ECE 68000: MODERN AUTOMATIC CONTROL

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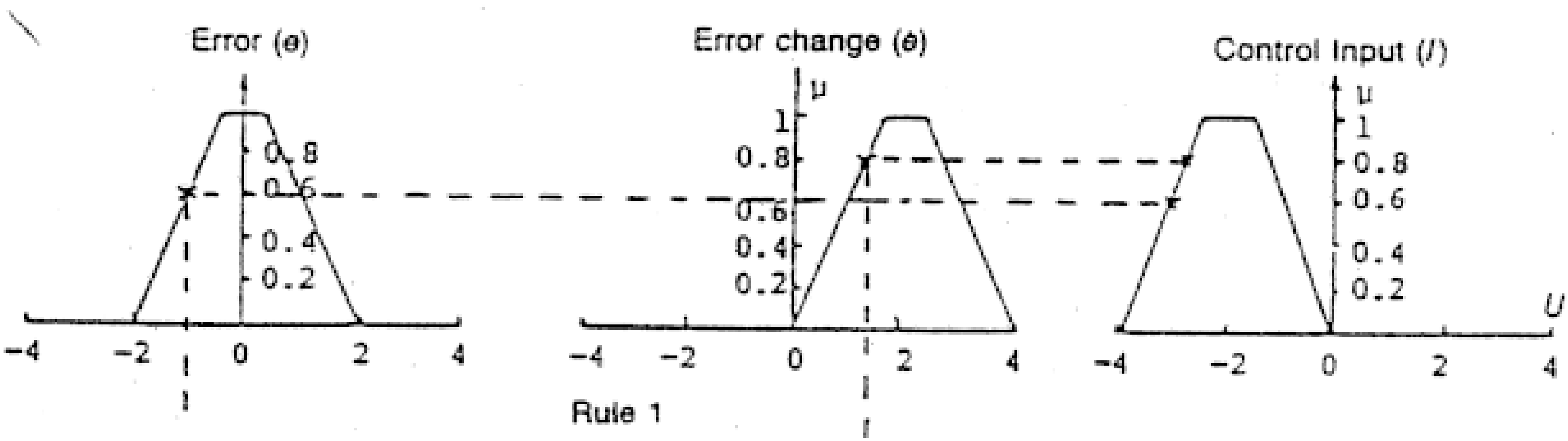
Fuzzy Logic Control Design

Computing With Words---Example

- Our example uses data from the paper by Y.F. Li and C.C. Lau, "*Development of fuzzy algorithms for servo systems*," IEEE Control Systems Magazine, pp. 65--72, April 1989
- Rule #1: IF the error is ZE and the error change is SP THEN the control is SN
- Rule #2: IF the error is ZE and the error change is ZE THEN the control is ZE
- Rule #3: IF the error is SN and the error change is SN THEN the control is SP
- Rule #4: IF the error is SN and the error change is ZE THEN the control is LP

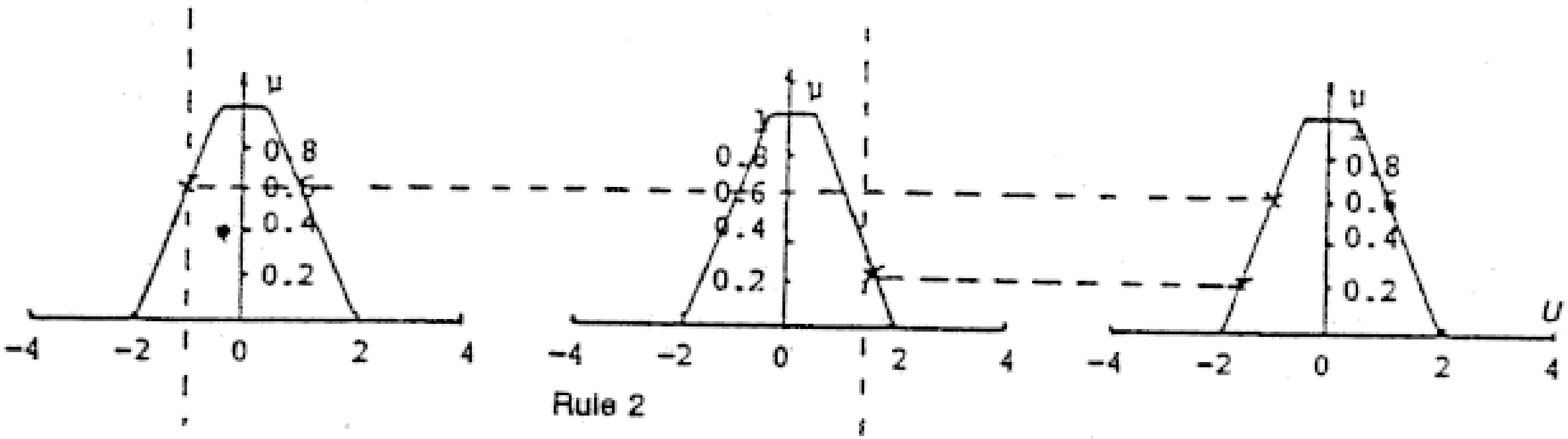
Defuzzification: Moving From Fuzzy Rules to Numbers

- Contribution of Rule #1



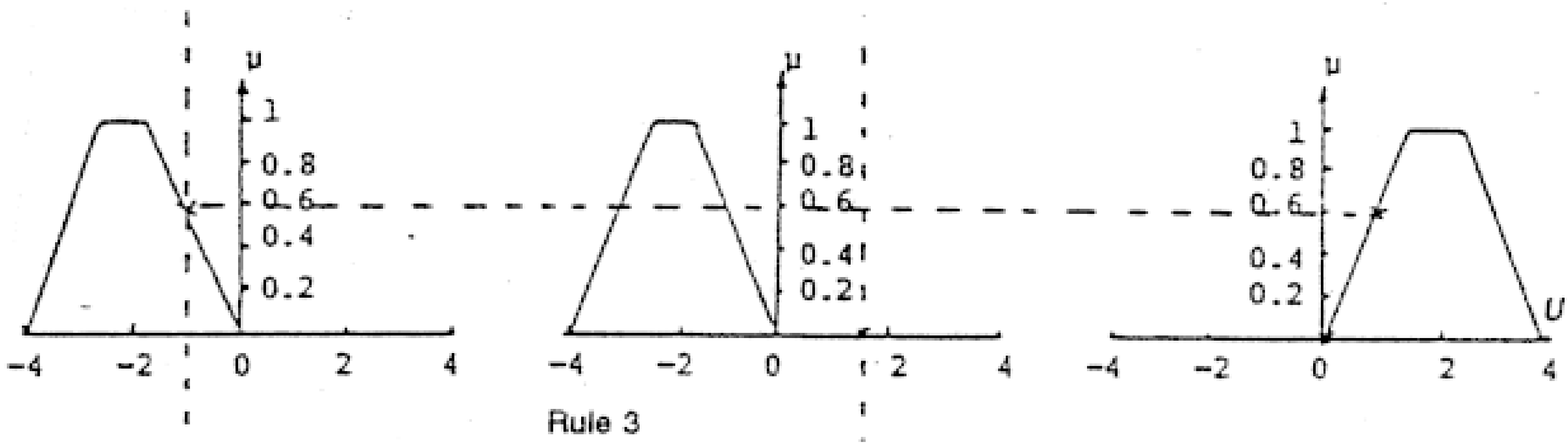
- Center-of-gravity---0.6×(-2)
- Center average defuzzifier--- 0.6×0.8×(-2)

Defuzzification: Contribution of Rule #2



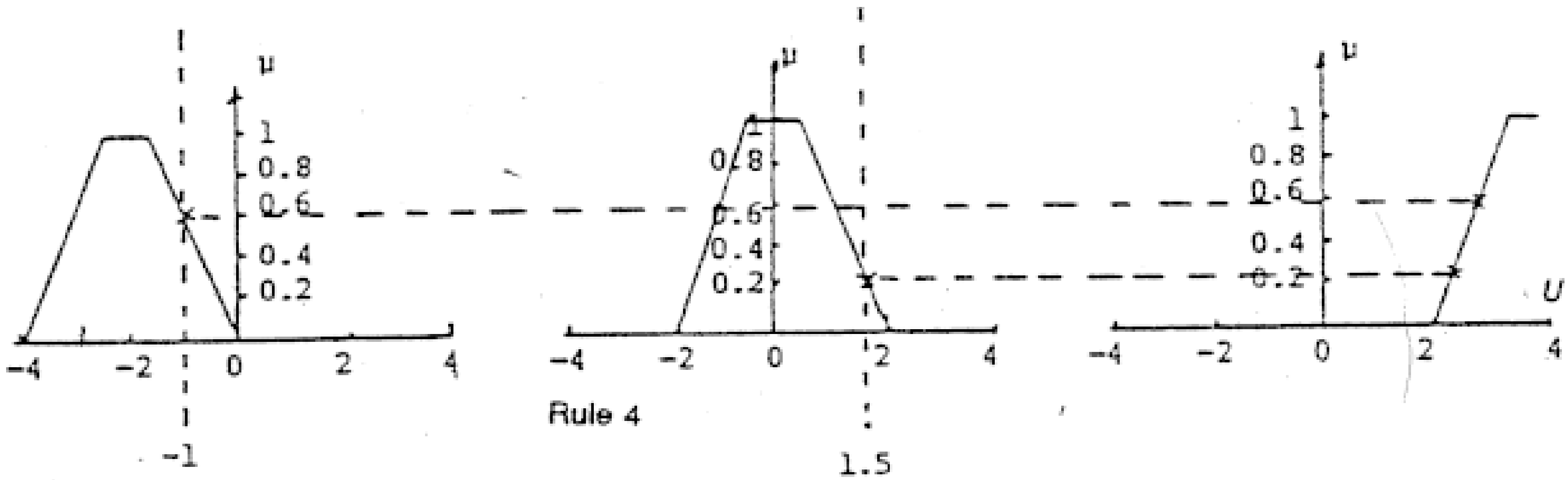
- Center-of-gravity---0.2×0
- Center average defuzzifier--- 0.6 × 0.2×0

Defuzzification: Contribution of Rule #3



- Center-of-gravity---0×2
- Center average defuzzifier--- 0.6×0×2

Defuzzification: Contribution of Rule #4



- Center-of-gravity---0.2×4
- Center average defuzzifier--- 0.6×0.2×4

Combining All Contributions Together

- Center-of-gravity

$$u = \frac{0.6\times(-2)+0.2\times 0+0\times 2+0.2\times 4}{0.6+0.2+0+0.2} = -0.4$$

- Center average defuzzifier (product inference rule)

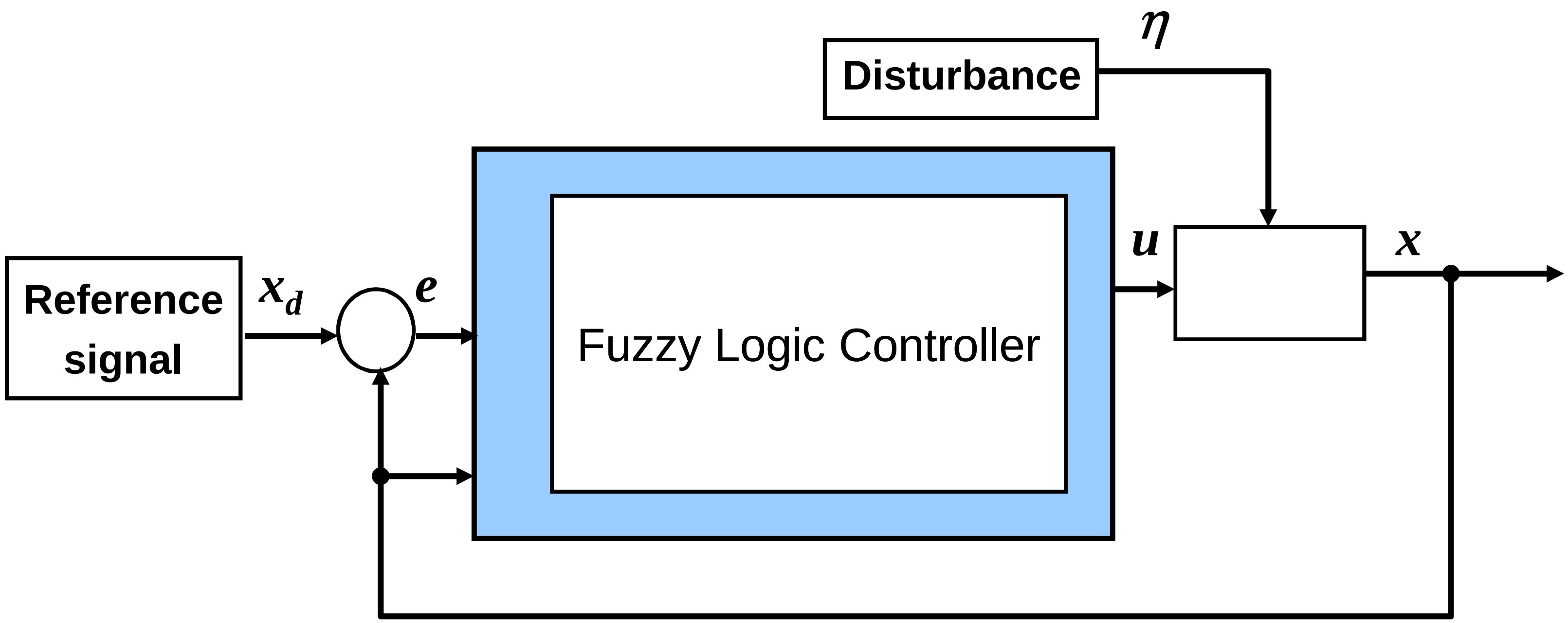
$$u = \frac{0.48\times(-2)+0.12\times 0+0\times 2+0.12\times 4}{0.48+0.12+0+0.12} = -0.67$$

Designing a Fuzzy Logic Controller for DC Motor---Control Objective

- Design a controller that forces the closed loop system output $x(t)$ to track a given reference signal $x_d(t)$

- Force the tracking error $e(t) = x - x_d$ to asymptotically decay to 0

Fuzzy Logic Controller (FLC) in the Loop

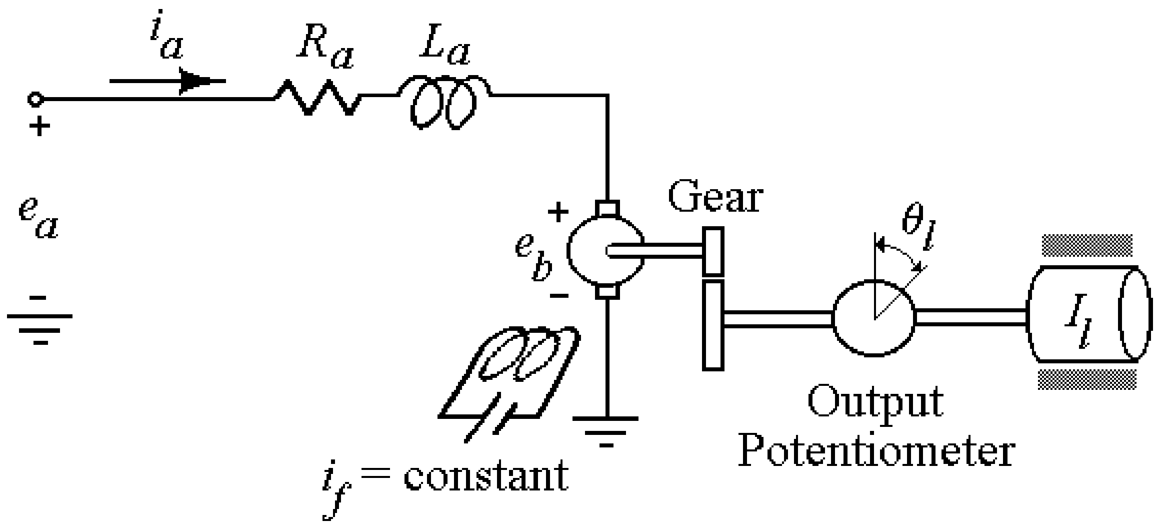


FLC Design Algorithm

- Identify ranges of the controller inputs
- Identify ranges of the controller output
- Create fuzzy sets for each input and output
- Translate the interaction of the inputs and outputs into IF-THEN rules, and then form the rules matrix
- Decide on the defuzzifier, and then use it to generate the control surface
- Implement the controller, test it, and modify it if necessary

Fuzzy Logic Tracking Control of a DC Motor

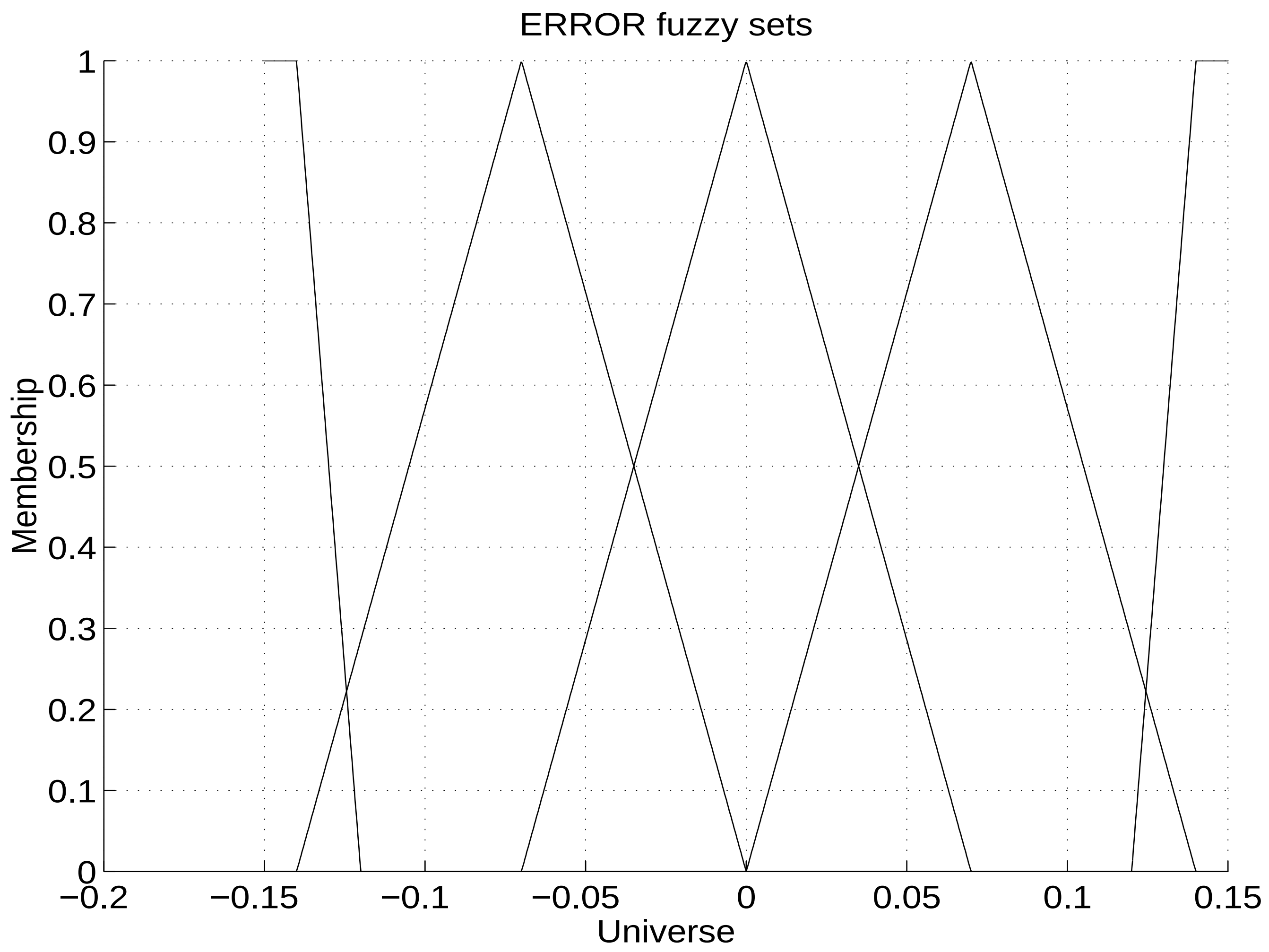
DC motor schematic



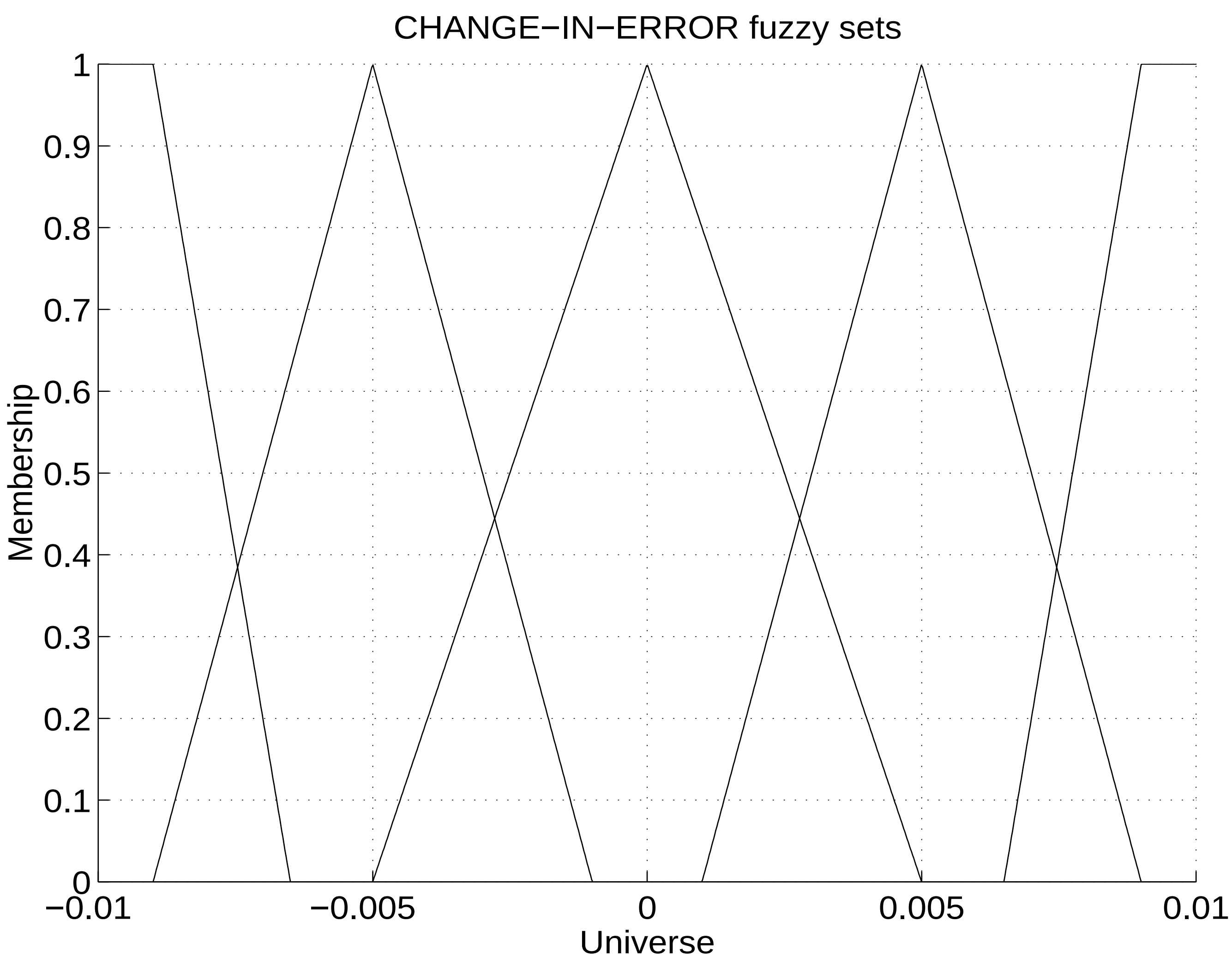
More On the Control Objective and the Plant

- DC motor--- Electro-Craft Corporation MOTOMATIC system
- Control objective---design a simple fuzzy logic tracking controller, simulate the dynamical behavior of the closed-loop and test the design in the lab
- Math model of the DC motor needed for simulations

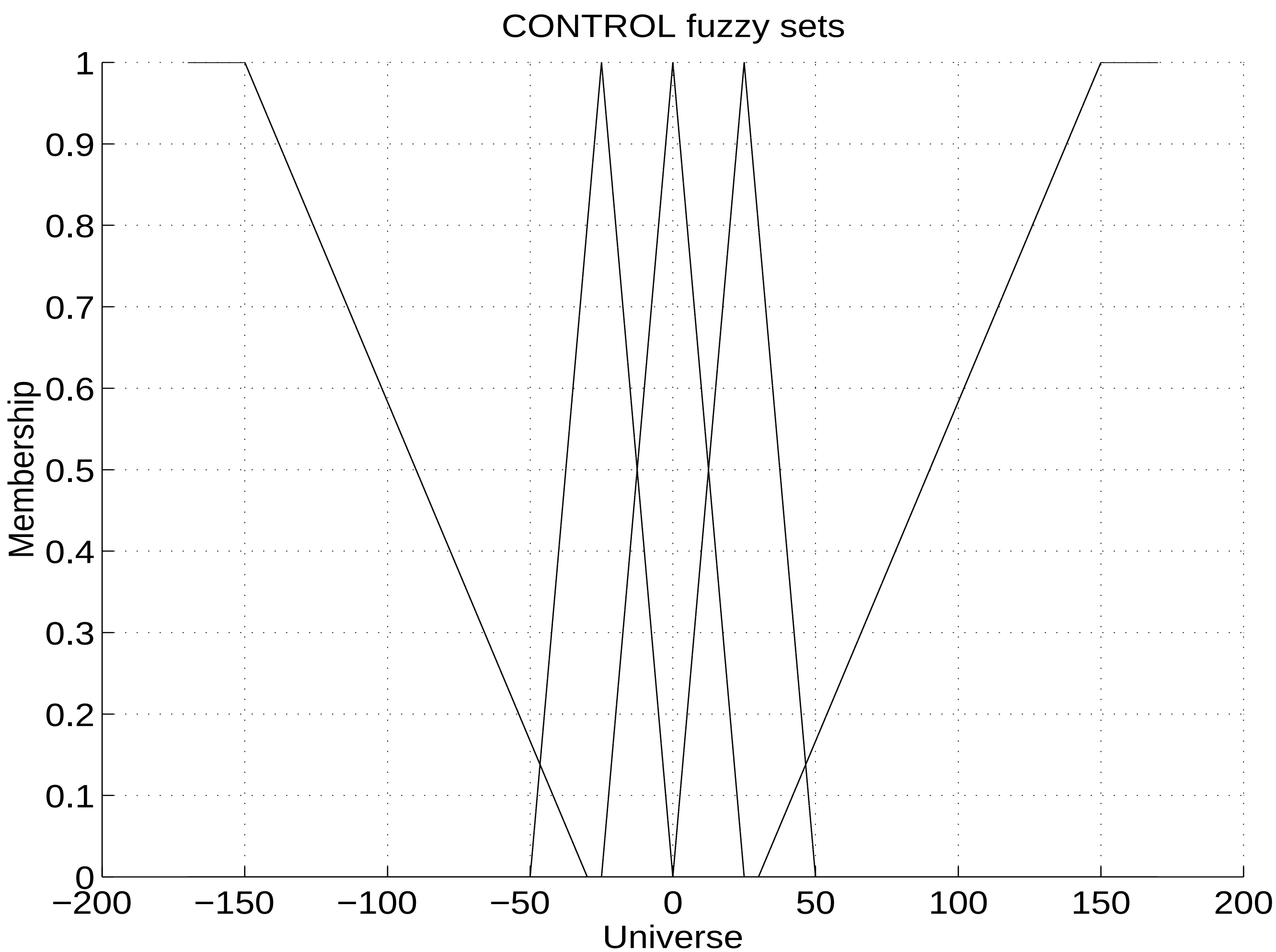
Tracking Error Fuzzy Sets



CHANGE-IN-ERROR Fuzzy Sets



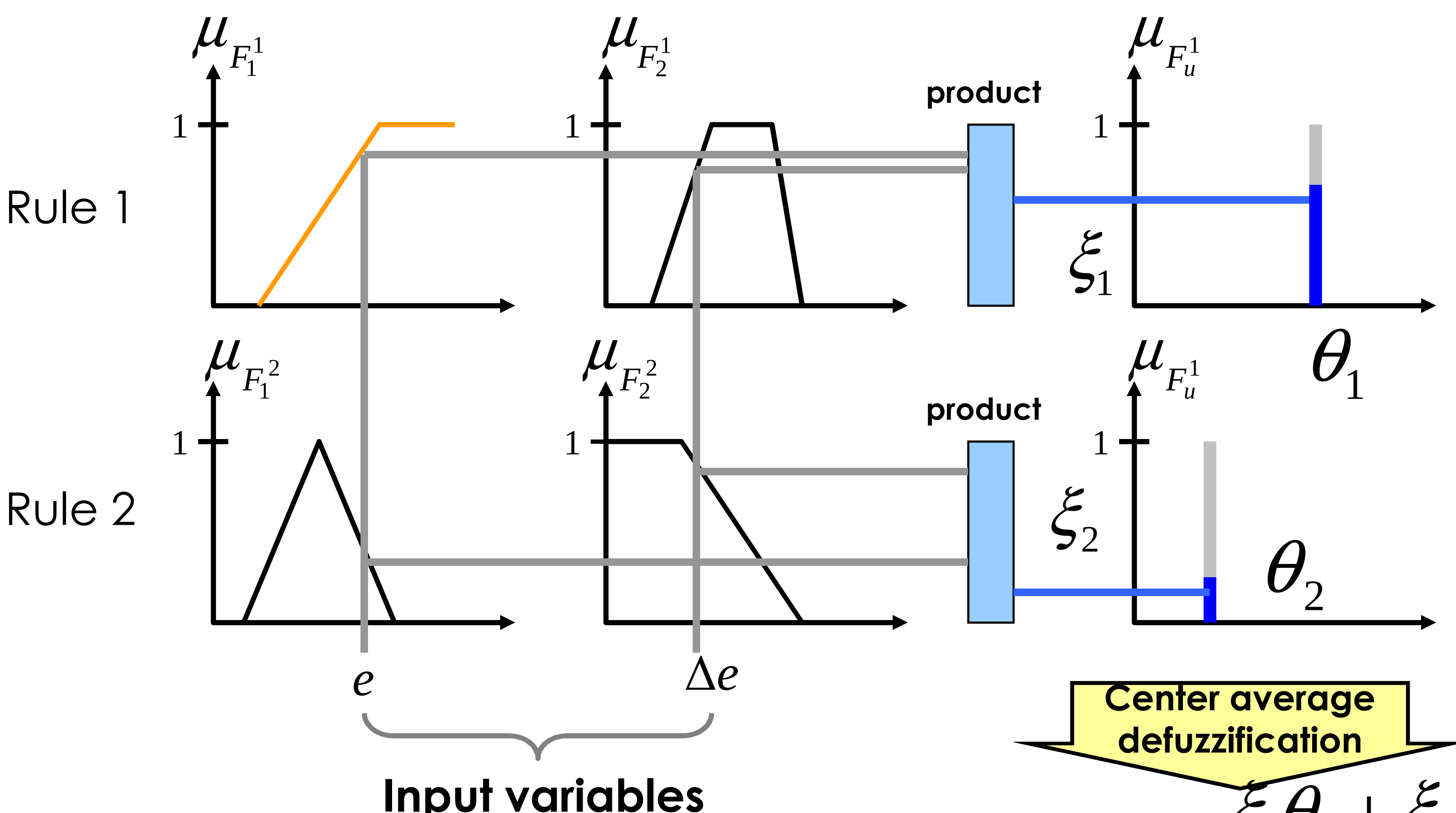
Control Action Fuzzy Sets



Rules Matrix

Change-in-error	LN	N	ZE	P	LP
Error					
Large Negative (LN)	LN	LN	LN	N	ZE
Negative (N)	LN	LN	N	ZE	P
Zero (ZE)	N	N	ZE	P	P
Positive (P)	N	ZE	P	LP	LP
Large Positive (LP)	ZE	P	LP	LP	LP

Center Average Inference System



Control action $$u = \frac{\xi_1\theta_1 + \xi_2\theta_2}{\xi_1 + \xi_2}$$

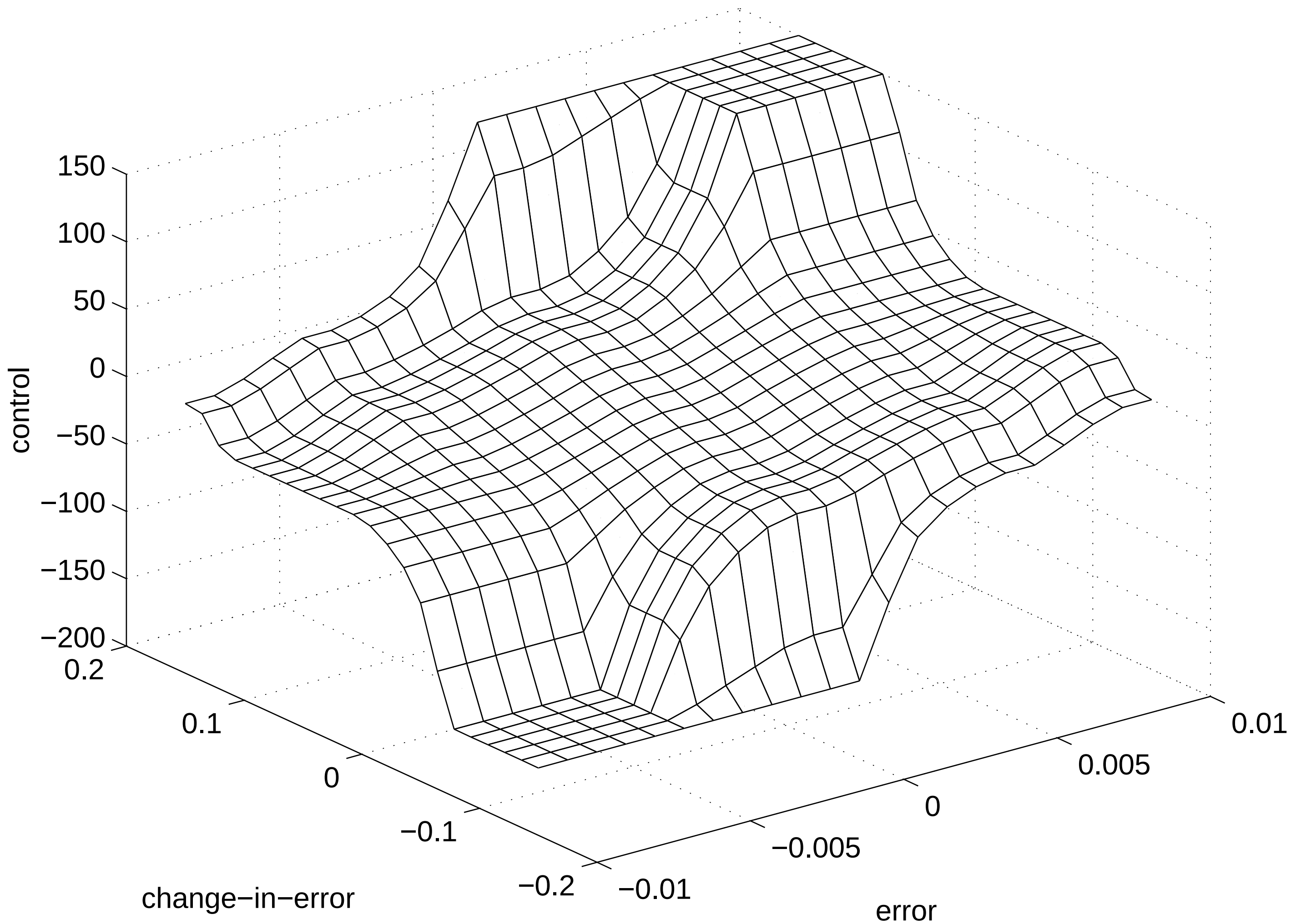
Defuzzifier

Center average defuzzifier for a two-input controller

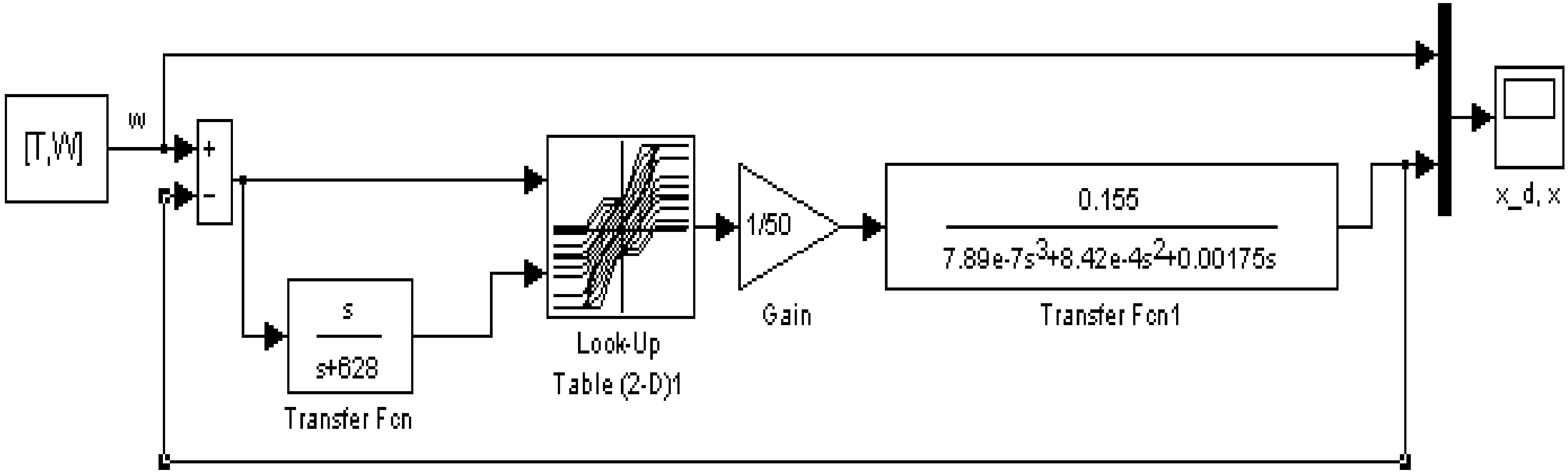
$$u = \frac{\sum_{l=1}^{M} \mu_{A_l}(e)\, \mu_{B_l}(\Delta e)\, \theta_c^l}{\sum_{l=1}^{M} \mu_{A_l}(e)\, \mu_{B_l}(\Delta e)}$$

where θ_c^l is the centroid of the control action fuzzy set and M is the number of fuzzy rules

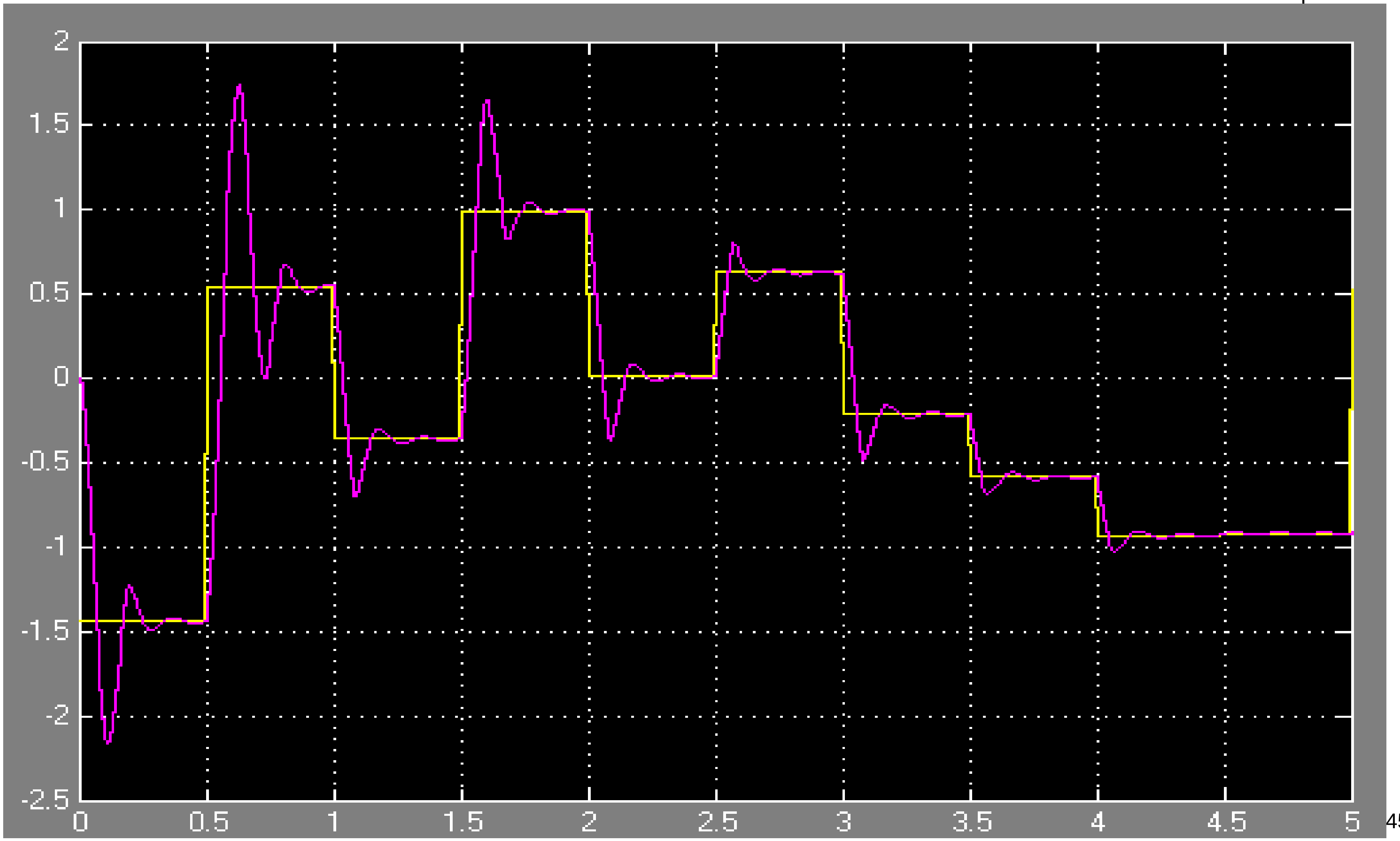
Control Surface



FLC in SIMULINK



Simulation Results



Improving the Performance of FLC

- Excessive overshoot
- Fine tune the controller
- Good results when changed the error range of the tracking error from

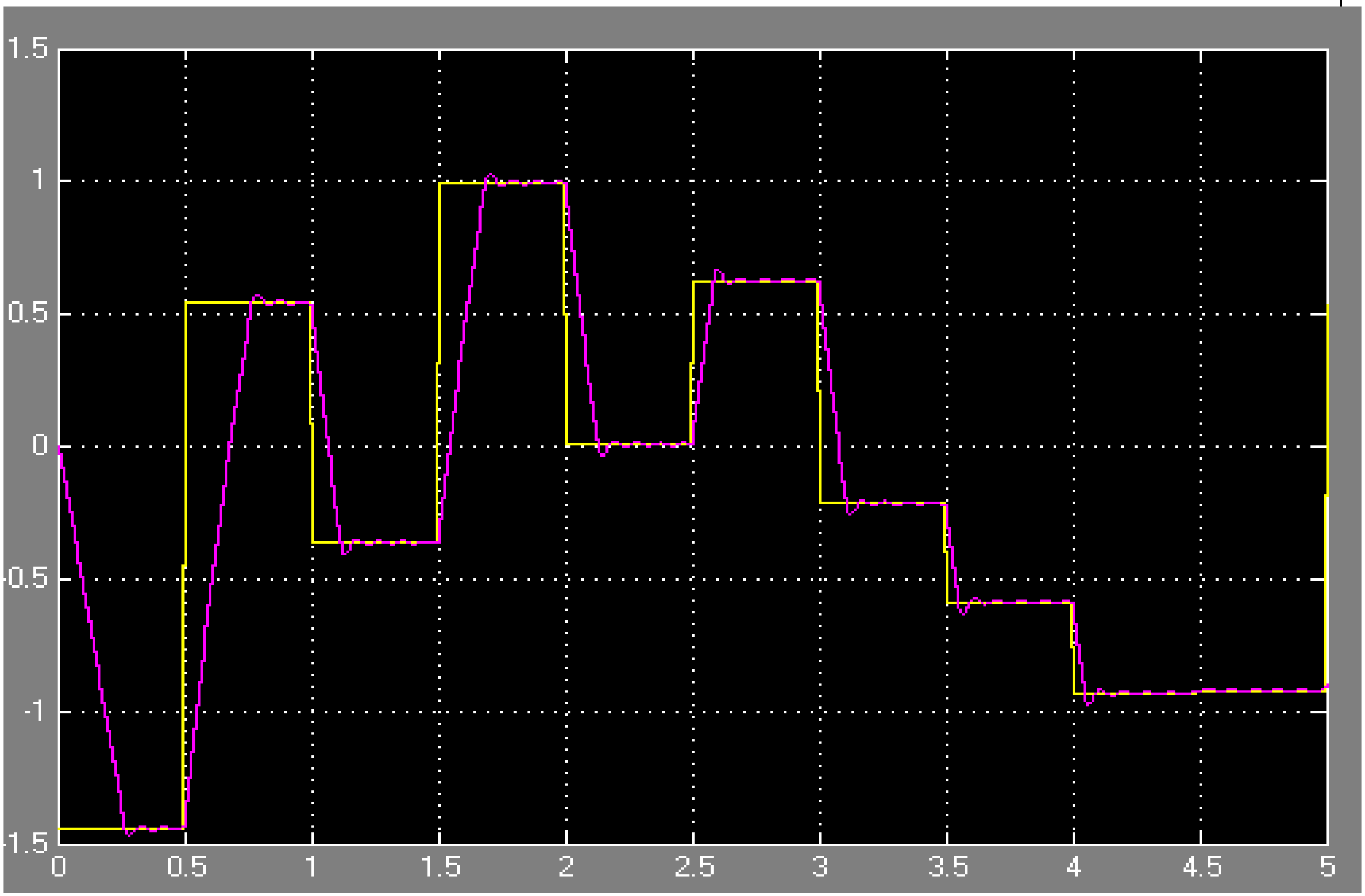
$$[-0.15, 0.15]$$

to

$$[-0.1, 0.1]$$

New Tracking Error Fuzzy Sets

FLC Improved Performance



Summary

Fuzzy Logic Control:

- incorporates linguistic description of the controller action, rather than a mathematical plant model, to compute the control action---computing with words
- different ways to achieve high controller performance---use a two-range controller consisting of coarse and fine parts to regulate the large tracking error and small tracking error
- use more fuzzy sets, this in turn requires more fuzzy rules