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APPLICATION OF FUZZY LOGIC IN CONTROL SYSTEM USING SIMULATOR GUNT RT124

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ABSTRACT
Fuzzy logic is derived from the theory of fuzzy sets. Fuzzy control is the application of fuzzy logic in process control where the mathematical description of the system is not possible or too complex. Fuzzy control enables implementation of human heuristic knowledge for control the system. For the fuzzy control a set of linguistic terms and rules of the experts is used. This paper presents a methodology of fuzzy control vehicle with pendulum using simulator Gunt RT124. The purpose of the simulation is to keeping inverted pendulum in vertical position during acceleration of the vehicle. Display include a selection of input variables, compiling base of rules, defining the terms for fazzification and defazzification which determined control signal for the movement of vehicles.
Keywords: fuzzy logic, fuzzy control, inverted pendulum, simulation

1. INTRODUCTION
Today, computer technologies are presented in almost all areas of human activity. Using computer technology in engineering systems, the application of the highest standards of automation and engine control is achieved. To describe dynamical behaviors of the system, a few methodologies can be used; Conventional control method is based on differential and algebraic equations or graphic approach with structure system graph [1]. In addition to the mathematical description of the system, models based on artificial intelligence are increasingly using. Applying advanced technologies and soft computing methodologies in controls system better possibilities for modeling nonlinear control system is accomplished. It can be done by using artificial intelligence technologies, in witch model could be based on knowledge heuristic, simulation, expert system, fuzzy logic and control, neural network, etc. [5]. In this paper, a fuzzy controller for an inverted pendulum system is presented in two stages. Description of inverted pendulum as one of basics non-linear system, and simulation of fuzzy control modeling approach by using simulator Gunt RT 124 has been done.

2. DESCRIPTION OF THE VEHICLE WITH INVERTED PENDULUM
Carrier vehicle with inverted pendulums is one of the basic nonlinear models**.** As a nonlinear system, the inverted pendulum is used to analyze inputs signals received from sensors and perform a control signal for stabilization pendulum in vertical position [2,3]**.** Stabilization control of an inverted pendulum include the position of the vehicle using mid point and limited distance in both directions. The fuzzy controller for the inverted pendulum has four input signals: angle between the inverted pendulum and the vertical position, angular velocity of the inverted pendulum, position and velocity of the vehicle. Fuzzy simulator Gunt RT 124 is designed for students in educational purposes.
The purpose is to create a fuzzy control system, system test and fine tune controller with online debugging interface and analysis of parameters. The simulator Gunt RT 124 is non-linear one-dimensional system with strong coupling, consists of the vehicle model, fuzzy control unit and software program. The task of this simulation is to bring inverted pendulum into centre position, and at

the same time, control the position of the vehicle within the limits of the available distance. Motor drives driving wheel, and thus the vehicle. Because of inertial mass, the pendulum is moving in the opposite direction from the direction of the acceleration of the vehicle. Vehicle with inverted pendulum consist of these elements, as shown in figure 2. 1. inverted pendulum, 2. vehicle, 3. vehicle position sensor, 4. drive motor, 5. amplifier, 6. microcontroller, 7. PC with development system, 8. pendulum inclination sensor.

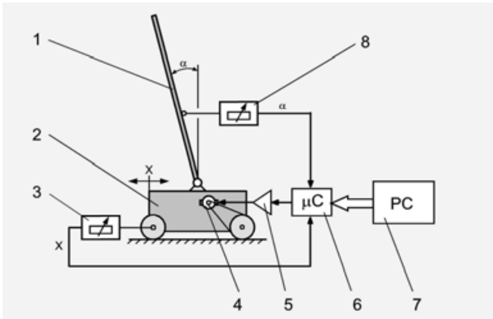

Figure 1. elements of the vehicle with inverted pendulum

3. DESCRIPTION OF FUZZY CONTROL ELEMENTS

The aim of fuzzy logic theory, with its application in fuzzy control, is to describe nonlinear system dynamics by establishing fuzzy input-output relation expressed in forms of If-Then rules. Fuzzy system performs transformation from expert knowledge and heuristic base into a suitable signal for processing in computer software. With this method, it is possible to solve problems in systems that are difficult to be expressed by mathematical or conventional control methods only. Fuzzy system is multi input – single output system [4]. Figure 2. present fuzzy control approach with following elements; input signals in form of membership functions, rule base presented in form of if-then rules, fuzzification and defuzzification process, fuzzy inference for making decisions and output control process signal [5].

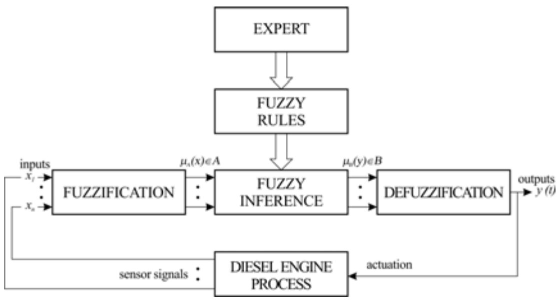

Figure 2. Fuzzy model structure diagram

3.1. The input element

The input element is used to acquire measured values. These binary coded measured values, acquired from external measured electric signals, are provided to the fuzzy controller. For each of four input signal the membership function is added. The element that is located within a set has a certain percentage of membership in that set [7].

3.2. The rule base element

Compiled by experts, it is used to define the set of rules that determines the control behavior of the fuzzy controller. A fuzzy quantity, received from input variable to the mechanical system, is present in the form of If-Then rules. Some of possible methods for determining a knowledge or rule base for fuzzy model is Takagi and Sugeno's method [6]. Takagi and Sugeno's (T-S) fuzzy model extends the linguistic rules to rules with consequent in the form of linear functions of antecedent or premise variables:

$$R^{(j)}: \; If \; x_1 \, is \, A_1^j ..... \; And \; x_n \, is \, A_n^j ..... \; Then \qquad y^j = c_0^j + c_1^j x_1 + ... + c_n^j x_n \tag{1}$$

c_i^j is a consequent parameter, y^j is the system output due to rule $R^{(j)}$, and i = 1,2,....,J.

Each rule represents a locally linear model. The final output of the fuzzy model is inferred by taking the weighted average of the y^j :

$$y = \sum_{j=1}^{J} w^j y^j / \sum_{j=1}^{J} w^j \tag{2}$$

where weight w_j implies overall truth value of the j-th rule premise part and is calculated as:

$$w_j = \prod_{k=1}^{n} A_k^i (x_k) \tag{3}$$

The advantage of this fuzzy linear model is that the parameters c_i^j of the model can be easily identified from numerical data (using ANN with adequate learning methods).

3.3. Fuzzification process

The fuzzy membership sets are used to define the truthfulness of a variable. Each input variables from sensors turns into fuzzy quantities. The quantities have a descriptive character and form the basis of the data. Each weighted value is assigned to a fuzzy quantity. Fuzzy quantities from the rule base are converting into crisp set values, using one of this method; maximum criterion (MAX), center of gravity (COA) or mean of maximum method (MOM).

3.4. Fuzzy inference

It specifies rules that are applicable are recorded. Each state is described in linguistic expression. It is possible to determine affects for each rule in the behavior of fuzzy controllers. Every action of the rules is described by the linguistic expression. The degree of application each rule defines the concept of weighted linguistic term in determining the behavior of fuzzy controllers. The control value for the motion of the vehicle is then determined in defuzzification process.

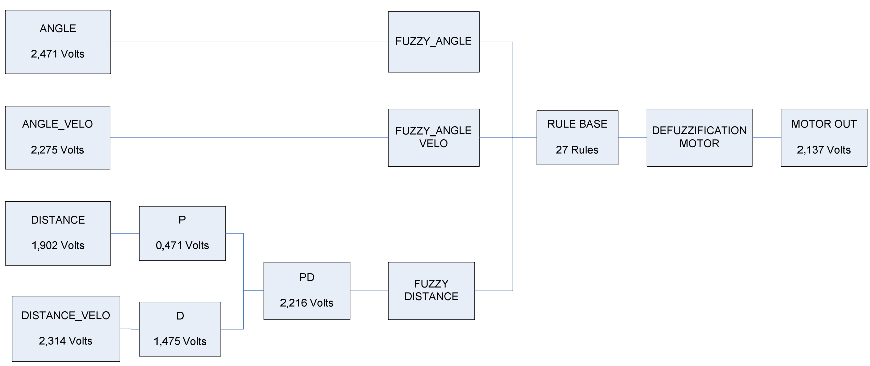

Figure 3: Structure Fuzzy control graph for simulation

The structure for fuzzy control with its element is shown in figure 3. and 4. The project structure is consists of input variables, proportional variables, addition element, fuzzification element, rule base, deffuzification element and outputs signal for vehicle control.

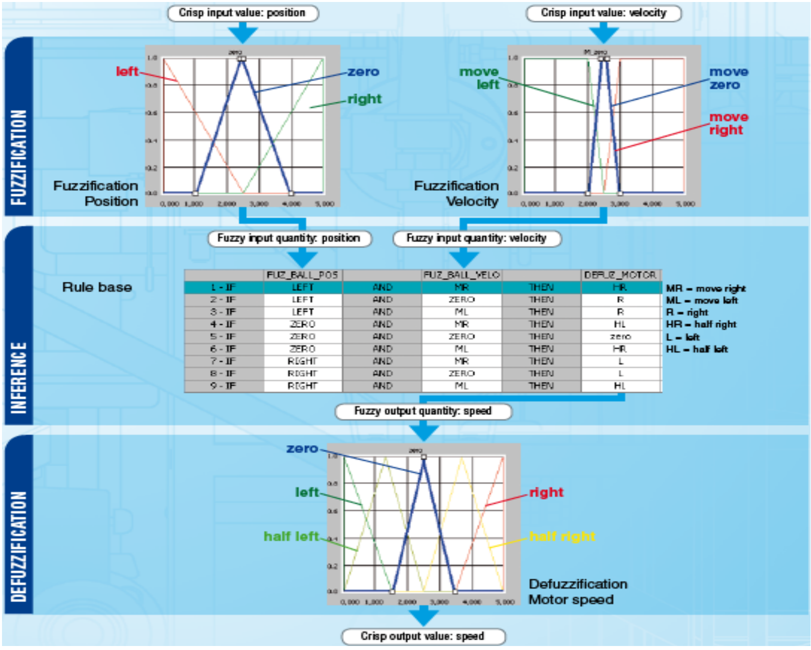

Figure 4. Graphical shell of fuzzy control for simulator Gunt RT 124

4. CONCLUSION

Well accepted by experts, fuzzy systems have been applied to a wide variety of fields ranging from engineering and automation control, signal processing, communication, etc. Vehicle with inverted pendulum is one of the basics model for implementation fuzzy control approach. The simulator Gunt RT 124 allows presenting the principle of fuzzy control process with a graphical programming interface. This model enables a fine tuning of a fuzzy control system, for a nonlinear and unstable system, by using debugging interface. This system can be easily upgraded by adding new rules to improve performance.

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