Technical Paper for the International Aerial Robotics Competition-Mission 9

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ABSTRACT

In the 9th mission in International Aerial Robotics Competition (IARC) a fleet of quad-rotors will demonstrate behaviors, including manipulation of large objects, fast outdoor operations over long distance, interaction with frames of reference, aerial robotic repair of mobile platforms, optical recognition and navigation using PS/Optical/Magnetic only. The Zero-One Team form Nanjing University of Aeronautics and Astronautics has put forward the Son-Mother drone solution. The mother-drone is used for long-distance and quick transportation of the sub-drone, and the sub-drone is used to complete the antenna replacement.

Ⅰ INTRODUTION

1.1Mission 8 Introduction

Our autonomous aerial robot will receive as a payload, one replacement communications module. Upon command, our aerial robot will take off and fly at less than an altitude of 15 m to a distance of approximately 3 km to apprehend a Hunter-Killer vessel. The aerial robot will then remove the communications module from the Hunter-Killer (dropping it on site) and replace it with the communications module payload that it is carrying. Upon completion of the module swap, your aerial robot will return to its point of origin and land. Speed is critical. Due to fuel and energy constraints, as well as the expected time that the Hunter-Killer vessel is within range, the entire mission must be completed in 9 minutes. Your design team's task is to create an aerial robot that can:

1. Fly fully autonomously
2. Use ONLY onboard computing (no data links except for kill switch and safety pilot override)
3. Avoid obstacles including
   a. other aerial robots
   b. physical obstacles
4. Conduct the mission successfully (replace the module and return home) in under 9 minutes.

IIHARDWARE

2.1 Mother-Platform

DJI Matrice 600 Pro is a stable and reliable flight platform, which continues the high load and excellent flight performance of the Matrice 600, the modular design further improves the reliablity and convenience. Besides, it includes the flight controller, GPS, a rechargeable battery system as well as a dedicated remote controller. Thus the Matrice 600 Pro has the ability to manage the most complex tasks and we can focus on our work.

Figure 1 DJI Matrice 600 Pro

2.2Sub-Platform

The sub-platform uses homemade drone which uses Pixhawk 4 autopilot, its wheelbase is 800mm, and payload is 4 kg. This sub-platform is equipped with a manipulator which is used to replace the antenna.

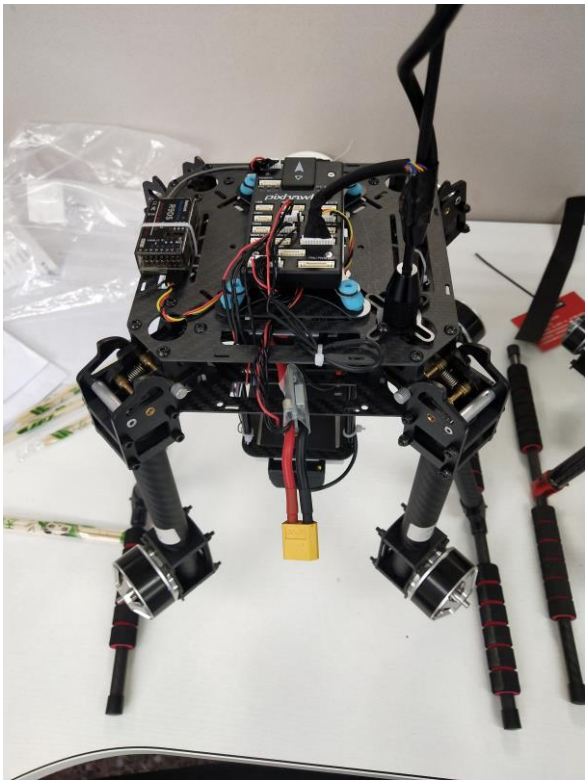

Figure 2 Homemade Drone

2.3 Onboard Computer

The Nvidia Jetson Xavier NX is a powerful onboard computer that transforms drones into autonomous robots which turn vision into reality. It benefits from the new cloud native support, which can accelerate the NVIDIA software stack to 10W, and its performance is more than 10 times that of its widely adopted predecessor Jetson TX2, making it possible for any user who wants to build customized, autonomous drone solutions.

Figure 3 Nvidia Jetson Xavier NX

2.4 RTK

The DJI D-RTK is a GPS and barometer system specially designed to provide centimeter-level positioning accuracy. Using dual antennas, its heading reference is more accurate than a normal compass sensor, and it is able to withstand magnetic interference from metal structures. It is easily for user to get the drone to the desired position with high accuracy.

Figure 4 DJI D-RTK

2.5 Gimbal Camera

The DJI ZENMUSE Z3 is a gimbal camera with self_stabilization system, and it can be applied to the Matrice 600 Pro using Lightbridge or Lightbridge 2. Z3 uses Sony's 1/2.3-inch senor, which can take 12 million pixel photos and 4K ultra-high-definition video at 30 frames per second, it makes it possible for us to get the target image in real time and to process and recognize the given sign.

Figure 5 DJI ZENMUSE Z3

2.6 Design of manipulator

We design a special manipulator, it consists of a docking device and a replacement device. When the sub-drone close to the mast in a certain distance, the docking device will hold the mast tightly. Then the replacement device will execute antenna replacement task.

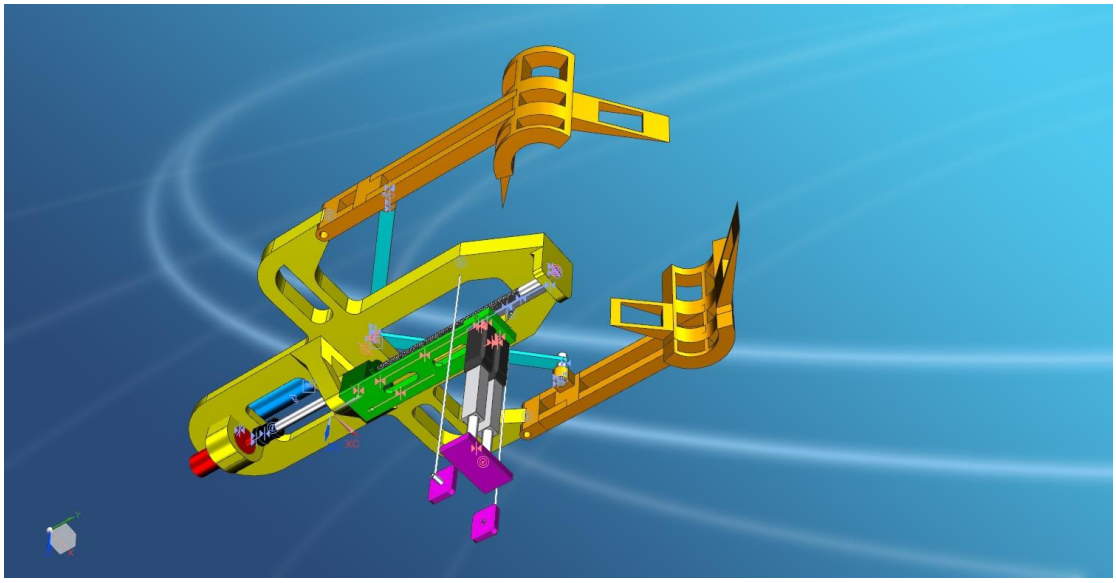

Figure 6 Manipulator

III SOFTWARE

3.1Obstacle avoidance

On the basis of communication and map modeling, the artificial potential field method is proposed for obstacle avoidance and path planning of aerial robots.

The artificial potential field method path planning is a kind of virtual force method proposed by Khatib. Its basic idea is to design the movement of the robot in the surrounding environment into an abstract artificial gravitational field. The target point generates a "gravity" to the mobile robot, and the obstacle generates a "repulsion" to the mobile robot, and finally through seeking a combined force To control the movement of the mobile robot. The path planned by the potential field method is generally smooth and safe.

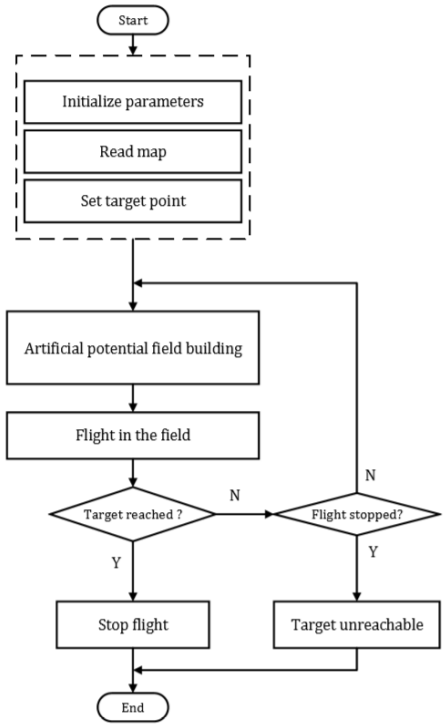

Figure 7 Obstacle Avoidance Algorithm Structure

3.2Target recognition and positioning

According to the mission requirements, the drone should recognize the blue mark of the mast first, and use RTK to provide the precise position coordinates of the mast for the drone to hover; secondly, the manipulator recognizes the communication module, adjusts the actuation mechanism, and removes the communication module from the mast. And then install the communication module that needs to be replaced on the mast. We have designed a visual recognition and positioning algorithm based on edge detection, which can accurately recognize the edge and center of the marker and give precise coordinate positions for the UAV flight control system and manipulator control system.

Figure 8 Identify The Antenna

3.3 Control of manipulator

The manipulator is the key to intelligent docking with the mast. It is related to the completion of this task. The development of the manipulator includes two parts: structural design and control.

The manipulator uses DJI's Robotmaster development board, based on the STM32 HAL library, which can realize visual positioning and actuation mechanism control. The development board communicates with NIVIDIA TX2 through the universal serial port, and realizes real-time control of the manipulator through the drone's onboard computer.

The manipulator performs different stages of work according to the instructions given by the onboard computer, and feeds back the real-time working status to the onboard computer.

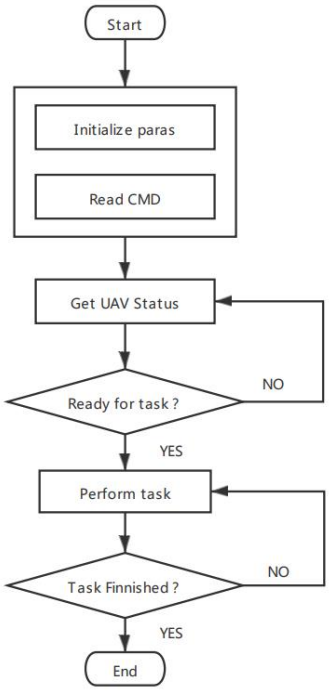

Figure 9 Manipulator Control Structure

IVConclusion

In this paper, we put forward the Son-Mother drone solution. The mother-drone is used for long-distance and quick transportation of the sub-drone, and the sub-drone is used to complete the antenna replacement. The sub-drone is visually positioned to the mast, and controlled to approach the antenna. After the sub-drone close to the mast in a certain distance, it will use the docking device to connect the sub-drone and the mast fixedly, and then complete antenna replacement.

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