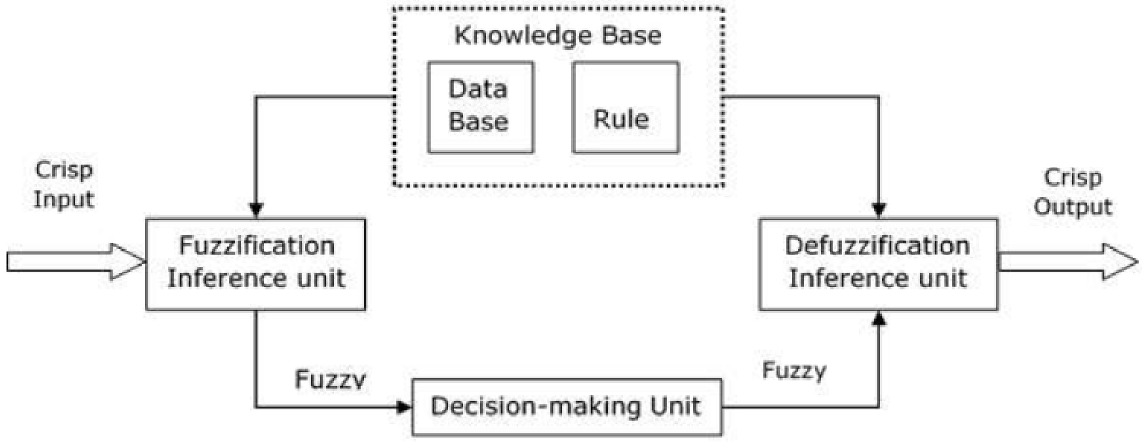
What is A Fuzzy Inference System (FIS)?

A Fuzzy Inference System (FIS) is a computational model used for approximate reasoning, particularly in systems where precise mathematical modelling is difficult or impractical. FIS is based on fuzzy logic, a mathematical framework that deals with reasoning that is approximate rather than precise.



Here's a detailed breakdown of how a Fuzzy Inference System works:

Fuzzy Sets: Fuzzy logic operates on fuzzy sets, which are sets where elements have degrees of membership rather than being strictly in or out of the set. For example, in a temperature control system, "hot" might be a fuzzy set with elements having degrees of membership ranging from 0 to 1, where 0 means "definitely not hot" and 1 means "definitely hot".

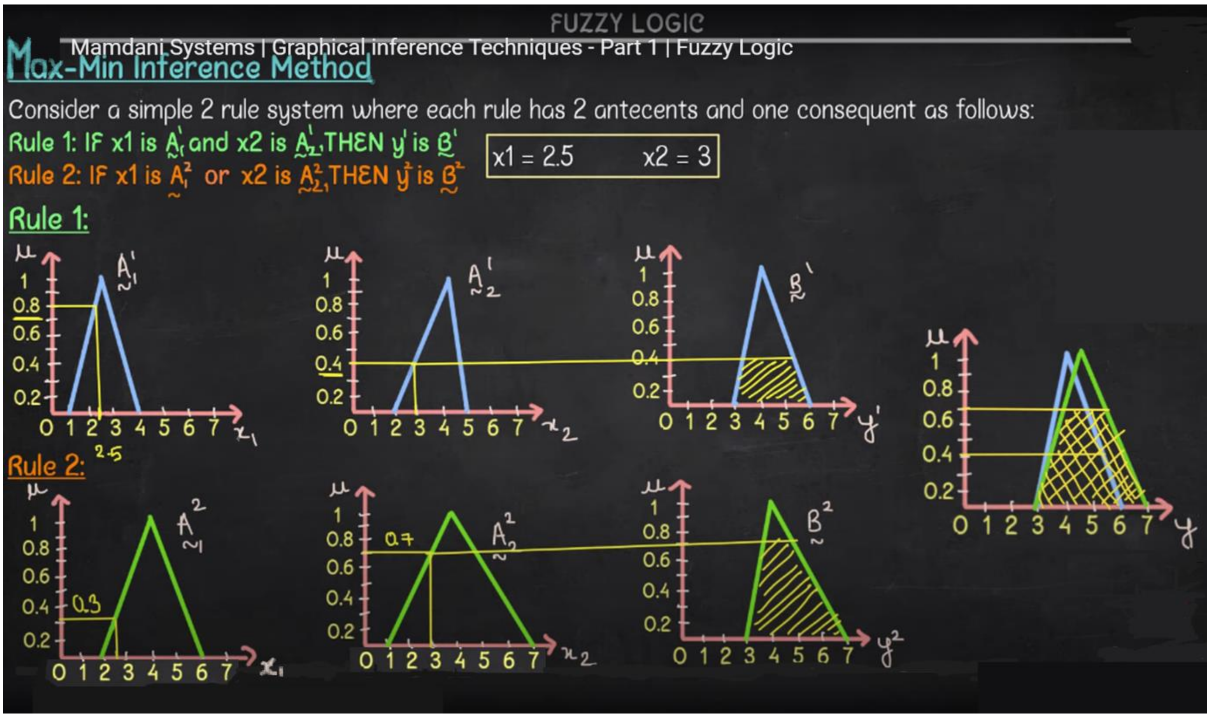
Linguistic Variables: In FIS, input and output variables are often represented linguistically rather than numerically. For instance, instead of using "temperature = 72 degrees," we might say "temperature = moderately warm." These linguistic variables are then mapped to fuzzy sets.

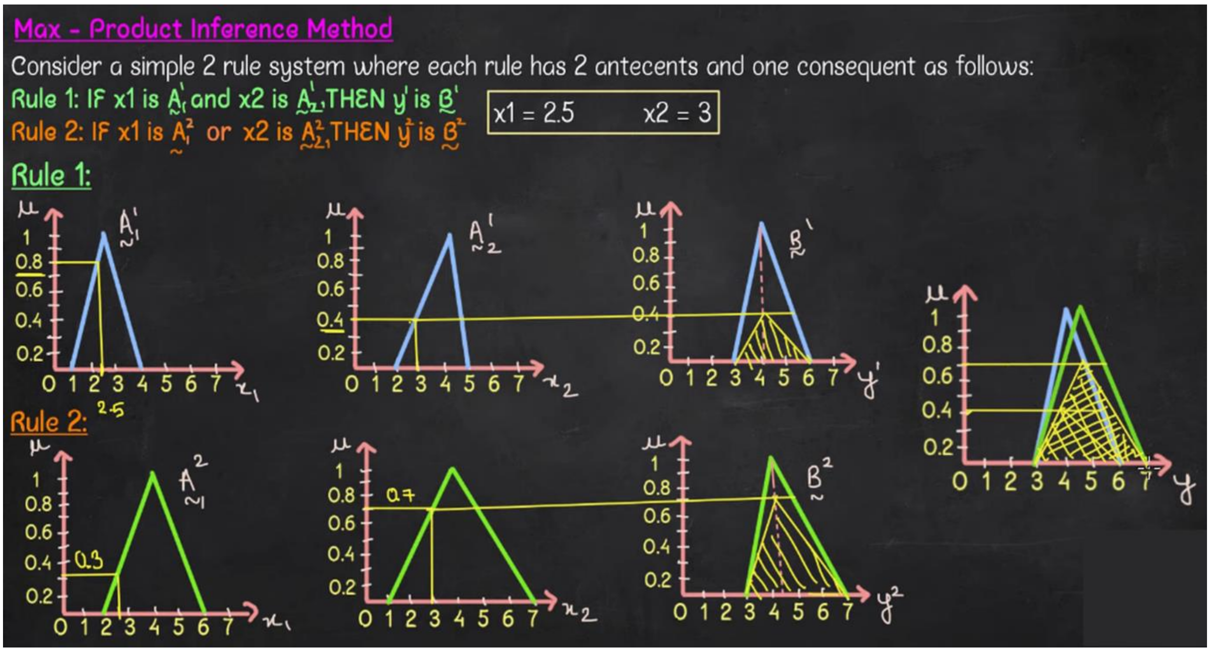
Membership Functions: Each linguistic variable is associated with one or more membership functions, which define how input values are mapped to degrees of membership in fuzzy sets. These functions can take various shapes, such as triangular, trapezoidal, or Gaussian, depending on the nature of the variable and the problem domain.

Fuzzy Rule Base: The fuzzy rule base contains a set of fuzzy if-then rules that encode expert knowledge or heuristic information about the system. Each rule consists of an antecedent (if-part) and a consequent (then-part), both of which involve linguistic variables and fuzzy logic operations. For example, a rule in a temperature control system might be "If the temperature is moderately warm and the humidity is high, then decrease the cooling."

Fuzzy Inference Process: When a FIS receives input values, it uses fuzzy logic to evaluate the degree of membership of these values in the fuzzy sets defined by the input variables. Then, using the fuzzy rule base, it determines the degree to which each rule is satisfied based on the input values. This process is often called "fuzzification."

Combination of Rules: Once the degrees of fulfilment for each rule are determined, they are combined to obtain fuzzy sets representing the system's output variables. This step is typically done using fuzzy logic operators like AND, OR, and NOT.





Defuzzification: Finally, the fuzzy output sets are converted back into crisp values through a process called defuzzification. This process involves aggregating the fuzzy output sets to obtain a single output value, often using methods like centroid calculation or weighted average.

Fuzzy Inference Systems are used in various fields, including control systems, pattern recognition, decision-making, and data analysis, where precise mathematical models are either unavailable or impractical due to the inherent uncertainty and imprecision in the problem domain. They provide a way to capture and utilize expert knowledge or heuristic rules effectively, allowing systems to make intelligent decisions based on uncertain or incomplete information.

Defuzzification :

Defuzzification is the process of converting fuzzy sets, which represent vague or fuzzy information, into crisp or precise values that can be used for decision-making or control in real-world applications. This process is essential in Fuzzy Inference Systems (FIS) because while fuzzy logic allows for approximate reasoning and linguistic descriptions of variables, ultimately, real-world actions often require precise numerical values.

Here's a detailed explanation of the defuzzification process:

Fuzzy Output Sets: Before defuzzification can occur, the FIS produces fuzzy output sets based on the fuzzy rules and input variables. These fuzzy output sets represent the possible outputs of the system, each with a degree of membership indicating how strongly the output belongs to that set.

Aggregation: If there are multiple rules contributing to the same output variable, their fuzzy output sets need to be aggregated. This aggregation step combines the individual fuzzy output sets into a single fuzzy set that represents the overall output of the system. Aggregation methods commonly used include taking the maximum (for OR operations) or minimum (for AND operations) of the membership degrees across all contributing rules.

Defuzzification Methods: Once the fuzzy output set is obtained, it needs to be converted into a crisp value. There are several defuzzification methods used for this purpose:

a. Centroid Method: This is one of the most common defuzzification methods. It calculates the center of gravity, or centroid, of the fuzzy output set. The centroid represents the "center" of the fuzzy set and is often interpreted as the most representative value of the output. Mathematically, the centroid is computed as the weighted average of the universe of discourse (the range of possible output values), with the membership degrees as the weights.

b. Weighted Average: In this method, each possible output value is weighted by its degree of membership in the fuzzy output set, and the weighted average of these values is computed. This method is straightforward and can be customized to prioritize certain regions of the output space based on application-specific criteria.

c. Mean of Maxima (MOM): MOM method involves finding the maximum membership value(s) in the fuzzy output set and then taking the mean (average) of the corresponding crisp output values associated with those membership values. This method is particularly useful when the output set has multiple peaks.

d. Bisector Method: The bisector method identifies the point on the x-axis (the output variable's domain) where the area under the fuzzy output set's curve is divided equally into two parts. This method is straightforward but may not always produce intuitive results, especially for asymmetric fuzzy output sets.

Output Selection: Once the crisp output value is obtained through defuzzification, it can be used for decision-making or control purposes in the system. The selected output value represents the system's response or action based on the fuzzy logic reasoning applied to the input variables.

Defuzzification is a crucial step in the Fuzzy Inference System workflow, as it bridges the gap between fuzzy logic-based reasoning and real-world implementation by providing actionable, precise output values from fuzzy input information. The choice of defuzzification method depends on the specific requirements of the application and the characteristics of the fuzzy output sets involved.