

Mobile Platform Based on ROS and LIDAR for Mapping in Civil Construction

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Abstract. The civil construction industry is one of the fastest growing industries in Brazil economically, but it is one of the less grown in terms of application of technologies and innovations. There is a scarce number of studies related to the development and use of mobile platforms applied to construction site environments. With these motivations, this paper presents the development of a mobile platform to be used as a tool to help and improve the inspection process in the construction industry and minimize the costs of acquiring an industrial mobile platform. We explain the materials used in its construction, its electrical schematic and its modeling in Solidworks 3D. The vehicle was shipped with the Robot Operation System (ROS), which used the SLAM algorithm, along with the Rplidar S2 sensor to generate 2D maps. The comparison of the work floor plan with the 2D maps resulted in values very close to the actual measurements. The results ensure that the application of the platform is successful in hostile environments. As a scientific contribution, this innovative study validated the platform navigation planning in horizontal and vertical directions to obtain less shadow in the scene, using the work floor plan as a reference.

Keywords: LIDAR · SLAM · Hector · ROS · Civil construction · Mobile platform

1 Introduction

According to Delgado et al. [1], the construction industry is one of the most important economic sectors in the world. Construction expenses represent a growth from 9% to 15% of most countries' economic performance and, in many cases, represent half of the country's investment in civil construction. The civil construction performance in Brazil in 2022 grew 6%, compared to the industrial segment, which in the same year grew 4.5%, according to the Brazilian Construction Industry Chamber[1]. Despite this,

[1] Available at: https://cbic.org.br/construcao-civil-deve-crescer-6-em-2022-diz-cbic/.

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the construction industry has suffered from labor shortages, security risks, and low automation worldwide [2].

Robotics has emerged as a promising technology in the construction industry with the potential to improve productivity and safety. Nonetheless, the adoption of robotics in the construction industry still faces many challenges due to the unique characteristics of each building. According to Xiao et al. [2], the civil construction process presents a lower standardization and control level at the construction site.

Additionally, mobile robotics have been widely used in industry, performing complex tasks in different working conditions and environments [3]. Efficient navigation is one crucial capability of autonomous mobile robots. For navigation, mobile platforms need a map for path planning, known as SLAM (Simultaneous Localization and Mapping) [15, 16].

Due to fewer academic works in this area, this paper presents the development of a mobile platform built to be used in rough terrain, usually found on construction sites in civil construction. This vehicle was shipped with the Robot Operation System (ROS) to integrate the Hector SLAM package, along with the RPlidar S2 sensor for carrying out the environment mapping through 2D maps. These maps were compared with the floor plan of a medium-sized building at the city of Breu Branco, Pará, Brazil. The search shows the details of the objects inside the construction site identified in the 2D maps. This study presents the results through the comparison between two experiments that carried out the construction site scanning in two different directions, and the best result was obtained with the experiment that used the movement in the vertical direction and presented the lower uncertainty measurement when comparing the areas of the floor plan with 2D map.

This article is organized as follows: in the 2nd Section, the related works are presented; in the 3rd Section, the methodology applied in the study is described; in the 4th Section, the results and discussions are presented; and in the 5th Section, the conclusions and future work are described.

2 Related Works

Searches were carried out in scientific databases, such as the IEEE Xplore, Science Direct, MDPI, Scopus, and Google Scholar to find studies related to ROS and SLAM mapping algorithm, using the LIDAR laser sensor in complex unstructured environments.

Ding et al. [4] conducted a review about using SLAM taking into account rough and complex terrain. The agricultural environment was selected where SLAM is applied using three main fundamental types: light detection and range SLAM, Visual SLAM, and Sensor Fusion SLAM. Their work discusses the applications and perspectives of SLAM as a technology in agricultural mapping and navigation.

Yu et al. [5] proposed to improve the Hector SLAM algorithm using sensor fusion. The experiments demonstrated the accuracy of robot positioning and mapping. The final results also show the effectiveness and validity of the proposed algorithm.

Asadi et al. [6] designed a robotic computer vision system to generate a map of the real world and the obstacles present in a walkable space. The map was generated by the

SLAM algorithm with a camera to perform the navigation and capture of the objects in the scene. The system was applied in three outdoor environments, demonstrating real-time applicability to different outdoor scenes.

Shen et al. [7] developed a ROS-based platform using the LIDAR laser sensor for building 2D-SLAM maps in a real environment. In the map building stage, they used three algorithms: Gmapping, Hector-SLAM, and Cartographer, which were compared and evaluated. The results show that Gmapping has the highest mapping accuracy in small and simple areas. The second algorithm, Hector-SLAM, is more suitable for a prolonged environment like a corridor. And the third algorithm, Cartographer, seems to present more advantages in complex environments, such as a maze format.

Zhao et al. [8] developed a mobile platform with an adaptive robot navigation and positioning system that works with four-wheel drive based on ROS. The platform built maps using Gmapping, Karto SLAM, and Hector SLAM algorithms. Karto SLAM stood out as the one that presented high robustness to improve the accuracy of map building. The system can accurately locate, build an environmental map, and achieve accurate navigation, through simulation and practical application in a real environment.

Çelik et al. [3] designed an autonomous mobile robot using a LIDAR laser sensor based on ROS technology. The robot was developed to execute different SLAM algorithms for planning the best path. Thus, the user can define the robot's movement from the initial to the desired final point. In the Gazebo simulation environment, it was observed that the proposed algorithm produced a 1% to 3% shorter path compared to Dijkstra's shortest path algorithm.

Najim et al. [9] designed a mobile robot with multidirectional wheels to move indoors with narrow corridors controlled by ROS. The SLAM algorithm and the LIDAR laser sensor were used to create the environmental map and determine the robot location and position. This research conducted practical experiments of moving the robot inside a corridor to create an environmental map to avoid obstacles. The real-time map estimation results were efficient for robot positioning and navigation.

The presented works are recent research about using LIDAR sensor and SLAM algorithm in map building, navigation and positioning. The experiments mentioned above do not involve or develop robots adapted for construction sites but for controlled environments, such as corridors or laboratories [3, 5, 7–9]. Studies carried out in platforms at irregular terrains, such as agriculture, mostly use commercial platforms, such as the Husky A200 [4, 6]. Therefore, there is a shortage of studies on developing and using mobile platforms aimed at civil construction and minimizing the acquisition costs of a mobile industrial platform.

3 Methodology

This research aims at developing a mobile platform to be used in a rough terrain of construction sites. This section explains the platform's modeling and development, the materials used, the electrical diagram, and the experiments carried out with the platform.

3.1 Mobile Platform Modeling in Solidworks 3D

The platform was initially modeled in Solidworks 2023 as a way to measure the amount of material that would be needed for its construction. Also, its dimensions were analyzed to verify the feasibility of the supported equipment within its internal space. Figure 1 displays the 3D model of the mentioned mobile platform.

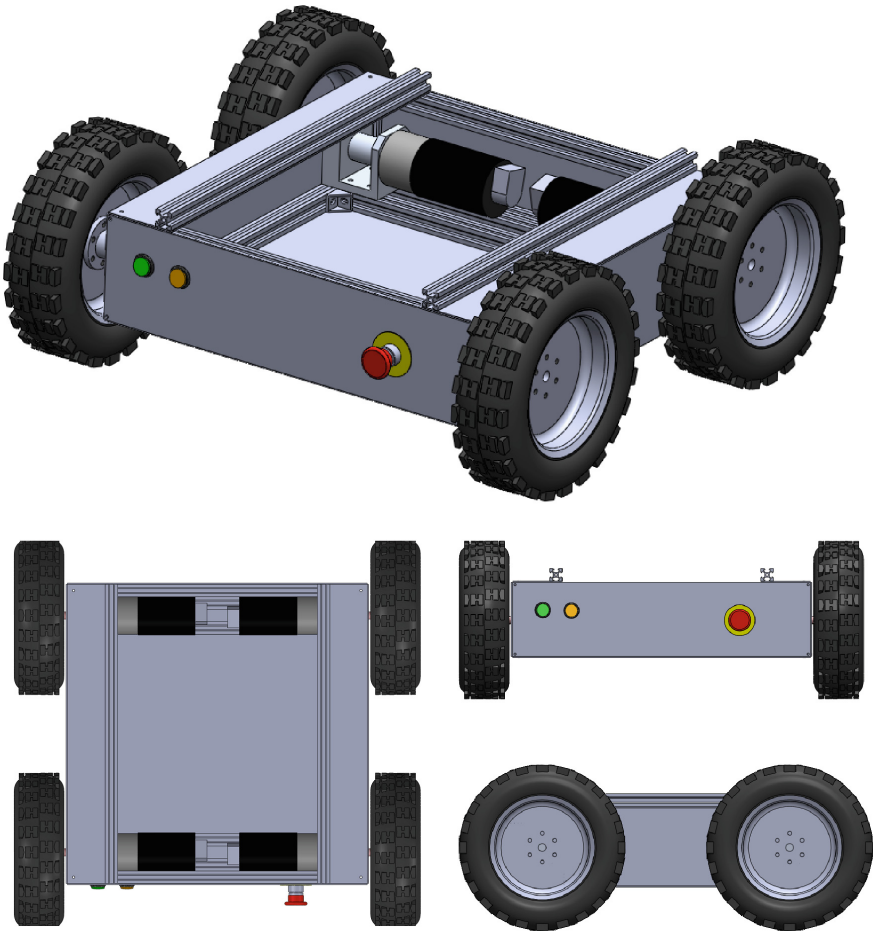


Fig. 1. Mobile platform 3D model.

3.2 Mobile Platform Development

The mobile platform was developed for rough terrain, so a closed chassis design was adopted as a way to not expose the electronic equipment loaded on the platform to the hostile environment of the construction site. The vehicle's chassis was made entirely

of 20 × 20 mm structural aluminum and it was covered with 2 mm aluminum sheets. The vehicle's structure is composed of four off-road wheels, and each wheel contains an motor coupled to its axle, allowing four-wheel drive. Figure 2 shows the mobile platform and its structural items.

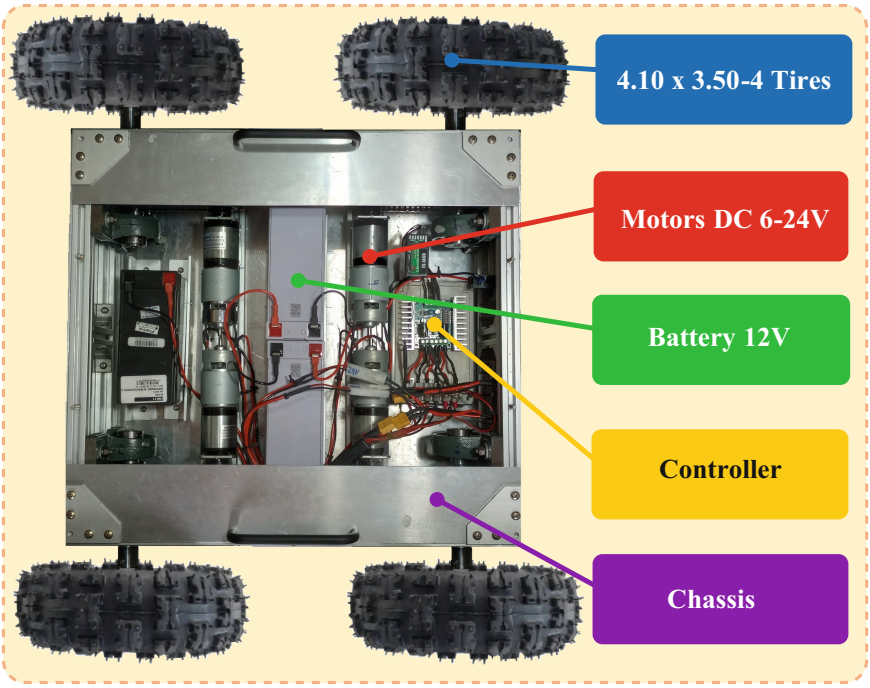


Fig. 2. Mobile platform made up of the following components: tires, motors, battery, controller, and chassis.

Table 1 presents the description and justification of the structural and electrical items used in the mobile platform construction.

A manual control panel was developed at the back of the vehicle, containing buttons and a display with the following functions: green button to turn on/off the platform; orange button to turn on/off the power of the onboard electronic components; display to show batteries charging; the red emergency button used to cut off the batteries supply voltage and the motor controller, causing the platform to stop working, in case there is a risk of accident in data collection. Figure 3 shows the mobile platform control panel.

3.3 Platform Electrical Diagram

The platform electrical scheme was developed to work teleoperated, using the 6-channel FLYSKY radio transmitter that transmits to a receiver of the FS iA6B. This receiver was switched to channels CH5 and CH6, which send a 5V signal to channels S1 and S2 of the Sabertooth controller, which controls the motors. The controller was initially configured

Table 1. List of structural and electrical items in the platform

Item	*Description*	*Justification*
Tire	*Scott Ottobock, Off-Road type, measuring 4.10 X 3.50 and Rim 4*	Because it is suitable for rough terrain
Motor	*Chihai, model CHP-42GP-775, voltage ~ 6-24V, planetary gearbox, torque 4.0 N.m, shaft diameter 8mm, weight ~ 730g and speed 120rpm*	Because it offers high torque and planetary gearbox
Battery	*Moura, 12v voltage, 9ah current and No-break type*	Due to its high longevity and current
Controller	*Sabertooth 2x12, voltage ~ 18-24V and current 12A*	Because it enables control of high current and high voltage
Chassis	20 × 20 mm structural aluminum and 2mm aluminum sheets	Because aluminum minimizes the structure weight

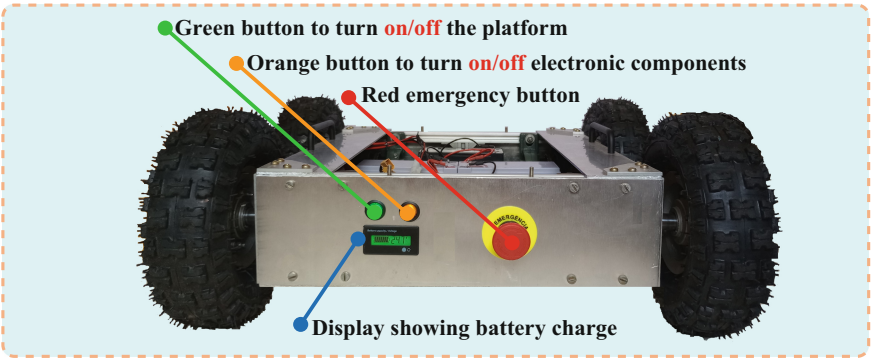


Fig. 3. Manually operated mobile platform panel.

by switching its switch in positions 1 and 5 for OFF and 2, 3, 4, and 6 for ON to enable its control via radio signal. This board controls the motors through channels S1 and S2. Each channel fed two motors on the right side and two on the left. This pair connection allowed four degrees of freedom for the platform, moving forwards, backward, and turning around its axis to the right and left sides. Each motor works with 24V, therefore the vehicle has two 12V batteries, connected in series at ports B+ and B-, providing 24V and a 9ah current, necessary to power the motors. The motors on the left side are connected to the M1A positive and M1B negative ports, and those on the right side are connected to the M2A positive and M2B negative ports. Figure 4 shows the electrical connections for the receiver, controller, motors, and batteries.

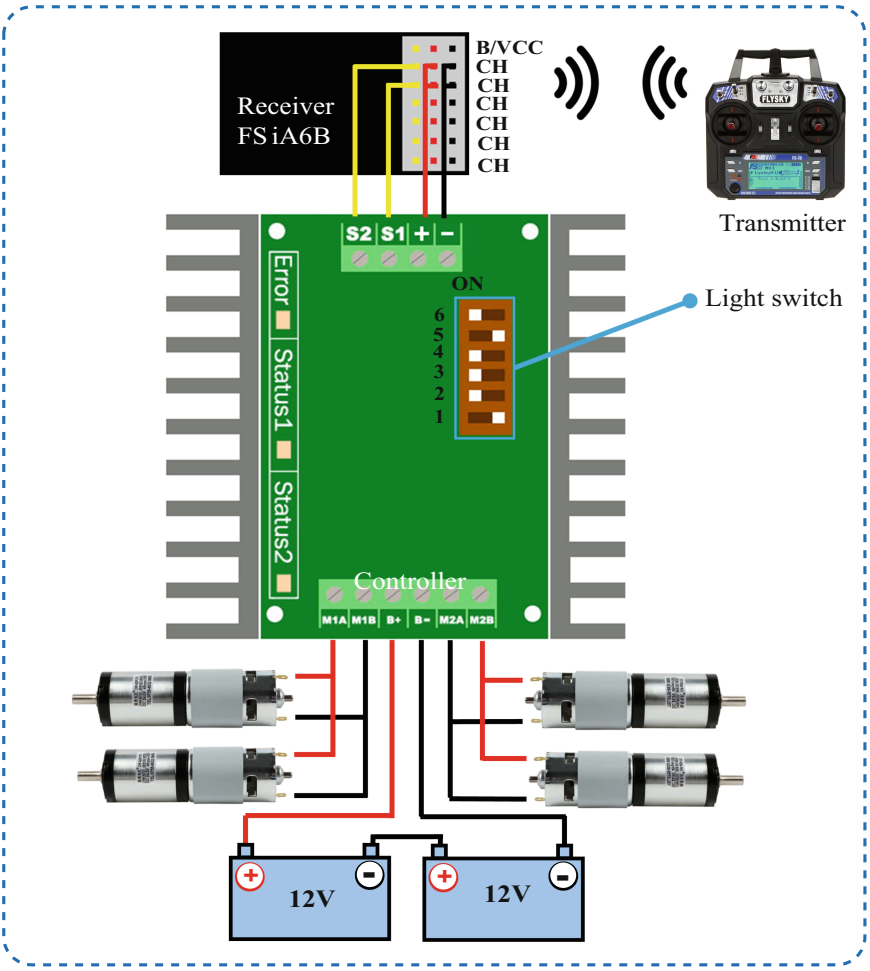


Fig. 4. Scheme of electronic components embedded in the platform.

3.4 Mobile Platform Experiments

A laptop computer with a RPlidar S2 sensor was attached to the mobile platform to scan the surface of the work. The platform was teleoperated through radio control.

This project used the Ubuntu 20.04 operating system to run the ROS middleware, which integrates running programs called nodes for mapping a civil construction environment. The laser scanner node links with the ROS master node to enable message exchange between low-level devices and the ROS. Figure 5 schematically shows the laser scanner node /rplidarNode, sending a /scan message to the ROS master.

For data entry, the RPlidar S2 sensor scans the walls through its laser that measures the properties of the reflected light to obtain the distance between the object and the sensor. The maximum range of the RPlidar S2 sensor is 18m. This sensor writes the

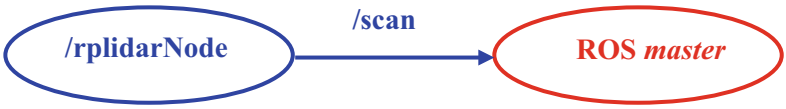


Fig. 5. Message exchange flowchart of between the /rplidarNode node and the ROS master node.

scanned data to the computer's USB port. Data is read from the USB port to be sent to ROS.

The Hector SLAM package was installed on ROS to create the SLAM environmental map, which uses the hector mapping function to generate an environmental map and simultaneously estimate the 2D pose of the platform in the environment. This map will be displayed over lines in a grid format in the RViz interface. The generated map can be saved containing two files, one of which has the extension TFW, which is used by GIS applications that contain the map's location, scale, and rotation; the second file is a TIF-type image stored. Combining these two files makes it possible to locate and navigate in SLAM. Figure 6 shows the overall system block diagram.

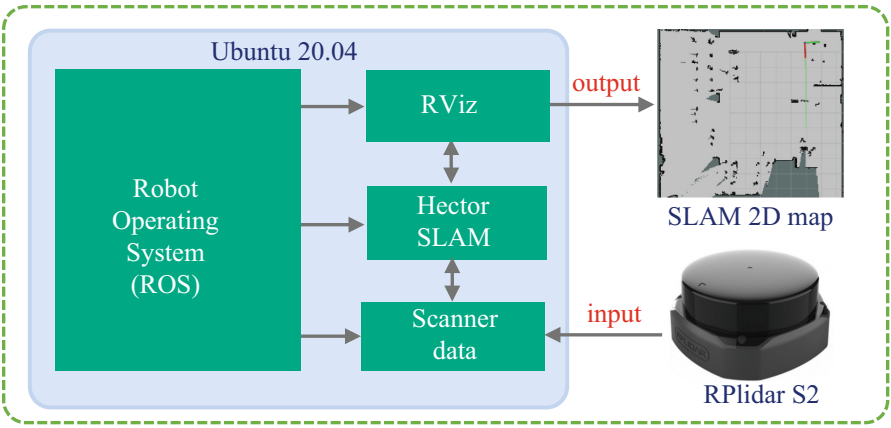


Fig. 6. Flowchart of input and output steps. At the input, data is generated by the RPlidar S2 sensor, and at the output, the SLAM map is displayed on the RViz interface.

3.5 SLAM Map Generation and Comparison with the Work Floor Plan

To create the 2D map, the mobile platform embedded with a laptop containing ROS was used to control the RPlidar S2 sensor. In the environment in which the research was carried out, the experiments took place on the first floor of a medium-sized construction site during business hours, when workers were moving. In the first experiment, the platform was scanned using the movement in the vertical direction of the work floor plan. The second experiment performed the scanning with the movement in the horizontal direction. These scanning types were selected from the experiment performed by Köseoğlu

et al. [10]. The objective was to verify the best way to reduce the shadow areas of the 2D map and reach better measurement accuracy.

The grid measurement of the generated 2D map was used to get the area measurement of each experiment for performing comparisons between the floor plan area and the 2D map area. Figure 7 shows the grid generated in the 2D map. Each square generated in the image measures 1 × 1 m and enables the comparison of the floor plan with the 2D map.

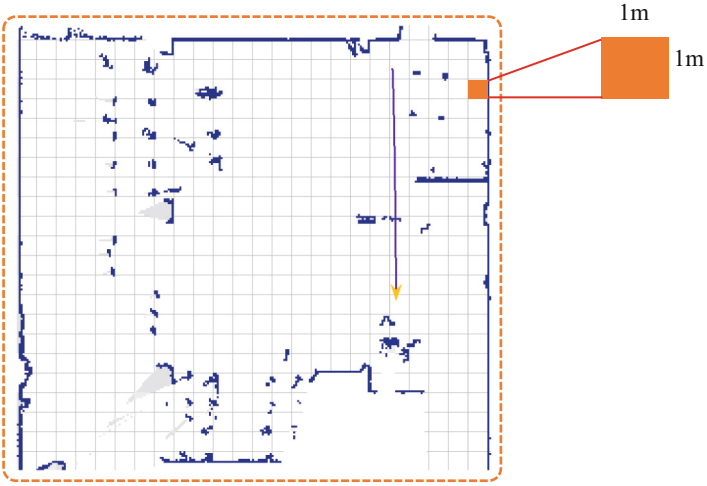


Fig. 7. Grid generated on 2D map with each square measuring 1 × 1 m.

4 Results and Discussion

The mobile platform was developed for the construction industry and designed for rough off-road terrain. Its electronics were shipped and protected from construction site waste, and its system relies on ROS, according to Zhao et al. [8].

This platform made it possible to inspect the work without the need for high financial expenses with the acquisition of a mobile industrial platform. Compared with existing platforms in the literature, two significant differences were observed. The first difference is that authors who did not develop the platform used mobile industrial platforms adapted for construction sites [11–13]. As for the second difference, the authors who developed the platforms did not adapt the platforms to irregular terrain found in civil construction [3, 7, 14]. Figure 8 shows the comparison of mobile industrial platforms adapted for construction sites with platforms developed in the academic environment and generally used in laboratories.

Before using the mobile platform in a real environment, it was submitted to the evaluation of a robotics specialist, who is the director of a robotics and automation company in Brazil. The platform was analyzed and submitted to tests to validate its

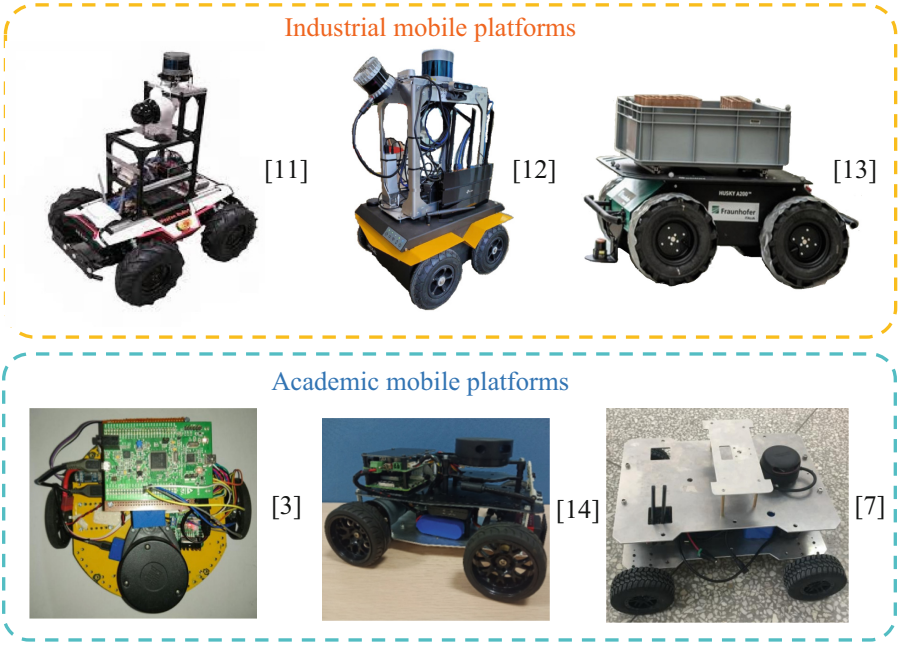


Fig. 8. Comparison between industrial and academic mobile platforms found in the literature.

electronics and mechanics. The expert's assessment was described in a technical report[2]. After the evaluation, it was possible to verify that the platform can be used in construction sites with the supervision of a human being, since, in case of emergency, it is possible to stop the platform quickly.

After completing the development of the mobile platform, the first test was carried out in a real environment to observe its ability to move and overcome common obstacles in construction. To this end, the platform was placed in a room containing two environments separated by a small wall and three support columns. The vehicle was teleoperated to navigate the environment to construct the 2D map. Figure 9 shows the correlation of the structures in the environment compared to the generated 2D map. The red arrow shows the wall separating the environments, and the blue arrows show the columns distributed on the construction site, presenting the level of accuracy of the 2D map generated.

Communication between the operator and the mobile platform has not failed during the experiment, showing that the communication system is safe and can be used in this environment. The platform battery spent 1.7V to conduct the experiments in an operating time of 20 min. Consumption was within the expected range for the two batteries connected in series. The platform traveled around the environment and recorded the evolution of the 2D map from 0 m to 6 m. With this technique, it was possible to observe the best direction of movement in the environment, detecting the shadow areas for each interval. Figure 10 shows the intervals and evolution of the 2D map.

[2] The complete technical report is available at the link: bit.ly/3NaKlgC.

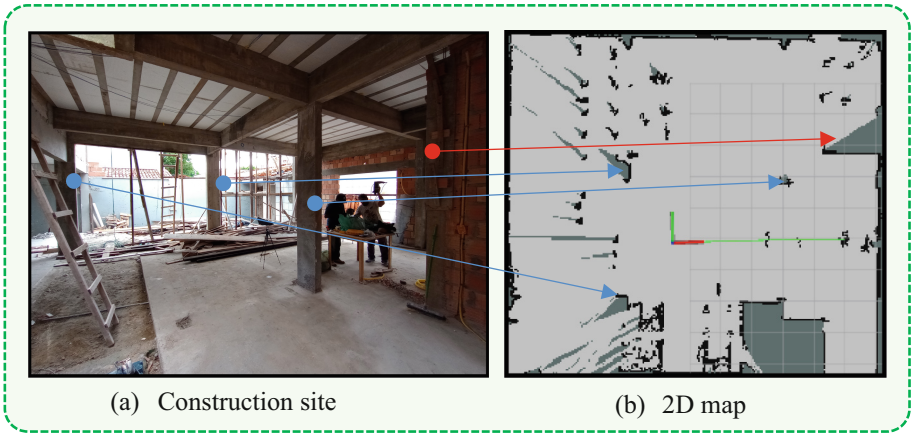


Fig. 9. Correlation between the construction site and the 2D map.

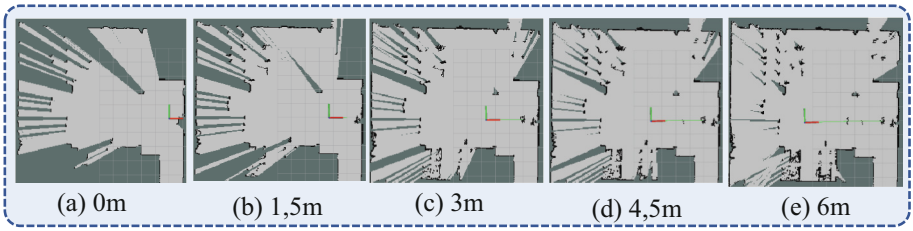


Fig. 10. Evolution of the 2D map according to the distance covered by the platform.

In the image acquisition stage, we noted the importance of moving the platform around the construction site, defining the best direction for the platform to move around the site, and generating a 2D map with few shadow areas. Figure 11 shows the test conductor teleoperating the platform to perform the movements inside the construction site. First, the movement of the platform is in the vertical direction. In this sense, there were few shadow areas, and when comparing the floor plan with the 2D map generated, we obtained an area of ~130.35 $\pm$ 0.75 (m^2). In the second experiment, the platform movement was in the horizontal direction. In this sense, they presented many shadow areas in the created 2D map, and comparing the floor plan with the 2D map, we obtained the following area ~129.75 $\pm$ 1.33 (m^2). We obtained the same area with small measurement uncertainty compared to the first experiment. The shadow areas were created by three columns, a small wall that separated two environments, and the rubble scattered on the floor.

Among the contributions of this work, we highlight the detailed process explanation and the knowledge transmitted when carrying out the mobile platform development to meet civil construction demands. In this area, the adoption of technologies is still scarce compared to other areas [17]. We also emphasize that the level of assertiveness of the 2D mapping compared with the floor plan was satisfactory, as well as the reduced uncertainty values verified in the analyzed areas. Another contribution also consists of

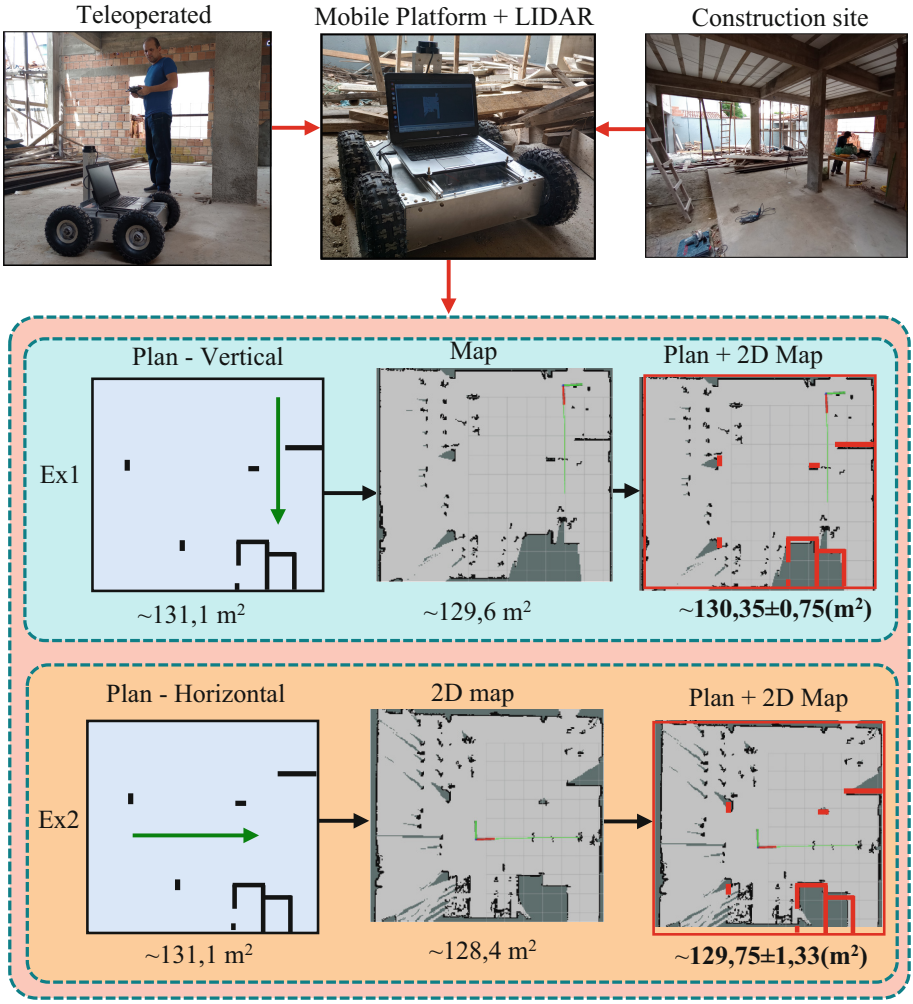


Fig. 11. Flowchart shows the stages of the two experiments carried out at the construction site with the mobile platform.

the richness of details observed in the mapping concerning the real environment, in which columns, walls, and objects found in the scene through mapping can be specified. Finally, in Table 2, we present the price comparison between industrial mobile platforms and the proposed platform, showing that it is possible to reduce costs for developing a mobile platform for construction industry.

This mobile platform can be applied in several construction areas and serve as a tool for workplace inspections, as a mobile agent to communicate between teams, and as support in improving the evolutionary construction process. This work is innovative in the use of mobile robotics in the construction industry, a segment where the inclusion of technological innovations is still very scarce.

Table 2. Price comparison between industrial platforms and the proposed platform.

Platform	*Price*
Proposed platform	$ 1,565.00
Scout 2.0[3]	$ 12,900.00
Jackal J100[4]	$ 19,092.00
Husky A200[5]	$ 20,328.00

5 Conclusions

This research developed a teleoperated mobile platform used to generate 2D maps with the SLAM algorithm and ROS. This system was proposed as a tool for the construction industry. The 2D maps were used to compare the floor plan of a medium-sized project located at Breu Branco, Pará, Brazil.

In the image acquisition stage, we noted the importance of moving the platform around the construction site and defining the best direction for the platform to move around it and 2D map generation with few shadow areas. In the experiment comparison stage, the best result was obtained with the first experiment, in which the measurement uncertainty of the area was much smaller than in the second experiment, confirming the significant result of the platform application. Therefore, this study validated the platform navigation planning in horizontal and vertical directions to obtain less shadow in the scene, using the work floor plan as a reference.

As novelty, this study contributes to increase the use of technologies in the construction industry, by proposing the application of mobile robotics to help improve the inspection process inside a construction site.

For future work, the mobile platform will support 2D map autonomous scanning. Therefore, an Inertial Measurement Unit (IMU) will be added to correct the SLAM algorithm on inclined surfaces. Encoder sensors will also be added for motors to check speed and distance traveled. Finally, the SLAM map will be used to plan the robot's navigation to follow a determined path and avoid obstacles in a real environment.

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