Development of an autonomous navigation system for automatic industrial inspection

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***Abstract*—In this paper, we propose an autonomous navigation system to perform automatic industrial inspection, ensuring the smooth operation of facilities. Thanks to the use of a 3D map, the robot is able to navigate in complex environments that would not be explorable otherwise.**

I. Introduction

Industrial inspections play a central role in maintaining the reliability and efficiency of industrial sites. Traditionally, human operators have been responsible for conducting these inspections, identifying potential irregularities in machinery and infrastructure. However, this approach has shown to be time-consuming and hazardous in dangerous environments.

By using autonomous robotic systems for inspection, these issues can be resolved. Thanks to recent advances, robots are able to autonomously navigate complex environments, gather visual and sensor data, detect anomalies, and transmit the collected information for analysis and decision-making.

II. Related Work

In the field of automatic inspection, there are studies that have explored the use of autonomous robotic systems. HVDC converter stations have been subject to automated daily surveillance tours conducted by a quadrupedal robot [3].

Other works have made contributions to the domains on which automatic robotic inspection is based. For instance, [1] shows how a 3d navigation system has been developed for the DARPA Subterranean Challenge while making use of a higher-level planning framework [5] suitable for both known and unknown environments. Among SLAM techniques, we can mention ART-SLAM [2], a system to perform point cloud-based graph SLAM, and LIO-SAM [4], a framework for lidar inertial odometry.

III. Methodology

To develop and implement the automatic inspection framework we took the following steps.

First, a skid-steering robot (Agilex Scout) was chosen as the robotic platform to utilize. It is equipped with a 64-plane Ouster OS-1 LiDAR featuring an internal 6-DoF IMU, and two Intel Realsense RBG-D cameras. An Intel NUC computer running Ubuntu 22.04 with ROS 2 Humble performs all the computation on-board.

For mapping and localization, in early trials, we used LIO-SAM [4] for ease of integration. As we moved to real industrial sites, which have proved to be more challenging, we opted for an extension of ART-SLAM [2]. While LIO-SAM requires LiDAR and IMU, our approach can work with LiDAR only, or with the addition of IMU and odometry. Regarding the autonomous navigation system, we adopted the work done by the CMU-OSU Team in [1], comprehending a local planner and terrain traversability analysis. The 3D capabilities of this system allow the robot to perform robust autonomous navigation in complex environments.

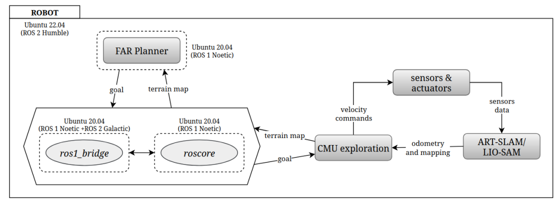

Fig. 1. Current architecture of the system.

On top of that, the FAR planner [5] is used to plan routes by building a global visibility graph along with navigation. It is able to work in unknown environments, generate and save a map, and reuse that map the following time.

IV. Experimental Activity

Initial autonomous navigation tests have been successfully conducted outdoors within the university campus. Additionally, further tests took place in underground tunnels, and the robot managed to travel along their entire length with no need for human intervention. It has been able to autonomously navigate to goals entered via a graphical interface while avoiding both static and dynamic obstacles.

Last, we took the robot to a real industrial building hosting a power plant. Both indoor and outdoor spaces had a large number of sensors providing measurements of machinery status. Here we collected data to build a dataset of a real-world industrial environment to later work on.

V. Conclusions and Future Work

In conclusion, our research presents an autonomous navigation system for automatic industrial inspection that offers advantages over manual methods. Further development and refinement can optimize its performance.

For instance, it would be useful to implement a system capable of handling recovery behaviors in case of failure or inability to reach a goal. A behavior tree would be the most suitable solution for this purpose.

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