⑤ • Use less than the whole neighborhood to select the next solution
⑥ • Add a frequency based tabu list to encourage the search to diversify

Question2 (10 Points)

Genetic Algorithm (GA) can be used to design a PID (Proportional-Integral-Differential) controller for closed loop plant control systems. A common configuration is shown in the following figure 1.

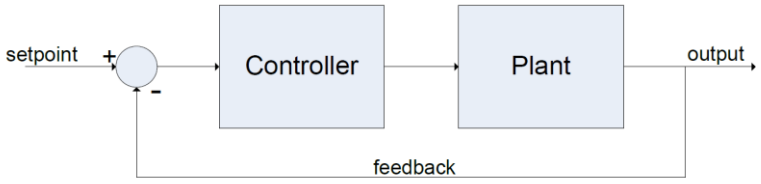


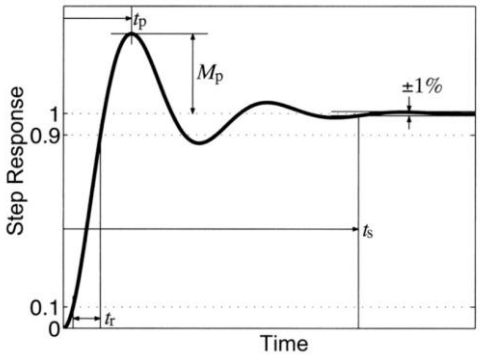
Figure 1. Closed-loop control system

Notice that the output of this system has an explicit impact on the input of the controller, which explains the "closed-loop" term. In this loop, the output of the system is what we would like to control to the set-point. So, the controller is being fed by the error.

The PID controller is specified by a transfer function of the form:

$$G_C(s) = K_p\left(1 + \frac{1}{T_I s} + T_D s\right)$$

Where K_p, T_I, and T_D are the controller parameters. The objective of the design is to obtain the values of these parameters that optimize the performance of the system. For a given plant transfer function, the performance of the system is typically evaluated by the step response of the system which is of the form shown in the figure below.



The performance is measured in terms of integral squared error (ISE):

$$ISE = \int_0^T (e(t))^2 \, dt$$

which is the integral of the square of the difference between the output and the steady state value (1 in this case), along with the values of the step response parameters: t_r (the rise-time), t_s (the settling time), and M_p (the maximum overshoot magnitude) which can be addressed as the percentage of the steady-state output. t_r and t_s are important, as they demonstrate how fast a system can work. M_p is of importance as well, as we may abide by the plant restrictions. So, **it is important to minimize all these performance measures.**

- minize rising time
Settling time
maximum overshoot magnitude.

In this problem you are provided with a function that gives you the performance measures if you provide it with values for the parameters K_p, T_I, and T_D. The function is

[ISE,t_r,t_s,M_p] = perfFCN([K_p;T_i;T_d]

It is a function in Matlab code that uses other functions of Matlab control toolbox.
Assume that the values of the controller parameters are in the ranges: $K_p \in (2, 18)$, $T_I \in (1.05, 9.42)$, $T_D \in (0.26, 2.37)$.

a. Develop a suitable **representation** for the solutions with precision of 2 decimal points.

b. Formulate a **fitness function** that you can use to evaluate a solution.

c. **Implement** GA algorithm to solve this problem, use a population of 50 individuals, number of generations of 150, crossover probability of 0.6 and mutation probability of 0.25. Use FPS parent selection strategy and an elitism survival selection strategy keeping the best two individuals across generations. Select proper crossover and mutation operators and solve the problem.

d. **Plot** the fitness of best solution in each generation across the generations.

In this part we would like to study the effect of the choice of the GA parameters:

e. Experiment with 2 different values for the number of generations (one less than original, one greater) and compare the results for the 3 different experiments.

f. Experiment with 2 other population sizes (one less than 50, one greater) and compare the results for the 3 different population sizes.

g. Experiment with 2 different crossover probabilities (one less than original, one greater) and compare the results for the 3 different experiments.

h. Experiment with 2 different mutation probabilities (one less than original, one greater and compare the results for the 3 different experiments.

*The supplementary files and an article on PID controller design are posted in this assignment module.