Technical Report of BUAA Irobot Team X

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ABSTRACT

This paper described the details of an autonomous aerial robot capable of exploring cluttered indoor areas and searching targets in the environment without external navigation equipment. The primary goal of the aerial robot is searching the bins and the incomplete code shown on the top of bins in the competition area and healing our teammate. To accomplish this task, several technical problems need to be solved, such as speech recognition, flight control, strategy formulation, path planning, image processing, target identification, and pose measurement etc. Histogram of Oriented Gradient (HOG), Kernelized Correlation Filter (KCF) etc. are combined for visual processing. They are integrated on the software platform based on android studio. Then, the software is written in the hardware platform based on DJI MAVIC PRO. Therefore, DJIs can be driven to achieve the competition task.

INTRODUTION

Statement of the Problem

The IARC 2019 requires the teams to construct four completely autonomous aerial robotic helpers. In the mission IARC 2019, the task can be described as a single person working with a team of aerial robots, attempts to retrieve components distributed within four locked bins and avoids the interference of opposing aerial robotic sentries and obstacles at the same time.

This task will challenge teams to develop several new behaviors of the aerial robots. First, the aerial robotic helpers will be commanded and controlled without electronic methods such as voice control. Next, it is necessary to equip aerial robots with the ability to have synergy and information interaction so that operator can understand the situation inside the field. Then, the aerial target designation is critical to searching for boxes and identifying passwords and it's also the basis of obstacle avoidance. Finally, the limited time (less than 8 minutes) also challenges the mission planning to be smart enough to make an acceptable decision.v

Conceptual Solution

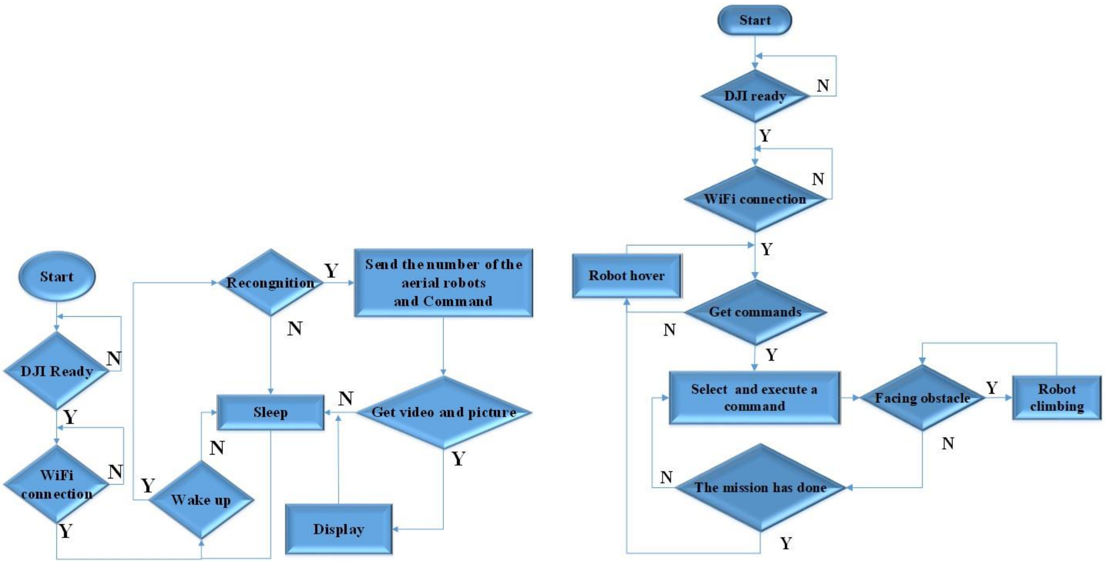
Several key points and solutions for IARC:

(1) Target identification: A new integrated algorithm based on HOG+KCF+DT is developed.
(2) Obstacle avoidance: DJI guidance and visual recognition are implemented to avoid the obstacles. Path planning module is also implemented to evade the obstacles based on artificial potential field method.
(3) Voice control and command: Offline voice wakeup recognition program is developed based on Baidu voice platform.
(4) Path planning and strategy formulation: four aerial robotic helpers will fly at different heights to search for boxes with parts and identify passwords along the respective path. In the meantime, therapeutic laser beam is normally open.

SOFTWARE

Software Platform

The flow of the Pad program and the flow of the mobile phone program is shown in Figure 1(a) and Figure 1(b).



(a) Pad program (b) mobile phone program

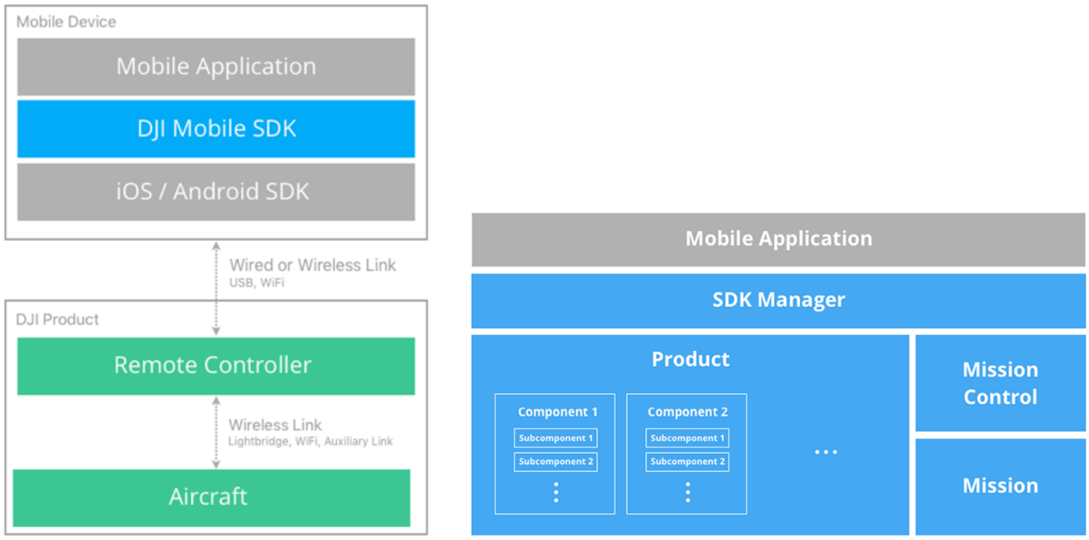
Figure 1.The flow of the software platform

DJI SDK

The DJI Mobile SDK is a software development kit designed to give developers access to the capability of DJI's aircraft and handheld camera products. The SDK simplifies the application development process by taking care of lower level functionality such as flight stabilization, battery management, signal transmission and communication.

DJI Mavic Pro is selected to be the flight platform in this task. With the new OcuSync image transfer technology, it supports remote control distances of more than 7km and connection with an additional mobile app to achieve real-time video sharing and viewing. Mavic is equipped with a Flight Autonomy system based on binocular stereo vision technology, which avoids obstacles easily and safely. It provides API for multiple control command that enable developers to add customized functions and further developed algorithms at the task level. DJI Mobile SDK is also open source, supporting different development platforms. Besides, equipped with DJI's smallest integrated high-precision three-axis mechanical stabilization head to date, it ensures stable shooting for target recognition.

Figure 2(a) illustrates how the DJI Mobile SDK fits into a mobile application, and how it is connected to a DJI aircraft. Figure 2(b) illustrated a mobile application which accesses the DJI Mobile SDK through several main classes.



(a) The relationship of the DJI Mobile SDK and the mobile application (b) A mobile application accesses the DJI Mobile SDK

Figure 2. DJI SDK

Baidu Voice

According to the requirements of the eight-generation mission to make the flying robot have the capability of non-electronic interaction, we developed and designed the offline voice wake-up recognition program based on the Baidu voice platform. Baidu voice is mainly used to realize the following two functions: 1. Wake up the flying robot through offline voice and prepare it for departure; 2. Conduct the on-site search through offline voice recognition commanding the flying robot.

The offline program developed based on Baidu voice has obvious advantages in accomplishing this task. Firstly, the voice command control of the air robot assistant completely deviates from the dependence on the Internet, so it can control the aircraft through voice even without the Internet. Secondly, the offline command words can be customized, and the recognition of offline command words is more sensitive. It solves the problem of recognition errors caused by the too complicated library provided by Baidu voice itself. Again, the Baidu voice SDK is open source, and only part of the code is needed for development. It saves the development time and effort largely for modification and debugging. Finally, just adjusting the certain parameters can realize far-field speech recognition to obtain strong anti-noise interference.

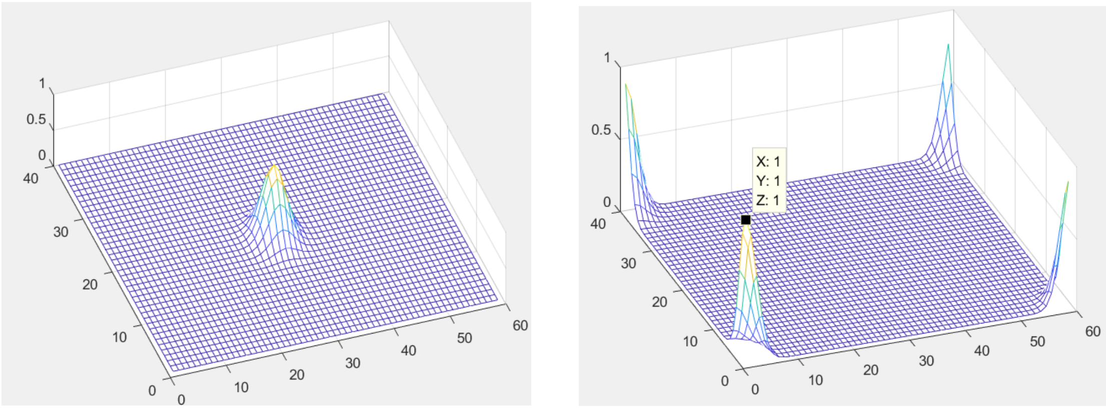
By integrating this voice program into our drone's flight control program, it is convenient for the operator to send voice commands through the phone or tablet, which can control the UAVs to do various actions. Because the program debugging is relatively simple, and it is allowed to define a wealth of offline command words, our voice control system can fully meet the field personnel's response to each state and can debug and run at any time according to the test conditions.

Tensorflow

A computer vision learning algorithm is employed to solve the feature extraction problem of boxes based on the *tensorflow* platform. Target feature extraction is performed with a combination of Histogram of Oriented Gradient (HOG) and Kernelized Correlation Filters (KCF) for boxes positioning and enemy airplane avoiding.

HOG is a vector description of a feature. Descriptor codes in HOG provide figure feature with fast computing speed and resistance against variation of lighting. HOG features of the targets are extracted and applied to train the parameters. Online detection will call the training results from the offline training to judge whether the HOG features are matched.

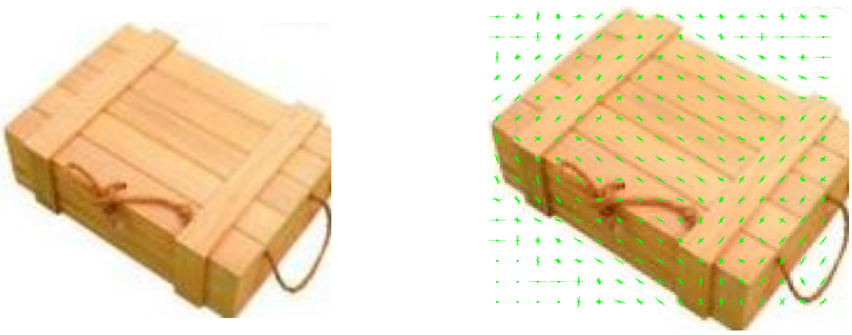
Furthermore, KCF algorithm based on HOG features is applied to track the target. *Gaussian Kernel* function is selected as the kernel function. The image of the *Gaussian Kernel* function is shown in Figure 3.



(a)Peak at center (b) Peak in the upper left corner

Figure 3. The image of the Gaussian Kernel function

The tracking object part which is signed target is selected after loading the first fame image. Then, the region is enlarged into 1.5 times. The enlarged region is named by patch. According to the boundary distortion, cosine window is applied to eliminate this effect. The result of this algorithm is shown in Figure 4.



(a) Target (b) HOG feature

(c) Result

Figure 4. The result of this algorithm

HARDWARE

Hardware Platform

The hardware platform of mission 8 is shown in Figure 5.

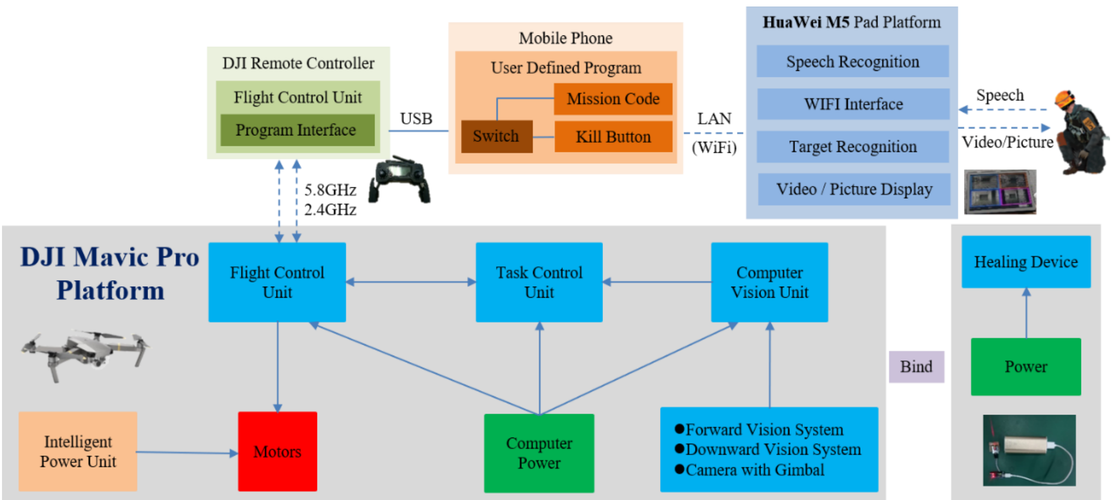


Figure 5. The hardware platform of mission 8

Aerial Robot

DJI MAVIC PRO is selected to be the flight platform in mission 8. MAVIC PRO is a portable folding aircraft equipped with forward looking and downward looking vision system. It provides API for multiple control command that enable developers to add customized functions and further developed algorithms according to the task. Furthermore, three axis mechanical platform and are supplied by the vision system. DJI Onboard SDK is offered, supporting different development platforms. The appearance and details of MAVIC PRO is shown in the Figure 6.

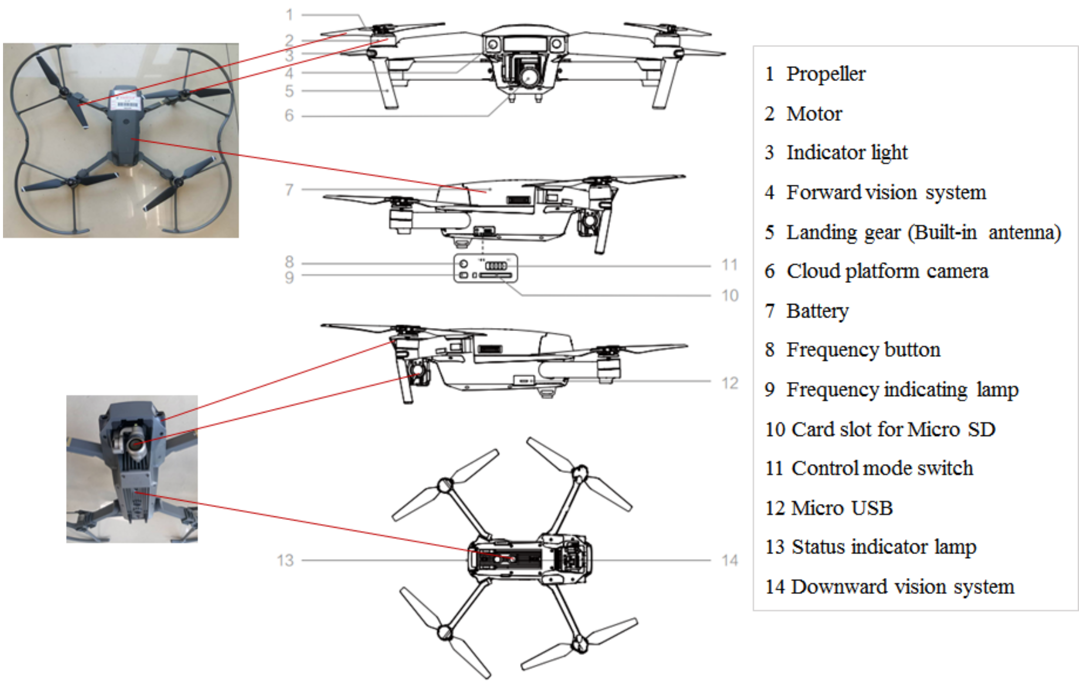


Figure 6. DJI MAVIC PRO

Vision System

The vision system consists of the forward vision system, the downward system and the camera with gimbal. The relationship of them is shown in Figure 7.

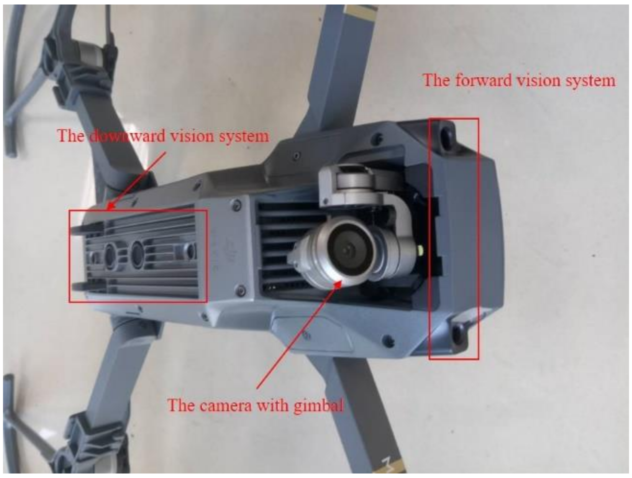


Figure 7. Vision system

As shown in Figure8, the forward vision system is on both sides of DJI MAVIC PRO. It is applied for searching the boxes and sensing the obstacle by vision image ranging. The observation range of the forward vision system is 60°. The downward vision system is located at the bottom of DJI MAVIC PRO. It consists of cameras and ultrasonic sensors. The position information is obtained by the camera. The altitude information is got by the ultrasonic sensor. The observation range of the downward vision system is 40°. The camera with gimbal is installed at the front of DJI MAVIC PRO. Smooth pictures can be taken by this camera. The range of the gimbal is from -90° to 30°.

Intelligent Flight Battery

The capacity of the intelligent flight battery is 3830mAh. The voltage of it is 11.4V. The battery life with no load is 20 minute. Therefore, it meets the time requirement of the competition. The intelligent flight battery is shown in Figure 8.

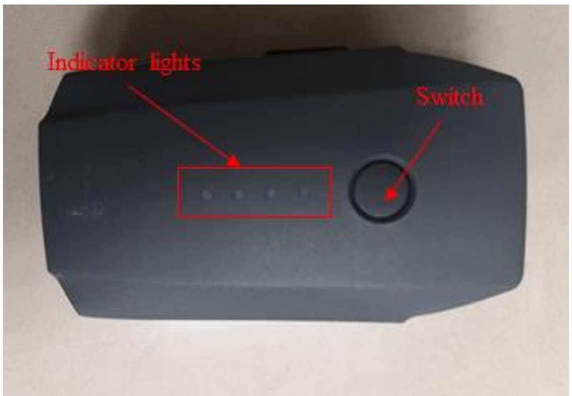


Figure 8. Intelligent flight battery

Healing System

Our aerial robotic helpers can heal laser hit wounds sustained by the person in the arena with a “surgical laser”. Healing beams is generated by the healing device. The healing device is designed by Arduino Pro Micro. The structure of the healing device is shown in Figure 9.

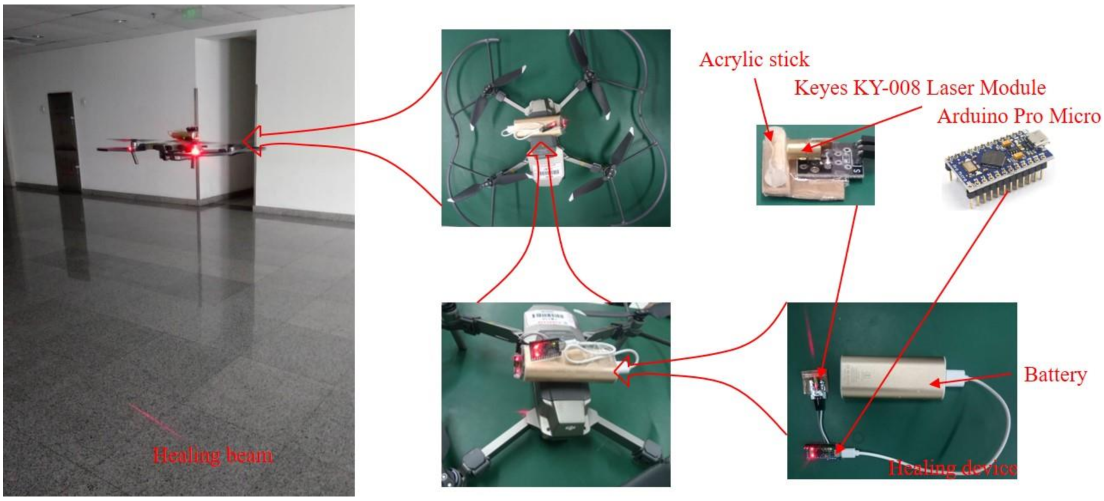


Figure 9. Healing device

As shown in Figure 4, the healing includes a battery, the Arduino Pro Micro, the laser transmitter and the acrylic stick. The frequency of the laser transmitter is 13kHz. The single point laser is converted to the healing beam by the acrylic stick. The healing device is fixed on the top of DJI MAVIC PRO by friction rubber. The healing beam is in the working state during the competition.

In order to meet the requirements of our air robot assistants for laser treatment of the operator, an additional laser beam is required, during which a pro micro panel with a rated voltage of 5v, a transmission wire, an LED light, a glass column, some wires, and a power supply are used.

First, the *Ardiuno* program is used to write a program that controls the LEDs to be turned on or off, and set the light-on period to 77 microseconds according to the requirements of the contest. The code is wrote into the panel after running the test successfully. As a result, the power, panel and the LED light together. Since the button battery is not enough to support for eight minutes, the charging power supply mode is selected to ensure that the LED light can emit light continuously during the mission period. Finally, the LED light is fixed on the side of the aircraft so that it emits a vertical downward beam, and the treatment laser beam is completed.

QR code recognition

Use QR code as a marker for visual recognition of drones， in addition to the advantages of simple production and low price, it also has high precision and low detection rate, divided into decoding system and coding system.

The decoding system can detect the marker in four steps: detection line segment, quadrilateral detection, homography and external parameter estimation, and payload decoding. The decoding system detects the line segments by calculating the gradient direction and size of each pixel on the image, and clustering pixels of similar gradient direction and size into a part. At this point, a set of directed segments in the image has been obtained. The next task is to find a sequence of line segments so that a quadrilateral can be formed. Using the direct linear transformation algorithm to calculate the homography matrix projected from the identification coordinate system to the 2D image coordinate system. Taking the coordinates of the four vertices of the quadrilateral in the image, the focal length of the camera, and the size information as input, the PnP algorithm is used to solve the pose information of the logo relative to the camera. The final task is to read bits from the payload domain. The relative coordinates of the identification of each bit field (small square) are calculated, and they are converted to the image coordinate system using the homography matrix, and then the obtained pixels are subjected to threshold segmentation.

Once the code value is decoded from the square, the next step is the encoding system to determine if the code value is valid. The purpose of the coding system is to maximize the number of distinguishable code values; to maximize bit errors that can be detected or corrected; to minimize false positives (FPR) and identify aliasing rates; to minimize the total number of bits per identification and the size of the identity . With a simple greedy algorithm, all possible rectangles are considered repeatedly and the one with the smallest error is preserved. Since the logo is generally small, the amount of calculation is not a bottleneck for the problem.

Through the identification test based on two-dimensional code, the unmanned aircraft cooperates with the autonomous formation with good precision and stability, which can be used for the unmanned aerial vehicle cooperative formation.

Protective Measures

(a) Propeller protection frame

Potential risks exist as the aerial robot is get out of control during the mission. Although there is a blind area of DJI MAVIC PRO Guidance obstacle avoidance technology, there are potential risks on obstacle avoidance in this range. For safety, we designed a rotor protection frame based on the shape structure of the propeller guard, which is installed on the four wing arms of the aerial robot respectively. The diagram of the propeller guards are shown in Figure 10.

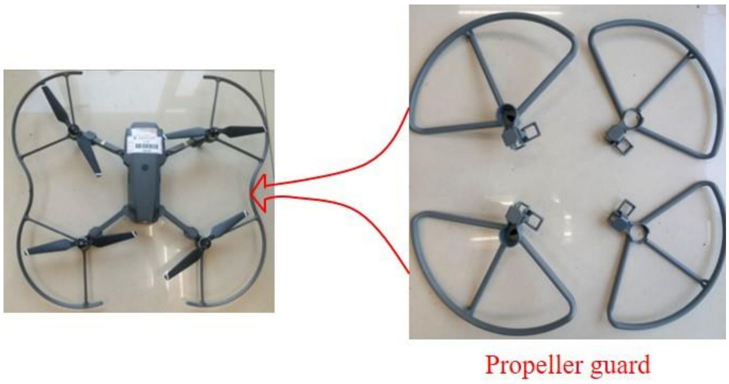


Figure 10. Propeller guard

(b) Emergency Measures

Emergency measures are adopted to make safe. The emergency button is designed on the screen of the phone which is operated by referees. If emergency happens, the safety measure is implemented to control the DJI MAVIC PRO landing. The diagram of the emergency measure is shown in Figure 11.

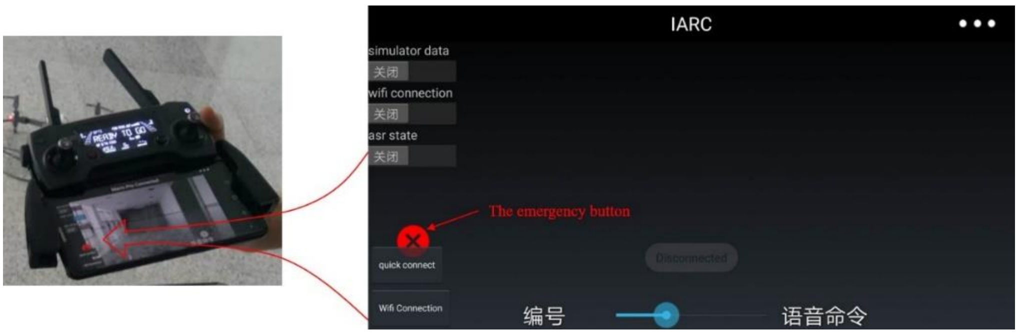


Figure 11. Emergency measure

STRATEGY

To accomplish the mission successfully, we divide the task into on-site search of the box, identification of the code and notification of the operator, the protection of the operator and departure from the stage, while avoiding the attack of the aerial robotic sentries and obstacles in the room. To complete these tasks and overcome the technical difficulties, we have made the following solutions separately.

Admission

After entering the stadium, the operator wakes up the four helper robots and gives them a command of searching. The aerial robotic helpers are designed to fly at different altitudes to avoid collision. After receiving the voice command from the operator, the helpers take off in turn and then start the task. Because the DJI Mavic Pro flying in the indoor environment needs to disable GPS, they cannot correct the flight path themselves. We design a certain program to control them flying to the predetermined position according to the assigned route. At the same time, the operator should avoid the laser attack of the enemy drone at the safe place in the field, and receive the live video broadcast of the helper robots through the tablet. The process of mission 8 is shown in Figure 12.

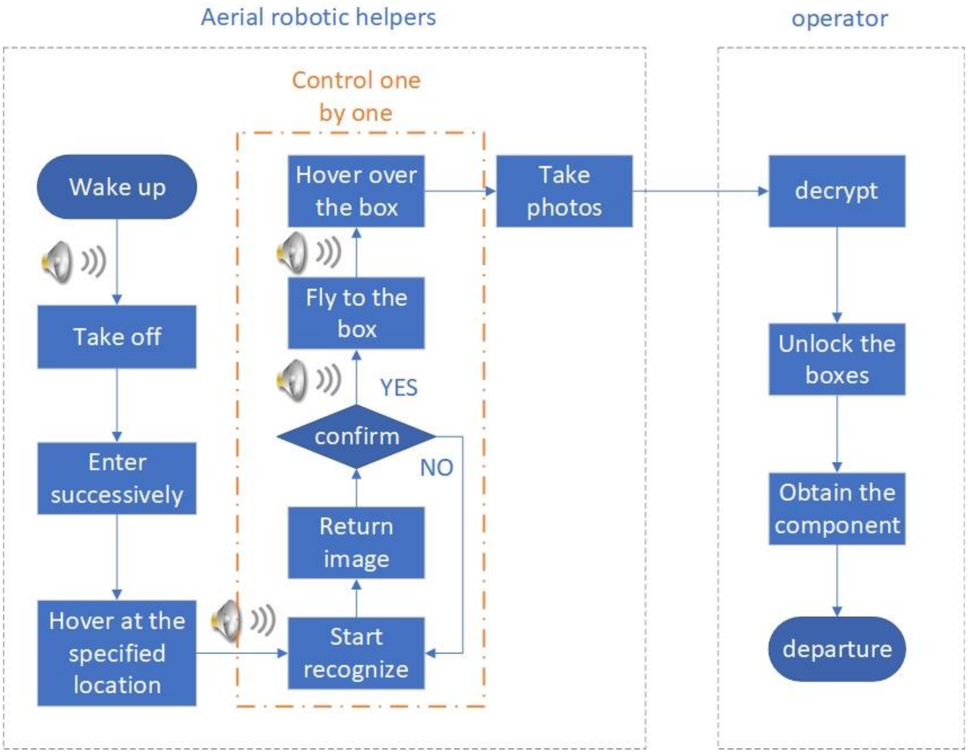


Figure 12. The process of mission 8

Search and Decrypt

By image processing and recognition technology, the helper robots can recognize the boxes, get the box position and fly to find the code. DJI1 is at the setting height and supervise the whole situation. DJI2 goes to the code in turn and hovers over them, takes photos and passes them to the operator. The operator deciphers the code and obtain the password according to the photos. And then he should find the boxes, unlock them to get the "critical object" and leaves quickly. In the meantime, DJI3 and DJI4 are hovering at a specified area, waiting to be dispatched at any time. The diagram of control is shown in Figure 13.

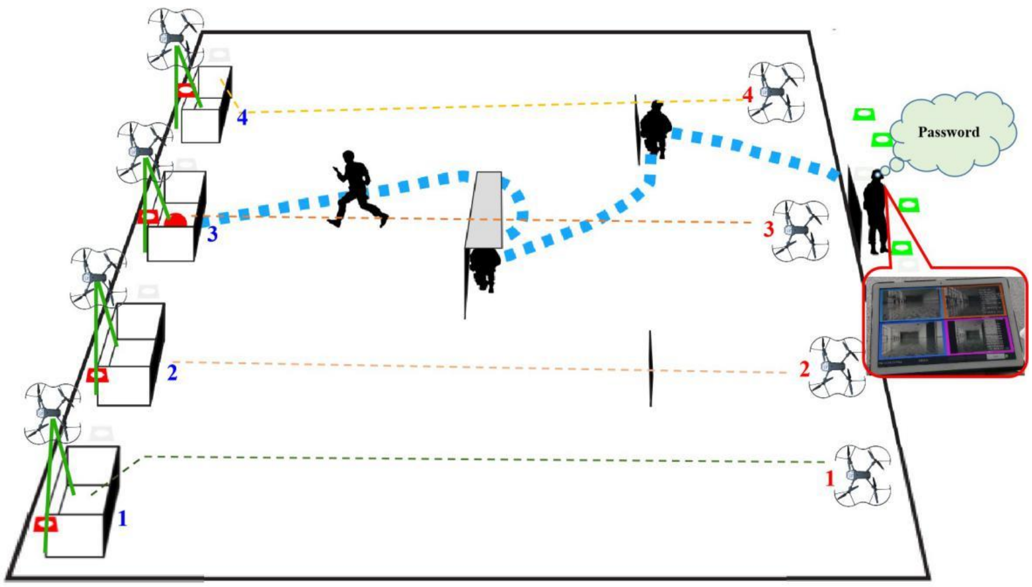


Figure 13. The diagram of control

Obstacle avoidance

Because of the existence of aerial robotic sentries and obstacle, obstacle avoidance is a key step for achieving the competition task. Obstacle avoidance mainly depends on the DJI Guidance, which combines the binocular vision with ultrasound. DJIs are distributed in different height to avoid collision. Furthermore, the strategy of obstacle avoidance is climbing up when obstacles are perceived.

Treatment

Our operator enters the stage and quickly finds the boxes as soon as he have decrypted the password. The surgical laser of our helper robots is always open. When the operator needs treatment, he goes to the nearest helper for treatment to save time and the consumption of helpers. After unlocking the password lock, he quickly leaves the room.

OPERATIONS

To keep the vehicle safe and complete the competition task, we developed a series of preparations for DJIs and handheld device.

Flight Preparations

(1) Check the whole vehicle hardware, ensure the attachments are fixed firmly and the propellers work well.
(2) Check the vehicle battery and plug into the vehicle. Check the battery of the healing system.
(3) Power on the vehicle.
(4) Check the communication links between the remote controller and the DJI. The remote controller links with a smart phone.
(5) Check the sensors and cameras. Confirm they are working normally.
(6) Check the emergency button.

Man-machine Interface

Huawei M5 is employed for us to observe the pictures that are taken by airborne cameras. Besides, it is applied for sending voice command.

(1) Check the returned images.

(2) Check the function of speech control.

TESTING

Gradual work has been done to test the whole system. The vision system based on feature extraction is employed to navigate precisely following the parameters of the controller. The vision navigation system is tested by a testing box. After all the simulation and unit testing, flight tests are done to verify the reliability of the whole system. The test scene is shown in Figure 14.

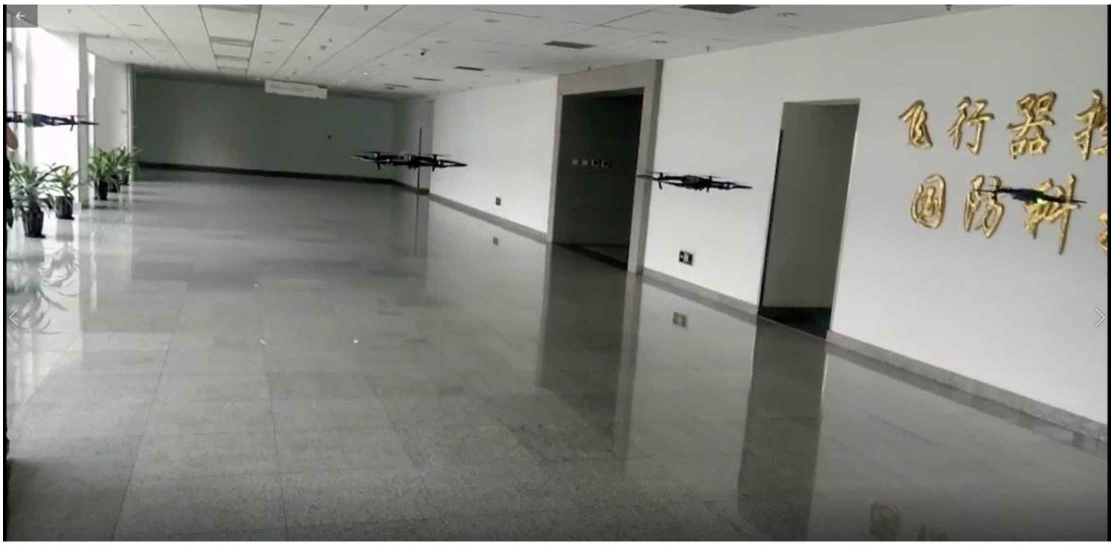


Figure 14. The test scene

CONCLUSION

Based on the research of DJI aerial robot platform, DJIs are made to have the ability of speech recognition and controlled, target searching and identification, autonomous navigation, obstacle avoidance, emergency landing etc. in the unknown environment to accomplish the searching task in mission 8. We expect that our vehicle can obtain the password behind the boxes and get the object in the boxes. Then, we can evacuate the competition area safely.

REFERENCES

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