Autopilot Design for Navion Aircraft Using Intelligent Controllers

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Abstract — The nonlinear mathematical model of autopilot control system for Navion aircraft is built from control surfaces (elevator, aileron and rudder) span change, and the autopilot controller is proposed to track the commanded angle in degree and keep aircraft stable. PID controller is carried out in most of autopilot control systems to be in charge of rotations for pitch, yaw and roll about the three axis x, y and z respectively. This paper says an efficient and fast tuning method based on a Genetic Algorithm (GA) to find the optimal parameters of the PID controller so that the desired system specifications are satisfied. Intelligent autopilot for 3 axis aircraft control system is achieved by applying GA to optimize the varying parameter of PID gains to even, using MATLAB. Thus, the most effective value is fed as an input in the autopilot program for the Navion aircraft.

Index Terms— Autopilot, Elevator, Aileron, Rudder, PID, Genetic Algorithm and Navion.

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1 INTRODUCTION

*T*HE objective of this paper is to control the attitude of an aircraft is controlled by three sets of surfaces: elevators, rudder, and ailerons through PID controller [1]. Autopilot commands can be fed directly to the surface actuators. By means of controlling these surfaces pilot can position the aircraft on a preferred flight path. The paper illustrates the application of Genetic Algorithm to tuning of 3 parameters of PID controller and thereafter using those values as parameters for the autopilot program which is fed into an aircraft as per requirements [2]. The performance evaluation part is encountered after the design of controller is executed comes in to light. The designed controller has to provide best control results irrespective of every situation like plant and equipment non linearity and plant saturation.
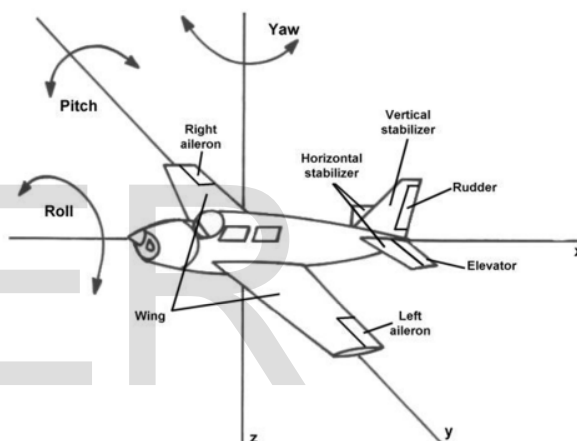
2 AIRCRAFT DYNAMICS

Aerodynamics concerns the motion of air and other gaseous fluids and other forces acting on objects in motion through the air (gases). In effect, Aerodynamics is concerned with the object (aircraft), the movement (Relative Wind), and the air (Atmosphere). There are 4 main forces that act on an aircraft in flight: they are weight, lift, thrust, and drag. It is the interaction between these four forces that result in an airplane's motion. An aircraft in flight is free to rotate in three dimensions, the axis that expand lengthwise (nose through tail) is called the longitudinal axis, and rotation regarding this axis is called roll. Pitching moment is the moment acting in

Fig. 1 Axes of Rotation

the plane containing the lift and the drag, i.e. in the lateral plane when the aircraft is flying horizontally. It is positive when it tends to increase the incidence, or raise the nose of the aircraft

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upwards. The axis that goes by vertically through the CG is called the

vertical axis, and rotation with reference to this axis is called yaw.
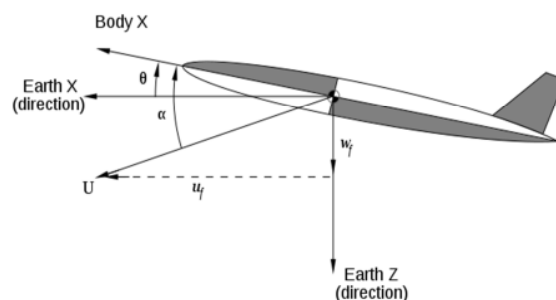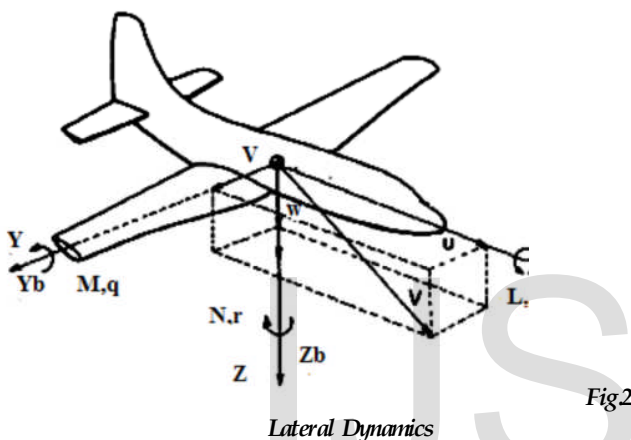
3 MATHEMATICAL MODELING

3.1 Aircraft Autopilot

In order to control the motion of the aircraft in its pitch and yaw planes as well as in the roll direction, three different autopilots are needed: roll, pitch and yaw autopilots. Regarding the transfer functions of the aircraft obtained according to its equations of motion, the mentioned autopilots can be properly designed

3.2 Lateral Dynamics

The derivation of lateral dynamic equations of motion, which represents the dynamics of aircraft with respect to lateral axis and longitudinal dynamic equations of motion which represents the aircraft's dynamics with respect to longitudinal axis is described in this section [3]. Lateral dynamics includes yaw, roll and sideslip motions of aircraft.

In this chapter, control of lateral dynamics of aircraft is explained. The forces, moments and velocity components in the body fixed frame of an

aircraft system are shown in Fig (2) where the aerodynamic moment components are represented by L, M and N the angular rate components of roll, pitch and yaw axis are represented by p, q and r and the terms u, v and w represents the velocity components of roll, pitch and yaw axes. Transfer function for rudder deflection angle to yaw angle is given by equation

$$\frac{\Delta\varphi(s)}{\Delta\delta_r(s)} = \frac{-4.6130S^3 - 47.9562S^2 - 11.8833S + 5.741}{S^4 + 9.4090S^3 + 14.0189S^2 + 48.4991S + 0.3979}$$

Transfer function for aileron deflection angle to roll angle is given by equation

$$\frac{\Delta\varphi(s)}{\Delta\delta_a(s)} = \frac{-32.32S^2 - 31.8S - 162.08}{S^4 + 8.402S^3 + 13.3S^2 + 51.5S + 0.569}$$

Fig 2

Lateral Dynamics

3.3 Longitudinal Dynamics

The characteristic analysis of aircraft pitch behavior consists of the combination of two linear transfer functions, describing long (phugoid) and short period stability characteristics called modes. The short period mode represents the instant response to vary, either in the form of control inputs or ambient disturbances. The short period poles control the description of short term flight behavior. Examining the short period stability poles reveal whether an aircraft is stable or not easily. The long period oscillation i.e. phugoid is not taken into consideration in this analysis for two reasons. First, the period of one oscillation in phugoid is much longer than any response of the short period mode, and finally the phugoid mode is only apparent for positive static stability. Modeling the pitch behavior of Navion aircraft required calculating a variety of control derivatives [1]. These control derivatives are measures of how forces and moments on an aircraft change as other parameters related to stability change. A complete set of control derivates can be used to mathematically model flight behavior. Therefore the transfer function of the pitch control system is given as,

Fig 3 Longitudinal Dynamics

$$\frac{\Delta\theta(s)}{\Delta e(s)} = \frac{11.7304s + 22.578}{s^3 + 4.9676s^2 + 12.941s}$$

4 GENETIC ALGORITHM

Genetic algorithm belongs to the group of optimization methods called as nontraditional optimization methods. GA tries to imitate natural genetics and natural selection. The main philosophy behind GA is survival of the fittest. As a result GA is used primarily for maximization problems in optimization. GAs does not suffer from the basic setback of traditional optimization methods such as getting stuck in local minima. This is because GAs work on the principle of natural genetics, which incorporates large number of randomness [4]. Since the genetic algorithm execution technique is not dependent on the error surface, solves multi-dimensional, non-continuous, non-differential and also for non parametrical problems. In particular, the design of GAs involves choices such as using a single or multiple populations. In either case, the size of the populations must be determined carefully, and for multiple populations, one must decide how many to use for computational task [5]. In account to count, the populations may remain isolated or they may communicate by exchanging individuals or some other information. Communication involves extra costs and additional decisions on the pattern of communications, on the number of individuals to be exchanged and on the frequency of communications.

5 FINEST SELECTION OF OPERATORS

5.1 Selection

Selection is the process used to select individuals for reproduction to create the next generation. This is determined by a fitness function that makes higher fitness individuals more likely to be selected for creating the next generation [7].

5.2 Reproduction and Crossover

After individuals are selected, reproduction engages crossing the individual's chromosomes to produce their offspring's chromosome. In the simple case, this engages exchanging genetic information by exchanging bits within the parent's chromosome. Crossover is a random process whereas not all parents selected for
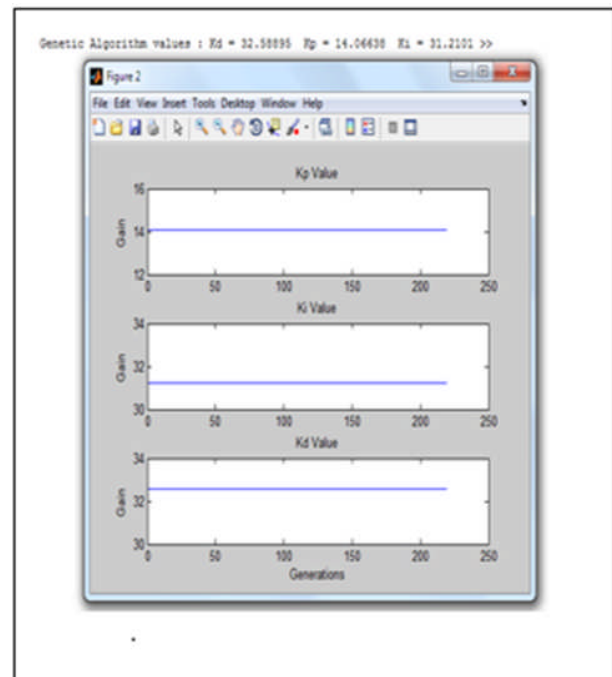
reproduction are mated. Probability of most genetic algorithms uses a crossover is vary from 0.60 to 0.90

5.3 Mutation

Premature convergence is a critical problem in most optimization techniques, consisting of populations, which occurs when highly fit parent chromosomes in the population breed many similar offsprings in early evolution time. Crossover operation of genetic algorithms (GAs) cannot generate quite different offsprings from their parents because the acquired information is used to crossover the chromosomes. A replacement operator, mutation, can search new areas in contrast to the crossover. Crossover is presented as exploitation operator whereas the mutation is exploration one. As Like crossover, mutation can also be performed for all types of encoding techniques. It is important to choose the best operators in GA, because it random selection, so one can achieve better solution of choosing another right kind of values

Operators	Kind	Gain
Selection	Rank method(Normal Geometric Selection)	Overcome from convergence problems
Cross Over	Arithmetic crossover	Linear combination of their parents
Mutation	Uniform mutation	Not needed fixed distribution for element

Table.1 GA Selection Of Operators

6 SIMULATION AND RESULTS

The genetic algorithm was initialized with a population of 80 and iterated for 100 s. The total amount of mutations was set to three and each of their bounds was set to ± 50. To ensure that all of the genetic algorithms had the exact same initial conditions the matlab command [rand('state',0)] used. This command guarantees that each population is initialized to the same set of values. The best population may be plotted to give an insight into how the genetic algorithm converged to its final values as illustrated in Figure 4.

The MSE objective function was chosen as the primary performance criterion for the remainder of this project due to its smaller rise time and smaller overshoot than any other method in conjunction with a slightly faster compile time due to there being just one multiplication to be carried after the error has been calculated.
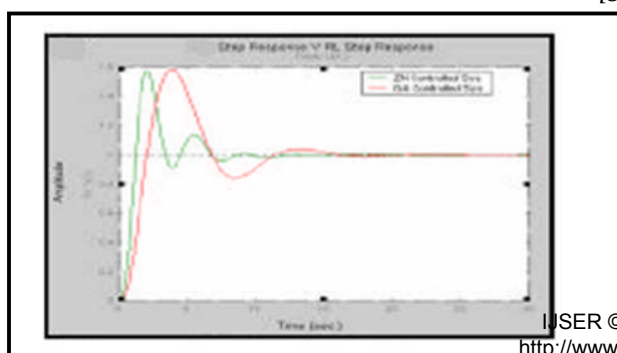
Genetic Algorithm tuned PID controller using MSE as objective functions. Table2 describes the steady state characteristics of each of the controlled systems. This is coupled with the fact that MSE has been a 'proven measure of control and quality for many years'. Below shown table describes the detailed performances measures and PID gain values for both ZN and GA.

1 *Fig.4 Generation of Kp, Ki and Kd*

Tuning Types	Kp	Ki	Kd	Max., Overshoot	Rise Time(s)	Settling Time(s)	MSE
ZN	12.8	28.9	20.7	6.5	2.2	2.8	0.245
GA	14.06	31.2	31.5	5.3	1.3	2.1	0.0466

Table. 2 Comparison of GA with ZN

7 CONCLUSION & RECOMMENDATIONS

It is hope that this project can be improved to include the implementation of tuning the PID controller via GA. This will have much impact in the optimization of the system under control. In conclusion the responses as shown in fig 4, had showed to us that the designed PID with GA has much faster response than using the traditional method. The traditional method is good for giving us as the starting point of what are the PID values. It has also shown me that there are numerous methods of PID tunings available in the academics and industrial fields.

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