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Fuzzy Logic Controller Design for Intelligent Robots

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Abstract

An increasing number of systems are using fuzzy logic to offer reliable and efficient control for a variety of uses. The method's many-valued logic foundation allows control rules and processes to be derived from both expert knowledge and general concepts. The concepts of fuzzy logic control are explained in this article, which uses simulations of linear and nonlinear control examples to illustrate the points.

Keywords: Fuzzy logic controller, Automatic Door, Rule Bases, Control, Membership Function.

I. Introduction

We'll employ fuzzy logic controllers to solve the issues mentioned in the preceding paragraphs. Fuzzy logic was first used in many branches of science and engineering in 1973 [10], when Lotfi A. Zadeh introduced a novel method for the analysis of complex systems and decision flows. But when engineers used fuzzy logic to solve industrial problems, it really became more popular [5]. This popularity can be ascribed to fuzzy logic's potent ability to give engineers a means of integrating human thinking into the control algorithm. Unlike traditional control theory, fuzzy logic design does not only rely on an approximate mathematical model of the plant, but this model can be useful for fine-tuning.

There are a lot of methods relevant to control of automatic doors, for instance; PIR sensors, Microcontroller, PID controller. However, the method used is fuzzy Logic, which is considerably a new method to the control of automatic doors, including input-output variables, rule bases, fuzzification, and defuzzification.

Automatic doors exemplify the challenges of designing emotionally welcoming interactive systems—a critical issue any system of incidental use [6]. Below, there are all of these descriptions and principles about this subject.

II. PRINCIPLE

In classical systems, the system is checked with electronic sensor by walking toward the door at a moderate speed. When about 5‟ (1524mm) from the opening, it should smoothly start sliding open and then stop without impact. Repeat on the other side of the opening. Move slowly through the door at 6" (152mm) per sec. The door should remain open. (See Figure 1) [1].

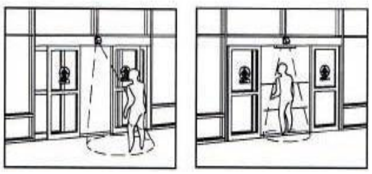

Figure 1: Automatic Door

III. Controller Fuzzy Logic Design

- One of the more recent control systems to gain popularity is the fuzzy logic controller. The fuzzy logic controller's basic principle is to use the If A Then B format to construct the rules that operate the controller in a heuristic fashion. Generally speaking, the components listed below [4] are used to build a fuzzy logic controller, as seen in Figure 2:
- • A rule base, consisting of a series of If-Then rules, that quantifies the expert's verbal explanation of how to attain effective management using fuzzy logic.
- • An inference mechanism, sometimes referred to as a "fuzzy inference" module or "inference engine"),This simulates the expert's judgment in evaluating and putting information regarding the most effective plant control to use.
- A fuzzification interface that translates controller input into data that can be readily utilized by the inference system to activate and apply rules.
- A defuzzification interface that transforms the inference mechanism's conclusions into useful inputs for the procedure.

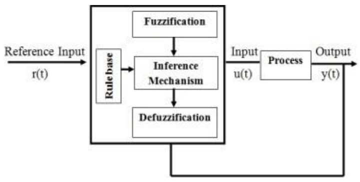

Figure 2: Fuzzy Controller Structure

The creation of the input and output of the membership functions is one of the primary components of the fuzzy logic design process [8]. The membership functions for the input and output are selected using the fundamental triangle and trapezoidal shapes. Most of the time, Control rule characteristics are what primarily affect fuzzy control performance, with membership shapes having a negligible effect [2]. In the process design of fuzzy logic Controller, fuzzy rules are defined for three input variables, and two output variable. Figure 3 shows this output and input variable (input= WS, DD, BMI output = DOS, DOL).

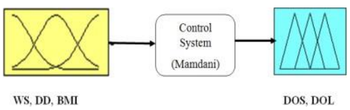

Figure 3

A. INPUT AND OUTPUT VARIABLES

1. Input Variables:

WS: Person"s **W**alking **S**peed [0−50 m/min].

WS=VS (Very Slow) − S (Slow) − M (Medium) − F (Fast) − VF (Very Fast)

DD: **D**istance to **D**oor of person [0−6 m]

DD=VC (Very Close) − C (Close) − M (Medium) − A (Away) − To Away (TA)

BMI: **B**ody **M**ass **I**ndex [18.5− 40 kg/m^2]

BMI= UW (Under Weight) − NW (Normal Weight) − OW (Over Weight) − IO (Indicates Obesity) − IO (Intermediate Obesity) − MO (Morbid Obesity)

2. Output Variables:

DOS: The **D**oor **O**pening **S**peed [0−500 rpm].

DOS= VS (Very Slow) − S (Slow) − M (Medium) − F (Fast) − VF (Very Fast)

DOL: The **D**oor **O**pening **L**ength [0−4m]

DOL= NL (Normal Length) − ML (Medium Length) − MAL (Medium−Average Length) − AL (Average Length) − FL (Full Length)

B. MEMBERSHIP FUNCTIONS:

1) For WS:

$$\text{VS};\ \mu v(x) = \begin{cases} \frac{10-}{10}, & 0 \le x \le 10 \\ 0, & x \ge 10 \text{ or } x < 0 \end{cases} \quad (1)$$

$$\text{S};\ \mu(x) = \begin{cases} \frac{x}{10}, & 0 \le x \le 10 \\ \frac{20-x}{10}, & 10 \le x \le 20 \\ 0, & x \ge 20 \text{ or} x < 0 \end{cases} \quad (2)$$

$$\text{M};\ \mu(x) = \begin{cases} \frac{x-10}{10}, & 0 \le x \le 10 \\ \frac{30-}{10}, & 20 \le x \le 30 \\ 0, & x \ge 30 \text{ or } x \le 10 \end{cases} \quad (3)$$

$$\text{F};\ \mu(x) = \begin{cases} \frac{x-25}{10}, & 25 \le x \le 35 \\ \frac{45-x}{10}, & 35 \le x \le 45 \\ 0, & x \le 25 \text{ or } x \ge 45 \end{cases} \quad (4)$$

$$\text{VF};\ \mu_{VF}(x) = \begin{cases} 0, & x \le 40 \\ \frac{x-40}{10}. & 40 < x < 50 \end{cases} \quad (5)$$

2) For DD

$$\text{VC};\ \mu_{VC}(y) = \begin{cases} 1-y, & 0 \le y \le 1 \\ 0, & y \ge 1 \text{ or } y < 0 \end{cases} \quad (6)$$

$$C;\ \mu(y) = \begin{cases} ,\ 0 \le y \le 1 \\ 2 - y\ ,\ 1 \le y \le 2 \\ 0\ ,\ y \ge 2 \end{cases} \quad (7)$$

$$M;\ \mu(y) = \begin{cases} y - 1.5\ ,\ 1.5 \le y \le 2.5 \\ 3.5 - y\ ,\ 2.5 \le y \le 3.5 \\ 0\ ,\ y \ge 3.5\ or\ y \le 1.5 \end{cases} \quad (8)$$

$$A;\ \mu(y) = \begin{cases} y - 2.5\ ,2.5 \le y \le 3.5 \\ 4.5 - y\ ,3.5 \le y \le 4.5 \\ 0\ ,y \ge 4.5\ or\ y \le 2.5 \end{cases} \quad (9)$$

$$TA;\ \mu_T(y) = \begin{cases} 0\ ,\ y \le 5 \\ y - 5\ ,\ 4 \le y \le 6 \end{cases} \quad (10)$$

3) *For BMI*

$$UW;\ \mu_{UW}(z) = \begin{cases} \frac{18.5 - z}{18.5}\ ,0 \le z \le 18.5 \\ 0\ ,\ z \ge 18.5\ or\ z < 0 \end{cases} \quad (11)$$

$$NW;\ \mu_N(z) = \begin{cases} \frac{z}{18.5}\ ,0 \le z \le 18.5 \\ \frac{24.9 - z}{18.5}\ ,18.5 \le z \le 24.9 \\ 0\ ,z \ge 24.9\ or\ z < 0 \end{cases} \quad (12)$$

$$OW;\ \mu_O(z) = \begin{cases} \frac{z - 18.5}{18.5}\ ,18.5 \le z \le 24.9 \\ \frac{29.9 - z}{18.5}\ ,25 \le z \le 29.9 \\ 0\ ,z \ge 29.9\ or\ z \le 18.5 \end{cases} \quad (13)$$

$$IO;\ \mu_I(z) = \begin{cases} \frac{z - 25}{25}\ ,25 \le z \le 29.9 \\ \frac{34.9 - z}{25}\ ,30 \le z \le 34.9 \\ 0\ ,z \ge 34.9\ or\ z \le 25 \end{cases} \quad (14)$$

$$IO;\ \mu_I(z) = \begin{cases} \frac{z - 30}{30}\ ,30 \le z \le 34.9 \\ \frac{39.9 - z}{30}\ ,35 \le z \le 39.9 \\ 0\ ,z \ge 39.9\ or\ z \le 30 \end{cases} \quad (15)$$

$$,z \le 40$$

$$S;\ \mu(a) = \begin{cases} \frac{a - 50}{100}\ ,50 \le a \le 150 \\ \frac{250 - a}{100}\ ,150 \le a \le 250 \\ 0\ ,a \ge 250\ or\ a \le 50 \end{cases} \quad (18)$$

$$M;\ \mu(a) = \begin{cases} \frac{a - 200}{100}\ ,200 \le a \le 300 \\ \frac{400 - a}{100}\ ,300 \le a \le 400 \\ 0\ ,a \ge 400\ or\ a \le 200 \end{cases} \quad (19)$$

F;

$$\mu(a) = \begin{cases} \frac{a - 350}{100}\ ,350 \le a \le 450 \\ \frac{550 - a}{100}\ ,450 \le a \le 550 \\ 0\ ,a \ge 550\ or\ a \le 350 \end{cases} \quad (20)$$

VF;

$$\mu_{VF}(a) = \begin{cases} 0\ ,0 \le a \le 400 \\ \frac{a - 400}{100}\ ,400 \le a \le 500 \end{cases} \quad (21)$$

5) *For DOL*

$$NL;\ \mu_N(b) = \begin{cases} 1 - b, 0 \le b \le 1 \\ 0, b \ge 1\ or\ b < 0 \end{cases} \quad (22)$$

$$ML;\ \mu_{ML}(b) = \begin{cases} ,\ 0 \le b \le 1 \\ 2 -\ ,\ 1 \le b \le 2 \\ 0\ ,\ b \ge 2 \end{cases} \quad (23)$$

MAL;

$$\mu_{MAL}(b) = \begin{cases} b - 0.5\ ,\ 0.5 \le b \le 1.5 \\ 2.5 -\ ,\ 1.5 \le b \le 2.5 \\ 0\ ,\ b \ge 2.5\ or\ b \le 0.5 \end{cases} \quad (24)$$

AL;

$$\mu_{AL}(b) = \begin{cases} b - 1\ ,\ 1 \le b \le 2 \\ 3 - b\ ,\ 2 \le b \le 3 \\ 0\ ,\ b \ge 3\ or\ b \le 1 \end{cases} \quad (25)$$

FL;

$$\text{MO; } \mu_{MO}(z) = \{\frac{z-40}{10}, z \geq 40 \quad (16) \qquad \mu_F(b) = \begin{cases} b-2, & 2 \leq b \leq 3 \\ 4-b, & 3 \leq b \leq 4 \\ 0, & b \geq 4 \text{ or } b \leq 2 \end{cases} \quad (26)$$

4) For DOS

$$\text{VS; } \mu_V(a) = \begin{cases} \frac{100-a}{100}, & 0 \leq a \leq 100 \\ 0, & a \geq 100 \end{cases} \quad (17)$$

The decision of fuzzy logic and its high impact process has multiple sources and controlled. the record. A set of rules contains these. The rules are essentially simple if-then statements that are clear and simple to comprehend because they are Nothing more than Standard English phrases. Common sense, data from everyday use, and controlled experimentation are the sources of the rules used in this paper.
Here, the rule sets that are used to determine the output are:

Table I ULE TABLE

Rule 1: If WS is VS	And DD is TA	And BMI is UW	Then DOS is VS	Then DOL is NL
Rule 2: If WS is VS	And DD is A	And BMI is NW	Then DOS is VS	Then DOL is NL
Rule 3: If WS is VS	And DD is M	And BMI is OW	Then DOS is S	Then DOL is ML
Rule 4: If WS is VS	And DD is C	And BMI is IO	Then DOS is S	Then DOL is MAL
Rule 5: If WS is VS	And DD is VC	And BMI is IO	Then DOS is M	Then DOL is AL
Rule 6: If WS is VS	And DD is TA	And BMI is MO	Then DOS is S	Then DOL is FL
Rule 7: If WS is S	And DD is TA	And BMI is UW	Then DOS is VS	Then DOL is NL
Rule 8: If WS is S	And DD is A	And BMI is NW	Then DOS is S	Then DOL is ML
Rule 9: If WS is S	And DD is M	And BMI is OW	Then DOS is S	Then DOL is ML
Rule 10: If WS is S	And DD is C	And BMI is IO	Then DOS is M	Then DOL is MAL
Rule 11: If WS is S	And DD is VC	And BMI is IO	Then DOS is F	Then DOL is AL
Rule 12: If WS is S	And DD is A	And BMI is MO	Then DOS is S	Then DOL is FL
Rule 13: If WS is M	And DD is TA	And BMI is UW	Then DOS is S	Then DOL is NL

Rule 14: If WS is M	And DD is A	And BMI is NW	Then DOS is S	Then DOL is ML
Rule 15: If WS is M	And DD is M	And BMI is OW	Then DOS is M	Then DOL is MAL
Rule 16: If WS is M	And DD is C	And BMI is IO	Then DOS is F	Then DOL is AL
Rule 17: If WS is M	And DD is VC	And BMI is IO	Then DOS is F	Then DOL is AL
Rule 18: If WS is M	And DD is M	And BMI is MO	Then DOS is VS	Then DOL is FL
Rule 19: If WS is F	And DD is TA	And BMI is UW	Then DOS is S	Then DOL is NL
Rule 20: If WS is F	And DD is A	And BMI is NW	Then DOS is M	Then DOL is ML
Rule 21: If WS is F	And DD is M	And BMI is OW	Then DOS is F	Then DOL is MAL
Rule 22: If WS is F	And DD is C	And BMI is IO	Then DOS is F	Then DOL is AL
Rule 23: If WS is F	And DD is VC	And BMI is IO	Then DOS is VF	Then DOL is FL
Rule 24: If WS is F	And DD is C	And BMI is MO	Then DOS is VS	Then DOL is FL
Rule 25: If WS is VF	And DD is TA	And BMI is UW	Then DOS is M	Then DOL is ML
Rule 26: If WS is VF	And DD is A	And BMI is NW	Then DOS is F	Then DOL is MAL
Rule 27: If WS is VF	And DD is M	And BMI is OW	Then DOS is F	Then DOL is AL
Rule 28: If WS is VF	And DD is C	And BMI is IO	Then DOS is VF	Then DOL is AL
Rule 29: If WS is VF	And DD is VC	And BMI is IO	Then DOS is VF	Then DOL is FL
Rule 30: If WS is VF	And DD is VC	And BMI is MO	Then DOS is VF	Then DOL is FL

WS- Walking Speed

VS−Very Slow, S−Slow, M−Medium, F−Fast, VF−Very Fast

DD- Distance to Door of person

C−Close, VC−Very Close, M−Medium, A−Away, TA−To Away

BMI- Body Mass Index

UW−Under Weight, NW− Normal Weight, OW− Over Weight, IO− Indicates Obesity, IO−Intermediate Obesity, MO− Morbid Obesity.

DOS: The Door Opening Speed

VS− Very Slow, S− Slow, M− Medium, F− Fast, VF− Very Fast

DOL: The Door Opening Length

NL− Normal Length, ML−Medium Length, MAL− Medium-Average Length, AL− Average Length, FL− Full Length

I. CALCULATIONS

The following are the calculations of rule table. Totally there are 30 rules, for each rules we have 5 different results, totally there are 150 results in which I have highlighted 30 results with calculation.

x=8.3m, y=5.6m, z=15.75 kg/m², a=55rpm, b=0.8m

$$\mu_{VS}(8.3) = \frac{10-8.3}{10} = \frac{1.7}{10} = 0.17$$

$$\mu_T(0.6) = 5.6 - 5 = 0.6$$

$$\mu_{UW}(15.75) = \frac{18.5-15.75}{18.5} = \frac{2.75}{18.5} = 0.148$$

$$\mu_V(55) = \frac{100-55}{100} = \frac{45}{100} = 0.45$$

$$\mu_N(0.8) = 1 - 0.8 = 0.2$$

x=15.2m, y=3.9m, z=20.9 kg/m², a=240rpm, b=1.5m

$$\mu(15.2) = \frac{20-15.2}{10} = \frac{4.8}{10} = 0.48$$

$$\mu(3.9) = 4.5 - 3.9 = 0.6$$

$$\mu_N(20.9) = \frac{24.9-20.9}{18.5} = \frac{4}{18.5} = 0.216$$

$$\mu(240) = \frac{250-225}{100} = \frac{25}{100} = 0.25$$

$$\mu_{ML}(1.5) = 2 - 1.5 = 0.5$$

x=25.75m, y=2.35m, z=26.85 kg/m², a=310rpm, b=2.2m

$$\mu(25.75) = \frac{30-25.75}{10} = \frac{4.25}{10} = 0.425$$

$$\mu(2.35) = 2.35 - 1.5 = 0.85$$

$$\mu_{OW} = \frac{29.9-26.85}{18.5} = \frac{3.05}{18.5} = 0.165$$

$$\mu_M(310) = \frac{400-315}{100} = \frac{85}{100} = 0.85$$

$$\mu_{MAL}(2) = 2.2 - 1.5 = 0.70$$

x=39m, y=1.4m, z=31.3 kg/m², a=400rpm, b=2.8m

$$\mu_F(39) = \frac{45 - 39}{10} = \frac{6}{10} = 0.6$$

$$\mu(1.4) = 2 - 1.4 = 0.6$$

$$\mu_I(31.3) = \frac{34.9 - 31.3}{25} = \frac{3.6}{25} = 0.144$$

$$\mu(400) = \frac{400 - 350}{100} = \frac{50}{100} = 0.5$$

$$\mu_{AL}(2.5) = 3 - 2.8 = 0.2$$

x=46.35m, y=0.6m, z=36.1 kg/m², a=480rpm, b=4m

$$\mu_{VF}(46.35) = \frac{46.35 - 40}{10} = \frac{6.35}{10} = 0.635$$

$$\mu_{VC}(0.6) = 1 - 0.6 = 0.4$$

$$\mu_I(36.1) = \frac{39.9 - 36.1}{30} = \frac{3.8}{30} = 0.126$$

$$\mu_{VF}(480) = \frac{480 - 400}{100} = \frac{80}{100} = 0.8$$

$$\mu_F(4) = 4 - 4 = 0$$

I. CONCLUSION

An application of fuzzy lgorithms in the design of the fuzzy sets for the fuzzy logic controller of the Automatic door has been investigated. This situation analysis ability has been incorporated in the door Which makes the door much more automatic and This process of designing and implementation controlled. Arrangement. Though process of the design is automatic. Despite its extreme simplicity, this demonstrates the benefits of integrating a fuzzy logic controller with a traditional automatic door.

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