**Fuzzy Inference System** (FIS), as a meaning of a word Inference is the process of obtaining new knowledge through existing knowledge, is composed of 3 main blocks which are

1. Fuzzyfication
2. Inference Engine
3. Defuzzifiaction

And block diagram representation of Fuzzy Inference System shows Figure 1.

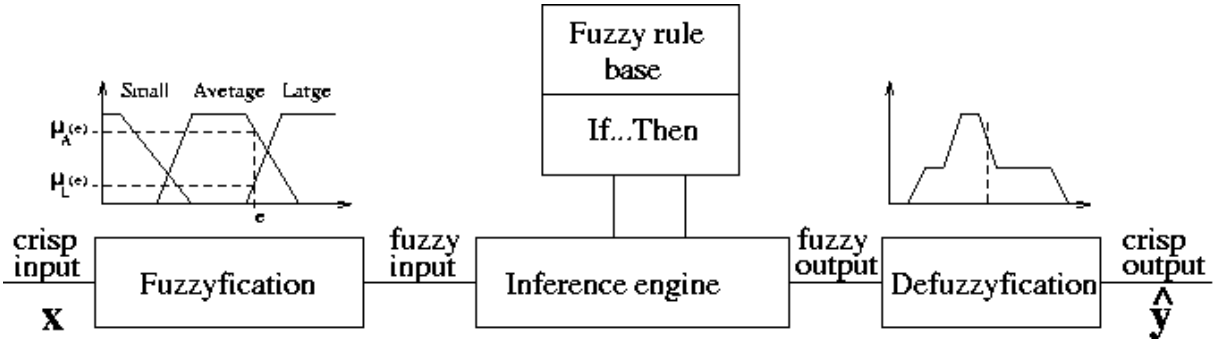


Figure 1: Fuzzy Inference System

- **Fuzzyfication :** The process of transformation crisp input linguistic variable using the membership functions stored in the fuzzy knowledge base.
- **Inference Engine:** Using If-Then type fuzzy rules converts the fuzzy input to the fuzzy output as shown Figure 2.

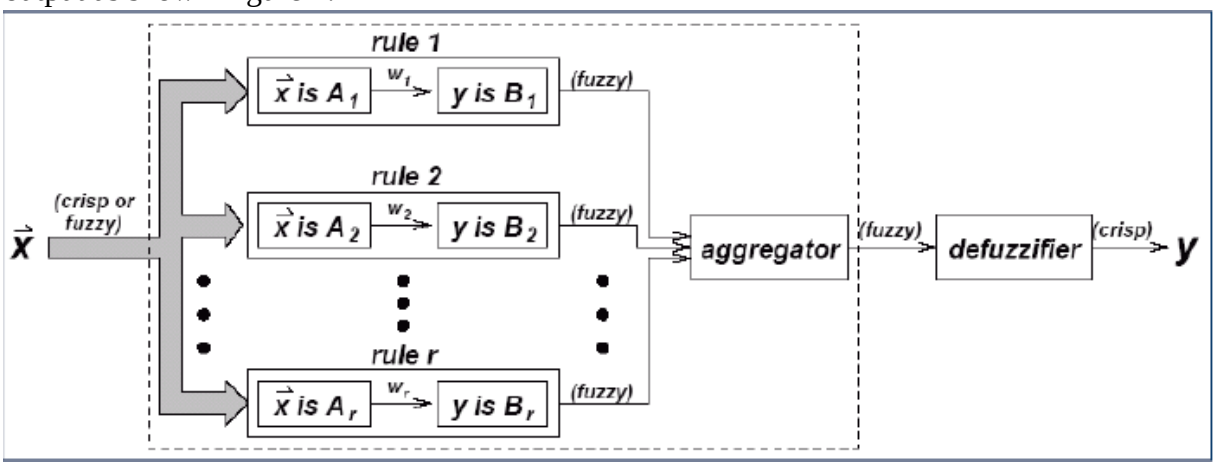


Figure 2: Inference Engine

- **Defuzzyfication:** Reverse process of fuzzyfication. The defuzzification of a fuzzy set is simply the process of conversion of a fuzzy quantity into a crisp value. There are many types of defuzzyfication process, here are some examples: (my MATLAB works is available from here.)
    - Centroid of the area under the output fuzzy set. This method is the default for Mamdani systems.
    - Bisector of the area under the output fuzzy set
    - Mean of the values for which the output fuzzy set is maximum
    - Largest value for which the output fuzzy set is maximum

- Smallest value for which the output fuzzy set is maximum

Fuzzy inference system is also known by numerous other names like fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems because it has been succefully applied in various fields such as automatic control, data classification, decision analysis, expert systems, and computer vision.

[3] A fuzzy inference system implements a **nonlinear mapping** from its input space to output space. The mapping then provides a basis from which decisions can be taken. The process of fuzzy inference involves all the membership functions, fuzzy logic operators and if-then rules. There are three types of fuzzy inference, which have been widely employed in various applications. The differences between these three fuzzy inferences, also called fuzzy models, Computational Intelligence: Fuzzy relations, rules, and inference lie in the consequents of their fuzzy rules, aggregations and defuzzification procedures. These fuzzy inferences are

1. Mamdani fuzzy inference
2. Sugeno fuzzy inference
3. Tsukamoto fuzzy inference

**Mamdani Fuzzy Models**

- Proposed in 1975 by Ebrahim Mamdani as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators.
- Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology.
- Mamdani's method was among the first control systems built using fuzzy set theory.

Using the Fuzzy Toolbox of MATLAB, writes ‘fuzzy’ on command line and press enter. And the ‘Fuzzy Logic Designer’ is appeared as a default is used Mamdani method as shown Figure 3.

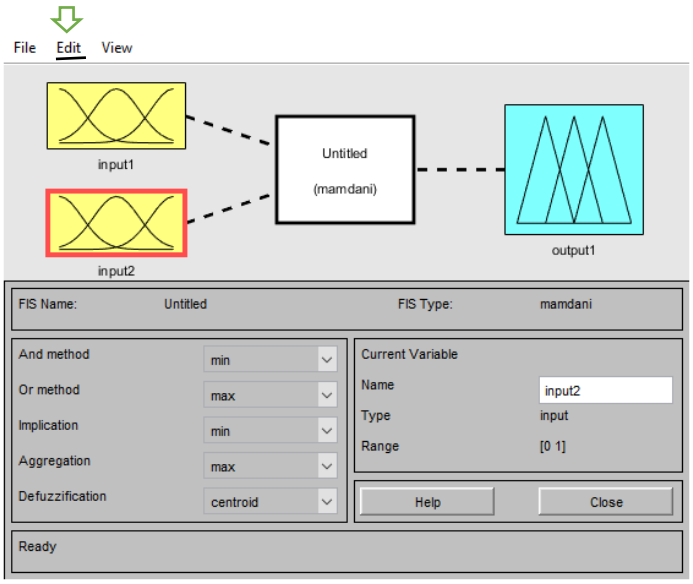


Figure 3: Fuzzy Logic Designer

You can customize type of MF and its values, number of inputs and outputs, rules and many things are related to your system using 'Edit'. You can import some projects to study different examples that are in the toolbox/fuzzy/fuzzydemos.

**Sugeno Fuzzy Models**

Sugeno fuzzy model (Figure 4) is also known as a TSK fuzzy model which was proposed by Takagi, Sugeno and Kang (Takagi and Sugeno, 1985; Sugeno and Kang, 1988) in an effort to develop a systematic approach to generate fuzzy rules from a given input-output data set. Typically fuzzy rule in Sugeno fuzzy model has the form

*If x is A and y is B then z=f(x,y)*

where A and B are fuzzy sets in the antecedent part, while z=f(x,y) is crisp function in the consequent part. Result of this method is to find using either 'weighted avarege' or 'weighted sum'.

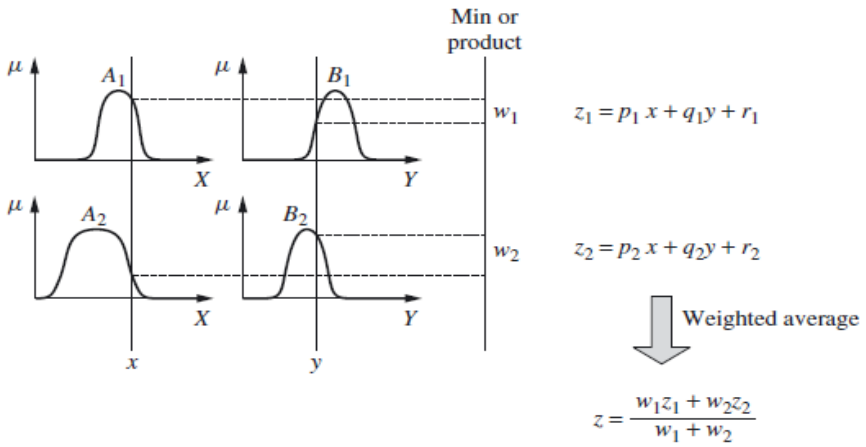


Figure 4: Sugeno Fuzzy Model

Again to design Sugeno Fuzzy Model using fuzzy logic toolbox of MATLAB, click 'File' from Fuzzy Logic Designer and then you can choose 'Sugeno' type from 'New FIS'.

**Tsukamoto Fuzzy Models**

The consequent of each fuzzy if-thenrule is represented by a fuzzy set with a monotonical MF. As a result, the inferred output of each rule is defined as crisp value included by the rule's firing strength. The overall output is taken as the weighted average of each rule's output. Since each rule infers a crisp output, the Tsukamoto fuzzy model aggregates each rule's output by the method of weighted average and thus avoids the time-consuming process of defuzzification. Figure 5 illustrates a two input single-output Tsukamoto fuzzy model.

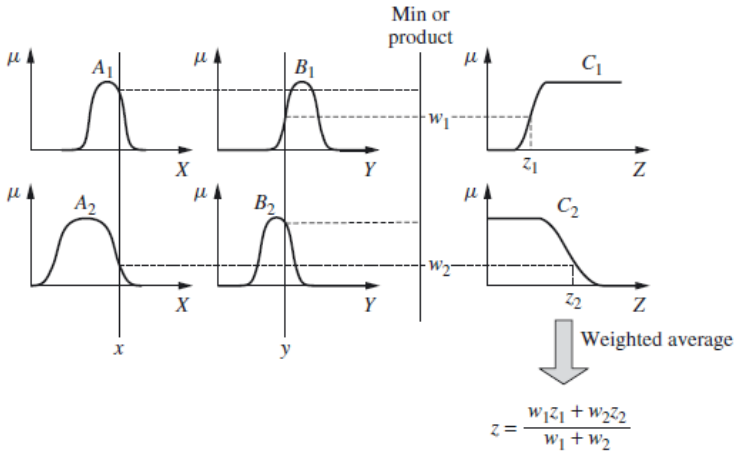


Figure 5: Tsukamoto fuzzy model.

**Sugeno vs. Mamdani fuzzy systems**

Because it is a more compact and computationally efficient representation than a Mamdani system, the Sugeno system lends itself to the use of adaptive techniques for constructing fuzzy models. These adaptive techniques can be used to customize the membership functions so that the fuzzy system best models the data.

The following are some final considerations about the two different methods.

| Advantages of the Mamdani Method | Advantages of the Sugeno Method |
|---|---|
| •It is intuitive.<br>•It has widespread acceptance.<br>•It is well suited to human input. | • It is computationally efficient.<br>• It can be used to model any inference system in which the output membership functions are either linear or constant.<br>•It works well with linear techniques (e.g., PID control).<br>•It works well with optimization and adaptive techniques.<br>•It has guaranteed continuity of the output surface.<br>•It is well suited to mathematical analysis. |

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