Team Syzygy Technical Design Paper for the Robotics Dojo Competition 2024

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***Abstract*—This paper introduces our custom-designed mapping and navigation robot, developed as a start with the end-goal being enhanced situational awareness and operational efficiency in challenging environments. By integrating advanced sensors and autonomous navigation capabilities, our robot provides reliable tools to navigate complex terrains and gather critical data in real-time.**

I. Introduction

In recent years, the demand for advanced mapping and navigation solutions has surged, particularly in critical applications such as search and rescue operations. As natural disasters and emergencies become more frequent, the need for efficient, reliable, and autonomous systems to assist first responders is paramount. This paper presents our custom mapping and navigation robot, designed to enhance situational awareness and operational efficiency in challenging environments.

Our robot stands as a testament to the collaborative spirit of the Robotics Dojo community, showcasing how collective expertise can lead to groundbreaking advancements in technology that ultimately save lives and improve operational outcomes.

II. Paper Contents

A. Design Strategy

We settled on keeping things as simple as possible both from the software as well as the hardware. This would involve using the least number of sensors as well as a simple design that had already been well researched. To summarize the principles:

1. A simple differential drive robot with 2 wheels.
2. Motor power over speed. We would go for slower motors with higher torques than faster motors. This was in line with past experience from the previous year's competition
3. Reuse of work from other people. Unless it was completely necessary to write our own software from scratch, we would try to use packages from other people and make changes to suit our situation. This meant that the development time would take considerably less time.
4. Utilization of the simulation environment. For rapid testing and a more flexible schedule for all of us, we would make use of the Gazebo environment to try out new implementations as well as different algorithms in Navigation and mapping before agreeing on what to use for the actual robot. This was achieved early on by creating a virtual replica of the gamefield in gazebo.

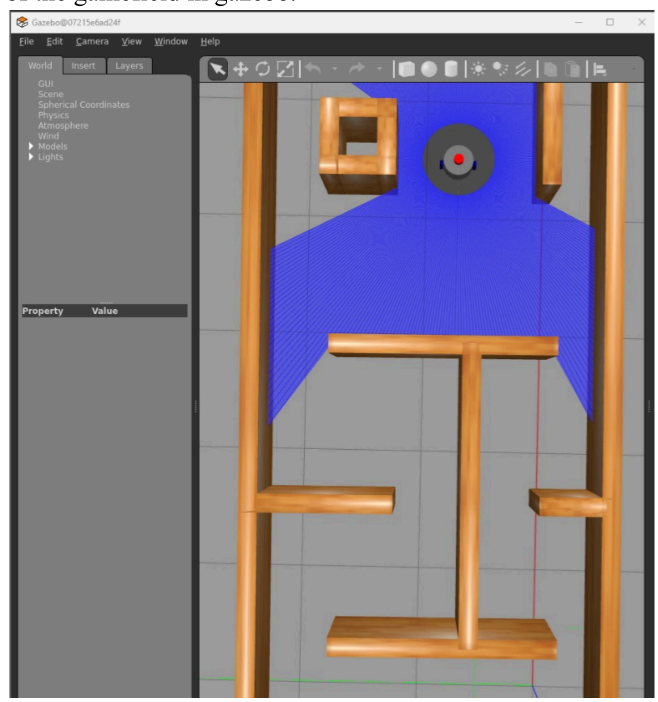

Figure 1. Virtual gamefield in gazebo

B. Vehicle Design

In line with our design strategy, we needed the simplest of chassis designs for the robot. We went for a differential drive robot with 2 motorized wheels. To further improve maneuverability, we decided to have the axle collinear with the diameter of the robot. 2 additional castor wheels are then used to aid in balancing the robot.

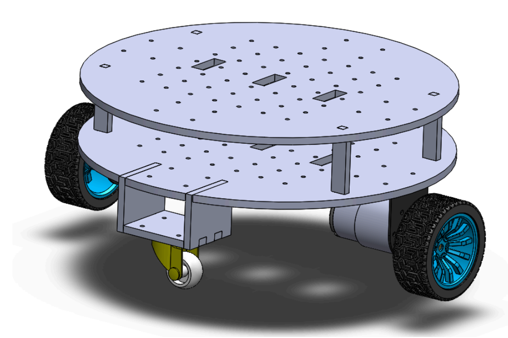

Figure 2: Mobile platform design

For the vehicle dimensions, the wheel separation radius is 250mm with a wheel radius of 65mm. For actuation, we favored torque and stability over speed. For this reason, we used 2 110 rpm 12V DC motors and installed an external encoder using a gear mechanism attached to the wheel. The body of the robot is made from 5mm thick acrylic sheet for its ease in laser cutting as well as being lightweight.

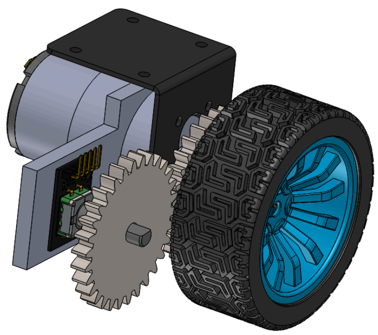

Figure 3. Encoder attachment

For sensors, we decided to use a simple Light Detection and Ranging (LiDAR) sensor for mapping as well as a rotary encoder to be used in odometry.

To power everything, we have 2 power sources:

- A 12V Li-Po battery. The choice to use a Li-Po battery over common Li-ion batteries was because the Li-ion batteries require a specialized battery management system to ensure all cells are balanced. In contrast, Li-Po batteries often come with a charger that handles the charge balancing. Li-Po batteries also have the advantage of being more compact. This battery supplies power to the motors
- A 5V 20000mAh power bank. This provides power to the raspberry pi which then powers the LiDAR and the Arduino mega. We decided to use a power bank as it allows powering the Raspberry pi over USB-C without the need for a voltage regulator. The power is also a lot more stable and eliminates any interference that would arise when a single source was used.

C. *Mapping and Navigation*

Mapping and navigation could further be broken down to the following parts:

1. Hardware interface - This allows the ROS2 packages to communicate and send commands to the Arduino Mega which then controls the hardware as well as reads the data from the encoders. This was archived using a customization of the ros_arduino_bridge repository from hbrobotics. The Arduino Mega then communicates via serial with the raspberry pi.
2. Mapping. This was achieved through the use of the SLAM toolbox as well as LiDAR data. To interface with the lidar, we used the official ROS2 package of sllidar. Adaptive Monte Carlo Localization (AMCL) from the SLAM toolbox is used to localize the robot using data from the lidar and the encoders.
3. Navigation: This involves both localization as well as path planning. To achieve this, we use the NAV2 package that uses AMCL for localization based on the map generated from the SLAM toolbox.
4. Controller manager. This is the interface between NAV2 and the hardware interface. It exposes the hardware controllers to ROS2 allowing for control using either the teleop-twist or with commands from NAV2

D. *Experimental Results*

The rapid development of the robot can be directly attributed to investment in simulation. A custom simulation environment was built on Gazebo and RViz and this enabled the rapid testing of ROS2 mapping and navigation packages.

Simulation also aided in the design of the robot's software architecture as the nodes were not only visible but their functions could be determined in simulation before being transferred to the physical robot.

Testing on the physical robot comprised unit testing and integration testing, Whereby unit testing refers to testing a single node or function such as the visualization of LiDAR data and integration testing refers to testing the entire robot i.e. using a teleoperation node to move the robot around the gamefield while creating the map.

With a keep-it-simple-first approach, independent units were tested first and additional functionality was then tested later. For example, individual motors were tested first, then a node was written to move both motors in all the four directions, and finally, a teleoperation node was written that allowed an operator to drive the robot around using their computer's keyboard.

Mapping using the LiDAR sensor was then integrated as the final step and the whole robot's functionality could be tested on the gamefield.

E. *Acknowledgements (optional)*

Our team wishes to acknowledge the support of the Japan International Cooperation Agency (JICA) for providing the resources necessary to build the robot.

Secondly, the team also wishes to acknowledge the support of Dr. Shohei Aoki, Ph,D for his support throughout the research and development phase.

F. *Appendix—Situational Awareness (optional)*

As the Robotics Dojo community embraces ROS2, the transition presents both opportunities and challenges. While ROS2 is an indispensable tool for advancing industry-focused research, its adoption may be hindered by the steep learning curve.

To address this, resources (including code and designs) will be open-sourced to provide a reference for future roboticists. Additionally, we will share our experience as well as tutorials on various Robotics Dojo channels such as YouTube and the Robotics Dojo Blog.

References

[1] R. Gandhinathan, "Chapter 2: Introduction to ROS-2 and its Capabilities," in *ROS Robotics Projects,* 2nd ed. Birmingham, UK

Basic format for periodicals:

[2] S. Karam, V. Lehtola, G. Vosselman, "STRATEGIES TO INTEGRATE IMU AND LIDAR SLAM FOR INDOOR MAPPING." *Remote Sensing and Spatial Information Sciences,*Volume V-1-2020*, August,* 2020.

[3] S. Kuzin, G. Sziebig, "SROS: Educational, Low-cost Autonomous Mobile Robot Design Based on ROS" IEEE/SICE International Symposium on System Integration (SII), January, 2020.