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Motion Planning of an Aircraft through Adverse Weather Conditions

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***Abstract*: Motion Planning is an effective way to determine the path of a vehicle and in this case, an aircraft. The objective here is to determine a safe passage for an aircraft when any adverse weather condition like storms or intense lighting lies ahead in the aircraft's flight path. With the help of Voronoi diagram and Dijkstra's Algorithm, the effective way points needed for aircraft navigation lying outside the area of disturbance is determined and the orientation of the way points with respect to the aircraft is determined as Euler's angles and those are fed to the designed flight control system. The flight control system is designed to navigate the aircraft out of the region. The whole system architecture is compact and depends on the control flow order.**

***Keywords*: Aircraft Flight Control system, Voronoi diagram.**

1. Introduction

An aircraft flight control system, controls the flight operations of an aircraft, maintaining its course by varying the flight parameters like altitude, velocity, control surface like rudder, elevator and aileron deflections. From the input to the output the whole system follows a specific order which can be depicted as System Architecture. The whole system follows a very simple architecture as shown in the Fig.1. The control works in an ordered fashion, first taking the input from the outside world using the GPS. The Voronoi Diagram and Dijkstra's Algorithm then works on the output from the GPS to determine the optimal path out of the area of conflict.

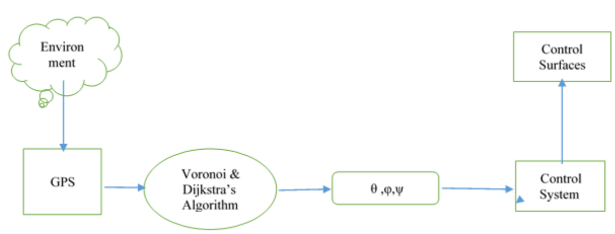

Fig. 1. System architecture

The required angle of roll, pitch and yaw are then fed to the aircraft flight control system which operates the control surfaces like the rudder, elevator and ailerons to deviate the aircraft from the path.

2. Path Planning

To determine the path out of the storm or bad weather region along the flight path of the aircraft at first the GPS data has to be collected. The Voronoi diagram and Dijsktra's Algorithm are used to determine the optimal flight path. A flight path is divided into a number of waypoints and the aircraft has to travel through those way point. What the Voronoi diagram does is to connect those way points to create the optimal path out of the adverse weather region. Voronoi divides the area of interest obtained from the GPS into number of regions and obtained different other way points nearer to the original waypoints while keeping them out of the area of adverse weather conditions. It then develops a number of coordinated V_x, V_y which contain all the desired waypoints. Both V_x, V_y can be arranged in matrix format.

$$. V_x = \begin{bmatrix} x_1^1 & x_1^2 \cdots x_1^n \\ x_2^1 & x_2^2 \cdots x_2^n \end{bmatrix}$$

$$V_y = \begin{bmatrix} y_1^1 & y_1^2 \cdots y_1^n \\ y_2^1 & y_2^2 \cdots y_2^n \end{bmatrix}$$

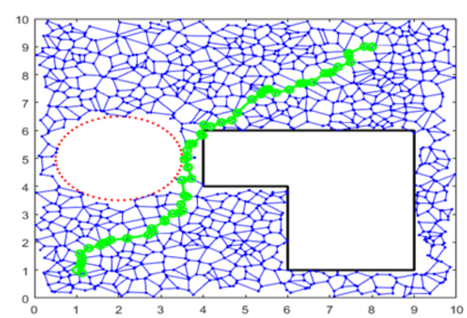

Fig. 2. Voronoi diagram

The superscript denotes the edge number and the subscript the end points of the edge. All these points are to be connected with each other to form the edges. The length between the edges is given by L which is a $n * n$ matrix. Fig 2 represents the Voronoi diagram.

$$L = \begin{bmatrix} L_{11}L_{21}L_{31} \dots L_{\eta_1} \\ L_{12}L_{22}L_{32} \dots L_{\eta_2} \\ L_1nL_{2n}L_{3n} \dots Lnn \end{bmatrix}$$

The element L_{ij} signifies the length between the nodes i and

j. It is to be noted that $L_{ij} = L_{ji}$ and $L_{ii} = L_{jj} = 0$. All the diagonal element will be zero. Once the nodes and edges are drawn the optimal distance and the required flight path can be determined. The edges and nodes falling inside the area of adverse weather are to be eliminated and the nodes, edges outside the area of conflict should be taken into account. This optimal path is to be decided by Dijkstra's algorithm. The figure below has a representation of the nodes and edges determined by the Voronoi diagram. Let us assume that the aircraft has to travel from node 1 to node 4 avoiding the areas under node 5,6,7,8. The two only possible ways are through node 1 2 3 4 and nodes 1 3 4. Out of this using Dijkstra's Algorithm the shortest will be selected. The structure is depicted in Fig. 3.

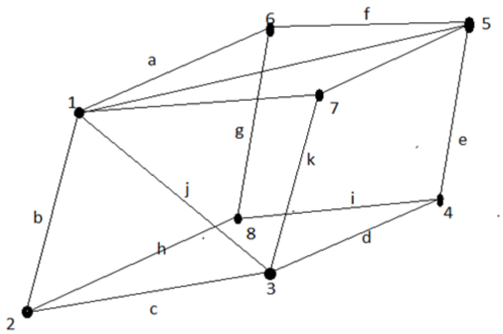

Fig. 3. Nodes and Edges from Dijkstra's Algorithm

3. Aircraft Flight Control System

The flight control system can be described in a top to down fashion starting with the outer structure. The inner loop contains four proportional integral (PI) controllers for pitch rate(q), pitch angle(θ), yaw angle(φ), roll angle(ψ). These PI controllers are connected to a subsystem are connected to Non- Linear Actuators, which are in turn connected to a subsystem as shown in Fig. 4 along with the outer loop.

A. Subsystem Block

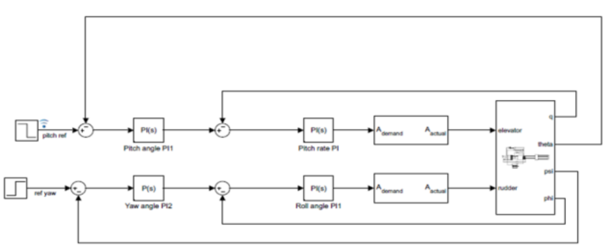

Fig. 4. Outer Structure

The subsystem of the flight control system mainly contains the aerodynamic block, a six degrees of freedom (6-DOF) block and a Euler Angles block. The whole layout of the Subsystem block is shown in Fig. 5. The inputs of the subsystem blocks come from the outer structure as the elevator and rudder deflection, rate of pitch (q). The Euler angle block essentially converts the Euler angles from radians to degrees, with the output roll(ψ), pitch(θ) and yaw(φ) angles in degrees. These roll, pitch and yaw angles along with the pitch rate (q) forms the outer loop of the outer structure. The Euler Angle Block is shown in Fig. 6.

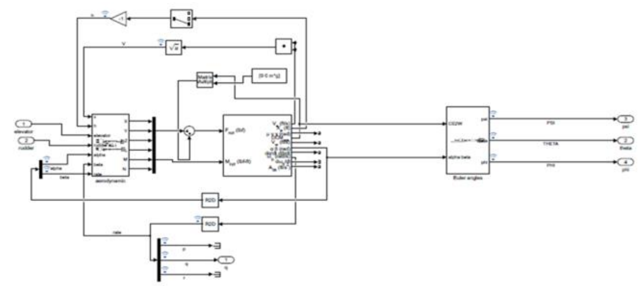

Fig. 5. Subsystem Block

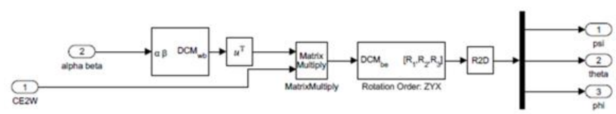

Fig. 6. Euler Angles Block

B. Aerodynamics Block

The aerodynamics block consists of the aerodynamic data for the aircraft. It has three blocks; a Longitudinal Control, Lateral Control and an Atmospheric model. The aerodynamic block is represented in Fig. 7. The inputs of the aerodynamic blocks are the angles alpha, elevator deflection, pitch rate and velocity of the aircraft for the Longitudinal Control; beta, rudder, yaw rate, velocity for the Lateral Control. The atmospheric model used is a COESA model whose input is only the altitude (h) in order to get the atmospheric properties. The outputs of this Aerodynamic Block are the Lift (L), Moments(M), Yaw force (N) and forces along ZYX axes (Z, Y, X).

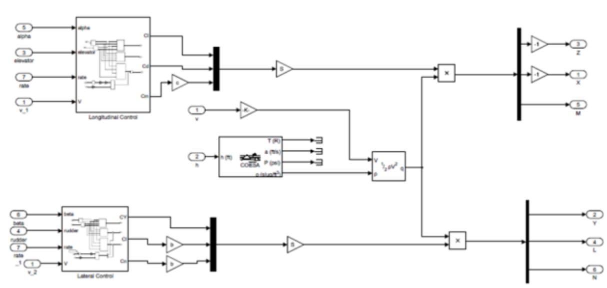

Fig. 7. Aerodynamics Block

C. Longitudinal and Lateral Control

The longitudinal control essential uses three pre-lookup blocks which are aircraft specific to obtain the different aerodynamic coefficients. The inputs of the longitudinal block are the alpha, elevator properties, pitch rate and velocity of the aircraft. The wing span(S) and the chord(C) length are also aircraft specific. All these parameters can be used to determine the coefficient of lift (C_L), coefficient of drag (C_D), coefficient of moment (C_M). The Fig. 8 represents the Longitudinal block.

Similarly, the Lateral block also follows a same architecture as the Longitudinal control. It follows a three pre-lookup tables structure to determine the coefficient of lift (C_L), coefficient of drift (C_Y), coefficient of yaw (C_N) from the input parameters of beta, rudder properties, pitch rate and velocity. The Fig. 9 represents the Lateral Control Block.

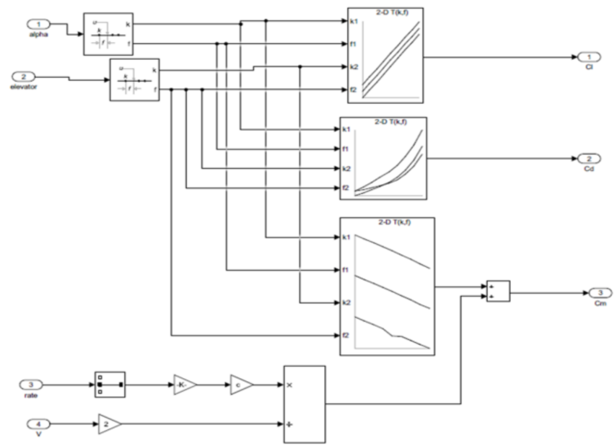

Fig. 8. Longitudinal Block

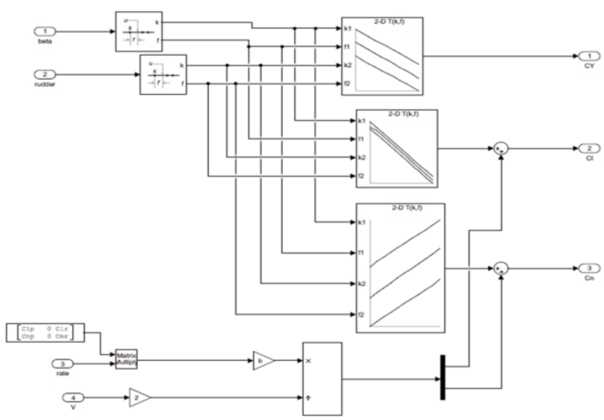

Fig. 9. Lateral Block

4. Conclusion

In this article, motion planning of an aircraft along with the system architecture has been discussed. The system architecture as shown in Fig 1 heavily relies on the output data that are obtained from the GPS (Global Positioning System) and the on-broad instruments like attitude indication, airspeed indication etc. Their outputs will act as inputs to the Flight control system. However, to ensure the safety of the aircraft, the control flow process has to be designed in such a way that it does not exceeds the tolerances of the aircraft control surfaces like maximum deflection angle. maximum load. The other parameters.

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