A Quadrotor Micro Aerial Vehicle for the 2013 International Aerial Robotics Competition

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ABSTRACT

Autonomous flight in a GPS-denied environment, such as indoor environment, is a world class engineering challenge. In this paper, we proposed a fully autonomous indoor flight solution. We designed a quadrotor micro aerial vehicle (QMAV) equipped with laser scanner, ultrasonic, inertial measurement unit (IMU), autopilot and a powerful onboard computer to compete in the 2013 International Aerial Robotics Competition (IARC). This QMAV is able to auto-takeoff, entry into a window, navigate and explore in an unknown GPS-denied building using Simultaneous Localization and Mapping (SLAM) algorithms.

1.INTRODUCTION

The 2013International Aerial Robotics Competition will be held in Grand Forks, North Dakota from August 5 to August 8. Current Mission is the mission 6 called “Top Secret”. This paper describes the QMAV designed by Harbin Engineering University to achieve this task.

Credible and actionable human intelligence (HUMINT) reports have been received from a mole within the Hesamic Republic of Nari’s Intelligence Organization. These reports indicate that highly sensitive information detailing plans to sabotage banking interests of a global organization may be stored in a security office located in the remote town of Rafq. A breach in security has been identified which may allow a small autonomous air vehicle to penetrate perimeter defenses so that the sensitive information can be stolen by the global organization in order to preempt any actions by the Nari government which would be deemed damaging to these unnamed global interests.

A vertical takeoff and landing (VTOL) vehicle is the best choice for the “Top Secret”. There are several candidates, such as helicopter, multicopter, airship etc. Considering the size, weight, safety, flight time and feasibility, we selected a quadrotor micro aerial vehicle (QMAV) to complete “Top Secret”. In recent years, the robotics community has shown an increasing interest in autonomous aerial vehicles, especially quadrotors. Low-cost and small-size commercial QMAV platforms are becoming

broadly available, and some of these platforms are able to lift relatively high payloads and provide an increasingly broad set of basic functionalities. However, most of the commercial platforms are not very suitable for the IARC because they often do not supply enough information needed by the high level control, while the German Ascending Technology company provides suitable platform for the IARC, named “pelican”, which seems to be a custom platform for the competition. Also, there are some open source projects that may be helpful for competitors, such as MicroKoper (MK), AutoPilotMega (APM), and MultiWii (MWC) etc. They are hardware open and/or software open.
The Harbin Engineering University (HEU) QMAV is a custom vehicle for the 2013 IARC, which equipped with laser scanner, ultrasonic, inertial measurement unit (IMU), autopilot and a powerful onboard computer.

2.QUADROTOR MICRO AERIAL VEHICLE

The QMAV weights less than 1.5 Kg, spans 75cm from blade tip to blade tip. There are four Sunnysky X2212 brushless motors with APC 1047 propellers, lifting maximum 2.5 Kg. *Figure 1* below shows a fully assembled vehicle.

Figure 1 A shot of QMAV auto takeoff

2.1 Frame

The frame is made from Carbon Fiber Composite, and the structure is designed with CATIA v5. The inherent resonant frequency of the frame is more than 100Hz while the vibration frequency caused by motors is about 60Hz. The vibration frequency is calculated from the motor speed, if the motor speed is 4200rpm, then vibration frequency is 4200/60 = 70 Hz. We can also measure the vibration frequency by accelerometer, the measured frequency is the same as the calculated value. *Figure 2* below shows the frame model.

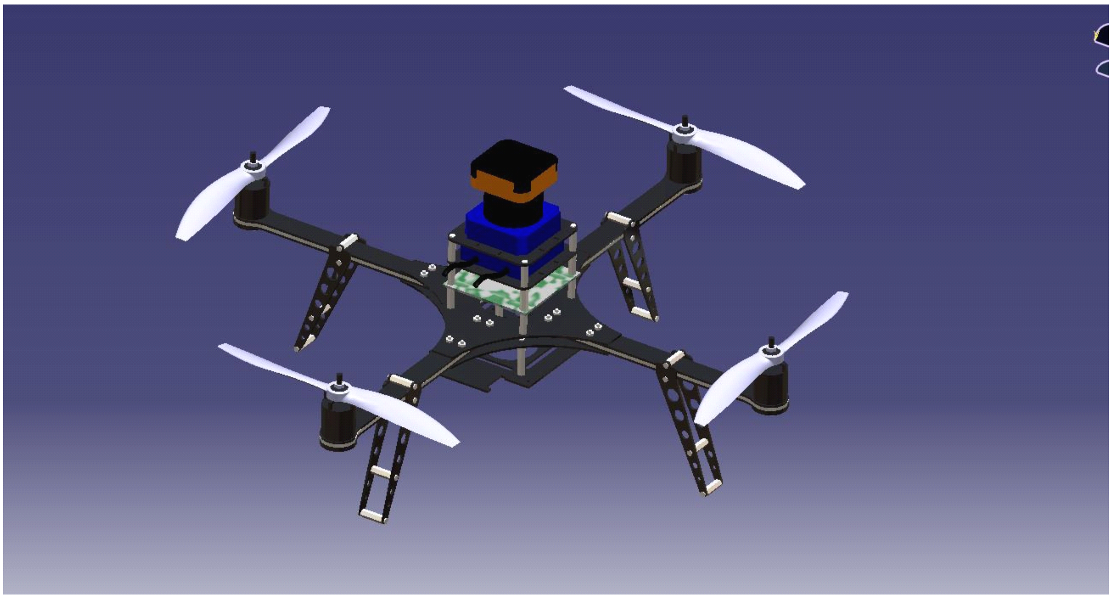

Figure 2 A frame model in CATIA V5

2.2 Autopilot

The autopilot automatically controls the altitude and attitude of the QMAV, including a six-axes IMU and an ultrasonic as basic components of a low-cost altitude, attitude and heading reference system (AAHRS) and an ARM7 controller. The attitude and altitude controller uses PID control law.

2.3 Sensors

Maxbotix ultrasonic height sensor: One Maxbotix ultrasonic height sensor is mounted below the quadrotor. It outputs with a frequency of 10Hz, has two kinds of output port, UART and analog voltage, measures from 24cm to 700cm.The ultrasonic sensor is pictured in *Figure3*.

Figure 3 Maxbotix ultrasonic height sensors

Hokuyo UTM-30LX Laser Range-Finder: A top-mounted laser range-finder returns a point cloud of 1080 points in a 270 degree, 30 meter range surrounding the vehicle at a rate of 40 scans per second. It weighs about 250g when cut the cable shorter. The Hokuyo is pictured in *Figure 4*.

Figure 4 Hokuyo UTM-30LX Laser Range-Finder

2.4 Computer

Advantech PCM-3363D-1GS8A1E: A fanless, low power, small size (96X90mm), low weight (200g without SATA disk) industrial personal computer (IPC) is mounted at the bottom layer of the QMAV. There is a windows XP operating system running in the computer. The Advantech IPC is pictured in *Figure* 5.

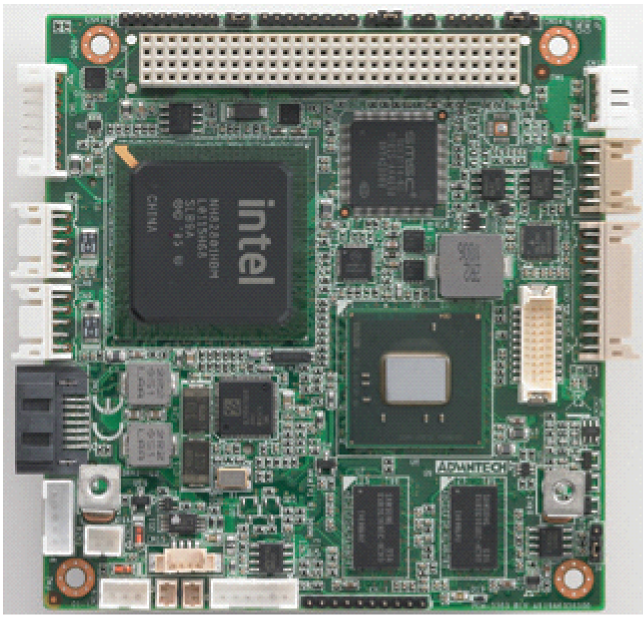

Figure 5 Advantech PCM-3363D-1GS8A1E

3. OPERATION

The QMAV is compatible for both autonomous flight and manual flight such as R/C controller and PC command. We have developed a Ground Control Station (GCS) to monitor the flight status of the QMAV and determine whether it need to switch to manual flight or just kill the vehicle. During both autonomous and non-autonomous flight, the vehicle feeds IMU data, height sensor data, motor commands, laser scans through a 433MHz wireless UART module.

4. AUTONOMOUS FLIGHT

The autopilot automatically controls the altitude and attitude of the QMAV with the help of AAHRS. Data of laser scans is send to the computer to run the SLAM algorithm, then the computer will send desired altitude and attitude commands to the autopilot through a RS-232 communication port.

5.CONCLUSION

We have designed and constructed a QMAV that is suitable for the IARC mission 6 “Top Secret”. It can autonomously takeoff, entry into and explore in an unknown GPS-denied building. The vehicle is currently undergoing testing under both manual and autonomous control. We hope it will have a good performance and make a big progress than the first time we join this competition in Beijing 2012.