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Research paper

Radio controlled quadcopter with augmented range and control for special missions requiring live data and video transmission

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Abstract

Recently, the natural and man-made calamities have been observed erratically with solutions provided majority of times being born by military and other rescue teams which is often a time-consuming process. This project focuses on such remote operations like surveillance of buildings, calamities hit areas by first understanding its behavior and later on have a platform for the others to enact by using the live data transmission on the Ground Station which can be a Computer, or any display networking device. The Flight Control also consists of 10 DOF IMU embedded along with the Microcontroller in order to stabilize the entire System. The scope of this project is to stabilize the semi-autonomous control system of an Unmanned Aerial Vehicle (UAV) for remote operations through live video data along with various parameters and sensor readings with real time graph plots generated and the location is updated on Google maps.

The initial step was to make a complete design of the Quad Copter on Solid Works with which real time mechanical simulations were achieved. Then the state space equation of quadcopter was derived by using Processing Software. Subsequently the link budget calculation, attainment of the PID gain values and real time Data Transmission of Video feed on finite number of computer and networking devices, real time sensor graphs and GPS location on Google Maps were implemented. Finally, the quadcopter was tested for some special applications.

Keywords: *Quad Copter; Augmented Range; Remote Operation; Data Transmission.*

1. Introduction

The UAV vehicle that has been selected for the project is a Quad Copter which is lifted and propelled by four rotors. These are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors which are vertically oriented motors. These vehicles are capable of vertical take-off and landing (VTOL), Loitering, holding an altitude as well as Return to Launch at the same time in case of failure operations provides easy movement in 3-D space by varying the speed of the motors for different configurations of the vehicle. The symmetric structure of Quad Copter makes it relatively easier to build the mathematics and complex equation for stability algorithms and achieving the physic-mechanics of the system. The structure is made up of F330 Fiber glass material, which is light in weight and provides rigidity. The Micro Quad Copter Structure developed is made up of F330 Fiber Glass material, which is light weight and provides Strength. In addition, the MEMS technology has led to the advent of highly precise Inertial Measurement Unit (IMU) which is the key to building a Quad Copter because of its ability to provide data of acceleration, angular velocity, earth's magnetic field as well as altitude. By the use of Complementary Filter data of displacement and Euler angles is obtained which is fed to the PID Control Loop to control each of the three axes i.e. Roll, Pitch and Yaw as well as the altitude. MEMS MPU 6000(3-Axes Accelerometer and 3-Axes Gyroscope), MS5611-01 Barometric Pressure Sensor along with 3-Axes HMC5883L Magnetometer also known as 10DOF IMU was thus used as the Stabilization Unit.

The GPS sensor that was selected was Broadcom BCM47511|UB2G GPS / GNSS Receiver. It contains the data of Latitude, Longitude and Altitude. It has a carrier frequency worth 1575.42 MHz. The GPS works perfectly in the outdoor environment. The sampling rate is appropriate enough so as to ignore the introduction of GPS moving algorithm.

For generation of Artificial Network ASUS 2.4 GHz routers and 2.4GHz TP-Link Repeaters are used for broadcasting the Network wide enough for appropriate communication at the ground station and the live data is transmitted using Samsung Microprocessor by installing the mobile phone itself GT-N7000 on the Quad Copter.

2. System overview

The Quad copter is very well modeled with a four rotors in a '+' (plus) configuration. This cross structure is quite thin and light, however it shows robustness by linking mechanically the motors. All the propellers axes of rotation are fixed and parallel. Furthermore, they have fixed-pitch blades and their air flow points downwards. These considerations point out that the structure is quite rigid and the only things that can vary are the propeller speeds. The basic concept is shown in Fig.1

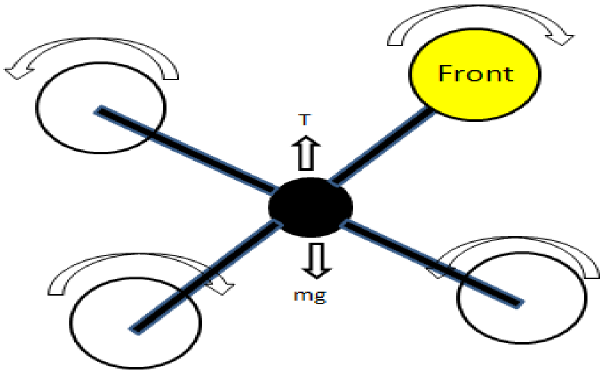

Fig. 1: Conceptual Diagram of a Quadcopter.

The electrical part of the copter comprises of cascading architecture of [2] Atmega 2560's and an individual Samsung Microprocessor for Auto Image stabilization Image data Transmission. The battery used for this purpose to power the whole system was 3 cell lithium polymer battery of rating 3300mAH. Extra GPS module has been integrated for the control of the copter in autonomous mode. Using of Ark bird 433mHz - UHF module has been used to convert the 2.4GHz frequency to 433mHz in order for higher order range of flight control and agility (up to 4 miles).
Sensors included in the built up of the system are following MPU 6000 MEMS Motion tracking sensor, MS5611-01BA Barometer Sensor for Altitude stabilization control algorithm and secondary flight control, Magnetometer HMC5883L for measuring magnetic strengths in different directions to overall increase the degrees of freedom of the overall flight control.
The complete integrated system is presented in the below Fig.2. It includes the external added camera module GT-N7000 connected with the help of cable ties and acrylic mounts.

Fig. 2: The Plus Chassis of the Structure.

Before the real fabrication and integration of the overall system it was created on Solidworks as shown in Fig.3 and analyzed for the mechanical stabilization and effects on the structure based on various thrust forces action and miscellaneous effects.

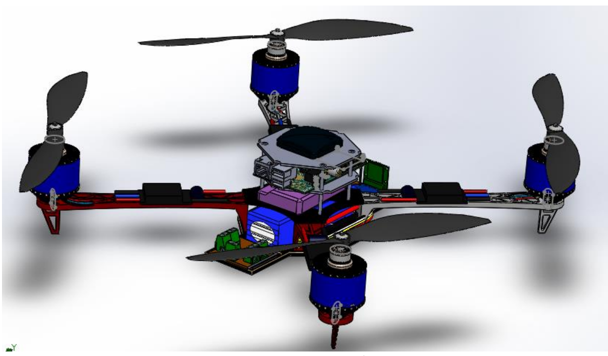

Fig.3: This is the Final Structural Design of the Auto-Quad System Being Simulated with the Software Solidworks.

The center part of the system comprises of the electronics and control systems.

1) The Structure is More Dynamically Balanced Compared other frame structure which were fabricated earlier.
2) Due to Symmetry of the Structure the Load is equally distributed and thus helps in stabilizing the Copter.
3) More Amount of Area is Available for Yaw Motion
4) Motor can be attached without disturbing CG.

3. Methodology

Control Systems and Algorithm Generation for Stable Flight
Control System is a heart of every semi-autonomous system. It is an important and integral part of space – vehicle systems, robotic systems, modern manufacturing systems and other industrial operations. Various control techniques have been developed over a period of time for designing control system for quad rotors. The two most important techniques are: Fuzzy Logic Control and PID Control.

3.1. PID control

PID Control Technique has been chosen as the PID controller produces the response with lower delay time and rise time compared with fuzzy logic controller.
Proportional plus rate describes a control mode in which a derivative section is added to a proportional controller. This derivative section responds to the rate of change of the error signal, not the amplitude; this derivative action responds to the rate of change the instant it starts. This causes the controller output to be initially larger in direct relation with the error signal rate of change. The higher the error signal rate of change, the sooner the final control element is positioned to the desired value. The added derivative action reduces initial overshoot of the measured variable, and therefore aids in stabilizing the process sooner. This control mode is called proportional plus rate control because the derivative section responds to the rate of change of the error signal as shown in Fig.4

$$u(t) = K_p.e(t) + K_d \frac{d}{dt}.e(t)$$

3.1.1. Proportional

The proportional term produces an output value that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain constant. The proportional term is given by:

$$P = K_p.e(t)$$

A high proportional gain results in a large change in the output for a given change in the error.

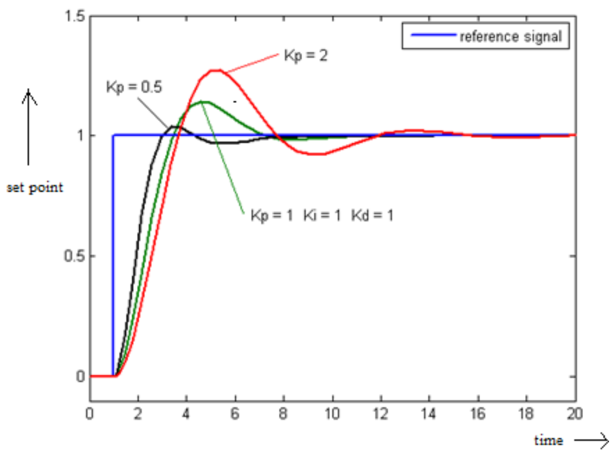

Fig. 4: Effect of Proportional Constant.

3.1.2. Derivative

The derivative of the process error is calculated by determining the slope of the error over time and multiplying this rate of change by the derivative gain K_D. The magnitude of the contribution of the derivative term to the overall control action is termed the derivative gain K_d. The derivative term is given by:

$$D = K_d \frac{d}{dt}.e(t)$$

Derivative action predicts system behavior and thus improves settling time and stability of the system as shown in Fig. 5

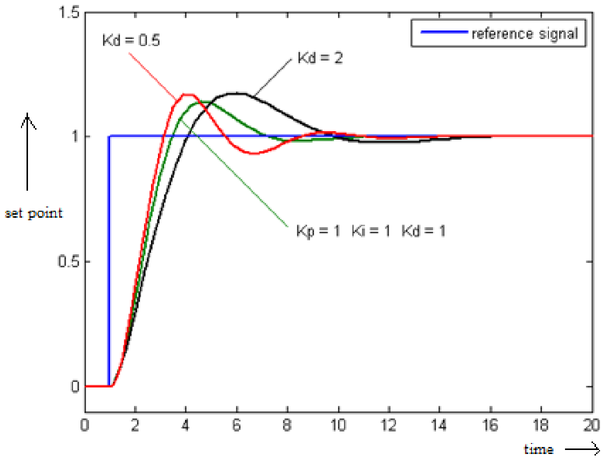

Fig. 5: Effect of Derivative Constant.

3.1.3. Integral

The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. The integral in a PID controller is the sum of the instantaneous error over time and gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain (K_i) and added to the controller output as shown in Fig. 6 in graphical manner.
The integral term is given by:

$$I_{out} = K_i \int_0^t e(T)dT$$

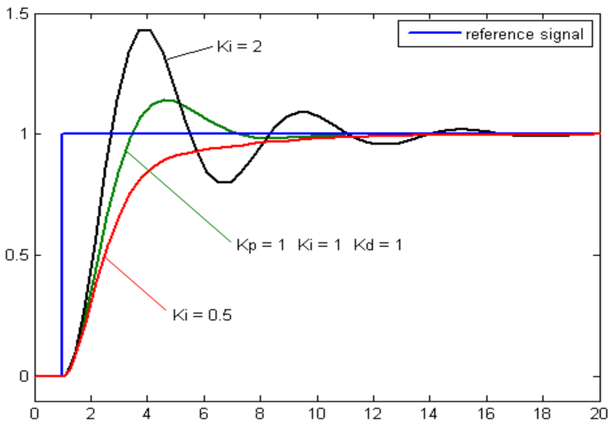

Fig. 6: Effect of Integral Constant

3.2. Complimentary filter

The values obtained by accelerometer and gyroscope contain a lot of noise so a filter needs to be implemented in order to remove the uncertainties from the signal. The gyroscope has a drift and in a few time the values returned are completely wrong. The accelerometer, from the other side, returns a true value when the acceleration is progressive but it suffers much the vibrations, returning values of the angle wrong. Hence accelerometer gives accurate value over a long period and gyroscope gives accurate value over short periods as shown in Fig. 7
So, a math filter is used to mix and merge the two values, in order to have a correct value. Complementary filters manage both high-pass and low-pass filters simultaneously. The low pass filter filters high frequency signals (such as the accelerometer in the case of vibration) and low pass filter filters low frequency signals (such as the drift of the gyroscope). By combining these filters, good signal is obtained, without the complications of other complicated theoretical filters such as the Kalman filter. The basic working is shown in Fig. 8.

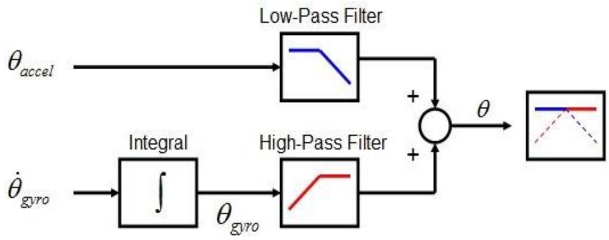

Fig. 7: Complimentary Filter.

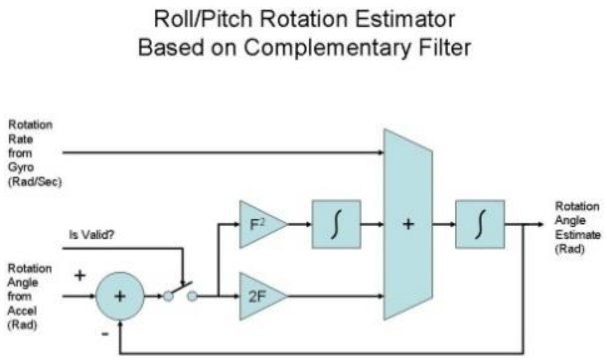

Fig. 8: Roll/Pitch Rotation Estimator Based on Complementary Filter.

Equation of complementary filter is given as follows:

$$angle(t) = \alpha * (angle(t-1) + gyro * dt) + (\beta * accelero)$$

Also, $\alpha + \beta = 1$

Where,
Angle (t) is orientation angle at time t (current time instance)
Angle (t-1) is orientation angle at time t-1 (previous time instance)
A and β are the complimentary filter constant.
DT is the sampling time period.
Gyro is the angular reading from gyrometer.
accelero is the angular reading from accelerometer.

3.2.1. Implementation of complementary filter

Double roll angle = (0.98*(rold+ gyro [0]*c)) + 0.02 * accel [0];

Double pitch angle = (0.98*(pold+gyro [1]*c)) + 0.02 * accel [1];

3.2.2. Implementation of PID controller

3.2.2.1. Pitch stabilization

pitch_error = ((p*9.5) - 0);

Difference = (abs (pitch_error-pitch_previous_error)/20);

Motor RPM= ((Kp_pitch* abs (pitch_error)) + (60) + (Kd_pitch *difference));

Fig. 9, 10 and Fig. 14 displays the working.

3.2.2.2. Roll stabilization

roll_error = ((r*9.5) - 0);

Difference = (abs (roll_error-roll_previous_error)/20);

Motor RPM= ((Kp_roll* roll_error) + (60) + (Kd_roll *difference));

Fig. 11, Fig 12 and Fig.13 displays the working.
The integral term accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a pure proportional controller. However, since the integral term responds to accumulated errors from the past, it can cause the present value to overshoot the setpoint value.

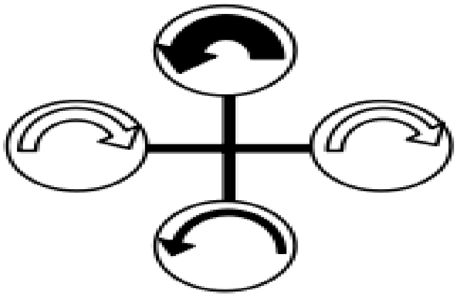

Fig .9: Pitch (Nose Up).

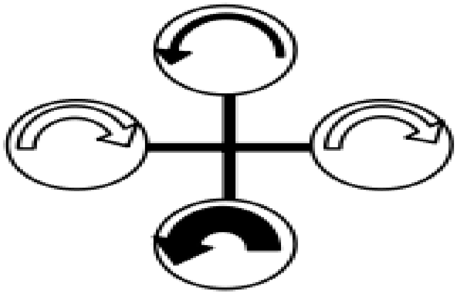

Fig .10: Pitch (Nose Up).

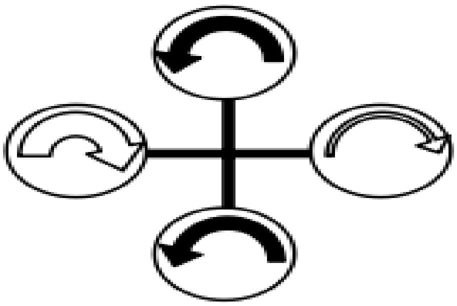

Fig .11: Roll (Left Side Up).

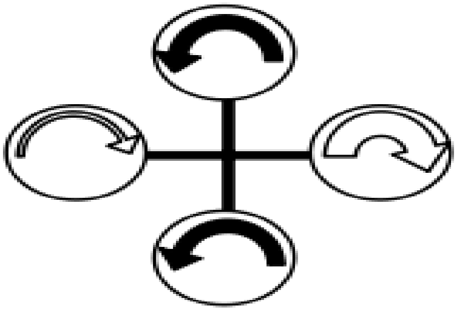

Fig. 12: Roll (Right Side Up).

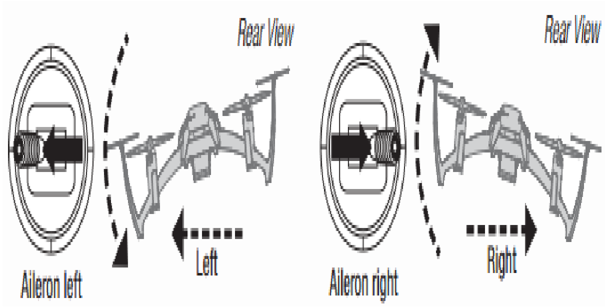

Fig. 13: Roll Stabilization and Control Movements.

3.2.2.3. Yaw control and stabilization

Yaw_angle = (ToDeg (heading));
yaw_error = ((Yaw_angle)-0);
difference = (abs (yaw_error-yaw_previous_error)/20);
Motor RPM = ((Kp_yaw* abs (yaw_error)) + (56) + (Kd_yaw *difference));
Fig. 15, Fig. 16 and Fig. 14 displays the working.

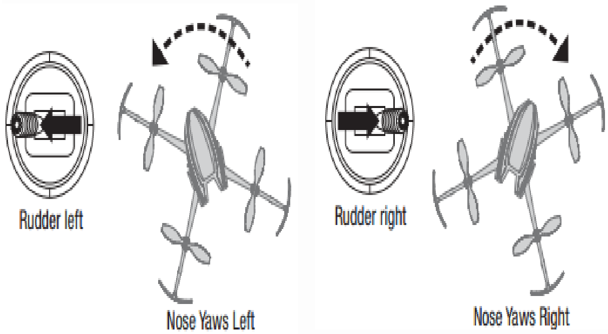

Fig. 14: Yaw Stabilization and Control Movements (Top View).

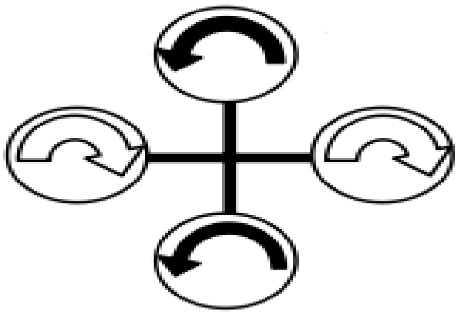

Fig. 15: Yaw (CCW).

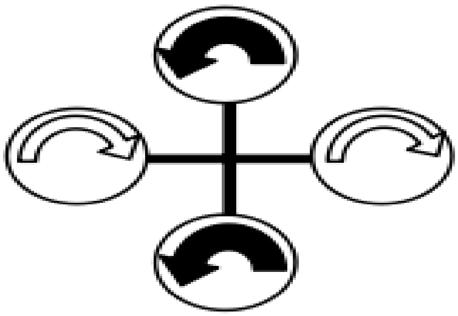

Fig. 16: Yaw (CW).

3.3. Altitude hold and control

The altitude control is achieved by controlling the motor power equally for all [4] motors of micro-copter.
Firstly, raw pressure, P and raw temperature, T, data are acquired from the barometer. Then temperature compensated pressure is calculated according to the following equation:

$$P_t = P\left(SENS_{T1} + TCS(T - T_{ref})\right) - \left(OFF_{T1} + TCO(T - T_{ref})\right)$$

Where the following constant are factory calibrated data which comes pre-programmed in the PROM of the barometer IC.
SENST1 is Pressure sensitivity
OFFT1 is Pressure offset
TCS is Temperature coefficient of pressure sensitivity
TCO is Temperature coefficient of pressure offset
Tref is Reference temperature
Now this temperature compensated pressure is used to calculate the current height according to the following simplified equation:

$$P_t = P_0 . e^{\left(-\frac{g.M.H}{R.T_0}\right)}$$

During start-up the height from sea level is calculated and saved as the current ground level for reference. During the flight the instantaneous height from sea level is calculated and compared with the reference height. This gives the current height from ground frame. Thereafter heights are referred in reference to ground frame. Now the error $e_{ht}(t)$, is calculated from the required height as:

$$e_{ht}(t) = H_{Rq} - H(t)$$

Again, a constrain of error ±2m is given so as to keep the control signal in a specified boundary and not to overshoot when change made in required height is huge. Now this error, $e_{ht}(t)$, is provided to the PI controller for generation of control signal. Thus, the control signal for altitude control is given as:

$$u_{th}(t) = K_p . e_{ht}(t) + K_i . \int_0^{\infty} e_{ht}(t). dt$$

Now the control signal is then fed to the respective motors for controlling the altitude of the micro-copter accordingly. Motor control value is generated as follows:

$$M_{all} = throtle + u_{ht}(t)$$

Simple understanding for the throttle concept is shown in Fig.17, Fig.18 and Fig. 19

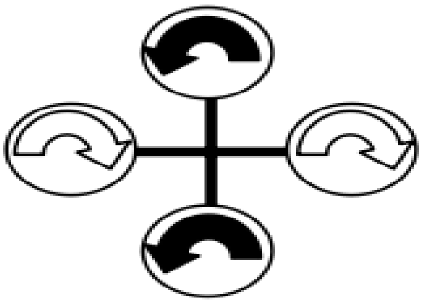

Fig. 17: Take-Off or Upward Motion.

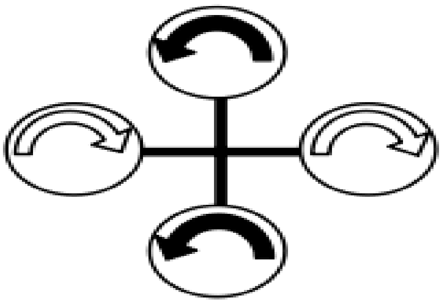

Fig. 18: Land or Downward Motion.

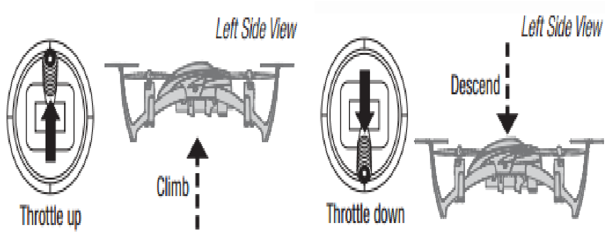

Fig. 19: Throttle Stabilization and Control Movements (Left View)

3.4. Altitude control algorithm

The Altitude control algorithm has been shown in the Control Loop algorithm which has been designed in such a way to increase the sampling rate (Update Rate) for the first time up to 50Hz and the second time to 100Hz. The Control Loop shown in Fig.20 represents the above criteria and explains step-by-step application of the control establishment along with quantized data accuracy.

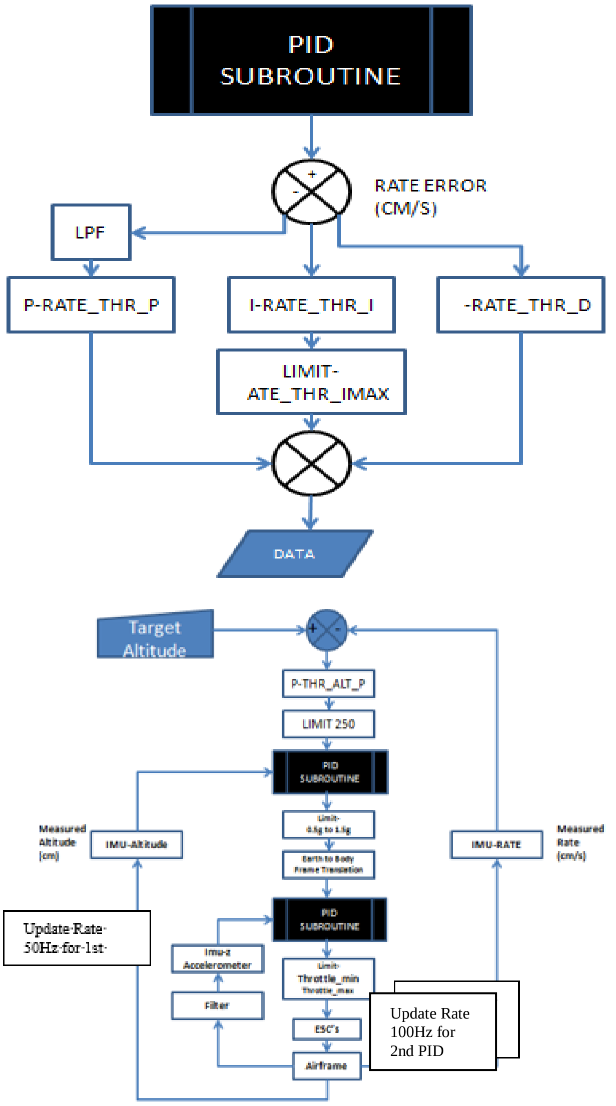

Fig. 20: Altitude Control Algorithm.

4. Communication and data handling

The communication can be subdivided into two parts:-

- RF Communication
- Artificial Network
- Unlocked for any Global GSM Carrier, in the operating frequencies with a data broadband activated SIM Card
- HSPA+/HSPA/UMTS 2100 MHz GSM/GPRS/EDGE 850/900/1800/1900MHz

- Connect up to 5 WiFi enabled devices at the same time.
- MicroSD Card Slot (up to 32GB) External Antenna Port. Sim card or Micro SD card are not included.

WI-FI Module

- Currently smallest wireless adapter to be hidden well in USB port
- Supports 150 Mbps 802.11n Wireless data rate - the latest wireless standard. Permits users to have the farthest range with the widest coverage. (Up to 6 times the speed and 3 times the coverage of 802.11b.).
- Power Saving designed to support smart transmit power control and auto-idle state adjustment
- Supports WMM (Wi-Fi Multimedia) Standard so that you can let different types of data have higher priority. It would allows better streaming of real-time data such as Video.

The Edimax wi-fi module has its in-built drivers in ARM11. So, the updation and installation of the drivers is easier and compatible with ARM11 controller. The scanning and data handling have been shown respectively in Fig. 21 and Fig. 22

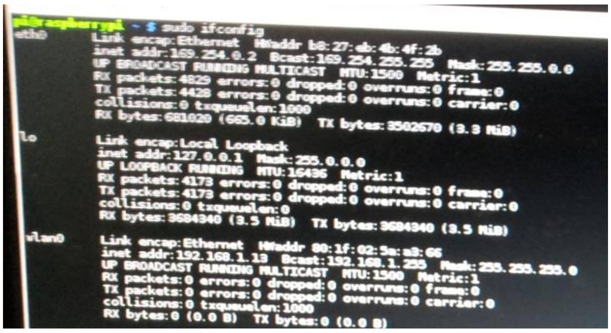

Fig. 21: Total Number of Connections Available Provided to the Processor and Controller.

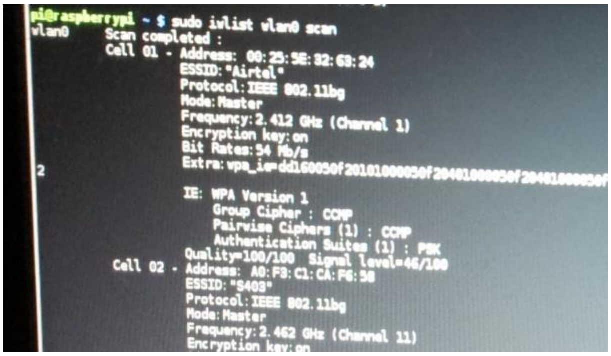

Fig. 22: The Scanning of the Area Done by Edimax

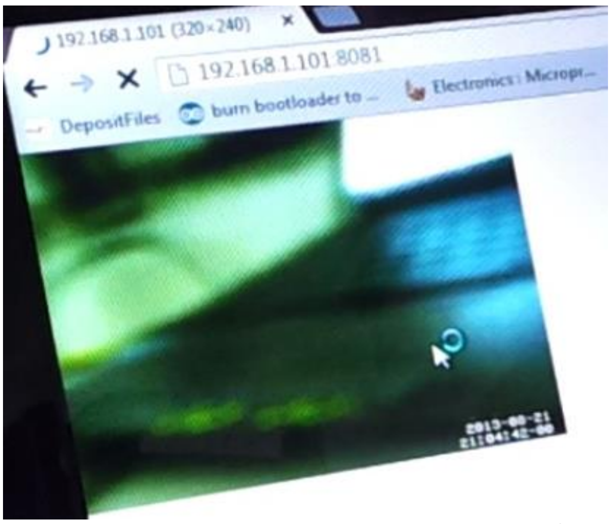

Fig. 23: The Live Data Handling / Streaming on Master Computer from the ARM Processor Remotely Controlled. the IP Address Tracked Along with Port Number for the Remote Device is shown as 192.168.1.101:8081.

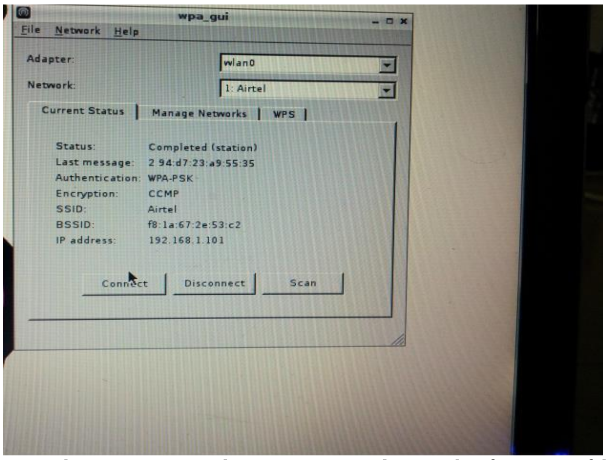

Fig. 24: The GUI Depicting the Connections and Network Information of the Wi-Fi Used. Display is on the Master Computer.

The GUI interface is tested in Airtel Network with authentication secured at WPA-PSK as shown in Fig.23.

5. Electronics and power distribution

5.1. Microprocessor overview

Specifications

ARM11

700MHzCPU 128 or 256mb RAM

Connections

- HDMI
- Composite RCA
- SD card
- 3.5mm audio jack
- 1 or 2 USB 2.0 ports (power via USB)
- Ethernet (model B only)

Size & Weight

86x53mm45g (1 1/2 Oz)

These specifications could perhaps be compared to a laptop from c2004, which isn't that long ago. Standard IC shown in Fig. 24.

Operating System

The ARM11 runs Linux, likely either Ubuntu or ArchLinux. Windows isn't a possibility yet as it doesn't support ARM11 (although there is talk of future versions supporting ARM7 so maybe one day). Note there's no hard drive, the OS is loaded via a SD card, which makes it easy switch between them.

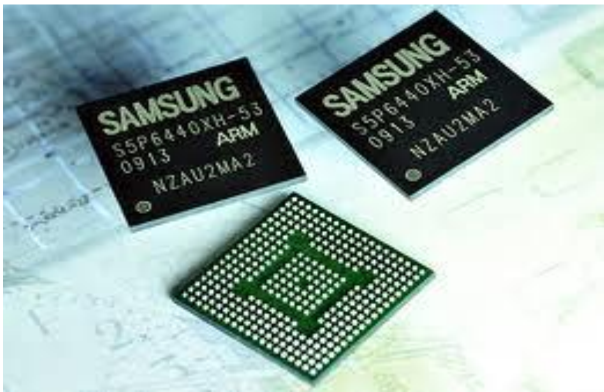

Fig. 25: ARM11 Processor ICS Copyrights Samsung.

5.2. Electronic speed controller (Esc)

An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled models, with the variety most often used

for brushless motors essentially providing an electronically-generated three phase electric power low voltage source of energy for the motor.
Features:-
Max. Amps-125A
The company used is Red Bricks having heat dissipation in mind. featuring over sized Aluminium heat sinks the Red Brick ESCs are slightly larger than many ESCs in their class, however this compromise in size is aimed at assisting to eliminate the problems associated with overheating.

5.3. Battery

A Lithium Polymer (LiPo) battery with the specifications mentioned in Table 1 was used to power the BLDC motors and on-board electronics.

Parameter	Specification
Configuration	14.8v
Pack Size	147 x 49 x 34mm
Capacity	4 cell
Weight	554g
Current(Minimum)	5000mAh

5.4. Microcontroller overview

- The microcontroller board is based on the ATmega2560 . It has a USB host interface to connect with Android based phones, based on the MAX3421e IC.

Specifications:
- Digital I/O Pins – 54
- PWM Pins – 14
- Analog Pins – 16
- UARTs – 4 (Hardware Serial Port)
- Clock Frequency – 16MHZ
- Power Jack
- ICSP Header
- Input Voltage – 7 – 12V
- Current By I/0 Pin – 40mA

5.4.1. The world coordinates system

Determination is done by a combination of various controlling ICs which act a s slave system to the Main microcontroller System. The Micro-controller has been designed by us indigenously and is under the testing stage.
Features of the controller are following:-
- We are using IMU system which includes the an accelerometer linear and angular; at the same time a Magnetometer to provide the correct position of the Earth's Magnetic Field Combine with a GPS and interfacing it with the main system through a combination mix of a Single Pole Double throw Analog Switch.
- The two passing signals will be FTDI-RX and GPS-RX communication via the SPDT Analog Switch to main MCU.
- We have determined the most simplified driving function carrying out our case structures and finally achieved the equation the following equation:-

The following controller is being displayed in Fig.25.
Generalized solution for the system of following variables:-
B1 is the first input
B2 is the second input
S is the selector pin
Y=Output
So, the output condition thus designed for simple circuit based outcome through the K-Map reduction processes we have:-

Y=B1*S+B2*nS

Where
n=negation or not.

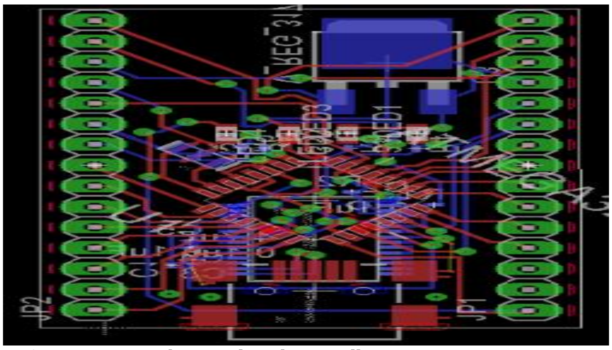

Fig. 26: Depicts the Developed Controller Using Atmega328p-AU.

This has been indigenously designed for the copter requirements

5.6. Transmitter-receiver setup

The physical device used was a standard wireless transmitter of Turnigy of 2.4GHz, which was then engineered for operation at different frequency viz. 433mHz. The 2.4GHz module is detached physically from the back-end of the remote and rather 433mHz transmitter is connected to the system.
This makes a very long range of data transmission approximately 4 miles(according to datasheet).
The following Fig. shows the total transmitter-receiver module used for the flight control.
The transmitter module has mainly three main connections namely Vcc, Ground and Signal. Using female to female connectors the connections are made between transmitter module and the wireless remote signal output from Atmega controller.

Fig. 27: Router Setup.

For a long range and high parallel data transmission Routers and Repeaters are used in the system. The Router used was ASUS 2.4 GHz. 1 ASUS 2.4 GHz RT-AC66U Dual Band 3x3 802.11 AC Gigabit Router
Fifth generation 802.11ac chipset gives concurrent dual-band 2.4GHz/5GHz for up to super-fast 1.75Gbps. ASUS AiCloud service: Access, stream, share, sync – all on the go with unlimited storage expansion. Gigabit Ethernet ports for the fastest, most reliable internet performance. AiRadar optimizes wireless coverage with detachable high-powered antennas
The following router is basically used to generate the artificial network which will be open and no proxy tunnel is required to be cleared. For consideration of optimal data connectivity and seamless transmission the appropriate dBi of high gain antennae are used. The High gain antennae used for the three ports are 9dBi High Gain as shown in Fig 27.

Fig. 28: ASUS 2.4 / 5 Ghz Router.

TL-WA5210G 2.4GHz High Power Wireless Outdoor CPE as Repeater

In telecommunications, a repeater is an electronic device that receives a signal and retransmits it at a higher level or higher power, or onto the other side of an obstruction, so that the signal can cover longer distances. It is a generic term that refers to several different types of devices; a telephone repeater is an amplifier in a telephone line, an optical repeater is an optoelectronic circuit that amplifies the light beam in a optical fiber cable; and a radio repeater is a radio receiver and transmitter that a radio signal. So, the repeater chosen for purpose of the project was TP-Link 2 TL-WA5210G as displayed in Fig.28.

Fig. 29: TP-Link TL-WA5210G Setup.

6. Navigation software and data handling

6.1. Overview

Linux is an open source OS which can be customized to communicate with the controller.

- Data collection from various sensors and conversion using ADC. Optional communication modes may include SPI, Serial and I2C in the later stages of development and sensor up comings.
- Live data transmission to ground station via FTP through internet.
- Sensor Data Processing is worked as there should be proper match of data with the Controller.
- Flight is controlled using control algorithms like PID, which are used to make the UMS hover in order to survey the whole area.

6.2. GPS overview

- GPS module communicates with microcontroller via serial interface. GPS data is transmitted to microcontroller every second or can be done 10 times a second at maximum.
- We are using $GPGGA string because it holds all the information we need.
- All requirements of the GPS section will be accomplished by this data format.
- After the data is received by AtMega 2560 ADK, it will be sent in directly through Cascaded ARM controller to the ground station and it can be tracked by the present co-ordinate and data logged it for post analysis.

6.3. GPS Data format

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,
M,x.x,xxxx*hh

1) UTC of Position
2) Latitude
3) N or S
4) Longitude
5) E or W
6) GPS quality indicator (0=invalid; 1=GPS fix; 2=Diff. GPS fix)
7) Number of satellites in use [not those in view]
8) Horizontal dilution of position
9) Antenna altitude above/below mean sea level (geoid)
10) Meters (Antenna height unit)
11) Geoidal separation (Diff. between WGS-84 earth ellipsoid and mean sea level. -=geoid is below WGS-84 ellipsoid)
12) Meters (Units of geoidal separation)
13) Age in seconds since last update from diff. reference station
14) Diff. reference station ID#
15) Checksum

6.4. Pseudocode

- Readings from various sensors will be taken using multiple threads so that the main program doesn't crash or freeze.
- This data along with data from the camera will be streamed through FTP server to the internet.
- On the ground station, the operator of the Copter would access the application via logging into his account.
- The application is designed such that it has a proper control panel with all the data at its display live.
- There would be 3 control panels, one for the video feed, sensor graphs and Google maps flight location.
- The data along with the live streaming would be saved on the SD card.
- Final Phase: Testing and validation after the Entire UMS Module is fabricated and verified.

7. Round station and telemetry

The ground station software is an open-source mobile application with an entry setup of username and password setup as shown in Fig.29. The GUI feed can also be delivered in the mobile as an application for remote operation. The live telemetry is shown in Fig. 30 and Fig. 31 respectively along with Latitude and longitude respectively.

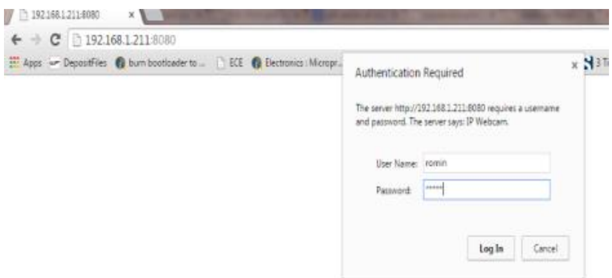

Fig. 30: GUI Entry.

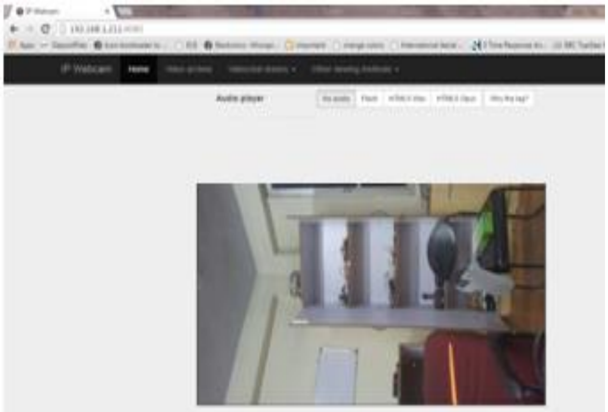

Fig. 31: The GUI for Video Feed

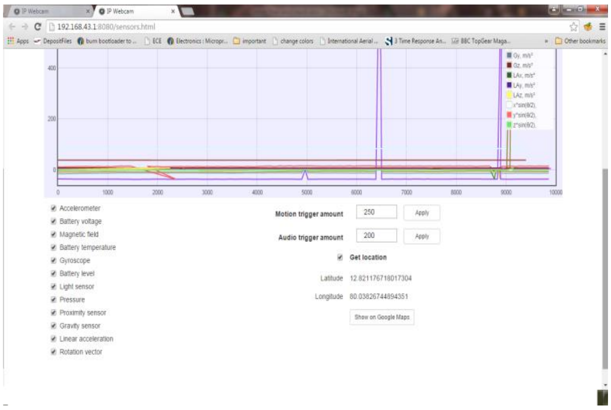

Fig. 32: GUI representing the entire Sensor Graphs Along with Latitude and Longitude Values

8. Conclusion

The project of Surveillance quadcopter with a live data transmission at ground Station for remote operations has been successfully studied and implemented. The quadcopter system was first studied using RC technique for understanding the system behavior during VTOL as well as during cruising state. Later, control system for autonomous VTOL and GPS navigation was designed and implemented. The implemented Complimentary Filter is helping Quad-copter in maintaining its orientation properly. The PID controller implemented is providing the desired control over the system. As live data transmission of various parameters at the ground station with video, sensor graphs getting plot and achievement of final location of the Quad Copter was difficult to achieve with proper stabilizations and Altitude Holding techniques. Hence, the use of routers and repeaters were made for the seamless data transmission and at the same time used the update rate PID filter for increasing the Sampling rate from 50Hz to 100Hz. The frame made up of ultra-durable polyamide nylon has provided good strength to the structure and withstood the test of time. The use of MEMS sensors has helped in reducing the weight and size of the micro-copter.

9. Applications

As the Quad-Copter was able to navigate along with live data transmission the following are the Potential Applications:
Currently, we use this test bed for carrying out the Satellite deployment test from the Container Module at different altitudes to study the impact forces and System behavior at various heights as shown in the Fig. 33, 34 and 35.
In addition, with few more changes in the structure we plan to use it for spraying pesticides in agricultural lands. As spraying pesticides and watering crops is a huge task for farmers, this problem can be tackled by making this quadcopter maneuver through the farm lands, spray water or chemicals and this work is currently in progress.

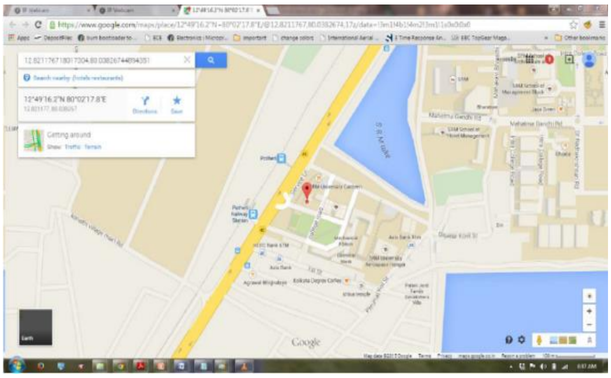

Fig. 33: Quadcopter Location on Google Maps: 12.8211, 80.0382 SRM institute of Science and Technology, Chennai.

Fig. 34: Quadcopter with Satellite Payload System.

Fig. 35: Quadcopter is Taking Off with a Satellite Payload.

Fig. 36: Quadcopter Hovering at an Altitude of 20 Meters and was Ready to Drop the Satellite Payload.

10. Scope for future work

SubGHz tranceiver can be used replacing the current 2.4GHz receiver in order to have more range around 4 miles.
Use of 3D markers attached in the Copter to establish a complete control in any Camera feedback environment
Monitoring Health of Plant units, carrying out survey and analysis of anything needed with help of camera by implementation of Image Processing.
3D Range finders can be implemented for virtual mapping of indoor as well as outdoor unknown areas for mapping and thus can act as another feedback for Navigation.

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