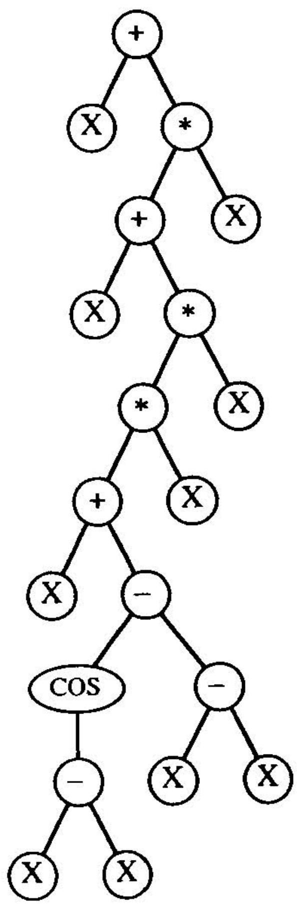
CS 5722/CEE 5290/ORIE 5340

Heuristic Methods for Optimization
Homework 13: Genetic programming
Assigned: Friday, November 21, 2014
Due: Wednesday, December 3, 2014

1. **Symbolic Regression**



The parse tree on the left represents the best solution from Generation 34 to a symbolic regression for

$$f(x) = x^4 + x^3 + x^2 + x$$

(a) Show that the parse tree represents f(x) exactly by writing out the exact mathematical equation represented by the parse tree and then combining terms so that you finally get

$$f(x) = x^4 + x^3 + x^2 + x$$

(b) Are there unnecessary terms in the parse tree? If yes, then write out the unnecessary terms in parse tree form.

2. **USING GENETIC PROGRAMMING SOFTWARE**

This problem set may be done with
GPLAB - A Genetic Programming Toolbox for MATLAB (by Sara Silva) which is freely downloadable from http://gplab.sourceforge.net/.
Or pySTEP Python version of Genetic Programming, http://pystep.sourceforge.net/
The data files can be downloaded from blackboard.
[Hint: make changes in the 'demo.m' file in the toolbox which is the solution of a different symbolic regression problem. Also, the manual is really helpful !]
Please upload the files you changed or created to Blackboard

SYMBOLIC REGRESSION OF $X^2/2 + 2X + 2$

Use a function set consisting of the addition (+), subtraction (-), multiplication (*), and protected division (%) to do a symbolic regression of the target function $X^2/2 + 2X + 2$. The protected division function % is protected against division by zero. Do not include random constants in the terminal set. Use a population of size of M = 1,000. Use Maximum number of generations to be run, G, of 151. Set:
crossover_fraction = 0.90,
copy_fraction = 0.10, and
mutation_fraction = 0.00.

QUESTIONS:
(a) Symbolic regression of $X^2/2 + 2X + 2$:**.**Fill the blank in the following tableau for this problem.
Tableau for symbolic regression of $X^2/2 + 2X + 2$

Objective:	
Terminal set	
Function set:	
Fitness cases:	The given sample of 21 data points(x_i, y_i), where the x_i come from the interval [-1,1]
Raw fitness:	The sum of the absolute difference between the expected output value and the value returned by the individual on all fitness cases
Standardized fitness:	Equals raw fitness for this problem
Hits:	Number of fitness cases for which the individual produces results within minus or plus 0.1% of the expected results
Wrapper:	None
Parameters	
Success predicate	Hits in 99% of the fitness cases (stop condition: the best-of-generation individual produces results within minus or plus 0.1% of the expected results in 99% of the fitness cases)

(b) Generation 0 performance: What is the fitness value and number of nodes for the best-of-generation individual of generation 0? Give the parse tree for this solution.

(c) Pick out some interesting-looking and explainable best-of-generation individual for some intermediate generation that illustrates progress toward the solution. Write out the parse tree for the individual, its generation number, and its fitness. Why this individual has an intermediate value of fitness (i.e., what is there about its structure that gives it intermediate fitness, as opposed to best, as opposed to what you saw at generation 0)?

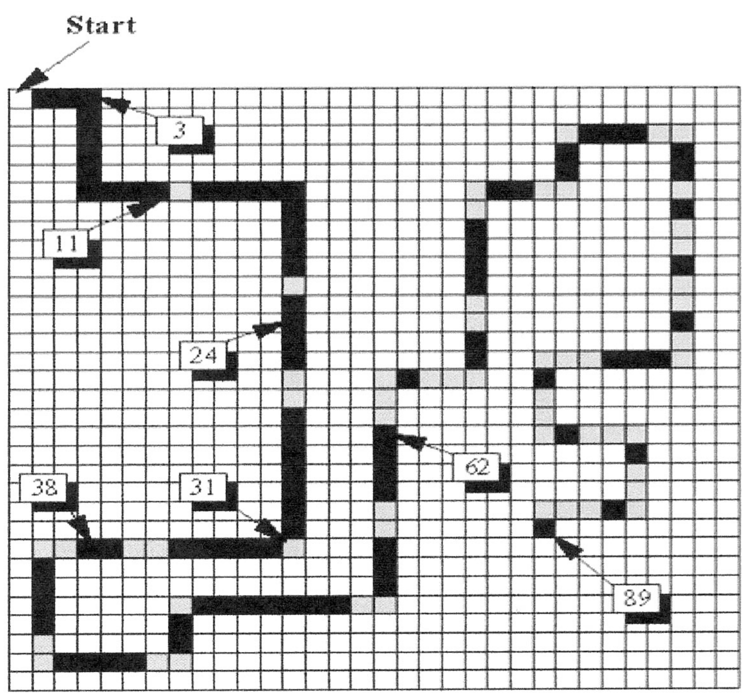
(d) The Best-of-Run Individual: Write the generation number of the final generation of the run, the best-of-generation individual of this final generation, and its fitness value.

(e)Was this a perfect (i.e., algebraically correct) or approximate solution to the problem?

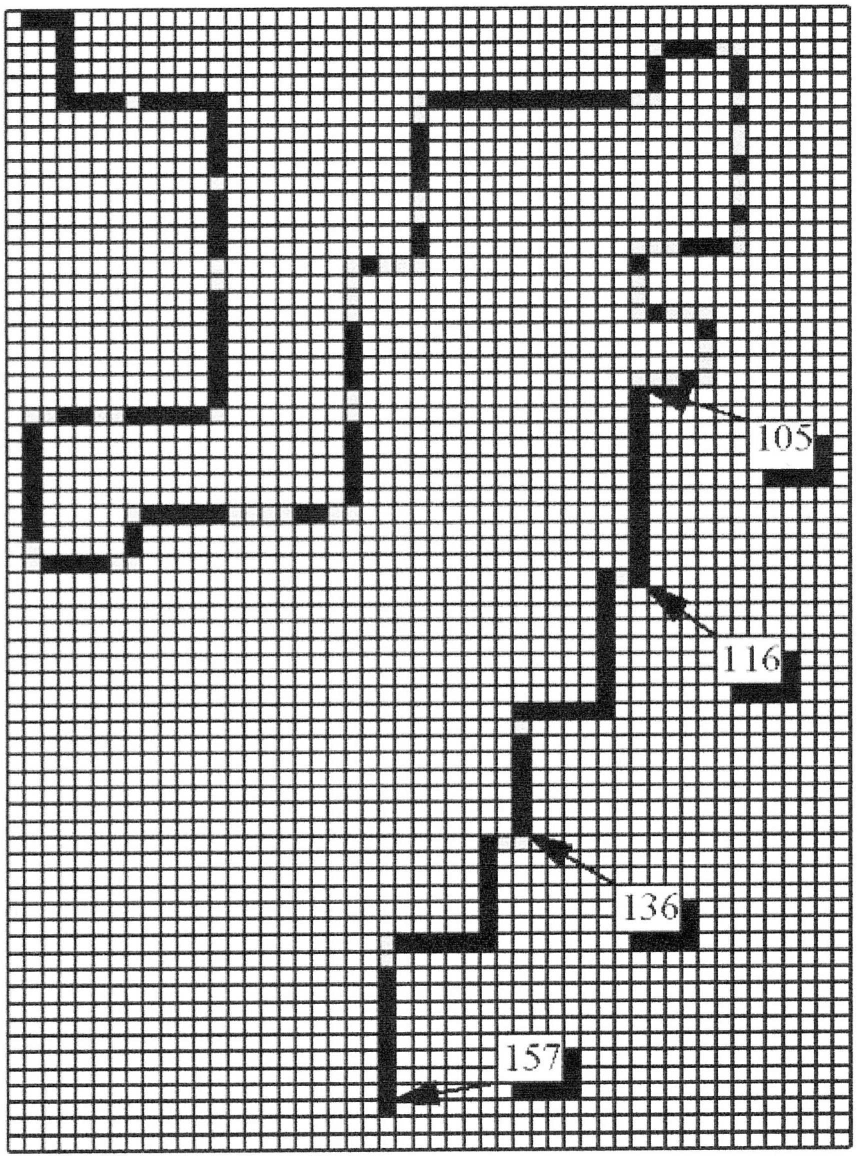
(f) Try running this problem at least more time (or until one run yields an algebraically correct solution). Write the generation number of the final generation of the run, the best-of-generation individual of this final generation, and its fitness value.

3. **Genetic programming:** In the lectures on genetic programming the definitions of functions, terminals, parse trees, and the Lisp function *ProgNm* (for arbitrary integer m) were given. Below is shown the Sante Fe Trail and an alternate trail, the Los Altos Hills trail is on the next page. There are situations at locations 116 and 136 on the Los Altos trail that do not occur on the Sante Fe trail.

a. Explain why the optimal policy for the Sante Fe Trail will not be optimal for the Los Altos trail. Be specific in which situations the Sante Fe policy will not work for the Los Altos Trial.
b. Assume you want to structure a genetic programming search for the optimal solution for the Los Altos trail. For the Los Altos trail, there is more food available (157 units), more grid cells, and you allow more time for a search for food (3000 time steps). Explain what your functions and terminals would be in a Genetic Programming search and how this would differ from the functions and terminals used for the search for the Santa Fe trail. Explain the reason for your answer. You do not need to provide the actual parse trees!



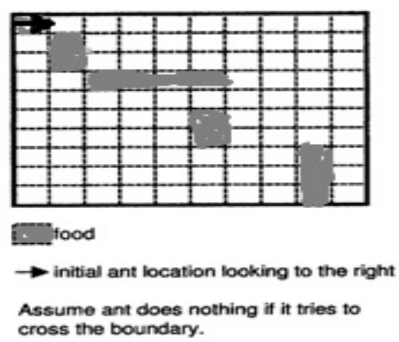
The Santa Fe Trail for the artificial ant problem.



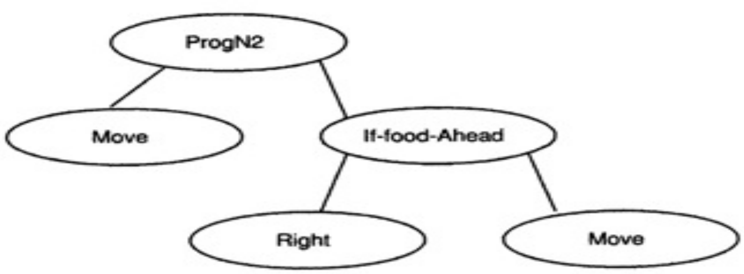
The Los Altos Hills trail for the artificial ant problem.

4. **Genetic Programming:** Assume you had an ant trail that you know has two corners that turn left and no corners that turn right. Also you know have food gaps of one, two , three or four adjacent spaces and these only occur on the straight part of the path. In other words there are <u>no gaps in food at the corners or within one space before or after the corner</u>. Give the parse tree that you think would be able to go through this path quickly with no unnecessary circles in the parse tree. (You are supposed to use your own human intelligence to solve this problem and do not need to implement a computer code. But of course you might get some ideas from the parse trees you have seen for other trails.)

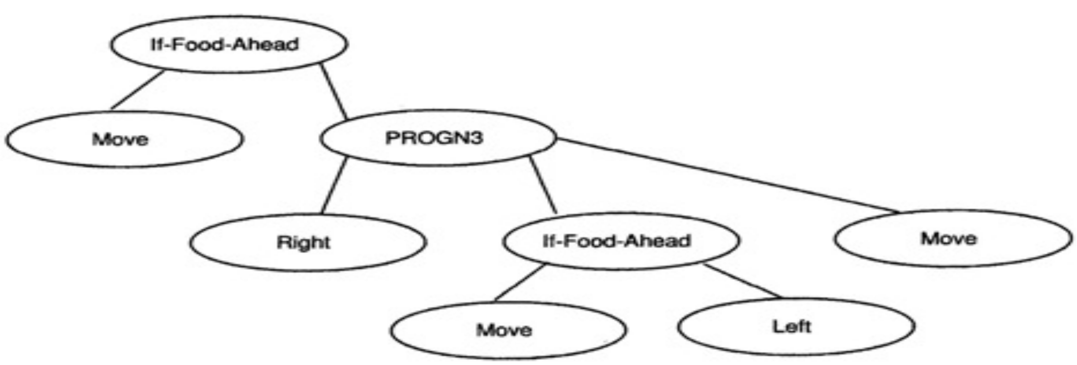
5. For the food diagram below, count how many pieces of food are eaten by an ant following solutions a) and b) (represented as parse trees) after 10 time steps? One time step passes when one of the terminal set commands is executed. (the ant starts at the upper left square with food in it)



a)



b)



Reference for Problem 1 (which you are not required to read): Regis, R., C.A.Shoemaker, "Local Function Approximation in Evolutionary Algorithms for the Optimization of Costly Functions," ***IEEE Transactions on Evolutionary Computation*** 8 (5) 490-505, 2004