The Application of SLAM in Life and Scientific Research

Yuanrui Song

Arizona College of Technology, Hebei University of Technology, Tianjin, China

215796@stu.hebut.edu.cn

Abstract. This article mainly focuses on the application of SLAM in technology and provides a literature review on the following aspects: 1) The application of SLAM in automatic parking of automobiles. This includes using AVP-SLAM for high-precision automatic parking in outdoor parking lots using convolutional neural networks, and using MOFISLM for high-precision automatic parking when indoor GPS signals are poor. 2) The application of SLAM in robotics. It includes three aspects. The first is using the GMapping algorithm to construct and locate maps with high accuracy, low computational complexity, and high robustness, enabling robots to plan the shortest path in unknown environments. The second is to use ORB-SLAM2, which can handle more complex situations, to navigate medical institution robots to improve hospital efficiency and reduce disease transmission rates. The third is for robots that perform tasks in complex and unknown terrains. The improved version of LAMP1.0, LAMP2.0, which is suitable for complex underground environments, can achieve multi robot collaborative cooperation with high accuracy and robustness. 3) Application of SLAM in the field of unmanned aerial vehicles. This article mainly elaborates on four aspects. The first is to use visual SLAM to achieve collaborative work between ground robots and drones, and to utilize the high camera advantage of drones to quickly build maps for ground robots, improve accuracy, and save time. The second is to utilize the application of VSLAM on unmanned aerial vehicles to contribute to agriculture. The third is ORB-SLAM3 to provide rapid and high-precision landing on deck for unmanned aerial vehicles in maritime missions. The fourth is using SLAM to assist unmanned aerial vehicles in landing in emergency or position situations (such, when GPS signals are lost).

Keywords: SLAM, robots, drones.

1. Introduction

SLAM technology, which refers to real-time positioning and map building technology. With the gradual intelligence of life and the improvement of image processing level, SLAM technology is also becoming increasingly popular, such as unmanned driving technology, drones, smart homes, and many other common things have applied SLAM technology. The real-time positioning and map building technology provided by SLAM technology is very important. Only after building the map can path planning be carried out for ground mobile robots, and only real-time positioning can make the executing robot understand what to do next. Moreover, SLAM technology has a high understanding of the environment. In addition, SLAM technology has strong robustness and can maintain extremely low failure rates during operation, which is very important for tools such as robots to perform tasks. In the rapidly developing AR technology in recent years, SLAM has solved the problem of device positioning and direction. SLAM technology has developed rapidly in recent decades and has achieved large-scale applications. However, there are still many problems with SLAM, such as large data errors obtained in strong and weak light environments (or excessive changes in lighting), or inability to use them during rapid motion, all directions for future research and improvement. Although the development of SLAM technology is currently very rapid, with its potential, if more people are interested in it and participate in research, the development of SLAM will be faster and its application will be more widespread. This article provides a literature review of multiple articles on the application of SLAM (automatic parking, robots, drones), to summarize the research and practical applications of SLAM in recent years, providing an appropriate direction for future research, and maximizing readers' interest in SLAM and accelerating its development speed. This article reviews the application of SLAM in outdoor automatic parking, indoor automatic parking, autonomous navigation of mobile robots, path planning and autonomous navigation of robots in medical institutions, collaborative work of multiple robots in complex underground environments, collaborative work between drones and ground robots, monitoring of objects by drones, landing of drones on deck, landing of drones in unknown and dangerous environments, and other aspects's application.

2. Application of slam in automatic parking system

With the gradual prosperity of society, vehicles are becoming more and more common in cities. Although vehicles facilitate the passage of citizens, parking is always a headache. Currently, a common phenomenon is that there are many cars but few parking spaces, and if in the downtown area, the size of the parking spaces is always very small, which leads to drivers not making any mistakes during the parking process, otherwise it is easy to bump into the car. So, automatic parking is a feature that people need today. In response to this phenomenon, Qin Tong et al. conducted a study on the automatic parking of cars in parking lots. Qin Tong and his team installed a fish eye camera on the car. They used convolutional neural networks to conduct specialized parking lot feature detection training using images collected in the parking lot. They detected parking lines and parking line corners (including speed bumps, guidance signs, etc.) from IPM images. Afterwards, Qin Tong et al. conducted experiments to evaluate the mapping metrics in outdoor parking lots (with strong GPS signals) and in underground parking lots (with no GPS signals). Through comparison, they compared the capabilities of ORB-SLAM2 and AVP-SLAM. Undoubtedly, positioning accuracy is the most important indicator, so they ultimately chose AVP-SLAM with higher positioning accuracy. Real-world automatic parking applications and experiments have been used to validate the suggested technology. AVP-SLAM achieved centimeter-level positional precision and a mapping error of 1.33% [1].

Compared to automatic parking in outdoor environments, the difficulty of automatic parking in indoor environments (similar to parking lots) is often higher because outdoor parking has a reliable information source while indoor information source signals are weak, and there are many reasons for the lack of mature SLAM systems and benchmark data collection ([2]). So this is a great challenge for the SLAM system of automatic parking. Shao Xuan et al. only conducted research on SLAM for automatic parking in indoor conditions. In this study, a look around camera system suitable for indoor automatic parking using MOFISSLAM was proposed, and the MOFISSLAM was calibrated and achieved optimal performance. A large-scale database containing sensor data during driving in typical indoor parking lots has been established. According to experiments, the positioning accuracy of MOFISSLAM is very high. Compared to other commonly used SLAM systems, MOFISSLAM has better mapping capabilities and is suitable for tilting parking spaces. However, when there are too many feature points in MOFISLAM, its frame rate may not meet the requirements. It may not be suitable for certain special parking spaces, such as parking spaces with non-parallel or vertical parking lines. In addition, this study has not yet been fully completed, and the MOFISSLAM system will be more stable when semantic landmarks are considered for loop closure in the future [2].

3. Application of slam in robotics

The SLAM system is very important in mobile robots, and SLAM is also a difficult problem in robot design. In most cases, robots must use SLAM to estimate the environment and locate themselves to achieve stable operation and task completion [3]. At present, SLAM is widely used in robots. Meng Zhaojun and others conducted a study on mobile robot SLAM. The study was conducted by comparing Hector Slam and GMapping algorithms. The GMapping algorithm has higher positioning accuracy, smaller computational complexity, lower overall corresponding demand, and higher robustness. Research has shown that the accumulation of errors in laser scanning matching during map construction is significant, and sparse pose adjustment (SPA) can significantly optimize the calculation process. To achieve map construction and positioning in larger scenarios, adding a closed-loop detection link can effectively improve the accuracy of the mapping. It is effective to use GMapping for autonomous navigation in ROS [4]. Afterwards, Meng Zhaojun and others conducted a real indoor experiment using a wheeled mobile robot paired with GMapping, with a chair as an obstacle. Experiments have shown that wheeled mobile robots can effectively plan the shortest path and navigate with sufficient accuracy.

The uses of robots are often diverse. During the COVID-19 pandemic, medical systems in various countries were under tremendous pressure. Medical robots using SLAM technology are effective. [5] Fang Baofu et al. conducted research on visual SLAM for robot navigation in medical institutions using visual SLAM (VSLAM). The study extended ORB-SLAM2 and improved SLAM's ability to treat objects segmented by neural networks as independent individuals, obtaining more advanced semantic information that can handle more complex situations and scenarios. MASK R-CNN, which has high accuracy in image instance segmentation, is used to extract semantic information and construct local semantic descriptors. The semantic descriptors are robust to lighting changes and can effectively describe the environment of key points. The real-scene experiment was conducted in the isolation buffer, and cleaning areas of the hospital, almost completely simulating the real working environment. The robot successfully understood the scene and completed navigation. To improve the accuracy of robot pose estimation, experiments were conducted to detect and eliminate dynamic targets, and significant results were achieved: Compared with other SLAM systems, the improved system has higher robustness and accuracy. And in terms of efficiency, the improved processing of dynamic objects should have extremely high efficiency. There is still great room for improvement in the real-time performance of the system in this study [5].

Special robots often need to complete tasks in complex terrains and often require multiple robots to collaborate together. Both of these requirements are very challenging. When using robots for search and rescue in unknown environments, high-precision SLAM is required to locate oneself and the person needing search and rescue [6]. To this end, Zhang Yun et al. researched SLAM using heterogeneous mobile robots in complex underground environments (dark, rugged, and with many unknown terrains). Before starting this study, the authors collected and evaluated real data on many robots working in caves. LAMP2.0 is the SLAM system for this study, which is an improved version of LAMP1.0 and is used in underground complex environments, and can achieve a system for joint localization and mapping of multiple robots. This study has improved the closed-loop detection module by using 3D registration technology to achieve high accuracy and robustness of the closed-loop. After experiments, it has been shown that LAMP2.0 has extremely strong performance, with an error of less than 2 meters and a trajectory length of 2.2km. It can also achieve map errors of less than 4 meters in very complex terrain, and LAMP2.0 can provide trajectory estimation for multiple robots. However, due to its centralized architecture, LAMP2.0 cannot be applied to more than four robot teams [6]. This is also the future research direction.

4. Application of slam in the field of unmanned aerial vehicles

Due to various limitations of ground mobile robots, the mainstream trend is for drones to replace robots or for drones to work together with ground robots [7]. However, traditional drones have poor mapping effects and cannot meet most needs. The usual SLAM method for aerial mapping of unmanned aerial vehicles is very effective [7]. Wang Chenjie et al. conducted a study on visual SLAM collaborative mapping and navigation of drones, utilizing the aerial perspective advantage of drones to efficiently provide ground robots with information that they are difficult to obtain, helping them quickly construct maps, greatly improving the work efficiency and ability of ground robots, and reducing work difficulty. At the same time, the project proposes a new SLAM visual method that combines point and line features, which can effectively autonomously locate and obtain maps in real-world environments with unclear textures. The simulation experiment of this study was conducted using Gazebo to simulate the real environment as much as possible, adding obstacles such as cars and trash cans to act as obstacles for ground mobile robots. The experiment showed that the project's actual and simulation experiments are similar, proving that the collaborative mapping and navigation of unmanned aerial vehicle vision SLAM has brought significant progress in mapping for ground robots. The efficiency of this experiment may decrease in complex real-world scenarios [7].

With the increase of the world population, the demand for food is also increasing. Traditional agriculture is often insufficient to provide such a large amount of demand. Precision agriculture is a way to improve yield and quality, and precision agriculture requires the participation of drones. The use of VSLAM on small unmanned aerial vehicles for crop detection is very effective [8]. A project by Sander Krul et al. researched the application of ORB-SLAM and LSD-SLAM algorithms on unmanned aerial vehicles in indoor agriculture. Experiments have shown that drones have significant advantages over traditional agriculture, and both VSLAM algorithms perform well, achieving positioning and navigation with small positional errors and completing tasks. By using eight camera images and monocular camera inputs for indoor agricultural environment mapping, changes in the level of detail between indoor agricultural environments can be obtained. Moreover, when drones replace humans in monitoring animals, they do not cause greater pressure on animals. In addition, the cost of using drones to monitor crops is reasonable [8].

These all demonstrate the outstanding role of drones using the VSLAM algorithm in agriculture. Drones are widely used in maritime missions, but landing on the deck of a ship during maritime missions is a challenge because ships and land are different. The landing of drones on ships requires consideration of the relative motion between overtime and drones, and the space on the deck is small, making the overall situation more variable [9]. SLAM can provide some assistance in this regard. Thomas Dutranois et al. studied SLAM for unmanned aerial vehicles to land on deck under different ocean and ship conditions, aiming to provide a solution for precise landing of unmanned aerial vehicles on offshore platforms. The project selected the ORB-SLAM3 algorithm and conducted simulation experiments using a fantasy game engine. This experiment simulated a real environment and showed that monocular vSLAM is more suitable for speed testing, while stereo cameras have higher accuracy in ATE RMSE. After loading the map, the accuracy of the monocular ORB-SLAM3 is greatly improved. So the improved monocular ORB-SLAM3 is more suitable for this project. In the future, the main task of this project is to implement it into the actual system [9].

The safety of drones needs to be considered, but of course, it is also a challenge. Often, unmanned aerial vehicles carrying out missions must land in unknown environments or emergencies (such as GPS signal loss) [10]. This is devastating for drones. A study by Yang Tao et al. used monocular SLAM combined with three-dimensional features and medium pass filters to attempt to solve this problem. This technology utilizes optical equipment to enable unmanned aerial vehicles to autonomously identify landing areas and establish three-dimensional terrain, thus achieving safe landing in positional conditions. The experiment of this project was conducted in a real environment, confirming that drones can accurately reconstruct map information, identify landing positions, reach their destination with the shortest path, and land safely after applying this technology, and have strong robustness. The application of this technology greatly reduces the economic losses of drones in emergencies and improves ground personnel's safety [10]. In addition, this technology can also collaborate with ground based mobile robots, utilizing the advantages of high cameras to provide accurate navigation routes for ground based mobile robots. This work has great potential [10].

5. Conclusion

Overall, in terms of automatic parking, SLAM technology has matured and is expected to quickly form a mature real vehicle parking system. Regarding robots, SLAM still has a lot of room for improvement, as the working environment of robots is extremely complex and the tasks that robots need to perform are also diverse. There is still a lot of room for improvement in SLAM, which is extremely important for drones and involves issues such as navigation and landing systems. In some special environments, such as areas where infectious diseases are prevalent, robots using SLAM can also play a significant role.

In summary, SLAM has an extremely wide range of applications and many advantages, playing an irreplaceable role in certain fields, such as multi robot collaboration and unmanned aerial vehicle automatic navigation. In addition, due to the research of a large number of researchers, SLAM is currently developing rapidly and has achieved many effective results that can be applied. According to the current development speed of SLAM, there is hope to achieve some new technological breakthroughs using SLAM in the future. Overall, SLAM is currently widely used in autonomous navigation, 3D modeling, AR, VR, and other fields, with relatively mature technology. This article provides a literature review on the applications of SLAM in fields such as automatic parking, robotics, and unmanned aerial vehicles. This article briefly introduces the research achievements and applications of SLAM in the past five years, provides some important data, and briefly explains the applications of SLAM in some fields. It also briefly explains some necessary improvement processes for SLAM, and summarizes the future development direction of SLAM. In the future, more devices, drones, and robots will apply SLAM, and SLAM will exist as a core technology in various devices. After integration with new sensors, SLAM technology will definitely have a greater breakthrough.

References

[1] T. Qin, T. Chen, Y. Chen and Q. Su. IROS. 5939-5945 (2021).

[2] X. Shao, L. Zhang, T. Zhang, Y. Shen and Y. Zhou. IEEE Trans Circuits Syst Video Technol32 4788-4803 (2022).

[3] A. Garulli, A. Giannitrapani, A. Rossi and A. Vicino, Proceedings of the 44th IEEE Conference on Decision and Control, 2041-2046 (2005).

[4] Z. Meng, C. Wang, Z. Han and Z. Ma, CACRE 110-116 (2020).

[5] Baofu Fang, Gaofei Mei, Xiaohui Yuan, Le Wang, Zaijun Wang, Junyang Wang, Pattern Recognition113, 107822 (2021).

[6] Y. Chang et al., IEEE Robot. Autom. Lett 7 (4). 9175 – 9182 (2021).

[7] WANG Chenjie, LUO Bin, LI Chengyuan, et al. AGCS 49 767-776 (2020).

[8] Krul, S.; Pantos, C.; Frangulea, M.; Valente, J. Drones 5 (2), 41 (2021).

[9] T. Dutrannois, T. -T. Nguyen, C. Hamesse, G. De Cubber and B. Janssens. ISMCR 1-7 (2022)

[10] Yang, T.; Li, P.; Zhang, H.; Li, J.; Li, Z. ELECTRONICS-SWITZ7, 73 (2018).