Homework Set 5

Due date: Monday, Feb. 10.

Written Exercises

HW5.1. Referring to the paper on GENIE (by Harvey et al.), the authors state that the representation of an image processing algorithm (or "pipeline") forms a graph rather than a tree. Explain what is mean here by "graph" (as opposed to "tree"), and explain (using pictures and an example of an algorithm if you like) why an algorithm in GENIE forms a graph. (10 points)

HW5.2. Fitness in GENIE is defined as a function of the "Detection Rate" and the "False Alarm Rate". (a) Define both of these terms. (b) Give an example of a classification task where the fitness needs to include only a term for the Detection Rate, and the False Alarm Rate does not need to be taken into account (i.e., you care only about whether your algorithm has correctly detected some actual positive examples, and are willing to put up with false alarms). (10 points)

HW5.3. (10 points) As part of their GOLEM project (evolving virtual robots to move and then creating physical versions via rapid prototyping), Hod Lipson and Jordan Pollack enlisted tens of thousands of people to donate CPU time on their home or work computers (see http://demo.cs.brandeis.edu/golem/download.html). The goal was to evolve increasingly complex robots by virtue of the extra CPU time. Lipson and Pollack recently ended this project, saying that:

> After accumulating several Million CPU hours on this project and reviewing many evolved creatures, we have concluded that merely more CPU is not sufficient to evolve complexity: The evolutionary process appears to be hitting a complexity barrier that is not traversable using direct mutation-selection processes, due to the exponential nature of the problem. We are now developing new theories about additional mechanisms that are necessary for the synthetic evolution of complex life forms.

Give three examples of biologically inspired mechanisms, not present in their original project (as described in class and in their paper) that you think might help in breaking this "complexity barrier". (10 points)

HW5.4. (a) Lipson and Pollack state in their paper that

> ...[W]e have demonstrated a robotic 'bootstrap' process, in which automatically designed electromechanical systems have been manufactured robotically. We have carefully minimized human intervention in both the design and fabrication stages. Apart from snapping in the motors, the only human work was in informing the simulation about the 'universe' that could be manufactured.

Give three examples of additional ways in which, in spite of the quotation above, there was "human intervention" in this project.

(b) Lipson and Pollack state in their paper that:

> Taken together, our evolutionary design system...and rapid prototyping machine form a primitive replicating robot...there are many, many further steps before this technology could become dangerous.

Give one possible way in which an actual self-reproducing robot might become dangerous, and one possible application in which it could benefit people. (10 points)

Computer Exercises

HW5.5. Use the code your wrote in Homework 3 and 4 to write a program that will use genetic programming to evolve strategies for the Prisoners' Dilemma. The fitness of an individual is its total score over 10 games each with each member of the population at the current generation, including itself.

(a) Do five runs with these parameter values:

Population size: 50

Number of generations: 50

Selection method: Fitness proportionate

Crossover rate: With probability 0.7, cross over parents

Mutation rate: With probability 0.1, mutate offspring (i.e., with probability 0.1, replace exactly one subtree with a randomly generated subtree)

Elitism is TRUE: Always copy the highest fitness individual into the next generation.

Out of your five runs, choose two runs and plot the best and average fitness in the population versus generation. For each of the two runs, take the individual with the highest fitness in the last generation, and report its fitness in the last generation and its total score playing 10 games against TIT FOR TAT. Explain what these two highest-fitness trees are doing (i.e., what is their strategy?).

(b) Now repeat the experiment in (a) using population sizes 100 and 500. Say something about how the system's behavior changes (or stays the same) for different population sizes.

(20 points)

HW 5.6. (a) Repeat the experiment in 5.5(a) (give the same plots, total scores against TIT FOR TAT, and analysis of strategies that was asked for in that problem) but with the probability of crossover set to zero. Does increasing the mutation probability to 0.2 have any effect? Does increasing the mutation probability to 0.5 have any effect?

(b) Now do the same as in 5.5 (a), but with the crossover probability to 0.7 per pair of parents, and set the mutation probability to zero. Does setting the crossover probability to 1.0 per pair of parents have any effect?

(20 points)

HW 5.7. Design your own new experiment with your code, varying some aspect of the experiment in 5.5(a). Write one or two paragraphs describing your experiment, present your results in the form of plots and tables, and analyze the results in one or two paragraphs.

(20 points)