Genetic Programming of Cognitive Models

Lee Spector (LSPECTOR@HAMPSHIRE.EDU)
School of Cognitive Science and Cultural Studies
Hampshire College
Amherst, MA 01002 USA

Evolutionary Computation and Cognition

Evolutionary computation systems are not themselves models of cognitive processes, but they do provide powerful tools that can be used in cognitive science. The technique of genetic programming (GP), in which computer programs are produced by means of natural selection, can support several new strategies for research on computational cognitive models. This abstract describes the use of a GP process as a team of systematically biased programmers, along with four new research strategies supported by this technology.

The Problem with Programmers

Computational cognitive models—computer systems that perform cognitive tasks in ways thought to be revealing about how those same tasks are performed by humans—are plentiful in cognitive science. Computational cognitive models are produced by programmers—researchers who encode theories into the actual code that a computer will run. In programming a cognitive model one must make many decisions for which there will be several reasonable choices. These choices often have complex and significant impacts on the performance of the model, and inferences from the behavior of the model are therefore conditional not only on the theory that inspired the model, but also on the details of the implemented computer program. Examples of programming choices that may have major impacts on performance include the data structures used to represent problem instances, numerical constants (e.g., network biases or default activation values), and the precise ways in which "lesions" are implemented. Even theories that are phrased in explicit computational terms often leave many such details underspecified; biases of programmers (intentional or not) will in such cases have large effects on the resulting models.

Genetic Programming

Genetic programming (GP) is an automatic programming technique based on natural selection (Koza, 1992). GP starts with a population of programs that are random combinations of problem-specific elements. Each program is assessed for fitness, and the fitness values are used to produce the next generation via genetic crossover and mutation. After some number of generations the best individual is designated as the result. Koza also presents a technique for determining the amount of *computational effort* required for GP to produce successful programs for a particular task.

Research Strategies

A general research strategy for using GP in cognitive science is to replace the biased humans who program cognitive models with GP processes. GP processes are also biased, but their biases are systematic, consistent across experiments, and subject to explicit experimental control. Four more specific versions of this strategy are as follows:

Show Sufficiency of Theorized Mechanisms

If a theory states that a particular set of computational mechanisms is responsible for a particular set of behaviors, then these mechanisms can be provided to a GP process; if a successful program is produced then the sufficiency of the mechanisms for the behavior will have been established.

Compare Different Sets of Mechanisms

The relative merits of different sets of mechanisms are often debated in cognitive science; GP can be run using each set of mechanisms in turn, and the relative computational efforts can be used as evidence in these debates (Spector & Luke, 1996). The evolved models can also be compared with respect to parsimony, efficiency, and other measures.

Breed and Dissect

GP with rudimentary program elements (e.g., arithmetic operators) can be used to produce programs that perform specific cognitive tasks; the resulting programs can then be analyzed for the use of theorized higher-order mechanisms.

Domain Analysis

The effort required to produce a successful program with GP can provide data on the difficulty of the modeled task; if it is very easy for GP to find successful programs, then the task may be too simple to serve as a good test of *any* model.

References

Koza, J.R. (1992). *Genetic Programming: On the Programming of Computers by Means of Natural Selection.* Cambridge, MA: The MIT Press.

Spector, L., & Luke, S. (1996). Culture Enhances the Evolvability of Cognition. *Proceedings of the Eighteenth Annual Conference of the Cognitive Science Society,* (pp. 672-677). Mahwah, NJ: Lawrence Erlbaum Associates.