# Computerized Fuzzy Logic Controlled of Syrup Mixing Process

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## Abstract

*Computer-controlled systems are the most interesting in today's world. Fuzzy systems have been used in a wide of application in business, science, medicine, psychology, decision making and other fields. The production of the beverages starts from the preparation of simple syrup (solution of sugar and water). So, this system controls the required amount of water and sugar to get the optimal mixing process. In this system, inputs of membership functions (water and sugar) are used. To get the optimal quality, there are four types of conventional control (zero, low, high, very high) for water and sugar as an output. Both inputs and outputs are analyzed by fuzzy logic control theory. Center of Gravity (CoG) defuzzification method is used in this system. This system is implemented by using C# programming language.*

## 1. Introduction

Fuzzy control provides a formal methodology for representing, manipulation and implementation a human's heuristic knowledge about how to control system. 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 terms of design simplicity and control performance. 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. Thus, FLC may be viewed as an approach combining conventional precise mathematical control and humanlike decision-making. [7].

This paper is structured as follows. We present background theory of fuzzy control system in section 2. In section 3, we present the proposed system architecture section 4 presents implementation of our system and section 5 is conclusion of our system.

## 2. Background Theory

Fuzzy logic captures the human experience of making complex decision based on uncertain or incomplete information, and produces exact results from imprecise data.

A fuzzy logic model with its fundamental input-output relationship consists of four components namely, the fuzzifier, the inference engine, the defuzzifier and a fuzzy rule base.

### 2.1. Fuzzification

The fuzzification is the process which determines the degree of membership of the input values to define fuzzy sets (linguistic variables). The function of fuzzifier is to transform crisp inputs into fuzzy inputs. A fuzzification interface converts controller inputs into information that the interface mechanism can easily use to activate and apply rules.

#### 2.1.1. Fuzzy Sets

A fuzzy set is a set whose elements have degrees of membership. A fuzzy set is represented by a membership function defined on the universe of discourse. The universe of discourse is the space where the fuzzy variables are defined. The fuzzy set is a range of values. Each value has a grade of membership between 0 and 1.

Fuzzy sets are used to quantify the information in the rule-base, and the inference mechanism operates on fuzzy sets to produce fuzzy sets, so how the fuzzy system will converts its numeric input unit into fuzzy sets so that they can be used by the fuzzy system. The concept of a fuzzy set is introduced by first defining a membership function [2].

#### 2.1.2. Membership function

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) [2].

Many types of curves can be used, but triangular or trapezoidal shaped membership functions are the most common because they are easier to represent in embedded controller.

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

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

where $[a_1, a_2]$ is the supporting interval and the point $(a_M, 1)$ is the peak.

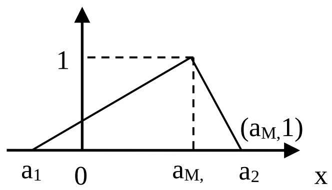



**Figure 1**. Triangular Fuzzy Set

### 2.2. Rule Base

Rule Base contains a fuzzy logic quantification of the expert' linguistic description of how to achieve good control. Linguistic variable describes an input universe of discourse. Fuzzy rules define the relationships between the inputs and outputs [3] [5].

The fuzzy Rule Base is characterized by construction of a set of linguistic rules based on experts' knowledge. The expert knowledge is usually in the form of IF-THEN rules, which can be easily implemented by fuzzy conditional statements.

### 2.3. Inference Mechanism

It also called an "inference engine" or "fuzzy interface" module), which emulates the expert's decision making in interpreting and applying knowledge about how best to control the plant. Inference uses a knowledge base of rules to determine the output sets for the input linguistic values. It computes the actual control signal as a linguistic variable for each set of input single [5] [6].

There are techniques: max-min composition, Max-min method, Geometric average minimum, Scalar product, Max-min Method is used inference engine.

### 2.4. Defuzzification

A defuzzification interface converts the conclusions of the inference mechanism into actual inputs for the process. Defuzzification process is the output of the interface process to derive a single "crisp" output value.

Among defuzzification techniques: Center of Gravity (CoG) method is used the crisp output value in this system.

**2.4.1. Center of Gravity (CoG):** It computes the centroid of the composite are representing the output fuzzy term. It is the most prevalent and physically appealing of all the defuzzification methods. A crisp output is chosen using the center of area and of each implied fuzzy set, and is given by

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

## 3. The propose system architecture

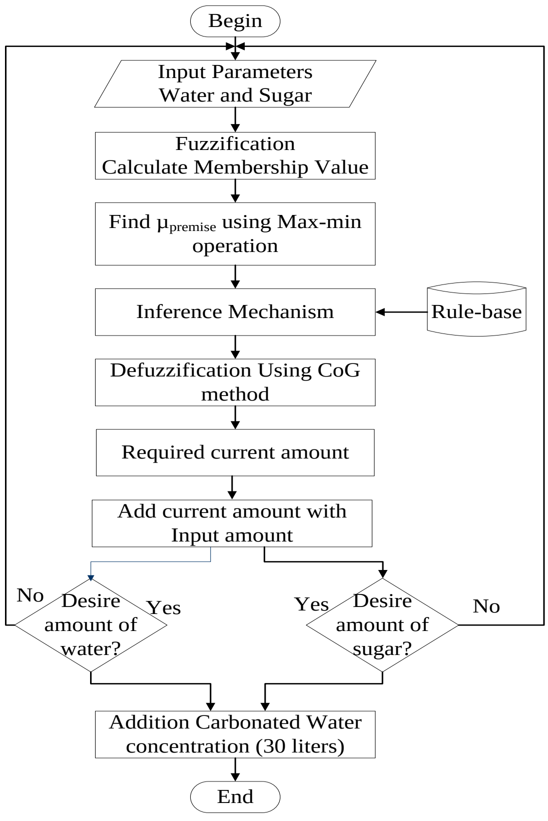
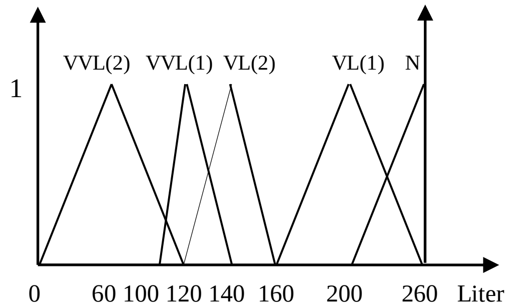



**Figure 2.** System Flow Chart

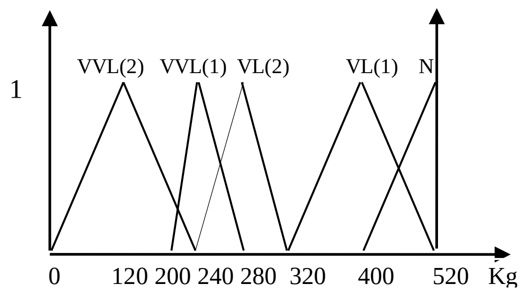
This system will accept the amount of water and sugar as the input values of make fuzzification. After defining the related fuzzy set values, membership values can be achieved and viewed in the text format as required. In the view of inference mechanism, fuzzy conclusion can be made by matching with Rule-base in Table 1. 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 devise of the system will be obtained. Step by step procedure of the proposed system is shown in figure 2.

This system controls the required amount of water and sugar to get the optima mixing process. The optimal output concentration is at most 15 seconds. With the application of fuzzy logic control, a relative short time of 15 seconds is used to get the optimal quality. Example membership functions for water and sugar are shown in figure 3, 4, 5 and 6.




VVL=very very low
VL =very low
N =normal

**Figure 3.** Membership Function of Water

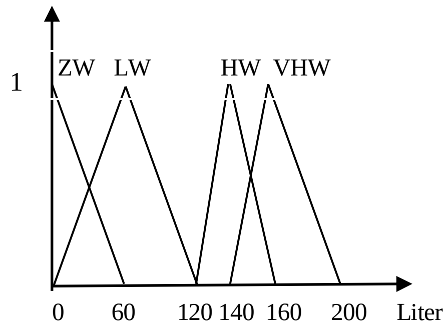



VVL=very very low
VL =very low
N =normal

**Figure 4.** Membership Function of Sugar

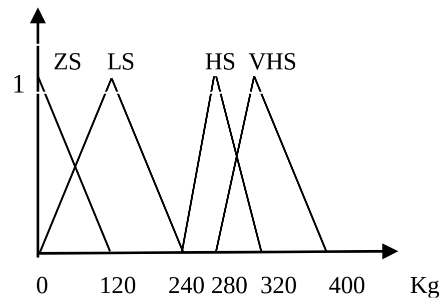
**Table 1.** Fuzzy Logic Control (FLC) Rules

| water / sugar | VVL(2) | VVL(1) | VL(2) | VL(1) | N |
|---|---|---|---|---|---|
| VVL(2) | VHW VHS | HW VHS | LW VHS | LW VHS | ZW VHS |
| VVL(1) | VHW HS | HW HS | LW HS | LW HS | ZW HS |
| VL(2) | VHW LS | HW LS | LW LS | LW LS | ZW LS |
| VL(1) | VHW LS | HW LS | LW LS | LW LS | ZW LS |
| N | VHW ZS | HW ZS | LW ZS | LW ZS | ZW ZS |




ZW =zero water
LW =low water
HW =high water
VHW =very high water

**Figure 5.** Membership Function for Output of Water




ZS =zero sugar
LW =low sugar
HW =high sugar
VHS =very high sugar

**Figure 6.** Membership Function for Output of Sugar

## 4. Experimental Result

In this system, user must firstly enter the amount of water and sugar. The input data is shown in figure 7. If the user wants to see the linguistic variables and membership value of the according input water, they must click the next button. This process form is shown in figure 8.

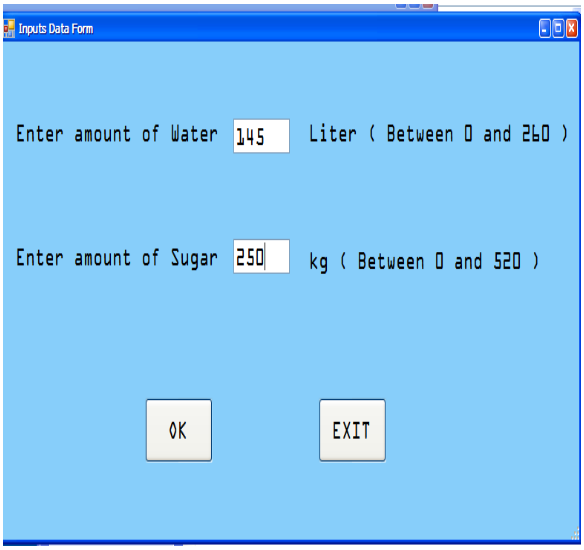



**Figure 7.** Input Form

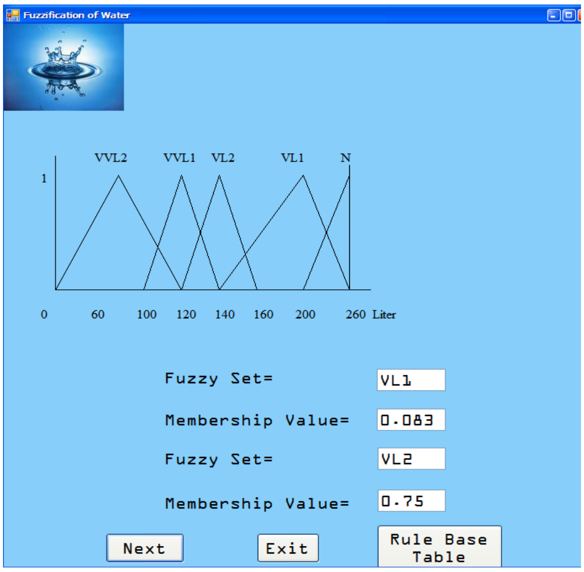



**Figure 8.** Membership Value and Fuzzy Sets of water


**Figure 9.** Membership Value and Fuzzy Sets of Sugar

And then, the user can also view these values for input sugar in the next form as shown in figure 9.

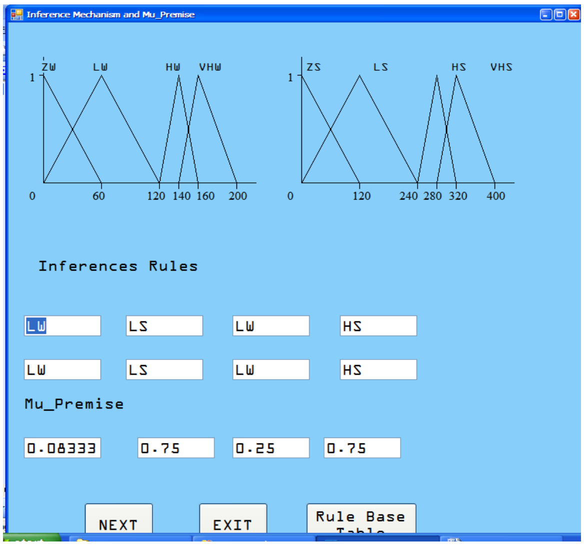



**Figure 10.** Outputs of individual rule

The form shows all of the outputs from the individual rules and premise of each rule by using minimum as shown in figure 10.

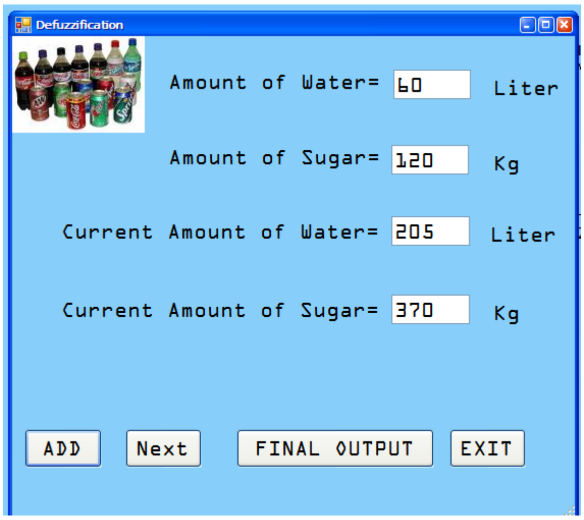



**Figure 11.** Defuzzification Form

The required amount of water and sugar can be viewed in the text box of amount of water and sugar. Then, the user must click the add button, the system can add the current amount with input amount. If this amount doesn't the desired amount, then user will click the next button. Figure 11 is the defuzzification form.


**Figure 12.** Defuzzification Form

If user click the next button, the system will process until the desired amount of water (260 liter) and sugar (520 kg) must be get. The required amount of water and sugar can be viewed in the text box of amount of water and sugar as shown in figure 12.

## 5. Conclusion

This system is computerized fuzzy logic control of syrup mixing process and is developed in C# programming language. Due to the fuzzy logic control (FLC), the required amount of water and sugar are able to calculate. Meaningful effectiveness of determine the required amount of water and sugar depend upon the fuzzy logic the rule which is constructed.

An advantage of fuzzy system is easy to underlying functionality of the system. Basically, there is a focus on the use of rules to represent how to control the plant in fuzzy control rather than ordinary differential equations.

## References


[1] G.J. KLIR AND T.A. FOLGER "Fuzzy Sets, Uncertainty and Information" State University of New York, Binghamton.

[2] H. Hellendoorn and M. Teinfrank "An Introduction to Fuzzy Control", 1996.

[3] J.Ross, Timothy; FUZZY LOGIC WITH ENGINEERING APPLICATIONS, McGRAW.HILL INTERNATIONAL EDITIONS, Electrical Engineering Series.

[4] Kurse, R, Gebhardat, J and Klawon, F "Foundations of Fuzzy Systems,"1994.

[5] L.A. Zadeh "Fuzzy Algorithm", 1968

[6] M. Bojadziev and G. Bojadziev "Fuzzy Sets, Fuzzy Logic, Application" Simon Fraser University and British Columbia Institute of Technology Vancouver, Canada, September 1995.

[7] Stachowicz M. S., Kochanska M. E., Fuzzy Modeling of the process, Proc. Of Second International Fuzzy Systems Association Congress, Tokyo, 1987.