Assignment 3: GA,ACO,PSO
(Due Date: July 30, 2016- midnight)

What to hand in: a report that contains:

- Typed solutions for the problems,
- The simulation results for the problems,
- Any written code that is used to generate the provided results.
- Questions are equally weighted.

Question 1. 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.

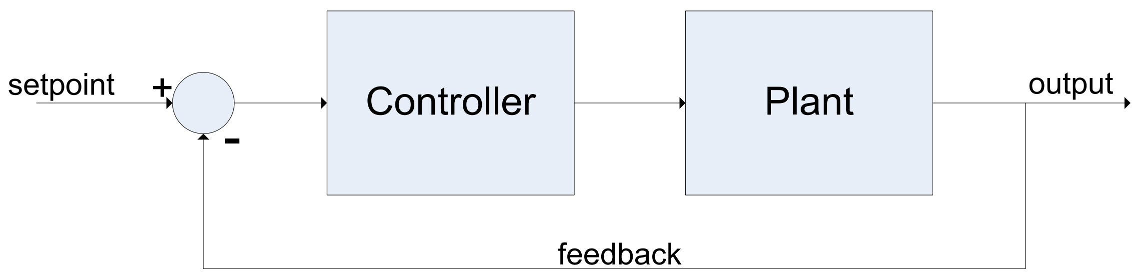

Figure 1. Closed-loop control system

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 figure 2.

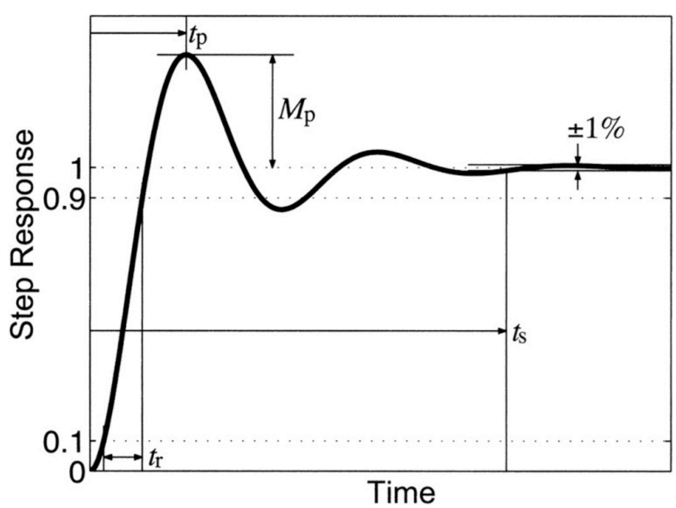

Figure 2. Step response parameters

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 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 a 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 3 different values for the number of generations and report the progression of the solutions.
f. Repeat e for 3 different population sizes.
g. Experiment with different crossover and permutation probabilities (within the guidelines given in class) and report the results.

Question 2. Ant Foraging Behavior and TSP

a) **NetLogo**[1] 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 experiments 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.

[1] NetLogo ver-4.1.3, Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

b) The target problem in this question is the 29-city TSP (known as Bays29 in literature). The distance between cities is symmetrical, and Euclidean distance measure is used. Each city must be visited once and only once. The objective is to minimize the sum of the Euclidean distances of a complete TSP tour. Ignore curvature of the earth. The 29 city coordinate matrix is listed below.

City #	X-coord.	Y-coord.
1	1150.0	1760.0
2	630.0	1660.0
3	40.0	2090.0
4	750.0	1100.0
5	750.0	2030.0
6	1030.0	2070.0
7	1650.0	650.0
8	1490.0	1630.0
9	790.0	2260.0
10	710.0	1310.0
11	840.0	550.0
12	1170.0	2300.0
13	970.0	1340.0
14	510.0	700.0
15	750.0	900.0
16	1280.0	1200.0
17	230.0	590.0
18	460.0	860.0
19	1040.0	950.0
20	590.0	1390.0
21	830.0	1770.0
22	490.0	500.0
23	1840.0	1240.0
24	1260.0	1500.0
25	1280.0	790.0
26	490.0	2130.0
27	1460.0	1420.0
28	1260.0	1910.0
29	360.0	1980.0

For this problem do the following:

1. Code a simple ACO algorithm to solve the problem. To do this you need to select a transition rule, select online and offline pheromone update rules, set a population size and select a stopping criterion.
2. Run your ACO algorithm.
3. Perform the following changes on your ACO code (one by one) and compare the results.
    a) Change the values of pheromone persistence constant 3 times
    b) Change the values of state transition control parameter 3 times
    c) Change the population size twice
    d) Turn off online pheromone update

Question 3 PSO and Application to Function Optimization

a) **NetLogo** has a model that implements a simple PSO in 2-D searching space [Models Library –> Computer Science –> Particle Swarm Optimization]. Refer to the work from Trelea[2] to change the model's parameters.

   i. Run experiments with different populations (30, 80), speed limits (2 and 6), particle's inertia (0.60, 0.729), personal-best (1.7, 1.494) and the global-best factor the same as personal factor. Examine the PSO algorithm's characteristics (speed of converge and ability to find global optima), report your observations.

   ii. What is the difference between the motion formulation of the given **NetLogo** implementation and the classical PSO? Explain the difference by referring to the code.

b) The six hump camelback problem is given as:

$$z = (4 - 2.1x^2 + \frac{x^4}{3})x^2 + xy + (-4 + 4y^2)y^2$$

where x and y lie between +/-5. The objective is to minimize z. The global minimum lies at (-0.089840, 0.712659) or (0.089840, -0.712659) where z = -1.0316285. The global optimum to the problem is given for reference purpose. Do not use it in your solution methodology.

1. Code a simple PSO to solve the problem. To do this you need to encode the problem, initialize a population, select a velocity update equation, and select a stopping criterion.
2. Run your PSO.
3. Perform the following changes on your PSO code (one by one) and compare the results.
   - Use Inertia Weight version of velocity update equation with Global Best
   - Use V_{max} version of velocity update equation with Global Best
   - Use Constriction Factor version of velocity update equation with Global Best
   - Change all three approaches above to Neighborhood Best
   - Use Guaranteed Convergence PSO (GCPSO)
   - Change the random number seed ten times
4. Please include your code with your homework.
5. Please describe your algorithm.
6. Please indicate that the percentage of each team member contributes to this assignment (only if you work with others).

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[2] [Trelea2003] I. C. Trelea. "The Particle Swarm Optimization Algorithm: Convergence Analysis and Parameter Selection". Information Processing Letter, vol. 85, no. 6, pp. 317-325, 2003.