Technical Status Report **April, 2003**

DARPA Agent Based Computing (ABC) Program, Taskable Agent Software Kit (TASK)

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Project: Multi-type, Self-Adaptive Genetic Programming for Complex Applications

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Accomplishments Since October 2002

• Demonstrated the emergence of collective behavior in two versions of the SwarmEvolve system. In particular we demonstrated the emergence of a form of multicellular organization in evolving populations of agents based on a traditional flocking algorithm (in SwarmEvolve 1.0), and the emergence of altruistic feeding behavior in a system that is considerably less constrained (as the agents are controlled by evolved computer programs). This latter system (SwarmEvolve 2.0) provides significant new avenues of study by allowing for agents of arbitrary complexity to evolve within complex, dynamic worlds (see below). A paper on this work will be published/presented at the Genetic and Evolutionary Computation Conference (GECCO) in Summer, 2003. Paper title: "Emergence of Collective Behavior in Evolving Populations of Flying Agents"; authors: Lee Spector and Jon Klein.

• Participated in the 8th International Conference on the Simulation and Synthesis of Living Systems (ALife 8). Spector presented three papers and Klein presented one:

> Spector, L. 2002. Adaptive populations of endogenously diversifying Pushpop organisms are reliably diverse. In R. K. Standish, M. A. Bedau, and H. A. Abbass (eds.), Proceedings of Artificial Life VIII, the 8th International Conference on the Simulation and Synthesis of Living Systems , pp. 142-145. Cambridge, MA: The MIT Press. http://hampshire.edu/lspector/pubs/spector-alife8.pdf
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> Klein, J. 2002. breve: a 3D simulation environment for the simulation of decentralized systems and artificial life. Proceedings of Artificial Life VIII, the 8th International Conference on the Simulation and Synthesis of Living Systems. Cambridge, MA: The MIT Press. http://www.spiderland.org/breve/breve-klein-alife2002.pdf
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> Spector, L., and J. Klein. 2002. Evolutionary Dynamics Discovered via Visualization in the

BREVE Simulation Environment. In Bilotta et al. (eds), Workshop Proceedings of the 8th International Conference on the Simulation and Synthesis of Living Systems , pp. 163-170. Sydney, Australia: University of New South Wales. http://hampshire.edu/lspector/alife8-visualization.html (web page includes full text and also graphics/animations)

Spector, L., and J. Klein. 2002. Complex Adaptive Music Systems in the BREVE Simulation Environment. In Bilotta et al. (eds), Workshop Proceedings of the 8th International Conference on the Simulation and Synthesis of Living Systems , pp. 17-23. Sydney, Australia: University of New South Wales. http://hampshire.edu/lspector/alife8-music.html (web page includes full text and also graphics/sound)

• Participated in the Sixth International Conference on Quantum Communication, Measurement, and Computing (QCMC). Publication:

Spector, L., and H.J. Bernstein. 2002. Communication Capacities of Some Quantum Gates, Discovered in Part through Genetic Programming. To appear in Proceedings of the Sixth International Conference on Quantum Communication, Measurement, and Computing (QCMC), to be published by Rinton Press. (prepress version with additional figures: http://hampshire.edu/lspector/pubs/spector-QCMC-prepress.pdf)

• Significantly advanced the integration of the Push programming language for evolutionary computation into the BREVE 3D simulation environment:

- C-language Push interpreter plugin (original was Lisp, Java versions by others).
- Push interpreter per BREVE agent.
- BREVE agents can perform/evolve arbitrary computations.
- Push/BREVE callbacks implement sensors/effectors.
- XML specification for Push standardization.

• Building on the enhanced Push/BREVE integration, produced a major upgrade to the SwarmEvolve system (now version 2.0):

- Behavior (including reproduction) controlled by evolved Push programs.
- No hard-coded species. Color, color-based agent discrimination controlled by agents.
- Energy conservation.
- Facilities for communication, energy sharing.
- Enhanced user feedback (e.g. diversity metrics, agent energy determines size).

• Implemented and experimented with alternative models for target dynamics as discussed in the OEF working groups. In particular, added “random walk” dynamics and clarified existing “linear drift” dynamics. Additional dynamics models can be rapidly integrated.

• Formalized measures of agent diversity, using the formula:

$$diversity(P) = \frac{\sum_{i \in P} \frac{|\{j \in P : \Delta(i,j) > \delta\}|}{|P|-1}}{|P|}$$

This is the average, over all agents, of proportion of remaining population considered “other” by some distance metric (big delta) and some threshold (little delta). Considered genotypic instances (based for example on code, code size), phenotypic instances (based for example on color, behavior, signals), and reproductive/developmental instances. Discussed relations to “entropy” based measures with Jim Crutchfield of the SFI TASK group.

• Corresponded with the University of Massachusetts TASK group on the development of a BREVE-based UAV simulator, for use in conjunction with their Proximity data mining system. The UMass group has now completed construction of a first version BREVE UAV simulator and we are planning further collaboration.

• Completed first integration of an “Elementary Adaptive Module” (EAM), as developed by the MIT/BBN TASK group, into the SwarmEvolve system:

- Now: single EAM per agent.
  Potentially: any number, any architecture.
- Now: servo EAM only.
  Potentially: all EAM types.
- New Push instructions: setServoSetpoint, setServoGain, servo.
- Initial indications: high utility.

• Presented several of the items above to TASK PIs (Miami, October 9-11). URLs for presentation slides:

- Keynote (Apple) format: http://hampshire.edu/lspector/TASK-Feb-2003.key.sit
- PDF format: http://hampshire.edu/lspector/TASK-Feb-2003.pdf
- Powerpoint format: http://hampshire.edu/lspector/TASK-Feb-2003.ppt

Current Plans

SPRING 2003

Continue investigation of the emergence of collective behavior and of MIT/BBN Elementary Adaptive Modules in SwarmEvolve.

Collaborate further with University of Massachusetts TASK group on UAV simulation in BREVE.

Investigate the addition of morphology evolution in SwarmEvolve or a successor system.

Enhance complexity/realism/OEF integration.

SUMMER 2003

Complete the integration of multi-type, self-adaptive genetic programming components into a 3D physical simulation environment.

Develop software and protocols for distributed simulation/evolution runs on high-performance computer clusters.

Use the experimental framework already developed (SwarmEvolve) to characterize conditions under which coordinated behavior is adaptive.

Disseminate research results at conferences and in publications.

ACADEMIC YEAR 2003/4

Upgrade existing experimental framework to use full physical simulation with evolved physical controllers.

Enhance support for Elementary Adaptive Modules (developed by the MIT/BBN TASK group) and evaluate their impact on evolvability and adaptation.

Implement additional target behaviors in the existing experimental framework , including evasive and co-evolving targets.

SUMMER 2004

With other TASK groups, generalize results and disseminate software products.

Disseminate research results at conferences and in publications.