Unmanned Hexrcopter of NUAA for 2018 International Aerial Robotics Competition

Wei zhiaqiang, Li Jiahuan, Yang Tiankai,Liu Yu
Nanjing University of Aeronautics and Astronautics

ABSTRACT

This paper briefly introduce the strategy of NUAA team for the 2018 International Aerial Robotics Competition. We describe a complete system which contains: air vehicle, flight control system, vision navigation system, obstacle-avoidance system and communication part. For complete this task, we focus on the visual navigation, vision technology is elaborated in this paper. Moreover, flight control system used for this competition is researched and development totally by ourselves. The precautions for the operations of hexrcopter are also described in detail.

1. INTRODUCTION

1.1 Statement of The Problem

The competition environment of Mission 7 of IARC is a square arena marked on the ground in an indoor GPS-free area. This square arena is 20 meters on each side. Ten iRobot Create programmable ground robots that placed at the center of the area begin to move toward the boundaries of the arena when the run begins. And four robots with tall cylinders extending vertically from their upper surface are placed on the ground. The job of the autonomous aerial robot is to analyze the directions of the various ground robots and redirect them toward the green side of the arena such that as many as possible cross over the green line. Aerial robots should also use its sense and avoid technologies to avoid moving vertical obstacles. Aerial robots must stay within the boundaries of the arena, but are allowed to go up to approximately two meters outside the boundary momentarily for up to 5 seconds. Based on the mission, the control process is divided into three critical stages. Stage 1:When the unmanned hexrcopter autonomously takes off, it should keep a certain height and determine the position and motional tendency of ground robots. Stage 2: Hexrcopter is required to lock target to control and make a control strategy. Stage 3: Hexrcopter is required to avoid moving vertical obstacles and herd the target toward the green side. Hexrcopter should repeat above processes until all of the ground robots go out of bounds of the arena or the time runs out.

1.2 Conceptual Solution to Solve The Problem

To complete the challenge, we have integrated the flight control, computer vision, radar obstacle avoidance system and mission-decision system to solve the problem. Vision system finds the targets by contour matching and color recognition, makes the judgment of whether the hexrcopter out of boundary or not by using histogram matching, and obtains the velocity value via optical flow. Obstacle avoidance system determines the position information of the obstacle relative to the aerobot, including the angle and distance by the radar. Mission-decision system is responsible for the optimization of mission execution. All information is finally handled and executed by the flight control system.The overall system architecture is shown in Figure 1.

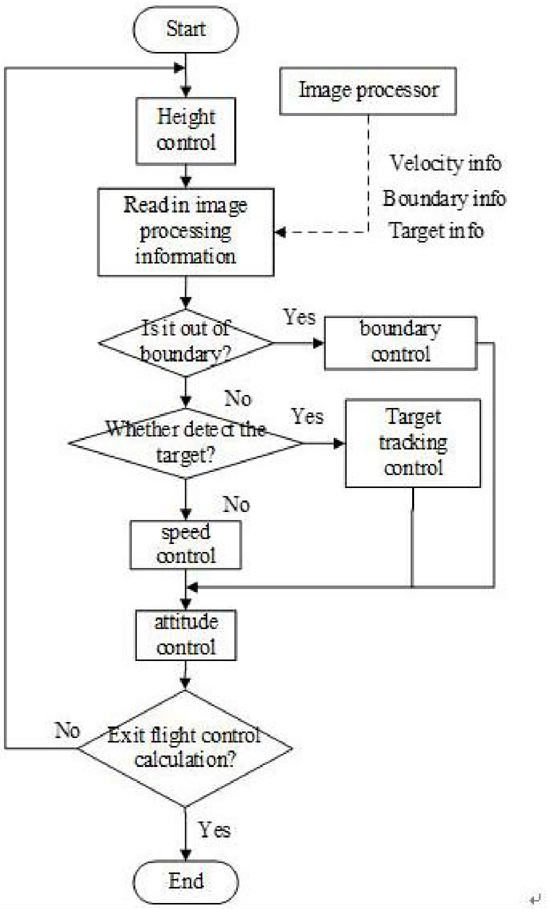

Figure 1.Overall System Architecture

1.3 Yearly Milestones

In 2014 we won the Best System Integration Award and Most Innovation Design Award. In 2015 we won the Best System Navigation Award. In 2016 we won the Most Innovative Design Award again.And in 2017 we won the Third Prize

2. AIR VEHICLE

2.1 Propulsion and Lift System

Propulsion and lift system of hexrcopter includes brushless motors, electronic governors, propellers and dynamical power. The system determines the maximum load capacity, endurance and mobility. Considering the hexrcopter with a load capacity more than 4Kg and an endurance time more than 10 min, we choose T-motor 4014 as brushless motors, with propellers （1445） and lithium battery(10 000mAh 25C 22.2V). The parameters of LangyuV3508 KV700 is shown in table1. Due to the above configurations, and the load currency is 14.1A when the throttle is 100%, our team uses Hobbywing30A as electronic governors. From table1, when the throttle is 65%, the pull is 710g， which means all of motors can provide lift with 2.84Kg. Therefore, this design meets the need of load capacity.

TABLE1. PARAMETERS OF MOTORS

Propeller(inch)	APC 12×3.8				
Voltage (V)	14.8				
Throttle	50%	65%	75%	85%	100%
Load-Currency(A)	2.5	4.5	8.3	10.6	14.1
Pull(g)	480	71	1020	1140	1360
Load(RPM/ Min)	5065	5742	6870	7305	7910
Power(W)	37	66.	122.84	156.88	208.68
Efficiency/w	12.9729297	10.66066	8.303484207	7.266700663	6.517155453

2.2 Guidance, Nav and Control

2.2.1 Stability Augmentation System

Attitude control is divided into two kinds of control， such as attitude holding and attitude tracking l, which the difference is decided by expected attitude input. The attitude holding is that the expected attitude is same with the input value and keep unchanged; otherwise, that's the attitude tracking control. The control block diagram is shown in Figure 2.

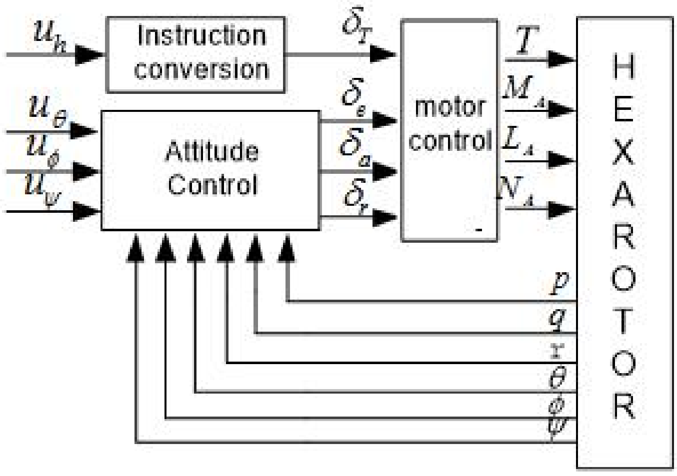

Figure2. Attitude Control Block

The detail of Attitude Control is shown in the Figure3.Attitude control using two-stage PID control, including rolling, pitch, heading three channel control law design.

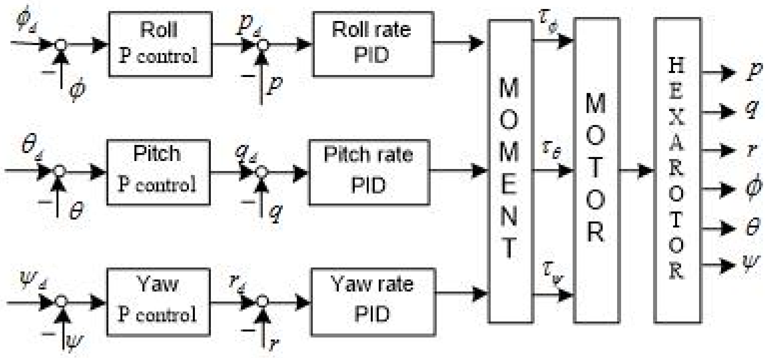

Figure3. The Detail of Attitude Control Block

2.2.2 Navigation

This task is done indoors, GPS is not available. Instead, we choose optical flow for visual navigation.

When the external world is projected onto the image plane of a camera, the movements of each point in this plane define the so-called motion field, from which information about the self-motion of the camera or about the structure of the scene can be inferred. When such movements are sampled, by means of a video stream for instance, the apparent motion of pixels in the image constitutes the optic flow, which is a convenient approximation of the motion field if the intensity of each pixel is preserved from one frame to the next. Several varieties of algorithm can be used to compute optic flow, differential methods call upon spatial temporal intensity derivatives, frequency-based methods use velocity-tuned filters in the Fourier domain, Correlation approaches rely on feature matching.

Optic flow is the apparent motion of image brightness patterns. Each pixel in the image could be assigned by a velocity vector in the motion field. Also, each pixel in the image plane could be matched with its own unique points in 3D environment. Figure4 shows the schematic of optic flow field and motion field.

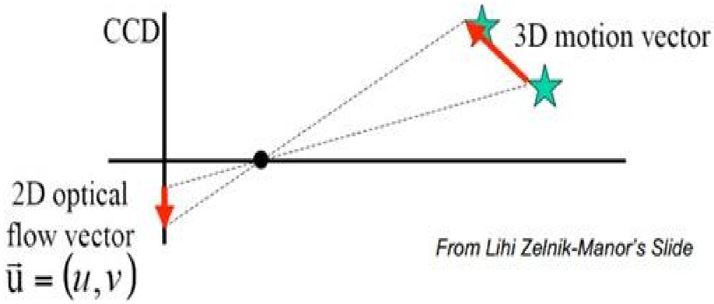

Figure4.Sketch Diagram of Optic Flow Field and Motion Field

The basic principles of optical flow method to detect moving objects are: give a velocity vector to each pixel of the image, which formed an image stadium. At a particular moment of movement, points on the image and points on three-dimensional objects correspondence.This correspondence can be obtained by projected relations. Therefore according to the characteristics of the velocity vector of each pixel, we can analysis the image dynamically.

2.2.3 Control System Architecture

An unmanned hexrcopter includes the following sensors: battery module, barometer(MS5611),ultrasonic sensor, AHRS(MTI-300),SD card, ground station, radio module ,receiver, mini PC, camera ladar, kill switch, electronic governors, brushless DC motors. The figure of control system architecture is shown figure 5.

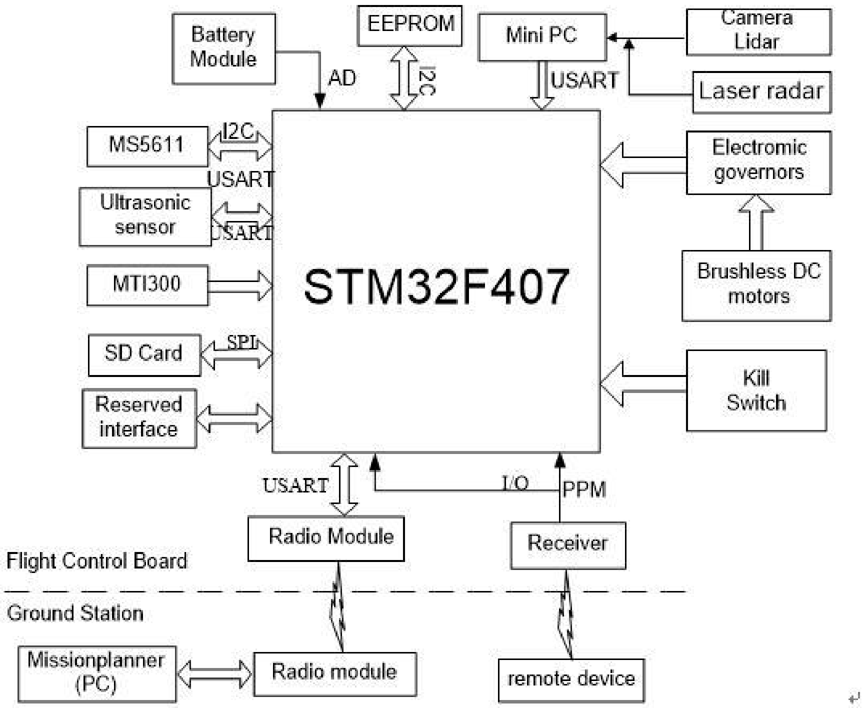

Figure5.Control System Architecture(Hardware)

3. PAYLOAD

3.1 Sensor Suite

3.1.1 GNC Sensors

In this competition, our GNC sensors include: camera, laser radar (UTM30LX), ultrasonic. Camera used to collect image information; LIDAR can get around the distance and angle; ultrasonic used to measure the height of UAV.

3.1.2 Mission Sensor

➢ Target Identification

Target Identification was performed by combining the color matching and contour matching. Convert the image into HSV space and perform red and green recognition. Add contour feature matching on the basis of color extraction to improve the accuracy of moving target detection. The figure of target identification is shown figure 6 .

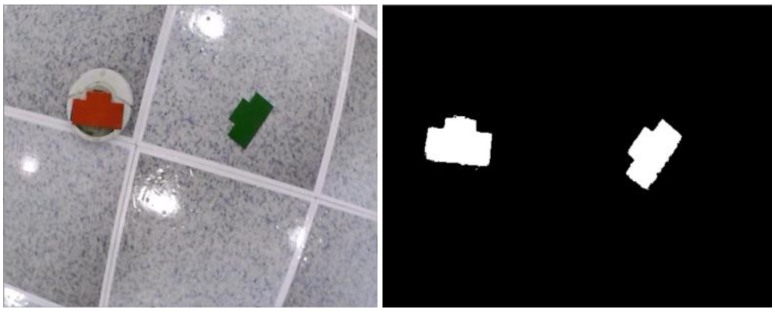

Figure6.Target Identification

➢ Boundary judgment

UAV must fly within the specified space, out of the boundary in a certain time is considered a foul. Whether out of boundary is judged by the vision. We collect the arena template and calculate the grayscale histogram in advance, compare each frame with the histogram of the template. There is an obvious distinct between template gray histogram and images which out of the boundary. As is shown in Figure7， the red curve stands for template histogram while the green curve represent the boundary image.

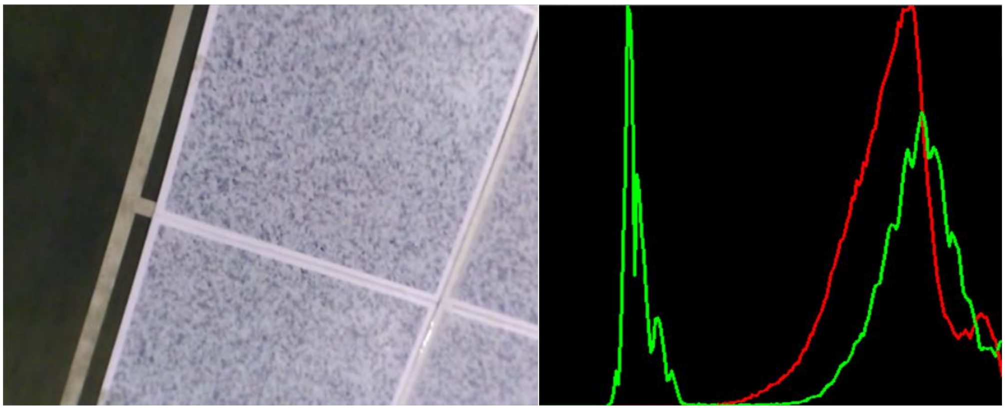

Figure7.Boundary Image and Grayscale Histogram

➢ Threat Avoidance

We use laser radar to avoid obstacles. As is shown in Figure8, the red area shows a closer distance from the obstacle, it is a dangerous area. And the green area is safe one. Laser radar can obtain the angle and distance of obstacles. Flight control system calculate the desired roll and pitch to avoid obstacles.

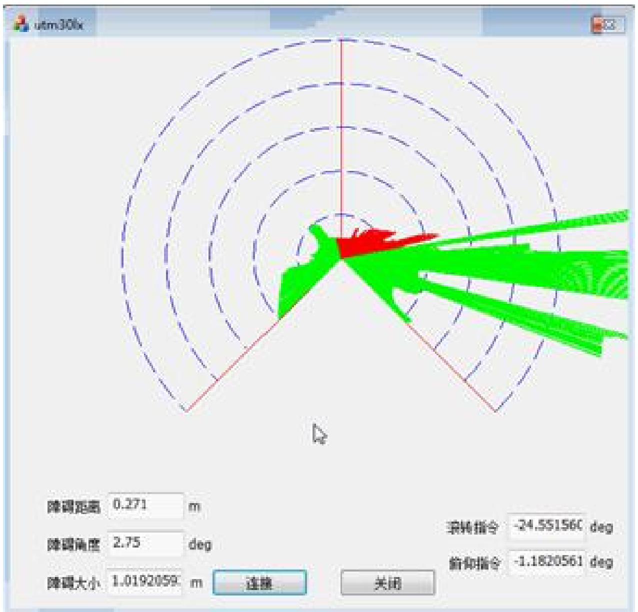

Figure8.Laser Radar Obstruction

3.2 Communications

For the communication between the flight control system and the ground station, our team uses the 3DR data transmission module which supports UART communication for wireless data transmission.It is the only remote control of the ArduCopter flight, and its control range directly determines the radius of the flight.3DR data transmission module transmission frequency of 433 kHz, outdoor maximum transmission distance of 700m. The material object of 3DR is shown in figure9.

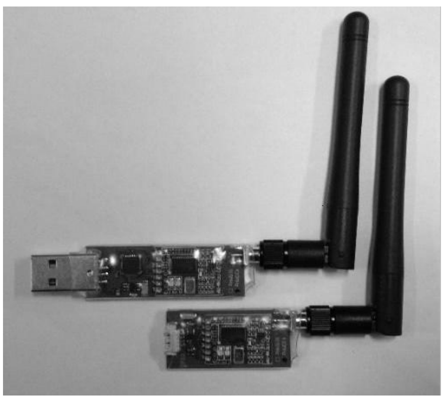

Figure9.Material Object of 3DR

3.3 Power Management System

This article uses lithium battery-powered, battery power in the flight process continues to consume. If you do not monitor the power supply, not only will cause the lithium battery over discharge, but also may cause multi-rotor UAV crash. In this paper, the low-voltage protection control function is added to the flight control system, and low-voltage alarm information is sent to the ground station. Through the AD interface to collect power battery voltage to determine the remaining battery power, the main controller to send low-voltage warning message to the ground station. The low voltage alarm ground station is shown in Figure 10.

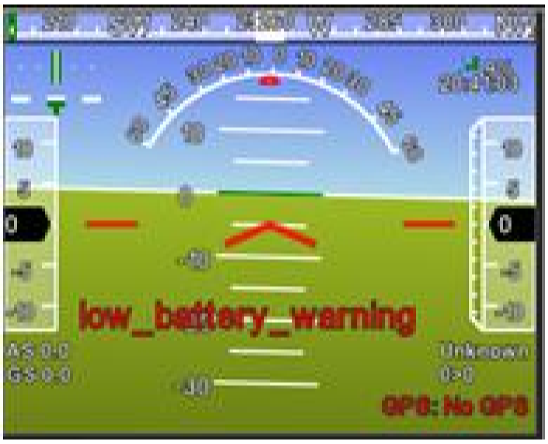

Figure10. Low Voltage Alarm Ground Station

4. OPERATIONS

4.1 Flight Preparation

4.1.1 Check List

1. Motor sequence and steering

The structure diagram of hexrcopter is shown in Figure 11.

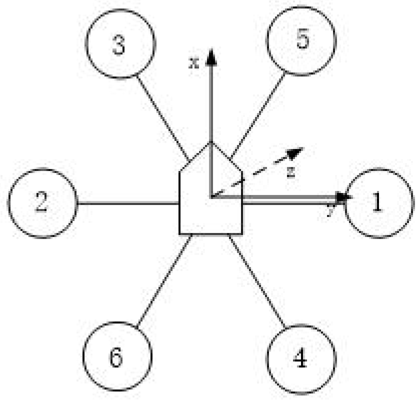

Figure 11.Hexrcopter Diagram

- Check whether the connection sequence of the flight control is consistent with the motor

2. Propeller inspection

- Check if the propeller is tightened
- Check the propeller positive and negative and the blade order

3. Power system

- Check if the battery is fully charged

4. Vision system

- Check whether the camera and mini-PC(used for image processing) are powered properly, and whether pan-tilt-unit(PTU) has stabilizing effects or not.

4.2 Man/Machine Interface

UAV's ground control station using Mission Planner, a full-featured application for the ArduPilot open source autopilot project, play the role of human-computer interaction. It is shown in figure12 By using the 3DR data transfer module, we can set the various functions of the flight control function and monitor the UAV’s status while in operation. The remote log can be recorded, viewed and analyzed, which greatly help us to solve some problems with flight control in the early preparation.

Figure12.Man/Machine Interface Diagram

5. RISK REDUCTION

5.1 Vehicle Status

5.1.1 Shock/Vibration Isolation

The vibration of the blades and the motors during the whole flight will have negative impacts on the sensors and camera. Like noise for IMU and ghosting phenomenon for camera.

In order to reduce the impacts of vibration, the frame structure uses carbon fiber, it has good capacity of anti-impact and anti-collision. For the impact of IMU vibration, we use the shock absorber plate. For the image of the vibration, PTU was installed to suppress.

5.2 Safety

To prevent the occurrence of a sudden, the team using the remote control mode channel to the safety switch. Air vehicles may land under manual control of a safety pilot in the event of an emergency.

6. CONCLUSION

The NUAA team has developed an autonomous hexrcopter which has an ability of flying above the arena with vision navigation, sensing and avoiding moving special ground robots, interacting with the ground robots, and herding them toward the green side of the arena such that as many as possible cross over the green line. Based on above design, the NUAA team intends to complete the mission 7. The technology of mission has broad application prospect, such as reconnaissance, disaster relief, and monitoring.

7. REFERENCES

[1] SlawomirGrzonka, Giorgio Grisetti, Wolfram Burgard, " A fully autonomous indoor quadrotor," IEEE Transactions on Robotics, vol.28, no.1, pp.90-100, 2012.
[2] Aykut C. Satici, Hasan Poonawala, Mark W. Spong, "Robust optimal control of quadrotor UAVs,"Access, IEEE, vol.1,pp.79-93,2013.
[3] HamedJabbariAsl, HosseinBolandi, " Robust vision-based control of an underactuated flying robot tracking a moving target, " Transactions of the Institute of Measurement and Control, vol. 36, no.3, pp. 411-424, 2014.
[4] Kaiser MK, Gans NR, Dixon WE, "Vision-basedestimation for guidance, navigation, and control of anaerial vehicle,"IEEE Trans Aerosp Electron Syst, vol.46, pp.1064-1077, 2010.
[5] Junichi Ido, Yoshinao Shimizu, Yoshio Matsumoto, Tsukasa Ogasawara, " Indoor navigation for a humanoid robot using a view sequence. " The International Journal of Robotics Research,vol. 28, 2: pp.315-325,2009