University of Waterloo

Department of Electrical and Computer Engineering

ECE 457A Cooperative and Adaptive Algorithms

Assignment 3: Due Date – Nov 19th, 2021

- **The assignment should be done individually**
- **You should upload your answers as a PDF file on learn before 11:59pm of the deadline date**
- **Attach any codes used for the assignment separately as a compressed file to the same dropbox**
- **You can use any programming language (Matlab and python are preferred)**
- **Works with more than 30% similarity will be checked for originality**
- **Communicate any issues or concerns with the TAs**

Question1 (10 Points)

This is one of the QAP (quadratic assignment problem) test problems of Nugent et al.
20 departments are to be placed in 20 locations with five in each row (see below). The objective is to minimize costs between the placed departments. The cost is (flow * rectilinear distance), where both flow and distance are symmetric between any given pair of departments. The flow and distance matrices are attached to this assignment. The optimal solution is 1285 (or 2570 if you double the flows).

(note: rectilinear is also known as Manhattan distance)

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20

Figure 1: Layout of department locations

1. Code a simple TS to solve the problem. To do this you need to encode the problem as a permutation, define a neighborhood and a move operator, set a tabu list size and select a stopping criterion. Use only a recency based tabu list and no aspiration criteria at this point. Set the default neighborhood function to check the whole neighborhood.
2. Run your TS.
3. Perform the following changes on your TS code (one by one) and compare the results.
   - Change the initial starting point (initial solution) 10 times
   - Change the tabu list size twice – once smaller and once larger than your original choice
   - Change the tabu list size to a dynamic one – an easy way to do this is to choose a range and generate a random uniform integer between this range every so often (i.e., only change the tabu list size infrequently)
   - Add 2 aspiration criteria in 2 separate experiments: best solution so far, best solution in the neighborhood

- Use less than the whole neighborhood to select the next solution
- 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.

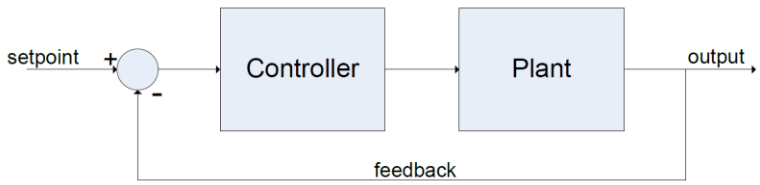


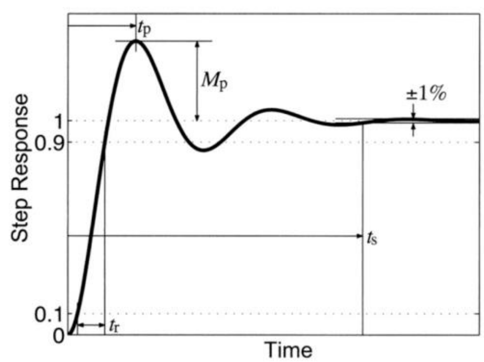
Figure 1. Closed-loop control system

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:

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

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.**

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.

Question3 (5 Points)

NetLogo* is a high-level multi-agent modelling environment, very suitable for fast creation of agent-based models. NetLogo has a large library of sample models. The model “ANTS” demonstrates a colony of ants forages for food. Though each ant follows a set of simple rules, the colony as a whole acts in a sophisticated way. The first part of this question is to experiment on the NetLogo’s ANTS model. **The model provides control sliders to change the model parameters**.

Run experiments with population (30, 50, 100), diffusion rate (40, 80), evaporation rate (10, 20) and different placements of the food sources. Examining the ant colony’s food foraging and transporting behavior (finish time), report your observations.

* NetLogo is a multi-agent programmable modeling environment. It is used by many tens of thousands of students, teachers and researchers worldwide. It also powers HubNet participatory simulations. It is authored by Uri Wilensky and developed at the CCL. You can download it free of charge. You can also try it online through NetLogo Web.