Fuzzy Logic Controller: An Overview and Applications

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Abstract—paper presented below is analysis of fuzzy logic controller which is carried out and proven that it is best suitable for autopilot system design. Modern day aircrafts heavily rely on automatic control systems for most of the functions and there is always a persistent demand for efficient controllers. There are already many control techniques and methods developed in the field of control engineering, but only the conventional control techniques which are more intuitive, are trusted enough in the aviation industry. However, the conventional techniques only work efficiently for linear systems but in real world, the aircraft dynamics are highly nonlinear and thus there is need for a controller which works perfectly for non-linear trajectories. Fuzzy logic control is a nonlinear control technique which uses a linguistic approach for controlling based on some sets of membership functions and rules.

Keywords: Fuzzy logic controller, Autopilot system, Fuzzy logic

I. INTRODUCTION

A fuzzy control system is control system based on fuzzy logic. Fuzzy logic is mathematical system that analyses analog input values in terms of logical variables that takes continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0(true or false respectively). [1][2]

Fuzzy logic is widely used in machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as the "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans. [1]

After the revolutionary invention of aircrafts by Wright brothers, the aircrafts soon started to adapt the concept of autopilots for making the pilot’s job easier. The first automatic flight controller in the world was designed by the Sperry brothers in 1912. The Sperry brothers developed an autopilot that was sensitive to the movements of an aircraft. Currently, the aircraft design relies heavily on automatic control systems to monitor and control many of the aircraft subsystems. Therefore, the development of automatic control systems has played an important role in the growth of civil and military aviation. [3][4]

Although, there have been many developed techniques to control a dynamic system using feedback such as PID control, LQ control and MPC etc. but very few control techniques are actually implemented in the real world flight control applications. The main reason behind not implementing the advanced optimal control techniques is that they are not intuitive and in aerospace where safety is a high priority, unintuitive techniques are not trusted enough to be implemented in real aircrafts. In the advanced modern aircrafts, the conventional PID (Proportional-Integral-Derivative) controllers are used extensively even though they are not very efficient for non-linear dynamic systems, mainly because of their intuitive nature, ease of operation and low cost. To overcome this flaw, an unconventional technique of Fuzzy Logic could be used as it has proven to be more efficient than PID controllers and depends on human experience and intuition.

The Fuzzy control has gained interests of many scientists from various research areas and there have been many successful applications.17 Fuzzy Logic Controller (FLC) is one of the artificial intelligence methods and its advantages are that it is a nonlinear and rule-based method; therefore no complex model is required. This type of Fuzzy control was expressed by Mamdani and is very popular compared to Takagi-Sugeno type which uses fuzzy sets to define the input variables but the output is defined by means of functions or LTI systems. Therefore, Takagi-Sugeno is considered to be more complicated but stability is guaranteed from this technique. [5]

II. ADVANTAGES OF FUZZY LOGIC CONTROLLER OVER OTHER CONTROLLERS:

- fuzzy logic controller is best suitable for non-linear systems-missile catching target is highly non-linear as we can’t predict target motion
- It is not possible to design a system according to our rules. Example: PID controller has got its own question. Our system will work according to predefined question.
- It’s not possible to design an autopilot system having multiple inputs.
- Fuzzy Logic could be used as it has proven to be more efficient than PID controllers and depends on human experience and intuition.

III. WORKING OF FUZZY LOGIC CONTROLLER WITH BLOCK DIAGRAM:

The general block diagram of fuzzy logic controller is described below.

![Block Diagram of Fuzzy Controller](image)

**Knowledge Base:**
It consists of rules and parameters for membership functions

- **Decision Logic:**
  It consists of interface operations on rules.

- **Fuzzification Interface:**
  It transforms crisp inputs to degree of match with linguistic variables

- **Defuzzification Interface:**
  Transformation of fuzzy result of interface to a crisp output

IV. APPLICATIONS OF FUZZY LOGIC CONTROLLER:

Fuzzy logic is becoming very popular in various applications of various fields because of its numerous advantages. Though it is an emerging technology, it is being applied in many fields. Applications of Fuzzy logic controller can be listed as follows:

a. **Aerospace:**
- Altitude control of spacecraft
- Satellite altitude control
- Flow and mixture regulation in aircraft deicing vehicles

b. **Automotive:**
- Trainable fuzzy systems for idle speed control
- Shift scheduling method for automatic transmission
- Intelligent highway systems
- Traffic control
- Improving efficiency of automatic transmissions

c. **Business:**
- Decision-making support systems
- Personnel evaluation in a large company

d. **Chemical Industry:**
- Control of pH
- Drying
- Chemical distillation processes
- Polymer extrusion production, a coke oven gas cooling plant

e. **Defense:**
- Underwater target recognition, automatic target recognition of thermal infrared images
- Naval decision support aids
- Control of a hypervelocity interceptor
- Fuzzy set modeling of NATO decision making.

f. **Electronics:**
- Control of automatic exposure in video cameras
- Humidity in a clean room
- Air conditioning systems
- Washing machine timing
- Microwave ovens
- Vacuum cleaners.

g. **Financial:**
- Banknote transfer control
- Fund management
- Stock market predictions.

h. **Marine:**
- Autopilot for ships optimal route selection
- Control of autonomous underwater vehicles
- Ship steering.
i. Medical:
- Medical diagnostic support system
- Control of arterial pressure during anesthesia
- Multivariable control of anesthesia
- Fuzzy inference diagnosis of diabetes and prostate cancer

j. Mining and Metal Processing:
- Sinter plant control
- Decision making in metal forming

k. Robotics:
- Fuzzy control for flexible-link manipulators
- Robot arm control

l. Securities
- Decision systems for securities trading

m. Signal Processing and Telecommunications
- Adaptive filter for nonlinear channel equalization control of broadband noise

n. Transportation:
- Automatic underground train operation
- Train schedule control
- Railway acceleration
- Braking, and stopping

V. CONCLUSIONS
Fuzzy Control has advantage that can deal with non-linear system and use human operator knowledge.

PID Controller has only 3 parameters to adjust control system shows good results in terms of response time and precision when these parameters are well adjusted.

Fuzzy controller has lots of parameters. The most important is to make a good choice of rule base and parameters are well chosen, response of system has very good domain characteristics.

One of the most important problems with fuzzy controller is that the computational time is much longer than for PID, because of complex operations as Fuzzification and particularly deFuzzification.

VI. REFERENCES


