An overview of aircraft control procedures in the presence of operator failure

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Abstract

Operator failures in controlled systems can reduce their operation, cause instability and even cause dangerous casualties and accidents. Flaw causes structural changes and parametric uncertainties in the control system, which requires a new modeling for the control system as well as new control methods. The design of the control is applied to the dynamic model in the presence of a defect in the radar, ellerron and motor operators. The intended damage for these operators is considered to be "locked in place", that is, after the defect, the control levels remain uncertain and constant. In this paper, we examine several different control methods for controlling the operation of operators in the presence of uncertainty.

Keywords: actuator fault, adaptive control, PID controller, back stepping control

1. Introduction

The manless plane, as it is clear from the name refers to a set of airplanes in which human beings do not lead the airplane actively and directly. Accordingly, manless airplane can also carry passengers, but its controlling operations can be done through local computers (within the plane) or central computers (pilot or the computer in land control centers). One of the issues which is highly important regarding these air planes is the independence of such aircrafts. If we can supply independence in such planes, we can use them to do operations when there is not any possibility to establish radio connections between the plane and land. Additionally, there are certain problems with airplanes that make it difficult to control them all by a pilot from a long distance. These factors mainly include issues perceived by the pilot sensually. Simply, independence refers to the ability to make humane decisions without interference of any human being. The researchers have been trying to realize such an action from the early years of the development of digital technology and it has only become possible during some recent years. The independence control level is such a broad issue that can categorize the research projects to achieve it. We can carry out new programming and compare the novel attempts to create independence in such aircrafts. The control independence level and the trend to make different generations of manless airplanes independent are represented in figure 2-3. As it can be observed in this figure, 10 different scales were determined to measure the independence level. In other words, Predator and Global Hawk manless airplanes which are currently in use have an independence level of 1 to 2. The project to manufacture Darpa auto-aircrafts 3 called J-UCAS was supposed to supply independence level 6 up to the year 2015. But this project was stopped in year 2006 and another project altered it. But UCAR is supposed to bring a high independence level (about 7 to 9). Anyway, the concept of automated control level is widely used to express the amount of independence in a manless airplane.

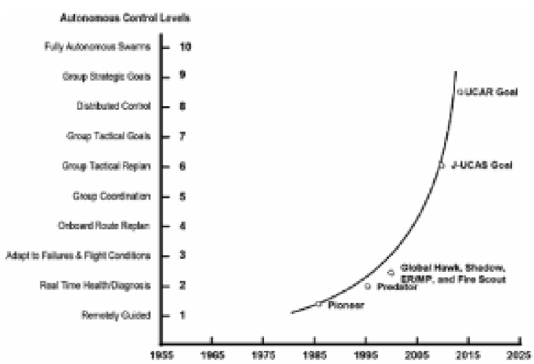

Fig.1. The control independence level and aircraft independence trend

2. Experimental section

To design modern airplane controllers we have used a model with 6 degrees of freedom. We have considered a similar model appropriate with motor trust. However, a model of an airplane with appropriate motor trust is not enough to control fracture. To compensate the airplane errors, such as radar error or mismatch of the operation of airplane motor, a model of the airplane with an independent adjustable trust seems necessary. In this part, first we describe a nonlinear model of an airplane with an independent motor trust and also independent right and left ellerrons. A linear dynamic model is going to be described in the end of this section. Unlike the model in appropriate motor trust, the airplane models with inappropriate motor trust cannot be isolated into separate longitudinal and latitudinal movement equations.

First we will deal with investigating the adaptive control method with the reference [1] model. In this method, the airplane control system calculates the differences through adapting the online data with the reference model data predetermined for the system and then applies the required control orders.

The proposed adaptive control method can return the airplane to stable and primary equilibrium status after the damages within a short period of time which is the same as the control goal. The airplane automatically returns to stable flight condition under normal or damaged conditions [2.[

In this section, results of simulations are represented to show the efficiency of the proposed adaptive design applied in airplanes with damages in radar, ellerron, and motor and airplane motor trust difference model has been utilized. First, a model of an airplane based on trust difference is introduced. Then, based on the introduced controller model design, the simulation of the model without any damage is carried out to assess the proposed controller. Then, we apply the damaged model and use the compensation project to reach feedback of the adaptive controller in the presence of damages in radar, ellerron, and motor.

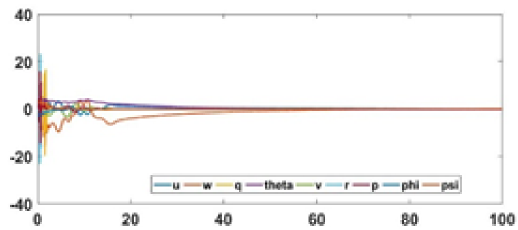

Fig.2. Studying the behavior of all operators with adaptive controllers

U is the forward velocity and w refers to downfall speed and q is the angular speed in turning of the angle and v refers to rightward velocity, r is the angular turning speed, p refers to angular speed in phi turning and psi turning angles.

Next, we represent a control system based on optimal linear regulator (LQR). The feedback control rule is represented as equation (1):

$$v_d(t) = Kx(t) \tag{1}$$

Where, $K \in R^{6*9}$ is the feedback interest matrix to minimize the index of square function performance.

$$J = \int_0^\infty (x^T Q x + u^T R u) dt \tag{2}$$

Where, $Q = Q^T > 0$ and $R = R^T > 0$ are weight matrixes. For $P = P^T > 0$ the satisfactory amount can be calculated through equation (3).

$$A^T P + PA - PBR^{-1}B^T + Q = 0 \tag{3}$$

And feed10back int erest K can be calculated through (4).

$$K = -R^{-1}B^T P \tag{4}$$

The optimal controller designed guarantees a fixed approximation of the closed loop system. Meanwhile, the performance of optimal controller is not satisfactory in the presence of indefinite errors of radar. Results of the sample have been represented in simulation results.

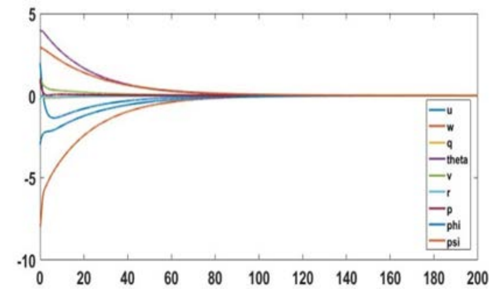

Fig.3. Studying the behavior of all operators with optimal controller

Proportionate-derivative controller and PID integral are among popular industrial controllers [5]. Today, more than 90% of industrial controllers are designed and implemented based on linear controllers with fixed PID coefficients. Usually controllers are enough to control a certain physical process. But, when physical conditions and environmental parameters change, they can not apply appropriate control.

Different methods have been proposed to enhance the efficiency, stability, and adaptability of PID controllers and some of them are as follows: self-regulation method [7], neural network [6], fuzzy control, predictive control, … .

Another method to improve the performance of the PID controller is to use a nonlinear coefficient along with input error to the PID controller. The role of this nonlinear coefficient is to regulate the amount of input error into the controller to foster and reach the optimal response.

This part has been formulated based on predictive control theory. The controller structure is designed in MIMO types for PID systems through coefficients considering the disturbances (a combination of predictive PID controller along with nonlinear observer of the disturbances). The basic tenets of designing predictive controllers and controllers based on predictive control are as follows:

a) Dynamic model: the model should be able to describe the system behavior properly in real world.
b) Cost function (target function): the goal of cost function 1 is to minimize control rule. In fact, control signals are calculated based on minimizing cost functions.
c) Optimization process: the controlling cluster to minimize the target function only applies the very first control order onto the process (model) and in next stages, the optimization operations are repeated again.

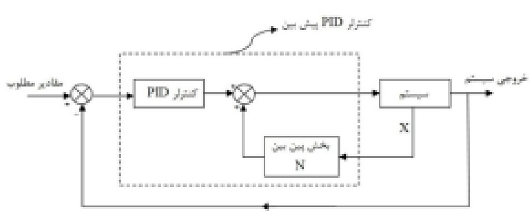

Fig.4.Block diagram of predictive PID controller

Next, we dealt with static back stepping method and modular adaptive back stepping.

In this part we describe non-adaptive or static back stepping [3] in systems with optimal degrees. Back-stepping method was first introduced in 1990 as a gestalt Lyapanov method. The reason to call this method as back-stepping refers to the fact that during the designing process, the designer returns one step back from the scullery equation which is the most distant from the control input (regarding the number of integrals) towards this control input and this is repeated as a gestalt process. This method has been successfully utilized in controlling the status of spacecrafts in quaternion terms which were used as a means of designing stable controller for spacecraft status in terms of reformed parameters of Rodriguez.

Unlike static back-stepping design [4], adaptive back-stepping utilize a type of integral nonlinear feedback. These integral derivations within the estimation of the parameter which is against the static nonlinear feedback rules, is considered as a dynamic feedback. Designing adaptive back-stepping investigated in this project includes a resistant control rule within its structure and it estimates the unknown parameter separately. This resistant control rule consists of a nonlinear damping term.

Conclusion

In conclusion section we will deal with studying the advantages and disadvantages of the methods mentioned hoping that the readers of this paper will simulate the results precisely and investigate about the graphic results of all the methods and achieve the more precise results.

The filtering method used here was a permanent order filtering method through which the damping coefficients are identified and the natural frequency of the filters are reduced from the load of the derivation of virtual controllers within the process of back-stepping. By observing the results of simulations carried out we can recognize the high precision of modular adaptive back-stepping nonlinear control method. Standard back-stepping and modular adaptive methods represented fixed reference signal trace by the airplane in without disturbance status with a high precision.

The modular adaptive controller in the presence of wheels with uncontrolled reactions showed less errors and a better trace compared to non-adaptive back-stepping method. This method has even represented a better performance compared to integral adaptive back-stepping method with regulation functions.

A nonlinear predictive PID controller has also been designed. The process of designing the controller above is based on predictive control principles. Also in the section requiring the entrance of disturbances into the structure of the controller, we have used a nonlinear observer of the disturbances to estimate the amount of input disturbance into the system. By entering the amounts of disturbances into the predictive controller estimated, the equations are rewritten in a way that we can extract nonlinear PID coefficients. The stability of the closed loop system has been approved based on dynamic stability of the closed loop error. In the designed controller, the range of prediction and the coefficient of disturbance observer in controller structure have been introduced as the design parameters and the effects of the designing parameters on the responses have been investigated.

The aircraft flight adaptive control in the presence of failures in radar, ellerron, and motor was implemented using a dynamic model based on the differences in trust. The coupling of longitudinal and latitudinal movements because of the use of the differences in trust, are among the important characteristics of this dynamic design. The adaptive compensator design guarantees the trace of variables of airplane status and the banks of the closed loop system in the presence of lack of uncertainties (faults). Results of simulations showed that the optimal regulator controller can not result in system stability when it is disturbed, but the adaptive compensator design not only analyzes the stability based on Lyapanov theory foundations in simulations, but also uses other remaining control levels and specifically the differences in motor trusts to retrieve the aircraft stability and this shows the efficiency of this method for a passenger carrier airplane. On the other hand, the introduced adaptive control design has a better performance in speed in retrieving airplane stability and also lower costs due to lack of need to the substructure of recognition of the error and also lack of need to know about the time and amount of the disturbance.

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