FUZZY LOGIC PROJECT

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COM2536

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ABSTRACT

This project is about one of the applications of fuzzy logic in the field of control; it is about how to measure the percentage of carbon dioxide in soft drinks depending on given pressure and temperature values using fuzzy logic. By implementing the Mamdani inference system method, the percentage of carbon dioxide can be measured in the sugary solution of the fizzy drink. Lastly, we'll obtain a crisp result of whether the drink is good, bad, or anything in between by 'defuzzifying' the output.

INTRODUCTION

In this section we'll explain the foundation of fuzzy logic concept and how we're going to use it in this project.

Fuzzy logic is a form of many-valued logic in which the truth value of variables may be any real number between 0 and 1. It is used to handle the concept of partial truth where the value is neither completely true nor completely false. Fuzzy logic was introduced in 1965 by the Azarian *Lotfi Zade,* considered to be the father of Fuzzy logic. fuzzy logic doesn't mean fuzzy thinking, but it is the method used to predict non-linear systems and uncertain conditions in the real world.

The goal of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing that is a list of if-then statements, called rules. Using those rules, we can determine the state or condition of an object. An example of a fuzzy system would be a water temperature controller: we use rules to define the range within which the water is considered to be cold, cool, normal, hot or very hot.

Fuzzy logic starts with the concept of **fuzzy sets**. A fuzzy set is a set without a crisp, clearly defined boundary. It contains elements with only a partial degree of membership, where traditional logic can have two states – 1 or 0 – fuzzy logic has 1, 0, and everything in between.

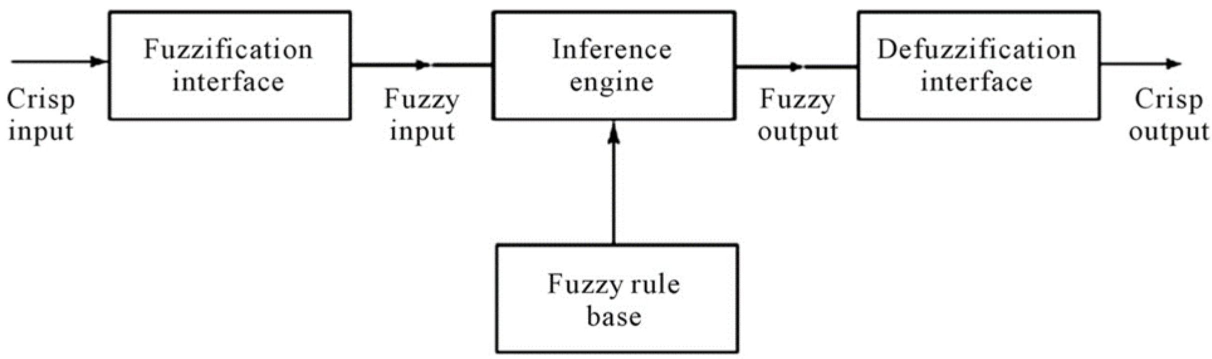
Fuzzy Inference System (FIS):

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made or patterns discerned. There are two main types of FIS, we will be using the **Mamdani inference method.**

Mamdani's method is the most commonly used in applications due to its simplistic structure of 'min-max' operations; It expects the output membership functions to be fuzzy sets. It was proposed in 1975 by the scientist Ebrahim Mamdani and can be implemented as follows:

1. Fuzzify all input values into fuzzy membership functions.
2. Execute all applicable rules in the rule base to compute the fuzzy output functions.
3. Defuzzify the fuzzy output functions to get crisp output values.

The following figure is the fuzzy inference system



As we can see there are four stages for in the fuzzy inference process:

- Fuzzification
- Rule base
- Decision making
- Defuzzification

1. **Fuzzification**

   Fuzzification is the process of converting a crisp set into a fuzzy set using the rule base. Many types of curves and tables can be used, but triangular or trapezoidal-shaped membership functions are the most common since they are easier to represent in embedded controllers.

2. **Rule Base**

   Contains the rules of the fuzzy system which map the truth values to the desired output truth values.

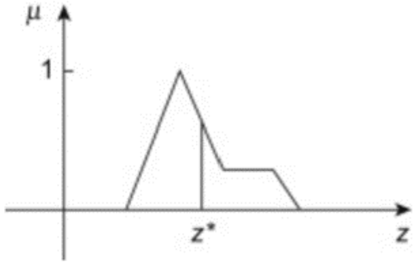
3. **Inference Engine**

   simulates reasoning process by making fuzzy inference on the inputs and IF-THEN rules.

4. **Defuzzification**

   Defuzzification is the process of representing the fuzzy output obtained from the fuzzy inference mechanism as a crisp output. There are several methods to perform this process and the one we're going to use in this project is the **Center of Area method.**

   This method is the most commonly used defuzzification method, it determines the center of the area of the fuzzy set and returns the corresponding crisp value. The following formulas are used to obtain the crisp value:



$$z^* = \frac{\sum \mu_C(\bar{z}) \cdot \bar{z}}{\sum \mu_C(\bar{z})}$$

CONSTRUCTION

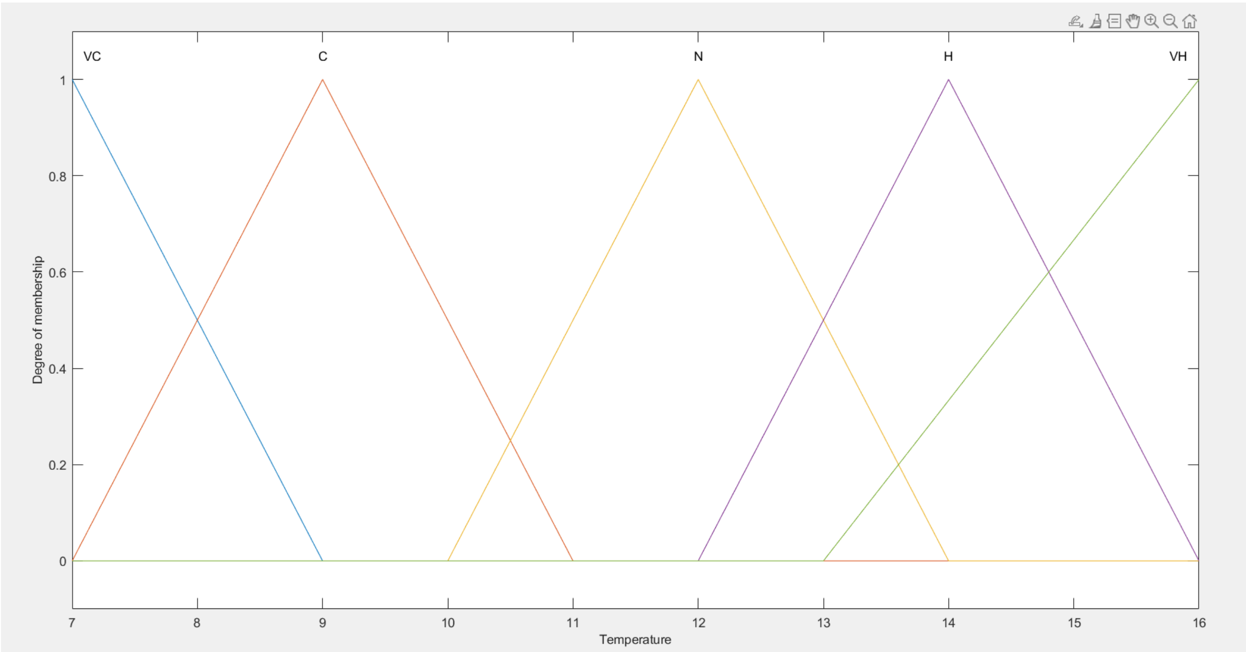
In this project, we will design a control system having two inputs with multiple antecedents using fuzzy logic to determine the percentage of carbon dioxide in a specific Fizzy drink (seven-up) depending on the given temperature and pressure values.

A) Fuzzification of the input variables:

In the fuzzification step we convert the crisp input to a linguistic variable using the membership functions stored in the fuzzy knowledge base.

We have two inputs:

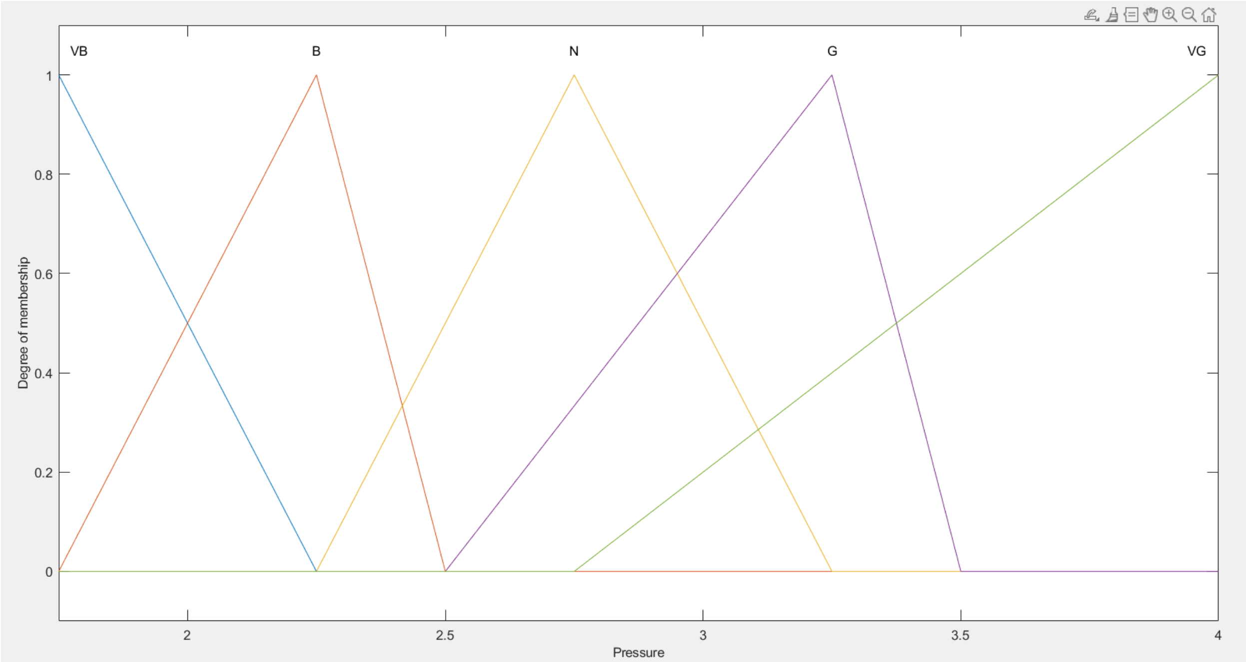
1) <u>Temperature</u>



The figure shows the temperature range is [7 16] and it's defined by five linguistic terms: **Very cold (VC), Cold(C), Normal(N), Hot(H), Very hot (VH).** It is also represented by a triangular membership function.

(Crisp quantity-> fuzzy quantity)

2) <u>Pressure</u>



The figure shows that the pressure range is [1.7 4] and it's defined by five linguistic terms: **Very bad (VB), Bad(B), Normal(N), Good(G), Very good (VG)** also it's represented by a triangular membership function.

B) Fuzzy Knowledge Base:

We have a total of 25 rules come by linguistic terms for Temperature and pressure :

If (Temperature is VC) and (Pressure is VB) then (POCD is N)

If (Temperature is VC) and (Pressure is B) then (POCD is N)

If (Temperature is VC) and (Pressure is N) then (POCD is G)

If (Temperature is VC) and (Pressure is G) then (POCD is VG)

If (Temperature is VC) and (Pressure is VG) then (POCD is VG)

If (Temperature is C) and (Pressure is VB) then (POCD is B)

If (Temperature is C) and (Pressure is B) then (POCD is G)

If (Temperature is C) and (Pressure is N) then (POCD is G)

If (Temperature is C) and (Pressure is G) then (POCD is G)

If (Temperature is C) and (Pressure is VG) then (POCD is VG)

If (Temperature is N) and (Pressure is VB) then (POCD is B)

If (Temperature is N) and (Pressure is B) then (POCD is N)

If (Temperature is N) and (Pressure is N) then (POCD is N)

If (Temperature is N) and (Pressure is G) then (POCD is G)

If (Temperature is N) and (Pressure is VG) then (POCD is VG)

If (Temperature is H) and (Pressure is VB) then (POCD is B)

If (Temperature is H) and (Pressure is B) then (POCD is B)

If (Temperature is H) and (Pressure is N) then (POCD is N)

If (Temperature is H) and (Pressure is G) then (POCD is N)

If (Temperature is H) and (Pressure is VG) then (POCD is G)

If (Temperature is VH) and (Pressure is VB) then (POCD is VB)

If (Temperature is VH) and (Pressure is B) then (POCD is B)

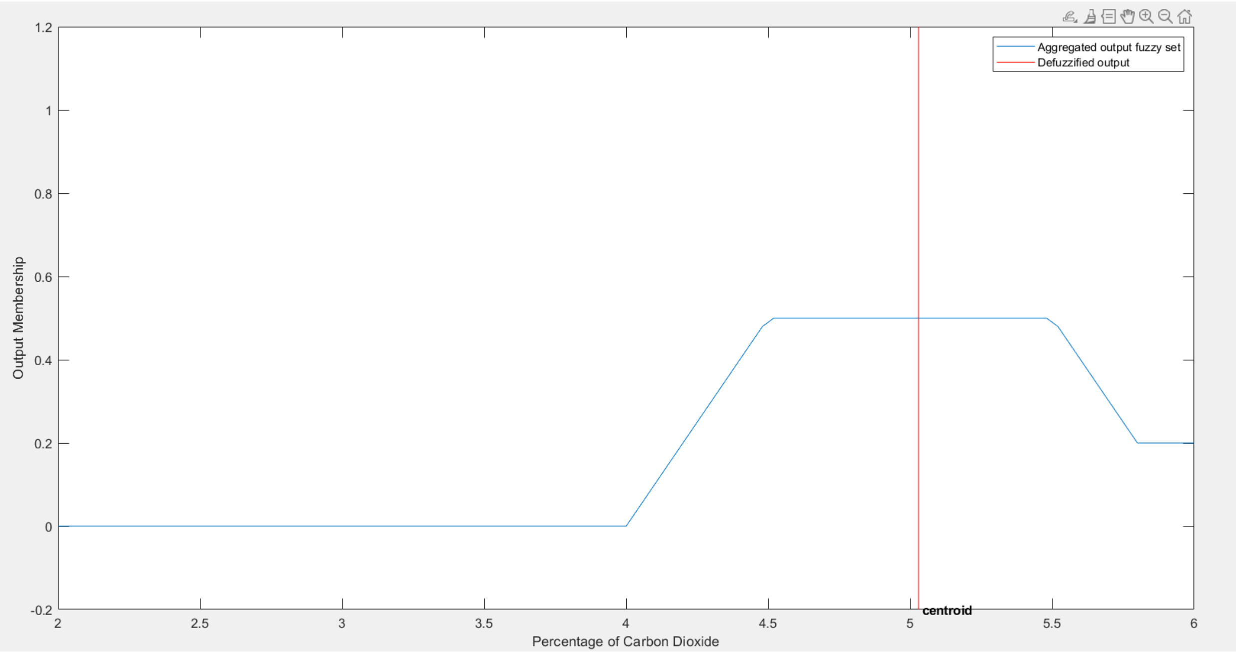
If (Temperature is VH) and (Pressure is N) then (POCD is N)

If (Temperature is VH) and (Pressure is G) then (POCD is N)

If (Temperature is VH) and (Pressure is VG) then (POCD is G)

C) Defuzzification:

In the defuzzification step, we'll convert the fuzzy output we got to a crisp output using the center of area (centroid) defuzzification method, it should return the center of gravity of the fuzzy set output along the x- axis. Let's take an example:

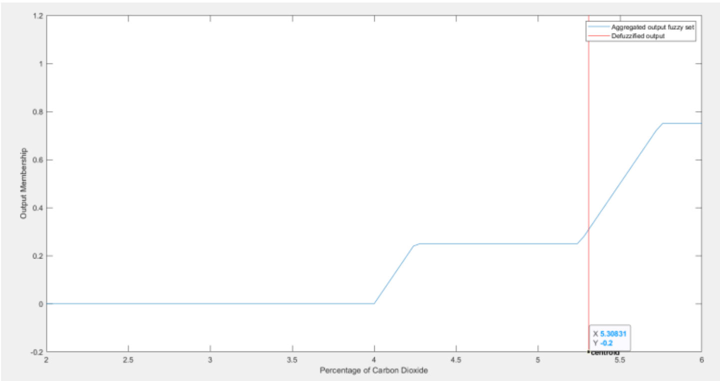


As shown in the figure above, the given temperature and pressure are 3 and 10, respectively. The percentage of carbon dioxide is approximately 5% in fizzy drinks. The blue graph shows our fuzzy output after applying the Mamdani inference method and the red line shows the defuzzification method we applied in order to get a crisp output.

IMPLEMENTATION:

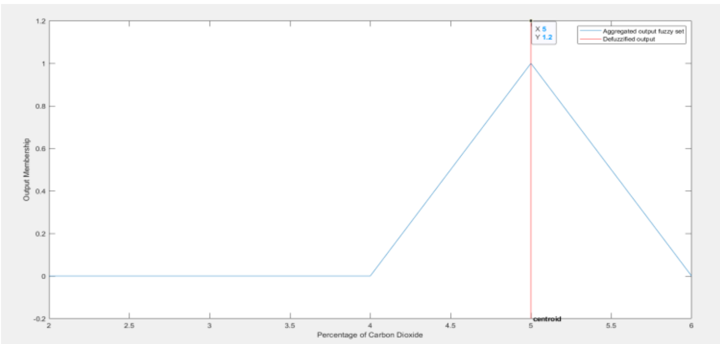
- **Example 1:** In the following graph, the Temperature is 7.5, and the Pressure is 3.25.

The final crisp output is 5.308.



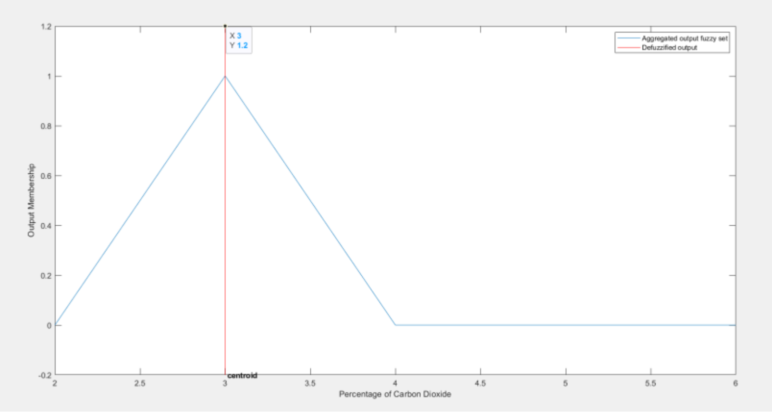
- **Example 2:** Here, the Temperature is 16, and the Pressure is 4.

The final crisp output is 5.



- **Example 3:** Finally, the Temperature is 12, and the Pressure is 1.75

The final crisp output is 3.



Aggregated output fuzzy set
Defuzzified output
X 3
Y 1.2
centroid
Output Membership
Percentage of Carbon Dioxide
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
2
2.5
3
3.5
4
4.5
5
5.5
6