DEVELOPMENT OF UNMANNED AERIAL VEHICLE (QUADCOPTER) WITH REAL-TIME OBJECT TRACKING

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Technology

In

Industrial Design

By

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Department of Industrial Design
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Rourkela-769 008, Orissa, India
May 2015

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DEPT. OF INDUSTRIAL DESIGN
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CERTIFICATE

This is to certify that the work in the thesis entitled, "**DEVELOPMENT OF UNMANNED AERIAL VEHICLE (QUADCOPTER) WITH REAL-TIME OBJECT TRACKING"** submitted by **Mr. Pritpal Singh** in partial fulfilment of the requirements for the award of **Master of Technology Degree** in the Department of Industrial Design, National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the work reported in this thesis is original and has not been submitted to any other Institution or University for the award of any degree or diploma.

He bears a good moral character to the best of my knowledge and belief.

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I certify that

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For each and every new activity in the world, the human being needs to learn or observe from somewhere else. The capacity of learning is the gift of GOD. To increase the capacity of learning and gaining the knowledge is the gift of GURU or Mentor. That is why we chanted in Sanskrit "*Guru Brahma Guru Bishnu Guru Devo Maheswara, Guru Sakshat Param Brahma Tashmey Shree Guruve Namoh*". That means the Guru or Mentor is the path of your destination.

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Pritpal Singh

ABSTRACT

In the previous decade, Unmanned Aerial Vehicles (UAVs) have turned into a subject of enthusiasm for some exploration associations. UAVs are discovering applications in different regions going from military applications to activity reconnaissance. This thesis is an overview of a particular sort of UAV called quadrotor or quadcopter. Scientists are often picking quadrotors for their exploration because a quadrotor can precisely and productively perform assignments that future of high hazard for a human pilot to perform. This thesis includes the dynamic models of a quadrotor and model-autonomous control systems. It also explains the complete description of developed quadcopter used for surveillance purpose with real-time object detection. In the present time, the focus has moved to outlining autonomous quadrotors. Ultimately, it examines the potential applications of quadrotors and their part in multi-operators frameworks. The Unmanned aerial vehicle (Quadcopter) has been developed that could be used for search and surveillance purpose. This project comprised of both hardware and software part. The hardware part comprised of the development of unmanned aerial vehicle (Quadcopter). The main components that were used in this project are KK2 flight controller board, outrunner brushless DC motor, Electronic Speed Controllers (ESC), GPS (Global Positioning System) receiver, video transmitter and receiver, HD (High Definition) camera, RC (Radio Controlled) transmitter and receiver. Software part comprised of real-time object detection and tracking algorithm for detecting and tracking of human beings that were done with the help of Matlab software. After achieving the stable flight, the camera installed on the quadcopter would transmit a video signal to the receiver placed on the ground station. Video signal from the receiver would then be transferred to Matlab software for further processing or for tracking human beings using real-time object detection and tracking algorithm.

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CHAPTER 1

1. Introduction

1.1. Background

Innovative work on unmanned aerial vehicle (UAV) and micro flying vehicle (MAV) are getting high consolation these days, since the application of UAV and MAV can apply to many areas such as salvage mission, military, filmmaking, farming, and others. Quadcopter or Quadrotor aircraft is one of the UAV that is major centers of dynamic explores in the recent years [26]. Contrast with physically versatile robot that frequently conceivable to limit the model to kinematics, quadcopter obliged dynamics to record for gravity impact and flight optimized powers. Quadcopter worked according to the force or thrust generated by four rotors connected to its body. It has four input and six yield or output states (x, y, z, θ, ψ, ω), and it is an under-activated framework, since this empower quadcopter has to convey more load.

A Quadcopter is a flying vehicle which utilizes quickly turning rotors to push air downwards, subsequently making a push energy keeping the helicopter on high. Customary helicopters have two rotors. These can be arranged as two coplanar rotors both giving upwards force and thrust, however turning in inverse headings (keeping in mind the end goal to adjust the torques applied to the assemblage of the helicopter). The two rotors can likewise be arranged with one fundamental rotor giving push and a littler side rotor situated horizontally and checking the torque delivered by the primary rotor. On the other hand, these designs require entangled hardware to control the heading of movement; a swashplate is utilized to change the approach on the principle rotors. With a particular end goal to deliver a torque, the approach is adjusted by the area of every rotor in each stroke, such that more push provided on one side of the rotor plane than the other. The muddled configuration of the rotor and swashplate system shows a few issues, such as expanding development costs furthermore outline unpredictability.

A quadrotor helicopter is a helicopter which has four equally spaced rotors, typically organized at the corners of a square body. With four free rotors, the need for a swash plate component can be reduced. The swash plate part is expected to permit the helicopter to use more degrees of opportunity. However, the same level of control can be achieved by using two more rotors.

The improvement of quadcopters has stalled until as of late because controlling four free rotors has turned out to be extraordinarily troublesome and inconceivable without electronic help. The diminishing expense of current microchips had made electronic and indeed entirely self-sufficient control of quadcopters achievable for business, military, and indeed specialist purposes.

Quadcopter control is very difficult to achieve. With six degrees of freedom (three translational and three rotational) and just four free inputs (rotor speeds), quadcopters are extremely underactuated. Keeping in mind the end goal to accomplish six degrees of freedom, rotational and translational movements are coupled. The ensuing progresses are exceedingly nonlinear, particularly in the wake of representing the muddled aeromechanic impacts. At last, dissimilar to ground vehicles, helicopters have almost no grating to keep their movement, so they must give their damping to quit moving and stay stable.

Table 1.1. Quadrotor flight control techniques used in various projects

Projects	Control Technique
STARMAC, Stanford University 2005, Waslander et al.,(2005)	Reinforcement Learning
OS4, EPFL, December 2006 Bouabdallah (2007)	Backstepping
Pennsylvania State University, Hanford, 2005	Proportional- Integral
Helio-copter, Brigham Young University, Fowers, 2008 Fowers	Visual Feedback
HMX-4, Pennsylvania State University, 2002 ALTUG et al.	Feedback Linearization
Quad-Rotor UAV, University of British Columbia Chen and Huzmezan (2003)	MBPC AND $H\infty$
Quad-Rotor Flying Robot, University Teknologi malasysia Weng and Shukri (2006)	Proportional-Integral-Derivative

1.2. Dynamic Model of a Quadrotor

The quadrotor helicopter is shown in figure 1. The two sets of rotors (1, 3) and (2, 4) turn in an inverse direction in place to adjust the moments and produce yaw movements as required [28]. On differing the rotor speeds inside and out with the same amount, the lift powers will change the height z of the framework. Yaw angle is obtained by accelerating the clockwise rotors or slowing down depending on the desired angle direction. The sense of the pitch and roll angle (positive or negative) affects the motion direction of x and y axis.

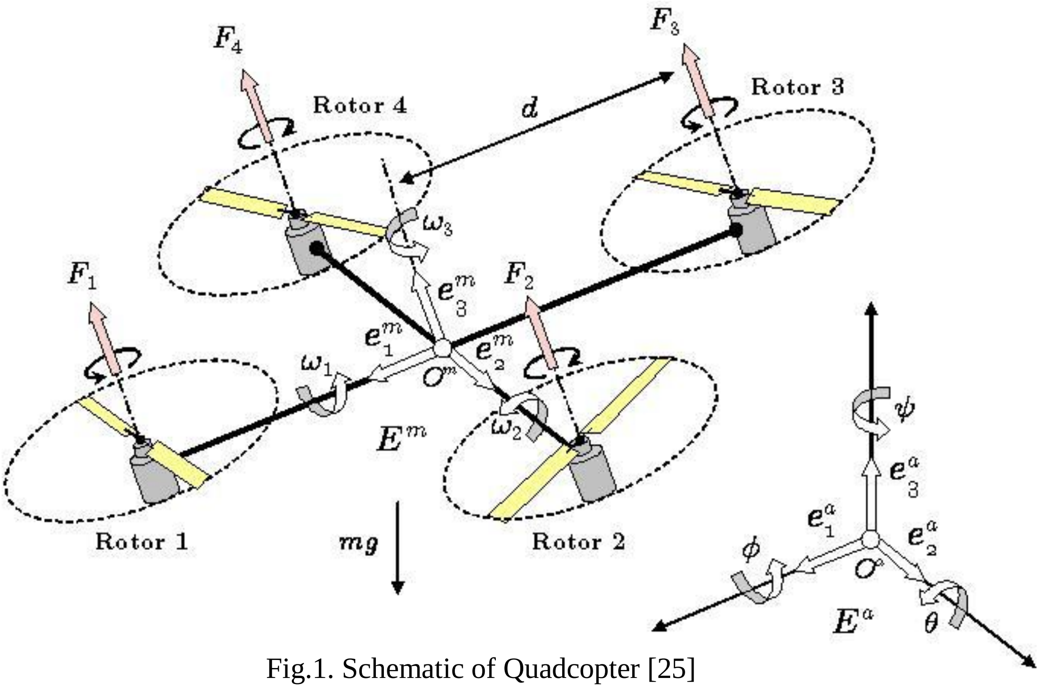


Fig.1. Schematic of Quadcopter [25]

The comparisons depicting the attitude and position of a quadrotor helicopter are essentially those of a turning rigid body with six degrees of freedom [6] [7]. These are differentiated from kinematic equations and dynamic mathematical statements [8] [57].

Let be two primary reference frames are (as shown in Fig. 1):

- the earth fixed inertial reference frame E^a : $\left(O^a, \overrightarrow{e_1^a}, \overrightarrow{e_{2,}^a}\overrightarrow{e_3^a}\right)$
- the body fixed reference frame E^m : $\left(O^m, \overrightarrow{e_1^m}, \overrightarrow{e_{2,}^m}\overrightarrow{e_3^m}\right)$

regidly appended to the quadrotor.

Let the vector $\zeta \triangleq [x, y, z]^T$ and $\eta \triangleq [\varphi, \theta, \psi]^T$ signify separately the elevation positions and the attitude angles of the quadrotor (Frame E^m) in the edge E^a with respect to a settled origin

O^a. The state of mind points {φ, θ, ψ} are individually called pitch angle $\left(-\frac{\pi}{2} < \phi < \frac{\pi}{2}\right)$, roll angle $\left(-\frac{\pi}{2} < \theta < \frac{\pi}{2}\right)$ and yaw angle $(-\pi \leq \psi < \pi)$.

The quadrotor is limited with the six degrees of freedom as per the reference frame E^m: Three interpretation or translation velocities $V = [V_1, V_2, V_3]^T$ and three rotational speeds $\Omega = [\Omega_1, \Omega_2, \Omega_3]^T$. The connection existing between the velocity vectors (V, Ω) and ($\dot{\zeta}$, $\dot{\eta}$) are:

$$\dot{\zeta} = R_t V \text{ and } \Omega = R_r \dot{\eta} \tag{1}$$

$$R_t = \begin{bmatrix} C\varphi C\psi & S\varphi S\theta C\psi - C\varphi S\psi & C\varphi S\theta C\psi + S\varphi S\psi \\ C\theta S\psi & S\varphi S\theta S\psi + C\varphi C\psi & C\varphi S\theta S\psi - S\varphi C\psi \\ -S\varphi & S\varphi C\theta & C\varphi C\theta \end{bmatrix} \tag{2}$$

$$R_r = \begin{bmatrix} 1 & 0 & -S\theta \\ 0 & C\varphi & C\theta S\varphi \\ 0 & -S\varphi & C\varphi C\theta \end{bmatrix} \tag{3}$$

Where *S*(.) and *C*(.) are the respective abbreviations of sin(.) and cos(.).

One can compose $\dot{R}_t = R_t S(\Omega)$ where S(Ω) signifies the skew symmetric matrix such that $S(\Omega)v = \Omega \times v$ for the vector cross-item × and any vector $v \in R^3$. In other words, for a given vector Ω, the skew-symmetric matrix S(Ω) is characterized as follows:

$$S(\Omega) = \begin{bmatrix} 0 & -\Omega_3 & \Omega_2 \\ \Omega_3 & 0 & -\Omega_1 \\ -\Omega_2 & \Omega_1 & 0 \end{bmatrix} \tag{4}$$

The derivation of (1) with respect to time gives

$$\ddot{\zeta} = R_r \dot{V} + \dot{R}_r V = R_t \dot{V} + R_t S(\Omega) V = R_t (\dot{V} + \Omega \times V) \tag{5}$$

$$\dot{\Omega} = R_r \ddot{\eta} + \left(\frac{\partial R_r}{\partial \phi} \dot{\phi} + \frac{\partial R_r}{\partial \theta} \dot{\theta} \right) \dot{\eta}$$

Utilizing the Newton's laws as a part of the reference frame E^m, when the quadrotor helicopter subjected to forces $\sum F_{ext}$ and moment $\sum T_{ext}$ connected to the epicenter, the dynamic mathematical statement is characterized as follows:

$F_{ext} = m\dot{V} + \Omega \times (mV)$ (6)

$T_{ext} = I_T \dot{\Omega} + \Omega \times (I_T\Omega)$

where m and I_T = diag[I_x, I_y, I_z] are separately the mass and the total inertia matrix of helicopter, $\sum F_{ext}$ and $\sum T_{ext}$ includes the outer strengths/torques created in the epicenter of a quadrotor as indicated by the direction of the reference frame E^m, for example,

$\sum F_{ext} = F - F_{aero} - F_{grav}$ (7)

$\sum T_{ext} = T - T_{aero}$

Where the forces {F, F_{aero}, F_{grav}} and the torques {T, T_{aero}} are clarified in the table I, where G = $[0, 0, g]^T$ is the gravity vector ($g = 9.81 m.s^{-2}$), {K_t, K_r} are two diagonal aerodynamic friction matrices.

Table 1.2. Main physical effects acting on a quadrotor

MODEL	SOURCE
$F = [0, 0, F3]^T$ $T = [T1, T2, T3]^T$	Propeller System
$F_{aero} = K_t V$ $T_{aero} = K_r \Omega$	Aerodynamic Friction
$F_{grav} = mR_t^T G$	Gravity Effect

The forces F and torques T produced by the propeller system of a quadrotor are:

$$F = \begin{bmatrix} 0 \\ 0 \\ \sum_{i=1}^{4} F_i \end{bmatrix} \text{ and } T = \begin{bmatrix} d\,(F2 - F4) \\ d\,(F3 - F1) \\ C\ \sum_{i=1}^{4}(-1)\,(-1)^{i+1} Fi \end{bmatrix} \quad (8)$$

Where d is the separation from the epicenter of a quadrotor to the rotor axis and c > 0 is the drag element. Equation (5), (6) and (7) gives the mathematical statement of the dynamic of rotation of the quadrotor expressed w.r.t the reference frame E^a:

$$F = mR_t^T \ddot{\zeta} + K_t R_t^T \dot{\zeta} + mR_t^T G \tag{9}$$

$$T = I_T R_r \ddot{\eta} + I_T \left(\frac{\partial R_r}{\partial \phi} \dot{\phi} + \frac{\partial R_r}{\partial \theta} \dot{\theta} \right) \dot{\eta} + K_r R_r \dot{\eta} + \left(R_r \dot{\eta} \right) \times \left(I_T R_r \dot{\eta} \right)$$

The dynamic model (9) of the quadrotor has six output parameters {x, y, z, φ, θ, ψ} and four free inputs. Hence, the quadrotor is an under-activated framework. We are not ready to control the majority of the states in the meantime. A possible combination of controlled yields can be {x, y, z, ψ} with a particular end goal to track the desired positions, more to a subjective heading and balance out the other two angles, which presents stable zero dynamic into the framework [5]. A decent controller should have the capacity to achieve a desired position and a fancied yaw angle while ensuring stability of the pitch and roll angles.

1.3. Quadcopter Motion Mechanism

Quadcopter can be described as a vehicle with four propellers joined to the rotor found at the cross casing. This go for altered pitch rotors driven to control the vehicle movement. The velocities of these four rotors are independent. By controlling the pitch, roll and yaw angle, the position of the vehicle can be controlled effectively.

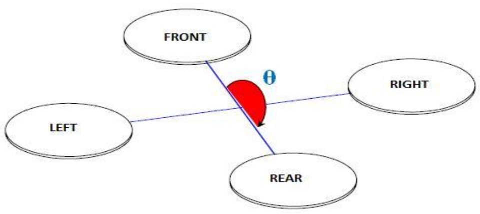


Fig.2. Pitch direction of quadcopter

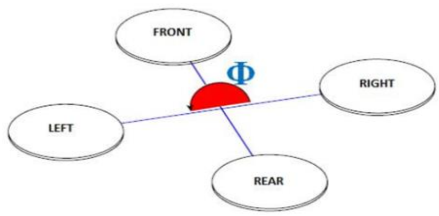


Fig.3. Roll direction of quadcopter

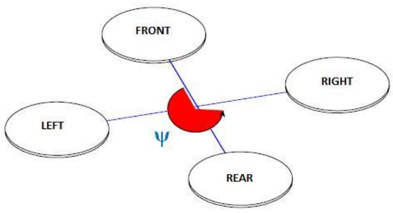


Fig.4. Yaw direction of quadcopter

Quadcopter has four inputs, and essentially the thrust is generated by the propellers attached to the rotors. The speed of each motor is controlled independently, and the motion or direction of quadcopter is controlled by varying the speed and direction of each motor.

Take-off and Landing Motion Mechanism

Take-off motion is the motion that lifts the quadcopter from ground to hover position. As shown in Fig. 5 there are total four motors, two rotating in the clockwise direction and two rotating in counter clockwise direction. To fly the quadcopter in hover position, increase the speed of each rotor simultaneously. For landing the quadcopter to ground decrease the speed of each rotor simultaneously as shown in Fig. 6.

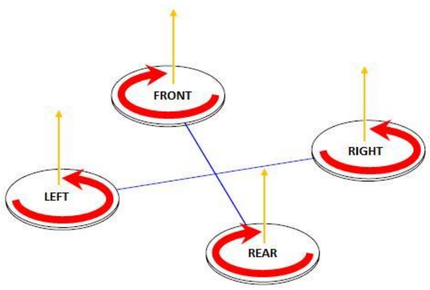


Fig. 5. Take-off motion

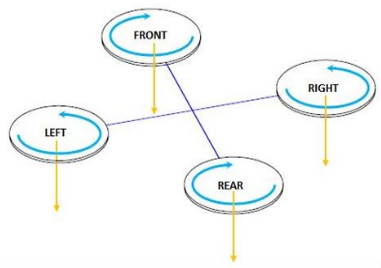


Fig. 6. Landing Motion

Forward and Backward Motion

Forward motion of the quadcopter is controlled by increasing the speed of the rear rotor and decreasing the speed of the front rotor simultaneously as shown in Fig. 7. Backward motion of the quadcopter is controlled by increasing the speed of the front rotor and decreasing the speed of the rear rotor simultaneously as shown in Fig. 8. Reducing the rear rotor speed and increasing the front rotor speed simultaneously will affect the pitch angle of the quadcopter.

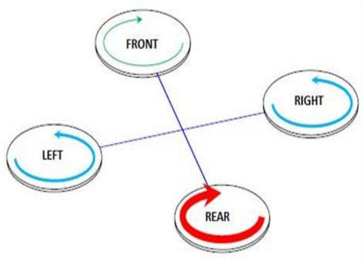


Fig. 7. Forward motion

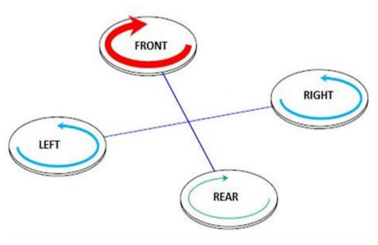


Fig. 8. Backward motion

Left and Right Motion

The left and right motions of the quadcopter are controlled by changing the yaw angle. By increasing the speed of the counter-clockwise rotor and decreasing the speed of the clockwise rotor simultaneously, quadcopter moves to the left side as shown in Fig. 9. Similarly by increasing the speed of the clockwise rotor and decreasing the speed of the counter-clockwise rotor simultaneously, quadcopter moves to the right side as shown in Fig. 10.

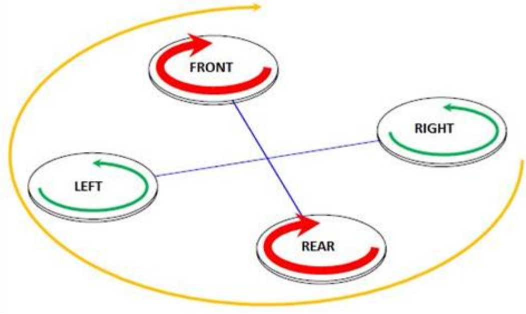


Fig. 9. Left motion

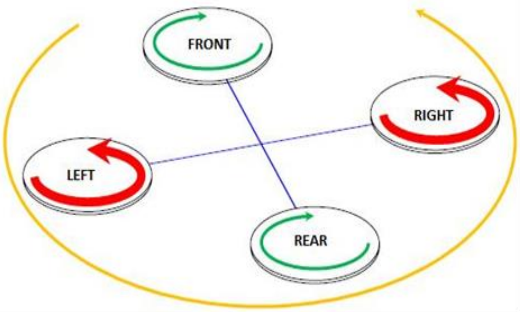


Fig. 10. Right motion

Hovering or Static Position

When two pairs of counter-clockwise and clockwise rotors rotate at the same speed, the quadcopter moves to hover position. At that time, the total addition of reaction torque is zero which allows the quadcopter to achieve hover position.

1.4. Objectives

a) To develop a UAV (Quadcopter) for surveillance purpose.

b) To maintain the stability of quadcopter during flight.

c) Track the quadcopter location with the help of GPS/GSM system.

d) To develop real-time object (Human being) detection and tracking algorithm using color feature and motion in Matlab software.

CHAPTER 2

2. Literature Survey

2.1. Overview

In the field of autonomous unmanned aerial vehicle (quadcopter) various works had already been done. The past research or literature survey of the quadcopter is categorized into three section based on 1) Automation and Control, 2) Aerospace Computing, Information and Communication and 3) Intelligent Robot. The literature survey for real-time object (Human being) detection and tracking using color feature and motion is also done.

2.2. Automation and Control

Bouabdallah's et al. [1] developed an indoor micro quadcopter. Recent advancement in sensor innovation, information transforming and incorporated actuators had made the development of smaller than expected mini robots entirely conceivable. A micro VTOL1 (vertical take-off and landing) framework depicted a valuable group of flying robots due to their stable capacities for small region monitoring and building investigation. They presented the dynamic modelling, mechanical design and control of indoor VTOL autonomous robot OS4. Controller was designed to control the vehicle orientation and to stabilize the vehicle in hover position.

Deng et al. [2] designed a micromechanical flying insect (MFI). Wing kinematic parameterization technique was used to provide wing motions to decouple three orientation: roll, pitch and yaw. LQR (Linear-quadratic regulator) controller was developed to provide stability to MFI in hovering position. Thorax and sensor models were used to design MFI. Roll, pitch and yaw angle and angular velocity were estimated using three sensors: magnetic compass, halteres and ocelli. The ocelli sensor measured the roll and pitch angles with the help of four photoreceptors. The magnetic compass measured the yaw angle according to the geomagnetic field and halteres sensor calculated the angular velocity using gyroscopic forces. Thorax and piezoelectric actuators were used to control each wing.

Wang et al. [3] described a micro flying robot and wireless helicopter for surveying the environment in disaster or hazardous conditions. They had designed the autonomous control system with automatic take-off and landing of robot. There were various sensors installed such as gyro sensor, speed sensor, acceleration sensor and GPS system was also installed to locate the robot. They installed two propellers which rotate in opposite direction. In both micro flying robot, and wireless helicopter, each D.O.F (degree of freedom) is controlled by adjusting the speed of propellers. PID controller stabilized the complete system using tuning but to obtain better performance H∞ controller was used.

Jeong et al. [4] designed an Omni-directional flying automobile. This system had the ability of both flying in the air and driving on the ground. It comprised of four wheels and four fans. A mechanism designed which allows quadrotor to change from flying mode to driving mode. The motion of the quadrotor was controlled by controlling the speed of each motor. Gyro and accelerometer were used to measure roll, pitch and yaw angle. For balancing of quadrotor, the accurate measurement of roll and pitch angle was essential. Therefore, they used Kalman filter for getting stable signals. After passing signal from Kalman filter, it was fed to PID controllers. The comparison of desired angles (roll, pitch and yaw) with filtered signal was done to get angle errors.

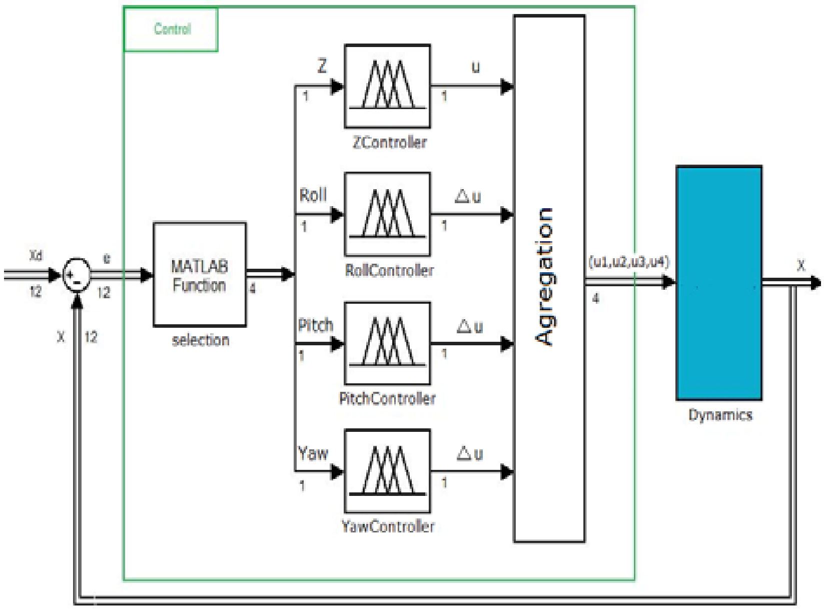
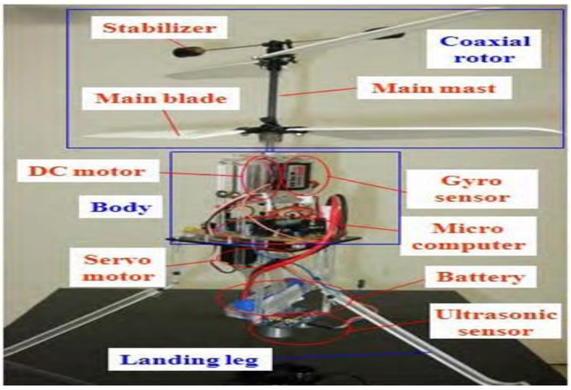


Fig. 11. Control Diagram [4]

Lim et al. [5] described the design and control strategy of a flying robot. The system consisted of landing legs, two rotors and a body. Two motors were used to control two rotors, and the third motor was used to control the centre of gravity. Ultrasonic and gyro sensor were used to measure altitude and orientation. The speed and direction of each motor were controlled by varying the pulse width of PWM signal.H8/3694F microcomputer was used for all computations to control the robot. The physical layout of the quadcopter is shown in Fig. 12. The block diagram of flying robot control system is shown in Fig. 13.



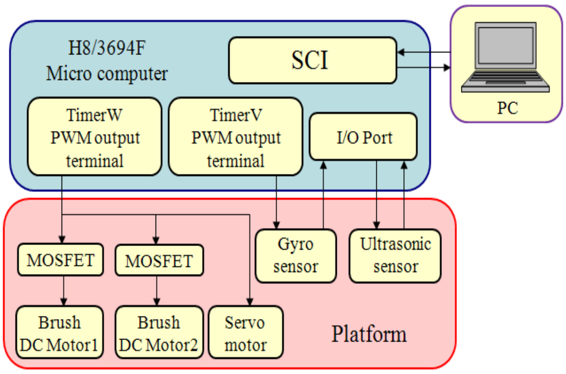


Fig. 12. Coaxial quadcopter [5]

Fig. 13. Control system [5]

Kivrak [6] designed the control system for a quadrotor flight vehicle equipped with inertial sensors. They had developed a non-linear model of quadrotor by using Matlab/Simulink. The control algorithm was designed to stabilize the height according to the linearized model in hovering position. The controller was designed on the physical platform using Simulink Real-Time Windows Target utility, personal computer, and data acquisition system. Three sensors utilized in this system are (i) Accelerometer (ii) Gyroscopes and (iii) Magnetometer. Roll and pitch angle were measured using the accelerometer. Three gyros were used to measure the angular velocities and magnetometer was used to measure the yaw angle. For driving the motors, PWM driving method was used. Linear Quadratic Regulator was designed to stabilize the attitude and to control the roll, pitch and yaw rate. The experiment was conducted to find the relationship between motor voltage and thrust generated by propellers.

Widyanto et al. [7] created an auto level control framework of v-tail quadcopter. Orientation control was actualized by PID control system. This control system used feedback information from the nine D.O.F MARG (Magnetic, Angular Rate, and Gravity) sensors. These sensors were utilized to calculate the orientation by using quaternion technique represented Kalman focused around fusion sensor. The test results demonstrated that the ideal control framework in x-axis was accomplished by deciding Kp, Ki, KD and KDd values which were 8.0, 2.2, 0.316 and 10, separately. Though for y-axis: Kp, Ki, KD and KDd values were 7.04, 1.72, 0.340 and 10. The control system had the steady state error less than one degree for both x and y axis.

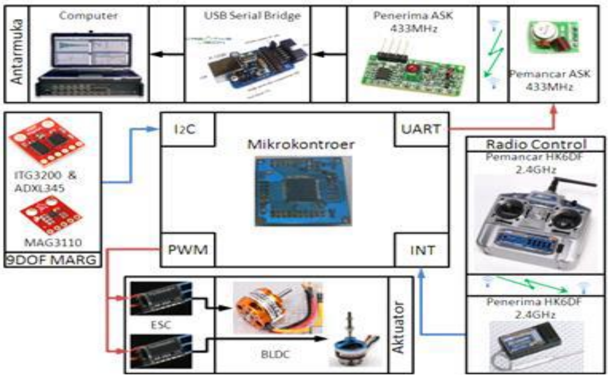


Fig. 14. Design and specification of quadcopter hardware [7]

Achtelik et al. [8] described a complete framework that was composed and actualized. In which the movement of a quadcopter was steadily controlled and focused on visual input and estimations of inertial sensors. They had created up a financially savvy and simple to setup vision framework. Active markers were finely intended to enhance perceivability under different points of view and robustness towards unsettling influences in the image based posture estimation. Additionally, position and heading controllers for the quadrotors were actualized to demonstrate the framework's abilities. The execution of the controllers was further enhanced by the utilization of inertial sensors of the quadcopter.

Sathiyabama et al. [9] designed a controller for quadcopter using Labview with image processing techniques. They had created a four rotor vertical take-off and landing unmanned air vehicle known as quadcopter aircraft. It was another model configuration system for the flight control of an autonomous quadcopter. The model was utilized to outline a steady and exact controller to create an image controlling technique using Labview to get the stability while flying the quadcopter.

Mahen et al. [10] described the configuration and improvement of land and water capable quadcopter. They presented the outline design for a land and water capable quadcopter with the assistance of CAD and CAE tools. The principal components used for creating this system were kk2.1 flight controller board, outrunner motor, electronic speed controller, transmitter and receiver. The configuration was started by the approximate payload and it is capable of bearing the weight of individual segments. In view of the rough weight of the quadcopter, the suitable motors and electronic parts were chosen. The determination of materials for the structure was focused on weight, strengths, mechanical properties and expense. First person view (FPV) was integrated into the system to carry out inspection and surveillance with the assistance from GPS receiver.

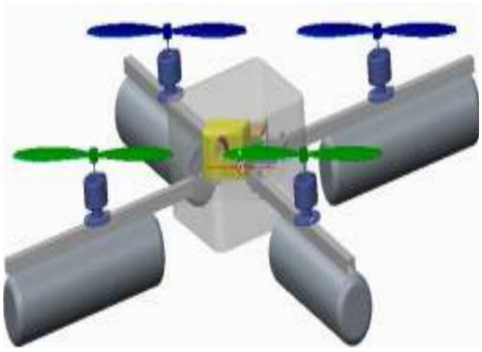


Fig. 15. Analysis of frame [10]

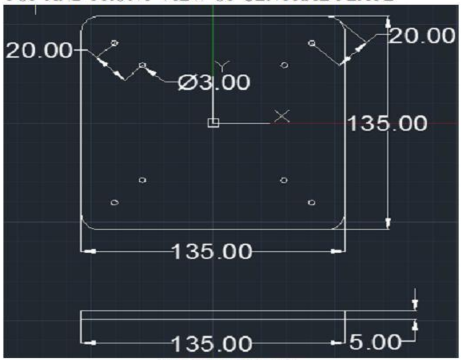


Fig. 16. 3D CAD model [10]

Shah et al. [11] described the design and development of the quadcopter in terms of improving the payload capacity of the quadcopter. Since the weight lifting capacity of the system was very less, so they had implemented a new design to improve it. All the mechanical components including frame were designed and assembled in modelling software CREO. The first work was to design all components parametrically and assemble all components at the correct position on the frame in CREO software. This software was used to analyse the strength of body when it is subjected to static and dynamic loading and also calculate the stress at each point in the frame. It also calculated the thrust and acceleration effect in the dynamic environment. ANSYS software was used to analyse the total deformation and von-mises stress under static loading.

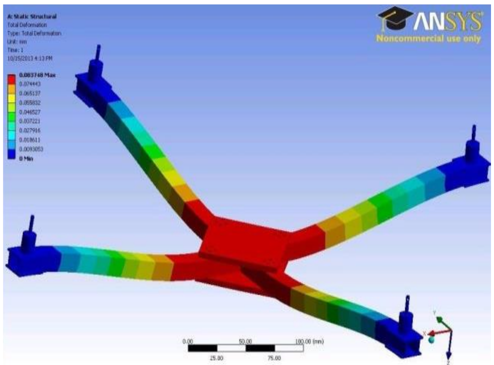


Fig. 17. Total deformation in static structural analysis [11]

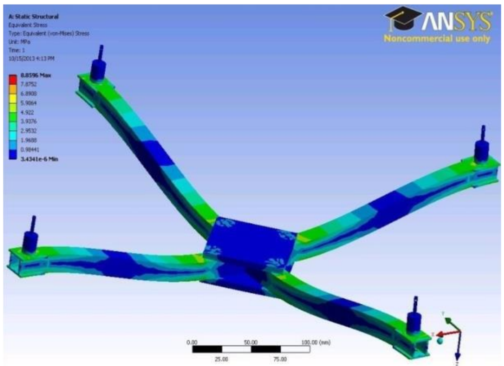


Fig. 18. Von-mises Stress developed inside the frame in static structure analysis [11]

Sa et al. [12] described the modelling, estimation and control of the level translational movement of an open-source and financially savvy quadcopter - the Mikrokopter. They had calculated the dynamics of its roll and pitch height controller, framework latencies, and the units connected with the qualities interchanged with the vehicle over its serial port. Utilizing this, they had made a level plane speed estimator that uses information from the inherent inertial sensors and an installed laser scanner. It executes translational control utilizing a control loop structural planning. They presented the exploratory results for the model and estimator, as well as closed-loop positioning.

Chee et al. [13] created an unmanned aerial vehicle fit for attitude estimation and adjustment through the usage of a non-linear integral filter and proportional-integral rate controllers. They had created crash avoidance plans and for height control, respectively. An outside route plan and crash avoidance algorithm was additionally proposed to upgrade the vehicle autonomy.

Rigatos [14] considered and compared non-direct Kalman filtering frameworks and particle separating techniques for assessing the state vector of Unmanned Aerial Vehicles (UAVs) through the integration of sensor estimations. He had used (i) Sigma-Point Kalman Filtering, (ii) Extended Kalman Filtering, (iii) Particle Filtering and (iv) Alternate Non-linear estimation method for estimation of the UAV's state vector.

Metni et al. [15] described the dynamics of a UAV for checking of structures and maintenance of bridges. They exhibited a novel control law focused on machine vision for semi-stationary flights over a planar target. The new control law utilized the homography matrix processed from the data received from the vision framework. The control algorithm was determined with back stepping systems.

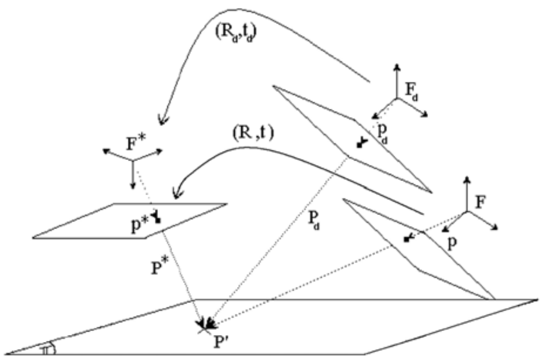


Fig. 19. Camera projection diagram showing the Reference frame (F^*), the current frame (F) and the desired frame (F_d) [15].

Siebert et al. [16] worked on mobile 3D mapping for surveying over earthwork utilizing an unmanned aerial vehicle framework. The extent of the introduced work is the execution assessment of a UAV framework that was fabricated to get portable three-dimensional (3D) mapping data quickly and self-sufficiently. The design of the system was based on Mikrokopter Quad XL. The inertial measurement unit was developed to measure the alignment, barometrical altitude and acceleration. The Flight control unit was used to control the speed of motors and also connected with GPS receiver and magnetic compass. With the help of GPS receiver, the quadcopter was able to follow 3D flight trajectory up to 100 waypoints.

Paula et al. [17] described the phases of identification, dynamic modelling and control of an unmanned aerial vehicle of type quad-rotor intended to capture pictures and video in high definition with relatively low cost. PID controllers were utilized for the control and adjustment of the structure as well as controlling the rotational rate of the four rotors.

Zhao et al. [18] described an integrated and practical control technique to unravel the leader–follower quadcopter flight control issue. This control method was intended for the follower quadcopter to keep the specified arrangement and stay away from the obstacles amid flight. The proposed control algorithm utilized a progressive methodology comprised of model predictive controller (MPC) in the upper layer with a powerful feedback linearization controller in the base layer. The MPC controller generated the advanced crash free state reference trajectory which fulfils all pertinent stipulations and vigorous to the input disturbances. The robust feedback linearization controller tracked the ideal state reference and decreases tracking errors amid the MPC overhaul interval.

Kim et al. [19] described wearable hybrid interface where eye motions and mental focus specifically impact the control of a quadcopter in three-dimensional space. This non-invasive and minimal effort interface addresses impediments to past work by supporting clients to finish their confused assignments in an obliged situation in which just visual feedback was given. The use of the two inputs increased the quantity of control commands to empower the flying robot to go in eight separate directions within the physical environment. Five human subjects took part in the analyses to test the attainability of the hybrid interface. A front perspective camera on the frame of the quadcopter gave the central visual feedback to every remote subject on a portable laptop display. Based on the visual feedback, the subjects utilized the interface to explore along pre-set target areas.

Chovancová et al. [20] concentrated on mathematical modelling and identification of parameters of a quadcopter models. There were many models of the quadrotor that could be utilized to create a controller. The body fixed frame and also the inertial frame were used to represent the non-linear model. The following model is characterized according to quaternions. The last exhibited model is close to a hover position, where a few moments and forces could be ignored. The parameters of the models could be obtained through experimentation, estimations or the blend of both ways.

Gupta et al. [21] described another methodology for the improvement of autonomous synchronic hexacopter aerial (ASHA) robot. The robot utilized six effective brushless DC motors, high effect pitch polymer propeller, electronic speed controllers (ESC), a flight controller and an RC controller. The new outline was confirmed on the grounds of structural dependability, dynamic examination, directional adaptability and dynamic controlling which gives a stable flight for more length of time (roughly 25 minutes), hovering impact and enhanced burden carrying limit up to 3.4kg that expanded its application.

Medeiros et al. [22] described PHM-based multi-UAV task assignment for identifying the application of integrated vehicle health management (IVHM) ideas focused on prognostics and health monitoring (PHM) procedures to multi-UAV frameworks. Considering UAV as a mission basic framework, it was required and needed to fulfil its operational goals with insignificant unscheduled interferences. So, it does bode well for UAV to exploit those strategies as empowering agents for the availability of multi-UAV. The principle objective was to apply data from a PHM framework to perform decision making with the help of IVHM structure. UAV RUL was processed by the method for a fault tree examination that it was nourished by a circulation capacity from a likelihood thickness capacity relating time and disappointment likelihood for every UAV discriminating parts. The IVHM system, for this situation, it was the assignment task focused on UAV wellbeing condition (RUL data) utilizing the receding horizon task assignment (RHTA) algorithm. The study case was created considering a group of electrical little UAVs and pitch control framework was picked as the basic framework.

Nemati et al. [23] described a quadrotor flying vehicle with rotors that could tilt around any one of its axis. The tilting rotor gave the additional preference regarding extra stable arrangements, made conceivable by extra actuated controls, when contrasted with a conventional quadcopter in the absence of tilting rotors. The tilting quadrotor configuration was proficient by utilizing an additional motor for every rotor that empowers the rotor to pivot along the axes of the quadcopter arm. It transforms the conventional quadcopter into an over-impelled flying vehicle permitting them to had whole control over the orientation and its position. The dynamic model of the tilting rotor quadcopter vehicle was inferred from flying and stable modes. The system incorporates the relationship between vehicle introduction plot and rotor tilt-edge. Moreover, a PD controller was intended to attain to the floating and route ability at any coveted pitch or move edge. The element model and the control configuration were confirmed with the assistance of numerical studies.

2.3. Aerospace Computing, Information and Communication

Bohorquez et al. [24] described an initial configuration idea for a micro coaxial rotorcraft utilizing custom manufacturing strategies. Issues connected with the practicality of accomplishing hover and thoroughly practical flight controls for a coaxial rotor design were addressed. A model vehicle was assembled, and its rotors were made to check in a custom drift stand used to calculate power and thrust. The main criteria for selecting the configuration of the vehicle were based on hover efficiency, compactness of folding, ease of payload packaging, simplicity of structure, controllability, and manoeuvrability. The two experiments were performed based on a single rotor with twisted and untwisted blades, and another one was based on coaxial configuration with untwisted blades. For prototype vehicle, coaxial rotor configuration was chosen.

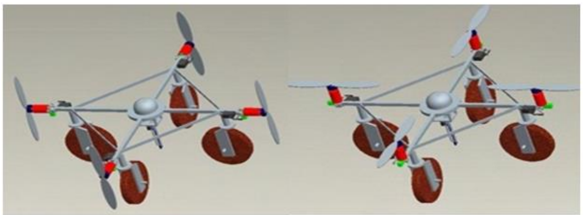


Fig.20. Schematic driving and flying mode

Fig. 21. Actual model showing driving and flying modes

Madani et al. [25] described a nonlinear dynamic model for a quadrotor in a structure suited for back going control plan. Because of the under-activated characteristics of quadrotor, the controller could put the quad rotor track three Cartesian position (x,y,z) and the yaw angle to their essential values and balance out the roll and pitch angles. The framework had been displayed into three interconnected subsystems. The under-actuated subsystem gave the dynamic connection of the horizontal positions (x,y) including roll and pitch angles. The second completely activated subsystem gave the motion of the vertical position z and the yaw point. The subsystem placed in the end gave the progress of the propeller strengths. A back venturing control was introduced to balance out the entire framework. The outlined approach was focused on the Lyapunov stability theory.

Hanafi et al. [26] described the advancement of remotely worked quadcopter system. The quadcopter was controlled through a graphical client interface (GUI) where the connection between GUI and quadcopter was built by utilizing a wireless framework. The quadcopter adjusting condition was sensed by FY90 controller and IMU 5 DOF sensor. For smooth landing, quadcopter was integrated with the ultrasonic sensor. Arduino Uno board handles all signals from sensors and then send the signals to control quadcopter propellers. The GUI was developed utilizing visual basic 2008 express as interfacing communication between the PID controller and the quadcopter framework. The developed system was stable during hover position and balances itself during flight. The quadcopter could carry the maximum load up to 250 grams.

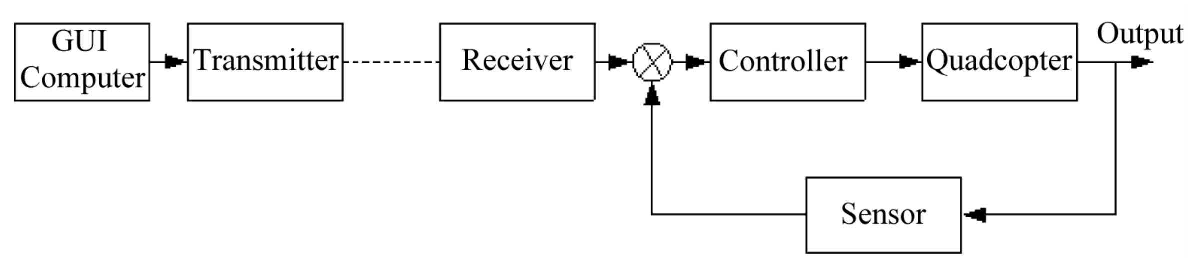


Fig. 22. Quadcopter controller [26]

Gadda et al. [27] described the design and development of quadcopter for border security with GUI system. During severe weather conditions, it becomes difficult to monitor the activities at the border. The system was designed in such a way that could monitor the unknown activities even in bad weather without letting others know. GPS was utilized to track the position of invader or our troops. This GPS information would be sent to Arm9 processor and passed on to operator or controller by means of Zigbee. The quadcopter was controlled by the operator through the IR remote. The operator would fly the quadcopter from the control station and observe the unknown activities with the help of wireless camera mounted at the top of the quadcopter.

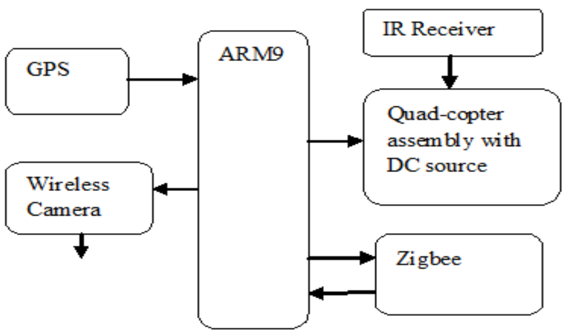


Fig. 23. Quad-copter Assembly [27]

Afghani et al. [28] designed an autopilot system for small helicopter type UAV. There were three independent control modules (i) Altitude control module (ii) Spinlock module and (iii) Horizontal drift control module. These modules were built around a high-performance microcontroller. The key features of this system were autonomous take-off and landing, payload capacity enhancement and safe flight in a closed environment. Infrared sensors were placed in a helicopter that gave the altitude information in the form of variable voltage. This voltage signal was converted to the digital signal with the help of ADC, and that was sent to the microcontroller that controls the PWM of the main propeller. A spin lock module controls the rotation of tail and the last module controls the two servo motors and slip ring assembly.

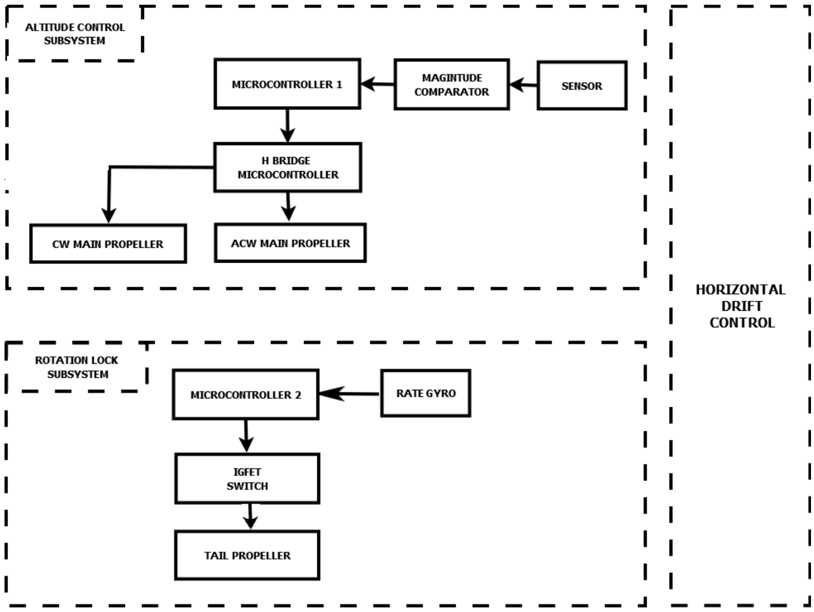


Fig. 24. Three Independent Control Modules [28]

Santos et al. [29] developed a fuzzy logic based intelligent system to control a quadrotor. A quadrotor comprised of four motors and the speed of each motor was controlled independently by varying the pulse width of PWM signal. The complete system had six degree of freedom, three for position and three for orientation. A simulation model of the quadcopter was controlled using fuzzy based intelligent system. Height, pitch, roll and yaw angle were the necessary inputs and power of each rotor act as output.

Hoffmann et al. [30] performed the experiment on quadrotor aircraft unmanned aerial vehicle (UAV). The experiment consisted of two components (i) a thrust test stand and (ii) STARMAC II, quadrotor prototype. A thrust test stand was developed to calculate the rotor and motor characteristics. A load cell was used to calculate the torques and forces. The microprocessor board was used to control the pulse width of PWM signals. PWM signal further controlled the speed of motors. With STARMAC II, indoor and outdoor flight testing was done.

Sanna et al. [31] described natural user interfaces (NUIs) and visual computing techniques to control the route of a quadrotor in GPS-denied indoor situations. A visual odometry algorithm permits the platform to explore nature self-sufficiently while the client could control complex moves by motions and body postures. This methodology makes the human–computer interaction (HCI) more instinctive, usable and opens to the client's requirements: as it was easier to use. The NUI exhibited in this quadcopter is focused on the Microsoft Kinect and clients could alter the relationship between motions/postures and platform orders, in this manner picking the more instinctive and compelling interface.

2.4. Intelligent Robot Strategy

Erginer et al. [32] described a model of a four rotor unmanned air vehicle with vertical take-off and landing (VTOL) known as quadrotor aircraft. They explained its control structural including vision-based system. They had proposed the controller design for the model of the quadcopter. Proportional Derivative (PD) Controllers were used to control yaw and pitch angle which further control x and y motions. The parameters used for the controller were Kp, Kd, Kp1, Kd1, Kp2, Kd2, Kp3 and Kd3 and their values were .82, 1.5, 3, 0.4, 80, 15, 100 and 50. They also carried out the simulation of the quadcopter in MATLAB. The vision-based system was designed which could see the pattern on the ground and can hover at a certain height over it.

Sefidgari [33] described the design of the autonomous quadcopter with real-time human body detection and tracking using image processing. The control of the quadcopter was done using PID controller, the parameters of which was enhanced by the genetic algorithm that is integrated into AVR microcontroller. For image processing purpose, a small CMOS camera was used with wireless sensor module for transferring data. For any object movement, it captured the image and applied the geometric algorithm to detect whether it is a human or other objects. The module was split into two parts, human body detector and decision-making system with the controller to control the altitude of quadcopter. Human body detector consists of two parts (i) geometric histogram and (ii) edge detector. They used the neural fuzzy genetic algorithm to control the altitude of quadcopter.

Fig. 25. Human body detection via edge detection method [33]

Fig. 26. Experimental mini quadcopter [33]

Gageik et al. [34] described the waypoint flight parameter comparison of an autonomous UAV. They described the impact of diverse waypoint parameters on the flight performance of a self-controlling indoor UAV integrated with inertial, weight, ultrasonic and optical sensors for controlling and positioning in a 3D environment. The impact of these parameters on the flight time and exactness of the flight way was examined. The step size and threshold value affect the speed and stability of autonomous quadcopter. The distance between the two executed waypoints was the maximum step size. The radius about the waypoint was the acceptance threshold. The flight control system comprised of waypoint control and waypoint conversion. A quadcopter had six degree of freedom, three for positioning and three for orientation. Empiric optimized PID controller was used for each degree of freedom.

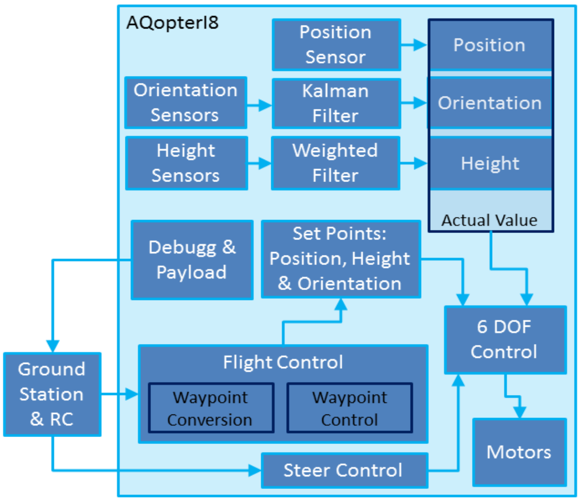


Fig. 27. System Concept [34]

Dong et al. [35] described the development of an unmanned aerial vehicle that comprised of an embedded system onboard and a ground station served by a portable computer. The software used in the onboard system performs many tasks such as data acquisition, servo driving, automatic flight control execution and data logging. The onboard system consisted of a framework that could perform multiple tasks. A behaviour based system was designed for automatic control. The ground station software utilized two layers system (i) data sending in background and (ii) data envision in the foreground. The system developed sends the real-time 3D data to the ground station.

Nicol et al. [36] introduced a direct approximate-adaptive control, utilized CMAC non-linear approximators, for an exploratory model quadrotor helicopter. The system overhauls adaptive parameters, the CMAC weights, as to attain both adaptations to obscure payloads and vigor to unsettling influences. In the test, the new strategy stops weight drift amid a shake test and adjusts on-line to a critical included payload though e-adjustment can't do both.

Courbon et al. [37] described a vision based autonomous navigation technique for a vertical take-off and landing of UAV that utilized a single embedded camera. This camera focused the point of interest from the natural landmarks. In the proposed methodology, pictures of nature were initially sampled and put as a set of ordered key pictures and arranged giving a visual memory of the surroundings. The visual navigation system linked the current image and the target image present in the visual memory. The quadrotor was driven along images using a vision-based control law.

Leong et al. [38] described low-cost microcontroller-based hover control design of a quadcopter. A minimal effort hover control mechanism was developed and actualized on the microcontroller for a kind of flying machine setup known as the quadcopter. Flight control gets to be easier as the quadcopter hovers at a steady level from the ground by itself, in the meantime permitting anybody to move it effectively at that tallness and perform operations like imaging. At the point when effectively actualized, the proposed hover control configuration would simplify the flight control of a quadcopter, particularly for apprentices and unskilled people.

Engel et al. [39] described a framework that empowers a low-cost quadcopter coupled with a ground-based portable computer to explore autonomously in already obscure and GPS-denied situations. The framework comprised of three parts: a monocular SLAM framework, a Kalman filter for information fusion and state estimation and a PID controller to create guiding commands. By a working framework, the primary commitment of this work is a novel, closed-form solution to gauge indisputably the size of the generated visual map from inertial and height estimations. In a broad set of tests, the framework had the capacity to explore in already obscure situations at absolute scale without obliging fake markers or outer sensors.

Moreover, they demonstrated its strength to transitory loss of visual tracking and delay in the communication process.

Miyoshi et al. [40] described the framework that acknowledged direct and multimodal interaction utilizing cameras and a microphone. The sensors were integrated into the system to detect human actions. The complete processing was done within onboard computer without any external devices. They designed a prototype of multimodal and interactive quadcopter capable of flying and reacting to human actions. They used micro control unit (MCU) and field programmable gate array (FPGA) for fast image processing and stable controlling during hovering. Two cameras were used, one was attached to the top, and another one was attached to the bottom. The quadcopter followed the movement of the hand with the help of cameras.

2.5. Major works done so far on autonomous UAV

REF.	FEATURE	METHODOLOGY	LIMITATION	ADVANTAGE
[1] [41]	Presented the mechanical design, dynamic modelling, sensing, and control of indoor VTOL autonomous robot OS43.	Micro VTOL1 systems.	Only designed for balancing during hover position of quadcopter.	Good control on quadcopter even at high speed.
[2] [42]	High state position control of the MFI was considered. Based on thorax model, wing kinematic parameterization strategy was created. A state space LTI model and a LQR controller were developed to attain stability.	Micromechanical Flying Insect utilized biomimetic method to build MAV that could provide excellent flight performance by using flapping wings.	High complexity of controller.	Good flight control.
[3]	Autonomous control system was designed for Micro-Flying Robot (MFR) and small helicopter X.R.B that could be used at the time of disaster. It dealt with	Firstly the experiment was conducted by using PID controller but because the range of stabilization was considerably	High cost and complex structure or model.	3D vision system was developed to observe the position of X.R.B and MFR.

	autonomous hovering control, guidance control of MFR, and automatic take-off and landing control of X.R.B.	narrow, the result could not obtained. To obtain better result H∞ controller was used.		
[4]	Omni-Flymobile was intended for both the ability of flying all around and driving on the ground. The Omni-Flymobile could be changed into a vehicle that explores on the ground.	Gyro and accelerometer was used to detect the angles roll, pitch and yaw. Kalman filter was used to get stable signals to detect angles. PID controller was used to generate angle errors.	Stability and accurate tracking of the system was low.	The system was designed for both flying as well as driving on ground.
[5]	On-line unique mark confirmation framework works in two stages: minutia extraction and minutia matching which was much quicker and more solid, was actualized for separating peculiarities from an information finger impression picture caught with an on-line inkless scanner.	Two motors were used to control two rotors, and the third motor controls the centre of gravity. The speed of rotors was controlled using PWM signals. Ultrasonic and gyro sensors were also used to measure height and direction of orientation.	Hardware complexity was more.	Easy to control flight.
[6]	A non-linear model was designed in Simulink and control algorithm was designed to stabilize the attitude based on the linearized model around hovering conditions and to actualize the controller on physical stage that utilized Simulink RTWT,	A quadrotor with a carbon fiber body casing was assembled and constant execution of a LQR control for the attitude stabilization was carried out.	Complex design.	The stability and control of the quadcopter was execellent.

	PC and information procurement card.			
[7] [43]	Auto level control system, which could be implemented using attitude and heading reference system that gave orientation information of the platform.	PID control method was used for Orientation control. Magnetic, Angular Rate, and Gravity sensor were used to measure the orientation angle by using quaternion algorithm.	The controller design of quadcopter was complex.	PID controller gave excellent performance in controlling orientation of quadcopter.
[8]	Active markers were used to improve the visibility towards image based on pose estimation. In addition, position and heading controllers for the quadcopter were actualized to demonstrate the framework's abilities. The execution of the controllers was further enhanced by the utilization of inertial sensors of the quadcopter.	The system was designed in which motion of rotors were controlled based on visual feedback and measurement of inertial sensors.	Sensitive to light and not suitable to use at high illumination area.	The tracking system was highly transportable and easy to set up.
[9]	Image controlling method was developed using Labview to achieve stability in flying quadcopter.	Arduino board was used for controlling the speed and direction of rotors.	Camera used was sensitive to light.	The quadcopter was controlled automatically without manual error.
[10]	A complete system was designed using KK2.1 flight controller board that provides excellent stability during hover position. GPS receiver was also integrated with	3D modelling of quadcopter was done using CREO 2 software, and structural part of quadcopter was sent to ANSYS software to analyse	Controlling of the quadcopter during the flight was difficult.	The stability of the system was excellent during hover position.

	the system that gave the location of the vehicle.	the stress and deflection.KK2.1 flight controller board was used for controlling the speed of rotors.		
44	The quadrotor was controlled by graphical user interface where wireless communication framework utilized to do the connection between GUI and quadrotor.	Graphical user interface, Arduino Uno microcontroller, FY90 controller and IMU 5DOF sensor.	For the load of 250gram and above, the quadcopter could not able balance itself.	Good stability during hovering position.
45	A fuzzy control system was developed to control a simulation model of the quadrotor.	Intelligent system based on fuzzy logic.	Control design was too complex.	Fuzzy controller had fast dynamic response and small overshoot.

2.6. Object detection and tracking based on background subtraction and optical flow technique

Wang and Zhao [46] proposed the movement detection by utilizing background subtraction system. In this video sequence is made out of a progression of video images which contains the features of geometry data of the target, separate pertinent data to analyze the movement of targets. The compression ratio was incredibly progressed.

Rakibe et al. [47] describe movement detection by creating a new algorithm based upon the background subtraction. In this firstly dependable background model based upon statistical is utilized. After that the subtraction between the current image and background image is carried out based upon threshold. After that the detection of moving object is carried out. Morphological filtering is carried out to remove the noise and settle the background interruption trouble.

Kavitha et al. [48] exhibited movement detection by overcoming the drawbacks of background subtraction algorithm. An effectively computed background subtraction algorithm has been utilized, which has the capacity to resolve the issue of local illumination changes, like shadows and highlights and worldwide illumination changes.

Shafie et al. [49] exhibited movement detection utilizing optical flow strategy. Optical flow can emerge from the relative movement of objects and the viewer so it can give critical data about the spatial arrangement of the objects and the rate of change of this positioning. Discontinuities in the optical flow can help in sectioning images into areas that correspond to distinctive objects.

Shuigen et al. [50] developed movement detection by utilizing a system based on temporal difference and optical flow field. It is great at adjusting to the dynamic environment. Firstly, an outright differential image is computed from two continuous gray images. The differential image is filtered by low pass filter and converted into binary image. Also optical flow field is computed from image groupings by Hron's algorithm. Thirdly, moving object area is discovered by indexed edge and optical flow field.

Devi et al. [51] describe movement detection utilizing background frame matching. This technique is exceptionally effective technique for looking at image pixel values in ensuing still frames captured after at regular intervals from the camera. Two frames are obliged to detect movement. First and foremost frame is called reference frame and the second frame, is called the input frame contains the moving object. The two frames are analyzed and the distinctions in pixel qualities are resolved.

Lu et al. [52] exhibited movement detection by proposing a real-time detection algorithm. In this algorithm incorporates the temporal differencing strategy, optical flow system and double background filtering (DBF) strategy and morphological processing methods to attain to better execution.

Wei et al. [53] describe an interactive offline tracking framework for bland color objects. The framework attains to 60-100 fps on a 320 × 240 video. The client can consequently effectively refine the tracking result in an intelligent way. To completely exploit client input and lessen client interaction, the tracking issue is tended to in a worldwide optimization framework. The optimization is productively performed through three steps. Initially, from client's info we prepare a quick object detector that places user objects in the video based on proposed features called boosted color bin. Second, we misuse the temporal coherence to create various object trajectories in view of a worldwide best-first technique. Last, an ideal object way is found by dynamic programming.

Jansari et al. [54] describe a differential approach for optical flow estimation in view of fractional spatial and temporal derivatives of the image signal. The correlation between background demonstrating method and Lucas-Kanade optical flow has been carried out for object recognition. Background subtraction strategies require the background model from many images while the Lucas-Kanade optical flow estimation technique is a differential two frames method, in light of the fact that it needs two frames to work. Lucas-Kanade technique is utilized which partitions image into patches and figuring a solitary optical flow on each of them.

Wang et al. [55] introduced a real time movement detection approach that is based on the combination of accumulative optical flow and double background filtering system to accomplish better execution. The collective optical flow system is utilized to get and keep a stable background image to adapt to varieties on ecological changing conditions and the double background filtering strategy is utilized to wipe out the background data and separate the moving object from it.

2.7. Summary

In this literature survey, the fundamentals of a quadrotor UAV are surveyed, and the different components that concern the quadrotor UAV including distinctive sensors, applications, and their focal points are reviewed. It begins with the fundamental control structure and portrays propelled applications that a quadrotor can be put to also. The field of UAVs and particularly quadrotors has more zones to create and move forward. These areas have led to significant improvements in computerization and robotics technology.

The change in different innovations has given further leads in enhancing the configuration and computing power that can be related with a quadrotor. Innovations like IC creation, concoction materials, and computer programs are not the just fields that influence UAVs, different areas signify the change and henceforth the exploration in this field is never finishing.

The vast majority of the research work is still in the design stage. It has been recognized that very little has been carried out as far as implementation and testing. A few issues must be determined by the organization of UAVs for common applications.

CHAPTER 3

3. Hardware and Software

3.1. Overview

The unmanned aerial vehicle was developed using various components and hardware such as KK2 flight controller board, out-runner brushless DC motor, electronic speed controller (ESC), video transmitter and receiver, HD camera, RC remote and receiver and li-po battery. For tracking and detection of human being from the quadcopter camera, the Matlab software was used for processing of videos obtained from the quadcopter camera.

3.2. KK2 Flight Controller Board

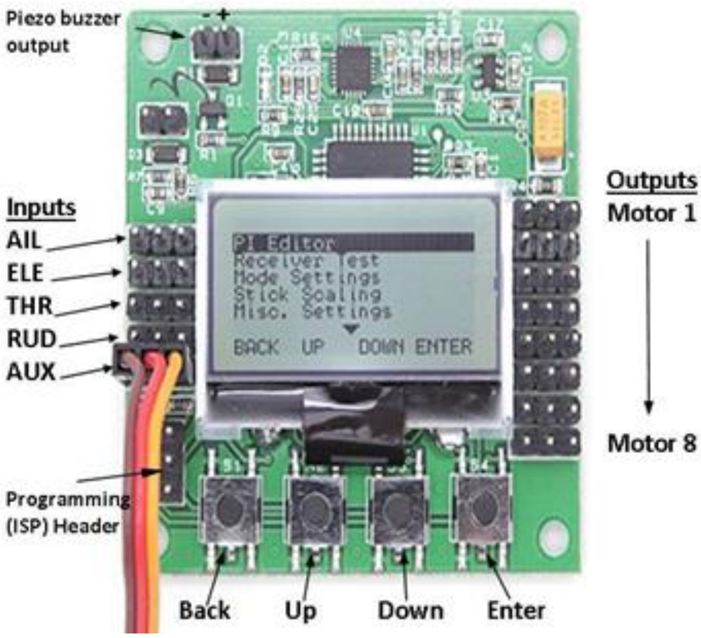


Fig. 28. KK2 flight controller board

KK2 flight controller board as shown in Fig. 28 is the central controlling unit of the quadcopter. Its main purpose is to stabilize the quadcopter during flight. It takes the signal from the gyroscope (for measuring orientation) incorporated into the board and sends the signal to Atmega324PA processor. It then sends the signal to electronic speed controller (ESC) for controlling the direction and speed of motors. The input pins of the board is connected to the RC receiver and output pins of the board is connected to the out-runner brushless DC motor using ESC's. This board controls and adjusts the roll, pitch and yaw angle. Roll angle is rotation around front to back axis, pitch angle is rotation around side to side axis and yaw angle is rotation around vertical axis as shown in Fig. 29. It controls the speed of individual rotor by controlling the throttle, pitch, roll and yaw as shown in Fig. 30.

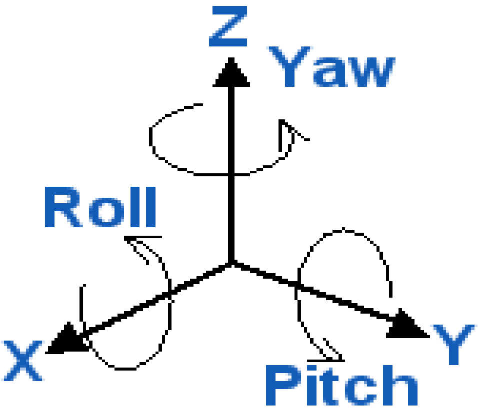


Fig. 29. Roll, Pitch and Yaw angle

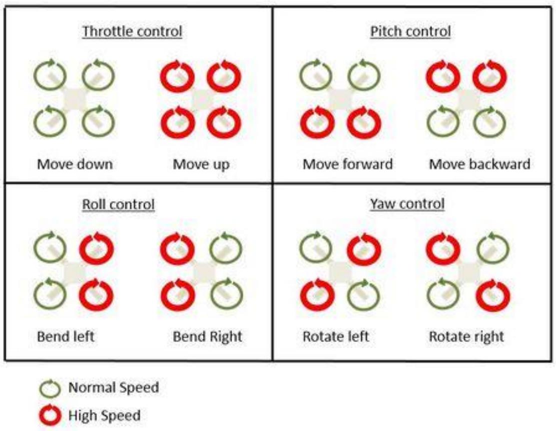


Fig. 30. Quadcopter motion mechanism

3.3. Out-runner brushless DC motor

Fig. 31. Out-runner brushless DC motor

The out-runner motor are basically brushless DC motor that are mainly used in RC helicopters, quadcopter or hexacopter. The outer shell of the motor spins around its winding just like the motors used in CD-ROM. The stator is the stationary part of the motor and rotor is the rotating part of the motor. The stationary winding is excited by brushless DC controller. The direct current is passed to 4 or more non adjacent windings and the gathering so empowered is rotated electronically based upon rotor position input. The quantity of changeless magnets in the rotor does not coordinate the quantity of stator poles.

3.4. Electronic Speed Controller

Fig. 32. Electronic Speed Controller

Electronic speed controller or ESC is a circuit that is use to control the speed and direction of the out-runner motor. It also coverts the voltage down to 5v for the RC receiver. It accepts the PWM signal for varying the speed of the rotor. By changing the pulse width of PWM signal, the speed of the motor also changes. As shown in Fig. 32 red, blue and black wires are connected to out-runner motor. Two wires red and black are connected to li-po battery and the last three wires red, orange and brown wires are connected to kk2 flight controller board.

3.5. Radio Transmitter and Receiver

Fig. 33. Radio Transmitter and Receiver

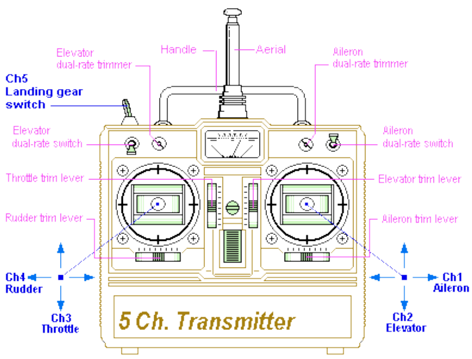


Fig. 34. Transmitter controls

The RC equipment consist of transmitter operated by operator or user on the ground and a receiver connected to the main controller board (KK2 flight controller) for receiving the signal or commands from the transmitter. The transmitter can have 4 or 6 or 9 channel depending upon the need. The transmitter sends the information or command by producing radio signal while the receiver is tuned to detect the signal. Fig. 34 shows the transmitter controls. For checking out the setting or for tuning the transmitter, T6config software was used.

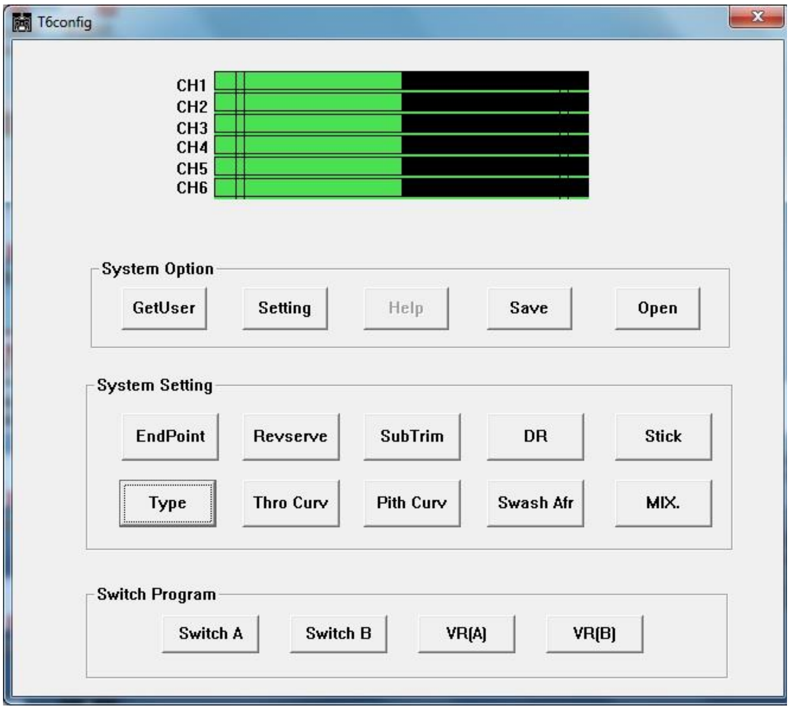


Fig. 35. Software for tuning transmitter (T6config)

3.6. LI-PO Battery

Fig. 36. LI-PO battery

Lithium polymer battery is basically a rechargeable battery based on lithium ion technology. It consist of 3 cells or 6 cells in a pouch format. This kind of batteries are mainly used in RC planes or helicopter or quadcopter. The working principle of the lithium polymer battery is based on intercalation and de-intercalation of lithium ions.

3.7. HD Camera and Video Transmitter/ Receiver

Fig. 37. Video transmitter and receiver

Fig. 38. HD Camera

HD Camera was mounted on the quadcopter for recording the video that was used for performing the surveillance tasks. The video captured by the camera was transferred to PC or laptop placed on the ground station using video transmitter and receiver. The video obtained from the camera was then used for detecting and tracking of humans by transferring that video in Matlab software. Real-rime object detection and tracking algorithm was applied to the video obtained from the camera.

CHAPTER 4

4. Methodology

4.1. Overview

This section describes the complete development of unmanned aerial vehicle (quadcopter) with real time object (human being) detection and tracking using color feature and motion. This project or work is split into two parts one is based on hardware and another one is based on Matlab software: 1) Development of unmanned aerial vehicle and 2) Real-time object detection and tracking using color feature and motion. This section only describes the hardware part. For the development of UAV (Quadcopter) various components and hardware are used such as KK2 flight controller board, out-runner motors, RC transmitter and receiver, video transmitter and receiver, propellers, lithium polymer battery, GPS receiver and electronic speed controllers.

4.2. Experimental setup for controlling out-runner motor speed

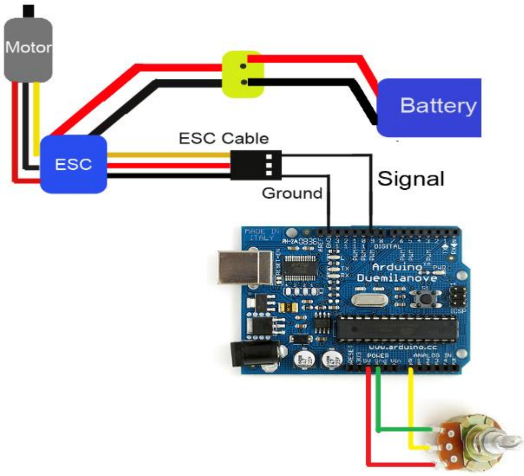


Fig. 39 Circuit diagram for controlling motor speed

Fig. 40 Physical layout for controlling motor speed

The circuit diagram for controlling the speed of out-runner DC brushless motor is shown in Fig. 39. The potentiometer was connected to the A0 pin of the Arduino board. Resistor R1 was connected to pin 12 to limit the base current of Q1 2N222 (transistor). Motor was connected using electronic speed controller to the Arduino board. By varying the pulse width of the PWM signal the speed of out-runner brushless DC motor could be controlled. The black and yellow color wire of ESC was connected to ground and pin 9 of Arduino. The red and black wire from ESC was connected to LI-PO battery and the connection for potentiometer is shown in Fig. 39.

4.3. GPS Tracking Unit

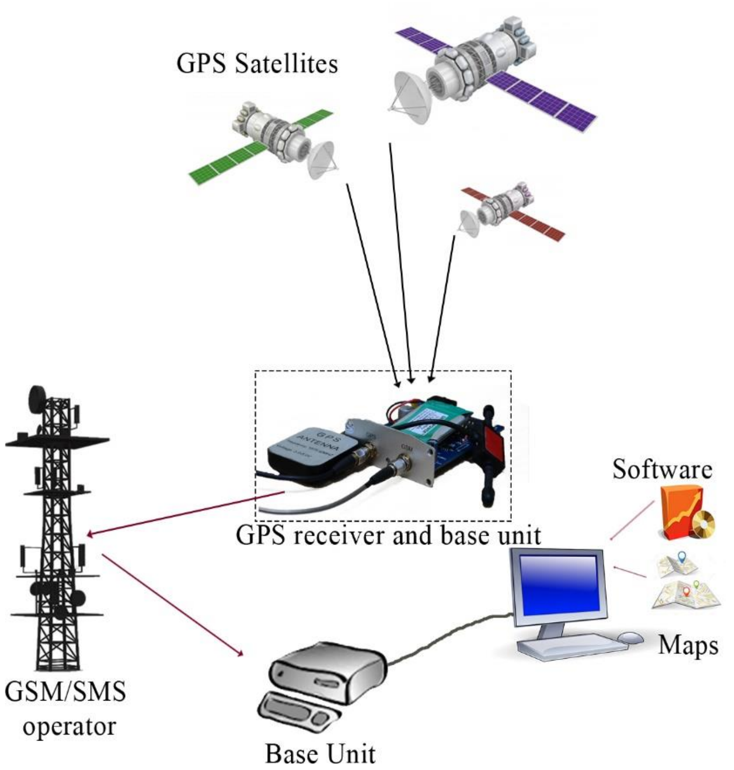


Fig. 41 Block diagram of GPS and GSM based tracking system for UAV

Fig. 42 GPS receiver module

The block diagram of GPS and GSM based tracking system for UAV is shown in Fig. 41. The GPS module shown in Fig. 42 was placed on the UAV for tracking its location. The GPS receiver receives the signal from the satellites for calculating the position of the quadcopter. Minimum three satellite signals are required for calculating the latitude, longitude and attitude.

The GPS receiver can only calculate the position of the UAV. GSM system was used for transmitting the location information to the user or operator. In this project, two types of tracking techniques were used: online tracking and offline tracking. Online technique was based on web application where one can see the location information live through google maps. In offline tracking, the location information was send to the user mobile in the form of latitude, longitude and attitude information.

4.4. Architecture of UAV (Quadcopter)

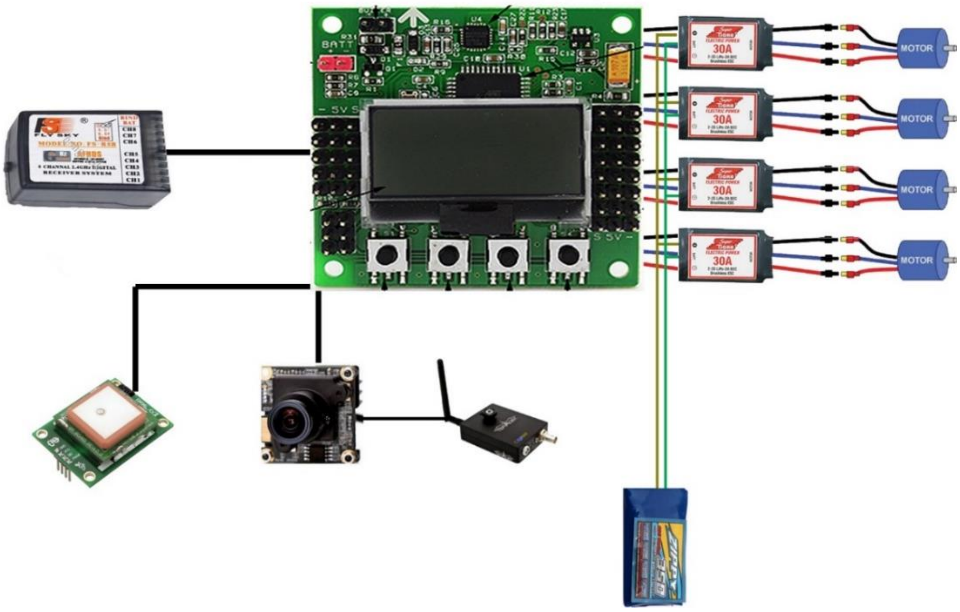


Fig. 43 Layout diagram for UAV (Quadcopter)

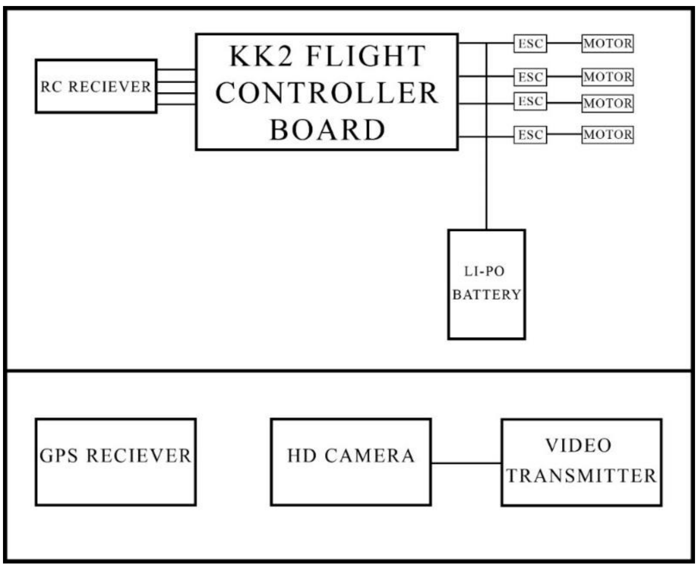


Fig.44 Architecture of UAV (Quadcopter)

The complete layout or connection diagram of the quadcopter is shown in Fig. 43. It comprises of KK2 flight controller board, out-runner brushless DC motor, GPS receiver, video transmitter and receiver, electronic speed controller, lithium polymer battery, HD camera and RC receiver and transmitter. ESC output wires red, blue and black was connected to the out-runner motors and its input wire red, blue and red was connected to KK2 flight controller board. The RC receiver was connected to four input pins of KK2 flight controller board. The green and brown wire of each ESC's were connected to LI-PO battery. The camera was connected with video transmitter for transmitting video signals to the receiver placed in the ground station.

The complete architecture of unmanned aerial vehicle (quadcopter) is shown in Fig. 44. The KK2 flight controller board is the central processing unit for the quadcopter. It has on-board gyroscope for measuring and maintaining orientation. It sends the signal to ESC's for controlling the direction and speed of the motors. Its main purpose was to stabilize the quadcopter in hover position. Electronic speed controller was used for controlling out-runner motor speed and direction. It only takes PWM signals from the board for controlling the motors. By varying the pulse width of the PWM signal the speed of the motors could be controlled. The out-runner motors were used because of its high rpm. The outer shell of the out-runner motor rotates around the windings. RC receiver was connected to KK2 flight controller board for receiving the signal from the remote or transmitter which was controlled by user or operator. The GPS receiver was placed on the UAV for achieving location information in the form of latitude, longitude and attitude. For tracking the location of UAV, both offline and online tracking techniques were used. HD camera was installed on the quadcopter for surveillance purpose. The video captured from the camera was transmitted to the receiver placed on the ground station using transmitter.

CHAPTER 5

5. Real-time object detection and tracking using color feature and motion

5.1. Overview of Real-Rime Object Tracking

A technique for automating the methodology of detecting and tracking objects utilizing color feature and motion was introduced. Video Tracking is the methodology of finding a moving object over the long distance using a camera. The main aim of video tracking is to relate target objects in consecutive video frames. The relationship can be especially troublesome when the objects are moving speedy with respect to the frame rate. An interchange situation that grows the unpredictability of the issue is the time when the tracking object changes orientation after eventually. For these circumstances video tracking frameworks typically utilize a movement model which depicts how the image of the target may change for distinctive conceivable movements of the object. In this work an algorithm is developed to track the real-time moving objects in different frames of a video using color feature and motion.

5.2. Introduction

Tracking can be characterized as the problem of assessing the trajectory of an object in the picture or image plane as it moves around a scene. The requirement for high power PCs, the accessibility of high quality and modest camcorders, and the expanding requirement for automated feature analysis has produced a lot of interest for object tracking algorithms. There are three key steps in feature analysis: recognition of target moving objects, tracking of such objects from frame to frame, and analysis of object tracks to perceive their conduct. In its least complex form, tracking can be characterized as the issue of evaluating trajectory of an object in the image plane as it moves around a scene. The main goal of this investigation is to track the real time moving objects in different video frames with the assistance of a proposed algorithm. Median filtering is a non-linear operation which is utilized as a part of image processing to decrease noise. A median filter is more viable than convolution when the objective is at the same time to diminish noise and save edges.

A variety of issues of current interest in computer vision require the capacity to track moving objects in live streaming for purposes such as inspection, video conferencing, robot navigation, and so on. The difficulties that drive a great part of the exploration in this field are the colossal information data transfer capacity inferred by high resolution frames at high frame rates, and the yearning for real-time intuitive execution. Various innovative routine have been proposed. Nonetheless, the vast majority of these routines use complex models, for example, edges, snakes, splines, formats or computationally expensive Eigen image or condensation algorithms. Despite the fact that these methodologies are expansive in their capacities offering reliable object recognition. In addition to tracking, they are so far not able to run on full video resolution images at high frame rates.

Color has been generally utilized as a real-time tracking frame works. It offers a few noteworthy points of interest over geometric signs such as computational simplicity, robustness under partial occlusion, rotation, scale and resolution changes. In the tracking framework, the color blobs are being tracked. The idea of blobs as a representation for image characteristics has a long history in computer vision and has various numerical definitions. It might be a reduced set of pixels that impart a visual property that is definitely not imparted by the surrounding pixels. This property could be color, texture, brightness, movement, shading, a mix of these, or some other striking spatio-temporal characteristics got from the signal.

Body movement analysis is an imperative innovation which combines modern bio-mechanics with Computer vision. It is broadly utilized as a part of intelligent control, human machine interaction, movement analysis and different fields. Presently, systems utilized as a part of moving object detection are chiefly the frame subtraction technique, the background subtraction strategy and the optical flow method.

5.3. Objective of Real-Rime Object Tracking

The aim of this paper is to track the real-time moving objects in distinctive video frames with the assistance of a proposed algorithm. To perform video tracking an algorithm dissects features in video frames and yields the motion of focuses between the frames. There are many algorithms each one having quality and shortcoming. Considering the proposed utilization is imperative when picking which algorithm to utilize. There are two noteworthy parts of a visual tracking framework, target representation and localization and filtering and information association.

Target representation and confinement is generally a base up methodology. These systems give a variety of tools for recognizing the moving objects. Finding and tracking the target object effectively is reliant on the algorithm though filtering and information association is generally a top down procedure which includes joining earlier data about the scene or object managing with object dynamics and development of diverse speculation.

The most widely recognized issue experienced in the object tracking is to discover the region of interest (ROI). Region of interest is the locale in which we find the required object in distinctive video frames. To find the required object in video frames, we need to first detect the movement of that object with the assistance of movement estimation feature, like Centroid or Bounding box.

Another normal issue which emerges amid the object tracking is that of light illumination and background which goes about as a noise and is the main issue which emerges amid the tracking of the object which can be separated by filtering the noise.

Issues identified with object tracking include developing great tracking algorithms, checking their capability and understanding their effect on image analysis framework. One of the major difficulties in object tracking is that of noise, complex object shape/movement, partial and full object occlusions, scene illumination changes, continuous processing requirements. This paper deals with the development of real-time object detection and tracking using color feature and motion.

5.4. Methodology of Real- Time Object Tracking

A few universally useful algorithm or approaches have been developed for object tracking. Since there is no general answer for the object tracking issue, these systems regularly must be consolidated with domain information so as to adequately tackle an object tracking issue for an issue space. Hence object tracking necessities to be approached from a wide assortment of points of view.

As we have now seen that amid the tracking of the object light brightening goes about as noise. Noise ought to be filtered out through processing, additionally we require that the time needed for the processing of the image or frame ought to be as low as could reasonably be expected, and also we have to see that the movement recognition and tracking of the object ought to be appropriate, in light of the fact that if there is no legitimate movement detection we will not be able to detect and track the target object.

In this thesis we bound to track the objects using color feature and motion [56]. Different algorithm or methods have been developed for detecting and tracking object using color feature and motion. A problem inside an object tracking exploration is the quest for a powerful measure of tracking quality. Diverse systems for tracking exist using distinctive attributes e.g., shape, surface, or color, and so on. These strategies perform diversely relying upon the application and are frequently looked at just subjectively.

5.5. Implementation of Real- Time Object Tracking

The implementation of the proposed work or approach is carried out utilizing MATLAB. The fundamental block diagram (Fig. 45) for detecting and tracking objects using color feature and motion is shown below:

The fundamental block diagram comprises of four blocks named as Information Acquisition, Pre-processing, Feature Extraction and Tracking. The objectives or purpose of these blocks are as per the following:

Information Acquisition: Information Acquisition intends to acquire the video frames utilizing the image processing Toolbox. The frames are gained with the assistance of the camera exhibit in/on your framework.

Pre-processing: In pre-processing, first it changes the color picture into gray, on the grounds that it is not difficult to process the gray image in single shade rather than three shades. Gray images obliges less time in handling. At that point we apply median filter to expel clamor from images or frames got from the video. The images or frames analyzed out with the assistance of the command "medfilt2" show in the Image Processing Toolbox.

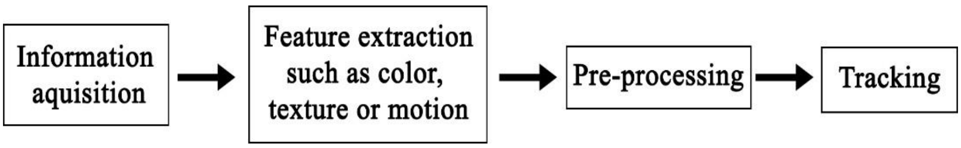


Fig. 45. Block diagram for object tracking

Feature Extraction: Selecting the correct feature plays the major part in tracking. The feature choice is nearly identified with the object representation. Different features needed for tracking are color, edges, optical flow, and surface or texture. In the proposed approach, we track the target object utilizing the color feature, particularly red, green and blue shade, in same way it is able to track the red, green and blue color objects in the video. After tracking the target object using color feature we are going to track object using motion. For motion detection and tracking we are using Frame difference technique and optical flow algorithm.

Tracking: Tracking of the target objects is carried out on the premise of the locale properties of the object, for example, Bounding box, Area, Centroid, and so forth. Here Bounding box property is utilized to track. Henceforth as the object moves distinctive areas in the video, the Bounding box additionally moves with it and hence diverse estimations of area properties are obtained. Hence the goal for tracking the objects in real-time using color feature and motion is achieved.

5.6. Validation of the Proposed Algorithm

The proposed algorithm for object detection and tracking using color feature is shown (Fig. 46) in the form of flowchart. The detail explanation of each block is given below the flowchart.

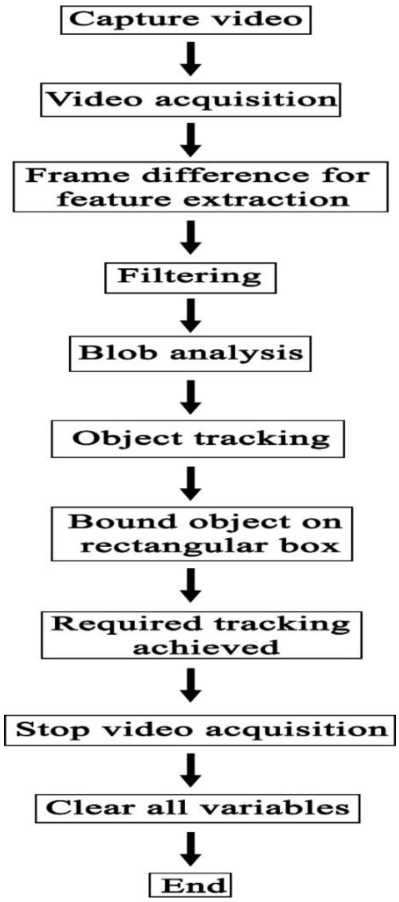


Fig. 46 Flowchart for object detection and tracking using color feature

The explanation of each block shown above is as follows:

1: Camera used for image processing or tracking the object capture the frames from video input using video acquisition function.

2: Specify the characteristics or property of video input.

3: Begin with video acquisition.

4: Create a loop that begins after 60 frames of acquisition.

This loop comprises of following steps:

a) Take the photo of the first frame from the video.

b) Presently to track the red objects continuously we need to subtract the red segment from the gray scale image to concentrate the red segments in the image.

c) Make use of median filter to remove noise.

d) Transform the gray scale image to binary image.

e) The pixels less the 300 pixels are eliminated.

f) Mark all the joined segments in the image to implement image blob analysis; here we get a set of properties for each one marked area.

g) Display the image.

h) A loop is used again to bound red color object in a rectangular formation.

5: Stop taking input from video camera.

6: Erase all data stored in memory.

7: Flush all variables.

The proposed algorithm for object detection and tracking using motion is shown (Fig. 47) in the form of flowchart. Motion detection and tracking can be done in three ways background subtraction, frame subtraction and through optical flow technique. We will be showing two ways one is through background subtraction and second is by optical flow technique.

The explanation of each block shown above is as follows:

1: Camera used for image processing or tracking the object, Captures the frames from video input using video acquisition function.

2: Specify the characteristics or property of video input.

3: Begin with video acquisition.

4: Separate the frames from video input.

5: After separating frames from the acquired video generate image sequence.

6: Perform background subtraction by subtracting background frame from current frame. In the event that the pixel difference is more than the set threshold T, then it confirms that the pixels occur in the moving object, otherwise, as the background pixels.

7: Image obtained after subtraction contains motion region and noise. Median filter is used to eliminate noise. Morphological technique is used for further processing. Vertical along with horizontal projection is utilized to detect the height of motion part.

8: After detection of moving object, object can be tracked using the area and centroid.

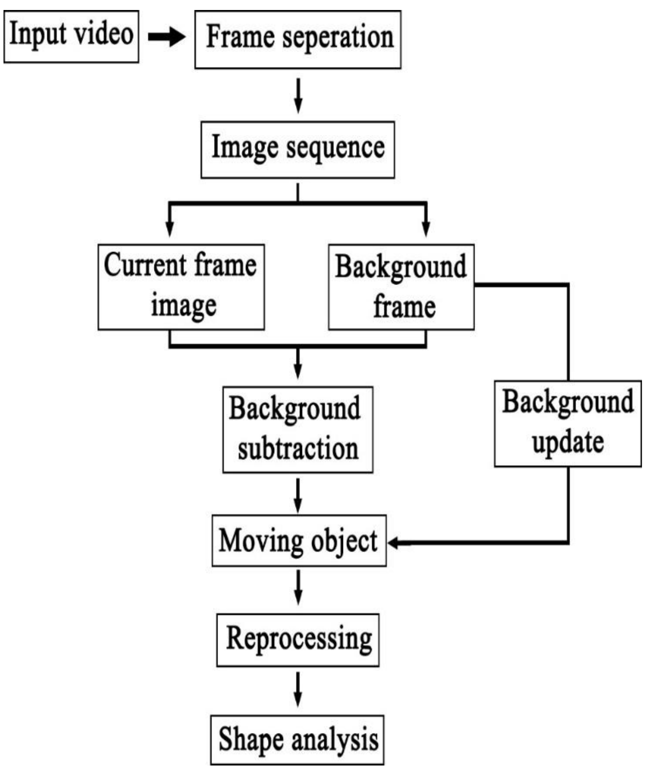


Fig. 47. Flowchart for object detection and tracking using background subtraction method

The algorithm for object detection and tracking using optical flow technique is shown in Fig. 48.

The explanation of each block shown above is as follows:

1: Make the Video Device framework object.

2: Make a framework object to calculate path and velocity of object movement from one video frame to another utilizing optical flow technique.

3: set up the vector field lines.

4: Make Video Player framework objects to show the videos.

5: Set up a processing loop to implement motion detection in the input video. This loop utilizes the framework objects you instantiated previously.

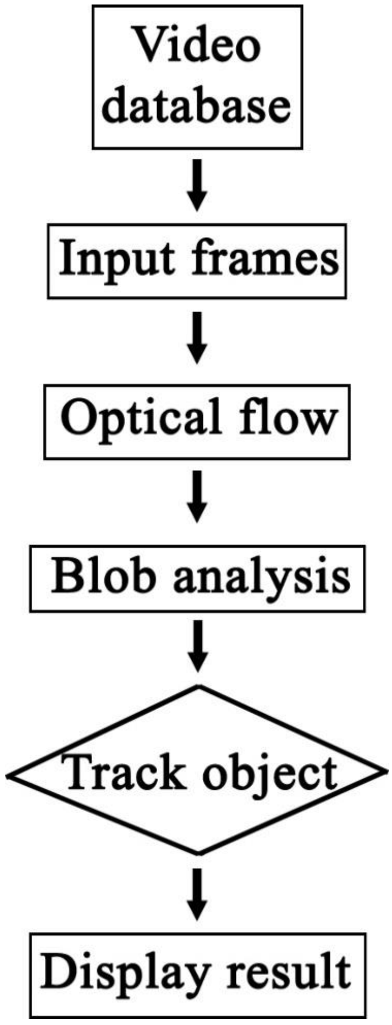


Fig. 48. Flowchart for object detection and tracking using optical flow method

This loop comprises of the following steps:

i) Build up for stream.

j) Process for first 200 frames.

k) Take a single image from imaging gadget or camera.

l) Process the optical flow for that specific frame.

m) Down sample optical flow field.

n) Create lines on the top of image.

6: Show video with movement vectors.

5.7. Summary

The algorithm has been developed for real-time object detection and tracking using color feature and motion. Tracking of the object is done on the basis of region properties such as centroid, bounding box etc. Here, motion detection and tracking is done using background subtraction and optical flow method.

Most of the time median filtering is used in image processing to remove noise during real-time object detection and tracking. Median filtering is far better the convolution technique when the aim to prevent edges and to eliminate noise.

CHAPTER 6

6. RESULTS AND CONCLUSION

6.1. Overview

This section describes the various results based on real-time object detection and tracking using Matlab software. It also comprises of various figures of UAV during its stable flight. The graph was also plot using Matlab for checking the relationship between static thrust vs rpm and dynamic thrust vs rpm.

6.2. Object tracking using color

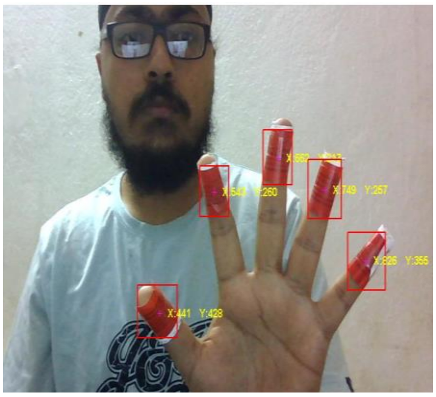


Fig. 49. Object tracking using red color

Fig. 50. Object tracking using RGB color

Fig. 49 shows the detection and tracking of red color object and also shows its centroid value in terms of x and y. Similarly, Fig. 50 shows the detection and tracking of red, blue and green color object. Detection and tracking of object was done by color feature and motion.

6.3. Object tracking using motion

Fig. 51. Object tracking using background subtraction

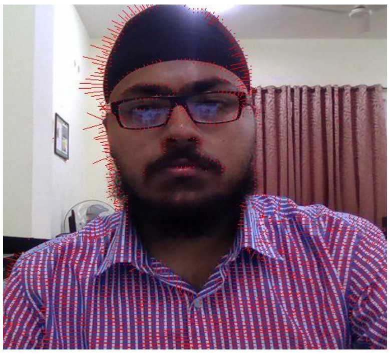


Fig. 52. Object tracking using optical flow

Two methods are implemented in this paper for object detection and tracking using motion. The first method is background subtraction as shown in Fig. 51. .The second method is optical flow technique as shown in Fig. 52.

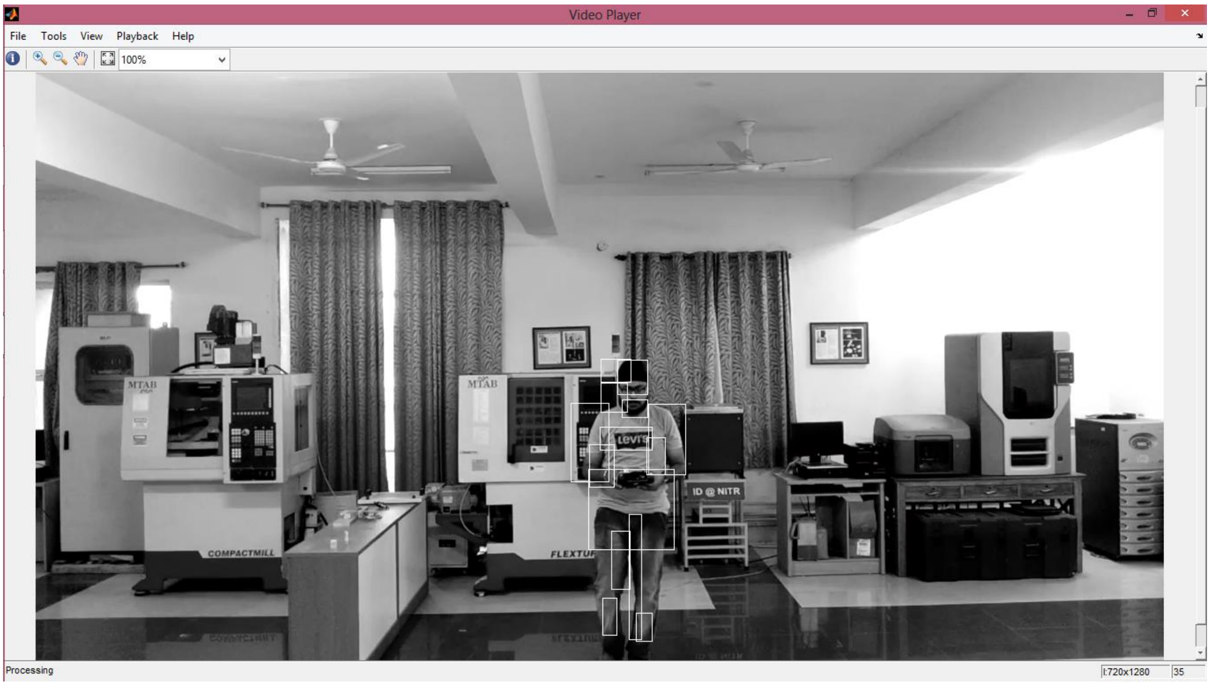


Fig. 53 (a). Object tracking using motion

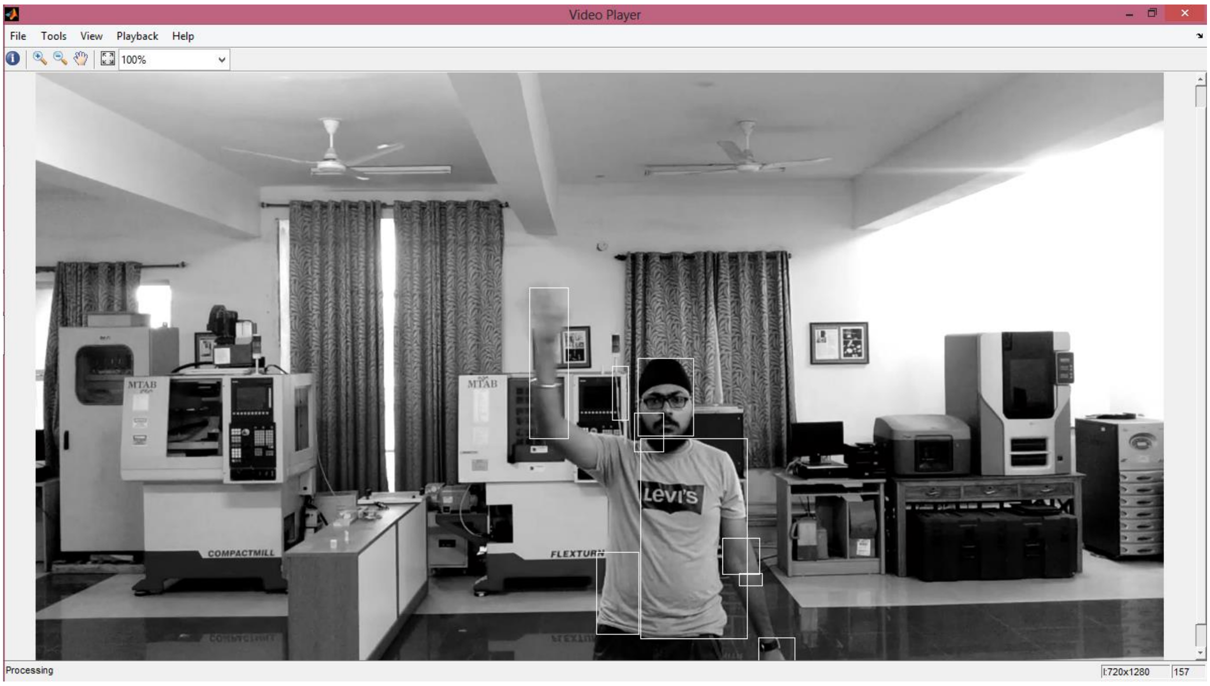


Fig. 53 (b). Object tracking using motion

Fig. 53 shows object detection and tracking of human motion using frame difference method.

6.4. UAV Flight control

Fig. 54. UAV stable flight

Fig. 54 shows the UAV (Quadcopter) stable flight, the experiment was performed to check the stability of quadcopter.

6.5. Tracking of UAV using GPS

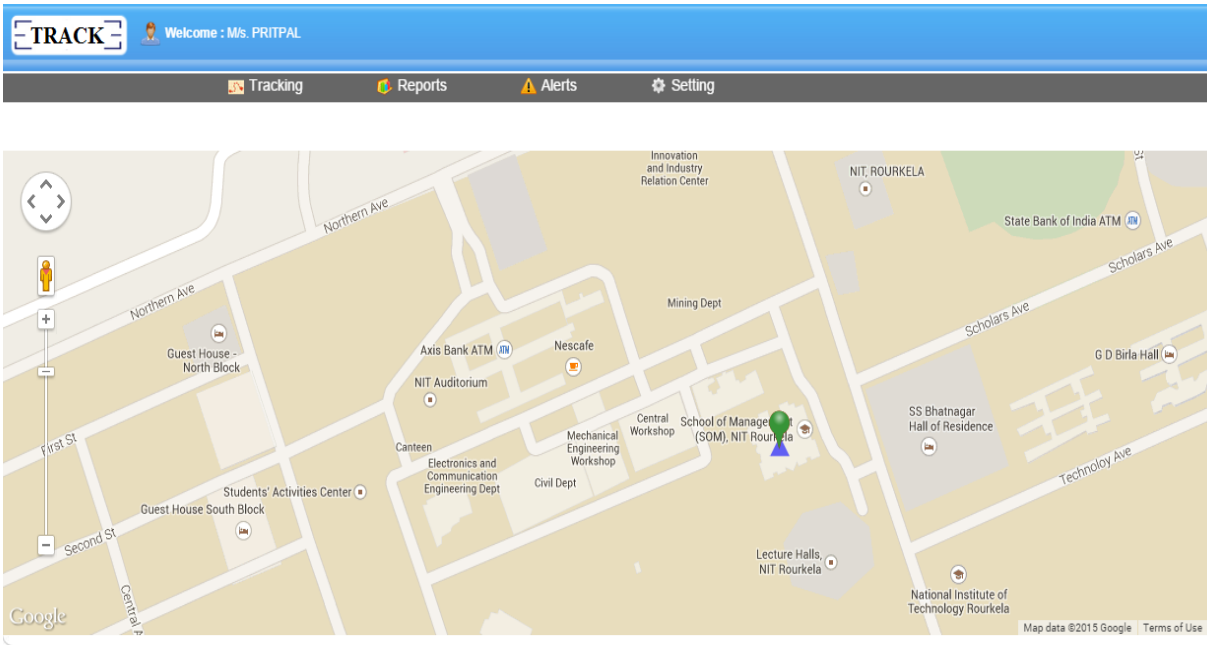


Fig. 55. Tracking using web application

Fig. 55 shows tracking of UAV (Quadcopter) using GPS receiver. One can see the location of UAV using google maps. Fig. 56 shows the offline tracking, the position information of the quadcopter is send to the operator mobile in the form of latitude, longitude and speed information.

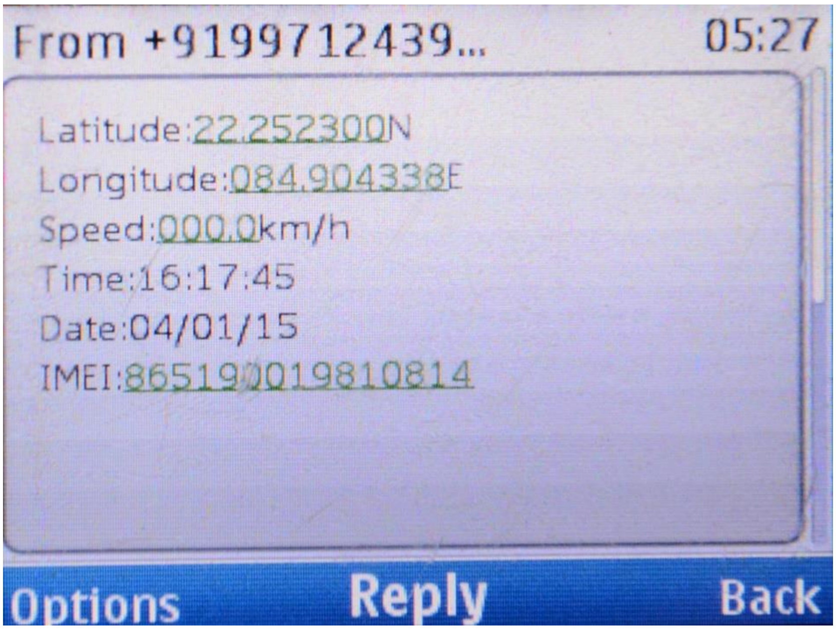
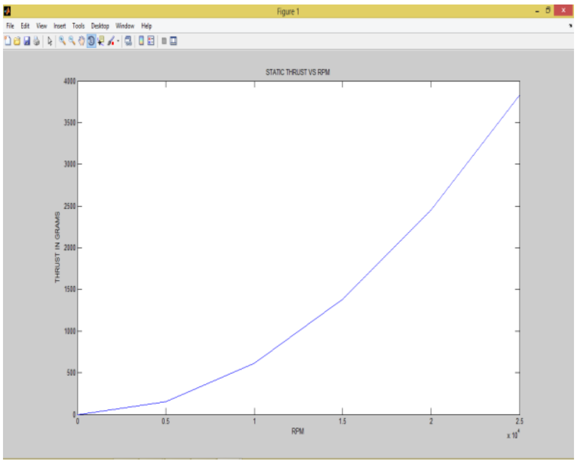


Fig. 56. Position information in the form of MSG

6.6. Thrust VS RPM



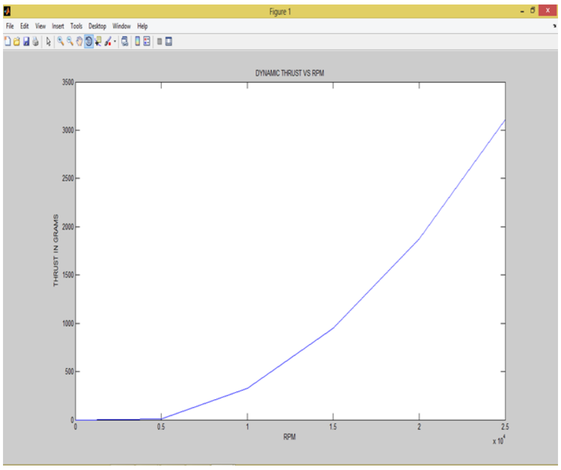


Fig. 57. Static thrust VS RPM

Fig. 58. Dynamic thrust VS RPM

The experiment was performed in Matlab to check the relationship between static thrust and RPM as shown in Fig. 57. Similarly, the relationship between dynamic thrust and RPM was found as shown in Fig. 58.

6.7. Conclusion

The unmanned aerial vehicle had been developed with real time tracking of human beings. The quadcopter has been developed for surveillance purpose that could be used in case of disasters like flood, earthquake etc. It has excellent stability during hovering position.

The algorithm has been developed for real-time object detection and tracking using color feature and motion. Tracking of the object was done on the basis of region properties such as centroid, bounding box etc. Here, motion detection and tracking was done using background subtraction and optical flow method.

Most of the time median filtering is used in image processing to remove noise during real-time object detection and tracking. Median filtering is far better the convolution technique when the aim to prevent edges and to eliminate noise.

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LIST OF PUBLICATIONS

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