Design of Fuzzy Logic Controller to Drive Autopilot Altitude in Landing Phase

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Abstract. Nowadays the automatic control science is an important filed. Its importance has been raised from equipment evolution and increased control requirements over the many science fields, such as medical and industrial applications. Hence, it was necessary to find ways for studying and working to develop control systems. This paper proposes study of an aircraft as control object in longitudinal channel during the landing phase, and study altitude due to its importance during this phase. This paper introduces the possibility of implementing automated control process using fuzzy controllers. Finally, comparing the results of fuzzy and traditional controllers has been discussed.

Keywords: Fuzzy logic controller, proportional-integral controller, autopilot.

1 Introduction

The Cybernetics Considered from the important science of modern times has come from the development of these important machines used and increase the requirements imposed on it in all industrial fields [4].

As a result of these requirements increased with the time it was necessary to develop the control modes that's used in these areas. So the need arise to find studies and methods of work on the development of this science. Happened in the twentieth century a quantum leap in the field of scientific development in all directions. Has appeared in recent decades, the theory of Fuzzy Logic, which had been widespread in practical applications, especially in the Control Systems has led to the emergence of the Fuzzy Logic Controllers [1].

2 Motivation of Paper

The importance of scientific research to study the possibility of implementing automated control operations in the control systems to replace traditional controllers by Fuzzy Controllers, to move to artificial intelligence in control systems in all fields [2].

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3 Research Methods

The research adopted on the method of mathematical modeling to control the aviation altitude in landing phase thus computerized simulation, and design of the proposed fuzzy controller using MATLAB [3].

3.1 The Principle of Building Control System in the Longitudinal Channel by the Center of Gravity of the Aircraft

The process of take-off and landing is considered of the most complex phases of flight due to large change parameters, especially in the final stage of it. We are always searching for the path of landing provides the requirements imposed on control systems, and from these paths that provides this process is the path of exponential landing as shown in the following equation [1]:

$$h = (h_0 + \Delta h_o)e^{-kx} - \Delta h_0 \tag{1}$$

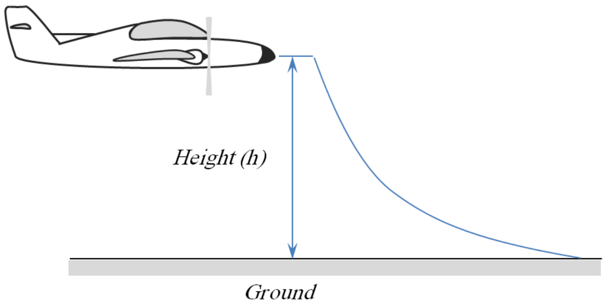


Fig. 1. The suggested path of landing

Based on the above the process of driving control systems in the last stage of the landing becomes control the aircraft altitude. The control of aviation altitudes is considered from the high levels of aviation control, where it is used during the implementation of trip aviation, take-off, landing and aviation at low altitudes. The transfer function for Elevator displacement is [2-13]:

$$\dot{h} + a_h^{\vartheta}\dot{\vartheta} + a_h^{\theta}\theta = 0 \tag{2}$$

The transfer function between θ and h is:

$$W_{\theta}^{h} = \frac{\vartheta}{s}$$

After that the function between h and ϑ according to the function between θ and ϑ as shown in the following equation:

$$W_{\vartheta}^{\theta}(s) = \frac{1}{T_{\theta}s + 1} \tag{3}$$

In the end the transfer function between pitch angle ϑ and elevator displacement is:

$$W_{\dot{\vartheta}}^{в}(s) = -\frac{k_{\dot{\vartheta}}^{в}\omega_{\alpha}(T_{\theta}s + 1)}{s^{2} + 2\xi_{\alpha}\omega_{\alpha}s + \omega_{\alpha}^{2}} \tag{4}$$

We will use the following equation to update the state variable for h:

$$\delta_{в} = k_{\vartheta}(\vartheta - \vartheta_{d}) + k_{\omega z}\omega_{z}$$

$$\vartheta_{d} = \frac{k_{h}}{k_{\vartheta}}(h - h_{d}) \tag{5}$$

Where [2]:

$\delta_{в}$:elevator displacement. - k_{ϑ}: constant of ϑ angle.

ϑ : current pitch angle. - ϑ_{d} : desired pitch angle.

$k_{\omega z}$: constant of the angular velocity of pitch.

ω_{z} : the angular velocity of pitch. - k_{h} : the constant of altitude.

h : the current altitude. - h_{d} : the desired altitude.

Based on the above the block diagram of the control system of aviation altitude as shown in the following figure [2]:

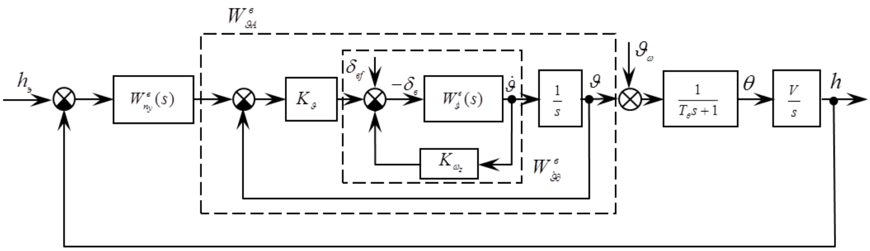


Fig. 2. Block diagram of the control system of aviation altitude

We can model this case using MATLAB according to the aviation system in which specific constants as the following [2]:

kh= $K_{н}$ =5; knew= K_{ϑ} =5.97;

kwz= $K_{\omega z}$ =2.53; ttheta= T_{θ} =0.3;

walfa= ω_{α} =1.61; psayalfa= ξ_{α} =0.335;

We must pointed here that the design of controllers and control systems to drive the movement of aircraft considered all the elements ideally (linear elements). However, the reality is different, where some parts of the system are nonlinear elements, for example execution units.

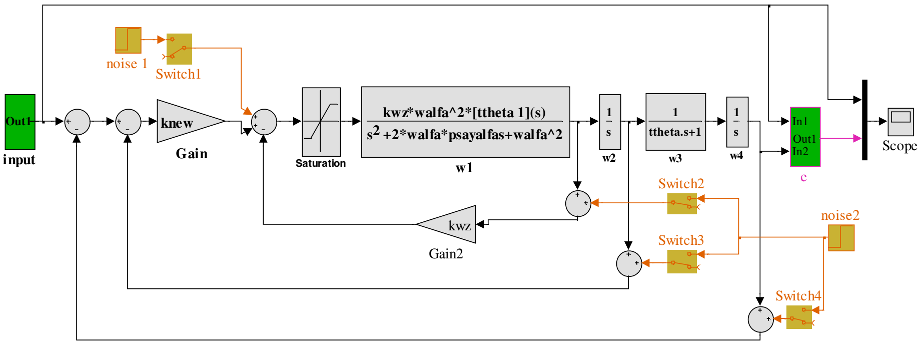


Fig. 3. Block diagram of the control system of aviation altitude in MATLAB with nonlinear elements

We must pointed here that the design Of the advantages of fuzzy logic that unaffected by nonlinear elements, thus the Fuzzy Controllers can be designed to able to deal with the disadvantages of traditional controllers.

4 Fuzzy Logic

This logic is based on some of the most important basic concepts [1]:

Fuzzy sets - Linguistic variables - Fuzzy variables - Linguistic rules.

5 Fuzzy Inference

This unit is the complete process of decision-making using fuzzy logic and it has four basic steps are [1]:

Fuzzification - Knowledge base - Decision-making - Defuzzification.

6 Using of Fuzzy Logic in Control Systems

Control idea is built on the of forming the basis of the control signals (Error Signals) in accordance with the law of a specific model for the effect on the plant and guidance of its processes to achieve the desired goal [1,10].

The main idea in the design of fuzzy control systems is replacing the traditional controller by fuzzy controller, which is built on the basis of Use of the fuzzy

Inference. Then the error signal becomes the input signal of fuzzy controller and processing by fuzzy inference system in fuzzy controller [10].

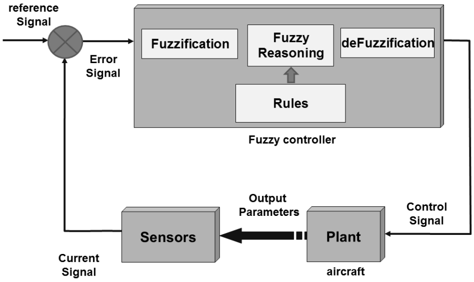


Fig. 4. General scheme of fuzzy control system

7 Design of Fuzzy Logic Controller

For the design of Fuzzy Logic Controller we must initially determine input and output variables for this controller in a case study [9,10]:

7.1. Input variable is the difference between the current altitude and desired altitude (Error signal).
7.2. Output variable is the altitude elevator displacement.

These signals in Fuzzy Logic are linguistic variables and we can describe it by fuzzy variables, thus we can give the input signal (Error) five cases and these cases are:

UL- A Positive Large Error. US- A Positive Small Error.
Z- No Error.
DS- A Negative Small Error. DL- A Negative Large Error.

According to above in design of the Fuzzy Logic Controller the diagram of the control system of aviation altitude with (FLC) becomes as shown in figure 5. [9,10]:

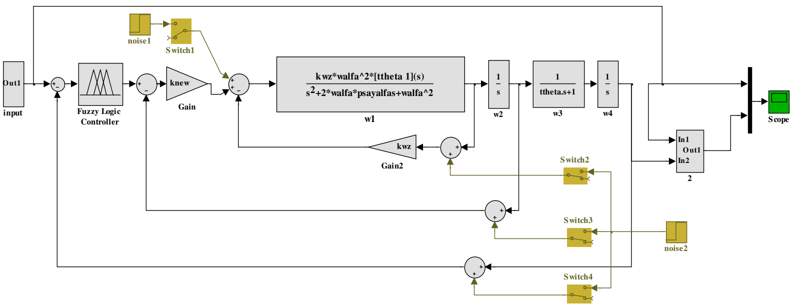
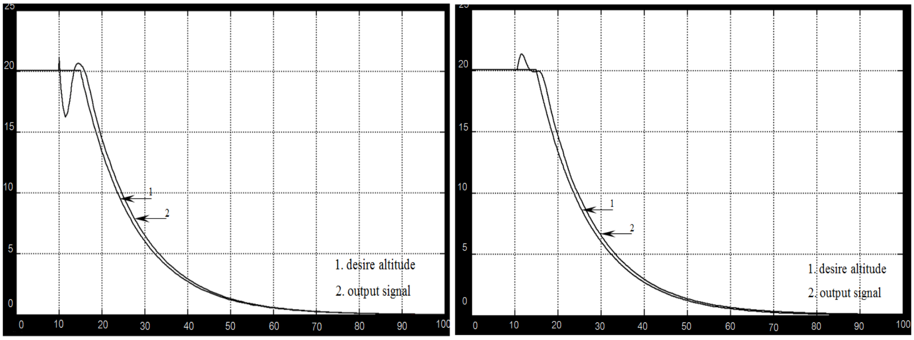


Fig. 5. Block diagram of the control system of aviation altitude with (FLC)

Now the results of comparing between the traditional system and fuzzy system with effect of nonlinearity and measurement error of angular velocity ω_z :

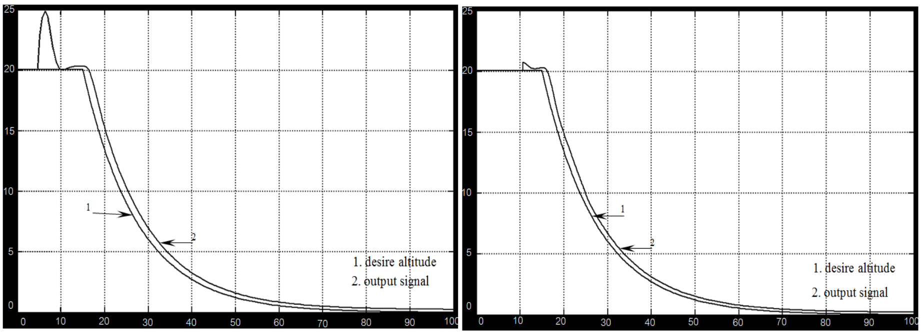
1. Effect of nonlinear elements:



a. Traditional system b. Fuzzy system

Fig. 6. The curve of aviation altitude with nonlinear element

2. Effect of measurement error of angular velocity ω_z :



a. Traditional system b. Fuzzy system

Fig. 7. The curve of aviation altitude with nonlinear element and ω_z

8 Final Conclusion

8.1. The modeling showed the possibility of using the fuzzy logic controller in the implementation of the process of landing in theory.

8.2. The possibility of design the fuzzy logic controller in nonlinear systems is easier than the traditional controller design.

9 Results

9.1. The modeling showed that preference of fuzzy logic controller better than the traditional controller when dealing with nonlinear elements in control systems fig. 6. And fig. 7.

9.2. The results showed that the possibility of dealing with some disturbances (ω_z) better than traditional controller fig. 8. And fig. 9

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