Assignment No. 3

Title: Fuzzy Logic Control of a Simulated Robotic Arm

Introduction: Robotic arm control requires handling uncertain and imprecise data. Traditional controllers may struggle when exact mathematical models are unavailable. Fuzzy logic provides a flexible approach by using linguistic rules to mimic human reasoning.

Fuzzy Logic System Design:

- Fuzzification: Defined linguistic variables for **error** (negative, zero, positive) and **change in error** (negative, zero, positive). Membership functions are triangular. Each crisp input is turned into membership grades in linguistic sets (neg/zero/pos).

- Rule base: Nine Mamdani rules encode expert knowledge (e.g., IF error is positive AND derr is zero THEN control is weak positive). Human-like if-then rules convert fuzzy inputs into fuzzy consequents (clipped MFs).

- Inference & Aggregation: Each rule firing strength is computed (min for AND), consequents clipped, and final output aggregated (max).

- Defuzzification: Centroid method produces crisp control. Compute centroid **(sum(mu(x)*x)/sum(mu(x)))** on the aggregated output to produce a crisp control value.

- Plant & Simulation: A simple discrete-time integrator simulates the arm:

  angle <- angle + dt * gain * control.

  Simulation stops when the error is below a threshold. Apply control, update the angle, and repeat until close to the target.

Methodology:

1. Defined fuzzy input variables: Error and Change in Error.
2. Defined fuzzy output variable: Control Signal.
3. Constructed membership functions (Negative, Zero, Positive).
4. Designed fuzzy rules such as:
   a. IF Error is Negative AND Change in Error is Negative THEN Control is Negative.
   b. IF Error is Zero AND Change in Error is Zero THEN Control is Zero.
   c. IF Error is Positive AND Change in Error is Positive THEN Control is Positive.
5. Implemented fuzzy inference using Mamdani method and defuzzification using Centroid method.
6. Simulated the robotic arm control system in Python.

Membership Functions

Membership functions define the degree to which a value belongs to a fuzzy set. In this project:

- Angle Error: {Negative, Zero, Positive}
- Angular Velocity: {Slow, Medium, Fast}
- Torque: {Low, Medium, High}

Rule Base

Some example fuzzy rules are:

1. IF Angle Error is Negative AND Angular Velocity is Slow THEN Torque is High.

2. IF Angle Error is Zero AND Angular Velocity is Medium THEN Torque is Medium.

3. IF Angle Error is Positive AND Angular Velocity is Fast THEN Torque is Low.

Conclusion:

This assignment demonstrated how fuzzy logic can effectively control a robotic arm without precise mathematical modeling. The rule-based system handled uncertainties and produced smooth control outputs. This approach can be extended to real robotic systems and other intelligent control applications.