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Design and Implementation of a Real Time Wireless Quadcopter for Rescue Operations

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ABSTRACT: *This paper presents the design and implementation of an aerial surveillance quadcopter for search and rescue applications. The aim of this research is to develop a real-time, compact and cost-effective drone that will be capable of search and rescue operations. The first phase of the paper considered modeling of the quadcopter while the second phase involved system implementation and simulation. The basic components used for the quadcopter design were Nirvaino Multi-rotor Flight Control Board, brushless motors, Electronic Speed Controllers (ESCs), SkyZone FPV Wireless Receiver, LiPoly Cell Battery, Mobius Camera, and 4mm Heat Shrink Tube. The design takes cognizance of the structure model, and hovering stability of the quadcopter. The frame of the quadcopter was made up of very light glass fiber to ensure stability while flying and also to reduce weight of the overall material. The entire design generated a compact and low cost surveillance quadcopter with weight of approximately 1.50kg; which can take photographs from environments with the aid of the onboard mounted camera. Live streaming was done with the help of laptop during flight.*

Keywords*:Quadcopter, Real-Time, Rotor-craft, Surveillance, Reconnaissance, Wireless Communication*

I INTRODUCTION

The need for flying vehicles was driven by advances in aeronautics, engineering, and embedded processing. Recent years, many researchers geared efforts towards flying compact robots or unmanned air vehicles (UAVs). [1], [2] and [3] defined flying robots as aerial vehicles without the onboard presence of pilots. The need for compact UAVs is to forestall the menace posed by flying large size drones in dangerous environments. Today, there are different kinds of available UAV's model which are named according to the number of rotor it has. Quadcopter is one of such devices which are made of four rotors positioned equidistant to the center of mass of the device in order to generate lift and maneuverability.

Besides that, quadcopters move with the aid of electric motor, basically with four upwards rotors that facilitate any maneuvers within its flying area. It is designed in such a manner that it has a closed loop control to maintain a predefined trajectory, have automatic take-off and landing capabilities, and rotates above particular moving or stationary object of target [4], [5]. The dimensions of a quadcopter can vary from the size of an insect to the size of an aerial vehicle depending on the type of application the UAV is meant for [5].

The first designed Quadcopter was utilized by the French engineer Etienne Oehmichen in 1924 [6], [7]. Recently designed quadcopters are small in size, and deployed for applications such as in mining detection, aerial photography and surveillance. The configuration designs of quadcopters could be plus (+) or cross (x) configurations where the later handles the more payload [6].

Quadcopters unlike other aircrafts derive their thrust and movement from individual motor assembly or a set of revolving airfoils, and are controlled by its major axes (namely pitch, roll and yaw) [8], [9]. The lift generators are run by high speed motor and balanced propellers which generate the thrust that lifts the craft above the ground level by pushing down the air flow. Quadcopters are controlled by varying the speed of its four rotors without any mechanical linkages required as obtainable in conventional helicopter [10].

This research is aimed at designing a real time wireless quadcopter that is appropriate for search and rescue operations. Ideally, the craft would be capable of autonomous flight and will be able to achieve a nominal flight altitude of about 7ft. The rest of the paper is organized as follows: Section 2 highlights related works in order to bring the work in this paper into perspective; Section 3 analytically details the design considerations, and specifications, with the system block diagrams description; Section 4 presents the results obtained from testing of the completed work, finally, Section 5 concludes the paper.

II REVIEW OF LITERATURES

[1] described the model of a flying robot with gripper mechanism for surveillance purpose. The authors used aluminum frame to reduce the weight of the flying robot. The flight was able to lift more payloads due to the use of 1800KVA runner motor. However, the flying robot has the challenge of less flight time. [11] designed a miniature wireless quadcopter that has the capability of flying about and hovering like a helicopter with the aid of extra added motors. The software and hardware were carefully integrated to ensure a miniature technology but could not carry much payload. [12] proposed and designed the system and algorithms necessary to allow a quadcopter to autonomous locate and land on a station target. The quadcopter was able to hover in place but could not carry much payload. It was also meant for data collection or surveillance systems that only cope with moderately short battery life. [6] in their design engaged an android operating system embedded in a smart phone to operate the quadcopter through graphical User Interface (GUI) and user's commands on the phone. The authors developed a small size UAV capable of taking photographs from environment though they did not consider issues of stability and carriage of higher payload other than the mounted camera. [9] developed a successful ISR quadcopter using cheap components. The author developed system platform that could be used as a low cost substitute to perform explosive detonation of army targets at high level of precision. The quadcopter however, could not resist much vibration and lacked stability.

Thus, amidst all the challenges listed above, this research is intended to design and implement a compact aerial surveillance quadcopter for search and rescue applications. The quadcopter would be capable of autonomous flight and will be able to achieve a nominal flight altitude of about 7ft. The total mass of the UAV will be below 2kg and the battery life will endure for at least 15 minutes. In all, the quadcopter will be capable of carrying moderate payload such as camera, and would be able to compensate for the external disturbances.

III METHODOLOGY

The concept of how quadcopters operate is fairly simple, but implementing each subsystem requires quite a bit of attention to detail in order for the aircraft to function properly. This section highlights the design methodology that was followed for the implementation of the quadcopter and details of how each subsystem works. The first phase of the project considered the design of the quadcopter while the second phase involved system implementation and simulation. The components used for the quadcopter design were duly tested and checked to ensure maximum safety and also to reduce cost.

3.1 Design Specification

The specifications for the design were listed in table 1 below and these determine the choice of suitable components.

Table 1: The specifications for the quadcopter design

Parameter	Value
Lifting thrust	7.50N.
Weight	Max. Component weight: 1.5kg
Battery	a. Type of cells – LiPoly cells (3S). b. Estimated flight time – 15mins.
Visibility	Suitable in clear weather only
Range of radio frequency coverage	1km
Frequency of video feed transmission	5.8GHz
Frequency of control signals	900MHz

3.2 Hardware Design

The following factors were put into consideration during design of the quadcopter.

3.2.1 The Quadcopter Body

The frame of the quadcopter was made of very light glass fiber. Many other materials such as aluminum and wood were considered. Aluminum was not used because of its inability to absorb vibration from the motors whereas wood could easily be destroyed by insects and weather conditions.The body of the quadcopter is divided into three parts: body frame, landing gear, and gimbal. The body frame enclosed all the needed components. The body frame was made slim with holes drilled to it to maintain stability while flying and to reduce the weight of the overall material. The width of the frame was 450mm and the height was 55mm. The gimbal was used to hold the camera in place and the landing gear was made to have a lower center of gravity for stability when landing the quadcopter.

3.2.2 Motors (brushless) and Electronic Speed Controllers (ESCs)

Before choosing a motor for the design, the total weight which the UAV was meant to take was determined, and then the thrust required to lift the quadcopter was worked out. This was necessary because if the thrust provided by the motors were too little, the quadcopter will not respond well to control and will even have difficulties taking off, and if the thrust was too much, it might become too agile and hard to control. A rule of thumb required for thrust is given as:-

$$Thrust = (weight * 2) \div 4$$ (For 2:1 thrust / weight ratio) (1)

Where: weight = estimated weight of loaded vehicle which is obtained by adding the individual weights of all motors, propellers, ESCs, camera etc. The list of components with their respective weight are tabulated in Table 2 below:

Table 2: List of the components with their respective weight estimates

S/N	Components	Estimated weight per unit	Number of units	Total Weight
1.	Brushless Motors	70g	4	280g
2.	Propellers	15g	4	60g
3.	Mobius Camera	39g	1	39g
4.	LiPoly Cell Battery	278g	1	278g
5.	Frame	270g	1	270g
6.	TURNIGY K-Force 30A Brushless ESC	25g	4	100g
7.	Power distribution Board	55g	1	55g
8.	4mm Heat Shrink Tube	10g	2	20
9.	SkyZone FPV Wireless Receiver	25g	1	25
			TOTAL	1127g

(Assuming all other minor components weigh not more than 373g so that the overall weight can be approximated to 1500g). For the quadcopter to hover, it has to beat gravity. Since the overall weight of the system is 1500g (Including the weight of the minor components), its four (4) motors and propellers have to produce at least 1500g of thrust in order to beat gravity. As we have 4 motors, each one has to produce 1500 ÷ 4= 375gof thrust (with assumptions that all motors/propellers produce equal thrust). Since it is general rule to have a 2:1 thrust/weight ratio for a standard quadcopter, the standard thrust therefore required for each motor is: 375g x 2 = 750g. From the above estimate for the thrust, Turnigy D2836/8 1100KV Brushless Outrunner Motor with the following specifications was chosen. Table 3 below gives the specifications for a 1100KV brushless outrunner motor.

Table 3: 1100KV Brushless Outrunner Motor specifications.

Components	Specification
Kv (rpm/v)	1100
Weight	70g
Max Current	18A
Max Voltage	15V
Total Length	49 mm

Given the equation for static thrust:

$$T = (2 * pi * r2 * rho * P2)0.3333$$

(2)

Where: T = thrust, r = propeller radius (in meters), rho= air density = 1.22kg/m3 $P = shaft\ power = voltage\ x\ current * motor\ efficiency\ (in\ watts)\ (15 * 18 * 75\%) = 202.5W$

(3)

The following assumptions were made: eta = 0.7, Motor efficiency = 50% (the maximum efficiency for a brushless motor is around 75% and happens around 90% of the motors maximum speed), Propeller radius = 1/2 the length of the propeller (given a 10 x 4.7 propeller) = 5 inches or 0.127m, current and voltage (for shaft power) = maximum current and voltage of the motor whose products gives the maximum power = 300W.

The estimated thrust for one motor therefore becomes:-

$$T = (2 * 3.142 * (0.127)2 * 1.22 * (202.5)2)0.3333$$ (4)

T = 17.18N

This value of thrust obtained by calculation based on estimation can be said to be close to the value of the thrust (max. pull) of 1130g as specified by the manufacturers. Therefore the choice of motor is justified.

In choosing ESCs for the motors, the amperage of the motors is put into consideration. For example, the selected motor draws a maximum of 20A current. So it is necessary to go for a speed controller with amperage higher than 20A. A 30A speed controller with battery eliminated circuit (BEC) output of 5V/2A is chosen. This means that 5V output from the ESC can power up the microcontroller and the servomotor (for camera gimbal). With this, the ESC can comfortably handle the most amperage that the motor will ever draw; and together with the suitable battery pack, the motors will always be able to pull all the energy it needs and so will be able to realize its full potential. In combination with the above motors and speed controllers, a 10 x 4.5 propeller is chosen as well.

3.2.3 On-Board Power Supply

The entire system is battery powered. The battery is a LiPoly 3S pack which has an output voltage of 11.1V and a capacity of 3000mAh. It is connected to the ESCs through the PCB in the frame. The electronic speed controllers (ESCs) which feature a built in battery eliminator circuit (BEC) of output 5V/2A then supplies the 5V which is required to power the microcontroller. The battery is also used to power the camera and the Skyzone transmitter.

In choosing a battery, it is usually ideal that the amperage of the battery pack should exceed that of the motor. This ensures that even when the motor is running at 100%, the battery will not hold it back. Therefore to have optimum power/weight combination, a battery pack just above the motors amperage should be chosen. The motor's amperage is calculated as follows: maximum power of motor = 270W, battery voltage (3s Li-Po) = 3 x 3.7V = 11.1V (Where 3.7V is the nominal voltage for each cell), maximum per motor amperage = 18A

$$For\ 4\ motors \Rightarrow 18A * 4 = 72A \quad (5)$$

A battery pack with amperage rating above 72A is therefore needed.

For a 3 cell Li-Po battery pack chosen with the following specifications: Minimum Capacity: 3000mAh, Configuration: 3S1P / 11.1v / 3Cell, Constant Discharge: 40C, Peak Discharge (10sec): 50C, Pack Weight: 278g.

$$Max.\ Amperage\ is\ given\ as: (3000mAh * 40C) \div 1000mA = 120A \quad (6)$$

The amperage of the battery well exceeds that of the four motors and so is very suitable for the design. Also, there is a relationship between the vehicle weight and battery run time. With this, the estimate flight time of the quadcopter can be determined. Firstly, the power required to produce the estimate thrust of 750g is determined. Since the motor's maximum power of 270W produces a thrust of 1718g, then the 750g thrust will be produced by: 750g x (270 ÷ 1718) W = 117.87W power.

With the required power, the current drawn from each motor can then be calculated:

$$I = P \div U \quad (7)$$

Where: I= motor current (A), P = motor power (W), U = battery voltage (V). Since 3s LiPoly cells with nominal voltage of 11.1V are being used, required current is 117.87 ÷ 11.1 = 10.62A (for one motor).

$$For\ 4\ motors \Rightarrow 10.62A * 4 = 42.48A \quad (8)$$

This is the current that the four motors will draw in order to hover the quadcopter.

Since the battery capacity and current consumption are known, the length of time the quadcopter can draw that amount of current from the battery can be calculated using equation (9) below.

$$T = (C \div I) * 60 \quad (9)$$

Where T= time (min), C = battery capacity (Ah), I = current (A)

$$T = (3.0 \div 42.48) * 60 = 4.24\ mins.$$

This time is the least flight time as the motors will not be operated at 100 percent power.

3.2.4 Image/Video capture device:

The image capture device is the FPV camera (Mobius Wide Angle C Lens). It has a resolution of 5mega pixels and is capable of capturing HD videos. It is connected to a 5.8GHz transmitter which transmits wirelessly to a 5.8GHz receiver, and also connected to a computer for live feeds. The image/video capture device (camera) is mounted on the tabs at the bottom plate of the main frame. The mounting tab holds the camera in place and the wide view angle of the camera eliminates the need for a servo motor. This ultimately reduced the weight and power requirement of the entire system.

3.2.5 GPS Navigation:

The GPS navigation enables the quadcopter to independently make its way to a given target location.

3.2.6 Motor Controllers (ESCs):

The microcontroller board's firmware monitors measurement devices (gyroscope, magnetometer and accelerometer) that make up the Inertial Measurement Units (IMU) to get the current state of the quadcopter, along with the operator's input (desired state) and sends signals to the ESCs attached to each of the motors. The ESCs use these inputs received from the microcontroller to deliver the power required to control the speed of the motors. Each ESC has a processor, firmware and other electronics that manage this task by rapidly switching the power to the motor on and off. Each motor moves either in a clockwise or anticlockwise direction. Figure 1 below is used to illustrate the quadcopter direction based on the variation of the speed of the motors.

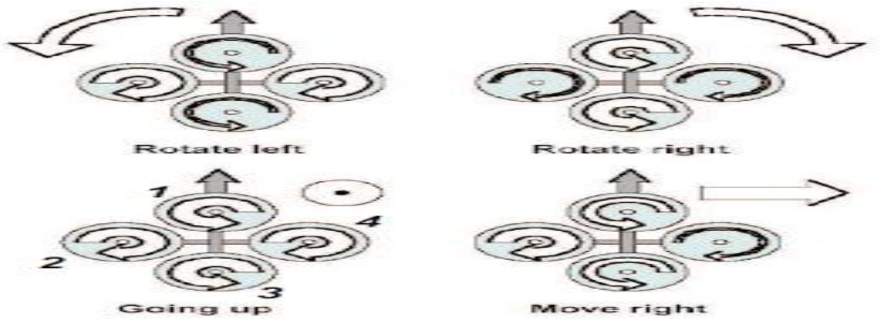

Fig. 1: Basic Motion of Quadcopters [11]

3.2.7 Communication System:

The laptop served as the main input for control signals and the signals were transmitted to the microcontroller and vice versa through the use of the Skyzone RF modules that have been configured to communicate with one another. This is displayed in figure 2 below:

Fig. 2: Communication System- the Skyzone RF Modules

A manual transceiver was also used to override the Autopilot mode of the quadcopter. Turnigy Transceiver shown in figure 3 was used. The transceiver system has a nine channel Transmitter and an eight channel receiver. It uses pulse position modulation encoding scheme at the transmitter and pulse code modulation encoding scheme at the receiver.

Fig. 3: Turnigy Transmitter

3.2.8 The Microcontroller:

Nirvaino Multi-rotor Flight Control Board is the primary flight controller at the heart of the Nirvainois Arduino Pro Mini's Atmel Mega368 8-bit AVR RISC-based microcontroller with 64k of memory. The block diagram in figure 4 below shows the input/output relationship of all other components to the microcontroller.

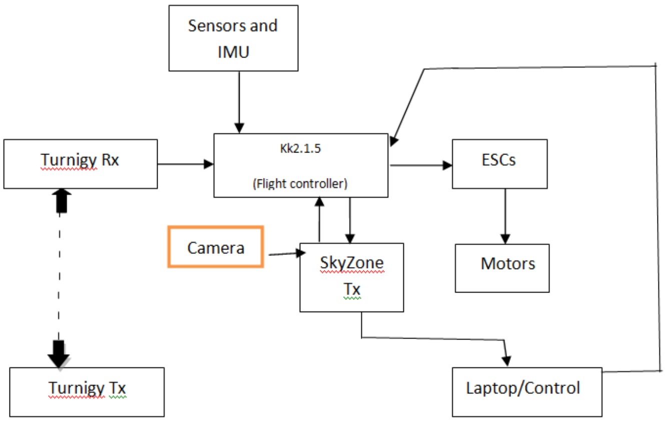

Fig. 4: Block diagram showing the input/output relationship of other components to the flight controller

3.3 Programming of Components
3.3.1 Microcontroller:
The microcontroller was programmed using the Arduino C. The Arduino platform is an attempt to simplify the process of writing codes without unduly limiting the user's flexibility. It is built on many other open-source projects, adapting them to the Arduino hardware and hiding their unneeded complexities. The Arduino software consists of two main parts: the development environment known as the IDE (Integrated Development Environment) and a core library, both open-sources. The Arduino development environment is a minimal but complete source code editor. It is a cross-platform application written in Java and usable under Windows, Mac OS X, and Linux. In it, users can manage, edit, compile, and upload their programs. All functions can be accessed from a set of seven toolbar buttons or a few drop-down menus. The user need not fiddle with makefiles or command line arguments, which can pose as a significant obstacle for a beginner. The environment includes a serial monitor, allowing the user to send data to and receive data from the board, easing debugging without requiring additional software.

3.4 Design Simulation:
After the system design, the quadcopter was first simulated before construction was carried out. The various parameters calculated were first used to simulate the quadcopter on MATLAB and Simulink. The figure 5 below shows the block diagram of the system.

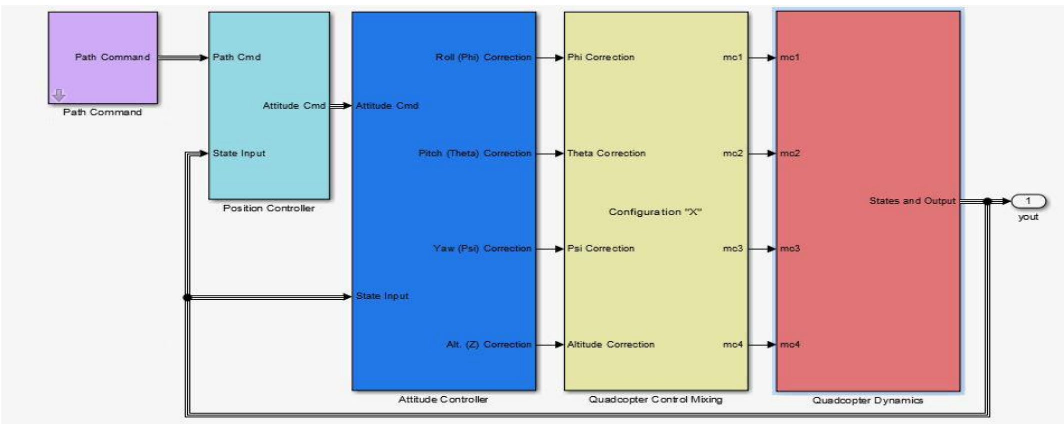

Fig. 5: The Overall Simulink System Model

The functions of these systems and their corresponding subsystems are explained below:

3.4.1 Path Command
This is used to set the desired position of quadcopter in terms of x, y and z axes coordinates as well as the yaw (for direction on the x-y plane). These parameters serve as the set points for the position controller. These variables can be loaded into the simulation through MATLAB workspace.

3.4.2 Position Controller:

The position Controller takes inputs from the Path command as its set Point and also receives the current position (state) of the quadcopter as feedback. It then compares this feedback with the set point to give the error. Using the error rotation formula:

$$\emptyset_d = -\sin(\psi)\, U_x + \cos(\psi)\, U_y \tag{10}$$

$$\theta_d = \cos(\psi)\, U_x + \sin(\psi)\, U_y \tag{11}$$

The position error in the body frame is computed and this is mapped to a body frame desired velocity. This desired velocity is then mapped to a desired attitude. The essence of this rotation is because the Inertial-frame velocity is used as the state to be controlled (Path command input).

3.4.3 Attitude Controller:

The attitude controller like position controller takes feedback from the output of the system as one of its inputs but takes its second input from the position controller. Attitude controller block contains full Proportional Integral Derivative (PID) controller which does the final attitude correction. The feedback to this block contains the current attitude and angular velocity of the quadcopter in x, y and z axes. The controller essentially compares the current state of the quadcopter with the set point and attempts to bring these various parameters to set point. The integral part of the PID ensures that the parameters remain at set point once achieved.

3.4.4 Quadcopter Control mixing:

The quadcopter control mixing block does control signal mixing depending on which quadcopter configuration used (plus (+) or Cross (×) configuration). It gets corrected parameters (ϴ, ψ, ϕ and Z) from the attitude controller and generates throttle commands for each motor. This command is what the quadcopter dynamics block use to actuate the motors.

Since our model is based on X-configuration, the equations below are used for the control signal mixing:

$$mc_1 = z_c - \theta_c - \phi_c - \psi_c \tag{12}$$

$$mc_2 = z_c - \theta_c + \phi_c + \psi_c \tag{13}$$

$$mc_3 = z_c + \theta_c + \phi_c - \psi_c \tag{14}$$

$$mc_4 = z_c + \theta_c - \phi_c + \psi_c \tag{15}$$

IV SIMULATION RESULTS

The data used for the quadcopter simulation was based on our system design as shown in Table 4 below. The individual parameters of the components that make up our quadcopter were carefully calculated. Some parameters such as Torque, Thrust and time constants were carefully estimated from already measured data of a similar system. This estimation was due to the unavailability of a test bench which was required to carefully monitor and measure these parameters.

Table 4: Quadcopter Modeling Parameters

Parameters	Value
Gross mass, m	1.5kg
Time constant	0.076s
Minimum throttle	5%
Thrust coefficient, cq	2.925e-9 NM/RPM2
%throttle to RPM conversion constant, cr	80.584RPM/%
Mass Moment of inertial across the x-axis, Jx	0.0085136kgm2
Mass Moment of inertial across the y-axis, Jy	0.0085136kgm2
Mass Moment of inertial across the z-axis, Jz	0.016334kgm2

The PID Controller gains of the various controllers were carefully tuned and appropriate gains were chosen based on the simulation results obtained. The simulation was run for 300 seconds and graphs were generated. Figure 6 shows the first plot of our system. Here, no external disturbance was added to the simulation. The Path command was such that the quadcopter will move a triangular path. From the graph: P, Q and R are angular velocities about the X, Y and Z axes respectively; Phi, theta and Psi are the Roll, Pitch and

Yaw angles; U, V and W are the translational velocities along the X, Y and Z axes respectively; X, Y and Z defines the position of the quadcopter along the X, Y and Z axes respectively.

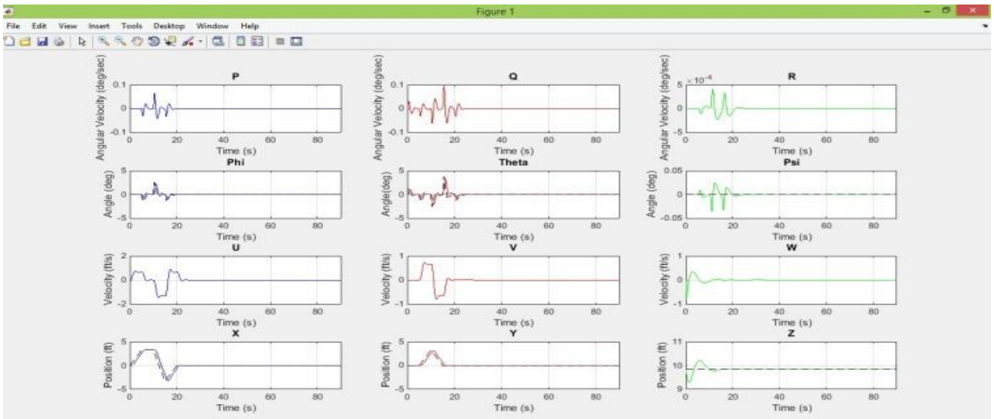

Fig. 6: Graphs of the Quadcopter Response against Time

The graph shown above represents a stable system. At first, there is an overshoot, but with time the controller sets each of these parameters to set point.

4.1 Disturbances

Figure 7 below indicates the quadcopter response to external disturbance along the X-axis

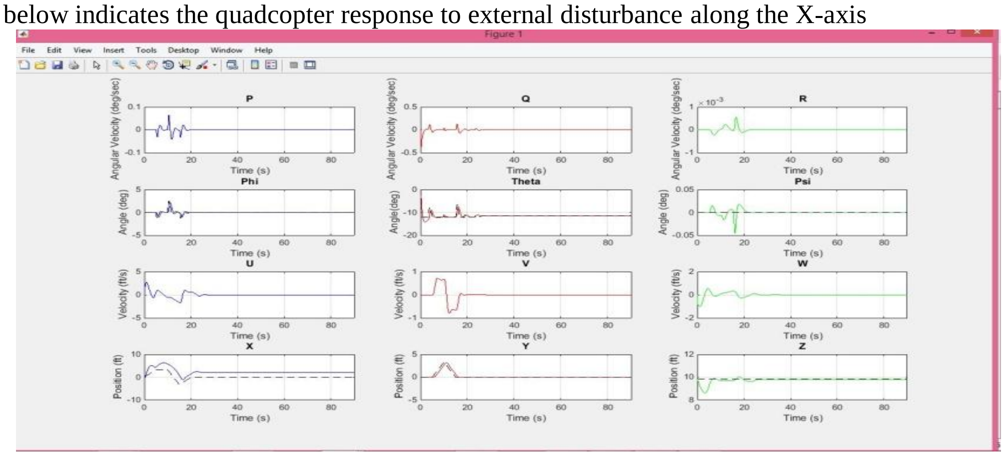

Fig. 7: Quadcopter response to external disturbance along the X-axis

Disturbance was simulated as force acting along the positive x-axis. The result of this simulation is on Fig. 7 above. As can be seen from the graph, the quadcopter was able to compensate for the external disturbance. Therefore, the PID controller logic is functional and it can be implemented for the actual system. The animated result- X-Y view of the quadcopter is shown in figure 8 below.

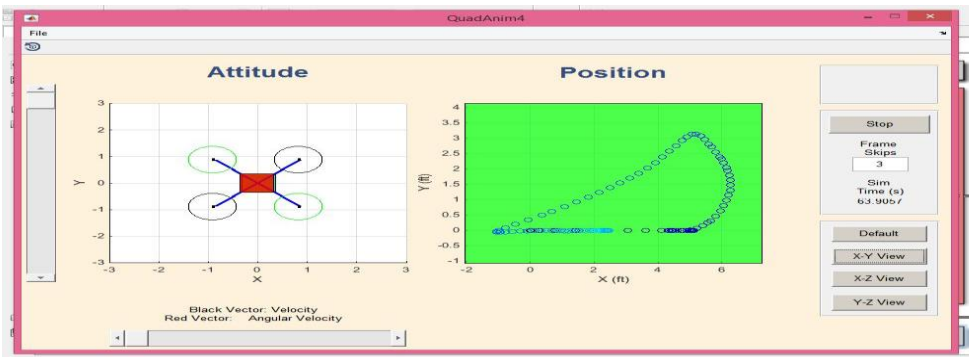

Fig. 8: Animated Result- X-Y view of the quadcopter

Fig 8 shows the path the quadcopter traced on the XY plane. This again shows that the PID algorithm can achieve stable flight.

V CONCLUSION

This paper designed and simulated a real time aerial quadcopter for search and rescue operations. A small size, less weight, intelligent, surveillance and reconnaissance quadcopter which can take the photographs from environment was realized through the aid of the onboard mounted camera while live streaming was done on the laptop during flight. After implementing and testing the quadcopter, the quadcopter met its weight requirement. Its approximate weight was 1.50kg. The motors and ESCs were successfully calibrated; the requirement of best minimized size was met; and communication from the ground control station to the quadcopter was achieved.

5.1 Recommendations

The motors should be firmly fastened to the arms of the chassis in order to reduce vibrations. When fixing the propellers to the motors a washer should be added to have a firm grip to prevent it from snipping off. Spare parts should be available in case of faults or need for replacement. The use of brushless motors will help not only in reducing vibrations but also consume lesser power. Also, use light materials for constructing the chassis to reduce the weight but also strong to withstand vibration from motors and propellers. The frame should be made such that there is enough clearance between each motor to make enough room for the rotation of the propellers. The frame should be aerodynamic. Assembling of the entire system should be done such that the center of mass is concentrated at the center of the system.

5.2 Research for Further Study

Power Improvement: Majority of the weight / mass of the system is due to the battery. This affects the total torque/ lifting power of the quadcopter. Also, batteries have very limited flight time. Research on a better alternative of power such as fuel cells should therefore be carried out.

REFERENCES

[1] Dukare, H. P., Bondre, M. B., Vidhate, A. R., Tiple, R. I. and Kumar, G. (2015). Design and Implementation of Flying Robot. International Journal of advanced Research in Computer Science and Software Engineering, vol. 5, Issue 2, pp 458 - 461.
[2] Salih, A. L., Moghavvemi, MMohamed, H. A. F. and Gaeid, K. S. (2010). Flight PID controller design for a UAV quadrotor. Scientific Research and Essays Vol. 5(23), pp. 3660-3667.
[3] Owczarek, N. & Pagano, C. (2014). DRONES: A Brief History and Design Overview. Ted Ullrich, Shelby Thompson, pp 1-11.
[4] Devaud, J. B., Najko, S., Nahedic, P., Maussire, C. Zante, E. and Marzat, J. (2012). Full Design of a low cost quadrotor UAV by student team. International Conference on System Engineering and Technology, Bandung, Indonesia.
[5] Ostogic, G., Stankovski, S., Tejic, B., Dukic, N. and Tegeltija, S. (2015). Design, Control and Application of Quadcopter. International Journal of Industrial Engineering and Management, vol. 6, No 1, pp 43-48.
[6] Pawar, S. G., Dongare, K., Dalvi, M., Doshi, S. and Das, K. K. (2015). Automated Quadcopter using Android Controlling System. International Journal of Engineering Sciences & Management, vol. 5, issue 4, pp 115- 119.
[7] D'Angelo, R. & Levin, R. (2011). Design of an Autonomous Quadrotor UAV for Urban Search and Rescue. Worcester Polytechnic Institute.
[8] Nakazawa, A. & Jin, B. X. Quadcopter Video Surveillance UAV. Dept. Electrical and Computer Engineering University of Victoria. Date Accessed: May, 2016.
[9] Sandhu, P. S. (2014). Development of ISR for quadcopter. International Journal of Research in Engineering and Technology, vol. 3, Issue 4, pp 181-189.
[10] Prem, K. P., Amirtharaja, S. Harie, S., Kishore, R. S. and Kiruba, V. (2015). Quadcopter Video Surveillance and Control Using Computer. International Journal of Electrical and Electronics Engineers, Vol. 7, Issue 1, pp 340-345.
[11] Maxwell, S. and Roophnath, R. (2014). Miniature Wireless Quadcopter. ASEE 2014 Zone I Conference, University of Bridgeport, Bridgeport, CT, USA.
[12] Mitra, S. (2013). Autonomous Quadcopter Docking System. Cornell University, pp1-37.