Squadron-II UAV technical paper for

International Aerial Robotics Competition

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Team Reconnaissance

ABSTRACT

The Team Recon from India present an indigenously developed Squadron 2 an autonomous quadcopter designed for the 7th mission of the AUVSI International Aerial Robotics Competition(IARC).This paper decribes the technical details of a quadrotor system to be used as an aerial robot for interaction with ground robots and demonstrate the mission requirements. The Squadron 2 exhibits the required behaviors of autonomous flight for interaction with multiple objects on ground to recognize, track and navigate in a sterile environment with no external navigational aids.The objective would be achieved using SURF algorithm running on ARM Processor with depth camera. Autonomous navigation is done by using optical flow with higher resolution and is also used for ground robot recognition and boundary scanning. The instant sensing by aerial robots and interaction between aerial and ground robots would be achieved - by depth sensor and a custom developed ANN and through the use of effective path based algorithms; also avoid interaction by competing multiple aerial robots but interact only on priority basis.

INTRODUCTION

Mission 7 of IARC conducted by AUVSI provides a challenging opportunity - as a technology sport - to create significant and useful mission challenges in aerial robotics behavior for the benefit of world.

Present challenge involves demonstration of three new behaviors viz., interaction between aerial robots and autonomous ground objects, navigation in a sterile environment (with no external navigation aids) and interaction between between competing autonomous air vehicles. The project requires to demonstrate capability to track randomly moving objects and interact physically with them; using off-the-shelf ground robots – iRobot Create Programmable Robots - that are available to all the teams.

Team Recon from India present an indigenously developed xICop 2 an autonomous quadcopter to be used as an aerial robot for further interaction with ground robots and demonstrate the mission requirements. The xIcop 2 exhibits the required behaviors of autonomous flight for interaction with multiple objects on ground to recognize, track and navigate.

A. STATEMENT OF PROBLEM

The main objective of the 7th mission of IARC requires an aerial robot that can demonstrate three new behaviors viz., interaction between aerial robots and autonomous ground objects, navigation in a sterile environment (with no external navigation aids) and interaction between between competing autonomous air vehicles. The project requires to demonstrate capability to track randomly moving objects and interact physically with them.

B. Conceptual approach

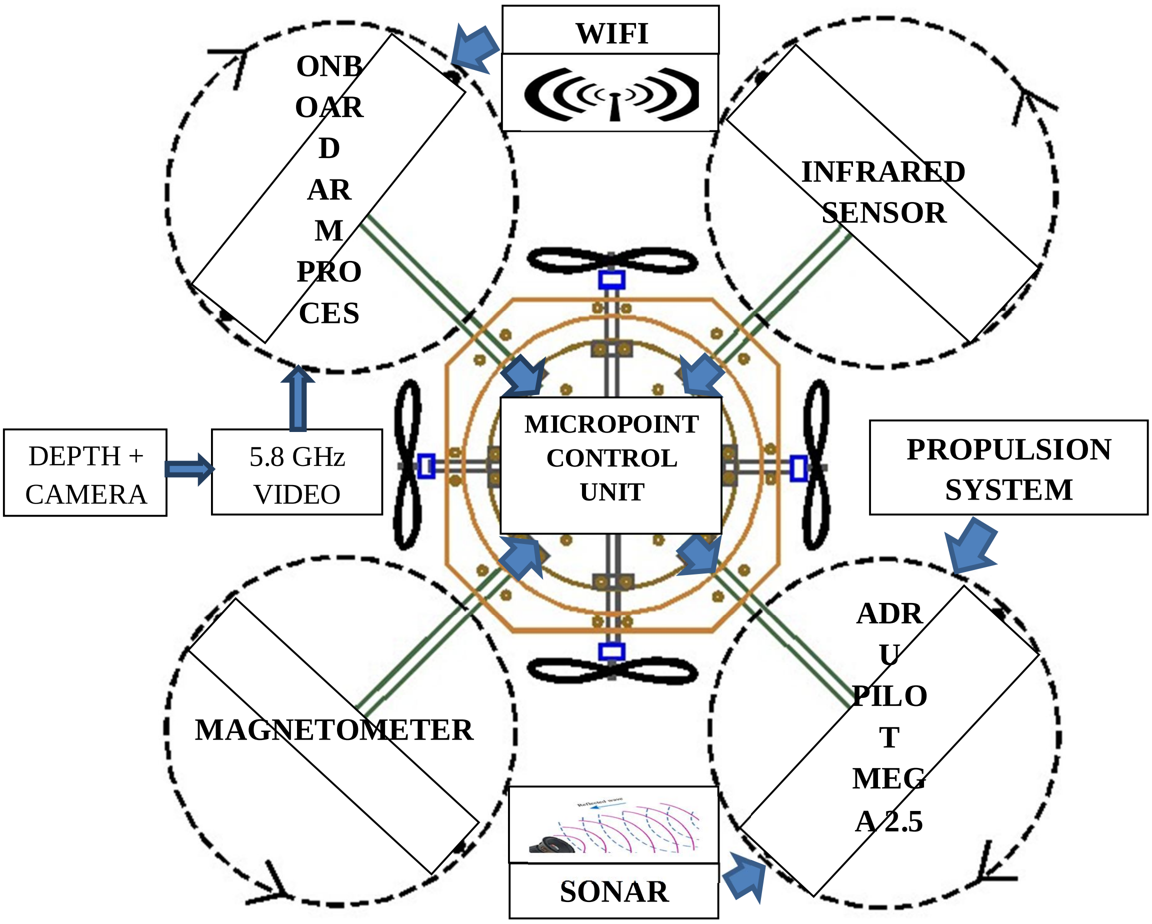
Team Recon from India present an indigenously developed xICop 2 an autonomous quadcopter to be used as an aerial robot for further interaction with ground robots and demonstrate the mission requirements. The xIcop 2 exhibits the required behaviors of autonomous flight for interaction with multiple objects on ground to recognize, track and navigate.

The squadron 2 is well within the size mentioned in the rules of 1.25 meters The objective would be achieved using SURF algorithm running on ARM Processor with depth camera. Autonomous navigation is done by using optical flow with higher resolution and is also used for ground robot recognition and boundary scanning. The instant sensing by aerial robots and interaction between aerial and ground robots would be achieved - by depth sensor and a custom developed ANN and through the use of effective path based algorithms; also avoid interaction by competing multiple aerial robots but interact only on priority basis.

PID is used to align the quadcopter with the ground robots and physically interact with them. Safety is a primary concern we have installed a kill switch that does not on the on board computer and works independently.

We fabricated the aerial robot from Carbon-fiber body, 3D printed joints and 3D printed propeller casing to ensure light weight and of robust design.

B1) Figure Of Overall System Architecture



C. *Yearly milestones*

This is the second time for the team Recon to participate in IARC. The last year's participation gave us some good experience and knowledge about the advanced technologies used .Through the experience and knowledge gained we are developing Squadron 2 for this mission and our progress is steady.

D. Air Vehicle

The Quadrotor is a mechanically simple vehicle, requiring only four motors to achieve all flight motions. Despite its simplicity, it is very capable of advanced flight. The key to flight movements beyond hovering is in differential thrust. Quadrotor are an ideal choice for autonomous reconnaissance and surveillance. Because of their small size, high manoeuvrability which makes it this suitable for indoor environment. With the installation Hall Effect Sensors, Optical Flow Sensors, Obstacle avoidance Sensors and Depth Camera, we could navigate the ground robot toward the green line.

Propulsion and Lift system

Team recon has used brushless motors and propellers for Squadron II. In a brushless DC motor, the brush-system assembly is replaced by an electronic speed controller. The elimination of brushes allows the brushless DC motor to achieve a greater efficiency over conventional brushed DC motors. Team Recon has settled with making the quad size small and we chose to use a tri-blade propeller which has the advantages like better acceleration and good manoeuvring, less noise and less vibrations.

Guidance, Navigation and Control

The MAV shall have an on-board RF receiver to interpret flight commands. The on-board RF receiver shall operate over the range specified by the competition requirements. The control system shall interface all electronic components associated with the propulsion system and any electronic components anticipated for future use.

YAW ANGLE: The angle between an aircraft's longitudinal axis and its line of travel, as seen from above. Left yaw is achieved in Squadron II when rpm of the motors 2 and 4 increases and rpm of motors 1 and 3 are at normal. Right yaw is achieved when rpm of the motors 1 and 3 increases and rpm of the motors 2 and 4 are at normal.

PITCH ANGLE: The angle between an object's rotational axis, and a line perpendicular to its orbital plane. To achieve pitch up rpm of the motors 1 and 2 increases and rpm of the motors 3 and 4 decreases and for pitch down rpm of the motors 1 and 2 decreases and rpm of the motors 3 and 4 increases.

ROLL ANGLE: The angle of rotation of a vehicle about its longitudinal axis. Right roll is achieved in Squadron II by increasing the rpm of 1 and 4 motors and decreasing the rpm of 2 and 3 motors. For left roll rpm of 1 and 4 motors is decreased and the rpm of 2 and 3 motors is increased

B1) Stability Augmentation System

Squadron II achieves stability by calculating its current position using the triple axis gyro and accelerometers, calculating the error signals between current point and set point using PID algorithm

B2) NAVIGATION

The inertial navigation system (INS) is an efficient navigation method but it can occur accumulative errors. To correct this error in the INS, this paper presents a novel optical-flow aided navigation method by studying the terrain aided navigation, which can implement the continuous error estimation of the INS by employing the extended kalman filter that regards optical-flow as its measurement parameter. Therefore, this aided method is similar to the terrain aided navigation except that the measurement parameter and equation are both derived from optical-flow instead of terrain height. Experiments with some actual aerial image sequences have proven the efficiency of this aided navigation method.

C) Flight Termination System

Squadron II is terminated using a kill switch. The kill switch is placed in the 2.4GHz transmitter and is manually controlled. When the kill switch is activated the quad gets disarmed and the motors will stop its functioning and the LEDs will start blinking. This brings the flight to immediate termination.

PAYLOAD

a) Sensor suite

a1) GNC Sensors

GNC Sensors used by Squadron II are Optical flow sensors and APM 2. The other sensors used are 3axis accelerometer, triple axis digital output gyros and barometric pressure sensors.


a2) Mission Sensors

a21) Target Identification

SURF algorithm is used in SQUADRON II for target identification. SURF (Speeded Up Robust Features) is a robust local feature detector, that can be used in computer vision tasks like object recognition or 3D reconstruction. The task of finding point correspondences between two images of the same scene or object is part of many computer vision applications. The matching is based on a distance between the vectors, e.g. Euclidean distance.

a22) Threat avoidance

Squadron II uses mapping of the images and with the aid of ultrasonic sensors to detect and avoid threats.

b) Communications

Squadron II communicates through long range 2.4GHz transreceiver module used for cameras and videos and 413 MHz transreceiver module used for telemetry. The system is integrated with arduino board programming and normal PPM is used for kill switch.

c) Power Management

Squadron II uses Arduino and Mosfet to control power output to the Electronic Speed Controllers and motors according to the requirement of the load and altitude. A steady 5V DC will be given to the onboard computer. We are using two batteries. Lipo 11.1v is used to power ESC and motors and 7.4v used to power electronic equipment of the quadcopter.

OPERATIONS

A. Flight Preparations

a1) Check List(s)

1. Make sure the power of battery is full
2. Check 2.4GHz connection
3. Check 4x motor controller
4. Check 4x motor blade orientation
5. Check RC radio
6. Check the status of quadrotor and the connection of avionics
7. Power on, check the switch of control rights
8. Check the communication between the quadrotor and the ground station

Once the physical check has been completed, a functionality test must be done:

1. Program the ON board computer flight controller
2. Power ON 2.4GHz transceiver
3. Power ON telemetry kit
4. Check LED indicators
5. Run onboard self-diagnostic program
6. Run automated checklist
7. Make a simple test flight to make sure the software system works fine

B. MAN/MACHINE INTERFACE

Man/machine interface is established by telemetry and onboard camera. The telemetry is connected with the ground station for real-time display of quadrotor flight status, including attitude, position and ambient environment and so on, which is used to judge whether the flight is normal. Telemetry is transferred to off board computer via 143 MHz transceiver. The camera link is established with high frequency 2.4 GHz transceiver module. Six channel RC controller is used to switch between modules and autonomous board and also act as a kill switch.

RISK REDUCTION

Safety has always been a primary concern, and the system was designed to be safe for all persons in close proximity to it during the competition. Many levels of risk reduction have been put in place in order to prevent personal injury and damage to hardware. The aircraft status is monitored by ground station software module and human operators.

A. Vehicle Status

The ground station monitors many properties of the quadrotor including: roll, pitch, yaw, height, motor commands, laser scan data and camera images. This can be done using Wi-Fi connection during the flight. The ground station will display the status and save them for further analysis.

a1) Shock/Vibration Isolation

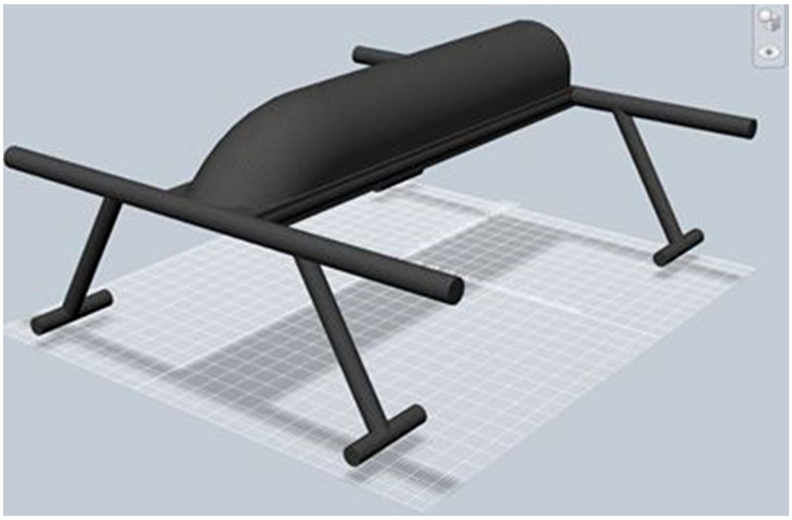
The primary source of vibration onboard vehicle is the propulsion system. The shock is from the rotation of motors, which will interfere the accelerometer and the ultrasonic sensor. For the ultrasonic sensor, we use anti-vibration pad to reduce the shock. We also use rubber washers to retard the shock and at the same time filter in the software is being used to reduce the effect of shock. We have balanced propellers to reduce the shock and vibrations.

a2) Electro Magnetic Interference (EMI)/Radio Frequency Interference (RFI)

B. Safety

To ensure the safety of people and the vehicle, a series of tests should be taken before the flight, as mentioned in checklist. We have already taken safety into account when designing the system. Firstly, we use small prop protection. Then we designed two emergency schemes. One is that we can stop the propellers via the data link between the ground station and quadrotor. The other one is that we can take over the quadrotor through one channel of RC controller. These two schemes uses different data link, improving the system security redundancy.

C. Modeling



D. Testing

Each system has undergone individual and integration testing to determine operational characteristics and functionality. Design changes are tested using the CATIA models as well as the Microsoft Robotic Development studio simulations before being implemented. After implementation, the system was tested using manual control before testing autonomous control.

CONCLUSION

Team Recon has designed Squadron II to meet the challenges of the 6th mission at IARC. This paper has detailed information about the air vehicle and payloads of the vehicle. Our system is in the initial stages of testing and we are very much hopeful that our first attempt will be successful and we will be a tough competitor in this event.

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