Improved Ground Robot Indoor Autonomous Navigation with MAV

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Introduction

Navigation is a basic skill for autonomous robots to perform tasks without human involvement. This project builds a system consists of a ground robot equipped with a laser sensor and a Micro Aerial Vehicle (MAV) equipped with a stereo camera. The commonly used navigation stack and gmapping algorithm are run on the ground robot. My goal is to test if the MAV can improve the performance of the navigation stack. Library-like test environments are designed to test and analyze the performance of the system.

Navigation Stack

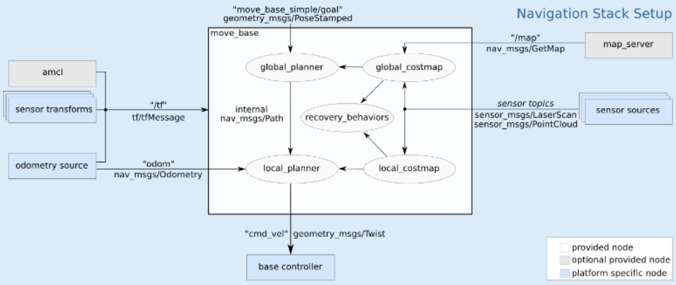

Fig 1: Navigation Stack Setup

The navigation stack is a commonly used package for ground robot to do path-planning and navigate. It takes in information from odometry and sensor streams and outputs velocity commands to send to a mobile base.

ORB detector

Oriented FAST and Rotated BRIEF (ORB) detector extracts feature points from images, it combines the advantages of Features from Accelerated Segment Test (FAST) detector and Binary Robust Independent Elementary Features (BRIEF) descriptor, which is fast, high recognitive rate and high tolerance to rotation. Besides, it only requires limited computation power, which makes it suitable to run on an MAV.

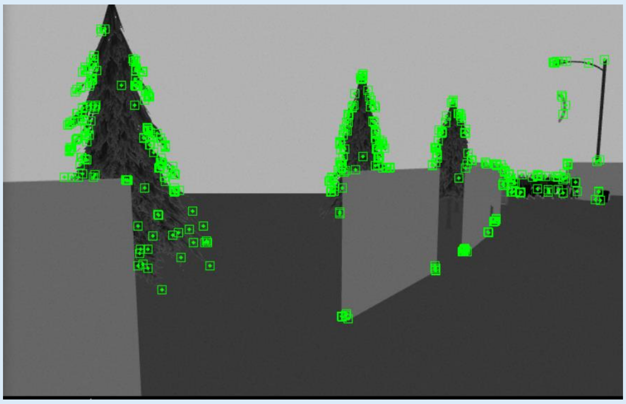

Fig 2: Feature points extracted by the ORB detector

Robot Operating System

The Robot Operating System (ROS) is a flexible framework for writing robot software. It is a collection of tools, libraries, and conventions that aim to simplify the task of creating complex and robust robot behavior across a wide variety of robotic platforms. This whole project is built on ROS nodes and topics. Popular applications like Gazebo and Rviz are used to visualize and conduct system tests.

Cost Map

2D layered Cost Map is an important component of the navigation stack and the key to fuse observations from the laser sensor and the stereo camera. A new layer is created to mark obstacles observed by the MAV.
As demonstrated in Fig 3, the MAV and the stereo camera are able to detect obstacles which cannot be observed by the onboard laser sensor.

Fig 3: Black points behind the wall is obstacles observed bv the MAV

Gazebo Environment

All tests are run in the Gazebo Simulation Environment. The environments are designed based on librarian scenario. The environment shown in Fig 4 is the basic one. Changes are made to make it more complicated. The start and goal points are the same. By comparing the performance of the robot navigation with or without the MAV, we can see to what extent the MAV improves the performance of the navigation stack.

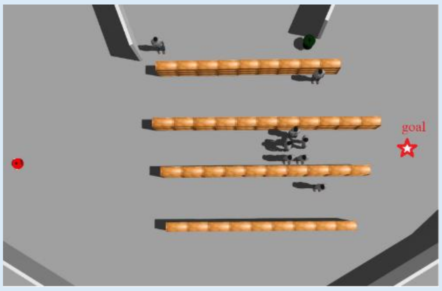

Fig 4: Test Environment

Demonstration

The experimental results show that the MAV provides information that is complementary to the detection from the onboard laser sensor, enables the navigation stack to do path-planning with a better knowledge of the environment without fully mapping the whole environment.

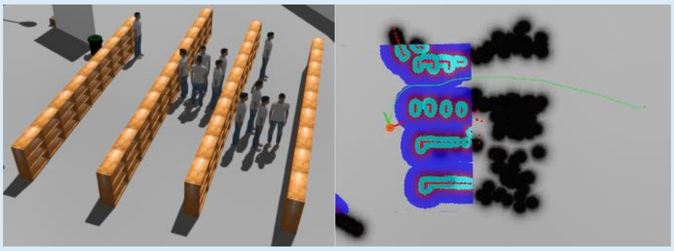

Fig 5: Better path-planning based on MAV observation.

In addition, dynamic environment with two walking people (actors) is also tested, which shows that the system is capable of working in a dynamic environment, which makes it promising to be deployed in a real environment.

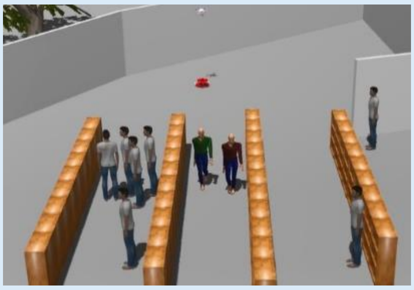

Fig 6: actors in the environment