



**Answer all the following questions:**

**Problem 1: (20 Marks)**

a. Use any heuristic optimization algorithm for tuning a PID controller gains of the plant:

- i. Draw the flow chart and explain the steps for designing the PID controller based on particle swarm optimization algorithm for tuning a PID controller gains of the plant. (5 Marks)
- ii. Draw the flow chart and explain the steps for designing the PID controller based on SCA algorithm. (5 Marks).

b. Two fuzzy sets  $A$  and  $B$  are represented by the following two membership functions: (4 Marks)

$$\mu_A(x) = \max\left(0, \frac{x-3}{7}\right) \text{ for } x \leq 10$$

$$\mu_B(x) = \max\left(0, \frac{x-8}{2}\right) \text{ for } x \leq 10$$

$$\mu_A(x) = \max\left(0, \frac{17-x}{7}\right) \text{ for } x > 10$$

$$\mu_B(x) = \max\left(0, \frac{12-x}{2}\right) \text{ for } x > 10$$

- i. Sketch these membership functions. (2 Marks)
- ii. What do  $A$  and  $B$  approximately represent? (2 Marks)

c. **Choose the correct answer for the following questions: (6 Marks)**

1. What is Fuzzy inference systems?

- |   |   |
|---|---|
| A. The process of formulating the mapping from a given input to an output using fuzzy logic | B. Changing the output value to match the input value to give it an equal balance |
| C. Having a larger output than the input  | D. Having a smaller output than the input   |

2. What are the Two types of Fuzzy inference systems?

- |                                 |                                 |
|---------------------------------|---------------------------------|
| A. Model-Type and System-Type   | B. Mamdani-Type and Sugeno-Type |
| C. Momfred-Type and Semigi-Type | D. Mihni-Type and Sujgani-Type  |

3. Where has fuzzy inference systems been implemented?

- |   |   |
|---|---|
| A. Wireless services, heat control and printers | B. Restrict power usage, telephone lines and sort data          |
| C. Simulink, boiler and CD recording            | D. Automatic control, decision analysis and data classification |

4. What is another name for fuzzy inference systems?

- |                           |                     |
|---------------------------|---------------------|
| A. Fuzzy Expert System    | B. Fuzzy Modelling  |
| C. Fuzzy Logic Controller | D. All of the above |

5. Mamdani's fuzzy inference method was designed to attempt what?

- |   |   |
|---|---|
| A. Control any two combinations of any two products by synthesizing a set of linguistic control rules obtained from experienced human operations. | B. Control a television and remote combination by synthesizing a set of linguistic control rules obtained from experienced human operations.    |
| C. Control a steam engine and a boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operations.  | D. Control a air craft and feul level combination by synthesizing a set of linguistic control rules obtained from experienced human operations. |

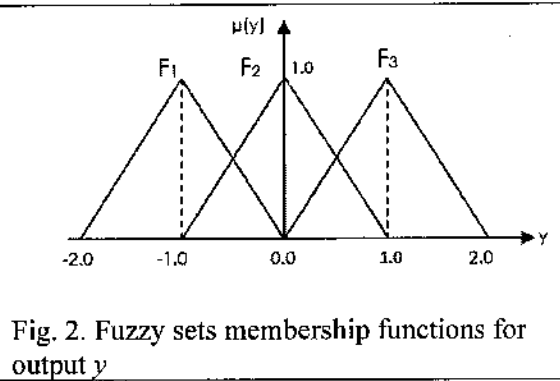
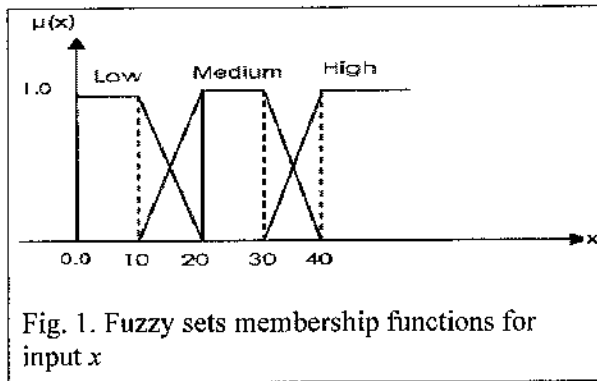
6. What is the purpose of aggregation?

- |   |  |
|---|--|
| A. To gather all the different fuzzy set outputs and combine them into a single fuzzy set outputs | B. To gather all the possible inputs and use the average to gain an output |
| C. To gather all the different fuzzy set outputs and average them out to get a single value       | D. To subtract all the output fuzzy set values from the input values       |

**Problem 2: (20 Marks)**

- a. What are the main components of a fuzzy control system ? Describe the function of each component in detail? [5 marks]
- b. Assume a simple fuzzy controller with input  $x$  and output  $y$ . The membership functions of fuzzy sets for the input and output are described in Figs. 1 and 2 respectively. The set of initial (non-optimal) fuzzy control rules are as follows:

- R1: If  $x$  is *Medium* then  $y$  is  $F_2$
- R2: If  $x$  is *Low* then  $y$  is  $F_3$
- R3: If  $x$  is *High* then  $y$  is  $F_1$



Suppose the current value of input  $x$  is equal to 35

- (1) Which fuzzy rules are fired, and what are their firing strengths? [5 marks]
- (2) What are the implied output fuzzy sets of the fired fuzzy rules? [5 marks]
- (3) What is the concrete value of  $y$  by doing defuzzification? [5 marks]

**Problem 3: (30 Marks)**

- a. Define the term set membership function, illustrating your answer with an example. Sketch the graph of your fuzzy membership function example. (10 Marks)
- b. Design a fuzzy controller for a refrigerator given the following technical specifications. The ideal temperature of the fridge is 2 degrees centigrade, while the variation in internal temperature is not expected to be more than +5 or -5 degrees. The maximum rate of change of temperature is expected to be within +2 or -2 degrees per hour. The output from your fuzzy controller is expected to power a compressor that ranges from 0 to 2 kW. Given a temperature of 4 degrees and a rate of change of temperature of -0.5 degrees per hour, what is the required compressor power output calculated by your controller.
  - i. Design a fuzzy logic controller (FLC) for this system. Draw the major block diagrams for the process as well as FLC.
  - ii. Show step-by-step your FLC design.

(Note, 3 fuzzy sets are represented homogeneously for each input variables and output variable respectively. ) (20 Marks)

< Good luck >