Squadron-xIcop UAV technical paper for International Aerial Robotics Competition

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ABSTRACT

The team Recon presents Squadron-xICop an UAV Quad rotor designed for the 6th Mission of the AUVSI International Aerial Robotics Competition (IARC). This paper describes the details of a Quad-rotor Unmanned Aerial Vehicle capable of exploring the unknown indoor environment without relying on any external navigational aids. Using image recognition Surf algorithm, the vehicle is able to recognize posted Arabic signs and a flash drive. This vehicle is capable of autonomous movement and navigation throughout, an unknown building using Simultaneous Localization and Mapping (SLAM) algorithms. The ultrasonic sensor along with collision avoidance algorithm ensures real-time path planning and pattern recognition.

INTRODUCTION

a) Statement of the problem

The main objective of the 6th mission of the International Aerial Robotic competition needs an UAV that can travel through an unknown confined environment in search of a specific target. The vehicle needs to drive into a cluttered environment through a window of 1m x 1m size and requires locating and bringing back a flash drive.

The general restrictions on the vehicle are as follows:

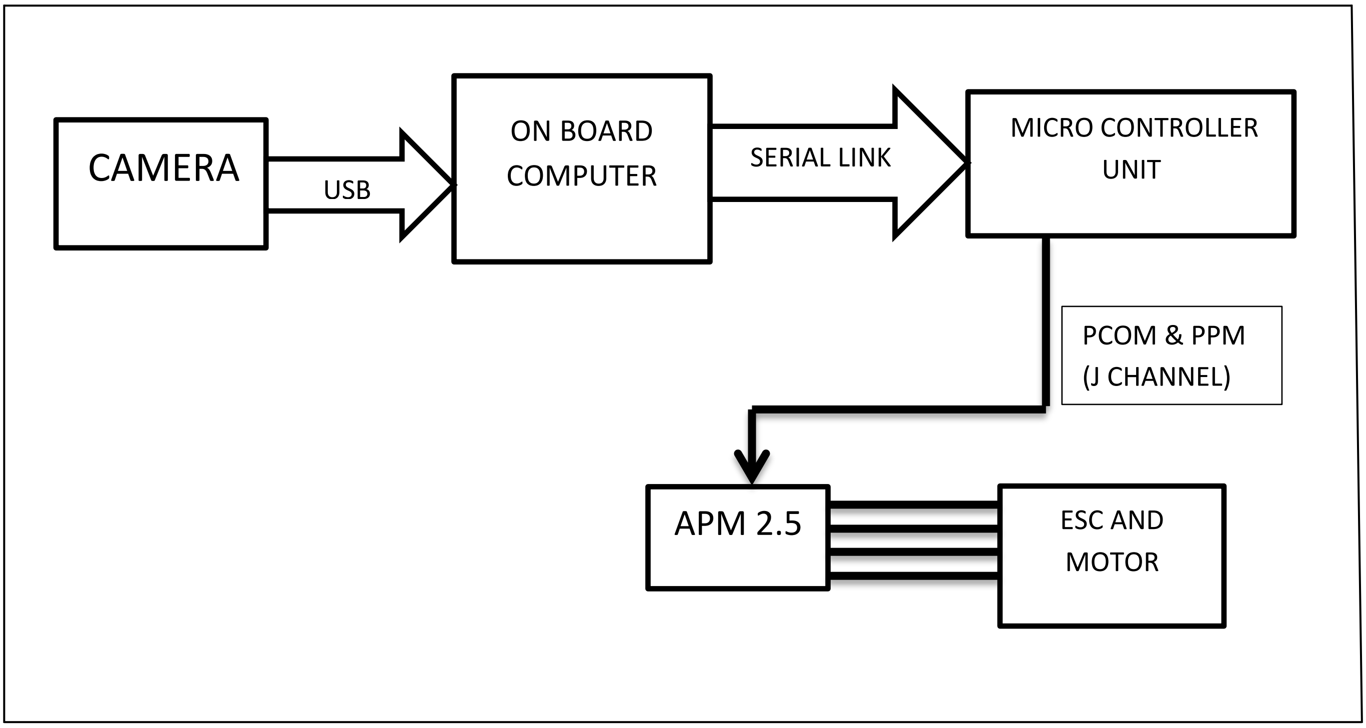
- Must not weigh more than 1.5kg
- Must not exceed 1m in any dimension
- Must operate electrically
- Must have a termination mechanism that will immobilize the propulsion system

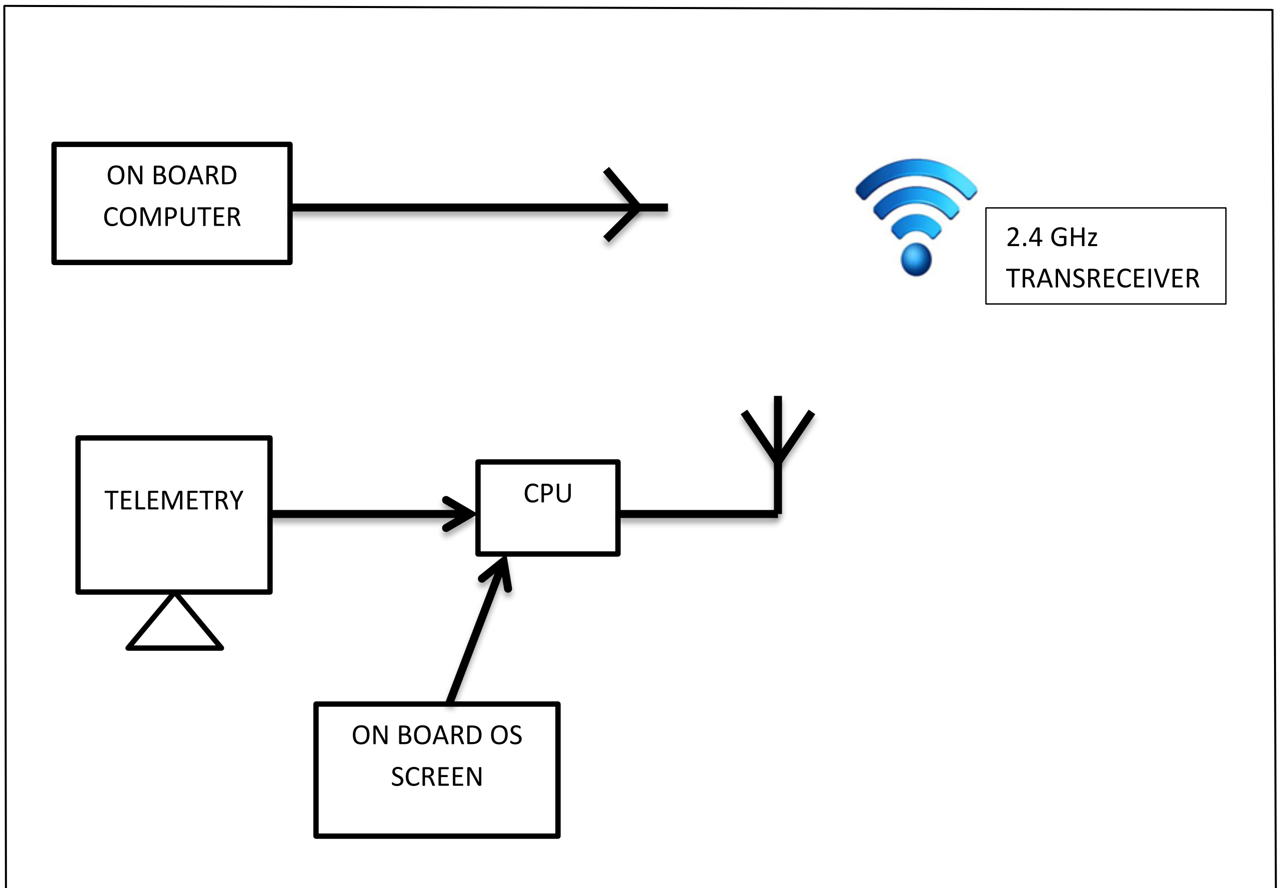
b) Conceptual approach

Team Squadron-xIcop at Hindustan University has designed autonomous Squadron-xIcop Unmanned Aerial Vehicle to head out for the search of the flash drive in a confined indoor environment. SLAM algorithm is used for the navigation of the vehicle through the confined environment. Image processing methods are used to detect whether the LED is in on/off state. SURF algorithm is used to identify Arabic signs. Using the same SURF algorithm flash drive recognition is done. Laser barrier kill switch recognition. Flash drive will be retrieved using a robotic arm which has semi-spherical degree of freedom.

c) **Yearly Milestones**

This being our first attempt at IARC, we intend to develop an Unmanned Aerial Vehicle (UAV) capable of autonomous navigation in unknown cluttered indoor environment and complete IARC mission 6.





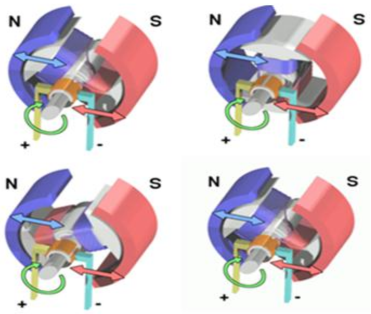
System architecture

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 MAVs are an ideal choice for autonomous reconnaissance and surveillance because of their small size, high manoeuvrability, and ability to fly in very challenging environments.

a) Propulsion and Lift system

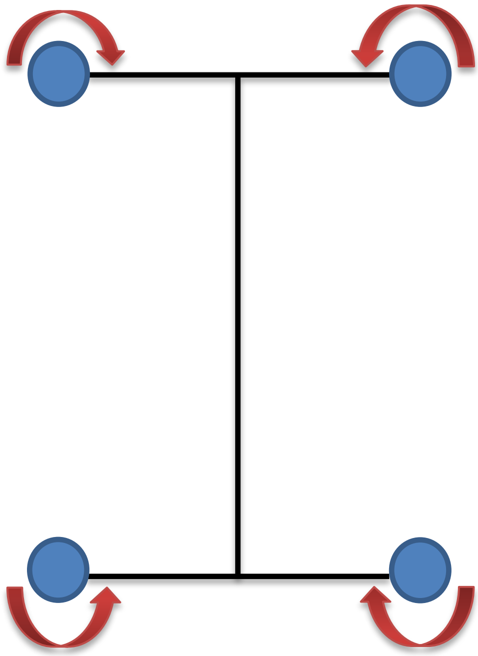
Team recon has used brushless motors and propellers for Squadron-xIcop. In a brushless DC motor, the brush-system assembly is replaced by an electronic speed controller. The elimination of brushes allows the brushless DC motor to achieve a greater efficiency over conventional brushed DC motors.
Team 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.



Brushless Motors

b) 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.



Squadron-xICop

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-xIcop 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-xIcop 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-xICop 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*

Squadron-xIcop uses SLAM for navigation. Various features of SLAM are as follows:

- Mapping

  SLAM in the mobile robotics community generally refers to the process of creating geometrically consistent maps of the environment.

  SLAM is tailored to the available resources, hence not aimed at perfection, but at operational compliance. The published approaches are employed in unmanned aerial vehicles, autonomous underwater vehicles, planetary rovers, newly emerging domestic robots and even inside the human body.

- Sensing

  SLAM will always use several different types of sensors to acquire data with statistically independent errors. Statistical independence is the mandatory requirement to cope with metric bias and with noise in measures.

  Such optical sensors may be one dimensional (single beam) or 2D- (sweeping) laser rangefinders, 3D Flash LIDAR, 2D or 3D sonar sensors and one or more 2D cameras.

- Locating

  The results from sensing will feed the algorithms for locating. According to propositions of geometry, any sensing must include at least one lateration and (n+1) determining equations for an n-dimensional problem. In addition, there must be some additional a priori knowledge about orienting the results versus absolute or relative systems of coordinates with rotation and mirroring.

c) Flight Termination System

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

b) Communications

Squadron-xIcop 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-xIcop 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

- Check RC radio
- Check 413MHz
- Check 2.4GHz connection
- Check 4x motor controller
- Check DIN socket connector
- Check kill switch position
- Check 4x motor blade orientation

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

- Program the ON board computer flight controller
- Power ON 2.4GHz transreceiver
- Power ON telemetry kit
- Enable autonomous mode in RC controller
- Check LED indicators
- Run onboard self-diagnostic program
- Run automated checklist
- Quad is flight capable if there is no error

b) Man Machine Interface

MMI is established by telemetry and onboard camera. Telemetry is transferred to offboard computer via 143 MHz transreceiver. The camera link is established with high frequency 2.4 GHz transreceiver 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. During the flight, these properties are recorded for further analysis in the future.

a1) *Shock/Vibration Isolation*

The primary source of vibration onboard the vehicle is the propulsion system. Electronic sensors are mounted on anti-vibration rubber pads. Propellers are balanced to reduce the vibrations.

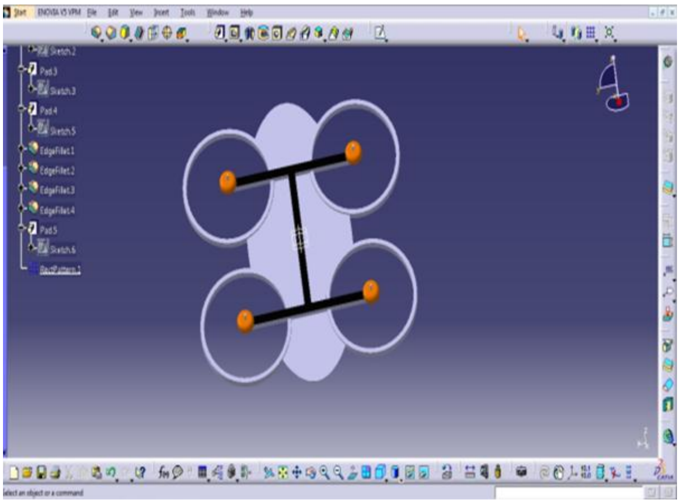
a2) *Electromagnetic Interference (EMI)/Radio Frequency Interference (RFI) Solutions*

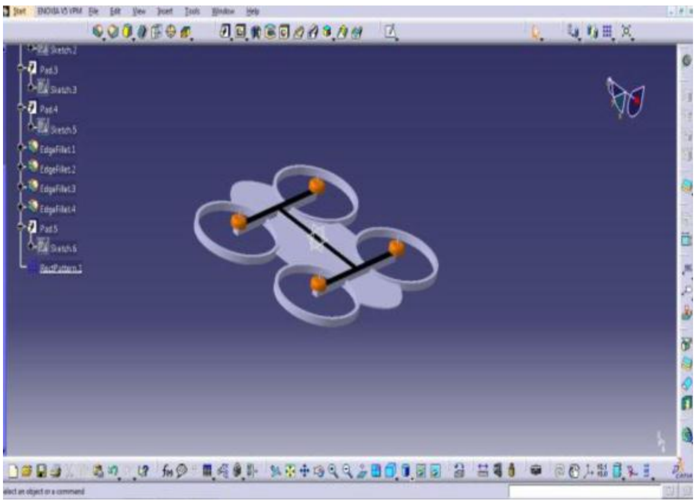
The chosen quadrotor platform has brushless motors, which has reduced EMI signature. Proper electric grounding and additional capacitors are used to provide further protection against EMI. A 2.4GHz transmitter was chosen for the video link, the safety pilot radio control link, and the data link. This eliminates the typical servo jitter affecting UAVs operating with 900MHz transmitters nearby. Possible interference between the different 2.4GHz systems is reduced by proper shielding and location of antennas.

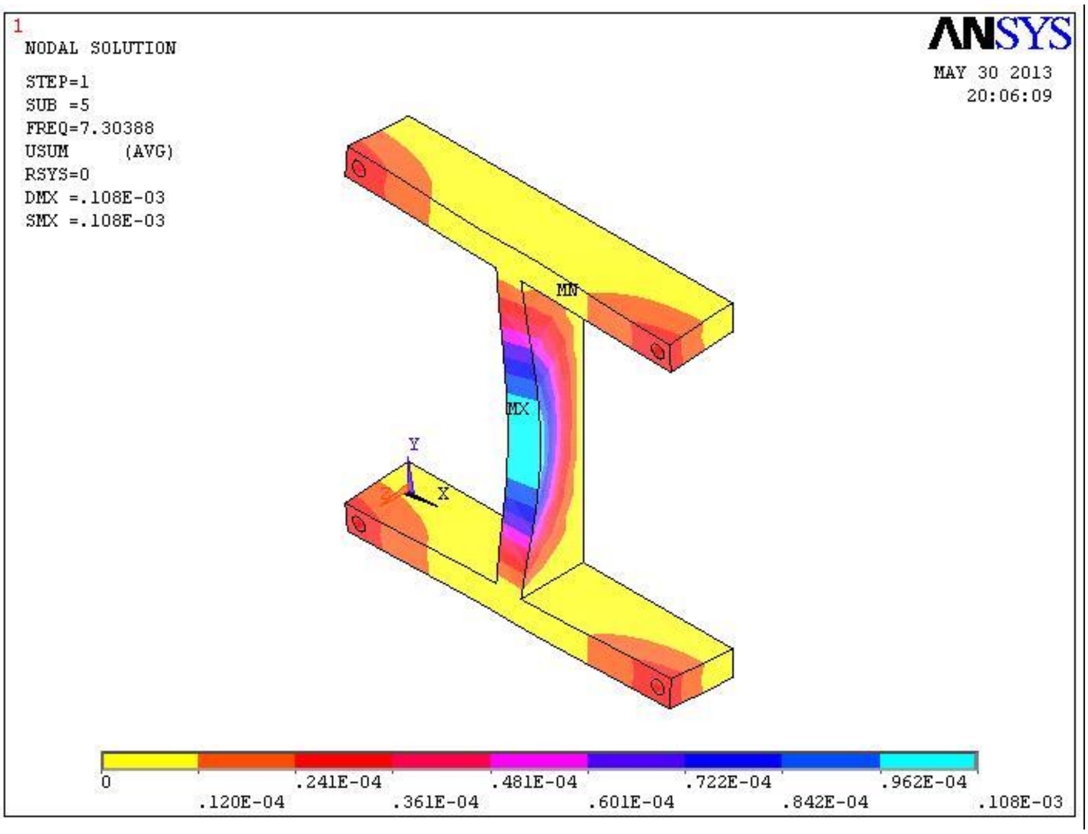
b) Safety

The Squadron-xIcop was designed with safety in mind. Effective measures have been taken to ensure safety during the autonomous flight. Controls can be manually overridden to avoid any vehicle damage or injury to any person. Further, the vehicle motion can be instantaneously killed using a “kill” switch to avoid any potential injury or crash.

c) Modeling And Simulation







Simulation used : Microsoft Robotic Studio

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-xIcop 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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