Satellite Guided Autonomous Border Patrolling and Video Vigilance Drone

Ali Akbar Siddique, Noman Ahmed Siddiqui, Muhammad Tahir Qadri

***Abstract* – Trespassing illegally into neighboring countries is a major concern for the government and certainly unavoidable in recent time due to the threat of terrorism, for saving the lives of their families and children many people try to enter another peaceful country illegally through land or sea routes. The same can be said for the drug and human trafficking, they too are huge concerns for the government to focus.In light of such events we require a system capable of providing evidence of trespassing and to apprehend the person suspected of trespassing, we have proposed such system to monitor territorial boundary and to provide information regarding any suspicious activity near the border area. A Quadcopter model is selected as an unmanned drone to continuous monitoring in our proposed system. The copter is equipped with theonboard GPS (Global Positioning System) and APM ArduPilot 2.6 as a base controller to acquire present co-ordinates of the copter with which they will be compared with those provided by the ground station in the form of a waypoints. Such a system may also be used for anti-spying missions**.

***Index Terms* – ArduPilot (APM 2.6), GPS (Global Positioning System), Video Vigilance, Quadcopter Model.**

I. INTRODUCTION

In recent times trespassing in the neighboring country knowingly or unknowingly is a critical matter and a huge concern for the authorities in charge for preventing such actions in the time of peace. Maritime trespassing is a major concern between the nations having sea borders at a close proximity, most of these trespasses occurs due the absence of a physical boundary and the lack of navigational tools available to the small fishermen or merchants. Untold number of innocent fishermen are arrested over the years for illegal trespassing the neighboring border unknowingly and are kept prisoners for decades. The absence of a physical boundary and lack of proper demarcation leaves small fishing boats and trawlers susceptible to illegally crossing territorial waters. For most of the time, whereabouts of imprisoned fishermen remains unknown to their respective families for years. America is using this technology at their Mexican border for the prevention of drug trafficking and illegal crossing. Another major problem in this regard is human trafficking, many people in poor countries takes some steps that are life threatening to them because of their lack education and ends up in the clutches of people who make them slaves and make them work without paying them and never let them see or talk to their families, not even let them know where they are and they are alienated to the outside world. To avoid such action, an aerial drone is required capable of patrolling and monitor almost all activities near the border area, which may play an important role in time of need and to take necessary precautions.

Although there are many manned vessels patrolling the borders but these manned patrols are costly if it is on a fairly regular bases, so it is imperative to design a cost effective solution for such problem. Anders Lyhne Christensen, Sancho Oliveira, Octavian Postolacheproposed a system in which a swarm of drown are introduce to patrol the sea border [1].Osi Van Dessel proposed a cost effective procedure for designing a drone suitable for performing almost all tasks [2].Rathinam, S. ; Univ. of California, Berkeley ; Almeida, P. ; ZuWhan *Kim* ; Jackson, Sproposed an autonomous UAV system to inspect and monitoring river boundaries, bridges and coastlines [3].Saranya C, Pavithira L , Premsai N, Lavanya H and Govindarajan R proposed a UAV system for structure and bridge monitoring purposes [4].

We proposed a system capable of patrolling a border guided by the satellite, weather it is on land or at sea. It will generate an alarm for the vessel about to cross the border or approaching towards the territorial boundary and it will also alert the concerned authority in charge for monitoring these actions, so they may take extra precautionary measures regarding the situation and avoid some unwanted tensions between the two neighboring nations.

II. MATHEMATICAL MODEL

Our choice of Unmanned Aerial Vehicle (UAV) is Quadcopter. The reason for this choice is our copter that we have tested is more durable in presence of heavy air current. It is capable of 6 DOF (Degree of Freedom) movement with 3 translational movement and 3 rotational movement, along with the 4 motor speeds controlled by our processor or controller. In order to achieve 6 DOF all the movements translational or rotational has to be coupled. Involvement of an aerodynamic effects renders our system to be completely non-linear. Unlike any other unmanned land vehicle, aerial vehicles produces less friction to prevent the motion, so to achieve the stability condition it has to produce its own damping.

$$\ddot{x} = (\cos\emptyset \sin\theta \cos\psi + \sin\phi \sin\psi)\frac{1}{m}U_1 - 0.5(D_x A_x \rho \dot{x}|\dot{x}|) \quad (1)$$

$$\ddot{y} = (\cos\emptyset \sin\theta \sin\psi - \sin\phi \cos\psi)\frac{1}{m}U_1 - 0.5(D_y A_y \rho \dot{y}|\dot{y}|)\text{Eq.2} \quad (2)$$

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$$\ddot{z} = (\cos\emptyset\cos\theta)\frac{1}{m}U_1 - g - 0.5(D_z A_z \rho \dot{z}|\dot{z}|) \qquad (3)$$

Eq.1,2 and 3 are the representation of linear translational movement of the coptor about x,y and z axis respectively.It is imperative to allign these in a form to negotiate with one another to avoid any unnecessary or undefined movements which can or may cause a damage to our system.D_x, D_y and D_z are basically the translational drag coefficients and A_x, A_y and $A_z$are the areas of the propeller disks.

$$\ddot{\phi} = \dot{\theta}\dot{\psi}\left(\frac{I_y - I_z}{I_x}\right) + \frac{U_2}{I_x} \qquad (4)$$

$$\ddot{\theta} = \dot{\phi}\dot{\psi}\left(\frac{I_z - I_x}{I_y}\right) + \frac{U_3}{I_y} \qquad (5)$$

$$\ddot{\psi} = \dot{\theta}\dot{\phi}\left(\frac{I_x - I_y}{I_z}\right) + \frac{U_4}{I_z} \qquad (6)$$

Eq.4,5 and 6 are the representation of an angular movements of the copter as Yaw, Pitch and Roll.$I_x I_y$ and I_z are the inertias along the translatioal axix.

$$U_1 = t(\Omega_1^2 + \Omega_2^2 + \Omega_3^2 + \Omega_4^2) \qquad (7)$$

$$U_2 = t\ell(-\Omega_2^2 + \Omega_4^2) \qquad (8)$$

$$U_3 = t\ell(\Omega_1^2 - \Omega_3^2) \qquad (9)$$

$$U_4 = d(-\Omega_1^2 + \Omega_2^2 - \Omega_3^2 + \Omega_4^2) \qquad (10)$$

$\Omega_1, \Omega_2, \Omega_3$ and Ω_4 are the speed of the rotors. U_1 is the total thrust, with U_1 we can control the altitude of our copter by increasing or decreasing the speeds of the rotors all at the same time.U_2 is the Pitch movement, $U_3$is the Roll movement and U_4 is the Yaw movement. Here 't' is the thrust factor and 'd' is the drag factor. Drag factor is comes in handy when our coptor is hovering. By increasing or decreasing the speed of all four rotors simulaniously in a syncronized manner will result in an altitude control, however varing the speed of either on of the pair like (Ω_1 and Ω_3) cause our coptor to move along the y-axis with the pitch angle of 'θ'.At the same time if the variation is done on the opposite rotors like (Ω_2 and Ω_4) our coptor will move along the x-axix with the angle of 'ϕ'. Now is we apply the vector summission of both the pair our coptor will spin aroud the z-axis demonstrating the yaw movement denoted by 'ψ'.In Fig.1 one can observe the movements that can be achieved in along the axis.

III. HARDWARE MODEL

In our proposed system, we used APM ARDUPILOET 2.6as our core processor for flight control. APM provides us high quality of altitude and attitude control an approximate scale, with level flight and navigation assistance. Waypoint planning can be done at any time even during the flight using two-way wireless transceivers. APM is fully capable of controlling the copter including its takeoff and landing. It can support up to 127 waypoints no matter the distance between them, the only limitation is its battery.

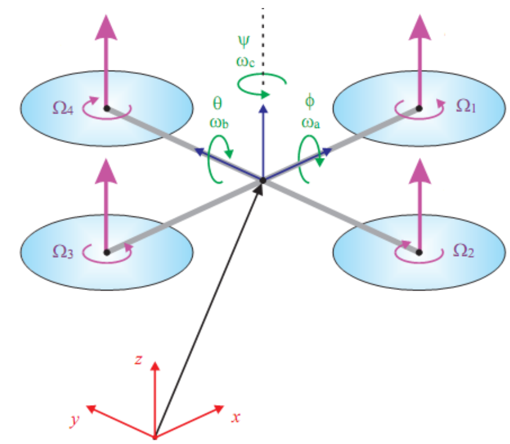

Fig. 1 Quadrant based representation of Quad rotor system

Fig. 2 Image of an APM Ardupilot 2.6

Fig.3 explains the block model of complete system APM as a center processor driving the ESC by providing appropriate duty cycle in order to synchronize the four rotors. Stability is key feature in the system, so to avoid any stability issues we have used onboard Magnetometer and other onboard sensors like Accelerometer, Gyro sensor etc. GPS (Global positioning system) is used to fetch the current co-ordinates of the copter for the waypoint matching and tracking. GPS gets the co-ordinates and fed them to APM to match them with the waypoint co-ordinates provided by the ground station wirelessly. Wireless camera is also mounted on the system used the purpose of vigilance and monitoring suspicious the activity near the border. Basically ESC (Electronic speed controller) drives the motors with an appropriate RPM (Rotation per Minute) for the copter to stay in the air and to track the next waypoint properly.

Magnetometer is used as an onboard sensor which is capable of measuring the magnetization of the magnetic material and in few cases can be used to identify the direction of the magnetic field at a point in space. Basically magnetic fields are the vector quantities which are characterized by both direction and strength, magnetometer tends to measure

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these quantities with respect to the magnetic field of the earth as a reference.

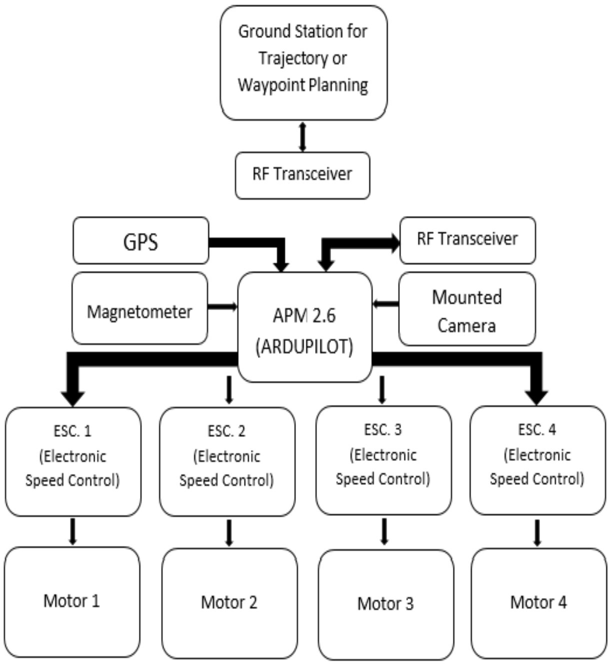

Fig. 3 Block Diagram of our Hardware Model.

Fig.3 displays the actual trajectory tracking in real time environment depending on the initial co-ordinates provided to the Quad rotor system. It matches the current co-ordinates of the system to the ones provided by the base station or ground station wirelessly in the form of waypoints. It follows the co-ordinates one at a time in an orderly fashion as provided from ground station, as long as it's traveling in the direction of the next waypoint or correct waypoint the error or the difference between them will be reducing otherwise if the error is increasing then our drone is heading in a wrong direction.

Fig.4 is the representation of the waypoint for the drone to follow, drone at its initial location will began to track the waypoint as soon as it receives one from the base station. Ground station sets the waypoints for the drone to follow and it follows them according to the co-ordinates provided to it by GPS.

IV. SOFTWARE MODEL

After system initialization the waypoint co-ordinates are fed to the copter wirelessly which are used to compare the actual co-ordinates of it received via GPS (Global Positioning System). It approaches towards the desired co-ordinates by using the error coefficient as a tracking agent and intend to reduce it in order to reach an exact desired location or a waypoint.

As soon as our copter reaches to its first waypoint co-ordinates, it fulfills the task and starts to track the next waypoint co-ordinates in a sequential order as was provided by the ground station. These waypoint can be varied according to the need, it's because there is a camera mounted on it which can be used for the purpose of vigilance. With it we can not only keep an eye on territorial border but can also stop illegal drug trafficking etc.

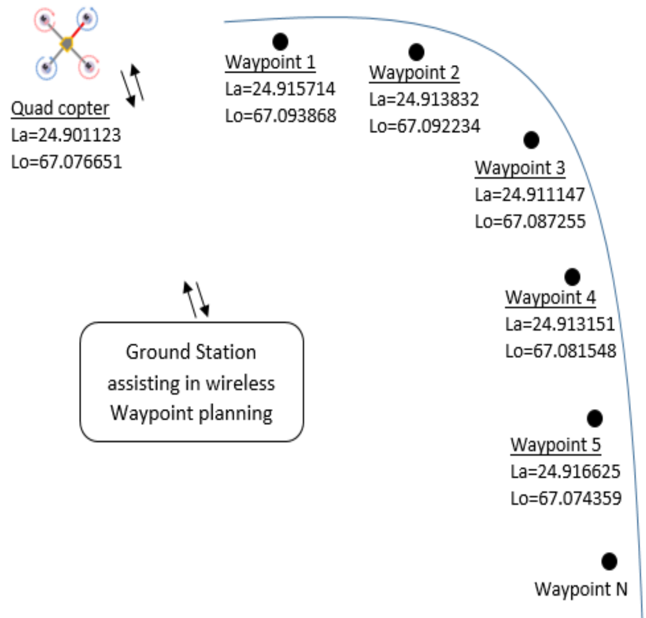

Fig. 4 Waypoint Trajectory Planning and Tracking.

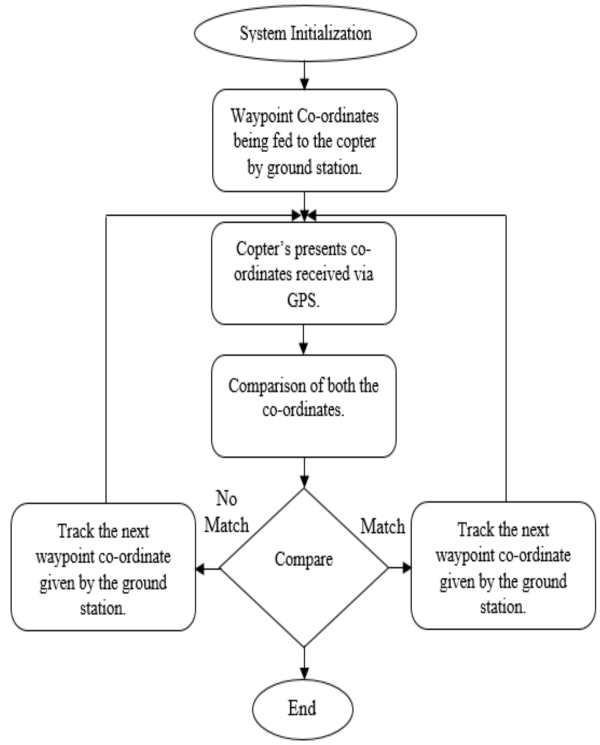

Fig. 5 Flow control of whole model.

V. SIMULATION RESULTS

Fig.6 is the representation of the altitude controlled step response of our copter model. It is approaching to 10 feet in

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about 14 to 16 seconds, it is basically a simulated result compiled for the model discussed in section 2.

Fig.7 represent the step response of an angular movement of the copter model. Angular movement includes Phi, Theta and Epsi representing the basics of Yaw, Pitch and Roll. X, Y and Z are the translational movement of the copter showing the 6 DOF in order to move freely in all direction without any problem. It intend to minimize the error to reach its desired state and make the system stable to move in the direction provided to it by the ground station. For the purpose of simulation we include some disturbance to avoid any inconvenience in flight testing. This was necessary as the weather can change randomly at the sea line and may cause problems for the copter to retain its stability in heavy breeze.

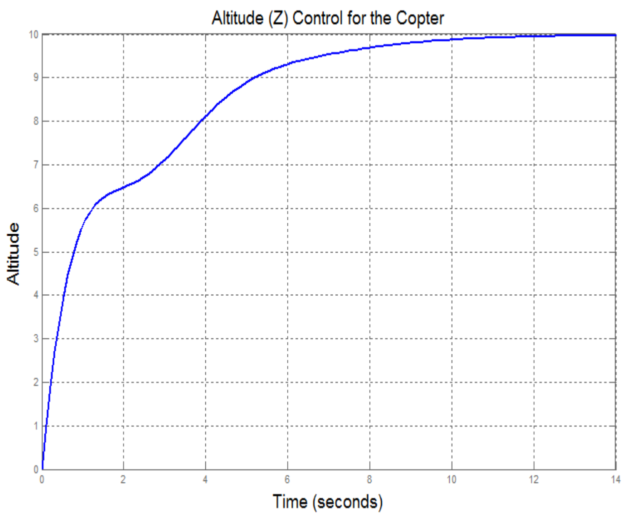

Fig. 6 Altitude (Z) control of the copter.

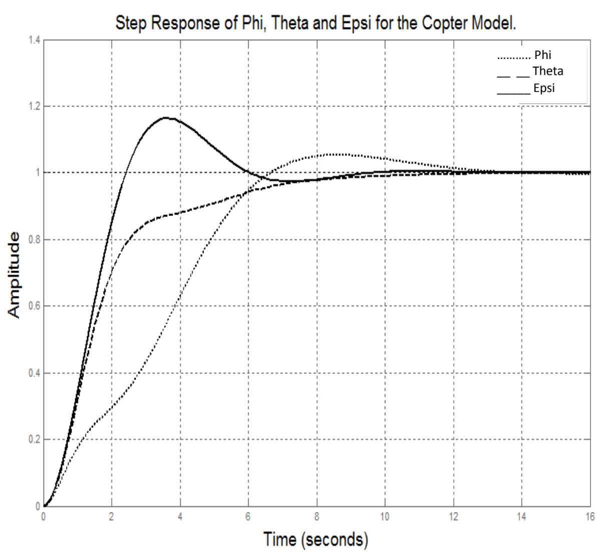

Fig. 7 Step Response of Phi, Theta and Epsi movement of the Copter.

VI. CONCLUSION

The conclusion draws from analyzing the data gathered from a mathematical model of a copter resembles to that of an actual hardware model proposed. Copter tracks the waypoints with precision and tends to follow them accordingly. Ground station plays an important role in all of its vigilance, this is where the actual monitoring is being done for any suspicious activity near the territorial boundary. Although there were some unwanted disturbance as expected and the drone performed with acceptable errors or variances. Our proposed system can be used for various tasks including anti-spying, avoiding the threat of drug and human trafficking and illegal trespassing efficiently and with limited resources.

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