Decision Making System for Type of Coffee Drinks by using Fuzzy Logic

San Thiri Aung, Nwe Ni
University of Computer Studies, Yangon
santhiriaung4@gmail.com

Abstract

I*n this system, decision making for the type of coffee drink is implemented by using fuzzy logic. Five types of coffee drinks: coffee with soft instants, coffee with normal instants, coffee latte, coffee espresso and coffee macchiato are considered. There are three instants to mix: milk, fresh milk and coffee powder. Fuzzy decision making system determine the type of coffee drinks according to the ratio of instants. The fuzzy control system consists of three main parts. There are fuzzification, inference engine and defuzzification. Center of Gravity (COG) defuzzification method is used in this system. This paper is implemented by using C# programming language.*

1. Introduction

In general, fuzzy controllers are special expert systems. Each employs a knowledge base, in terms of relevant fuzzy reference rules and appropriate inference engine to solve a given control problem. Many applications show that fuzzy logic controller (FLC) is superior to conventional control algorithms in term of design simplicity and control performance. In particular, the FLC methodology appears very appealing when the processes are too complex for analysis by conventional quantitative techniques or when the available sources of information are interpreted qualitatively, inexactly or uncertainly[1].

Fuzzy control provides a formal methodology for representing, manipulation and implementation a human's heuristic knowledge about how to control system. Control systems are everywhere around us and within us. Fuzzy systems have been used in a wide of applications in business, education, engineering, science, medicine, psychology, decision making and other fields.

2. Related Works

Many areas of applications can be used by fuzzy expert system and other theories such as multi-agent, neural or genetic algorithm. Area of robotics is one of the most rapidly developing research and industrial field. Target of this work is to design and to implement multi-agent fuzzy expert system for robotic soccer control. The goal is to provide a proof that connection of multiple methods of artificial intelligence is valid approach to develop a system capable of easy transfer of expert human knowledge and effective recognition of complex game situation [2].

Fuzzy system (FS) is any fuzzy logic-based system where fuzzy logic can be used either as the basis for the representation of different forms of system knowledge or to model the interactions and relationships among the system variables. FSs have proven to be an important tool for modeling complex systems in which, due to complexity or imprecision, classical tools are unsuccessful. Genetic algorithms (Gas) are search algorithms that use operations found in natural genetics to guide the trek through a search space. Gas are theoretically and empirically proven to provide robust search capabilities in complex spaces, offering a valid approach to problems requiring efficient and effective searching [3].

3. Background Theory

3.1 Fuzzy Set

Fuzzy set is a set containing elements that have varying degree of membership in the set. This idea is in contrast with classical or crisp sets because members of a crisp set would not be members unless their membership was full, or complete, in this set. Elements in a fuzzy set, because their membership need not be complete, can also be members of other fuzzy sets on the same universe. Elements of a fuzzy set are mapped to a universe of membership values using a function-theoretic form [4].

3.1.1. Membership Functions. Every element in the universe of discourse is a member of a fuzzy set to some grade, may be even zero. The grade of membership for all its members describes a fuzzy set, Such as Neg. In fuzzy sets elements are assigned a grade of membership, such as the transition from membership to non-membership is gradual rather than abrupt. The set of elements that have a non-zero membership is called support of the fuzzy set. The function that ties a number to each element x of the universe is called the membership function μ(x) [5]. Fuzzy numbers are used very widely in fuzzy logic applications. There are many fuzzy numbers. Following are some fuzzy numbers;

1. Triangular Fuzzy Numbers
2. Trapezoidal Fuzzy Numbers

A triangular fuzzy number A is defined as by the membership function as shown in Figure 1.

$$\alpha = F_A(x) = \begin{cases} \dfrac{x-a_1}{a_M - a_1} & \text{for } a_1 \le x \le a_M \\ \dfrac{x-a_2}{a_M - a_2} & \text{for } a_M \le x \le a_2 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where [a_1, a2] is the supporting interval and the point (a_M,1) is the peak.

$$\alpha = \frac{a_1^{(\alpha)} - a_1}{a_M - a_1} \quad and \quad \alpha = \frac{a_2^{(\alpha)} - a_2}{a_M - a_2}$$

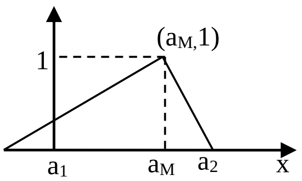


Figure 1. Triangular Fuzzy Set

To find the α-level intervals, setting in
$x^1 = a_1^{(\alpha)}$ for $a_1 \le x \le a_M$ and
$x^r = a_2^{(\alpha)}$ for $a_M \le x \le a_2$ gives.

A trapezoidal fuzzy number is shown in Figure 2.

$$\alpha = F_\alpha(x) = \begin{cases} \dfrac{x-a_1}{a_1^{(1)} - a_1} & \text{for } a_1 \le x \le a_1^{(1)} \\ 1 & \text{for } a_1^{(1)} \le x \le a_2^{(1)} \\ \dfrac{x-a_2}{a_2^{(1)} - a_2} & \text{for } a_2^{(1)} \le x \le a_2 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

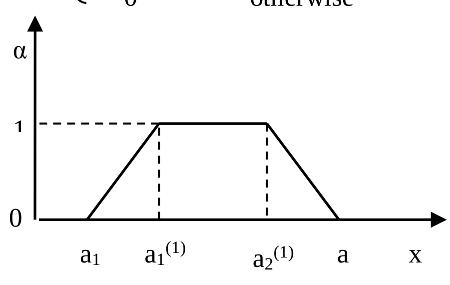


Figure 2. Trapezoidal Fuzzy Set

3.2. Fuzzy Control

The fuzzy controller has four main components (1) the rule-base holds the knowledge, in the form of a set of rules, of how best to control the system. (2) The inference mechanism evaluates which control rules are relevant at the current time and then decide what the input to the plant should be. (3) The fuzzification interface simply modified the inputs so that they can be interpreted and compared to the rules in the rule-base. And (4) defuzzification interface converts the conclusion reached by the inference mechanism into to inputs to the plant [6].

A rule-base (a set of If- Then rules), there are two general properties of fuzzy logic rule-base that are studied. These are "completeness" (i.e... there are conclusions for every possible fuzzy controller input) and "consistency" (i.e.… whether the conclusion that rules make conflict with other's rule conclusion) [6].

The inference mechanism, the inference mechanism has two basic tasks: (1) determining the extent to which each rule is relevant to the current situation as characterized by the inputs μ_i, i = 1, 2,…, n (we call this task "matching"); and (2) drawing conclusions using the current inputs μ_i and the information in the rule-base (we call this task an "inference step") [6].

The fuzzification interface, Fuzzy sets are used to quantify the information in the rule-base, and the inference mechanism operates on fuzzy sets to produce fuzzy sets; hence, we must specify how the fuzzy system will convert its inputs $\mu_i \in U_i$ into fuzzy sets (a process called "fuzzification") [6].

The defuzzification interface, a number of defuzzification strategies exist, and it is not hard to invent more. Each provides a means to choose a single output (which we denote with y_q^{crisp}) based on either the implied fuzzy sets or the overall implied fuzzy set (depending on the type of inference strategy chosen) [6].

Among defuzzification techniques: Center of gravity (COG) gravity is used the crisp output value in this system.

Center of gravity (COG): A crisp output is chosen using the center of area and of each implied fuzzy set, and is given by

$$y_q^{crisp} = \frac{\sum_{i=1}^{R} b_i^q \int y_q \mu B_q^i(y_q) dy_q}{\sum_{i=1}^{R} \int y_q \mu B_q^i(y_q) dy_q} \quad (3)$$

where R is the number of rules, b^q_i is the center of area of the membership function of B^p_q associated with the implied fuzzy set for the rule (j,k,…,l,p,q)

$$\int_{yq} \mu_{B^i_q}(y_q) = dy_q$$

The area under COG can be easy to compute since it is often easy to find closed-form expressions for , which is the area under a membership function. The fuzzy system must be defined

$$\sum \int_{yq} \mu_{B}{}^{i}{}_{q}\,(y_q) \quad dy_q \neq 0i$$

for all μ_i or y_q ^{crisp} will not be properly defined.

A center of gravity (C/G) control system for a vehicle includes sensors to measure the center of gravity shift and mass shift of the human body in relation to the vehicle, a controller to determine outputs, a dynamically adjustable vehicle system, and a power supply: The main advantages of the method is that the response of the measurement system to random deviations in the parameters is reduced by an order of magnitude, particularly from errors in setting the item.

4. The Proposed System Architecture

This system will accept the amount of fresh milk, milk and coffee powder as the input values to make fuzzification. After defining the related fuzzy set values, membership values can be achieved and viewed in the text format as required. In the view of inference mechanism, fuzzy conclusion can be made by matching with Rule-base. All of the outputs from the individual rules are combined into one term called the Logical Sum. This Logical Sum is analyzed. Consequently, these fuzzy conclusions can be defuzzificated to set crisp value by means of COG (Center Of Gravity) defuzzification methods. Finally, the crisp value that interfaces with the output device of the system will be obtained. Step by step procedure of the proposed system is shown in figure 3. Example membership functions for milk, coffee powder and fresh milk are shown in figure 4, 5, 6 and 7. Fresh milk fuzzy set is defined by triangular input membership functions with seven linguistic variables, labeled very less instants 2 (VLI2), very less instants 1(VLI1), less instants (LI), normal (N), more instants (MI), very more instants1 (VMI1) and very more instants 2 (VMI2). Milk fuzzy set is defined by triangular input membership functions with two linguistic variables, labeled very milk1 (M1) and milk2 (M2). Coffee powder fuzzy set is defined by triangular input membership functions with two linguistic variables, labeled very powder1 (P1) and powder2 (P2). Due to the Fuzzy Logic Control (FLC), the type of coffee and the strong of coffee are able to calculate. This thesis is a simulation program which determines the type of coffee and calculates the strong of coffee. In this thesis, the amounts of input instants are restricted and only the five type of coffee. In the fuzzification step, this system is used triangular input membership functions.

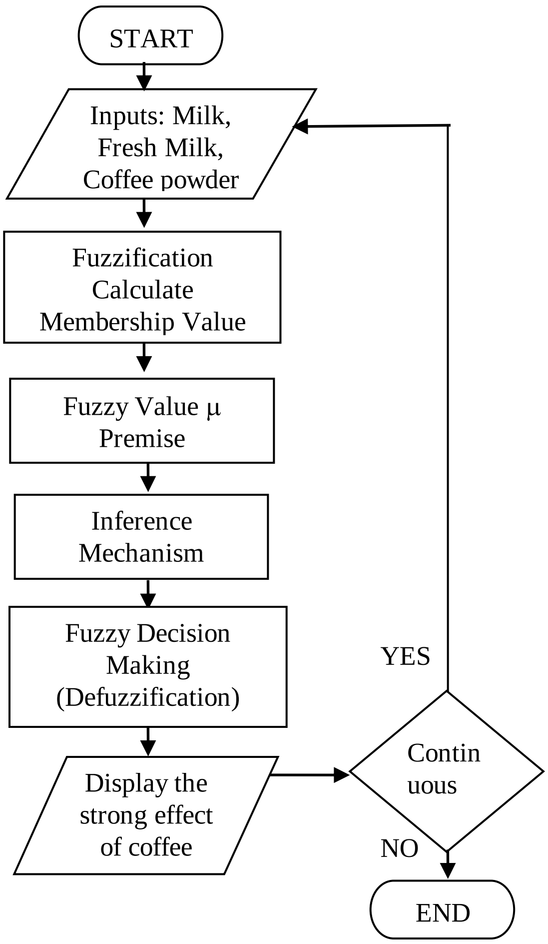


Figure 3. System Flow Chart

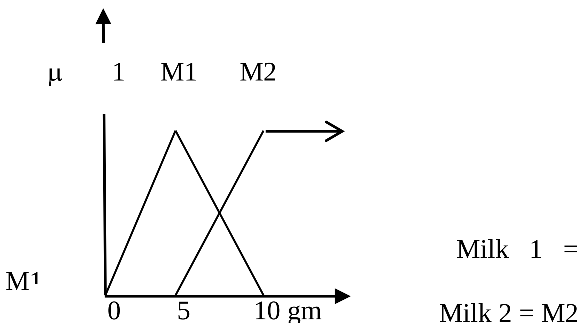
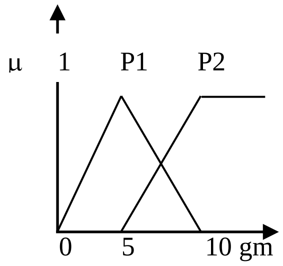
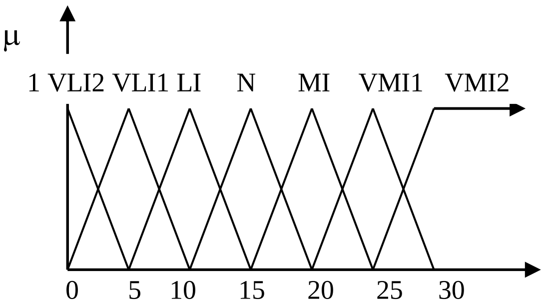


Figure 4. Membership Function of Milk



Coffee Powder1=P1
Coffee Powder2=P2

Figure 5. Membership Function of Coffee Powder



Very Less Instants2 =VLI2
Very Less Instants = VLI1
Less Instants = LI
Normal = N
More Instants = MI
Very More Instants1 =VMI1
Very More Instants 2 =VMI2

Figure 6. Membership Function of Fresh Milk

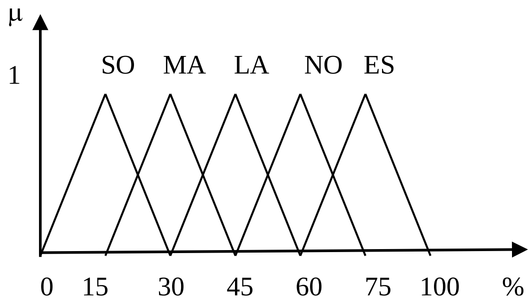


Figure 7. .Membership Function of Strong Effect of Coffee

Coffee with Soft Instants = SO
Coffee Macchiato =MA
Coffee Latte = LA
Coffee with Normal Instants =NO
Coffee Espresso = ES

Table1. Fuzzy Logic Control Rules

Milk	Fresh Milk	Coffee Powder	Type of Coffee
M1	VLI2	P1	N
M1	VLI1	P1	L
M1	LI	P1	M
M1	N	P1	S
M1	MI	P1	S
M1	VMI1	P1	S
M1	VMI2	P1	S
M1	VLI2	P2	E
M1	VLI1	P2	N
M1	LI	P2	N
M1	N	P2	L
M1	MI	P2	S
M1	VMI1	P2	M
M1	VMI2	P2	S

Table 2. Fuzzy Logic Control Rules

Milk	Fresh Milk	Coffee Powder	Type of Coffee
M2	VLI2	P1	N
M2	VLI1	P1	L
M2	LI	P1	M
M2	N	P1	S
M2	MI	P1	S
M2	VMI1	P1	S
M2	VMI2	P1	S
M2	VLI2	P2	N
M2	VLI1	P2	N
M2	LI	P2	N
M2	N	P2	L
M2	MI	P2	S
M2	VMI2	P2	M
M2	VMI1	P2	S

5. Experimental Result

At the start of this system, main form will be displayed as in Figure 8. In this form, there is an input menu at the top of the form. If the user wants to put the inputs to the system, the user must click this menu. Figure9. Is this input form. The user must enter the three inputs: milk, fresh milk and coffee powder. And the fuzzification button is to continue the next form: fuzzification. After the user clicks the fuzzification button, user can view as shown in Figure10. This form will be shown the linguistic variables and membership value of the according inputs.

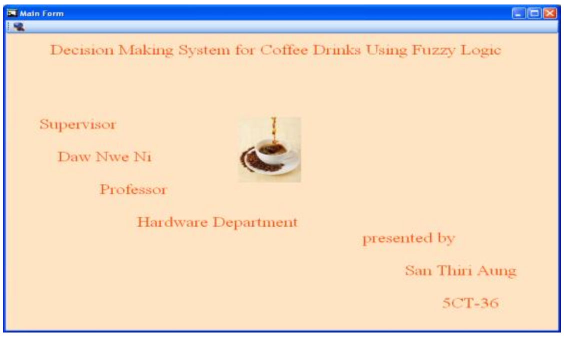


Figure 8. Main Interface Form

Figure 9. Inputs Form for Coffee With Normal Instants

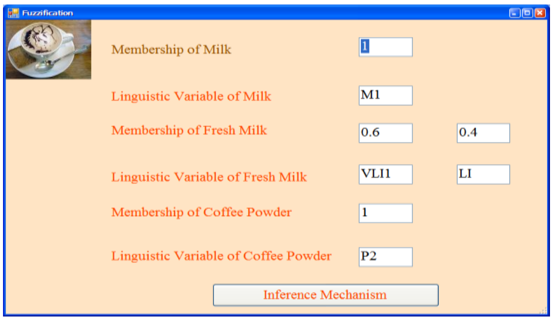


Figure 10. Membership Value and Fuzzy Sets of Inputs

6. Analysis between Coffee with Normal Instants and Coffee Espresso

For milk 5 gm, fresh milk 5gm and coffee powder is 10 gm, this system describes as the Normal instant coffee type shown in Figure 11 and its strong effect of coffee is 60%. For milk 13 gm, fresh milk 13 gm and coffee powder is 10g coffee Espresso type shown in Figure 12 and the strong effect of coffee is 75%. According to the ratio of the instants, the strong of coffee for coffee espresso is stronger than coffee with normal instants.

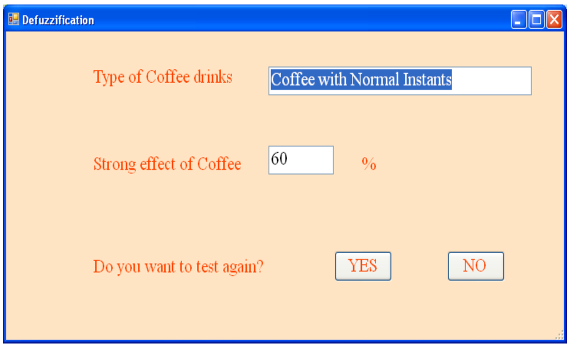


Figure 11. Defuzzification Form

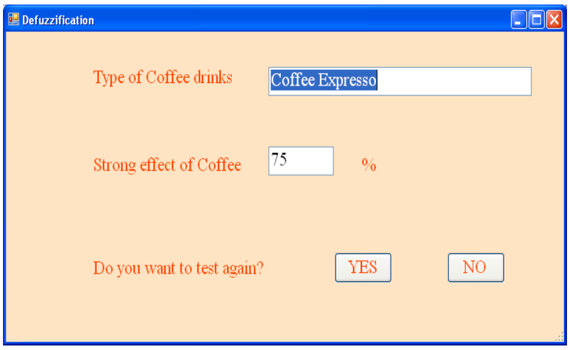


Figure 12. Defuzzification Form

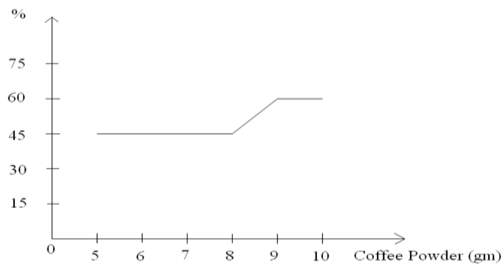


Figure 13. The Percentage of Coffee Powder Contents With Varied Coffee Powder

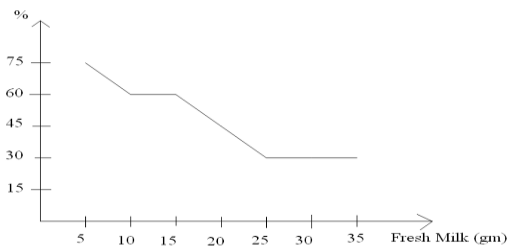


Figure 14. The Percentage of Coffee Powder Contents with Varied Fresh Milk

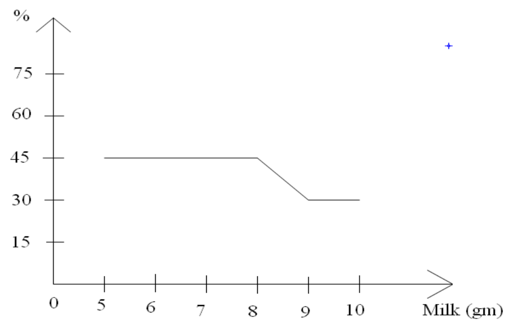


Figure 15. The Percentage of Coffee Powder Contents with Varied Milk

The resulted percentages of coffee powder containing in the mixture (coffee powder, fresh milk and milk) in different ratio of contents are shown in Figure 13, 14 and 15. In Figure 13, the amount of milk and fresh milk are fixed (milk is 5g and fresh milk is 10g) and the amount of coffee powder is varied (between 5g and 10g). In this case, the result percentage of coffee powder containing in the mixture is the same for the range of coffee powder contents 5g to 9g and the percentage is gradually increasing when the coffee powder is greater than 9g.In Figure 14, the content amount of milk and coffee powder are fixed (5g and 10g) and the amount of fresh milk is varied (between 5g and 35g). In this case, the result percentages of coffer powder content in the mixture are significantly varying based on the fresh milk contents. The more the fresh milk content contains, the less the percentage of coffee powder content is. In Figure 15, the content ratios of fresh milk and coffee powder are fixed (20g and 10g) and milk is varied (between 5g and 10g). In this case, the percentage contents of slightly varying based on the milk content.

7. Conclusion

This system is fuzzy decision making for type of coffee drinks and is developed in C# programming language. In this system, to mix a coffee drinks there are three input: milk, fresh milk and coffee powder. Meaningful Effectiveness of determine the strong of coffee depend upon the fuzzy logic the Rule which is constructed. Construction of Rule-base of fuzzy system is based on the advice and knowledge of the experts. The fuzzy output variable, the strong effect of coffee, will use five fuzzy variables on the normalized universe, 0 to 90 %. The output type of coffee are with soft instants (SO), coffee macchiato (MA), coffee latte (LA), coffee with normal instants (NO) and coffee espresso (ES). If user provides exact constant ratios for Coffee Espresso, Coffee Macchiato (MA), Coffee Latte, this system can decide the correct type of coffee. Otherwise, if user inputs the ratios which not exact ratios, the system can also efficiently decided with strong effect of coffee. In this system, Center of Gravity method is applied for defuzzification. So the strong effect of coffee containing in the mixture will be decided by using fuzzy logic.

8. References

[1] B. Philip, "Fuzzy Logic Control of Syrup Mixing Process in Beverage Production", Leonardo Journal of Science, ISSN 1583-0233, pp.93-108, July-December 2007.

[2] H. Daniel, "Multi-Agent Fuzzy Control of the Robotic Soccer", January 2007.

[3] H. Francisco and M. Luis, "Genetic Fuzzy Systems".

[4] J.R. Timothy, "Fuzzy Logic with Engineering Applications".

[5] J.Jan, "Design of Fuzzy Controllers", Aug 1998.

[6] M.P.Kevin and Y.Stephen, "Fuzzy Control".

[7] K.M.Passino and S. Yurkovich “Fuzzy Control” An imprint of Addsion-Wesley Longman.Inc., Columbus, Ohio State University, July 1997.

[8] M. Bojadziev and G. Bojadziev “Fuzzy Sets, Fuzzy Logic, Application” Simon Fraser University and British Columbia Institude of Technology Vancouver, Canada, September 1995.