Application of fuzzy approach to control systems modeling of the mobile robot

Mammadova Kifayat Aslan¹,
Quliyev Zaur Elxan²

¹ Department of Computer Engineering, Azerbaijan State Oil and Industry University; Republic of Azerbaijan
² Department of Computer Engineering, Azerbaijan State Oil and Industry University; Republic of Azerbaijan

Abstract.
In the article, the principles of construction and modification of the PID regulator were considered and the following results were obtained. In order to improve the characteristics of classical PID controllers, free and filter controllers have been applied to construct signals. The principle of open control given in PID regulators allows to reduce the regulation time and increase the stability reserve of the system, and also compensates for external effects. Fuzzy logic in PID controllers is mainly used in two ways: for the construction of the controller itself and for organizing the tuning of the coefficients of the PID controller. Both methods can be used simultaneously.

Keywords:
PID controller
fuzzy logic
fuzzy PID controller
fuzzy rules
fuzzy inference
2. Introduction

Fuzzy approach to control systems modeling has the following distinctive features: fuzzy models use "linguistic" variables instead of numerical variables; relationships between variables are described with the help of fuzzy judgments; complex relationships are described by fuzzy algorithms.

The two-wheeled robot system model is nonlinear, coup. Also there are other parameters in the system that were neglected in the derivation of the model such as the frictions, gear backlashes, etc. These led to a mathematical model that is not the exact model for the developed two-wheeled robot test rig. Therefore, fuzzy logic control algorithm is considered to develop a controller for the two-wheeled robot [1-3].

In closed-loop configuration, the tilt angle of the robot must be adjusted in the second loop (Fig. 1).

![Figure 1](image1)

**Tilt angle of the robot in closed loop configuration**

In the closed-loop configuration, the robot's left and right wheel motor input must be adjusted (Fig. 2).

![Figure 2](image2)

**Left and right wheel motor input of the robot in closed loop configuration**
In order to apply fuzzy logic methods, it is first necessary to express ordinary fuzzy variables as fuzzy. The facification process is illustrated in Fig. 2.

The error range is divided into subsets NB, NM, NS, Z, PS, PM, PB, and a membership function is created for the error from each set. The membership function depicted in Fig. 3 is a relatively common triangular shape.

The number of clusters can be arbitrary. There is a generally accepted notation for fuzzy sets: N – negative (Negative), Z – zero (Zero), P – positive (Positive); the letters S (Small), M (Medium), B (Big) are added to these markings. For example, the number of variables NL – negative large, NM – negative medium, PL – positive large, etc. can be any number. But increasing their number corresponds to the increase in the requirements for expert experience, which forms the rules for all combinations of input variables [4-6].

![Figure 3](image3.png)

**Figure 3**
**Division of the error variation area into triangular clusters**
NL, NM, NS, PS, PM, PL

Fuzzy logic in PID controllers is mainly used in two ways: for the design of the controller itself and for organizing the tuning of the coefficients of the PID controller. Both methods can be used simultaneously.

The most common structure of fuzzy logic (fuzzy PID controller) is depicted in Fig. 4. The controller input includes the error $e$, which is used to calculate the $\frac{de}{dt}$ derivative. Both quantities are first fuzzified (fuzzy is an English word that means fuzzy), then the calculated fuzzy variables are used in the fuzzy logic output block to obtain...
the control effect on the object. The control effect generated at the output of the controller enters the defuzzification block to describe the fuzzy variables in a fuzzy form [5-7].

The most three popular types of fuzzy controller structure that have been implemented and investigated in the literature are PD-type, PI-type, and PID-type fuzzy controllers. They provide enhanced performance than their conventional PD, PI, and PID counterparts especially with nonlinear application [7,8]. On the other hand, PD and PI fuzzy controllers possess the same characteristics as the conventional PD and PI respectively. However, the difficulty with implementing a PID-type fuzzy controller is that it requires three inputs which will increase the number of fuzzy rules leading to more complicated controller design (Fig.5).

**Figure 4**
PID-type fuzzy controller structure

**Figure 5**
Diagram of PID fuzzy controller
Use of artificial intelligence. When modeling a two-wheeled robot system, a fuzzy mathematical model is created due to the inaccuracy of other parameters, such as frictions, gaps in the movement of gears, etc., which are not taken into account. The resulting uncertain situation causes the system to work with errors, additional energy and time loss. Therefore, there was a need to develop a controller for a two-wheeled robot with a fuzzy logic control algorithm using an Artificial Intelligence approach. So, fuzzy logic should be used for the uncertainties created within the management.

Numerical variables were replaced by linguistic variables in the modeling of the hybrid fuzzy PID controller, which consists of the synthesis of fuzzy control with an intelligent method. With the help of fuzzy judgments, logical relationships between variables were established (Fig.1-2).

In this research work, the use of Artificial Intelligence approach made it possible to save time and energy, improve the characteristics and parameters of the two-wheeled mobile robot (Fig.3-4).

3. Conclusions.

A long list of successful applications of fuzzy logic in robot control systems can be presented. Two-wheeled robotic systems are an example. Autonomous two-wheeled robots have a wide range of applications (for example, a waiter robot, a baking robot, etc.). They must be able to navigate complex and dynamic environments, which can be challenging due to the uncertain and imprecise nature of data collected by sensors. Fuzzy logic has strong support for making autonomous vehicles safer and more efficient by enabling them to make more informed decisions based on uncertain and imprecise data.

The dynamic movement of a non-linear two-wheeled robot under conditions of incomplete information is widely studied in the field of robotics. Fuzzy logic allows robots to make more optimal decisions, especially dynamic systems based on uncertain and imprecise information. The two-wheeled robot allows the system to move easily in complex and dynamic environments. The development of fuzzy logic control systems according to modern applications is very important to create intelligent robots that can be used in wider applications. The continuous development of this field will create new
advanced and innovative applications of fuzzy logic in robot control systems.

Fuzzy control and control with PID controller were compared and confirmed that fuzzy control gives better response than PID control. A similar effect was observed in the normalized speed of the motors, which required less energy to balance and stabilize the two-wheeled robot with fuzzy control.

References:


