TEAM AERO-I

DELHI TECHNOLOGICAL UNIVERSITY

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ABSTRACT

The paper gives prominence to the technical details of the Unmanned Aerial Vehicle developed by the students of Delhi Technological University, India, which can navigate in indoor environments without the use of any external aid.

RUDRA, is designed to give a reliable autonomous flight by incorporating image acquisition and processing along with a commercial available autopilot. The vehicle communicates with the ground station to provide a real time picture of the quad rotor's view for a safe and an unfailing flight.

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1. Introduction

1.1 Mission Requirement Analysis

The 7th edition of competition focuses on the interaction of the aerial vehicle with the moving objects. At the same time, movement in the GPS denied environment that also without using any external aid has been the focal point.

While working in a confined space, we need to direct the i-robots (the grounded vehicle) towards the green line of the 20m*20m arena within 10 minutes.

After thoroughly analyzing the requirements for the mission, we penned down our objectives to achieve our goal before the deadline.

1.2 OUR APPROACH

After considering the above points, it was time to put these words into action and we came up with the following analysis

	PARAMETER	ANALYSIS
1.	Image Acquisition and Processing	Identify bot within the field of view and take appropriate decisions
2.	Design	Search for the most stable design of an aerial vehicle
3.	Controls and Circuits	Customization of sensors with autopilot and incorporating machine vision
4.	Communication and Networking	On board processing along with wireless communication with the ground station

2. DESIGN

2.1. APPROACH

The quest for the vehicle's design started as soon as the team started. We started with the single-duct design. Though the single duct design was simple and easier to make, but it was quite unstable because of having only one rotor. This makes the vehicle spin on its axis due to momentum balance. The next attempt was made for dual-rotor vehicle. It compensated for the few shortcomings of single rotor design, but still the stability was the key issue. The presence of two rotors on different axis needed proper alignment of the axis as well as the center of gravity. This design failed as far as agility and reflexes were concerned. The next step took us to the co-axial design- two rotors on the same spinning axis. Efforts were made to maximize the thrust by placing the rotor suitably apart so that the motion of one does not hinder the second. The effective rotor distance was calculated and center of gravity was placed in the middle of them. This design worked for the roll, pitch and yaw to some extent with the help of PID controllers. While working with the co-axial design, we came across the quad rotor concept.

2.2 VEHICLE CONCEPT

The design of quad rotor was popular for its agility and extra-stability. We headed toward this design by calculating the effective arm-length, minimum distance between the two rotors, minimum height of the rotor from the ground to avoid ground-effect. This design was first prototyped using Solidworks software and then finally fabricated using balsa-wood. The design worked really fine with an additional advantage of light weight leading to less inertial overshoot. The current design is taken from 3dRobotics quad frame and the center of gravity is maintained as close to the center of pressure for lesser inertial forces and better reflexes.

2.3 List of materials used:

1. **Quad frame.**
   3 DR Arducopter Quad C Frames

2. **Motors (x4)**
   Emax MT2213-920 KV

3. **Propellers (x4)**
   3DR APC Propellers 11x 47 Push-Pull Set

4. **Electronic Speed Controller (x4)**
   Power HD 40 Amp ESC

5. **Flight controller**
   3DR APM 2.5 Set

6. **Power distribution board**
   3DR Quadcopter Power Distribution Board

7. **Intel atom board.**

8. **Camera**
   Logitech 525 HD Webcam

9. **Distance sensor – SONAR**
   MB1240 XL-MaxSonar EZ4

10. **RC transmitter and receiver**
    Spektrum DX7s 7 CH Transmitter with AR8000

11. **Battery**
    Turnigy nanotech 3.3 (3300 mAh LiPo)

12. **Servo connecters**

3. FLIGHT CONTROL

3.1 OVERVIEW

After browsing for several autopilots on the net, we came across APM2.5 autopilot which not only served our purpose of coming up with a reliable and controlled flight, but also fit our pocket. Sensors were integrated with the autopilot to generate proper commands for the actuators.

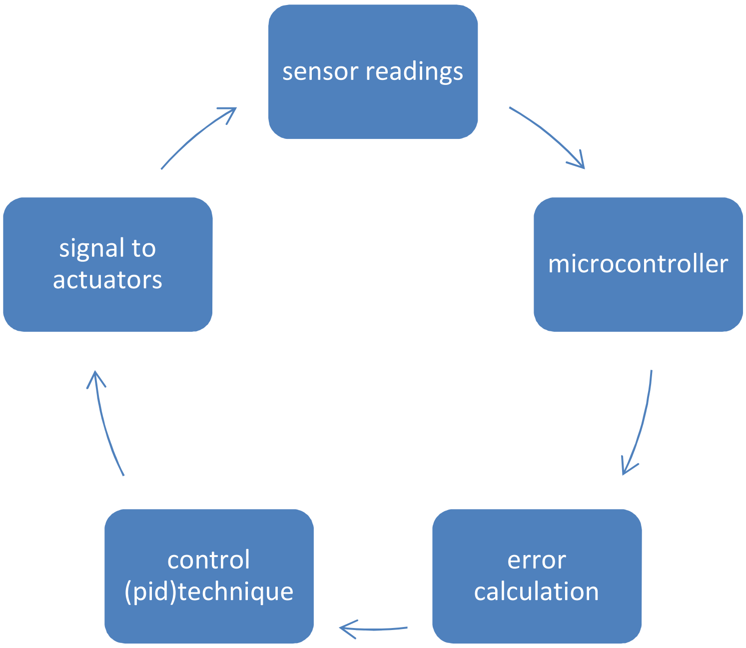
3.2 SELECION PROCESS

1. We needed to give stability to our vehicle maintaining a proper orientation in the space. APM 2.5 served this purpose. It has a 3 axis gyroscope along with a 3 axis accelerometer which provide accurate and precise tilt angles.
2. To maintain a constant height, use of sonar was a must.
3. In the initial phase, the quad rotor was given remote controlled flights using DX7S(2.4GHz). The stability of the vehicle was achieved by tuning different control parameters using the autopilot and mission planner.

3.3 OUR APPROACH

In the initial phase, we started to work on accelerometer and gyroscope. Stabilizing the quad copter using these two sensors was our prime motive. The values of the sensors for different positions were set and the motors were controlled using closed loop control.

PID technique was implemented for controlling the motors.

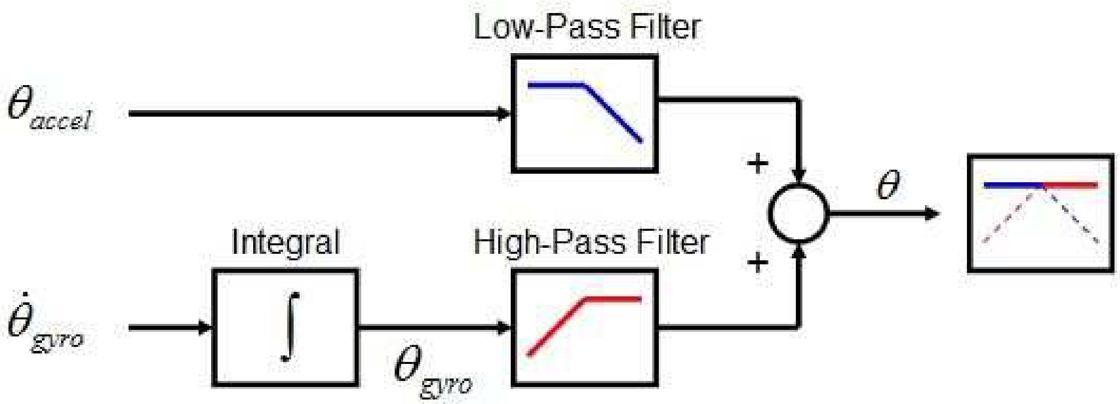


3.3.1 SENSOR CALIBRATION

There were two problems that were to be taken care of

1) Noise in the accelerometer reading

2) Reducing the drift in the gyroscope readings
   To counter both the above problems, complementary filter was implemented.



COMPLEMENTARY FILTER

The accelerometer readings are passed through a low pass filter and a high pass filter was used to counter the drifting effect of the gyroscope.

The readings achieved were considerable but still had a bit of noise which could not have been implemented on the quad rotor.

Then we decided to work on Kalman filter. The results obtained were satisfactory but controlling quad rotor was still a problem. The controlling methodology underwent several changes but in vain.

In the end we decided to work on autopilot apm 2.5 which actually helped us to achieve the desired stability.

3.3.2 FIRST FLIGHT

Remote controlled flight was given initially to finely tune Rudra. DX7S was used to accomplish this task

Then it was time to make it a bit autonomous. In the second stage ROLL was controlled through image processing and the throttle was still via remote control.

3.3.3 COMPLETELY AUTONOMOUS FLIGHT

After having tested ROLL and PITCH using image processing, it was time to make it completely autonomous i.e. throttle was fixed at one value using sonar and ROLL and PITCH using image processing.

4. Image Acquisition and Processing

4.1 OVERVIEW

We have laid emphasis on detecting objects and obstacles using image processing and then generating control signals for the actuators using an image processing algorithm using OpenCV.

4.2 APPROACH

In the beginning, we started image processing using color thresholding algorithms. After this the opencv code was integrated with the low level microcontroller to give instructions to the grounded vehicle to perform a certain set of instructions just on the basis of color thresholding.

After having achieved this, we started template matching and object detection and recognition.

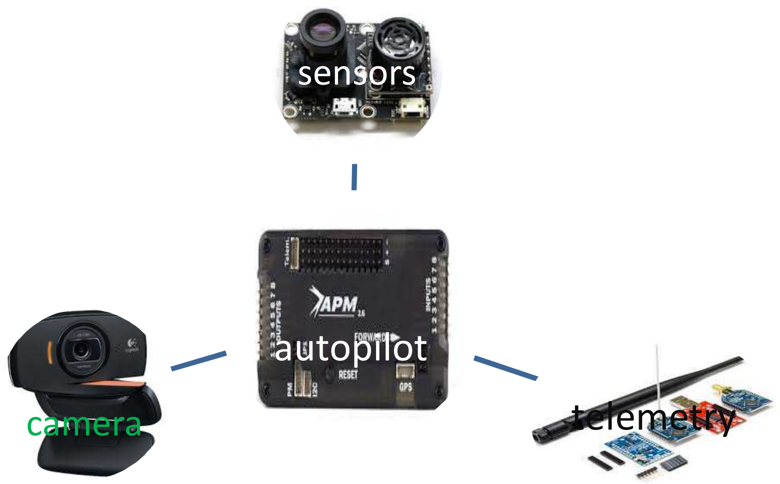
A code was developed for the same and was implemented on a grounded vehicle.

After achieving appropriate results and making some modifications in the code, it was tested on our vehicle. Although stability was an issue in the earlier stages of testing, but it was rectified by the some modifications in the flight control algorithm.

4.3 Imagery Peripherals

A high definition Logitech camera, C 525, is used for capturing image and an opencv code is used to process the captured image.

An on board processor in the form of Intel atom(1.6GHz) is used to do all further processing on board.



4.4 Image analysis

1. capture image
2. image segmentation
3. color thresholding
4. template/feature matching
5. communication with the microcontroller
6. generate control signals

5. COMMUNICATION AND NETWORKING

5.1 OVERVIEW

Communication between the high level controller and the low level controller was achieved by using a RS-232 cable. In this way, information from opencv was transferred to the low level controller and ,thereafter, control signals were generated to take appropriate actions.

Communication between the vehicle and the ground station was struck by using a wifi adapter which continuously helped us to monitor the quadrotor's vision.
In case there was any safety issue, killer switch was infused into action.

5.2 SELECTION PROCESS

APM 2.5 comes with its own telemetry kit. This telemetry kit is used to transfer the values of different performance parameters.
For imagery, using Xbee transreceiver module (2.4 GHz) was our first approach. But it works at a much lower data rates. So using a 2.4GHz Wifi adapter module seems to be better and a more viable option.

6. Conclusion

The development of quad copter for vertical takeoff and landing (VTOL) integrating image processing seemed to be a daunting task initially. But with sheer perseverance and hard work, Rudra is capable of taking a reliable and safe flight without the use of any external aid or mechanism.
Rudra aims at completing the task within 10 minutes of allotted time.
Learing was the key. We came up with several ways of tackling the problem statement and after

analyzing every aspect, we settled with the best suited approach.

7. ACKNOWLEDGEMENT

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