Kinematics and Plane Decomposition Algorithm for Non Linear Path Planning Navigation and Tracking of Unmanned Aerial Vehicles

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Abstract. Online planned course of the flight and obstacle avoidance are the major issues of exploitation faced in the real time implementation of Unmanned Aerial Vehicles (UAVs). The main application that are used in the UAV are path planning navigation and tracking. Our project uses two algorithms to derive the navigation control laws. The algorithms such as kinematics based algorithm and plane decomposition algorithm. The control laws rely on the two factors namely, proportionality and derivation factors. These factors guide the UAV in reaching the goal in a nonlinear path successfully. The surveillance mode and obstacle avoidance mode are taken as the important consideration in our project. In the surveillance mode UAV reaches the goal in the three dimensional space with the aid of navigation laws. In obstacle avoidance function, the obstacles are avoided in the course of its path of the flight and attains the destination with the navigation laws' assistance. The kinematics rules leads to the successful application of tracking and navigation of UAV in nonlinear path planning.

Keywords: Unmanned Aerial Vehicles (UAV), Navigation laws, Kinematics laws, obstacle avoidance, path planning.
1 Introduction

Unmanned aerial vehicles (UAV) is a particular group of aircrafts which can fly in the absence of the pilots on the aircraft. Unmanned Aerial Vehicles more normally acknowledged by their acronym UAV are essentially mobile robots used in aerial environment. The name “Unmanned Aerial Vehicles” suggests that these robots are operated by preprogrammed algorithms and therefore require very little human help at some point of operation. Nowadays the use of small UAV vehicles have increased, so is the impulse of applying them as a medium for photography and filming is gradually increasing. Unmanned plane vehicles include sensor payloads, the aircraft aspect and ground control station. They are constrained through the means of onboard digital device or through manage gadget from the floor. When it is controlled distantly from floor, its miles are referred to as RPV (Remotely Piloted Vehicle), it mandatorily needs dependable wireless media to manage. Allocated manipulate systems may be used for the discussion of massive UAVs, and may be set up aboard vehicle or also in trailers to enable the nearby closeness to UAVs which are restricted via variety or conversation abilities. One place of hobby is the potential to apply those cars as a medium for filming unique UAVs which can be in aerial navigation. Woefully, one of the maximum troubling component of this particular system is the venture of visually pursuing an aim in the live circulation from the cameras installed. Nowadays, various commercialized entities use a cell phone as their medium to show the stay circulation which sums up to the venture of locating the favored goal inside the video encase. The algorithms are translated to a smart code that's able to direct the UAV dynamically to follow a given desired course to acquire a unique purposewithvariousstiersofcourseselectionasnicallyattainingtheobstacle.

The most common movements using UAVs involve in achieving a table bound purpose, achieving a moving the purpose or following a shifting purpose at steady distance. The most common strategies used for the motive encompass imaginative and prescient primarily based sensors, audible sensors, GPS navigation machine, GPS/INS integration and included sensor gadget amongst others. Each of those techniques constitute an answer particular to the undertaking assigned to the UAV in a selected state of affairs. The two cases mentioned on this undertaking are 1) UAV following a shifting purpose in a 3 dimensional space with the objective of attaining the purpose the use of the navigation law offered within the task. 2) UAV following a moving aim in a three dimensional space inside the presence of obstacles inside the direction. UAVs require estimation when navigating in both indoor and outdoor environments. The opportunity of crashing in that aerial environment is excessive, as spaces are constrained, with many moving boundaries. Another essential aspect discussed in this undertaking deals with the idea of plane decomposition wherein a three dimensional area is split into two dimensional planes for the motive of simplifying the procedure of flight direction navigation. The derivation of the navigation law as well as a complete terminology used there in is discussed in detail so as to explain the whole procedure of UAV navigation and flight course manage. The “Obstacle Avoidance Mode” for the UAV is mentioned in detail that allows you to explain the capacity of the UAV to manoeuvre across the limitations present inside the path and effectively attain the intention the usage of an alternate path with the aid of deviating toward waypoints. This is achieved successfully by modifying the navigation parameters (proportionality and deviation factors) in the dimensional planes. MATLAB is used as a tool of choice for programming the processes and simulating it.

1.1 LITERATURE SURVEY

A cost-efficient remedy for unmanned aerial vehicle voyage in a worldwide positioning system-refused environment proposed by Shahrukh Ashraf.et.al [1] used optical flow–based set of rules with Kalman filters to offer the voyage during worldwide positioning system interruptions and worldwide positioning system
environments in 10th July, 2017. This thesis proposes intelligent processes to offer the navigation potential during long GPS blackouts and through GPS-refused environments employing optical flow and inertial sensors. A Modern Approach to an Unmanned Vehicle Navigation by Artur Janowski et al.[2] proposed, developed and tested methods for image data acquired by a single non-metric digital camera placed on mini UAV in 2016. The paper offers the approach of solving a UAV position, primarily based only on photograph statistics, as well as technique of UAV navigation supported via evolved approach and the main benefits and limitations. The method is based on photogrammetric and a modern computer vision process. An Algorithm for Autonomous Aerial Navigation Using MATLAB Mapping Tool Box by Mansoor Ahsan et al. [3] proposed aircraft elevation and leading controllers and an coherent set of rules for self-governing navigation by employing mat lab over specified areas in June 2012.

The linear administrators are assessed on non-linear aircraft model and navigation function is evolved for autonomous flight of UAV. Tracing of Compact Unmanned Aerial Vehicles by Steven Krukowski Aeronautics and Astronautics Stanford University, Stanford in 2012. In this dissertation, a photo processing subroutine is used in visually stalking compact UAVs. Matthew B. Rhudy [4] proposed Unmanned Aerial Vehicle Navigation Using Wide-Field Optical Flow and Inertial Sensors in 16th Jan, 2015. In this paper, a full state construction including velocity and attitude is capable enough to approximate the aircraft ground velocity to within 1.3 m/s of a GPS recipient remedy and a disentangled construction which presumes that the slanting and vertical velocity of the aircraft are trivial and capable in managing the attitude angles within 1.4 degrees standard divergence of error for twain arrays of flight report. Alexander Cerón [5] preferred the project Vision-Based Path Finding Strategy of Unmanned Aerial Vehicles for Electrical Infrastructure Purpose in 27th Sep, 2018. Here, the scrutiny is carried out by employing images encapsulated with a unmanned aerial vehicle.

The observing of power lines can be undertaken by making use of submissive sensors like cameras or active sensors namely, light detection and ranging (LIDAR) cameras, image processing techniques, and computer vision and in addition, control systems can also be availed. Hamid Teimoori Sangani [6] made a thesis on Topics In Navigation And Guidance Of Wheeled Robots in 13th July, 2009. The main theme of this thesis is to resolve the difficulty of real-time navigation and keeping track of Wheeled Mobile Robots (WMR) towards a target using range-only measurements. Christoforos Kanellakis George Nikolakopoulos [7] Survey on Computer Vision for UAVs: Current Developments and Trends 28th April, 2016. Unmanned Aerial Vehicle was proposed by Luis Ramos [8] in 21st Nov, 2013. The main objective of the project is to create and operate UAV for target reconnaissance, navigation, taking off and landing operations. Modelling and Control of MM-UAV: Mobile Manipulating Unmanned Aerial Vehicles by Matko Orsag [9] in 2013. This paper, however, explores the fundamental challenges in administrating a mobile manipulating UAV via a commercially accessible aircraft and a light-weight prototype 3-arm manipulator. Evaluating the accuracy of vehicle tracing details acquired from Unmanned Aerial Vehicles by Giuseppe Guido [10] in Oct, 2016. A video rectification system for vehicles trajectory accession is instigated. The procedure is based on OpenCV libraries.

Yuanwei Wu [11] proposed Vision-based Real-Time Aerial Object Localization and Tracking for UAV Sensing System in 19th Mar, 2017. The propounded nudge does not need any physical or labouring commencement for tracing and also succeeds chasing execution on a great number of image concatenations. Kalyani Chopade [12] proposed A Survey: Unmanned Aerial Vehicle for Road Detection and Tracking in Nov, 2015. This is for improving the performance of transportation systems. P. Om Prakasp [13] submitted a work on Navigation of Unmanned Aerial Vehicles in GPS Denied Region Using Vision Based Obstacle Detection in 2017. Here Sobels edge detection algorithm is used to discover
the dimension of the barrier of the specific encase of the video. Jay P. Wilhelm [14] published a paper on Vector Field UAV Guidance for Path Following an Obstacle Avoidance with Minimal Deviation in Aug, 2019. Ruiyong Zhai [15] submitted a paper Control and navigation system for a fixed-wing unmanned aerial vehicle in Nov, 2013. The entity is devised based on the inner loop and outer loop tactic. Wang et al. [16] proposed the article Vision-Aided Inertial Navigation for compact Unmanned Aerial Vehicles in GPS-Denied Environments in 10th Aug, 2012. This practice hypothesize that the approximate error state is consistent and unchangeable during and the second half of one visual calculation phase.

2 EXISTING METHOD

2.1 Types of sensors in UAV navigation

The navigation law helps in planning the course of the UAV successfully so that it attains the preferred mobilising target. The numerous modes availed for aerial trailing and navigation can be sorted extensively into classes of: 1) Sensor based totally navigation method and 2) Model based totally navigation approaches. Numerous sensors are typically utilized for the cause of UAV path drafting and navigation. The typically utilized kinds of sensors consist of vision based, inertial and sonar sensors. This chapter sheds light on a number of the most commonly used techniques for UAV course planning and navigation which include imaginative and prescient based sensors, inertial sensors, included sensor systems, hierarchical control and feedback linearization.

2.1.1 Vision sensors for UAV navigation

The UAV causes an easy trouble of horizon detection that suggests a simple instance that shows the capability of imaginative and prescient primarily based sensors. The UAV is used to differentiate among the ground and the horizon the use of visible sensors. Even though this project sounds easy, it employs surprisingly superior strategies along with rudimentary picture segmentation, real-time optimization, standard multilevel altering and comments stabilization. The information of manage idea based totally concepts used in figuring out the characteristic of vision sensors are beyond the scope of this assignment, the instance serves the purpose of illustrating the advantages of imaginative and prescient based sensors utilized in UAV path making plans and navigation.

2.1.2 Inertial sensors for UAV navigation

Inertial Navigation Systems (INS) is the maximum not unusual styles of inertial sensors utilized in aerial navigation. Comparing the welfare of inertial sensors with different sensors, these sensors have a tendency to perform uniquely on the presence of outside factors which include wind course, wind pressure, interference and many others. A common place shape of INS utilized in UAVs is described within the following determine:
Figure 1 – Outline of an Inertial Navigation System used in UAV

As shown in the Figure 1, the INS unit is made up of normally to be had bodily additives together with quad rotors, accelerometers, gyroscopes and microcontrollers. The INS is attached to the primary processor, which gives the main processor with sensing records. However, the main disadvantage of Inertial Sensors or INS/IMU is that the placement mistakes obtained for the duration of UAV tracking compound through the years which yields faulty outcomes.

2.1.3 Integrated sensor systems for UAV navigation

In order to recoup for some of the varied misconceptions experienced by a single sort of sensors engaged in UAV navigation, dissimilar types of sensors are combined or else coalesced into a single entity to produce optimal outcomes. Several types of coalescence prevail between dissimilar types of sensors like vision/acoustic and vision/inertial.

2.1.4 Hierarchical methods for UAV navigation

One of the most common model-based approaches used for UAV navigation is the hierarchical control method in which a control system using a hierarchical organizational structure is used for path planning. A simple hierarchical control system structure is displayed in the Figure 2:
The hierarchical architecture that integrates the Ground Control Unit (GCU) along with the onboard software which involve in UAV path planning and navigation. In the above figure both blocks are linked via a human operator. In onboard software many operations such as actual path control and navigation, path estimation, collision detection and avoidance are integrated which are helpful in navigation process. Using this architecture both optimal path planning and navigation solution for UAV is employed.
2.1.5 Feedback linearization for UAV navigation

Feedback linearization is a common approach used in controlling nonlinear system. In addressing the UAV environment a nonlinear dynamic motion employed the concept of dual controller. For example, feedback linearization is applied within an inner controller and also with linear outer controller to achieve robust navigation capabilities. Linearity is not invariant under nonlinear state feedback. Therefore, it may be possible to convert nonlinear system into linear system under this transformation. This is called feedback linearization. Adaptive feedback linearization is used for altering the incorrect estimation of the non-linearity. This utilizes lyapunov stability criteria and produces a parameter update rule that treats with time for the stability of the system.

This chapter gives a brief overview of some of the most commonly used methods for navigation and tracking for Unmanned Aerial Vehicles. Modes of UAV navigation using vision sensors, inertial sensors, integrated sensor systems, hierarchical control and feedback linearization are discussed with proper examples.

3 PROPOSED METHODS

Project uses navigation law based on the kinematics system. This law allows to successfully reach the desired goal. The kinematics based rule are very advantageous compared with other type of sensors and it also very reliable for the online path planning of the UAV. To achieve the trajectory control of the UAV we used navigation criteria such as proportionality and deviation factors. This is one of the major advantages of these laws.

3.1 Definitions and kinematics modeling of UAV motion

The movement of a UAV mobilising in a three dimensional space ((x,y,z) Cartesian co-ordinate system) can be delineated with the aid of the upcoming diagram:

![Figure 3 – Delineation of UAV motion in 3 dimensional space](image)

The terms appearing in the figure can be defined as:

The velocity \( \mathbf{v}_r \) of the robot in the 3 dimensional spaces.
The Euclidean distance $r_r$ from the origin to the robot in the 3 dimensional space.
The projection $\rho_r$ in the $(x,y)$ plane.
The commensurating $x_r$ $x$ co-ordinate indicating the $x$ position of the robot at any given time in the 3 dimensional spaces.
The commensurating $y_r$ $y$ co-ordinate indicating the $y$ position of the robot at any given time in the 3 dimensional spaces.
The commensurating $z_r$ $z$ co-ordinate indicating the $z$ position of the robot at any given time in the 3 dimensional spaces.

3.2 Definitions of the flight path, heading and line of sight angles

Figure 4 – Representation of the flight path angle, the heading angle and the line of sight Angles

$\phi_r$: flight path angle (angle steering the motion of the robot in vertical direction)
$\psi_r$: heading angle (angle steering the motion of the robot in horizontal direction)
$\sigma_1, \sigma_2$: line of sight angles of the robot with respect to origin.

3.3 Plane decomposition method

In order to simplify the mathematical derivations, the 3 dimensional space is converted into 2 dimensional space: the $(x,y)$ plane and $(x,z)$ plane. The plane decomposition process can be explained using the following figures:
The co-ordinates of the robot at any point in space can be defined by the following equations:

Co-ordinates in (x,y) plane: \( x_r = \rho_r \cos(\sigma_2) \) , \( y_r = \rho_r \sin(\sigma_2) \)

Co-ordinates in (r,z) plane: \( r_r = \rho_r \cos(\sigma_1) \) , \( z_r = \rho_r \sin(\sigma_1) \)

### 3.4 Line of sight angles in the (x,y) and (r,z) planes

The planes have been defined by decomposing the 3 dimensional space, we expound the line of sight angles for the respective planes. Let \( L \) be the line of sight and the direction of vector \( L \) is towards the goal from the robot. The projection of vector \( L \) in the (x,y) plane is denoted by \( L_{xy} \). The co-ordinates of the robot and the goal are defined as \( (x_r, y_r, z_r) \) and \( (x_g, y_g, z_g) \) respectively. Taking into consideration the coordinates of the robot and the goal, the line of sight angles in the respective planes can be defined as:

- \( \tan \sigma_{xy} = \frac{y_g - y_r}{x_g - x_r} \) where \( y_g = y_g - y_r \) and \( x_g = x_g - x_r \)

- \( \tan \sigma_{rz} = \frac{z_g - z_r}{r_g} \) where \( z_g = z_g - z_r \) and \( r_g = \sqrt{(x_g - x_r)^2 + (y_g - y_r)^2} \)

The above equations are valid for the case of moving a goal. In our assumed case, the goal isn’t moving therefore the coordinates of the goal will remain the same; however, the line of sight angles vary with time.

### 3.5 Kinematics equations and dynamic constraints

The kinematics equations defining the motion of the moving robot in a 3 dimensional space can be deduced based on the values of the various parameters discussed above. The kinematics equations of motion can be modelled as follows:

\[
\begin{align*}
\dot{x}_r &= \nu_r \cos(\varphi_r) \cos(\psi_r) \\
\dot{y}_r &= \nu_r \cos(\varphi_r) \sin(\psi_r) \\
\dot{z}_r &= \nu_r \sin(\varphi_r)
\end{align*}
\]

Where, \( \dot{x}_r \) , \( \dot{y}_r \) and \( \dot{z}_r \) are the velocity components defining the motion of robot in the 3 dimensional space. \( \nu_r \) is the velocity of the robot.

\( \varphi_r \) is the flight path angle (angle denoting motion in vertical plane)

\( \psi_r \) is the heading angle (angle denoting motion in horizontal plane).

For the sake of the simplicity, the quantity \( \nu_r \cos(\varphi_r) \) can be denoted as \( \nu_1 \), resulting in the following kinematics equations in the (x,y) plane:

\[
\begin{align*}
\dot{x}_r &= \nu_1 \cos(\psi_r) \\
\dot{y}_r &= \nu_1 \sin(\psi_r)
\end{align*}
\]
### 3.6 Obstacle Avoidance

This thesis ought to be victorious when the robot mobilizes towards a motionless or a target in motion and gradually attains it without experiencing any barriers in the path and traverse in a nonlinear path. Any obstacle in the path of the robot is treated as a sphere. As discussed earlier, the method of plane decomposition is used we use projections of the spherical obstacle in the 2 dimensional planes. The graphical representation of obstacles in both horizontal and vertical planes is as shown below:

![Obstacles in the (x,y) and (r,z) planes](image)

Figure 7 – Obstacles in the (x,y) and (r,z) planes

Figure 7 (a) and (b) depicts the obstacles in the (x,y) and (r,z) planes, respectively. In the (x,y) horizontal plane the velocity of the robot is defined by \( \upsilon_1 = \upsilon_r \cos(\phi_r) \). The angle formed by the robot with the (x,y) plane is as we know. The projection of the spherical obstacle on the horizontal plane is denoted by a circle named \( \text{Ob}_{xy} \) as shown in figure 8 (a). Now, the robot is moving towards the obstacle. At any given point in time (let us assume at time \( t_1 \)), the robot encounters an obstacle within its line of sight. Let us say that at time \( t_1 \), the robot (assumed as a point) forms a cone with the circular obstacle in 2 dimensional (x,y) plane as shows in figure 8 (a). The angle formed by this cone is denoted by the term \( \epsilon_1 \). \( A_{xy} \) and \( B_{xy} \) are the waypoints in (x,y) plane where the robot deviates to avoid collision against the obstacles. The divergence in the horizontal (x,y) plane is referred to as “Zero slope deviation”.

Similarly, in the vertical (r,z) plane the velocity of the robot is denoted by \( \upsilon_r \). The angle formed by the robot with the (r,z) plane is \( \phi_r \). The angle formed by the collision cone in the (r,z) plane is denoted by \( \epsilon_2 \). The projection of the obstacle in the vertical plane is denoted by \( \text{Ob}_{rz} \). The waypoints in the vertical plane are denoted by \( A_{rz} \) and \( B_{rz} \). The divergence of the robot towards the waypoints in the vertical plane(r,z) is called “infinite slope deviation”.

### 3.7 Zero deviation and infinite slope deviation

The desired heading angle’s new value can be given by the equation:

\[
\Psi_{r,\text{des}} = N_1\text{new} \cdot \sigma_{xy,p} + c_1\text{new}
\]

Where,

\[
\Psi_{r,\text{des}} = \text{Desired value of heading angle to avoid collision \( N_1\text{new} = \text{New value of proportionality factor} \) \( N_1 \) for (x,y) plane \( c_1\text{new} = \text{New value of deviation factor} \) \( c_1 \) for (x,y) plane}
\]

\[
\sigma_{xy,p} = \text{Line of sight angle for waypoint in (x,y) plane}
\]
Also, the new value of the desired flight path angle can be given by the equation:

\[ \phi_{r_{\text{des}}} = N_2\text{new} \sigma_{r_z_p} + c_2\text{new} \]

Where,

- \( \phi_{r_{\text{des}}} \) = Desired value of flight path angle to avoid collision
- \( N_2\text{new} \) = New value of proportionality factor \( N_2 \) for \((r,z)\) plane
- \( c_2\text{new} \) = New value of deviation factor \( c_2 \) for \((r,z)\) plane
- \( \sigma_{r_z_p} \) = Line of sight angle for waypoint in \((r,z)\) plane.

### 3.8 Derivation parameters for Obstacle avoidance

For successfully achieving obstacle avoidance and maintaining a smooth trajectory, the values of the flight path and the heading angles at time \( t_1 \) should advance smoothly to the desired values \( \psi_{r_{\text{des}}} \) and \( \phi_{r_{\text{des}}} \). This can be expressed by the following equations:

\[ \begin{align*}
\psi_{r_{t1}} &= N_1\text{new}_p (t_1) + c_1\text{new} + b_1
\phi_{r_{t1}} &= \sigma_{r_z_p} (t_1) + c_2\text{new} + b_2
\end{align*} \]

The algorithm for obstacle avoidance can be developed by taking the values of \( N_1\text{new} \) and \( N_2\text{new} \) as 1.

### 3.9 Examples of obstacle avoidance

#### Zero slope deviation:

This deviation is achieved in the horizontal \((x,y)\) plane by deviating to either left or right of the obstacle. The proportionality factor \( N_1 \) and deviation factor \( c_1 \) are changed for navigation process. The zero slope deviation can be attained by deviating towards the waypoints \( A_{xy} \) or \( B_{xy} \) in the horizontal plane. The condition for collision avoidance in the horizontal plane is that the heading angle \( \psi_r \) should not lie in the interval \([\sigma_{xy} - (\epsilon_1)/2, \sigma_{xy} + (\epsilon_1)/2]\), where \( \sigma_{xy} \) is the line of sight angle in the horizontal plane and \( \epsilon_1 \) is the collision cone width angle in the horizontal plane. Zero slope deviation can be displayed graphically in the Figure 8:

![Figure 8 In horizontal plane (a) without deviation (b) with zero slope deviation](image)

#### Infinite slope deviation:

This divergence is achieved in the vertical \((r,z)\) plane by deviating to either upward or downward of the
obstacle. The proportionality factor $N_2$ and deviation factor $c_2$ are changed for navigation process.

![Figure 9 In vertical plane (a) without deviation (b) with infinite slope deviation](image)

The zero slope deviation can be attained by deviating towards the waypoints $Arz$ or $Brz$ in the vertical plane. The condition for collision avoidance in the vertical plane is that the flight path angle $\phi_r$ should not lie in the interval $[\sigma_{rz}(\pm c_2)/2, \sigma_{rz}(\pm c_2)/2]$, where $\sigma_{rz}$ is the line of sight angle in the vertical plane and $c_2$ is the collision cone width angle in the vertical plane. Infinite slope deviation can be displayed graphically in the Figure 9:

4 RESULTS FOR SUVEILLANCE AND OBSTACLE AVOIDANCE MODE

4.1 Simulation results for surveillance mode

The starting point of the aim is given (10, 5, 3) and for the robot is given as (12, 6, 3). The robot pace is always significant than the target pace.

![Figure 10 – The starting point of the robot (red dot) and the aim (green dot) at time t=0 in3 dimensional space](image)

![Figure 11 – Initial point of robot (red star) and the aim (green star located on extreme left bottom) in the horizontal (x,y) plane at time t=0](image)
Figure 12 – Starting point of the robot (red star) and the aim (not visible at time t=0 due to the constraints provided) in the vertical (r,z) plane at time t=0.

Figure 13 – The position of the robot and the aim after 5 steps in the 3 dimensional space (we can see that the robot is gradually approaching the target).

Figure 14 – The position of the robot and the target after 5 steps in the horizontal (x,y) plane.

Figure 15 - The position of the robot (red star) and the aim (green star) after 5 steps in the vertical (r,z) plane.

Figure 16- The position of the robot and the target after 15 steps in the 3 dimensional space (we can see that the robot has now reached the target).

Figure 17 – The position of the robot (red star) and the target (green star) after 15 steps in the horizontal (x,y) plane.
Figure 18 - The position of the robot (red star) and the target (green star) after 15 steps in the vertical (r,z) plane.

Figure 19 - The position of the robot and the target after 35 steps in the 3 dimensional space (we can see that the robot has once reached the target, bypassed it and is reached it again).

Figure 20 – The position of the robot (red star) and the target (green star) after 35 steps in the horizontal (x,y) plane.

Figure 21 – The position of the robot (red star) and the target (green star) after 35 steps in the vertical (r,z) plane.
4.2 Simulation results for obstacle avoidance mode

It is assumed that the robot deviates in the horizontal plane only towards a waypoint A. The values assumed for input variables are $c_1 = \frac{\pi}{4}$, $x_{g0} = 13$, $x_0 = 3$, $y_{g0} = 7$, $y_0 = 5$, $z_{g0} = 4$, $z_0 = 4$, $x_a = 3$, $y_a = 4$.

Figure 22 - The starting point of the robot (red dot) and the aim (green dot) at $t=0$ in the 3 dimensional space

Figure 23 - The starting point of the robot (red star) and the aim (green star located at top right corner) at time $t=0$ in the horizontal ($x,y$) plane

Figure 24 - The starting point of the robot (red star) and aim at time $t=0$ in the vertical ($r,z$) plane

Figure 25 - The position of the robot and the aim after 15 steps in the 3 dimensional Space (we can see that the robot is advancing towards the moving target)
Figure 26 – The position of the robot and the aim after 15 steps in the horizontal (x,y) plane

Figure 27- The position of the robot (red star) and the aim (green star) after 15 steps in the vertical (r,z) plane

Figure 28 - The position of the robot and the aim after 50 steps in the 3 dimensional space (we can clearly see that the robot has deviated from its original course and is approaching the target gradually by following the alternate path)

Figure 29 – The position of the robot (red star) and the aim (green star) after 50 steps in the horizontal (x,y) plane
5 CONCLUSION

Project uses kinematics based algorithms for planning the path and navigation for Unmanned Aerial Vehicles. Kinematics derivations are elucidated considering the movement of a UAV and the units entailed in those equations are obtained and recounted. The plane decomposition practice is used to lessen the difficulty in planning the path in a 3D space by transforming it into 2D space. Both course of the flight or flight path angles and heading angle of the robot being ascertained by the line of sight angles. The Control laws are being obtained for the flight path and heading angles, this encompasses the navigation specifications such as proportionality and deviation factors. These navigation criteria are availed with differing degrees to reach the adequate trajectory control, incorporating path smoothness and obstacle avoidance. The obstacle avoidance means comprises the collision cone method. The notion of waypoints towards which the robot drifts in a variant path is also noted. Also the dynamic curbs hindering the movement of the robot and the aim in the 3D space are also contemplated. Finally, MATLAB code is availed for the simulation in two places: 1) Surveillance mode 2) Obstacle avoidance mode. Simulation shows the beneficiary effects of the above stated methods. Kinematics based algorithm is a high level control algorithm and it is very effectual than other algorithms like (k-means, kalman filter) and it is helpful in many military applications, weather forecasting, aerial photography by using surveillance mode.

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