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Development of an Autonomous Navigation System for Indoor Mobile Robots

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Introduction

The development of an autonomous navigation system for indoor mobile robots has become a pivotal focus in robotics, aiming to enable machines to move independently and intelligently within confined, structured environments like homes, hospitals, warehouses and office spaces. Unlike outdoor systems that rely heavily on GPS, indoor navigation faces specific challenges such as the absence of global positioning signals, cluttered and dynamic surroundings and the need for high-precision movement in narrow and obstacle-rich areas. To overcome these challenges, robots must be equipped with an integrated system of perception, mapping, localization, path planning and motion control. This system allows them not only to perceive their environment and determine their position within it but also to make real-time decisions that guide safe and efficient movement to target destinations without human input. As industries increasingly deploy robots for automation, service and assistance, a reliable indoor navigation system becomes essential for achieving true autonomy and operational efficiency [1].

Description

An autonomous indoor navigation system typically begins with perception, the robot's ability to sense and understand its surroundings. This is achieved using a range of sensors including LiDAR, depth cameras, ultrasonic sensors and IMUs, which collect data about the environment. The collected data are processed through Simultaneous Localization And Mapping (SLAM) algorithms such as GMapping, Cartographer, or ORB-SLAM that enable the robot to create a real-time map while localizing itself within it. Visual SLAM, in particular, is advantageous in GPS-denied indoor environments, utilizing image data to extract features and track movement. The map constructed allows the robot to differentiate between static and dynamic objects, which is essential for navigating safely and adapting to changes like moving people or furniture.

Once a robot is localized within its environment, the path planning module computes an optimal trajectory to the target location. Global path planning algorithms such as A, Dijkstra, or RRT are used to identify a safe and efficient route by evaluating a grid or graph representation of the environment. To account for real-time obstacles and environmental changes, local planning algorithms like Dynamic Window Approach (DWA) or Timed Elastic Band (TEB) are used to continuously adjust the path. This ensures that the robot can respond dynamically to new obstacles or humans moving through its path. The integration of cost maps and risk zones also helps the robot to choose paths that prioritize safety and efficiency, especially in densely populated indoor areas.

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Executing the planned path requires a precise motion control system that translates navigation commands into mechanical actions. Depending on the robot's design such as differential drive or omnidirectional wheels control algorithms like PID controllers are used to regulate motor output and maintain stable, smooth movement. Software frameworks like the Robot Operating System (ROS) provide modular platforms for integrating all subsystems including sensor drivers, mapping, planning and control. Additionally, simulation tools like Gazebo are used for testing navigation logic in virtual environments before physical deployment. The combination of robust software, real-time sensor data and intelligent control mechanisms enables the robot to navigate autonomously, handle complex scenarios and operate continuously with minimal human intervention [2].

Conclusion

In conclusion, the successful development of an autonomous navigation system for indoor mobile robots hinges on the seamless integration of perception, mapping, localization, planning and control components. These systems must not only function accurately within confined, dynamic environments but also adapt in real-time to unexpected changes and obstacles. As the demand for indoor robotics grows across industries from healthcare and logistics to smart homes and service sectors the need for robust, flexible and intelligent navigation systems becomes ever more critical. With continued advancements in sensor technology, AI-driven algorithms and open-source platforms like ROS, the future of autonomous indoor navigation holds immense promise for reshaping the way robots interact with and move through human-centered spaces.

Acknowledgment

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Conflict of Interest

None.

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