

# Fuzzy Logic - Inference System

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 [tutorialspoint.com/fuzzy\\_logic/fuzzy\\_logic\\_inference\\_system.htm](https://www.tutorialspoint.com/fuzzy_logic/fuzzy_logic_inference_system.htm)

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Fuzzy Inference System is the key unit of a fuzzy logic system having decision making as its primary work. It uses the “IF...THEN” rules along with connectors “OR” or “AND” for drawing essential decision rules.

## Characteristics of Fuzzy Inference System

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Following are some characteristics of FIS –

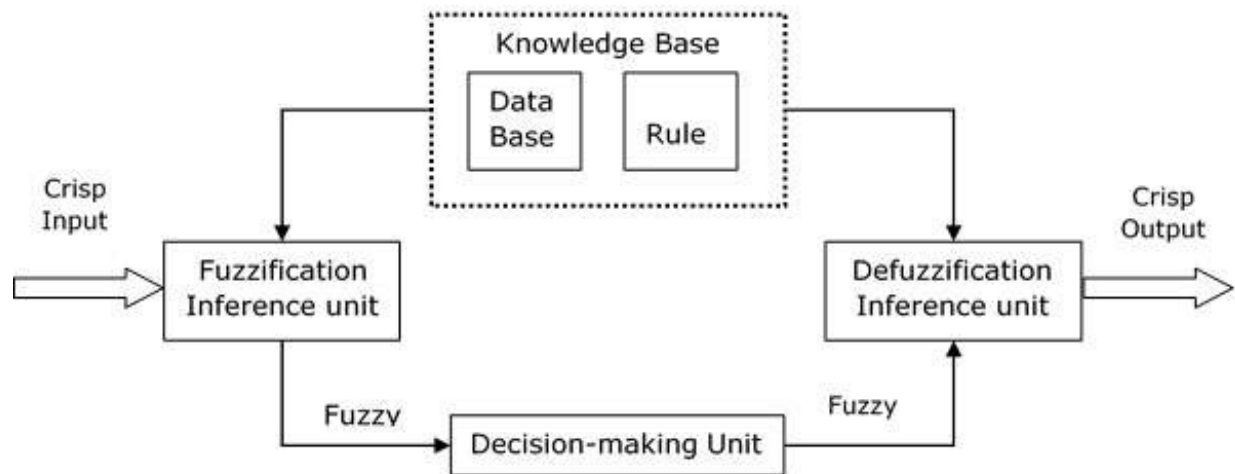
- The output from FIS is always a fuzzy set irrespective of its input which can be fuzzy or crisp.
- It is necessary to have fuzzy output when it is used as a controller.
- A defuzzification unit would be there with FIS to convert fuzzy variables into crisp variables.

## Functional Blocks of FIS

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The following five functional blocks will help you understand the construction of FIS –

- **Rule Base** – It contains fuzzy IF-THEN rules.
- **Database** – It defines the membership functions of fuzzy sets used in fuzzy rules.
- **Decision-making Unit** – It performs operation on rules.
- **Fuzzification Interface Unit** – It converts the crisp quantities into fuzzy quantities.
- **Defuzzification Interface Unit** – It converts the fuzzy quantities into crisp quantities. Following is a block diagram of fuzzy interference system.



## Working of FIS

The working of the FIS consists of the following steps –

- A fuzzification unit supports the application of numerous fuzzification methods, and converts the crisp input into fuzzy input.
- A knowledge base - collection of rule base and database is formed upon the conversion of crisp input into fuzzy input.
- The defuzzification unit fuzzy input is finally converted into crisp output.

## Methods of FIS

Let us now discuss the different methods of FIS. Following are the two important methods of FIS, having different consequent of fuzzy rules –

- Mamdani Fuzzy Inference System
- Takagi-Sugeno Fuzzy Model (TS Method)

## Mamdani Fuzzy Inference System

This system was proposed in 1975 by Ebhasim Mamdani. Basically, it was anticipated to control a steam engine and boiler combination by synthesizing a set of fuzzy rules obtained from people working on the system.

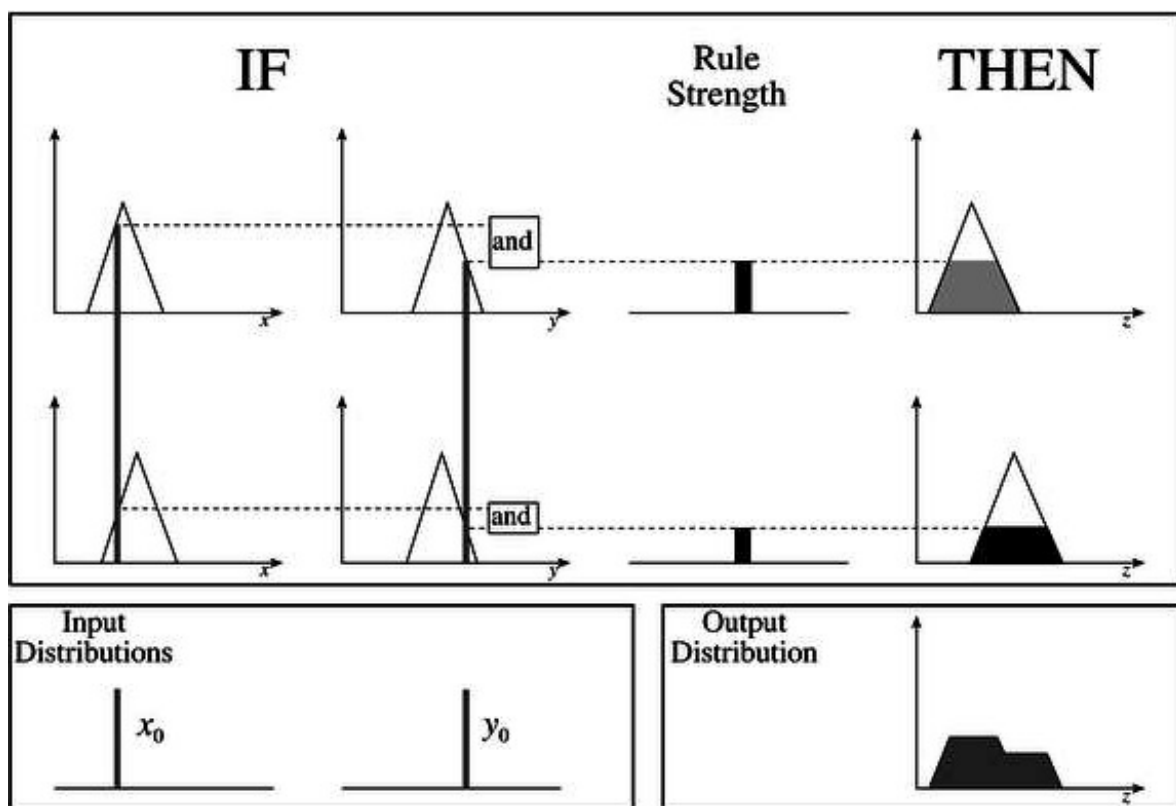
## Steps for Computing the Output

Following steps need to be followed to compute the output from this FIS –

- **Step 1** – Set of fuzzy rules need to be determined in this step.

- **Step 2** – In this step, by using input membership function, the input would be made fuzzy.
- **Step 3** – Now establish the rule strength by combining the fuzzified inputs according to fuzzy rules.
- **Step 4** – In this step, determine the consequent of rule by combining the rule strength and the output membership function.
- **Step 5** – For getting output distribution combine all the consequents.
- **Step 6** – Finally, a defuzzified output distribution is obtained.

Following is a block diagram of Mamdani Fuzzy Interface System.



## Takagi-Sugeno Fuzzy Model (TS Method)

This model was proposed by Takagi, Sugeno and Kang in 1985. Format of this rule is given as –

$$\text{IF } x \text{ is } A \text{ and } y \text{ is } B \text{ THEN } Z = f(x, y)$$

Here,  $A, B$  are fuzzy sets in antecedents and  $z = f(x, y)$  is a crisp function in the consequent.

## Fuzzy Inference Process

The fuzzy inference process under Takagi-Sugeno Fuzzy Model (TS Method) works in the following way –

- **Step 1: Fuzzifying the inputs** – Here, the inputs of the system are made fuzzy.
- **Step 2: Applying the fuzzy operator** – In this step, the fuzzy operators must be applied to get the output.

## Rule Format of the Sugeno Form

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The rule format of Sugeno form is given by –

*if  $7 = x$  and  $9 = y$  then output is  $z = ax+by+c$*

## Comparison between the two methods

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Let us now understand the comparison between the Mamdani System and the Sugeno Model.

- **Output Membership Function** – The main difference between them is on the basis of output membership function. The Sugeno output membership functions are either linear or constant.
- **Aggregation and Defuzzification Procedure** – The difference between them also lies in the consequence of fuzzy rules and due to the same their aggregation and defuzzification procedure also differs.
- **Mathematical Rules** – More mathematical rules exist for the Sugeno rule than the Mamdani rule.
- **Adjustable Parameters** – The Sugeno controller has more adjustable parameters than the Mamdani controller.