SATHYABAMA UNIVERSITY

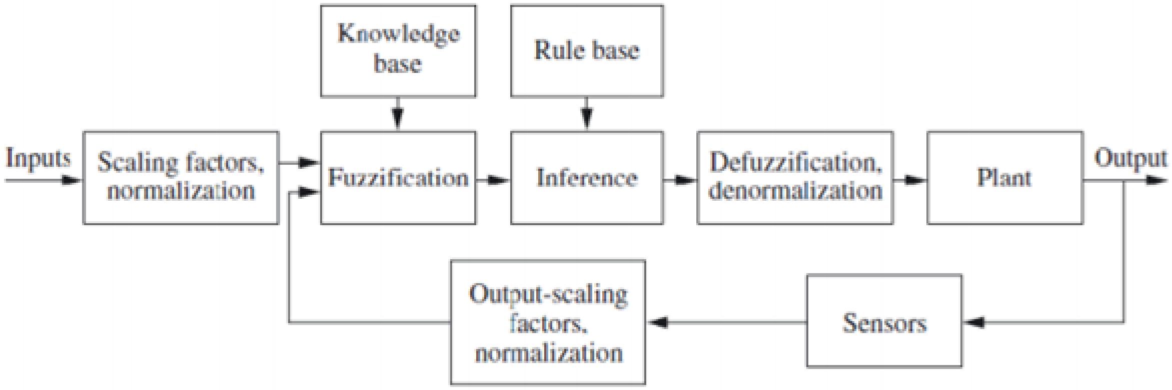
SECX1048 FUNDAMENTALS OF FUZZY LOGIC AND ARTIFICIAL NEURAL NETWORK

UNIT – II FUZZY LOGIC CONTROLLER AND ITS APPLICATION

Fuzzy Logic Controller:

Simple Fuzzy Logic Controllers First-generation (non-adaptive) simple fuzzy controllers can generally be depicted by a block diagram such as that shown in the figure.

The knowledge-base module in the figure contains knowledge about all the input and output fuzzy partitions. It will include the term set and the corresponding membership functions defining the input variables to the fuzzy rule-base system and the output variables, or control actions, to the plant under control.



The steps in designing a simple fuzzy control system are as follows:

1. Identify the variables (inputs, states, and outputs) of the plant.

2. Partition the universe of discourse or the interval spanned by each variable into a number of fuzzy subsets, assigning each a linguistic label (subsets include all the elements in the universe). 3. Assign or determine a membership function for each fuzzy subset.

4. Assign the fuzzy relationships between the inputs' or states' fuzzy subsets on the one hand and the outputs' fuzzy subsets on the other hand, thus forming the rule-base.

5. Choose appropriate scaling factors for the input and output variables in order to normalize the variables to the [0, 1] or the [−1, 1] interval.

6. Fuzzify the inputs to the controller.

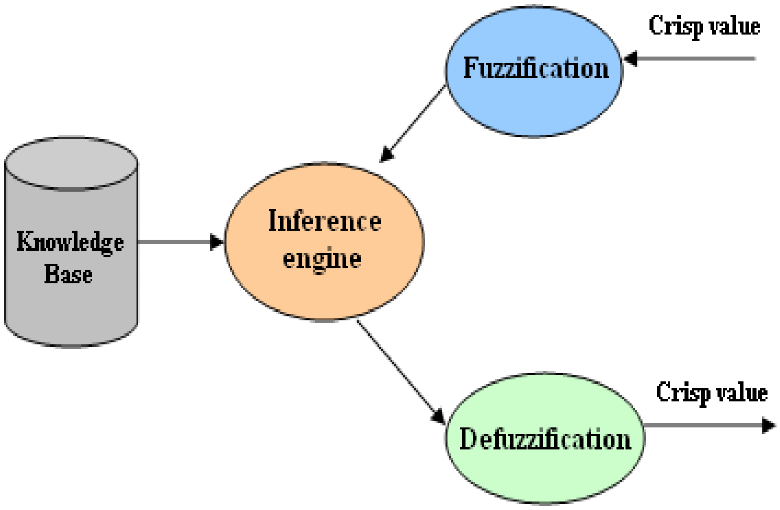
7. Use fuzzy approximate reasoning to infer the output contributed from each rule.

8. Aggregate the fuzzy outputs recommended by each rule.

9. Apply defuzzification to form a crisp output.

Fuzzy Inference Engine: Job of this unit is to select an appropriate rule representing different conditions and to fire that rule to produce an outcome.

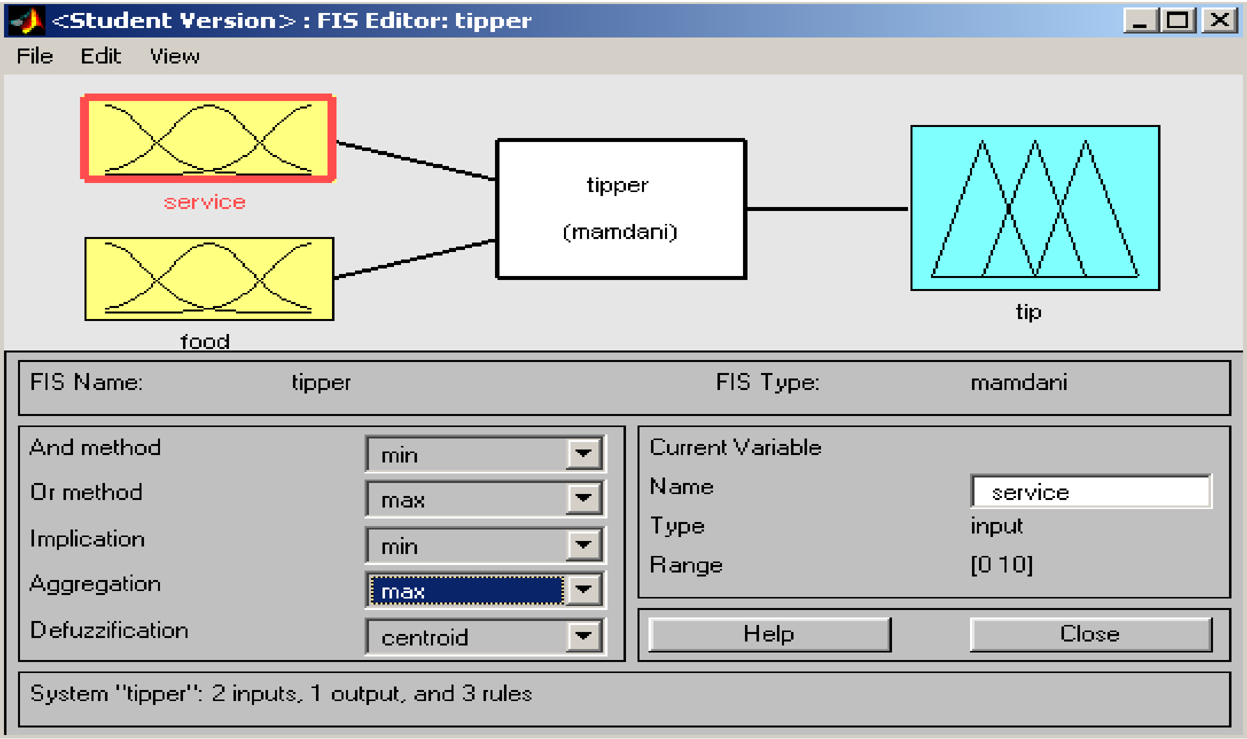
- A Fuzzy Inference System (FIS) is a way of mapping an input space to an output space using fuzzy logic
- FIS uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data.
- The rules in FIS (sometimes may be called as fuzzy expert system) are fuzzy production rules of the form:
    - *if p then q,* where p and q are fuzzy statements.
- For example, in a fuzzy rule
    - if x is low and y is high then z is medium.
    - Here x is low; y is high; z is medium are fuzzy statements; x and y are input variables; z is an output variable, low, high, and medium are fuzzy sets.
- The antecedent describes to what degree the rule applies, while the conclusion assigns a fuzzy function to each of one or more output variables.
- Most tools for working with fuzzy expert systems allow more than one conclusion per rule.
- The set of rules in a fuzzy expert system is known as *knowledge base*.
- The functional operations in fuzzy expert system proceed in the following steps.
    - Fuzzification
    - Fuzzy Inferencing (apply implication method)
    - Aggregation of all outputs
    - Defuzzification



- In the process of fuzzification, membership functions defined on input variables are applied to their actual values so that the degree of truth for each rule premise can be determined.
- Fuzzy statements in the antecedent are resolved to a degree of membership between 0 and 1.
  - If there is only one part to the antecedent, then this is the degree of support for the rule.
  - If there are multiple parts to the antecedent, apply fuzzy logic operators and resolve the antecedent to a single number between 0 and 1.
- Antecedent may be joined by OR; AND operators.
- In the process of inference
  - Truth value for the premise of each rule is computed and applied to the conclusion part of each rule.
  - This results in one fuzzy set to be assigned to each output variable for each rule.
- The use of degree of support for the entire rule is to shape the output fuzzy set.
- The consequent of a fuzzy rule assigns an entire fuzzy set to the output.
- If the antecedent is only partially true, (i.e., is assigned a value less than 1), then the

output fuzzy set is truncated according to the implication method.

- If the consequent of a rule has multiple parts, then all consequents are affected equally by the result of the antecedent.
- The consequent specifies a fuzzy set to be assigned to the output.
- The implication function then modifies that fuzzy set to the degree specified by the antecedent.
- The following functions are used in inference rules.
- *min* or *prod* are commonly used as inference rules.



FIS Name: tipper

FIS Type: mamdani

And method: min

Or method: max

Implication: min

Aggregation: max

Defuzzification: centroid

Current Variable

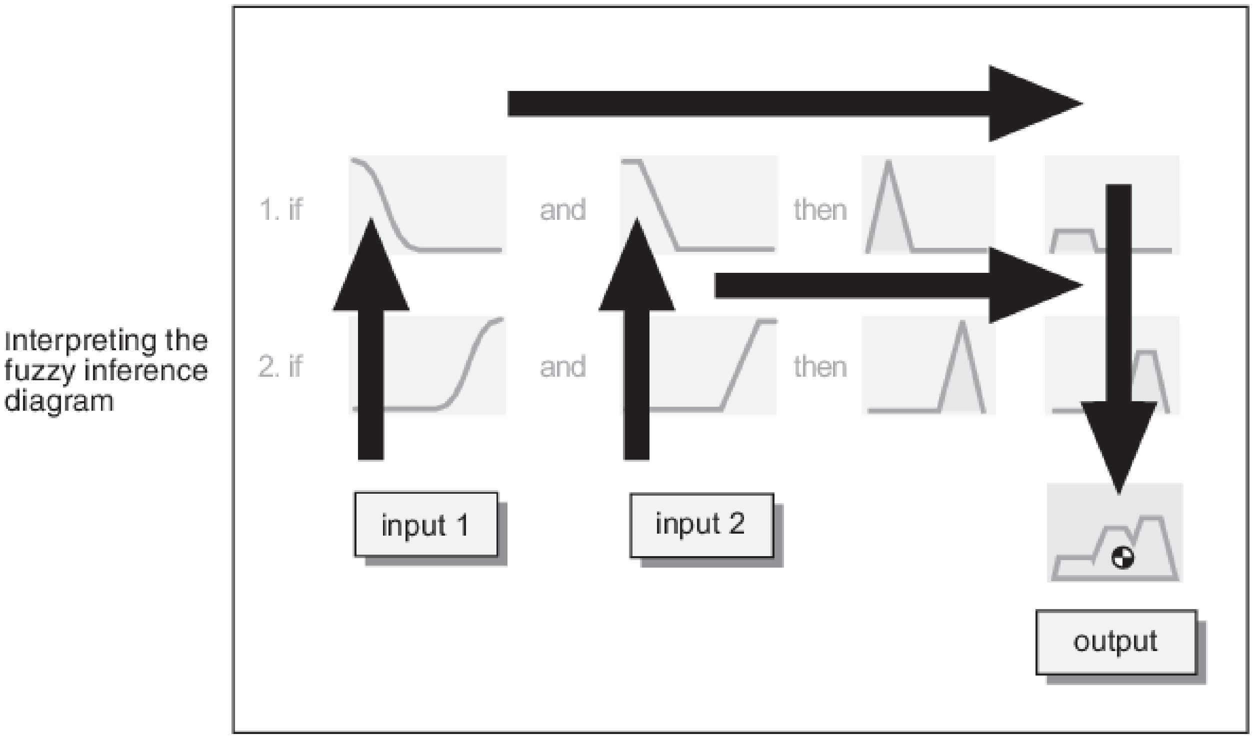
Name: service

Type: input

Range: [0 10]

System "tipper": 2 inputs, 1 output, and 3 rules

Fuzzy inference system in MATLAB environment



Fuzzy inference in MATLAB environment

Knowledge Base: Place in which different information related to the problem are stored here. It's the collection of expert knowledge about the problem. Advantages of fuzzy knowledge base :

- Comprehensibility
- Parsimony
- Modularity
- Explainability
- Uncertainty
- Parallelism
- Robust

Rule base system: Collection of rules representing different environment are kept. Rules are framed by assigning relationship to fuzzy linguistic variables.

Decision Making Logic (DM)

This is the block responsible for fuzzy control outcomes. Making decisions under uncertainty is tough since, we have to handle bulk information’s. Different classifications in this category are,

- ✓ Single person single objective decision making
- ✓ Multi person single objective decision making

- ✓ Multi person single objective decision making
- ✓ Multi person Multi objective decision making

Decision making in FLCS is based on:

- ✓ Synthetic Evaluation - Individual evaluation by the expert.
- ✓ Rank ordering- Based on ranks of the rules. Rules are prioritized.

- ✓ Preferences and consensus- when multi persons are involved in DM, rules are selected based on individual preferences and degree of consensus.

- ✓ Fuzzy multi objective based on BAYESIAN Method – this method is based on Bayesian technique in which we calculate utility function is calculated for every option of selection.

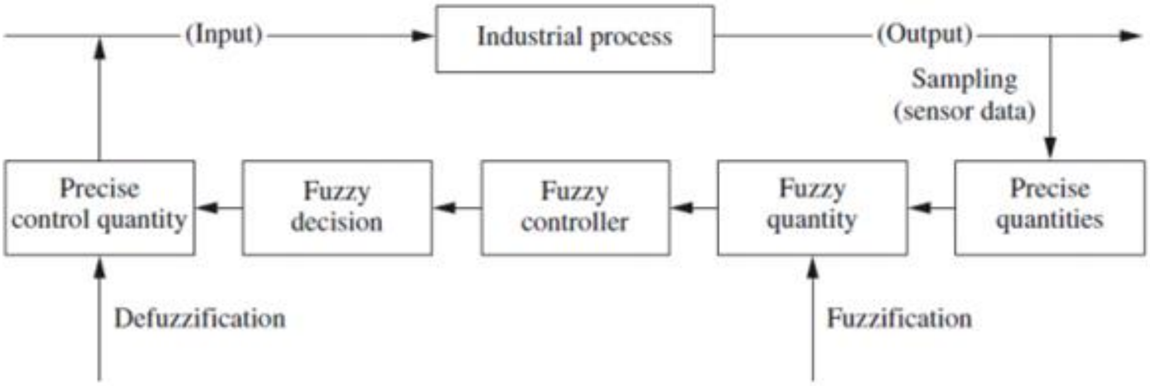
EXAMPLES OF FUZZY CONTROL SYSTEM DESIGN

Most control situations are more complex than we can deal with mathematically. In this situation, fuzzy control can be developed, provided a body of knowledge about the control process exists, and formed into a number of fuzzy rules. For example, suppose an industrial process output is given in terms of the pressure. We can calculate the difference between the desired pressure and the output pressure, called the pressure error (e), and we can calculate the difference between the desired rate of change of the pressure, dp/dt, and the actual pressure rate, called the pressure error rate, ($\dot{e}$). Also, assume that knowledge can be expressed in the form of IF–THEN rules such as:

IF pressure error (e) is “positive big (PB)” or “positive medium (PM)” and

IF pressure error rate (˙e) is “negative small (NS),”

THEN heat input change is “negative medium (NM).”



FUZZY LOGIC CONTROL SITUATION

The linguistic variables defining the pressure error, “PB” and “PM,” and the pressure error rate, “NS” and “NM,” are fuzzy, but the measurements of both the pressure and pressure rate as well as the control value for the heat (the control variable) ultimately applied to the system are precise (crisp). An input to the industrial process (physical system) comes from the controller. The physical system responds with an output, which is sampled and measured by some device. If the measured output is a crisp quantity, it can be fuzzified into a fuzzy set .This fuzzy output is then considered as the fuzzy input into a fuzzy controller,which consists of linguistic rules.

The output of the fuzzy controller is then another series of fuzzy sets. Since most physical systems cannot interpret fuzzy commands (fuzzy sets), the fuzzy controller output must be converted into crisp quantities using defuzzification methods. These crisp (defuzzified) control-output values then become the input values to the physical system and the entire closed-loop cycle is repeated device. If the measured output is a crisp quantity, it can be fuzzified into a fuzzy set.

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Fuzzy Control also includes in the following domains:

Environmental control:

Air conditioners

Humidifiers

Domestic Goods:

Washing Machines/Dryers

Vacuum cleaners

Toasters

Refrigerators

Consumer Electronics:

Television

Photocopiers

Hi-Fi Systems

Automotive systems:

Vehicle Climate Control

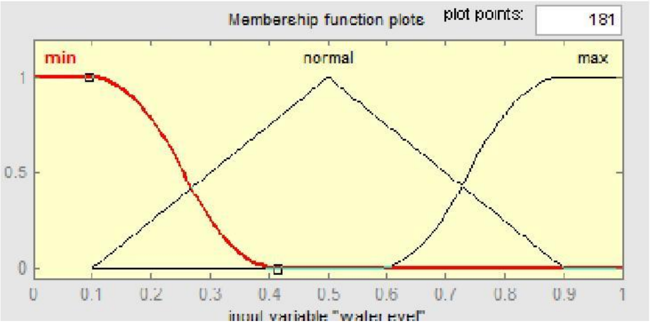
Automatic Gearboxes

Application of Water level controller using Fuzzy logic

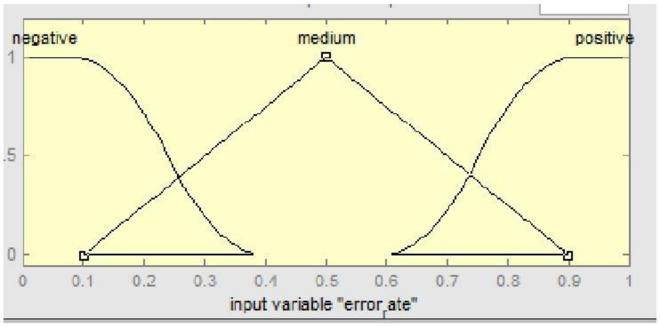
Step 1: Identify the i/p and o/p variables. Here in this case minimum and maximum level are inputs and valve position is output variables.

Step 2: Assign an appropriate membership function and perform Fuzzification process. i/p1 is water_level, i/p2 is error_rate. Valve position is the output being controlled.

The membership graphs for i/p and o/p variables are given in Figure a,b and c .For water level three functions and for error rate again three membership functions are used.

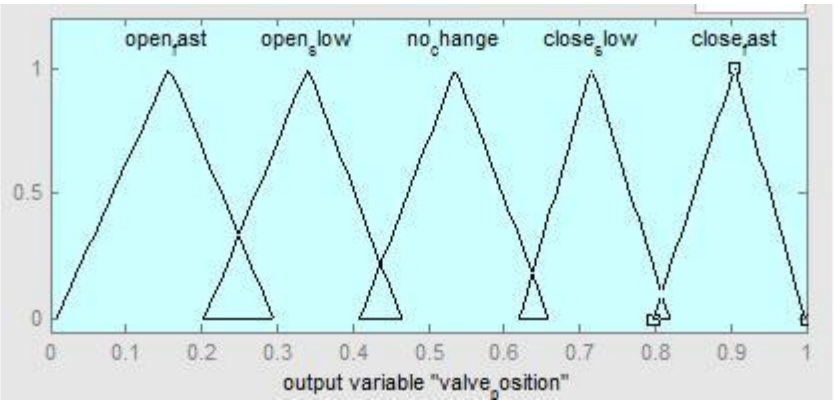


Fig(a) I/p membership function for water_level



Fig(b)I/p membership function for error rate

For output variable Valve_position we consider open slow, open fast ,close slow, close fast and no change as linguistic variables, which is shown in Figure c.



Fig(c) I/p membership function for output variable valve_position

* These responses are generated using MATLAB software.

Step 3: Framing of rules are done as follows

Rule 1: IF water_level is min AND error_rate is negative THEN valve position open_fast

Rule 2: IF water_level is max AND error_rate is positive THEN valve position close_fast

Similarly rules are framed for remaining conditions and these rule outcomes are aggregated.

Thus a fuzzy water level controller is designed.

Application of fuzzy logic in Temperature controller

Step 1: Identify the i/p and o/p variables. Here let us consider Room_temperature and environment_temp as i/p and cooler state as output variable.

Step 2: Assign an appropriate membership function and perform Fuzzification process.

Room_temp is assigned with less ,medium and high linguistic variables

For the o/p parameter environment_temp linguistic terms assigned are min ,normal and more .

Step 3: Rules are framed by assigning relationships. For example

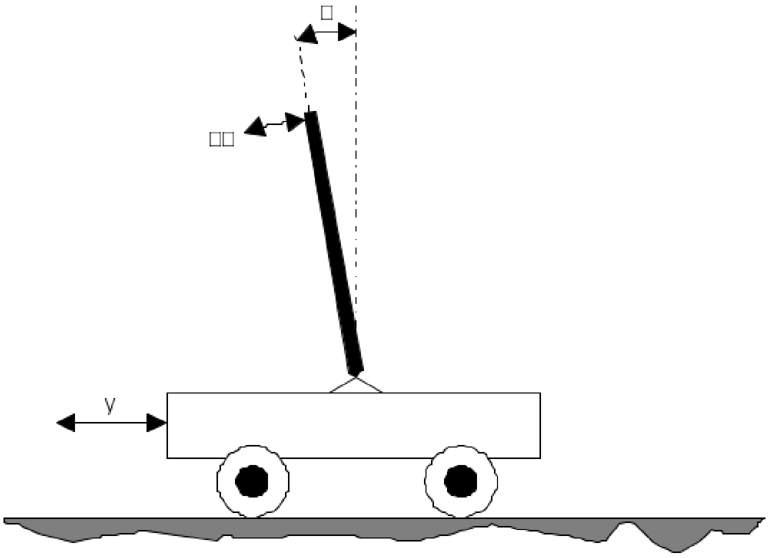
(a) IF room_temp = less AND environment_temp = min THEN cooler = ON

(b) IF room_temp = High AND environment_temp = more THEN cooler = OFF

The rules are fired as per the situation and the outcome is defuzzified. This defuzzified crisp output is given to the instrument. Thus a fuzzy room temperature controller is designed.

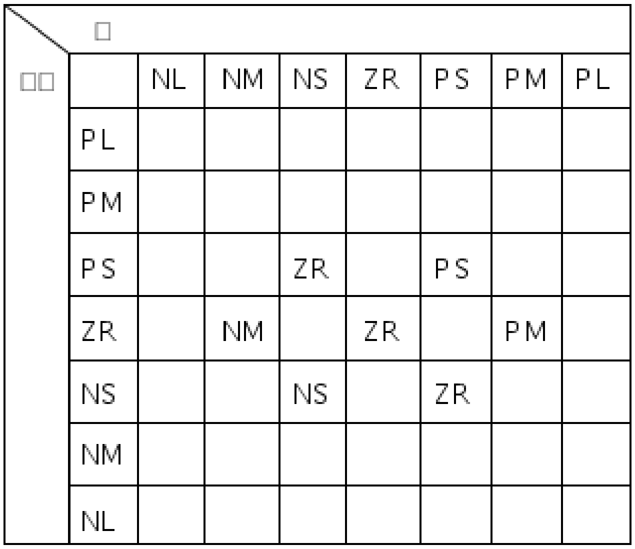
Application of fuzzy logic to inverted pendulum control

This is a classic fuzzy control application. The task is to keep an inverted pendulum balanced on a mobile platform .Platform can move left and right moved by an electric motor .Motor can operate at different speeds controlled by current.

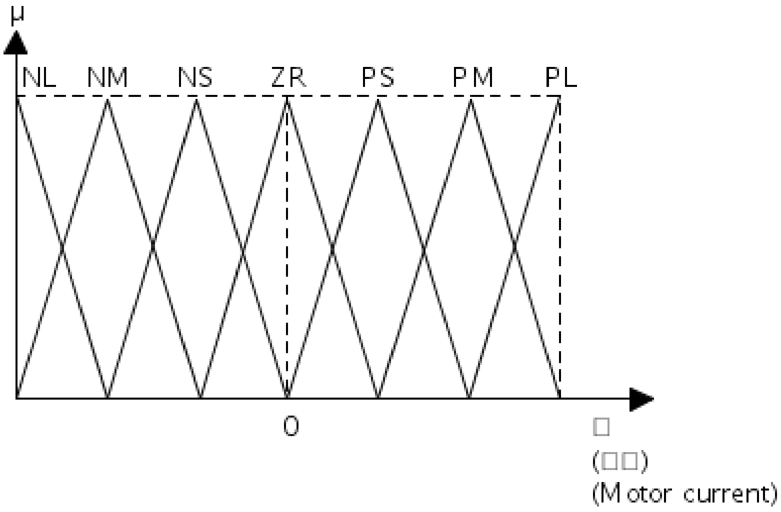


- Two inputs
    - angle of pendulum
        - positive or negative

    - angular speed of pendulum
        - positive or negative
- One output
    - current to motor
        - positive or negative



		□						
□□		NL	NM	NS	ZR	PS	PM	PL
	PL							
	PM							
	PS			ZR		PS		
	ZR		NM		ZR		PM	
	NS			NS		ZR		
	NM							
	NL							



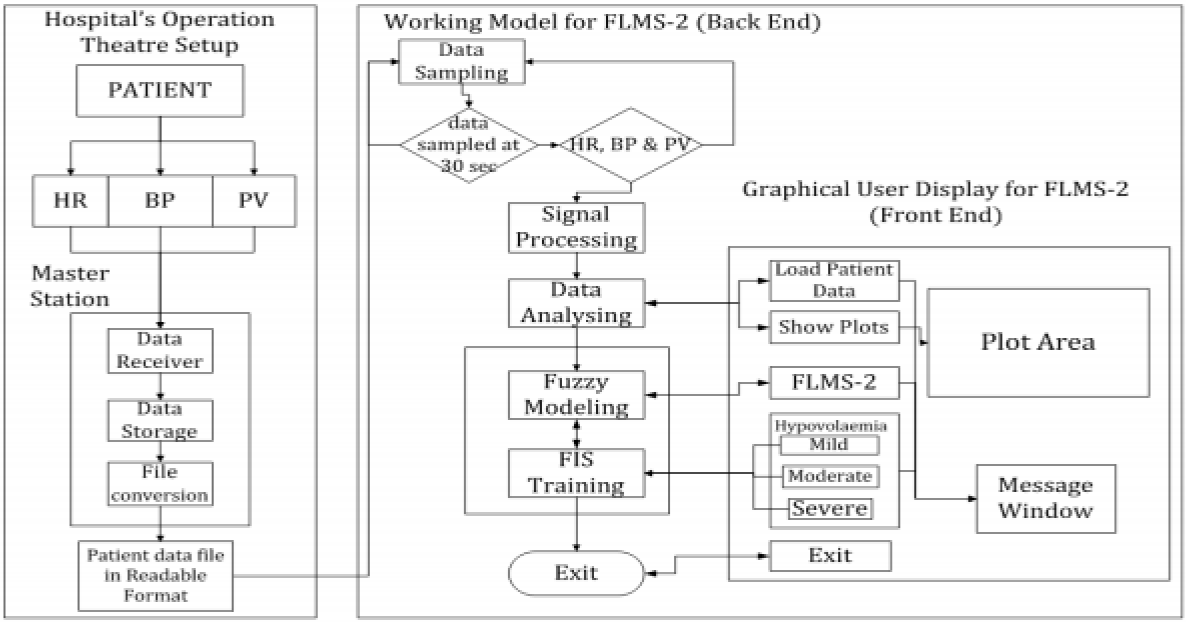
Fuzzy representation of the challenge

MF range from “Negative Small” (NL) to “Positive Large” (PL) . This has been used as a demo for fuzzy control chips.

Application of fuzzy logic to control blood pressure during anesthesia

A fuzzy logic controller that controls mean arterial pressure (MAP), which is taken as a parameter for depth of anesthesia during surgery, is described. The control rules make use of the error between the desired and the actual values of MAP as well as the integral of the error.

The test conditions for the detection of hypovolaemia were classified as: mild, moderate, and severe. The following four principles were set before the generation of alarms in the system: Principle 1- Sampling period: The system checks the sampling period of the input data which should be 30sec. Principle 2- Three Inputs: The system is set to accept only three inputs which are HR, BP, and PV.



(Source: MIRZA MANSOOR BAIG et al. “Fuzzy Logic Based Smart Anaesthesia Monitoring System in the Operation Theatre”, WSEAS TRANSACTIONS on CIRCUITS and SYSTEMS”, Issue 1, Volume 11, January 2012**)**

Therefore, if any input data set is missing, the system will return the present alarm status as false, and wait for the next 15 minutes of the data set. Principle 3- Membership Functions: The limits of the membership functions were set after considering the following points: • The limits are set so that the FLMS-2 can detect the changes in the parameters, rather than the crisp numerical values and filtered data were divided into five-minute intervals. • The relative value of each parameter (such as HR) is found by removing its average and dividing the result by its standard deviation (SD) for each five-minute interval.

QUESTIONS FOR PRACTICE

PART A

1. **What is a fuzzy logic controller?**
2. **Define fuzzy inference?**
3. **What is fuzzy decision making?**
4. **Write about knowledge base?**
5. **What is deffuzification interface?**

PART B

1. **Discuss about any two applications of fuzzy logic controller?**
2. **Explain FLC with neat diagram and discuss advantages and disadvantages?**
3. **Write in detail about application of FLC for inverted pendulum example?**
4. **Explain in detail about application of FLC for blood pressure control using anesthesia?**
5. **Discuss in detail about application of FLC for water level controller?**