Fuzzy System to Temperature Control

The oven has a sensor that takes a temperature reading every minute, and a resistance to heat the oven, whose temperature will be controlled by a control voltage.

The system will consist of two input variables and one output variable:

- **Temperature Difference:** difference between the current temperature and the target temperature.
- **Temperature Increase:** difference between the current temperature and the previous temperature. Indicates the rate of change in one minute.
- **Control voltage:** amount of voltage to be applied to the resistor to control the temperature.

Rules

- If the difference is negative
  - and the increment is negative, then increase the voltage
  - and the increment is zero, then increase voltage
  - and the increment is positive, then maintain the voltage
- If the difference is zero
  - and the increment negative then increase the voltage
  - and the increment is also then maintain the voltage
  - and the increment is positive then decrease
- If the difference is positive
  - and the increment negative then maintain
  - and the increment is zero then decrease
  - and the increment is positive then decrease

Fuzzification

Input Variable 1

- Name: **D** (Temperature Difference: Current - Target)
- Linguistics tags:
  - Negativo: if current temperature is below the target
  - Cero: if current and target temperatures coincide
  - Positivo: if current temperature is over the target
- Universe of Discourse: real numbers
- Membership functions:

$$\mu_{negativo}(x) = \begin{cases} 1, & x \le -1 \\ -x, & x \in (-1,0) \\ 0 & x \ge 0 \end{cases}$$

$$\mu_{cero}(x) = \begin{cases} x+1, & x \in [-1,0] \\ -x+1, & x \in (0,1] \end{cases}$$

$$\mu_{positivo}(x) = \begin{cases} 1, & x \ge 1 \\ x, & x \in (0,1) \\ 0 & x \le 0 \end{cases}$$

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Input Variable 2

- Name: **T** (Temperature Increase: Current - Previous)
- Linguistics tags:
  - Negativo: if the current temperature has decreased.
  - Zero: if it is the same as the current temperature
  - Positivo: if the current temperature has risen
- Universe of Discourse: real numbers
- Membership functions:

$$\mu_{negativo}(x) = \begin{cases} 1, & x \le -0.5 \\ -x, & x \in (-0.5,0) \\ 0 & x \ge 0 \end{cases}$$

$$\mu_{cero}(x) = \begin{cases} x+1, & x \in (-0.5,0] \\ -x+1, & x \in (0,0.5) \end{cases}$$

$$\mu_{positivo}(x) = \begin{cases} 1, & x \ge 0.5 \\ x, & x \in (0,0.5) \end{cases}$$

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Output Variable

- Name: **V** (Control Voltage)
- Linguistics tags:
  - Disminuir: resistance will decrease temperature.
  - Mantener: resistance will not change the temperature
  - Aumentar: the oven's resistance will increase the temperature
- Universe of Discourse: real numbers
- Membership functions:

$$\mu_{disminuir}(x) = \begin{cases} 1, & x \in [-1,-0.5] \\ -x, & x \in (-0.5,0) \end{cases}$$

$$\mu_{mantener}(x) = \begin{cases} x+1, & x \in [-0.5,0] \\ -x+1, & x \in (0,0.5] \end{cases}$$

$$\mu_{aumentar}(x) = \begin{cases} 1, & x \in [0.5,1] \\ x, & x \in [0,0.5) \end{cases}$$

Inference

- Assuming the following input values:

  D=-0.5 T=0.7

1. **Antecedent Evaluation**:
   - Variable D: $\mu_{negativo}(-0.5) = 0.5$ $\mu_{postivo}(-0.5) = 0$ $\mu_{cero}(-0.5) = 0.5$
   - Variable T: $\mu_{negativo}(0.7) = 0$ $\mu_{postivo}(0.7) = 1$ $\mu_{cero}(0.7) = 1$

- Rules: R3 y R6
  - Antecedent(R3)=min(0.5,1)=0.5
  - Antecedent(R6)=min(0.5,1)=0.5

2. Consequent Evaluation

- TRUNCATION

$$\mu_{disminuir}(x) = \begin{cases} 1, & x \in [-1,-0.5] \\ -x, & x \in (-0.5,0) \end{cases} \Rightarrow \mu_{disminuir}(x) = \begin{cases} \underline{0.5}, & x \in [-1,-0.5] \\ -x, & x \in (-0.5,0) \end{cases}$$

$$\mu_{mantener}(x) = \begin{cases} x+1, & x \in [-0.5,0] \\ -x+1, & x \in (0,0.5] \end{cases} \Rightarrow \mu_{mantener}(x) = \begin{cases} 0.5 & x \in [-0.5,0.5] \\ \end{cases}$$

3. Agregation

$$\mu_{resultado}(x) = \begin{cases} 0.5 & x \in [-1, 0.5] \\ 0 & x > 0.5 \end{cases}$$

Defuzzification

Centroid method

$$C = \frac{\sum_i x_i \times \mu(x_i)}{\sum_i \mu(x_i)}$$

$$C = \frac{(-1 \times 0.5) + (0.5 \times 0.5)}{0.5 + 0.5} = -0.25$$