Project 1 on Fuzzy Systems

Speed control of a workbench mechanism using fuzzy controllers

System

A high-precision workbench mechanism utilizes a precision tachometer and a direct-drive dc motor, as shown in Fig.1, [1]. The goal is to maintain high accuracy in the steady state of speed control. To have zero error in the steady state, we choose controllers with proportional-integral action. The control system using fuzzy controllers is shown in Fig.2.

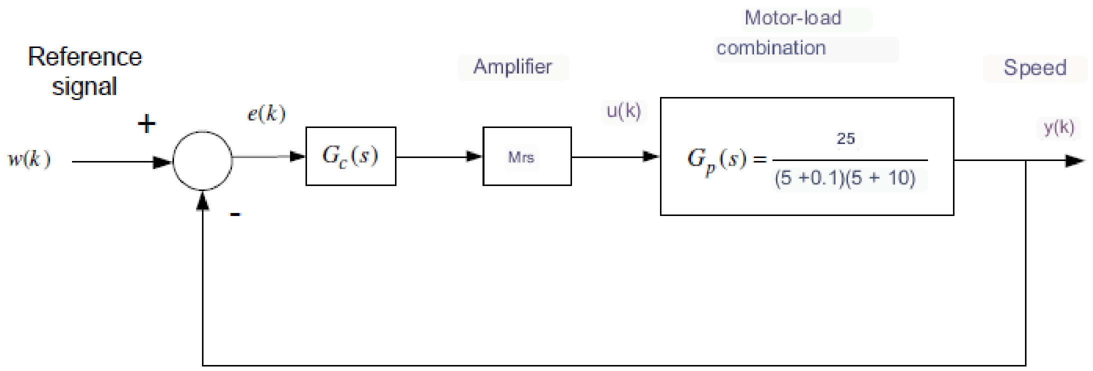
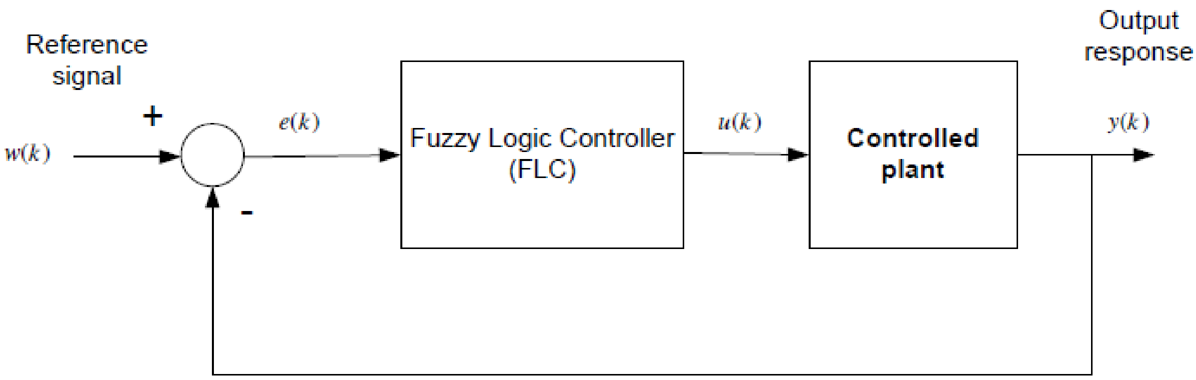


Fig.1



- r(k) is the reference signal.
- y(k) is the system's output.
- e(k) is the error of the reference signal with respect to the system output.
- u(k) is the control law (controller output)

We consider that the maximum speed of the worktable we are interested in is

max = 50 (rad / sec).

Design of linear control

For zero error in the steady state of the speed control we choose a linear PI controller of the form:

$$G_c(s) = K_p + \frac{K_I}{s} = \frac{K_p(s+c)}{s}, \quad c = \frac{K_I}{K_p}$$

Determine the parameters of the linear controller so that the following specifications are met.

1. Canopy for step entry less than 8%.

2. Rise time less than 0.6 seconds.

To design the linear controller, we follow the principles of classical automaton.

control, using the control toolbox program of MATLAB.

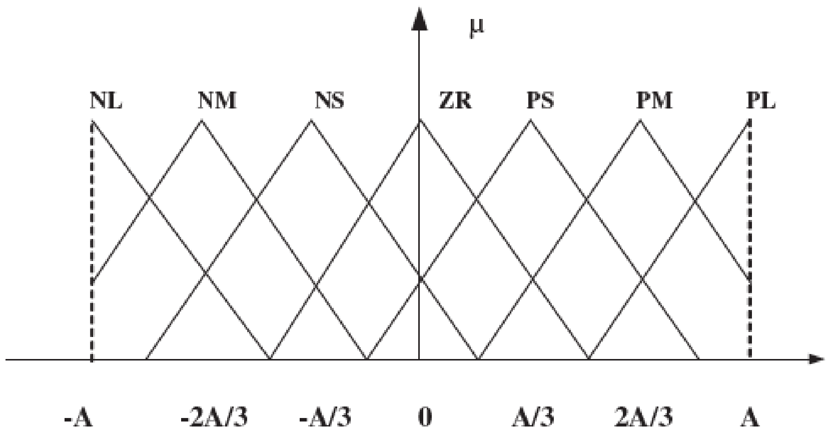
- Place the neutral of the controller between the -0.1 and -10 poles of the controlled system, in a position close to the dominant pole, i.e., -0.1.
- Enter the open-loop function in the system, in the form:

  ì $\dfrac{K(s+c)}{(s+0.1)(s+10)}$
- Create the root locus of the system with rlocus.
- Select from the locus diagram a gain K corresponding to closed-loop pole positions and damping factor appropriate for the specifications set.
- Calculate the closed-loop function (with unit feedback) of the system, using for example the command feedback (sys-open-loop, 1, -1).

- Calculate the step response of the closed loop system, using the commands step(sys-closed-loop), lsim, plot etc.
- If the specifications are met, the process is terminated. Otherwise, follow a trial-and-error process, trying different gain values.
- For the optimal gain value K chosen earlier, calculate the gains K, and the gains K_p and K_l of the controller.

Designing a Fuzzy controller (FLC)

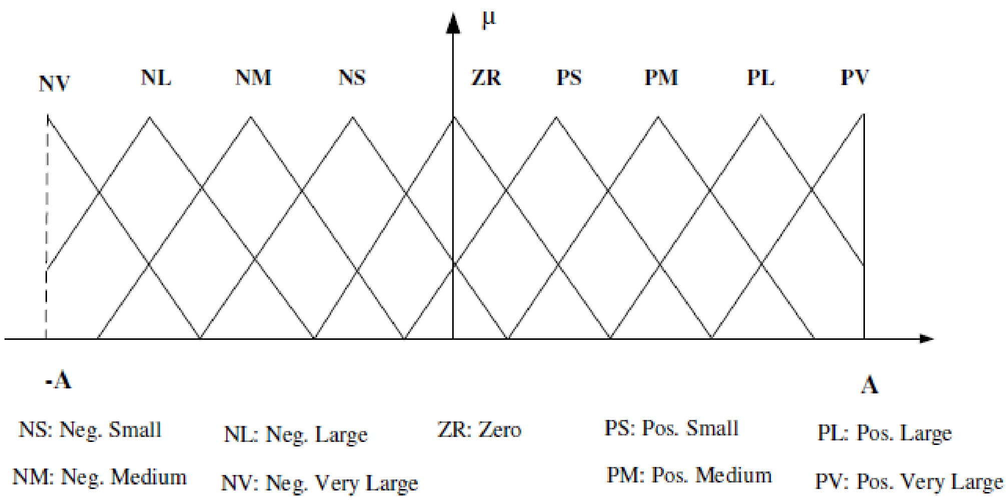
- To have zero steady-state error for the velocity, we again choose a FZ-PI type fuzzy controller.
- The implementation of the closed loop system will be done in discrete time with a sampling interval T = 0.01 sec.
- The verbal variables of the error E are described by seven verbal values as shown in Fig.2 (a).
- The verbal variables of the error change $\dot{E}$ are described by seven verbal values as shown in Fig.2 (a).
- The verbal variables of the change of the control signal $\dot{U}$ are described by nine verbal values as shown in Fig. 2(b).



NS: Neg. Small NL: Neg. Large ZR: Zero PS: Pos. Small PL: Pos. Large

NM: Neg. Medium PM: Pos. Medium

Σχ.2 (α)



Σχ.2 (β)

Requirements

- Initially scale the error and error variance so that the normalized quantities vary in the interval [-1,1].
- Configure the rule base of the fuzzy controller, based on the meta-rules of the closed loop system.
- Create a program in matlab environment that implements the closed-loop fuzzy controller-motor system.

Scenario 1

a) Controller's design and responses

- Adjust the scaling gains so that the closed-loop response for step excitation r = 50* stepfun has better characteristics than that of the linear controller, i.e., overshoot less than 5% and rise time less than 0.6 sec. As initial values of the gains consider those determined for the linear controller in the previous phase of the work.
- Present the response of the system and the system's output, in relation to the responses of the linear controller.

b) **Operation of the controller's base**

- From the basis set, consider an excitation where e is NS and Δe is NS. Graphically present which rules are triggered, and which partial inferences arise.
- Which is the overall conclusion based on the disambiguation method?

c) Interpretation of the FLC Control

- Generate the 3D surface of the output of the fuzzy controller $\Delta u(k)$ with respect to its inputs e(k) and Δe(k).
- Interpret this figure based on the form of the controller's rules**.**

Scenario 2

- Next, two different profiles of the reference signal are examined, as shown in Fig.3 and Fig.4.
- For the selected fuzzy controller parameters, plot the closed-loop system speed response for the two different reference signal scenarios.
- Based on the responses, comment on the FLC's ability to monitor ramp inputs

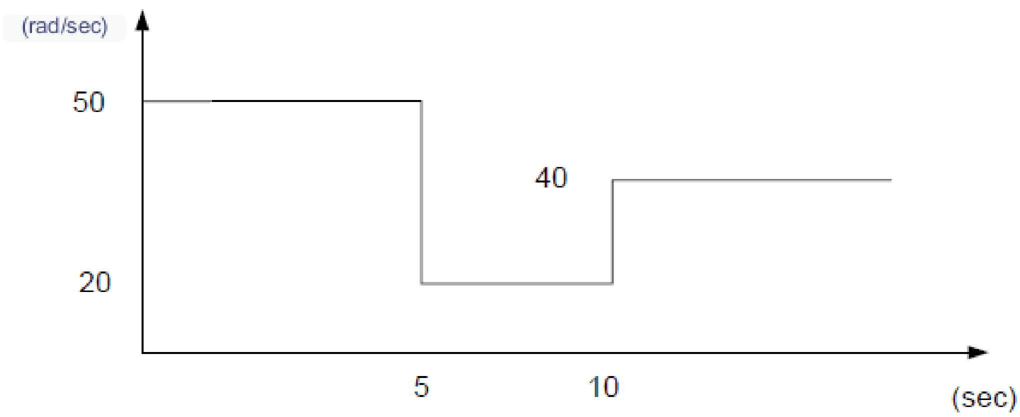


Fig. 3

Fig. 4