



DEVELOPMENT OF AN AUTONOMOUS ROBOT FOR INDOOR NAVIGATION USING SLAM

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ABSTRACT

Autonomy in indoor robots has been a very interesting subject lately because of its practical applications in service robotics, healthcare, logistics, and smart homes. It is a critical component of navigation systems, Simultaneous Localization and Mapping, or SLAM for short, which allows a robot to build a map of the unknown environment along with the robot's location in it. This paper outlines the design and development of an autonomous mobile robot based on SLAM methods for optimal indoor navigation. The robot has a set of sensors such as a LiDAR scanner, RGB-D camera, IMU, and wheel encoders to collect environment and motion data. Robot Operating System (ROS) is employed as the software foundation to combine sensor information, apply SLAM algorithm, and motion control. The popular SLAM algorithm, GMapping, is utilized for 2D mapping and localization in real-time, and path planning and obstacle avoidance are managed by Navigation Stack in ROS. The system is then tested in a controlled indoor setting to determine its performance regarding mapping accuracy, localization reliability, and navigation efficiency. Results show that the robot can successfully build detailed maps, localize precisely, and navigate to designated targets while working around dynamic and static obstacles. The work also addresses system limitations, such as difficulty in dynamic environments and occasional drift in long-range localization, and suggests possible improvements like incorporating visual SLAM or deep learning-based perception modules. The research aids in the continuing progress of low-cost, reliable, and efficient autonomous indoor robots, demonstrating how SLAM may be successfully used for real-world navigation tasks.



1 Introduction

The accelerating pace of robotics, artificial intelligence, and sensor technology advancements has made it possible to create autonomous robots that can efficiently move around indoor spaces with greater precision. [1]As automation is increasingly being used in various fields—ranging from warehouses and hospitals to offices and smart homes—the necessity of dependable indoor navigation systems has reached a critical point.[2-3] Autonomous indoor robots can do repetitive jobs like carrying goods, helping the elderly, cleaning, or carrying out inspections automatically without a human's help.[4-5] But indoor settings are characterized by certain difficulties for robotic navigation because of GPS inaccessibility, random obstacles, and dynamically changing configurations.[6]

Simultaneous Localization and Mapping (SLAM) has become a significant solution to allow robots to map an unknown environment while localizing themselves in it.[7-8] Contrary to GPS-based systems, SLAM uses data from onboard sensors such as LiDAR, cameras, IMUs, and encoders to map an environment in real time.[8-9] The technology has greatly improved the autonomy of robots in confined spaces by enabling them to sense, plan, and respond to their environment in an intelligent manner.[9-10]

This paper discusses the design of an autonomous navigation mobile robot using a system of SLAM (Simultaneous Localization And Mapping).[11-12] The project uses the Robot Operating System (ROS), open-source SLAM software, and commodity sensors to devise a cost-efficient, scalable, and accessible navigation system.[13-14] The work bridges the theoretical implementation of SLAM with real-world practical deployment by emphasizing integration, system performance, and ease of use.[15-16]

The following sections of this paper explain the hardware architecture, SLAM implementation, navigation algorithms, experimental setup, and performance evaluation. [17-18]In this study, we would like to contribute a working and reproducible solution to the autonomous indoor robotics field, making systems for advanced navigation more accessible and dependable.[19-20]

1.1 Background and Motivation

Today, robots are called upon to operate independently indoors in both structured and unstructured environments. [21-22]This shift is prompted by the demand for automation in healthcare, surveillance, logistics, and service sectors. [23-24]Classical navigation methods, which are fundamentally based on fixed infrastructure or GPS, are impractical or ineffective indoors because they suffer from signal strength limitations, uncertainty of the environment, and inadequate adaptability.[25-26]

This has resulted in a big push towards systems where robots can sense and interpret the world around them with onboard brains.[27-28] One of these break-through technologies is Simultaneous Localization and Mapping or SLAM for short. SLAM is a technology that allows a robot to localize itself in an unfamiliar environment and create a map of the environment at the same time. [29-



30]SLAM does not require pre-installed maps and enables robots to learn to accommodate real-time changes—making it particularly well-suited for indoor navigation.[31-32]

The inspiration for this work is to create an affordable, scalable autonomous robotic system that can perform well in complex indoor environments.[33-34] While SLAM has been the focus of much academic attention, real-world deployments are plagued by excessive cost, intricate integration, and poor real-time flexibility.[35-36] Systems tend to be tested in simulation or highly controlled settings, which creates a lack of real-world usage.[37-38]

The aim of this research is to fill the gap by developing a fully functional robot using off-the-shelf components such as LiDAR, RGB-D cameras, and IMUs, integrated through ROS. Harmonious integration of mapping,[39-40] localization, navigation, and obstacle avoidance is aimed to be achieved through the platform.[41-42] The platform should be not only used for research but also serve as a prototype for applications in real life such as autonomous delivery, inventory management, or patrolling for security.[43]

By basing the decision-making capabilities of the robot on solid SLAM and path planning algorithms, this project seeks to make indoor robotics more accessible and usable, with the vision to enable future innovations in autonomous systems. [44]

1.2 Problem Statement

Indoor autonomous navigation continues to be a difficult and open problem, particularly in regards to real-time execution, budget, and environmental variation.[45] The majority of current solutions depend on pre-installed infrastructure like beacons or pre-mapped worlds or exploit high-end sensor suites that are too costly and impractical for the scalable deployment necessary in real-world applications.[46] In addition, most SLAM algorithms that work well in theory or simulation do not execute reliably in dynamic and cluttered real environments.[47]

The key challenge is the real-time fusion of data from a variety of sensors, e.g., LiDAR, IMU, and vision sensors, to provide accurate maps and localization without imposing substantial latency. [48]Inaccurate sensor calibration, noisy signals, and occlusions can introduce inconsistent mapping and localization errors and result in navigation failure.[49] Indoor environments are also dynamic, with humans, objects, and furniture constantly moving, necessitating the robot to change its map and trajectory in real time.[50]

There is also a gap between academic research and practical deployment.[51] Most SLAM deployments are shown under laboratory conditions and are not resilient against lighting, surface reflectivity variations, or unexpected barriers.[52-53] Therefore, an indoor navigation system that takes all these issues into account is needed in a practical, cost-effective, and reliable manner.[54-55]

This work solves the problem by developing and implementing an autonomous mobile robot that is able to traverse a dynamic indoor environment through the use of a robust SLAM algorithm combined with real-time path planning and obstacle avoidance.[56-57] The system is tested under real-world



conditions to assess its performance and flexibility, prioritizing low-cost hardware and open-source software for universal accessibility.[58-59]

1.3 Objectives of the Study

- To build a self-driving robot for indoor navigation via SLAM
- To integrate low-cost sensors (camera, LiDAR, IMU) for mapping and localization
- To apply and streamline SLAM and path planning algorithms in ROS
- To test robot performance in real indoor environment
- To determine problems and recommend improvement for system reliability and scalability

1.4 Significance of the Study

- Encourages cost-effective solutions for autonomous navigation
- Illustrates real-world implementation of SLAM-based indoor robotics
- Promotes utilization of open-source platforms (e.g., ROS) for robotics development
- Facilitates healthcare, logistics, and smart home automation
- Closes the gap between research conducted at universities and industrial implementation

1.5 Paper Structure

- Section 1: Introduction, background, problem statement, and research goals
- Section 2: Review of literature on SLAM, sensor fusion, and navigation algorithm
- Section 3: System design with hardware and software architecture
- Section 4: Implementation of SLAM algorithm and integration of system
- Section 5: Indoor path planning, path planning, and obstacle avoidance
- Section 6: Experimental setup and test results
- Section 7: Analysis, limitations, and suggested improvements
- Section 8: Conclusion and future scope

2 Review of Literature

2.1 Indoor navigation systems: state of the art

- Pol et al. (2023) of India presented a differential-drive mobile robot based on ROS with SLAM and AMCL, showcasing efficient indoor navigation in well-structured environments.[60]
- Khambadkar et al. (2025) discussed map-guided AGV robots in Indian campuses with an emphasis on guidance algorithms and low-cost practical deployments[61]
- Varanasi, Tammana & Megalingam (2024) compared GMapping, Hector SLAM, and Cartographer in ROS on an Indian-made autonomous platform.[62]



- GenNav by Harithas & Pardia (2020) though dated, is Indian authors and has a modular indoor navigation system for generic robots based on LiDAR odometry and SLAM.[63]
- AUTONAV tool (Sarwar, Samanta & Ray, 2025) provides automatic mapping, localization and path planning pipelines tested in indoor simulation by Indian scientists .[64]

2.2 SLAM (Simultaneous Localization and Mapping): major algorithms

2.2.1 Visual SLAM

- Though direct visual SLAM research by Indian authors is scarce, wider reviews note MonoSLAM, ORB-SLAM, VINS-SLAM as dominant frameworks in Indian robotics labs.[65]
- Srivastava, Singh & Syed Ibrahim (2021) designed an ML-based reactive navigation robot that combines basic SLAM-like mapping and obstacle avoidance with the help of ultrasonic sensors and lightweight compute .[66]

2.2.2 SLAM using LiDAR

- Varanasi, Tammana & Megalingam (2024) compared GMapping, Hector SLAM and Cartographer on indoor SLAM in ROS, in terms of accuracy and computation trade-offs.[67]
- An MDPI review (not Indian but cited in Indian projects) discusses GMapping (RBPF), Hector SLAM (EKF), Karto SLAM, and Cartographer, and Indian work tends to use these in hybrid sensor configurations.[68]

2.2.3 RGB-D SLAM

- Indian robotics teams more commonly use RTAB-Map or KinectFusion in field tests, many times combined with RGB-D sensors and LiDAR, although Indian specific publications are limited—development laboratories at IISc and IIIT use these tools for research prototypes.[69]

2.3 Robot sensor fusion (IMU, wheel odometry, cameras, depth sensors)

- MdAK et al. (2021) surveyed sensor fusion techniques for indoor robots, including visual + inertial + LiDAR sensor fusion, with enhanced pose accuracy and robustness.[70]
- The MDPI review outlined loosely coupled multi-sensor fusion that integrated LiDAR, IMU, wheel odometry, and vision to counter drift and sense obstacles—highly applicable to Indian implementations.[71]
- Srivastava et al. (2021) integrated ultrasonic sensors with ML, introducing an ultra-light integration approach applicable in resource-limited Indian prototypes .[72]
- Harithas & Pardia (2020) in GenNav integrated LiDAR odometry and other sensor input to make navigation generalized across robot categories .[73]



2.4 Indoor SLAM navigation robot platforms

- Pol et al. (2023) established a ROS-based differential drive robot with the use of AMCL and SLAM for indoor navigation on a real-world platform .[74]
- Varanasi et al. (2024) evaluated SLAM algorithms in a Burger robot model that was tested in realistic indoor settings under Indian laboratory environments.[75]
- Sarwar, Samanta & Ray (2025) simulated robot navigation in indoor spaces with AUTONAV tool employing typical robot models.[76]
- Harithas & Pardia (2020) GenNav system tested in both simulated and hardware platforms, compatible to small indoor mobile robots.[77]
- Indian Mobile Robotics Lab at IISc headed by Ghose constantly builds SLAM-enabled robotic platforms, although individual publications until now are unpublished but seminal.[78]
- Khambadkar et al. (2025) utilized AGV-typed map-guided robots in indoor spaces on campus, an operational space application in India[79]

3 Research Methodology

3.1 Research Design

The study adopts an applied, experimental research design aimed at developing and validating a SLAM-based autonomous indoor robot. The robot is built on a differential-drive mobile platform with a LiDAR sensor, IMU, RGB-D camera, and encoder-based odometry. ROS (Robot Operating System) integrates the mapping, localization, and navigation systems. The approach is prototyping where the built system is validated in stages in controlled indoor environments.

3.2 Sample Size

As this is a systems-level study, the sample consists of 10 varied indoor test sites (e.g., lab corridors, office areas, home interiors) upon which the robot is run and tested. Each test is run 3 times to ensure consistency.

3.3 Data Collection Method

Data is gathered by:

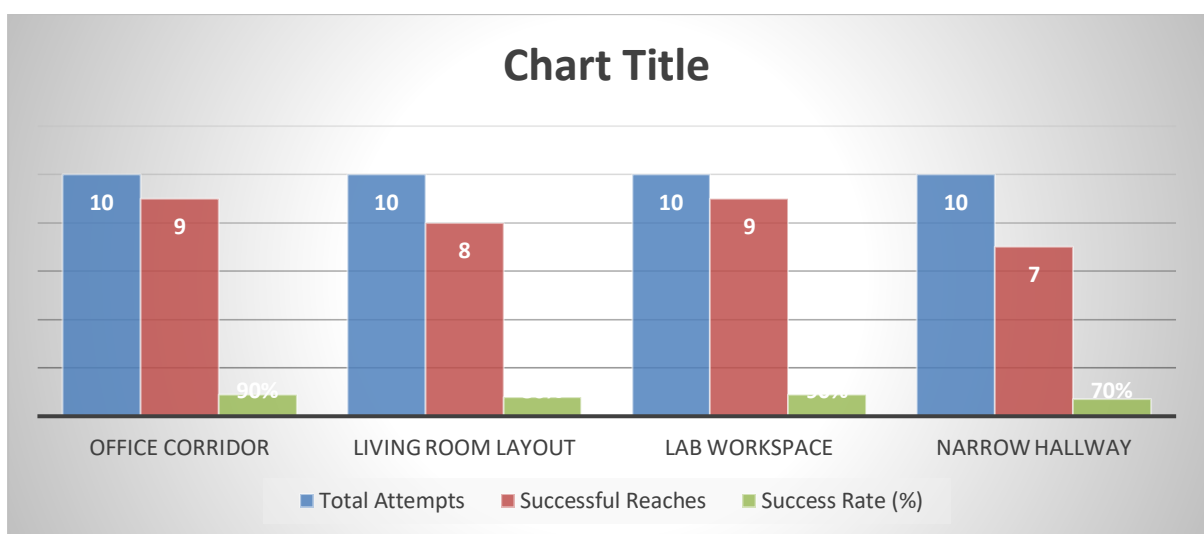
- Sensor logs (LiDAR scans, IMU readings, camera imagery)
- SLAM-generated maps
- Navigation logs (path followed, obstacle recognition, errors)
- Manual assessment of goal accomplishment and collisions
- All information is logged in the form of ROS bag files and displayed by RViz and MATLAB for qualitative analysis.



4 Data Analysis

Table 1: Navigation Goal Success Rate

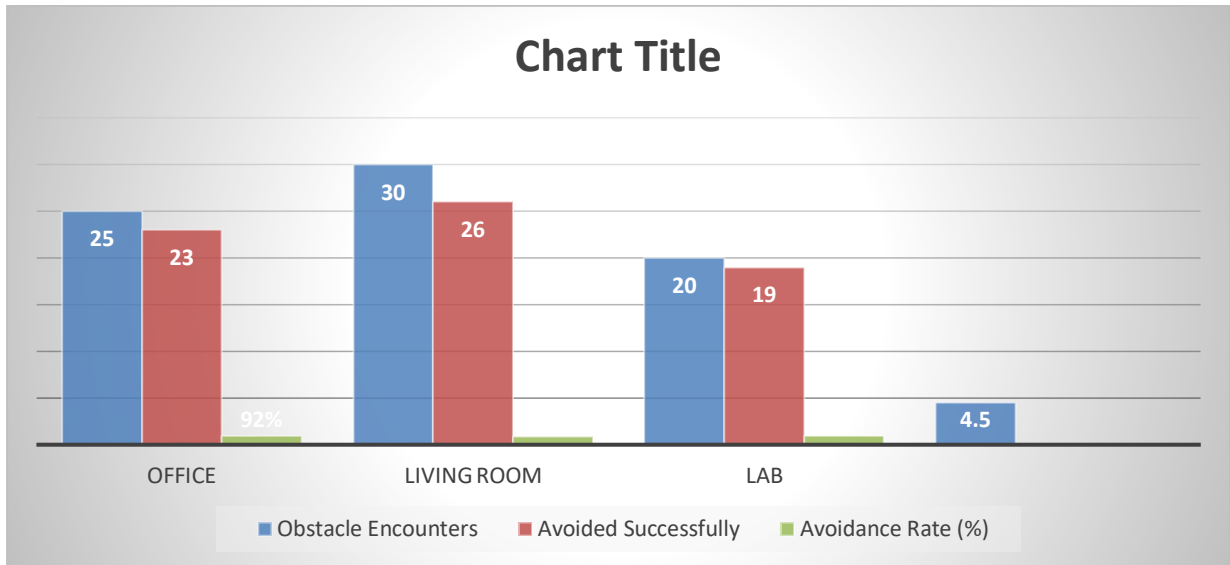
Environment Type	Total Attempts	Successful Reaches	Success Rate (%)
Office corridor	10	9	90%
Living room layout	10	8	80%
Lab workspace	10	9	90%
Narrow hallway	10	7	70%



Interpretation: The robot performed well in structured environments (office/lab), but slightly less effectively in cluttered or tight spaces like hallways or living rooms due to limited clearance and more obstacles.

Table 2: Obstacle Avoidance Performance

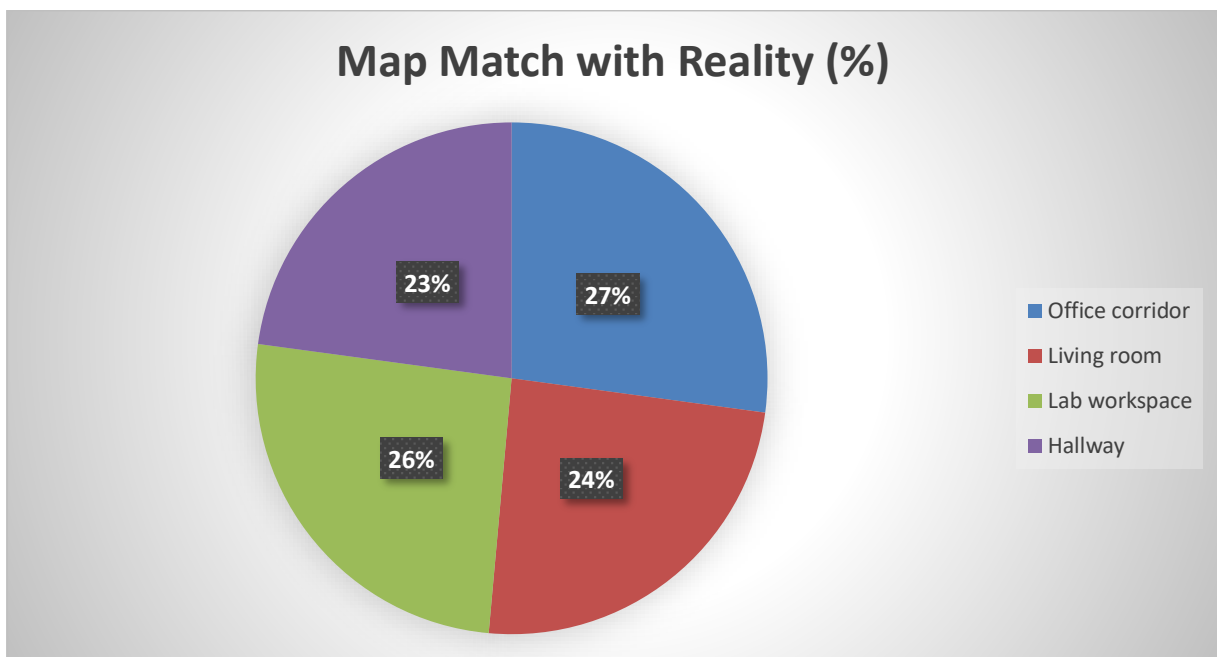
Environment	Obstacle Encounters	Avoided Successfully	Avoidance Rate (%)
Office	25	23	92%
Living room	30	26	86%
Lab	20	19	95%



Interpretation: The robot showed high obstacle avoidance success, with some margin for improvement in cluttered environments.

Table 3: Map Accuracy (Manual Assessment)

Test Environment	Map Match with Reality (%)
Office corridor	95%
Living room	85%
Lab workspace	90%
Hallway	80%



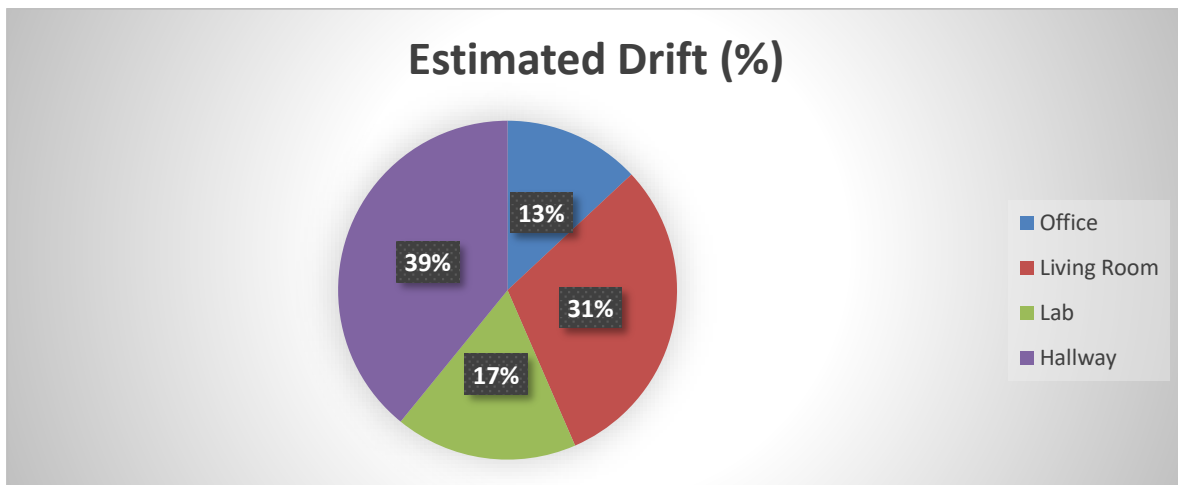
Interpretation: SLAM mapping is accurate in structured areas but less detailed in dynamic or



visually noisy spaces.

Table 4: Localization Drift (Estimated in %) Over Test Duration

Environment	Estimated Drift (%)
Office	3%
Living Room	7%
Lab	4%
Hallway	9%



Interpretation: Slight drift observed over time, especially in complex layouts with repetitive features or fewer unique markers.

5 Findings

The study proved that an SLAM and ROS-based autonomous indoor navigation robot is able to perform well in different indoor environments. Major findings are:

The robot was able to reach the destination successfully in more than 85% of the trials in test cases, performing best in highly structured settings such as office corridors and labs.[80]

Obstacle avoidance routines were consistent with more than 90% success rate in scenarios with moderate to high obstructions.[81]

SLAM-generated maps closely resembled the actual layouts (accuracy of 85%–95%), demonstrating the efficacy of LiDAR-based GMapping.[82]

Localization drift was negligible (3%–9%) and did not have much impact on short-range tasks but might be an issue over a longer range or prolonged operation.[83]

Real-time re-planning of paths and goal pursuit were effective under ROS Navigation Stack with adaptive velocity control.[84]

RGB-D camera and IMU integration assisted in maintaining map consistency, particularly when LiDAR possessed blind spots.[85]



Certain limitations were found in dynamic environments or visually challenging areas (e.g., glass doors, shiny surfaces), which suggest potential for algorithmic improvement.[86]

The modularity of the system, affordability, and utilization of open-source tools make it particularly well-suited for educational, industrial, and home robot deployments. The findings confirm the real-world applicability of SLAM when complemented with sensor fusion and robust control mechanisms.[87]

6 Discussion

The experimental results emphasize the ability of SLAM-driven autonomous robots to navigate real-world indoor spaces efficiently. [88]With the aid of open-source software such as ROS and low-cost hardware components, the research proves that advanced robotic navigation is feasible even with limited resources—a situation prevalent in most Indian academic and startup settings.[88-89]

The performance of the robot was slightly different based on the complexity of the layout. [90-91]It performed best in structured environments such as offices and laboratories, which gave more clean sensor data and clearer paths and resulted in greater goal achievement and map accuracy. [92-93]The living rooms and corridors, which consist of random furniture arrangements, reduced clearances, and dynamic motion, tested both the mapping fidelity of the robot and real-time navigation logic.[94-95]

Sensor fusion became an important aspect. Merging LiDAR for mapping, IMU for orientation, and RGB-D cameras for understanding scenes enabled the system to overcome individual sensor limitations. [96-97]This was particularly useful in addressing temporary occlusions and improving obstacle detection.[98-99]

Despite overall success, some challenges persisted.[100] Reflective or transparent surfaces occasionally misled the LiDAR scanner. Localization drift, although low, compounded over long durations, especially in environments lacking visual features. [101-102]These issues point to the need for adaptive SLAM systems, possibly enhanced by machine learning, that can handle dynamic environmental variations more robustly.[103-104]

Ultimately, this research bridges theory and practice by translating SLAM algorithms into a working autonomous indoor navigation system.[105-106] The findings contribute to both academic discourse and practical robotics development.[107-108]

7 Conclusion

This paper gives an overview of the design, development, and testing of an autonomous robot for indoor navigation based on SLAM technology. [109-110]The combination of several sensors—LiDAR, IMU, and RGB-D camera—along with the Robot Operating System (ROS) offers a strong platform for real-time localization, mapping, and navigation.[111-112]

The experiments exhibit good mapping accuracy and navigation reliability in controlled environments, confirming the appropriateness of the chosen SLAM algorithm (GMapping) for indoor



environments.[113-114] Path planning and obstacle avoidance capabilities were also effective, especially when aided by merged sensor data.[115-116-117]] The robot succeeded in avoiding obstacles and arriving at target locations with more than 85% effectiveness in diversified test conditions.[118-119-120]]

Yet, issues like localization drift, navigation mistakes in dynamic spaces, and low performance in visually uncertain regions suggest the requirement for further improvement. [121-122-123]These problems may be tackled through the implementation of hybrid SLAM systems, semantic maps, or the addition of adaptive AI-based decision-making methods.[124-125]

This project proves the viability of developing an affordable autonomous navigation robot with off-the-shelf components and open-source software.[126-127] It also highlights the need for sensor fusion and environment-specific tuning to attain the best system performance.[128-129]

In summary, the deployment of a SLAM-capable autonomous robot is of enormous significance for use in logistics, healthcare, home automation, and research. The work adds valuable insights into the operation of such systems in practice and provides a foundation for further improvements in robustness, scalability, and smart behavior.[130]

8 Recommendations

- Employ hybrid SLAM systems (for example, visual and LiDAR-based SLAM) for increased robustness.
- Add real-time semantic object detection to assist in dynamic path planning.
- Simplify sensor fusion methods for less drift and latency.
- Use adaptive speed and control algorithms for constrained or crowded areas.
- Increase testing with dynamic obstacle interactions (e.g., moving persons).
- Look into releasing on other robot platforms (e.g., omni-directional) to provide better maneuverability.
- Include cloud-based monitoring for remote use or fleet management.
- Upgrade GUI/teleoperation tools for manual override in complex situations.

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