Simulation and Real Time Implementation of Visual SLAM in an Indoor Environment Using a Quadcopter

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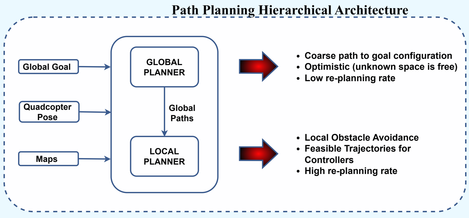
Introduction

This project focuses on the simulation and real-time implementation of a visual Simultaneous Localization and Mapping (SLAM) algorithm in an indoor environment using a quadcopter. The system integrates a variety of modern technologies including the Intel RealSense D435 depth camera for vision, a Raspberry Pi 4 for onboard processing of data, and a Pixhawk 4 for flight control. The project aims to address the challenges of autonomous navigation in GPS-denied spaces by enabling the quadcopter to map its surroundings and determine its position in real time. The SLAM algorithm, RTAB-Map is first tested and refined in a simulated environment using Gazebo and ROS to ensure its robustness and accuracy before being deployed in a realworld indoor setting. The use of the Intel RealSense D435 enhances the quadcopter's capability to generate detailed 3D maps, while the Raspberry Pi 4 processes the complex SLAM computations. The project successfully implemented RTAB-Map on a quadcopter with a Raspberry Pi 4B companion computer. Autonomous navigation and obstacle avoidance using the A* algorithm was also achieved on the map. This implementation resulted in 2D grid and 3D point clouds maps of the environment with minimal deviations between generated and estimated trajectories. This project demonstrates the feasibility and effectiveness of using a low-cost, off-the-shelf components and opensource software to achieve autonomous navigation, contributing to the development of more efficient UAV systems for indoor applications.

Figure: Path planning(left) and quadcopter assembly(right)

SLAM and Path Planning

- SLAM enables the quadcopter to navigate and map indoor environments autonomously.
- RTAB-Map is used for real-time, graph-based SLAM.
- Path planning ensures a collision-free route to the destination.
- Combines global and local planners for obstacle avoidance.
- Real-time processing allows quick updates to changing environments.



Methodology

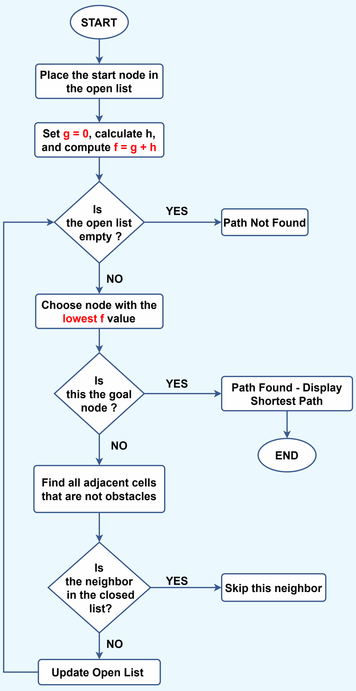


Figure: A* algorithm flowchart

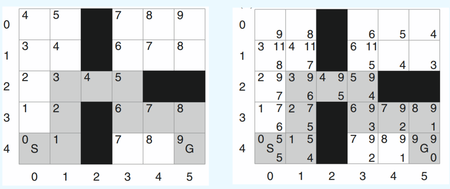
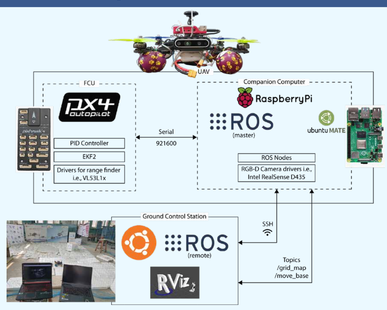


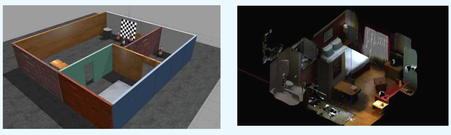
Figure: Grid Cell Map for A* algorithm

System Overview

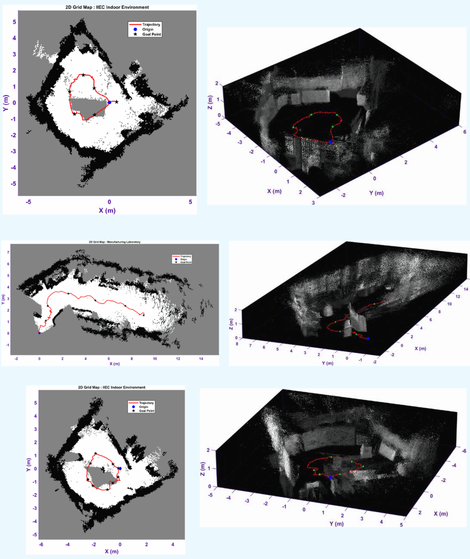


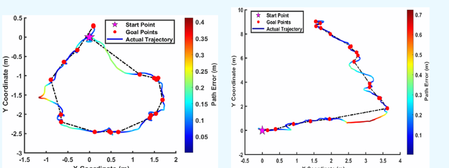
Real world environments

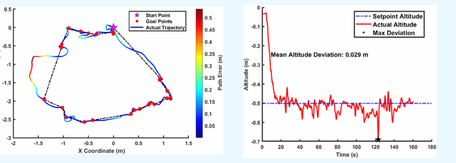
Simulation environments



Flight Tests and Results







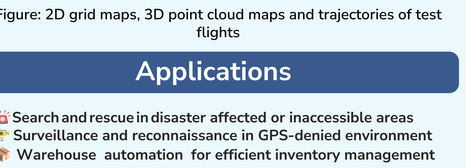


Figure: 2D grid maps, 3D point cloud maps and trajectories of test flights

Applications

- Search and rescue in disaster affected or inaccessible areas
- Surveillance and reconnaissance in GPS-denied environment
- Warehouse automation for efficient inventory management
- Exploration of confined or hazardous spaces like caves and collapsed structures

Conclusion

- SLAM successfully generated accurate 3D maps for reliable localization.
- Integration of SLAM and path planning enabled effective obstacle avoidance.
- 2D path planning showed limitations in complex environments.
- Indoor navigation was robust; outdoor testing validated system performance.

Flight Test Videos