CAUC's Aerial Robot for IARC 2015

Lu Huo, Yongzheng Shi, Long Zhao, Yunhao Zhang, Nan Jiang,

Xiaoli Wang, Zeyan Yan

Civil Aviation University of China

ABSTRACT

In this paper, the technical details of a Quadrotor system are presented, and it can avoid the obstacles to make ground robots attain the desired position, without rely on any external navigation aids. The navigation system is composed of a small computer and some sensors. We obtain absolute position estimation by a monocular visual odometry framework. A motion detector is introduced to implement rapid tracking. Furthermore, we build a motion predicting model to find strategy of tracking and interception.

I. INTRODUCTION

Quadrotor aerial robots have extensive application prospects because of its small size, stable flight, strong maneuverability and the ability of taking off, hovering, flying and landing in a restricted area. At present, the quadrotor aerial robots have been applied in many fields such as power line patrol, territory exploration, flood relief, forest fire prevention, and have been a hotspot in UAV research[1,2]. Indoor complex environment is an enormous challenge to the autonomous navigation of quadrotor aerial robots, which is mostly solved by global positioning equipments like VICON. The improvement of sensor technology, especially the development of MEMS devices, the improvement of microprocessors and power devices, the application of new material and the increasing of battery life, provide necessary hardware support for the development of quadrotor[3]. To complete the 7th mission of the International Aerial Robotics competition, a quadrotor aerial robot is designed, and the technological details are introduced in this paper.

A. Statement of the Problem

Mission 7 will challenge teams to demonstrate three new behaviors that have never been attempted in any of the past six IARC missions. First, aerial robot should interact with moving autonomous ground robots. Second, the aerial robot should navigate in a sterile environment with no external navigation aids such as GPS or large stationary points of reference such as walls. Third, the aerial robot should compete with the other autonomous air vehicles.

The 7th mission of the International Aerial Robotics competition requires aerial robot which avoid the obstacles to make the number of ground robots attain the green line in Fig1.1 as much as possible. The whole process should be limited to 10 minutes. Vehicles must be unmanned and autonomous. They must compete based on their ability to sense the environment of the competition arena. The size of any aerial robot shall be limited to 1.25 meters in any dimension. There is no weight limit.

B. Conceptual Solution

To accomplish this mission, an aircraft is made all by ourselves firstly. The PID algorithm is used to control the roll, pitch, yaw and height and the results shows the navigation requirement can be perfectly satisfied. The aircraft is equipped with one laser range finder, tow cameras. The range finder is used to measure the distance between the aircraft and robot with tall cylinder extending vertically from their upper surface. The bottom camera is mainly used to search the target ground robots and navigate for the aerial robot.

C. Yearly Milestones

This is the third time for the CAUC team to participate in IARC. The aircraft is designed to complete the 7th mission and it will have the ability to navigate and explore the whole environment, detect the target ground robots and avoid the robot with tall cylinder. This year we have improved the design of the navigation system and tracking algorithm and optimized control strategy by a motion predicting model. The MAV has realized many functions, such as identifying and tracking the target ground robots, avoiding obstacles and so on.

II. Air Vehicle

A. Aerial Platform

The platform is made by carbon fiber to lower the weight . The basic structure of the platform is shown in Fig 2.1.

Fig2.1 Basic structure of the platform

There are three major systems: the propulsion system, the flight control system and the navigation system, as shown in Fig 2.2.

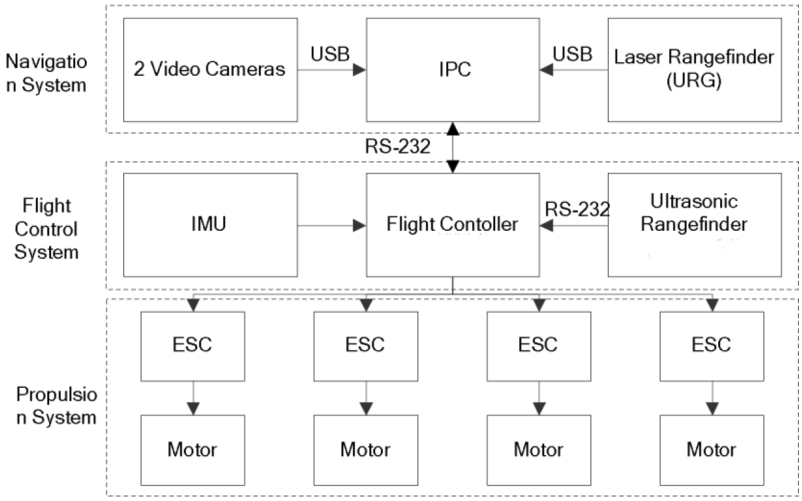


Fig2.2System hardware structure

B. Propulsion and Lift System

The propulsion system provides power for the platform. It consists of four Xaircraft 2215 brushless DC motors (Fig 2.3) and matching propellers. Four ESCs (Electronic Speed Controller) are used to control the speed of the motors. The ESCs transform the PWM signal to alternating voltage signal, which controls the speed of the DC motors.

All the electrical power supply is from a rechargeable lithium battery of 4000mAh, which meets the requirement of the task.

Fig2.3 Xaircraft 2215 brushless DC motor

C. Flight Control System

An open source flight control *PIXHAWK* autopilot is used. Considering the coupling of the system, a double loop PID[4] control method is adopted. The inner loop controls the attitude, i.e. the rotation angle. The outer loop controls the displacement, i.e. the location x y z.

D. Navigation System and Control

The key issues of this mission are the navigation and strategy for the UAV. The hardware of the navigation system is based on an inter IPC, which is equipped with Core i5 processor, and a URG laser range finder and a camera. The IPC is used to process the data from laser and cameras and then transform the results to the flight control system; at the same time, it also monitors the attitude of the aircraft. The navigation system communicates with the flight control system though serial port, by sending the commands in string format.

The laser range finder is used for self-localization, obstacle avoidance and path planning of the aircraft. As the map is mostly given, a grid map is drawn as an indication of indoor environment and then laser is used to acquire environment data.

With the down-forward camera, a visual odometry algorithm based on landmarks is proposed to MAV state-estimation. We recognize linear intersections through camera as landmarks. Navigation system fused the navigation from artificial landmarks with IMU data through the EKF.

In order to track the objects, the edge and color features of objects [5-6] have been integrated and combined with the algorithm of phash [7] object detection based on perceptual algorithm on the foundation of Camshift. The tracking algorithm process is illustrated in Fig2.4.

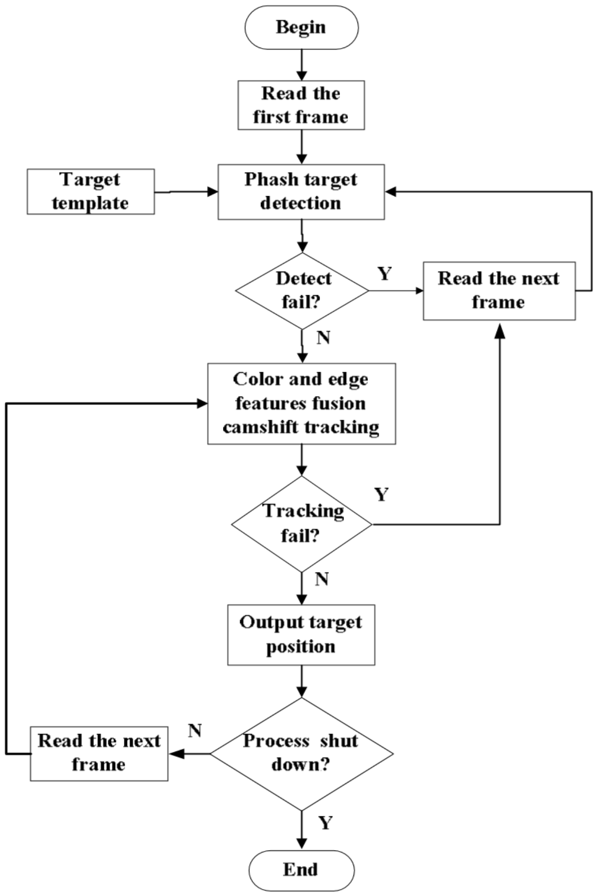


Fig2.4 Ground target tracking algorithm

In the first frame, Phash target detection algorithm is utilized to scan the entire window, calculate the Hash code of each scan window, comparing them with the Hash code of the target template to get hamming distances. The window, whose hamming distances is the minimum distance and less than 5, is the target window, used as the initialization window of Camshift tracker which based on edge and color features fusion for target tracking. It will restart Phash detector to regain the tracking target if tracking is fail.

A control strategy based on application of decision tree ID3 algorithm was proposed to implement multi-moving targets tracking control on the ground.

E. Flight Termination System

An IARC common kill switch is necessary for safety. It provides a simple and effective means of killing power to the motors through the use of a separate radio control receiver. When quadrotor loses control, the operator can take over the flying quadrotor through RC or just press the kill button.

III. Payload

A. Sensors

A laser range finder and a camera are mainly used to offer the navigation information. The laser range finder used is the Hokuyo URG-04LX-UG01. It is capable of measuring distances up to 4m and has a maximum detection area of 240 degrees, with a resolution of 1mm and 0.31 degrees respectively.

B. Communications

The onboard IPC and the flight controller communicate via usb interface. The IPC also has a wireless LAN through which it can communicate with a ground station computer, on which the status of the vehicle can be monitored.

IV. Operations

A. Flight Preparations

A pre-flight checklist has been developed in order to ensure the security of the pilot and potential bystanders.

1) Setup the Ground Control Station, make sure all devices work properly.
2) Check Wi-Fi transceiver connection.
3) Turn on the transmitter and make sure all buttons are set to the right position.
4) Program the UAV with the latest stable code.
5) Do a small test to check if the quadrotor is ready to fly.
6) Check the IPC and run the necessary software.

B. Man/Machine Interface(MMI)

This MMI system is composed of Remote Controller for manual mode and Control Station in Navigation System for autonomous system.

The WFT07 Remote Controller produced by the company of WFLY is used to let the aircraft fly manually and then change into the autonomous mode. When an emergency happens, it can also be used to stop the aircraft.

The Control Station has the ability of monitoring, communication setting and so on. The monitoring interface is capable of displaying the real-time state of the quadrotor including attitude, heading, altitude and location. The whole flight can be easily monitored from the pre-taking-off phase to the final landing.

V. Risk Reduction

A. Vehicle Status Monitoring

The ground station computer communicates with the IPC via wireless network, on which we can easily monitor the status of the vehicle. All mouse movements and keyboard signals are transferred from the local computer (ground station computer) directly to the remote computer (IPC) over the network (via LAN or Internet), relaying the graphical screen updates back in the other direction.

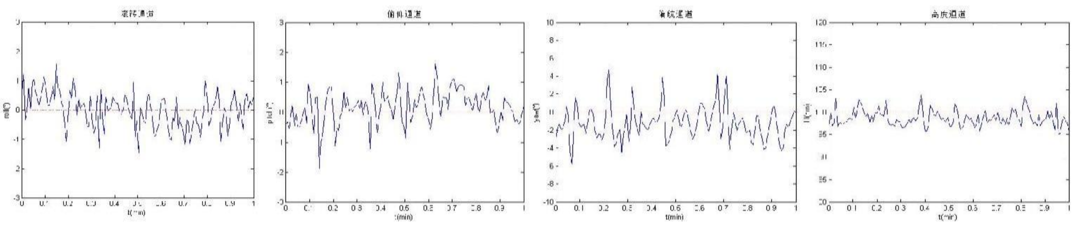
B. Safety to Bystanders

The protecting frame shown in fig 5.1 helps protect the vehicle as well as the bystanders, facilities and equipments around. It is made by carbon fiber, which is strong enough to protect the vehicle and people without adding too much weight to the platform.

Fig5.1 protecting frame

C. Simulation and Testing

The environment similar to the real environment of the mission is built and the aircraft is tested in it. Attitude control and position control have been finished and the data is obtained during the tests and are shown in fig5.2.



(a)Roll (b)Pitch (c)Yaw (d)Height

Fig5.2 Attitude control results

Test of Localization and Detection: we set a series of way points as targets, the MAV can fly following the way stably. Furthermore, the tracking ground targets test result is shown in fig5.3 and fig 5.4

Fig5.3 The experiment of tracking ground targets

Fig5.4 The experiment of tracking ground target

Control strategy simulation: Motion of ground robots and obstacles in the venue are simulated to test the control strategy. The simulation scene is shown in fig5.5

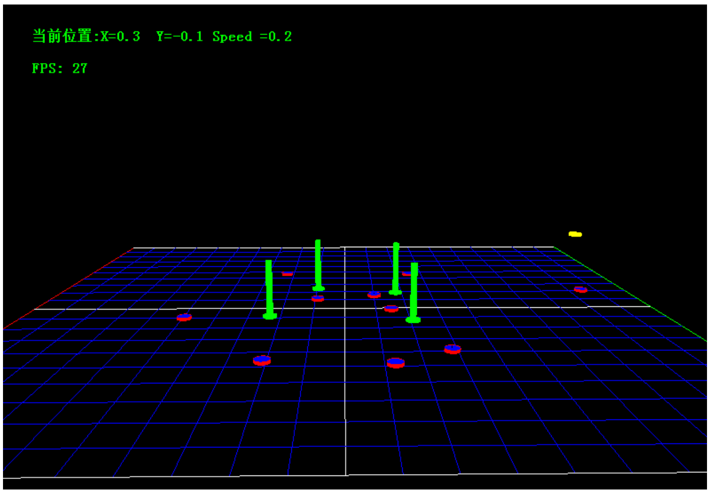


Figure 5.5. The simulation scene

VI. Conclusion

In this paper, the technical details of a quadrotor system are presented, and it can avoid the obstacles to make ground robots attain the desired position, without rely on any external navigation aids. The quadrotor platform with three subsystems is developed. The information from the laser range finder and ultrasonic range finder is used to perceive the environment. Two video cameras are mounted on the vehicle, which are used to detect specific targets. So far, Control architecture development have been finished, corresponding test and simulation are currently in progress.

Acknowledgments

The Civil Aviation University of China Aerial Robotics team wishes to thank Dr. GAO Qingji, HU Dandan , NIU Guochen ,WANG Xuqiao and many other students for valuable contributions.

References

[1] ZHAN Lei, HE Renqing, XIE Yang, LONG Yan. Intelligent navigation system based on four-rotor micro UAV[J]. Electronic Measurement Technology. 2011,34(6):1-3.

[2] WANG Xu. The key technologies of the four-rotor aerial vehicle in the transmission line inspection[D]. Baoding: School of Electrical & Electronic Engineering, 2011.03.

[3] YANG Yungao, XIAN Bin, YIN Qiang, LI Haotao, ZENG Wei. Current Research Situation of Frameworks and Control of Quadrotor Unmanned Aerial Vehicles[C]. Proceedings of the 30th Chinese Control Conference. July 22-24, 2011, Yantai, China.

[4] Samir Bouabdallah, Andre Noth, Roland Siegwart. PID vs LQ control techniques applied to an indoor micro quadrotor[C]. Proc of the 2005 IEEE International Conf on Robotics and Automation. Barcelona, Spain:ICAR'05.2005.

[5] Yuan S, Li J H, Han J. An Adaptive Target Tracking Algorithm Based on Multi-Feature Fusion[C]//Biomedical Engineering and Computer Science (ICBECS), 2010 International Conference on. IEEE, 2010: 1-4.

[6] Zhou Z, Wu D, Peng X, et al. Object Tracking Based on Camshift with Multi-feature Fusion[J]. Journal of Software, 2014, 9(1): 147-153.

[7] Wu D, Zhou X, Niu X. A novel image hash algorithm resistant to print–scan[J]. Signal processing, 2009, 89(12): 2415-2424.