26/01/23

Fuzzy Control System (or) Fuzzy logic System

The block diagram of fuzzy control system is as given below:

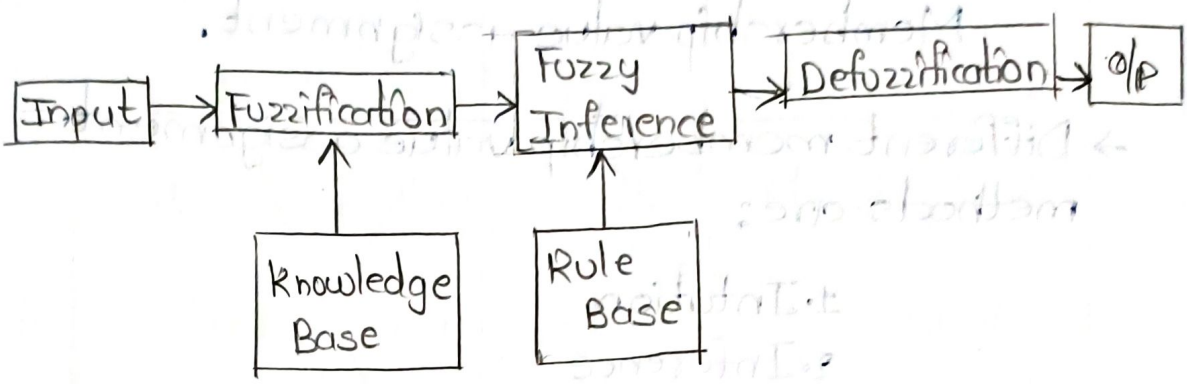


Fig: Block diagram of fuzzy Control System

The main components of a fuzzy logic control system are

1. Fuzzification
2. Fuzzy Inference
3. Defuzzification

1. Fuzzification:

→ Fuzzy logic Controller does not understand Crisp logic (or) Crisp values.

→ It only understands fuzzy membership functions.

→ Fuzzification is defined as conversion of Crisp logic (or) Crisp values into fuzzy membership functions.

The following are the two important steps for the fuzzification process:

Step-1:

Choosing a suitable membership function which is purely depends upon conditions given in application.

Step-2:

Membership value assignment.

→ Different membership value assignment methods are:

1. Intution
2. Inference
3. Rank ordering
4. Angular Fuzzy Membership functions
5. Inductive reasoning

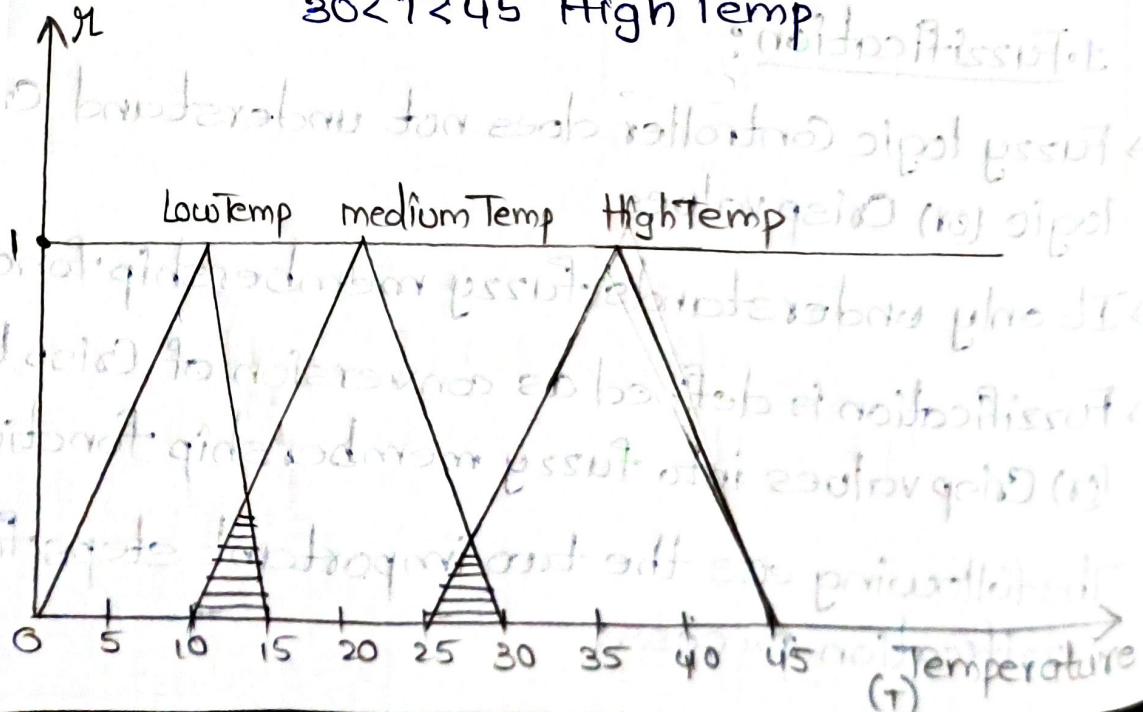
Examples of Fuzzification:-

Example-1:

$0 < T < 15$ LowTemp

$15 < T < 30$ Medium Temp

$30 < T < 45$ High Temp

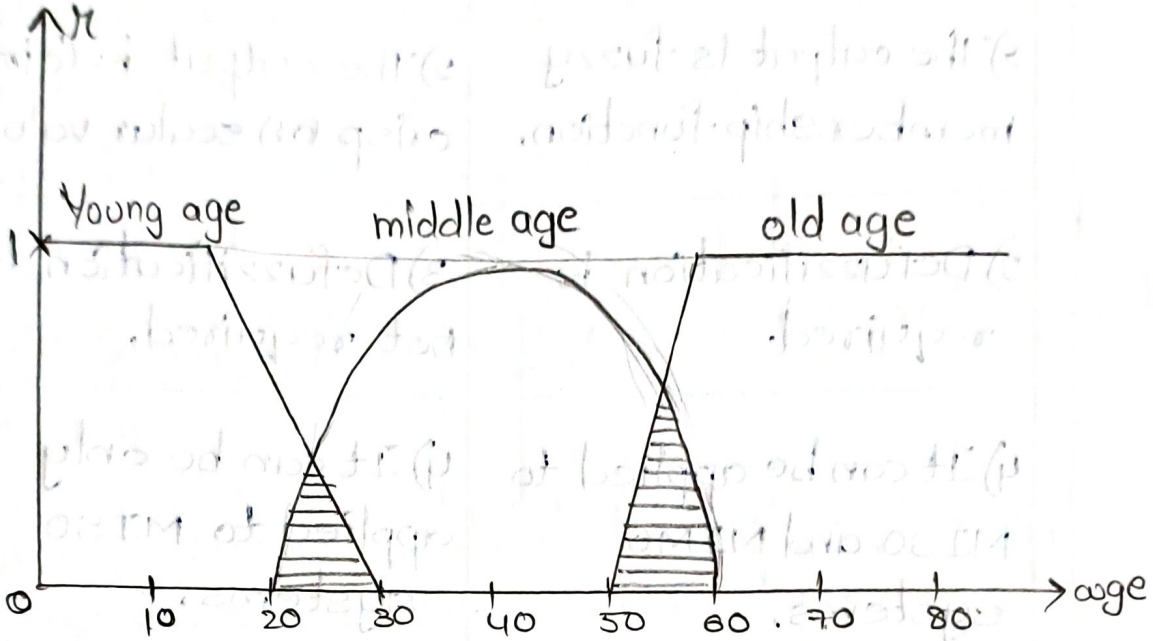


Example-2:

0 < age < 30 Young-age

30 < age < 60 Middle age

age > 60 old age



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2. Fuzzy Inference System (FIS):

→ An FIS is one which will map (or) convert the inputs into the outputs with the help of rules from the "Rule Base".

→ The output of the Fuzzy logic controller may be fuzzy membership functions (or) Crisp value based on the Fuzzy inference system used.

→ The different fuzzy inference systems are:-

1. Mamadani Fuzzy inference System
2. Sugeno Fuzzy inference System.

Mamadani FIS	Sugeno FIS
1) Developed by Scientist E.Mamadani	1) Developed by a scientist T.Sugeno
2) The output is fuzzy membership function.	2) The output is (directly) crisp (or) scalar value.
3) Defuzzification is required.	3) Defuzzification is not required.
4) It can be applied to MISO and MIMO systems.	4) It can be only applied to MISO systems.
5) The design is complex, not flexible.	5) The design is simple and flexible.
6) Applications: medical diagnosis	6) Applications: To find the performance of a aircraft with respect to altitude.

3. Defuzzification:

→ Defuzzification is nothing but conversion of fuzzy membership functions into crisp (or) scalar value.

→ The following are the different methods used for defuzzification process,

1. Maximum membership principle.
2. Mean Max method.
3. Weighted average method.
4. Centroid method
5. Centre of Sums method.

Rule-Based System (or) Development of rule-based system

→ The FIS produces output by implying (or) applying rules from the rule-base on the input member ship function.

→ The fuzzy variables which understand by the fuzzy controller as given below:

S.No	Fuzzy variables	Name
1.	PB	Positive Big
2.	PM	Positive Medium
3.	PS	Positive Small
4.	ZE	zero
5.	NB	Negative Big
6.	NM	Negative Medium
7.	NS	Negative Small

In the rule-base, fuzzy rules are written using simple if and THEN statements.

Syntax:-

IF antecedent THEN consequent

IF antecedent1 THEN consequent1

'n'-no.of rules:

IF Antecedent1 THEN Consequent1
IF Antecedent2 THEN Consequent2
⋮
IF Antecedent n THEN Consequentn.

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Formation of Rules

A set of rules in the rule base is formed using the following statements.

1. assignment statements
2. conditional statements
3. unconditional statements

1. assignment statements:

Assignment statements are those with which the values are assigned in the variables.

It is shown with symbol '='.

These assignment symbols (or) statements are necessary in forming fuzzy values / fuzzy rules.

Ex:-

y = low
sky color = blue
climate = hot
variable A = 5;
p = q + r
temperature = high

The assignment statements found to be restricted to single value.

2. Conditional statements:

In this statements some specific conditions are mentioned.
If the conditions are satisfied then it enters into the loop and executes the necessary information in the loop.

Ex:-

```
IF marks > 50
    THEN PASS

IF speed > 1500
    THEN STOP
```

3. UnConditional Statements:

There is no specific condition that has to be satisfied in this form of statements.
for example, push the button and stop.

Decomposition of Rules

Decomposition of rules is used to represent compound (or) complex rules into simple manner by using fuzzy operations and properties.

The following are the two decomposition rules:

1. multiple conjunctive antecedents
2. multiple disjunctive antecedents

1. multiple conjunctive antecedents:

It make use of one of the fuzzy operation intersection.

let us consider the following example,

If $\tilde{A}_1 \cap \tilde{A}_2 \cap \tilde{A}_3 \cap \dots \tilde{A}_n$ THEN $\tilde{B}_1$

$\mu_{\tilde{A}_R}$ let

$$\tilde{A}_R = \tilde{A}_1 \cap \tilde{A}_2 \cap \dots \tilde{A}_n$$

$$\Rightarrow \mu_{\tilde{A}_R}(x) = \min\left(\mu_{\tilde{A}_1}(x), \mu_{\tilde{A}_2}(x), \dots \mu_{\tilde{A}_n}(x)\right)$$

IF $\tilde{A}_R$ THEN $\tilde{B}$

2. multiple disjunctive antecedents:

It make use of OR operator (or) fuzzy union operator.

let us consider an example,

IF $\tilde{A}_1 \cup \tilde{A}_2 \cup \tilde{A}_3 \cup \dots \tilde{A}_n$ THEN $\tilde{B}$

let

$$\tilde{A}_R = \tilde{A}_1 \cup \tilde{A}_2 \cup \dots \tilde{A}_n$$

$$\Rightarrow \mu_{\tilde{A}_R}(x) = \max\left(\mu_{\tilde{A}_1}(x), \mu_{\tilde{A}_2}(x), \dots \mu_{\tilde{A}_n}(x)\right)$$

IF $\tilde{A}_R$ THEN $\tilde{B}$.

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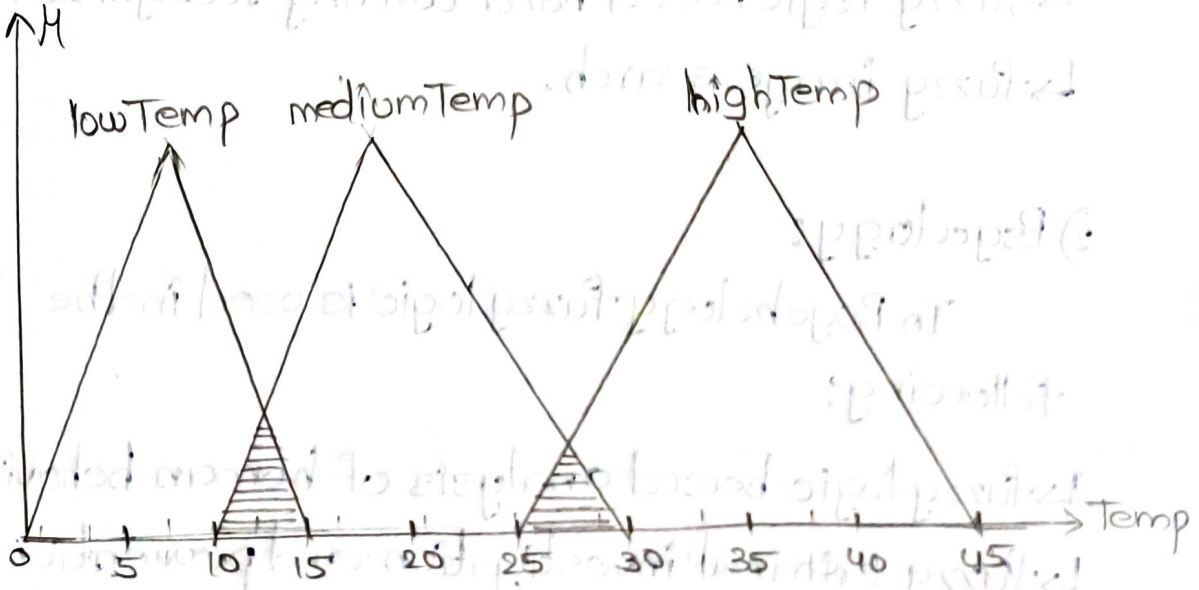
Linguistic Variables

A normal variable can store only numerical value, character (or) integer, but statements cannot be stored.

A linguistic variable is one which doesnot store any numerical value but only stores words or sentences in a natural or artificial language.

Ex:-

$0 < T < 15$ lowTemp
$15 < T < 30$ mediumTemp
$30 < T < 45$ highTemp



Linguistic variable:

Temperature = {lowTemp, mediumTemp, highTemp}

* A linguistic variable can also be defined as a fuzzy set of different fuzzy sets.

Linguistic variable is characterized by

$(X, T(x), U, G, M)$

where,

X = name variable

T(x) = values of linguistic variable

U = Universe of Discourse

M = Set of all semantic conditions. (low)

G = Set of syntax condition.

Applications of fuzzy logic Controller

There are various areas of fuzzy logic applications.

1) Pattern recognition and classification:

↳ fuzzy logic based speech recognition.

↳ fuzzy logic based hand writing recognition

↳ fuzzy image search.

2) Psycology:

In Psychology fuzzy logic is used in the following:

↳ fuzzy logic based analysis of human behaviour.

↳ fuzzy criminal investigation and prevention based on fuzzy logic reasoning.

3) Transportation:

↳ train schedule control

↳ train braking and stopping

4) electronics:

↳ fuzzy controllers is used in air controller systems washing machines, micro wave, etc.

5) Finance:

↳ The fuzzy logic controller is used in finance to stock market prediction and fund management.

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Fuzzy Decision Making

It is an activity which includes the steps to be taken for choosing a suitable alternative from the available for certain goal.

The following are the three important steps to be followed for fuzzy decision making.

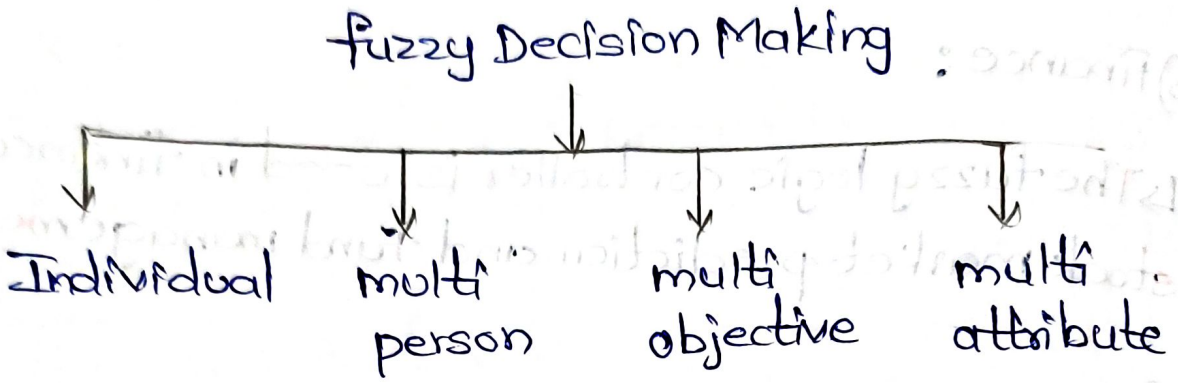
Step-1: Determining the set of alternatives.
In this step, the alternatives are different solutions from which the decisions has to be taken must to be determined.

Step-2: Evaluating of alternatives.
Here the alternatives must be evaluated so that the decision can be taken about one of the alternatives.

Step-3: Comparition between alternatives.
In this step, comparision between the evaluated alternatives is done to find the best alternative

(or) solution.

Different fuzzy decision making methods are given below.



1. Individual Decision making:

In this type of decision making a single person is responsible for taking decisions.

2. multi person decision making:

In this type of decision making expert knowledge from various persons is utilize to make decisions.

3. multi objective decision making:

This decision making is used when several objectives are to be realized.

It is important to acquire proper information related to the satisfaction of the objectives by various alternatives.

4. multi attribute decision making:

It takes place when the evaluation of

alternatives can be carried out based on several attributes of the object.

- the attributes can be numerical datas, linguistic datas, qualitative datas.