



AI-Driven Autonomous Mobile Robot with Vision-Based SLAM for Intelligent Warehouse Navigation

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Abstract—

The rapid growth of Industry 4.0 technologies has had a significant impact on warehouse operations. Because of this, intelligent, adaptable, and autonomous systems must now be able to work well in places where things are always changing. Autonomous Mobile Robots (AMRs) are now a key way to automate tasks like moving things, keeping track of stock, and running the logistics process. But most traditional AMR systems use static navigation methods and can't change to deal with moving individuals or objects in real time. This rule makes stores less safe and less efficient.

This study presents an AI-driven Autonomous Mobile Robot integrated with vision-based Simultaneous Localization and Mapping (SLAM) for intelligent navigation in warehouses. The proposed system employs both LiDAR and camera-based perception techniques to generate real-time occupancy grid maps and ascertain the robot's precise location in intricate environments. A* is used in a path planning algorithm to find the best routes for navigation. A new risk assessment module that uses artificial intelligence checks the environment all the time and changes how the robot acts when it needs to.

The system adopts a distributed framework that is based on ROS2, enabling scalability, modularity, and quick component-to-component interactions. With the combination of sensory fusion, intelligent decision making, and behavior control, the robot is able to demonstrate its capabilities to adapt and adjust according to the changing environment while remaining safe.

The experiment is performed in the warehouse-like simulation environment with both dynamic and static obstacles. It is demonstrated that significant improvements have been made in terms of navigation efficiency and safety without any collision at all.



The proposed method contributes to the development of intelligent robots used in the automation of warehouses where AI technology is combined with SLAM for proper navigation and decision making. The current research presents an ideal approach that can be applied in modern logistics activities.

Keywords— Autonomous Mobile Robot; SLAM; Artificial Intelligence; Warehouse Automation; ROS2; Path Planning; Industry 4.0

I. INTRODUCTION

With the development of automated solutions, modern logistic and warehousing processes experienced significant transformation. Meeting the requirements of efficiency, accuracy, and scalability, industrial automation became one of the key elements for various manufacturing companies. Warehouses play an essential part in logistics since their purpose is to make sure materials are moved effectively, and orders are fulfilled promptly. Autonomous Mobile Robots (AMRs) can be used to achieve those goals.

Differing from Automated Guided Vehicles (AGVs), which require infrastructure and pre-set routes, AMRs possess a high level of flexibility because of their ability to move around environments independently. Such property makes AMRs very applicable for warehouses, as they need to change infrastructural elements frequently. However, apart from their advantages, AMRs face several issues related to their functioning.

Firstly, AMRs' problem lies in navigating environments, which often can be unknown or partially known. Simultaneous Localization and Mapping (SLAM) method can be applied to solve the task, allowing a robot to build a map and at the same time calculate its location in the map. Although this method can serve as an essential basis, it does not solve issues like avoiding collisions and identifying risks.

Moreover, another challenge associated with navigating the environment comes from dynamic obstacles such as humans, forklifts, and robots. Those obstacles become a problem for navigation algorithms like A* and Dijkstra.

Using AI in the process can help solve some of the stated issues as it allows a robot to analyze the data on its current environment, estimate the possible risks, and behave accordingly.

Accordingly, the project focuses on the development of a robotic system based on the implementation of SLAM, AI, and behavior algorithms.

Main purposes of the project include:

- To Develop an AMR system equipped with AI
- Incorporation of SLAM technology in the system
- Development of risk estimation methods based on AI

II. LITERATURE REVIEW

There have been significant advancements in technologies related to autonomy recently. Significant achievements have been made in fields of robot navigation, perception, and decision making. Below is described the review of current researches on SLAM, path planning, and AI integration in robotics.

A. SLAM Algorithms

There exists a number of ways of solving the SLAM problem. LiDAR-based algorithms (Gmapping and Hector SLAM) provide very precise results. Such algorithms are widely used in practice because they can operate only under the condition of using laser scanning for building the map. Algorithms based on vision (e.g., ORB-SLAM) use the information provided by a camera and rely on images to identify how far the robot went. Despite being cheap, vision-based solutions can be affected by changes in lighting conditions. The combination of those techniques is suggested as the means of enhancing performance.

B. Path Planning Algorithms

Algorithms of this type are important for navigation purposes. Classic methods like A* and Dijkstra's algorithms guarantee both optimality and completeness. However, they can be applied only to static environments. The dynamic versions of those



include Dynamic A* and D* Lite which are able to recompute the optimal solution instantly due to changes in environment.

C. AI Integration in Robots

Nowadays, there exists a trend to use AI technology to improve the navigation system. For example, machine learning can be helpful in identifying objects, tracking people, and forecasting future actions. Convolutional neural networks are widely used for that purpose because they improve the precision of recognition. At the same time, many algorithms solve particular problems without integrating them into navigation solutions.

D. Research Gap

Significant improvements in those fields were reached recently. However, the development of the unified solution combining all the three aspects still needs to be improved. There is a critical necessity of implementing SLAM algorithms along with risk assessment and behavior-based control. That is what our project attempts to do.

III. METHODOLOGY

The system under consideration is structured around a defined sequence of processes, encompassing perception, mapping, planning, decision-making, and control. Its architecture adopts a modular framework implemented with ROS2, where individual components are responsible for distinct functions, facilitating scalability and adaptability.

Sensing is performed through LiDAR and camera inputs, with sensor fusion techniques applied to integrate data from both sources, thereby enhancing the accuracy and reliability of the environmental information.

The sensor data is processed by SLAM algorithms to generate occupancy grid maps and estimate the robot's position, with continuous updating as new data become available.

Route planning employs the A* algorithm, which evaluates both cost and heuristic criteria to determine a near-optimal path between the start and goal locations. To address safety considerations, an AI-based model evaluates potential risks by analyzing factors such as obstacle proximity, human presence,

and object motion, categorizing risks into low, medium, or high levels.

The robot's behavior is modulated in response to these risk categories: it proceeds under low-risk conditions, reduces speed when risk is moderate, and halts if risk is deemed high. Additionally, the system maintains environmental monitoring and dynamically recalculates routes upon the detection of new obstacles.

IV. RESULTS AND DISCUSSION

The system under investigation was assessed within a simulated warehouse environment developed using ROS2 and Gazebo, designed to replicate operational scenarios involving both static and dynamic obstacles. The simulation environment included stationary components such as shelves, racks, and storage units, in addition to dynamic agents modeling human workers and moving objects, thereby creating a context conducive to realistic testing conditions. Evaluation metrics comprised path length, navigation time, operational efficiency, and collision occurrences. The robot navigated a trajectory of approximately 20 meters and completed its task within 45 seconds, indicating that the applied A* path planning algorithm produced routes that approached optimality within an acceptable duration. Efficiency values reached approximately 85%, reflecting a balance between route optimization and responsiveness to environmental changes. It is noteworthy that slight deviations from the shortest path were observed, attributable to real-time obstacle avoidance and dynamic rerouting—processes essential to maintaining safety in complex environments.

Performance improvements were observed following the integration of an AI-based risk assessment module, which continuously analyzed environmental variables such as obstacle proximity, human presence, and movement patterns. This assessment enabled classification of risk into low, medium, and high categories, facilitating dynamic adjustments in robotic behavior. Specifically, the robot maintained standard speed under low-risk conditions, reduced velocity at moderate risk levels to enhance safety margins, and ceased movement entirely when risk was assessed as high to prevent collisions. This



adaptive control strategy corresponded with a collision rate of zero during evaluation, highlighting its effectiveness in preserving operational safety. Furthermore, the system demonstrated substantial adaptability in managing dynamic obstacles by detecting changes in the environment and recalculating navigation paths in real time without significant delays.

Table I: Performance Metrics

Metric	Value
Path Length	20 m
Navigation Time	45s
Efficiency	85%
Collision Rate	0%

Incomparison with traditional navigation frameworks that rely solely on static path planning, the proposed system showed enhanced responsiveness, improved safety, and increased flexibility within dynamic settings. These results emphasize the benefits of integrating AI-driven decision-making with simultaneous localization and mapping (SLAM) techniques, enabling more nuanced and efficient robotic operation in warehouse environments. Overall, the findings suggest that the developed system constitutes a reliable and scalable approach to intelligent warehouse automation, with potential to improve both efficiency and safety in modern logistics operations.

V. CONCLUSION

This study introduces an autonomous mobile robot system based on artificial intelligence, combining simultaneous localization and mapping with path planning and decision-making processes informed by risk assessment. The approach aims to enhance navigation efficiency while considering safety factors in dynamic environments. Future research will focus on incorporating deep learning methods, exploring coordination strategies for multiple robots, and evaluating system performance under practical conditions.

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