6. FUZZY LOGIC SYSTEMS

Fuzzy Logic Systems (FLS) produce acceptable but definite output in response to incomplete, ambiguous, distorted, or inaccurate (fuzzy) input.

What is Fuzzy Logic?

Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO.

The conventional logic block that a computer can understand takes precise input and produces a definite output as TRUE or FALSE, which is equivalent to human's YES or NO.

The inventor of fuzzy logic, Lotfi Zadeh, observed that unlike computers, the human decision making includes a range of possibilities between YES and NO, such as:

CERTAINLY YES
POSSIBLY YES
CANNOT SAY
POSSIBLY NO
CERTAINLY NO

The fuzzy logic works on the levels of possibilities of input to achieve the definite output.

Implementation

- It can be implemented in systems with various sizes and capabilities ranging from small micro-controllers to large, networked, workstation-based control systems.
- It can be implemented in hardware, software, or a combination of both.

Why Fuzzy Logic?

Fuzzy logic is useful for commercial and practical purposes.

- It can control machines and consumer products.
- It may not give accurate reasoning, but acceptable reasoning.
- Fuzzy logic helps to deal with the uncertainty in engineering.

Fuzzy Logic Systems Architecture

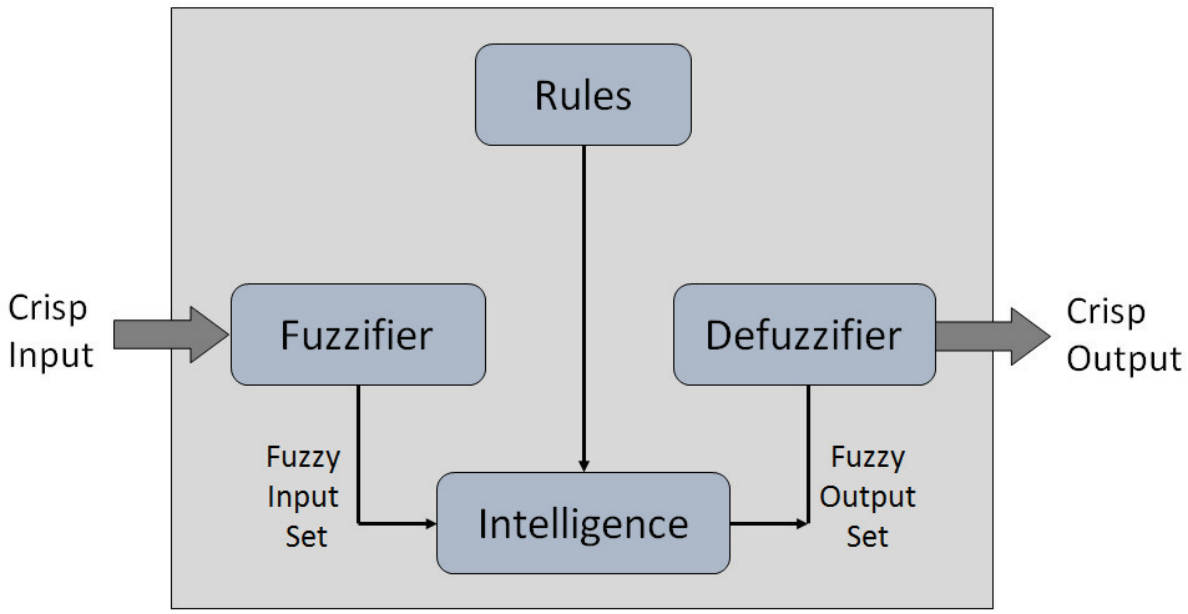
It has four main parts as shown:

1. **Fuzzification Module:** transforms the system inputs, which are crisp numbers, into fuzzy sets.

   It splits the input signal into five steps such as:

LP	x is Large Positive
MP	x is Medium Positive
S	x is Small
MN	x is Medium Negative
LN	x is Large Negative

2. **Knowledge Base:** It stores IF-THEN rules provided by experts.
3. **Inference Engine:** It simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.
4. **Defuzzification Module:** It transforms the fuzzy set obtained by the inference engine into a crisp value.



These **membership functions work on** fuzzy sets of variables.

Membership Functions

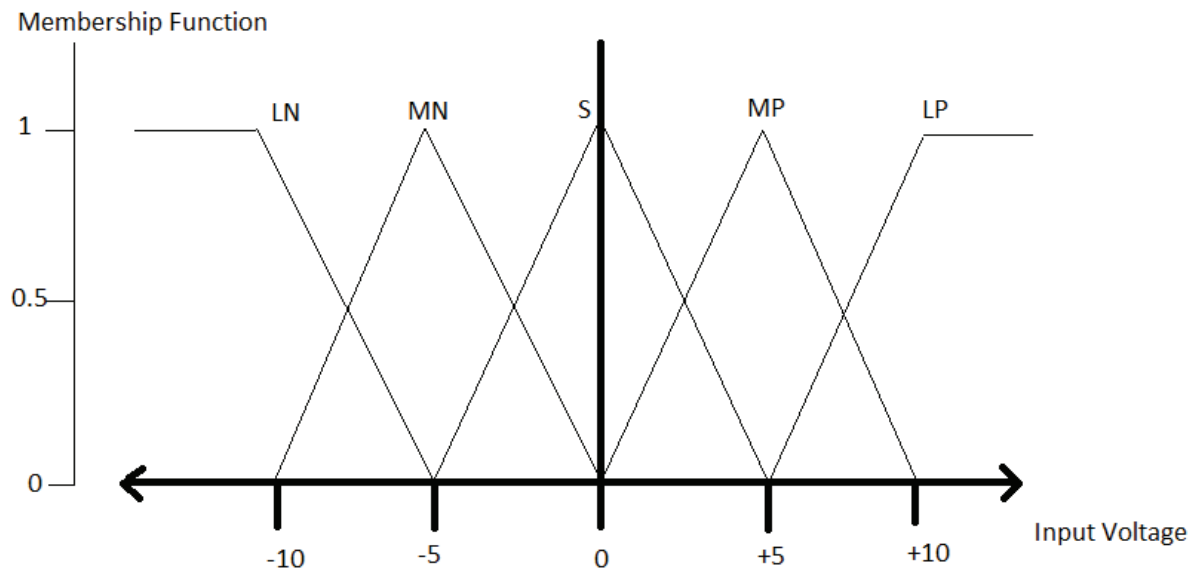
Membership functions allow you to quantify linguistic term and represent a fuzzy set graphically. A **membership function** for a fuzzy set *A* on the universe of discourse *X* is defined as $\mu_A : X \rightarrow [0,1]$.

Here, each element of *X* is mapped to a value between 0 and 1. It is called **membership value** or degree of membership. It quantifies the degree of membership of the element in *X* to the fuzzy set *A*.

- *x* axis represents the universe of discourse.
- *y* axis represents the degrees of membership in the [0, 1] interval.

There can be multiple membership functions applicable to fuzzify a numerical value. Simple membership functions are used as use of complex functions does not add more precision in the output.

All membership functions for **LP, MP, S, MN,** and **LN** are shown as below:



The triangular membership function shapes are most common among various other membership function shapes such as trapezoidal, singleton, and Gaussian.

Here, the input to 5-level fuzzifier varies from -10 volts to +10 volts. Hence the corresponding output also changes.