and Future Work

The comprehensive literature review has identified optimal algorithms and detailed design approach for autonomous medical robot navigation. For this case, the future work to be done to achive the robot's functionality is as follows:

- Testing in a simulated university lab depicting hospital environment
- Implementation of selected algorithms on physical robot
- Development of user interface for medical staff
- Integration of sensor fusion for improved perception
- Performance evaluation and optimization of different navigation algorithms

References

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