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REVIEW ON SLAM IMPLEMENTATION FOR AUTONOMOUS TRAVERSAL OF LOGISTIC ROBOTS

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Abstract : This research paper is a review on the application of Simultaneous Localization and Mapping (SLAM) techniques in the development of an autonomous logistics robot. The objective is to investigate how SLAM can enable robots to navigate and map dynamic environments while efficiently performing logistics tasks. The paper reviews the fundamental principles of SLAM, discusses its relevance in autonomous navigation, and highlights the specific challenges and considerations when applying SLAM to logistics applications. Furthermore, the paper presents case studies and real-world examples of existing autonomous logistics robots that leverage SLAM, providing insights into their performance, capabilities, and potential future developments. The findings of this research emphasize the importance of SLAM as a key component in building efficient and adaptable autonomous logistics robots.

Keywords - Autonomous traversal , ROS, Visual SLAM, Visual Odometry

I. INTRODUCTION

[4]This article guides a stepwise walkthrough of:

- Overview of autonomous logistics robots
- Literature review and Research objectives
- Explanation of SLAM principles and algorithms
- Importance of SLAM in autonomous navigation
- Types of SLAM approaches (feature-based, occupancy grid, etc.)
- Role of SLAM in mapping and localization
- Integration of SLAM with perception systems
- Multi-robot coordination using SLAM
- Challenges and Future Directions
- Conclusions

II. LITERATURE REVIEW

1) *Rajesh Kannan Megalingam, Chinta Ravi Teja, Sarath Sreekanth, Akhil Raj [1] ROS based Autonomous Indoor Navigation Simulation Using SLAM Algorithm.*

This paper is based on the Robot Operating System (ROS) framework. It checks the flexibility of a SLAM based mobile robot and its perception of an indoors environment.

2) Trang Nguyen Hoang Thuy [2] Situations In Construction Of 3d Mapping For Slam

This paper is mainly to help us better understand SLAM. The SLAM approach has become one of the most advanced engineering methods used for mobile robots to build maps in unknown or inaccessible spaces. Update maps before a certain area while tracking current location and distance.

3) Jaafar Ahmed Abdulsaheb [3] Real-Time SLAM Mobile Robot and Navigation Based on Cloud-Based Implementation

This study investigates the feasibility of a mobile robot navigating and discovering its location in unknown environments, followed by the creation of maps of these navigated environments for future use.

4) *Cyril Roussillon[4] A Generic and Real-Time Visual SLAM Implementation*

This article presents a new open-source C++ implementation to solve the SLAM problem, which is focused on genericity, versatility and high execution speed. It is based on an original object oriented architecture, that allows the combination of numerous sensors and landmark types, and the integration of various approaches proposed in the literature. The system capacities are illustrated by the presentation of an inertial/vision SLAM approach, for which several improvements over existing methods have been introduced, and that copes with very high dynamic motions. Results with a hand-held camera are presented.

III. RESEARCH, STUDIES AND FINDINGS

Now it is the time to articulate the research work with ideas gathered in above steps by adopting any of below suitable approaches:

A. Bits and Pieces together

A logistics robot is a robotic system designed to assist in various tasks related to logistics and supply chain management. These robots are typically used in warehouses, distribution centers, and manufacturing facilities to automate repetitive or physically demanding tasks, streamline operations, and increase efficiency.

Here are some common features and functionalities of logistics robots:

1. Material Handling
2. Autonomous Navigation
3. Inventory Management
4. Collaborative Operation

[1]Visual SLAM, or Simultaneous Localization and Mapping, is a technique used in computer vision and robotics to simultaneously construct a map of an unknown environment and determine the location of a camera or robot within that environment. It combines the tasks of mapping and localization into a single process.

B. Use of Simulation software

To implement SLAM, several software components are typically required. Here are some essential software tools[3] and libraries commonly used for SLAM implementation:

- **Robot Operating System (ROS)**: ROS is a flexible framework widely used in robotics for building and controlling robotic systems. It provides a set of libraries, tools, and conventions that facilitate communication between different components of a robotic system. Many SLAM algorithms and packages are available in the ROS ecosystem
- **Sensor-Specific Software:** Depending on the sensors used for SLAM, specific software tools or drivers may be required. For example, if you are using a depth camera like the Microsoft Kinect, you might need libraries such as OpenCV for image processing and the libfreenect library to interface with the Kinect sensor.
- **Development Tools and IDEs:** Software development tools and integrated development environments (IDEs) can be used for coding, debugging, and analyzing SLAM algorithms. Popular choices include C++ development tools (e.g., GCC, CMake), Python with scientific computing libraries (e.g., NumPy, SciPy), and IDEs like Visual Studio Code, CLion, or Eclipse.
- **Simulation Environments**: Simulation environments allow for testing and evaluating SLAM algorithms in virtual environments before deploying them on real robots. Tools such as Gazebo, V-REP, or Unity can provide simulation capabilities for SLAM experimentation.

IV. APPLICATION OF SLAM IN LOGISTICS ROBOT

Highlights of the Application of SLAM in [6] Logistics Robotics:

- **Enhanced Navigation:** SLAM enables autonomous robots in logistics to navigate complex and dynamic environments by simultaneously localizing themselves and mapping their surroundings in real-time.
- **Efficient Warehouse Automation**: SLAM techniques can be applied in warehouse automation to create accurate maps of the facility, enabling robots to autonomously navigate aisles, locate inventory, and optimize order fulfillment processes.
- **Real-time Inventory Management**: By utilizing SLAM, logistics robots can maintain accurate and up-to-date maps of inventory locations, facilitating efficient inventory management, retrieval, and restocking operations.
- **Optimal Path Planning:** SLAM algorithms assist in generating optimal paths for robots to navigate within warehouses, minimizing travel distances and maximizing efficiency in order picking and sorting processes.
- **Dynamic Environment Adaptability:** SLAM enables logistics robots to adapt to changes in the environment, such as the movement of objects, rearrangement of shelves, or introduction of new obstacles, ensuring reliable and safe navigation.
- **Improved Order Fulfillment**: With SLAM, robots can efficiently navigate to different order locations, accurately pick items, and sort them for packaging and shipment, enhancing the speed and accuracy of order fulfillment processes.
- **Collaboration with Human Operators:** SLAM-based logistics robots can collaborate with human operators in shared workspaces, ensuring safe and efficient interaction by accurately mapping their surroundings and predicting human movement.
- **Potential for Last-mile Delivery**: SLAM can be utilized in autonomous robots for last-mile delivery, enabling them to map and navigate complex urban environments, locate addresses, and deliver packages efficiently.

- **Integration with Machine Learning**: SLAM algorithms can be integrated with machine learning techniques to improve mapping accuracy, object recognition, and prediction capabilities in logistics robotics.
- **Future Advancements:** Ongoing research in SLAM and logistics robotics focuses on addressing challenges like dynamic environments, human-robot collaboration, and exploring new applications beyond warehouses, opening avenues for further advancements and innovation in the field.

These highlights showcase how the application of SLAM in logistics robotics revolutionizes warehouse automation, enhances order fulfillment processes, improves navigation efficiency, and opens up new possibilities for autonomous robots in the logistics industry.

V. METHODOLOGY

[2]SLAM (Simultaneous Localization and Mapping) is a crucial technique used in autonomous navigation systems to enable robots or vehicles to navigate and map their environment in real-time. Here's how SLAM is typically used in autonomous navigation:

- Localization: SLAM helps the autonomous system determine its own position within the environment. It uses sensor data, such as camera images, lidar scans, or depth sensors, to estimate the robot's pose (position and orientation) relative to a given map or the previously observed environment. By continuously updating the robot's position, SLAM allows it to track its location as it moves.
- Mapping: Simultaneously with localization, SLAM constructs a map of the environment. It uses the sensor data mentioned earlier to build a representation of the surroundings, which can be a 2D or 3D map. The map can include features such as walls, obstacles, landmarks, or even semantic information about objects in the environment. SLAM algorithms merge the new sensor measurements with the existing map, updating and expanding it as the robot explores.
- Loop Closure: Loop closure is a vital step in SLAM that helps correct errors and improve map accuracy. When the robot revisits a previously observed location, loop closure algorithms detect and close the loop by recognizing that it has returned to a known area. This allows the system to correct accumulated errors, refine the map, and improve localization accuracy.
- Path Planning and Navigation: Once the robot has a reliable map and accurate localization, it can plan its path and navigate autonomously. The SLAM system can provide the necessary information to a path planning algorithm, which generates a safe and optimal path from the robot's current position to a desired destination. The robot can then use this path to control its motion and avoid obstacles while moving through the environment.

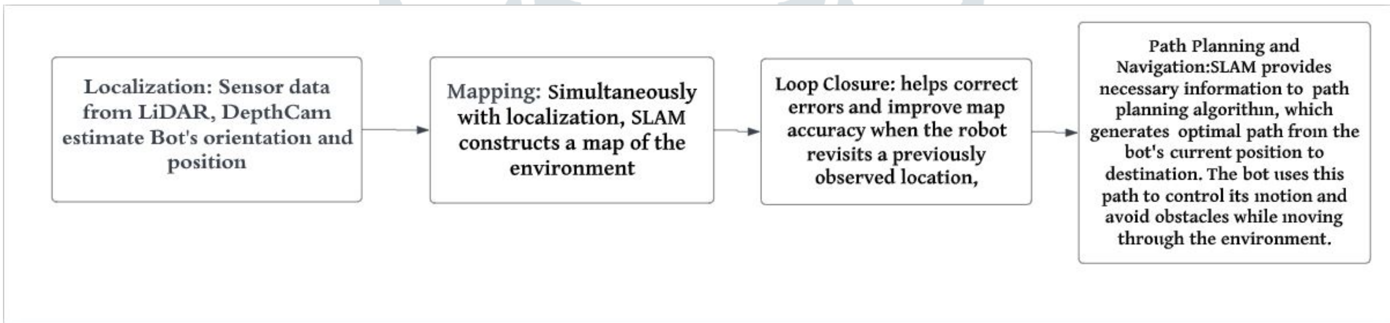

Figure 1: Block Diagram of SLAM Method

VI. OBJECTIVES AND DELIVERABLES

A. To build an inexpensive, sturdy robot body, capable of carrying reasonable weight of goods
B. To configure a superior quality of Image Processing technique in order to map the bot’s environment
C. To study the environment and terrain of traversal of the bot
D. To propose an effective and fast routing algorithm to complete the required tasks
E. To develop an app similar to a delivery system to achieve the said objectives.

[1]SLAM plays a crucial role in enabling autonomous systems to understand and interact with their surroundings. It allows robots or vehicles to navigate in unknown or dynamic environments, build maps on-the-fly, and make informed decisions about path planning and obstacle avoidance. By combining localization, mapping, and loop closure, SLAM provides a foundation for autonomous navigation in various applications, such as self-driving cars, drones, or robots operating in complex environments.

To develop an autonomous logistics robot, capable of functioning in institutional and industrial shop floors alike. The robot will be capable of storing necessary goods in its housing, mapping its surroundings and automatically traversing to the desired location. The bot can also be summoned and controlled through a mobile application.

VII. CONCLUSION

Looking at the immense advancements of Robotics and automation in practically every aspect of modern lives, it is perhaps high time to replace the manual parts with highly accurate autonomous machines. This autonomous traversal bot will be used in industries and academia alike in order to reduce physically strenuous process and automate tasks in order to complete them efficiently and faster. A low cost and highly efficient robotic systems are very much needed in today’s world.

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The paper is made as a consolidation of works and materials of referenced authors thus cited, along with research of ours. All credits of materials go to respective owners.

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