Real-Time Optical Navigation for Automated Library Services Using Mobile Robots

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Introduction

The advent of mobile robotics has opened new possibilities for automating mundane tasks, and one such application is in the realm of library services. Our research explores the potential of mobile robots to revolutionize the way libraries manage book collections and returns. By deploying robots equipped with real-time optical navigation, we can streamline the process of locating and retrieving books, as well as accurately placing returned books back on shelves.

This innovative approach leverages the Dewey Decimal Classification system, enabling robots to identify books by their spine labels and navigate through the library with precision. Our study delves into the intricacies of trajectory planning and control systems, aiming to enhance character recognition accuracy and ultimately provide a reliable redundancy for GPS-based navigation in autonomous vehicles.

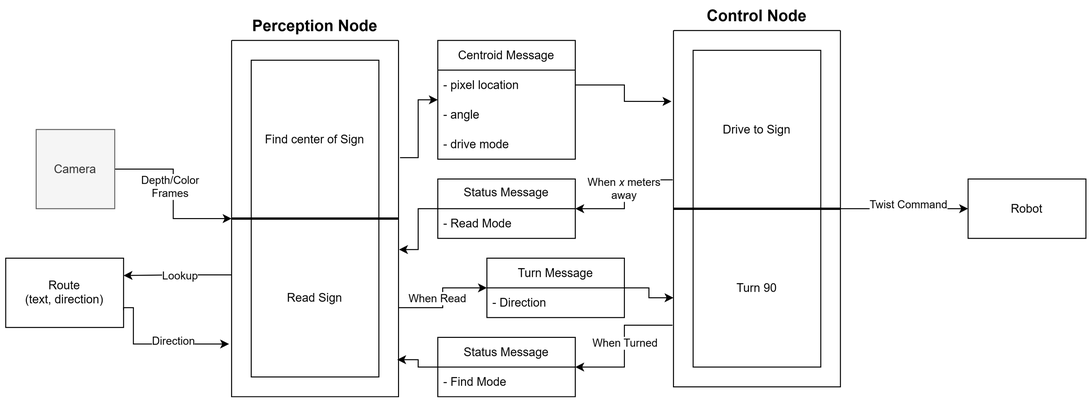
Objective

- **Autonomous Library Management:** To develop a mobile robot system capable of automating library tasks such as book collection and return, utilizing real-time optical navigation.
- **Optical Navigation System:** To integrate a camera and compute module on the Scout Mini mobile robot for identifying and retrieving books based on visual cues.
- **Trajectory Planning and Control:** To implement a control system that optimizes driving behavior for enhanced character recognition accuracy during navigation.
- **System Analysis:** To analyze the performance of the optical navigation system under various conditions and configurations to determine its reliability and efficiency.

Materials and Methods

- **Robot Platform:** Utilization of the Scout Mini mobile robot integrated with a camera and NVIDIA Jetson Orin module.
- **Software Tools:** Development of a real-time optical character recognition (OCR) pipeline using Python libraries such as OpenCV and Tesseract
- **Trajectory Planning:** Implementation of a trajectory planning and control system focused on driving behavior that enhances character recognition accuracy.
- **Testing Environment:** Construction of a test course with signs and books to simulate a library environment for navigation testing.

Current Progress



Discussion

- Our ongoing research project has made significant strides in developing an optical navigation pipeline tailored for library environments. By leveraging visual cues similar to street signs, we aim to enhance mobile robot navigation within these spaces. Although we are still in the early stages of implementing the pipeline, our progress includes successfully establishing communication with the robot via the Controller Area Network (CAN) bus and sending manual control signals via ROS (Robotic Operating System). While testing remains pending, this groundwork sets the stage for future validation and optimization. As we continue, we anticipate refining the pipeline's accuracy and robustness, ultimately contributing to more efficient and reliable autonomous library services.

Summary and Conclusions

The research conducted on real-time optical navigation for automated library services using mobile robots has demonstrated significant advancements in autonomous systems. By integrating a camera and compute module onboard the Scout Mini robot and developing a real-time optical character recognition (OCR) pipeline, the study will successfully implement a trajectory planning and control system. This system emphasizes driving behavior that enhances character recognition accuracy, enabling the robot to navigate using visual cues similar to street signs.

A constructed test course and subsequent analysis under various optical conditions will provide novel insights into the effectiveness of optical navigation. It is anticipated that the findings will suggest that optical navigation can serve as a reliable redundancy for autonomous vehicles, reducing dependency on GPS and mapping. This approach promises to improve precision in navigation instructions, offering a robust solution for both library management tasks and autonomous vehicle routing.

Future Work

As this research continues, there are several things in mind. Fully implementing the overall perception, planning, and control pipeline remains a priority. Additionally, creating a testing environment to evaluate the viability of the optical navigation approach could guide the future of the project. Furthermore, extending the application of optical navigation beyond library environments to other real-world scenarios warrants investigation

References

- Létourneau, D., Michaud, F. & Valin, JM. "Autonomous Mobile Robot That Can Read," 2004
- R. P. Júnior and M. R. Petry, "Robot Localization Through Optical Character Recognition of Signs," 2019
- S. K. Nagavi, M. S. Gothe, and P. S. Totiger, "Optical Character Recognition based Auto Navigation of Robot by Reading Signboard," 2015
- H. Lu, B. Guo, J. Liu and X. Yan, "A shadow removal method for tesseract text recognition," 2017
- H. N. Alim, N. Tamami and A. H. Alasiry, "Automated Library System Mobile Robot using A-Star Algorithms," 2022

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