SYNOPSIS

1.	**Title of the Project**	DESIGN AND DEVELOPMENT OF AN AUTONOMOUS GROUND VEHICLE FOR WAREHOUSE MANAGEMENT Project Reference No.: 46S_BE_0547
2.	**College and Department**	Sahyadri College of Engineering & Management, Mangalore-575007 Interdisciplinary: (Mechanical Engineering and Computer Science Engineering)
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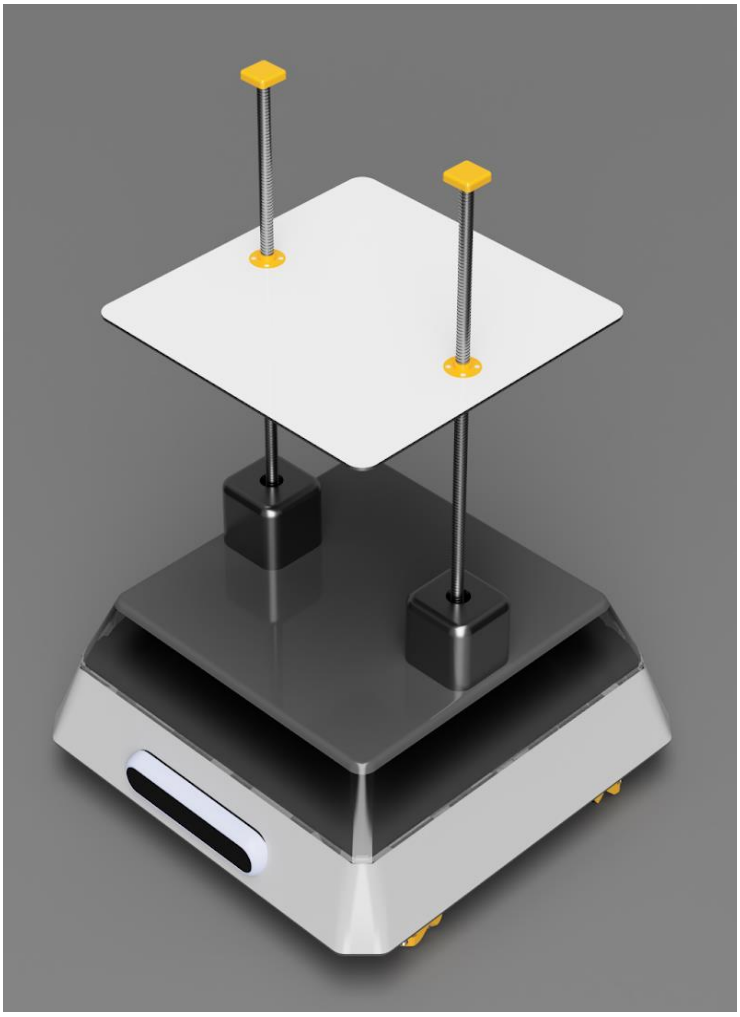
4.	**Keywords**	Automation, Warehouse, ROS, LiDAR, Lead screw, Object detection.
5.	**Introduction**	Unmanned Ground Vehicles are widely used for a variety of purposes nowadays. Collaboration between different types of robots from different manufacturers or even self-developed robots within the same ecosystem is becoming more popular. With the advancement of robotics and computer science, manufacturers and Industrial Robotics have reached a point where they are concentrating their efforts on developing systems that are more agile and adaptable to changes in the environment. Customer satisfaction is a primary objective in today's economy, and it necessitates production tailored to customer needs at lower costs, with greater reliability, and of higher quality, because customers drive business. Warehouse management involves large numbers of labor due to the high demand of online shopping, and laborers in warehouses need to follow strict social distancing. Of course, automation was well advanced in the warehouse world long before the pandemic. The trend dates all the way back to the late nineteenth century, when the conveyor belt was invented. However, today's distribution robots are entirely different, emulating human actions and thought processes.

6.	**Objectives**	• To design an Autonomous Ground Vehicle for Warehouse Management. • To Make Warehouse Management more accurate and efficient. • To Develop a Mechanism to Detect and Map the environment for agile and robust operation. • To integrate ROS framework, SLAM and object detection for Automation. • To perform Simulation, Analysis and Implementation of the AGV.  Fig 1: Conceptual Design in Fusion 360
7.	**Methodology**	This project aims to design, develop and fabricate an autonomous ground vehicle. In this context, we propose a solution of developing an autonomous robotic platform capable of doing multiple tasks thus avoiding unnecessary repetitive work, contact between humans and helps to increase productivity. Compared with traditional human work, robots and autonomous systems have advantages such as the ability to perform tasks with high accuracy, efficient path planning, increased flexibility and safety.

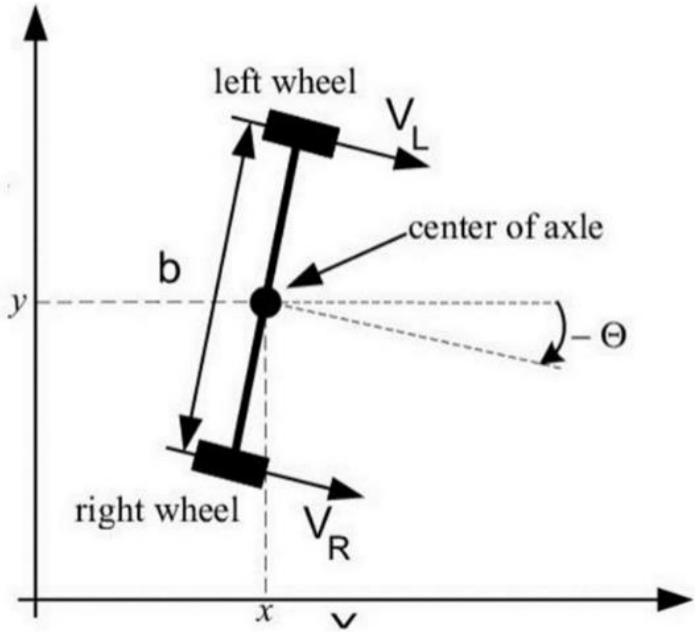
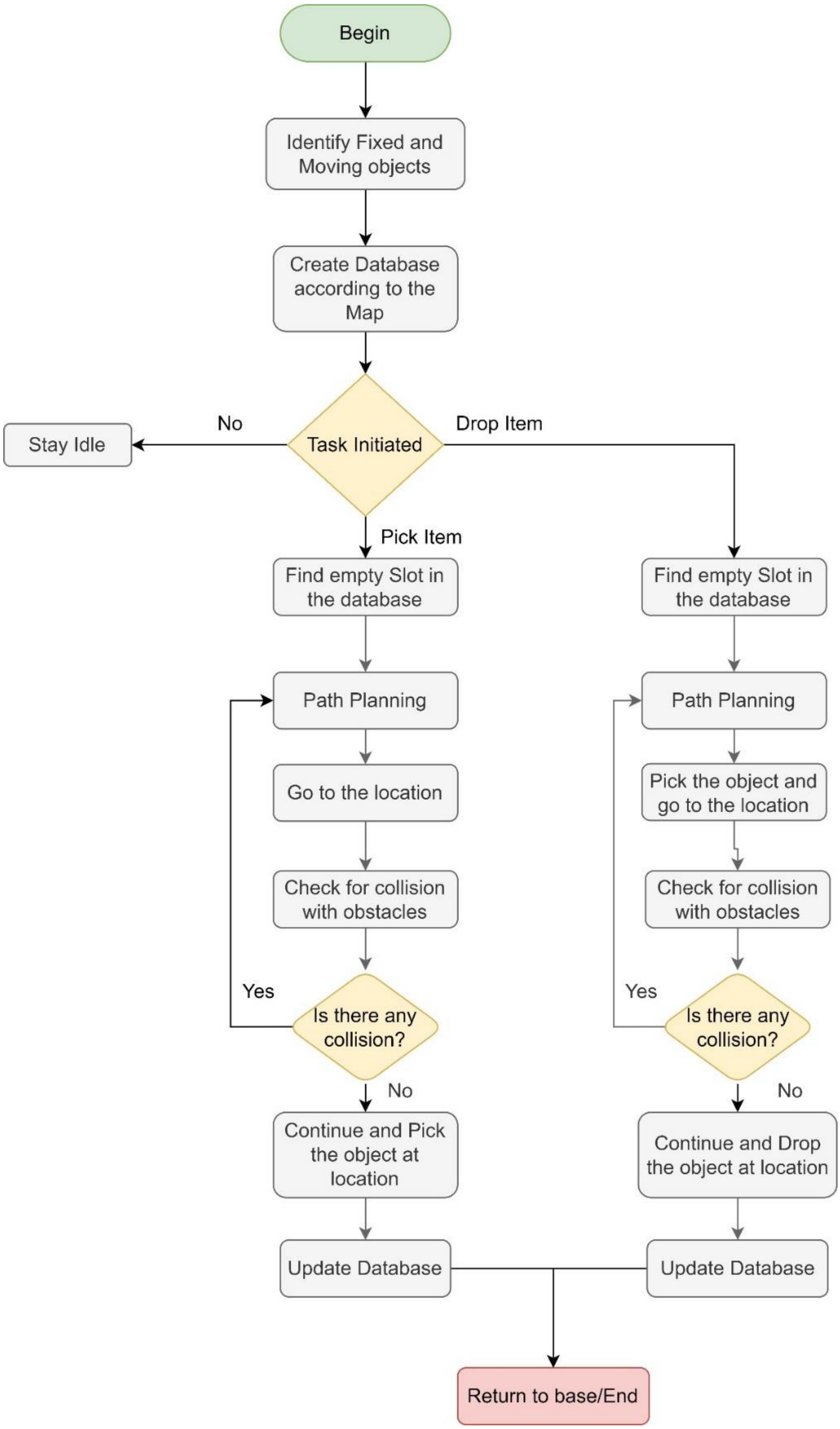
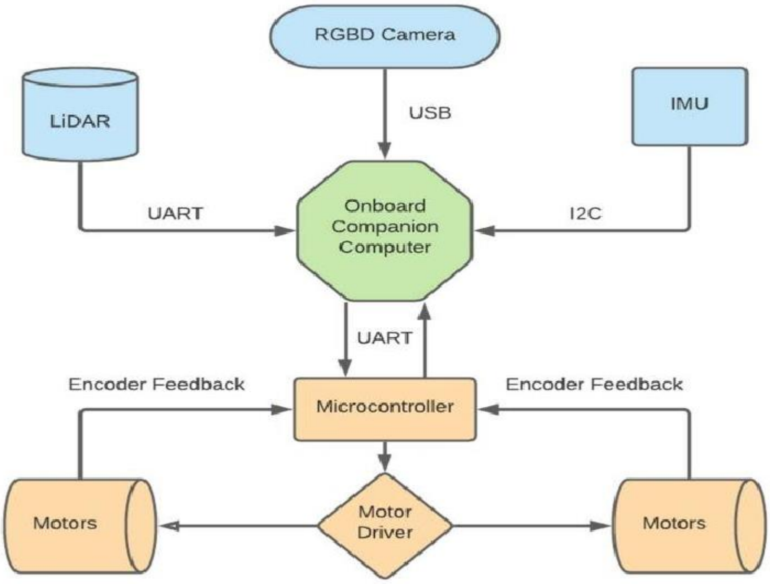


Fig 2: Differential Drive Kinematics

Workflow:

1. Initially the bot creates a virtual map of the warehouse using SLAM (Simultaneous Localization and Mapping) algorithm. This is done using the Lidar and encoder motors simultaneously.
2. Next, the AMCL (Adaptive Monte Carlo Localization) is used to locate the pose of the robot in the given map.
3. Using SLAM, we can identify and locate any Fixed and Moving objects.
4. A database is created with details of the contents of the warehouse after creating a map for the same. By scanning the ArUco code on a compartment using the RGBD camera the contents of that compartment can be accessed from the database created previously.
5. There are mainly 2 tasks for the bot. Pick Item and Drop Item. The Warehouse manager will initiate the task according to the need.
6. According to the task, the bot finds the location using the database and analyses the shortest path with the help of A* algorithm.
7. After traveling to the location, the bot will perform the initiated task and update the database.
8. Finally, the bot will return to the base point and wait for the next task.

		 Fig 3: Overall Software Architecture

		 Fig 4: Hardware Architecture

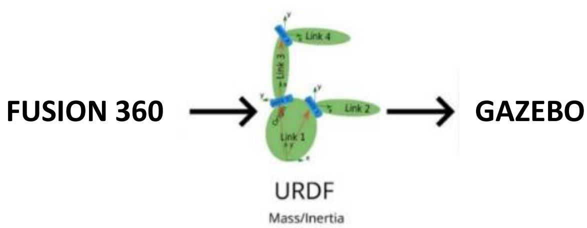
8.	**Results and Conclusions**	**Results:** The proposed robot is benchmarked against different use cases using the 3D dynamic simulator Gazebo for faster iteration and accurate results. To achieve full autonomy and robust navigation, the Robot Operating System (ROS) framework is employed for high-level activities such as Simultaneous Localization and Mapping (SLAM) and Path Planning. The ROS framework is distinguished by the fact that all sensors are treated as ROS nodes. This approach has the advantage of not affecting other executables if one fails, making it more robust and adaptable than a system based on a centralized runtime environment. The navigation stack of our robot consists of two planners, global and local to increase the robustness while planning paths. Global planner uses A* algorithm to navigate from the initial pose to final goal location while local planner uses Dynamic Window Approach (DWA) to plan short paths while avoiding obstacles and moving towards the goal location. It's more than a matter of finding workers to fill each position.  Fig 5: URDF Generation Workflow

Fig 6: Fabrication of the AGV

After loading the model in **Gazebo Environment**, the robot is initialized and starts publishing its joint states into a certain **ROS** topic. Initially the **G-mapping** node is launched which takes input from lidar and odometry data and starts generating the map. **RVIZ** tool is used to visualize the mapped data. The teleoperation node is used to operate the robot manually to perform the mapping operation. Once the mapping of entire area is completed, the generated map is saved using map server node available in ROS.

The map server stores the map in PGM and YAML format which contains the whole details of the environment mapped. To perform autonomous navigation along with obstacle avoidance, the AMCL node is launched along with move base node. AMCL node needs previous map as an input to estimate the pose of the robot using particle filters. The red arrow represents the estimated pose from the algorithm. The goal can be given using the RVIZ tool or from ROS API for C++ and Python.

Simulation Results:

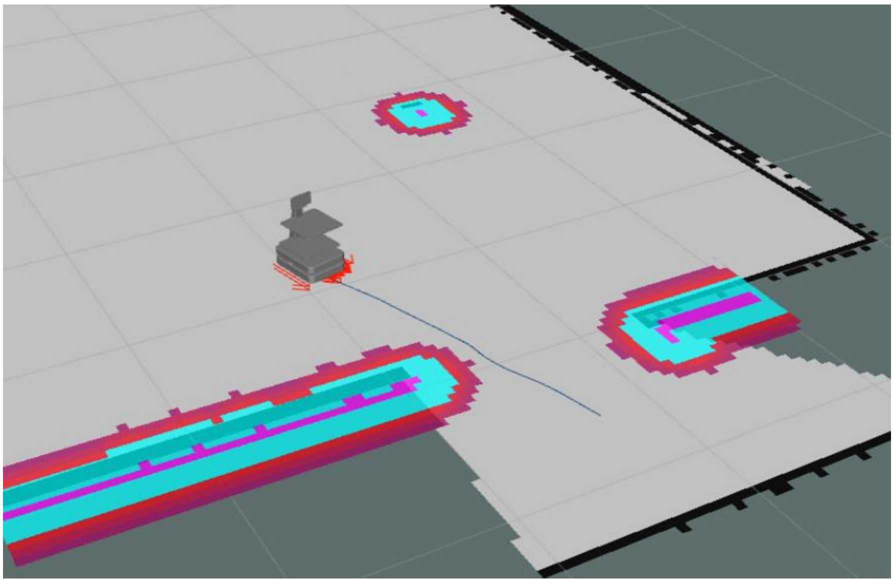


Fig 7: Robot Operating in obstacle rich environment

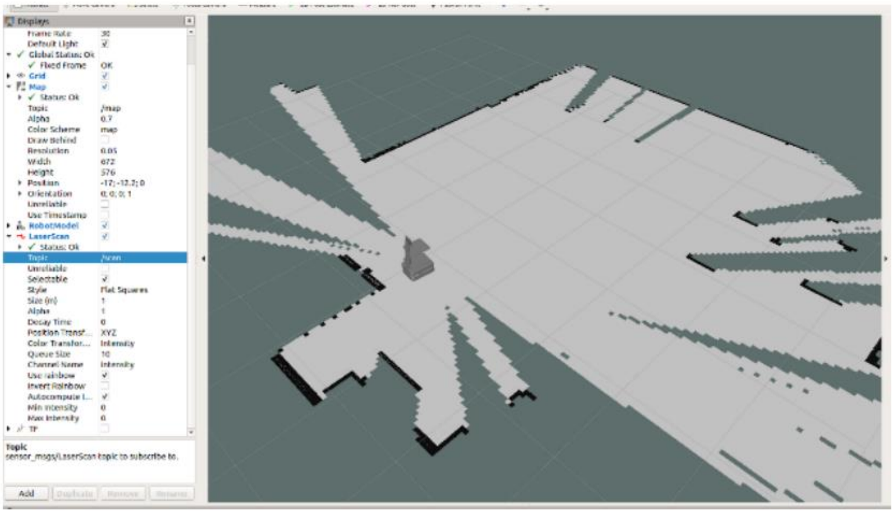


Fig 8: Mapping using LiDAR

Conclusion:

A novel method was used for solving the problem of navigation and obstacle avoidance for a ground robot in indoor environment where using GPS is unreliable. Data from various sensors like lidar, IMU, camera, wheel encoders are fused to estimate the pose of the robot accurately and with increased robustness. Results from both simulation and real-world prototype are obtained, validated and showed that robot was successful to navigate in unknown indoor space and avoid obstacles.

9.	**Scope for Future Work**	The following are potential areas for further development in this project: 1. Utilizing reinforcement learning techniques to address the navigation problem and comparing its efficacy with the current approach. 2. Implementing a navigation stack that solely relies on camera data to reduce the need for multiple sensors. 3. Integrating industrial-grade motors to facilitate heavy lifting tasks. 4. Developing communication systems that enable swarm robotics. 5. Testing the system in a real-world warehouse environment. 6. Creating an ecosystem that can support the implementation of this technology in larger warehouses. 7. Implementing docking systems for the AGV. 8. Establishing a reliable system for the lead screw mechanism and conducting thorough testing. These proposed areas of development are expected to enhance the performance of the existing system and make it more efficient in addressing the needs of the industry.