Proceedings of the 2023 International Conference on Machine Learning and Automation
DOI: 10.54254/2755-2721/38/20230547

Research on the SLAM technology moving away from high-precision maps in the context of autonomous driving

Yan Zhu

School of Advanced technology, Xi'an Jiaotong-Liverpool University, SuZhou, Jiangsu, 215000 ,China

devilrock8969@gmail.com

Abstract. SLAM(Simulation Localization and Mapping) technology is widely used in the fields of unmanned driving, autonomous robots and augmented reality. Real-time localization and mapping capabilities provide important support for autonomous driving. In this paper, we present a review of the implications of SLAM technology away from high-precision maps in autonomous driving scenarios, and the concept and production process of high-precision maps, as well as their role and advantages in autonomous driving, are discussed. Then, the application, significance, and advantages of SLAM technology in autonomous driving scenarios are discussed in detail, and the advantages of SLAM technology in environmental adaptability, real-time performance, cost and scalability, and safety in emergency situations are emphasized. Finally, the challenges faced by the current SLAM technology in autonomous driving are analyzed, and the development prospects of SLAM technology in the field of autonomous driving in the future are discussed.

Keywords: SLAM, Autonomous Driving, High Precision Map, Intelligent Transportation.

1. Introduction

As an important development direction in the field of intelligent transportation, autonomous driving technology is constantly receiving high attention and investment from global automobile manufacturers and technology companies. The core requirements of autonomous driving systems are to be able to achieve accurate positioning and navigation in unknown environments, and to ensure that vehicles can travel safely and efficiently. To achieve this goal, high-precision maps are widely used in autonomous driving systems as an important auxiliary tool to provide accurate environmental information and navigation guidance [1].

However, the traditional high-precision map production process is cumbersome and costly, and it is difficult to adapt to complex urban environments, areas with poor signal, or dynamically changing road conditions [2] In this context, SLAM technology, as a key technology for real-time localization and mapping, has attracted increasing attention from the autonomous driving industry [3]. SLAM technology can locate the position of the vehicle in real-time in an unknown environment and build a map of the surrounding environment at the same time. Its advantages of environmental adaptability, real-time performance and cost-effectiveness are particularly obvious in autonomous driving scenarios.

This paper will focus on the significance of SLAM technology away from high-precision maps in autonomous driving scenarios and analyze the advantages of SLAM technology in environmental perception, navigation decision-making, and safety in order to provide reference and guidance for the further development of autonomous driving technology. At the same time, we will deeply explore the challenges faced by the current SLAM technology in autonomous driving, and look forward to the future application prospects of SLAM technology in the field of autonomous driving. Through the research in this paper, we hope to contribute to promoting the development and implementation of autonomous driving technology for safer and smarter mobility.

2. SLAM technology

SLAM technology is a key technology that is widely used in the fields of unmanned driving, autonomous robots and augmented reality. It allows unmanned mobile systems to locate themselves in an unknown environment in real time and simultaneously build a map of the surrounding environment. The development of SLAM technology enables autonomous vehicles to achieve high-precision positioning and navigation in the absence of GPS or other prior positioning information.

In classic SLAM systems such as the LOAM system based on a LiDAR sensor, Google's cartographer project, and VINS and ORB-SLAM based on a vision sensor, the composition of the classic SLAM system is summarized as four key parts: sensor data collection, front-end processing, back-end optimization, and map construction.

2.1. Sensor data acquisition

At the beginning of the SLAM system, for the reception of sensor data, the time synchronization and coordinate system calibration of multi-sensor data will be carried out in the machine system with insufficient calibration, and then the "data cleaning" work will be carried out to filter invalid values and outliers, and the point cloud (or image) dedistortion process will be carried out [4].

2.2. Front-end processing

Based on the preprocessed sensor data, the multi-sensor fusion technology was used to estimate the robot's pose. The specific scheme of multi-sensor fusion can be based on a filtering method or an optimization method, and it can be a loosely coupled system or a tightly coupled system. The choice of fusion scheme is related to the robot sensor layout and scene requirements. The matching algorithm based on LiDAR or vision can be scan-to-scan or scan-to-map. The matching algorithm can be selected according to the requirements of the scene, but no matter what fusion scheme and matching algorithm are used, the goal is to achieve high-precision, high-efficiency, and highly robust odometer pose estimation.

2.3. Backend Optimization

It is an essential part of the contemporary SLAM system to eliminate the error accumulated by the front-end odometer to ensure the global consistency of the trajectory in the SLAM process. The back-end is generally a combination of loop detection and pose optimization to complete the elimination of front-end odometry errors. The specific loop detection algorithm schemes are similar, and in general, the efficiency and robustness of loop recognition are worked on. The optimization of global pose is based on excellent open source optimization libraries such as ceres, g2o, gtsam. In general, the construction of the pose map is also based on the Key Frame (LiDAR pose or Camera pose) as the optimization object, supplemented by loop detection constraints, global sensor GNSS, landmark and inertial sensor constraints or factors to complete the maintenance process of the pose map [5].

2.4. Map Building

According to the pose map information maintained in the SLAM system, the pre-processed environmental sensor data information (point cloud, image features) is spliced to complete the construction and saving of the point cloud (feature) map. In addition, the intermediate data in the SLAM process can also be saved, such as trajectory, pose map, key frame point cloud (feature), two-dimensional raster map, etc.

In a word, a robot, such as a car, starts from an unknown location in an unknown environment, locates its position and attitude through repeated observations of environmental features during movement, and then builds an incremental map of the surrounding environment according to its position, so as to achieve the purpose of simultaneous localization and map construction. For example, the mapping car is equipped with various sensors, such as lidar, camera, GPS, IMU, etc., and completes high-precision mapping tasks of the geographic environment through slam technology.

Since the concept of SLAM was put forward in the 1980s, SLAM technology has gone through a history of more than 30 years. The sensors used in SLAM systems are constantly expanding, from the early sonar, to the later 2D/3D lidar, to various cameras such as monocular, binocular, RGBD, ToF, and the fusion with inertial measurement unit (IMU) and other sensors. The algorithm of SLAM has also changed from filter-based methods (EKF, PF, etc.) to optimization-based methods, and the technical framework has also evolved from single thread to multi-thread.

So far, SLAM technology can be said to be the basis of the implementation and application of autonomous driving, such as sensor calibration, time synchronization, data preprocessing, multi-sensor fusion, loop detection, pose graph optimization and map construction, etc., but autonomous driving will strengthen the intervention of perception module and decision-making control module on the basis of it. In particular, the perception module will have a greater stage performance in automatic driving, highlighting the detailed description and expression of the complex needs of automatic driving, and helping automatic driving technology to still operate stably and safely in complex scenes.

3. High-precision maps and autonomous driving

High-precision maps, generally speaking, are electronic maps with higher accuracy and more data dimensions. The higher accuracy is reflected in the accuracy to the centimeter level, and the more dimensional data is reflected in its inclusion of surrounding static information related to traffic in addition to road information. It is a necessity for high-level autonomous driving. It can capture the location of the vehicle, road conditions and surrounding environment, etc.

The process of making high-resolution maps can be simply divided into three stages: data collection, data processing, and data relabeling and layer processing.

In addition, lidar and cameras are also used to obtain 3D environmental information around the vehicle. Unlike traditional SLAM systems, lidar point clouds and camera images are no longer used for the matching algorithm at this stage, but only for providing environmental information.

The stitched original map is then used for "semantic extraction" to automatically obtain necessary information from the original map, such as road information such as lane lines, slope, curvature, and facility information such as traffic signs, road edge types, traffic lights, and intersections [6].

The construction of the original point cloud map is similar to the map construction technique in the SLAM system, pose optimization and point cloud superposition are performed on the point cloud data of each frame to generate the original point cloud map. Then, on the basis of the original point cloud map, various lane line information, road dividers, and facility information in the road environment are established, and finally a complete high-precision map is generated [7][8][9].

In autonomous driving scenarios, SLAM technology is far from the meaning of high-precision maps.

The so-called "getting rid of" high-precision maps for autonomous driving is not equivalent to the fact that autonomous driving does not need maps. What we really want to "get rid of" is the restrictions and constraints of the traditional high-precision map production process. In the alternative scheme, "crowdsourcing" only changes the way of data collection, storage and information extraction in high-precision map production, but the technical scheme of map generation and construction is still roughly the same as before.

4. Discussion

Although the combination of slam technology and high-precision maps can provide more comprehensive, accurate and robust autonomous driving solutions. However, in complex urban environments, dense high-rise areas or areas with poor signal, high-precision maps are not reliable.

DOI: 10.54254/2755-2721/38/20230547

Finally, it still depends on the intelligence of the car itself, that is, whether its own response to unfamiliar environments and emergency situations can meet the needs of autonomous driving in a safe and reliable way [10].

In the autonomous driving scenario, the significance of SLAM technology away from high-precision maps is mainly reflected in the following aspects.

Traditional high-precision maps need to collect a large amount of precise geographic information in advance during the production process, which limits the adaptability of autonomous driving systems. SLAM technology can build maps in real-time in unknown environments, making autonomous vehicles more adaptive and flexible. Even in the absence of high-precision maps, SLAM technology can localize and navigate in any environment.

Autonomous driving systems require real-time perception and decision-making capabilities, especially in complex urban environments, high-density areas, or places with poor signals. Traditional high-precision maps may not be able to update and reflect changes in the environment in time, while SLAM technology can build and update maps in real time to provide more accurate positioning and navigation information for vehicles [11].

The production of high-precision maps requires a lot of manpower and material resources, and the cost is high. SLAM technology is relatively low-cost and can be extended and applied in different environments, making it suitable for different types of autonomous driving vehicles.

In emergency situations, high-precision maps may not provide sufficiently accurate information, while SLAM technology can help vehicles quickly adapt to changing environments, provide more reliable localization and navigation, and enhance the safety of autonomous vehicles in emergency situations.

5. Conclusion

SLAM technology is of great significance to get rid of high-precision maps in autonomous driving scenarios. It realizes real-time positioning and mapping, which provides key support for autonomous driving systems. SLAM technology improves the environmental adaptability, real-time performance, and safety of vehicles and reduces the cost of the system which provides strong support for the popularization of autonomous driving technology. Although high-precision maps play an important role in specific scenarios, the continuous advancement of SLAM technology brings more flexible and efficient solutions to autonomous driving technology. SLAM technology has great potential to solve the challenges of map building in complex urban environments and will advance the development of autonomous driving technology.

References

[1] Gupta, A. K. and U. Shanker (2022). "A Comprehensive Review of Map-Matching Techniques: Empirical Analysis, Taxonomy, and Emerging Research Trends." International Journal of Web Services Research 19(1).

[2] Bao, Z. B., S. Hossain, H. X. Lang and X. K. Lin (2023). "A review of high-definition map creation methods for autonomous driving." Engineering Applications of Artificial Intelligence 122.

[3] Ren, Weijian, Gao, Qiang, Kang, Zhaohai, Huo, Fengcai and Zhang, C. (2022). "A review of synchronized positioning and map building techniques for mobile robots." Computerized Measurement and Control 30(02): 1-10+37.

[4] Hao, Feifan, Ma, Xiangyue, Li, Haoyang and Liu, Zhongfu (2022). "A review of detection sensors and their fusion technologies for self-driving cars." Shanxi Electronic Technology (03): 93-96.

[5] Liang Shuang, Ni Xiaochang, Dong Jiaoling, Gao Mengjie and Du Bowen (2022). "A review of LIDAR-based SLAM algorithms." Information and Computers (Theoretical Edition) 34(03): 59-61.

[6] Qin, Tong, et al. “A Light-Weight Semantic Map for Visual Localization towards Autonomous Driving.” 2021 IEEE International Conference on Robotics and Automation (ICRA), 2021, doi:10.1109/icra48506.2021.9561663.
[7] M. Schreiber, C. Knoppel, and U. Franke, “Laneloc: Lane marking ̈ based localization using highly accurate maps,” in 2013 IEEE Intelligent Vehicles Symposium (IV). IEEE, 2013, pp. 449–454. [17]
[8] A. Ranganathan, D. Ilstrup, and T. Wu, “Light-weight localization for vehicles using road markings,” in 2013 IEEE/RSJ International Conference on Intelligent Robots and Systems. IEEE, 2013, pp. 921– 927.
[9] J. Jeong, Y. Cho, and A. Kim, “Road-slam: Road marking based slam with lane-level accuracy,” in 2017 IEEE Intelligent Vehicles Symposium (IV). IEEE, 2017, pp. 1736–1473.
[10] Cadena, C., L. Carlone, H. Carrillo, Y. Latif, D. Scaramuzza, J. Neira, I. Reid and J. J. Leonard (2016). "Past, Present, and Future of Simultaneous Localization and Mapping: Toward the Robust-Perception Age." Ieee Transactions on Robotics 32(6): 1309-1332.
[11] Soorchaei, B. E., M. Razzaghpour, R. Valiente, A. Raftari and Y. P. Fallah (2022). "High-Definition Map Representation Techniques for Automated Vehicles." Electronics 11(20).