International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

LiDAR SLAM FOR INDOOR ROBOT NAVIGATION IN DYNAMIC ENVIRONMENT

Haritha J, Vinu N, Gokulakannan B, Dinakar S

Haritha J, Dept. of Electronics and Instrumentation Enginnering, Anna University, IN

Vinu N, Dept. of Electronics and Instrumentation Enginnering, Anna University, IN

Gokulakannan B, Dept. of Electronics and Instrumentation Enginnering*, Anna University, IN*

Dinakar S, Dept. of Electronics and Communication Engineering*, Anna University, IN*

***

Abstract - ***Indoor SLAM system using LIDAR data that can track moving obstacles with good accuracy and reliability. This paper introduces an LIDAR-based SLAM method for changing environments, where the environment changes due to dynamic objects, and is designed specifically for indoor settings. The LIDAR data is combined with advanced algorithms to provide high-precision localization and keeps the map updated, even in complex and tight areas. Separation of static and dynamic feature extraction Adaptive filtering techniques makes this enhancement on localization accuracy and performance in general. The results of our experiments are quite good: they demonstrate a consistent and safe navigation in dynamic, indoor environments.***

Index Terms –LIDAR SLAM, Indoor Robot Navigation, Dynamic Environments, Filtering, Localization and Mapping.

1. INTRODUCTION

The rise of autonomous systems, especially in the domain of robotics, has facilitated groundbreaking inventions changing the way machines interact in the real world. One of the critical challenges in this domain is the ability to enable robots with indoor environment navigation autonomously without reliance on traditional GPS. Such spaces require robots to use sophisticated technologies that enable them to develop an immediate realization of their environment as they adapt to the constantly changing dynamics of indoor spaces. This is where Simultaneous Localization and Mapping, abbreviated as SLAM, comes in-a complex framework that enables robots to both self-localize and map their surroundings simultaneously. For instance, one LIDAR-based SLAM is considered to be accurate and reliable. Such accuracy makes it the key indoor navigation technology for any robot. LIDAR is a remote sensing technique that works by shooting laser beams to measure the distances of objects nearby. Such technology, with its ability to precisely detect the environment, is very important for SLAM systems.

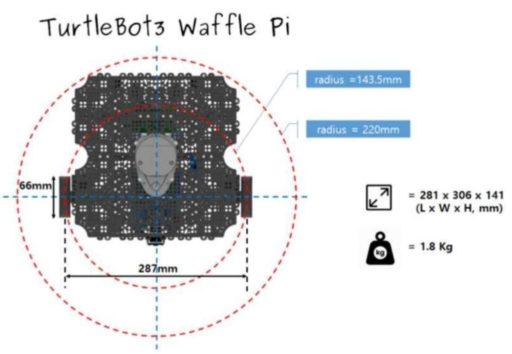
The technology with this sensor involves emitting laser pulses that bounce off surrounding objects and return to the sensor. Each pulse has associated with it a time taken to return, allowing for creation of a detailed map of the environment. This process allows robots to make high-resolution 3D maps of their surroundings, which facilitates precise navigation. The challenge greatly becomes more complex when the environment is not static. Dynamic parts include moving people, shifting furniture, and other operational machinery, which can introduce noise and uncertainty into the SLAM process that may compromise the ability of the robot to accurately map its environment and locate itself in it. The dynamic character of indoor environments sets LIDAR-based SLAM apart from the rest. Most SLAM algorithms that are based on traditional algorithms assume a static environment in which the underlying problem is to separate the movement of the robot from the environment. In this case, even though the environment is dynamic, the position of the robot needs to be delineated from static and transient elements that are included in the map. Such complexity requires a certain integration of adaptive techniques whereby the SLAM system filters out or deals appropriately with dynamic objects, thus ensuring the reliability and robustness of the navigation system. The paper explores a particular LIDAR-based SLAM approach adapted for indoor navigation in dynamic environments

2. LITERATURE REVIEW

This was at the heart of many years of robotics research- SLAM, which stands for Simultaneous Localization and Mapping. SLAM is considered a critical technology that makes it possible for a robot to develop a map of its environment, which simultaneously helps determine its position in that map. Advances in sensor technologies, computational power, and algorithms have seen SLAM develop into one of the most advanced technologies over time. Most of these developments, however, include the integration of LIDAR sensors in SLAM systems that rely on the fact that LIDAR is able to produce highly accurate maps even in poorly structured indoor environments.

During the early stages, SLAM systems relied on visual and ultrasonic sensors. However, these methods were highly constrained, especially for applications in complex indoor settings. For instance, Visual SLAM was sometimes successful but very poor at areas of low light intensity or with fewer clear distinguishable features. The ultrasonic sensors were noisy, with poor resolution, and were less expensive. Such noisy sensors posed severe challenges to the reliability of mapping. All these problems LIDAR technology aimed to resolve by giving an ability of a sensor in producing highly spatially accurate detailed 3D maps.

All this aside, the greatest challenge is one of dealing with dynamic environments. Even LIDAR-based SLAM algorithms tend to assume environments are generally static. When something in the environment is being moved by a person, or even furniture, encounters the robot, these assumptions of static environments can lead to mistake localization and mapping. This can be achieved by developing dynamic SLAM approaches that differentiate between static and moving objects. Wolf and Sukhatme proposed a method that utilized a probabilistic framework for detecting and tracking dynamic objects in the environment. This would update the map in real time, ensuring the SLAM system does not get misled by temporary changes.



TURTLE BOT 3

3. PROPOSED SYSTEM

Interest in SLAM for indoor robot navigation has increased in recent years since SLAM is able to produce autonomous navigation in complex and dynamic environments. Maintaining accurate, real-time mapping and localization is the core challenge of indoor navigation, particularly in environments where objects and people change constantly. This system proposed depends on LIDAR-based SLAM to handle the challenge. Nonetheless, it supplies a solid framework for indoor robot navigation.

The proposed system consists of a modular architecture that integrates LIDAR sensors, a SLAM algorithm, and a dynamic environment adaptation module. The LIDAR sensor is the primary component for environment perception. It continuously scans the surroundings to provide high-resolution point clouds that represent distances and shapes of objects around the robot. Such point clouds are required for generating a real-time map of the environment.

The SLAM algorithm will build and update the map, but at the same time, track the robot's location within that map. In this paper, the variant of the PF-SLAM algorithm is employed; this algorithm is particularly efficient and accurate in dynamic environments. PF-SLAM relies on a probabilistic method to estimate the robot's position by holding a set of hypotheses, such as particles, which can be said to represent the possible locations. This will help in dealing with the uncertainty that is an integral part of dynamic environments.

In this system, the LIDAR sensor is the primary means of gathering environmental data. It continually scans the surrounding space of the robot, generating very detailed 2D or 3D point clouds of the surroundings. Point clouds are analyzed to identify important features, such as walls, furniture, and other stationary objects for building a proper map. LIDAR data aids the system to detect and monitor moving objects, which enable it to differentiate between static things and moving objects.

The system's path planning module takes the generated map from the SLAM algorithm to determine the most efficient route to a robot's destination. In the algorithm, static as well as dynamic obstacles have been taken into consideration in order for the robot safely be able to navigate complex environments. The system has the obstacle avoidance feature wherein the use of live LIDAR data for collision detection is used in real-time modifications of the path. The proposed system will be tested in a variety of indoor environments, such as offices, warehouses, and public spaces, to evaluate its performance under differentconditions. The key metrics for evaluation will include localization accuracy, map quality, and the robot's ability to navigate around dynamic obstacles.

International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

4. RESULT AND DISCUSSION

The paper focuses on the improvement of localization and navigation of mobile robots in indoor environments by combining LIDAR and GPS systems. The results obtained from this study are a clear reflection of the efficiency of such a combined approach, particularly in dynamically changing environments with tight spaces.

1. Localization Accuracy: LIDAR GPS integration improved localization accuracy a lot. The experiment observed the periodic updating of the robot's position with GPS data, thereby correcting the error accumulation of the LIDAR system; thus, localization improved much.

2. Navigation Efficiency: The robot had successfully passed through small alleys with high accuracy. In all the above sensors combined, it was adjusted that during navigation into the surroundings complex, it doesn't hit and get struck anywhere.

3. Error Reduction: It was observed that the error increase with time was the significant problem in LIDAR-based localization; it happened especially in those environments that contain many new and dynamic objects. The incorporation of GPS data resulted in the reduction of accumulated error, thus preventing huge deviations in the path of the robot.

4.Algorithm Performance: The proposed method was implemented using ROS for the algorithm and was then tested. It is with this that it could be proven that the robot could actually move through some challenging environments. Very high accuracies were noted for reaching the set positions, but validations on effectiveness needed to be shown.

5. Dynamic Environment Handling: The authors said that in dynamic environments where objects and people are in constant motion, the integrated use of LIDAR and GPS would provide a suitable robust solution for ensuring accurate localization, which was necessary for safe and reliable operation of a robot.

Discussion

One of the crucial achievements of integrating LIDAR and GPS in indoor navigation with robots is this: traditionally, the localization method often utilizes LIDAR-sourced information alone and readily expands the error in a dynamic environment when compared to these locations. This master's thesis used this as an aspect for change in including information given through GPS, acting as the stable reference for calibration to the summing errors elicited from the use of LIDAR.

Indoor GPS is somewhat relatively new because usually GPS signals are weak in interior halls. However, research in this area validates how periodically updated indoor GPS values adequately correct LIDAR based localization errors, provided they are hybrid using benefits. The high precision of LIDAR and the stability of GPS in absolute positioning.

Another direction for improvement is on the handling of fully dynamic scenarios, with items moving swiftly and unpredictably among people. While the work does show that the method still performs very well within mildly dynamic scenarios, it still does not attain comparable high-level accuracy when dealing with fully chaotic scenarios.

GAZEBO SIMULATION:

INPUT:

```
cd ~/catkin_ws/src/
git clone -b kinetic-devel https://github.com/ROBOTIS-GIT/turtlebot3_simulations.git
cd ~/catkin_ws && catkin_make
```

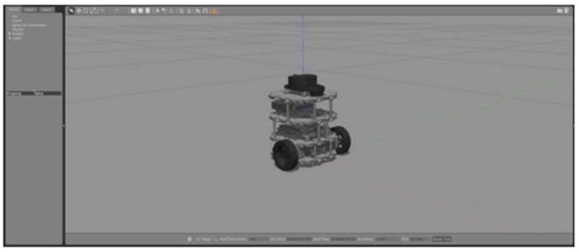
```
export TURTLEBOT3_MODEL=burger
roslaunch turtlebot3_gazebo turtlebot3_empty_world.launch
```

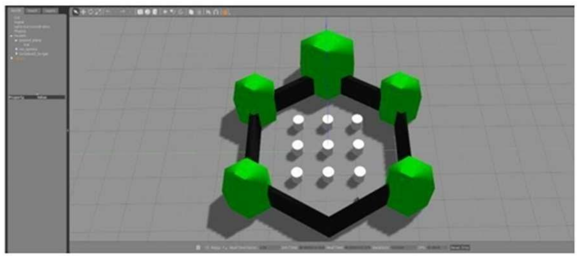
```
export TURTLEBOT3_MODEL=waffle
roslaunch turtlebot3_gazebo turtlebot3_world.launch
```

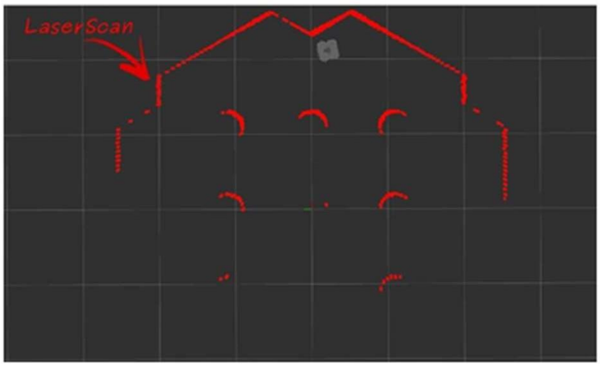
```
export TURTLEBOT3_MODEL=waffle_pi
roslaunch turtlebot3_gazebo turtlebot3_house.launch
```

```
roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch
```

OUTPUT:







CONCLUSION:

In conclusion, LIDAR and GPS integration for indoor robot localization and navigation is a major advancement in the development of autonomous mobile robots. The method solves the main problems that have been associated with dynamic environments and tight spaces and presents a robust solution for the improvement of accuracy and reliability in robot navigation. This technology continues to improve on such a foundation so that more sophisticated systems may be achieved, but which could extend from capabilities into applications as well for indoor mobile robots

REFERENCE:

Ganeshmoorthy, M. S., & Suresh, G. R. (2015, March). Path planning algorithm for autonomous mobile robot in dynamic environment. In 2015 3rd International Conference on Signal Processing, Communication and Networking (ICSCN) (pp. 1-6). IEEE

Guan, R. P., Ristic, B., Wang, L., & Palmer, J. L. (2019). KLD sampling with Gmapping proposal for Monte Carlo localization of mobile robots. Information Fusion, 49, 79-88
Kermorgant, O. (2018). A magnetic climbing robot to perform autonomous welding in the shipbuilding industry. Robotics and Computer-Integrated Manufacturing, 53, 178-186.

Kumar, N. V., & Kumar, C. S. (2018). Development of collision free path planning algorithm for warehouse mobile robot. Procedia computer science, 133, 456-463
Moore, T., & Stouch, D. (2016). A generalized extended kalman filter implementation for the robot operating system. In Intelligent autonomous systems 13 (pp. 335- 348). Springer, Cham

Ogiso, S., Kawagishi, T., Mizutani, K., Wakatsuki, N., & Zempo, K. (2015). Self-localization method for mobile robot using acoustic beacons. ROBOMECH Journal, 2(1), 1-12

Perez-Grau, F. J., Caballero, F., Viguria, A., & Ollero, A. (2017). Multi-sensor three-dimensional Monte Carlo localization for International Journal of Advanced Robotic Systems, 14(5), 1729881417732757.