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Teaching the evolution of behavior with SuperDuperWalker

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Abstract. SuperDuperWalker is a software-based framework for experiments on the evolution of locomotion. It simulates the behavior of evolving agents in a 3D physical simulation environment and displays this behavior graphically in real time. A genetic algorithm controls the evolution of the agents. Students manipulate parameters with a graphical user interface and plot outputs using standard utilities. The software supports an inquiry cycle that has been piloted in CS193T: Biocomputational Developmental Ecology at Hampshire College.

Keywords. Physical simulation, genetic algorithms, biology,

The science curriculum at Hampshire College[2] emphasizes original student inquiry at all levels, including first-semester courses and courses for non-majors. This puts a premium on tools and methodologies that allow for genuine inquiry by novices. As a result, Hampshire College faculty have developed a range of methodologies and technologies for student-active inquiry-based science education, and they have also studied the efficacy of these methods [1,4,7,8,9].

Klein's *breve* simulation system [3] allows programmers to quickly build interactive physical simulations that are rendered in realtime using the OpenGL 3D graphics library. It supports arbitrary computations expressed in an object-oriented language and it also supports the integration of customized graphical user interfaces. While developed primarily for experiments in complex adaptive systems and artificial life (e.g. [6]), it has also proven useful as an environment for inquiry-based courses on artificial life, artificial intelligence, and algorithmic arts.[3] In the present contribution these methods are applied to a course for first-semester students on issues in evolutionary biology.

The artificial intelligence technology in this system is used not to automate pedagogy (although such extensions are conceivable) but rather to produce a rich virtual world in which experiments can be conducted. The "biology" of this virtual world is, of course, an abstraction that differs in innumerable ways from that of the real world, but it nonetheless allows students to explore important principles of evolutionary dynamics.

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[2]See http://www.hampshire.edu

[3]See for example http://hampshire.edu/lspector/cs263/cs263s04.html

Figure 1. The SuperDuperWalker graphical user interface.

Klein's "Walker" program, which is included as a demo in the *breve* distribution, uses a genetic algorithm in a manner inspired by Dawkins's "Biomorph" [2] and Sims's virtual creatures [5] to evolve four-legged walking creatures. Creatures that travel longer distances than their competitors are allowed to reproduce and to produce children that are varied by mutation. The "SuperWalker" program, which is also included as a demo in the *breve* distribution, adds an additional degree of freedom, allowing not only the leg controllers but also the leg segment lengths to evolve. SuperDuperWalker further extends SuperWalker by adding many more degrees of freedom (for example the number of legs, number of leg segments, leg placements, and several other parameters may also evolve) and by providing a graphical user interface (see Figure 1) that allows non-programmers to conduct experiments.

Evolving creatures are displayed in real time as they compete with one another in fitness tournaments. Snapshots of two individual creatures are shown in Figures 2 and 3. The movies from which these snapshots were taken are available online, along with SuperDuperWalker source code and related teaching materials.[4] The software produces tabular output that can be imported into off-the-shelf spreadsheet software, manipulated, and graphed (as in Figure 4).

The software was used in a fall semester, 2004 course at Hampshire College, CS193T: Biocomputational Developmental Ecology. The instructors demonstrated the software and its use in an inquiry cycle of hypothesis formation, experiment design, data collection, and analysis. Students were then expected to conduct their own inquiry cycles (based on their own hypotheses) in an in-class lab and to produce a lab report. Several students also used SuperDuperWalker experiments as the basis of their final projects at the end of the semester.

We expect the technology used in SuperDuperWalker, which combines physical simulation with a graphical user interface and the strategic use of artificial intelligence algorithms (such as genetic algorithms), to present additional opportunities for inquiry-based education across the curriculum.

[4] http://hampshire.edu/lspector/superduperwalker.html

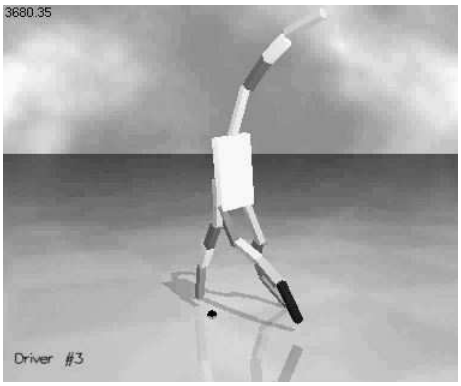

Figure 2. A snapshot of an evolved creature.

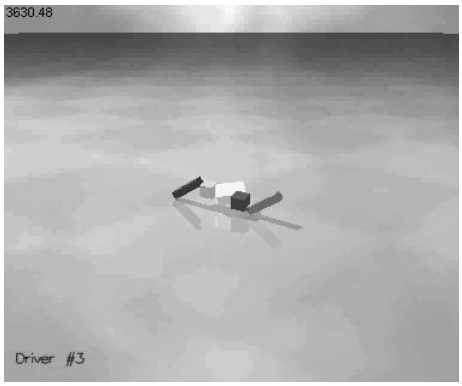

Figure 3. A snapshot of an evolved creature.

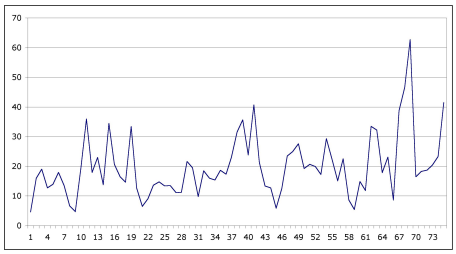

Figure 4. A graph of average distances traveled (on the y axis) for each 4-creature tournament (with later tournaments to the right) over the course of a SuperDuperWalker run.

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