Team Technical Paper

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ABSTRACT

This paper describes our aerial robot, including the mechanical system, hardware system and software system. This robot is designed to be an autonomous robot for robot herding tasks, capable of navigating using visual information and finishing different tasks, mainly following the rules of IARC 2018. This paper introduces both the hardware design of the robot and the algorithms we have proposed and implemented.

INTRODUCTION

Statement of the problem

For the task stated by rulebook, our aerial robot needs to interact with ground robots, and navigate in an environment without external navigation aids. In detail, aerial robot has to physically have contact with ground robots, find a way to herd all of them to the green line, and use onboard sensors to perform navigation.

Conceptual solution to solve the problem

First and foremost, a robust aerial robot is needed. Being able to fly safely and smoothly is the basis for further maneuvers.

In order to do indoor navigation without GPS, we naturallycome to the idea of using visual information. A camera could be a good example. By recognizing the lines on the ground, aerial robot could count the number of lines it has crossed to get its position.

As far as interaction with ground robots is concerned, we first have to recognize them, also by camera. Then a planner must be designed to design the route and maneuvers for aerial robot to perform the action of herding.

Figure of overall system architecture

Shown in figure 1 is the overall system architecture. On the bottom are the input sensors and hardware, including sensor to detect vertical obstacles, flight control firmware and camera for navigation and ground object recognition. Up a layer are the drivers for the hardware, and pre-processing of data.

We use ROS for the system. flight control firmware is accessed by ROS through mavlink. Other sensors have corresponding packages from ROS. Both image and flight control information are used to calculate the optic flow, which is used to determine the position of aerial robot.

Onthe top layer, we have local costmap to do navigation, and SMACH for complex task planning.

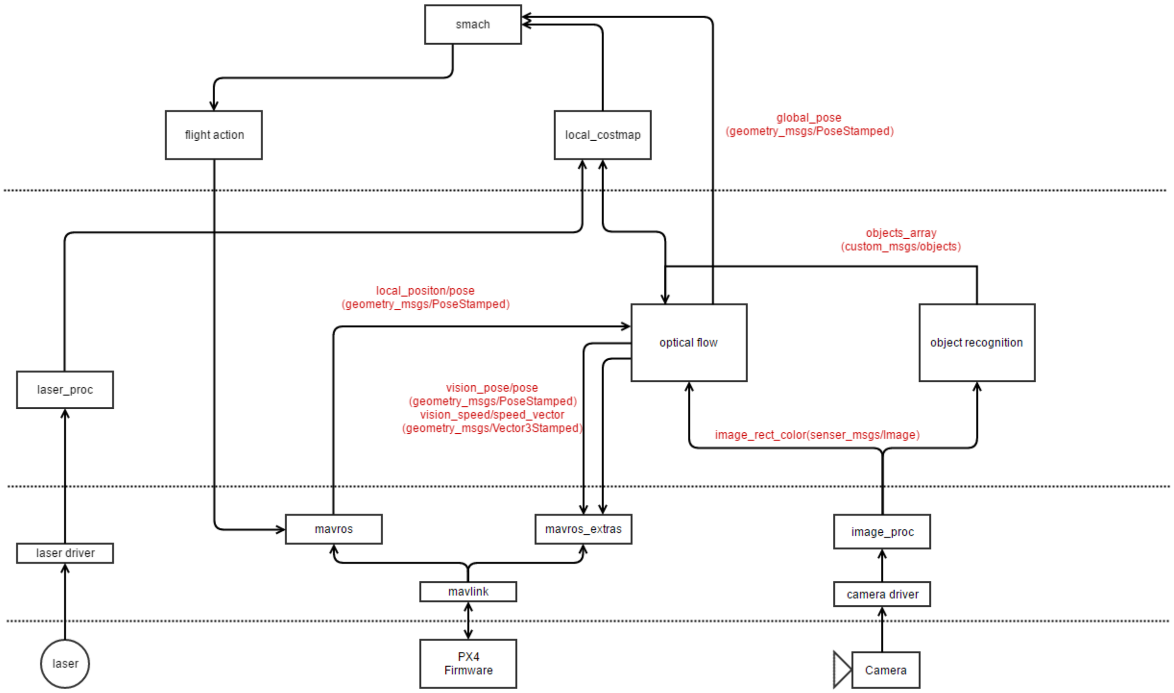

Figure 1. Retrieval mechanism solenoidconfiguration.

AIR VEHICLE

Propulsion and Lift System

We useDJI M100 as hardware platform. It is a quadcopter equipped with DJI 3510 motors and DJI 1345s propellers.

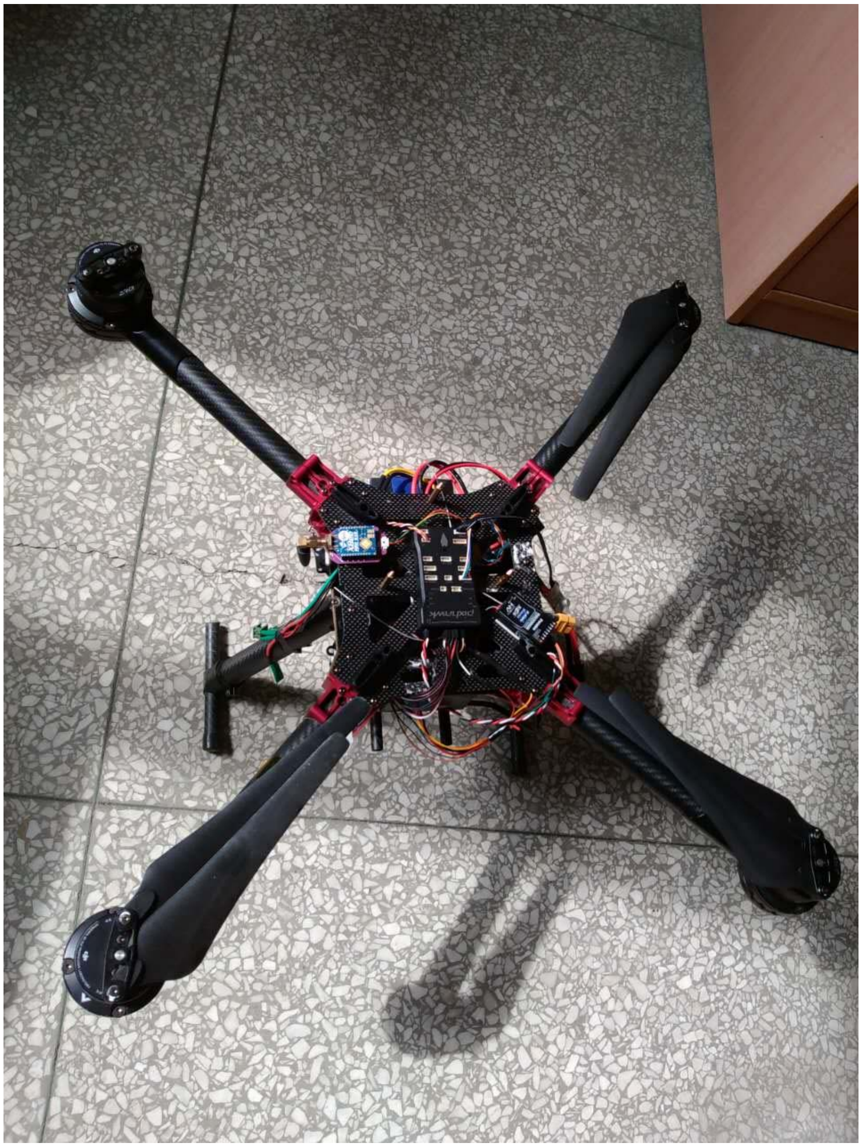

Figure 2. Flight platform of THBOT

Guidance, Nav. And Control

Control of aerial robot is done by N1 flight control system. Guidance and navigation is done by processing image acquired by onboard camera and ultrasonic sensors.

Hough Transform and corner detection are adopted for guidance. Navigation is done by using sensors to build a cost-map and then decide which way to go.

OPERATIONS

Environment Awareness

The aerial robot has to be aware of its position and the position of ground objects. These information are calculated by using only visual information. Robot's own position is estimated by the navigation system. And ground object recognition is done by color blob detection. In addition, once color blobs are identified, a mask is immediately imposed on the original image before feeding it to the navigation system. By using this measure, the chance of error in navigation is greatly reduced.

Collision avoidance sensors also come into play for environment awareness. Ultrasonic sensors constantly check for obstacles in all four directions, making sure aerial robot will not hit any of the vertical cylinders moving in the arena.

Flight Plan

Planning was first done in matlab environment, using Simulink 3D Animation. Different strategies are tested on this platform.

The algorithm first detect the velocity direction of each ground robot in sight. Then it decides whether to interfere their movement or not. A loss function is proposed to determine the likelihood of each ground robot getting to the green line by itself. Then the one with over threshold loss value will be assigned as the one aerial robot will have interaction with. After the maneuver is done, another round of analyzing and planning continues.

RISK REDUCTION

Vehicle Status

Our aerial robot is equipped with shock absorber in each support leg, reducing the impact of taking off and landing. Flight control module is mounted through a rubber mounting device, which damps the vibration. On board camera is fixed to a 2D gimbal to get stabilized and sharp images.

Modeling and Simulation

Huge amount of testsare done by software simulations. Since ROS is highly compatible with simulation software Gazebo, we established a simulation environment in Gazebo, and run tests on it. Ground robots are abstracted as round cylinders. Both ground robots and vertical obstacles' moving behaviors are programmed to match the description in the notebook. Ground texture is added in order for navigation to perform normally.

After thorough test in the simulation environment, we bring the whole system to the real world to validate the effectiveness of our system.

CONCLUSION

Aswe have introduced in the above sections, our aerial robot is a quadcopter equipped with complete set of guidance, navigation and flight control system, 5-direction ultrasound sensors and cameras. We developed, implemented and adopted algorithms for localization and object recognition. With such efforts, the aerial robot becomes intelligent and is capable of completing sensing and avoiding maneuvers.

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