# GP+Echo+Subsumption = Improved Problem Solving

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## Abstract

Real-time, adaptive control is a difficult problem that can be addressed by EC architectures. We are interested in incorporating into an EC architecture some of the features that Holland's Echo architecture presents. Echo has been used to model everything from cultures to financial markets and many things in-between. However, the typical application of Echo is a simulation to observe the dynamics of the modeled elements such as found in control problems. We show in this paper that some aspects of Echo can be incorporated into Genetic Programming to solve control problems. The paper discusses EAGP (Echo Augmented Genetic Programming), a modified GP architecture that uses aspects of Echo, and subsumption. We demonstrate the usefulness of EAGP on a robot navigation problem.

## 1 BACKGROUND

### 1.1 ECHO

Echo, as described by Holland in the book Hidden Order [Holland95], is an umbrella architecture consisting of various models for experiments with complex adaptive systems (CAS). An Echo architecture has a number of independent "agents" that exist within a particular environment. The hallmark of an Echo simulation is the development of interactions between agents that allow them to thrive in the environment, creating complex communities of different types of agents. Interactions and agent types develop over time by allowing each agent to adapt to the environment and to the other agents in the community. To create an Echo model, Holland lists six criteria:

1. Simplicity: Echo "is meant for thought experiments rather than for emulation of real systems."
2. Geography: Agents in Echo should move within a "geography", where location "matters, in terms of the input an agent receives and how interactions with other agents occur.
3. Fitness: Fitness is not fixed externally but should depend on the context of the environment.
4. Mechanisms: The mechanisms in an Echo architecture should have counterparts in real CAS.
5. Frameworks: The developed model must allow easy insertion of other established CAS frameworks.
6. Analysis: The model should be amenable to mathematical analysis.

Holland also lists a set of properties and mechanisms that should be universally available in a CAS system that is listed in Table 1.

Table 1: The basic properties and mechanisms required for a CAS system

| Properties | Mechanisms |
|---|---|
| Aggregation | Tags |
| Nonlinearity | Internal Models |
| Flows | Building Blocks |
| Diversity | |

Most of these are self-explanatory. Flows involve the sharing of resources in the developed community of agents. Tags provide a means of identifying agents, and are the means for most interactions. Internal models are the "code" that drives the agent's interactions with the environment. Building blocks are the basic unit of heredity, the passing of useful information from parent to child, as found in GAs.

A number of Echo implementations exist. Gecko[Booth97] is an implementation of the Echo architecture specialized for modeling ecosystems. It focuses on spatial distribution and interactions as could be found in an ecology[Schmitz96]. Swarm[swarm] is a system for simulating multiple, interacting agents and has been used in implement a wide variety of CAS systems, including Echo-like systems.

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### 2.1.1 Third-Level Heading

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Fourth-Level Heading

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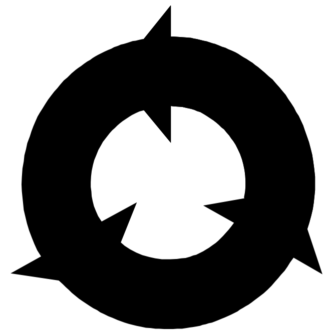

Figure 1: Sample Figure Caption

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One line space before the table title, one line space after the table title, and one line space after the table. The table title must be initial caps and each table numbered consecutively.

Table 1: Sample Table Title

| PART | DESCRIPTION |
|---|---|
| Dendrite | Input terminal |
| Axon | Output terminal |
| Soma | Cell body (contains cell nucleus) |

### 2.2.5 Style Issues

Mathematical symbols should be in *italics*.

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[1] Sample of the first footnote
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### Acknowledgments

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J. Alspector, B. Gupta, and R. B. Allen (1989). Performance of a stochastic learning microchip. In D. S. Touretzky (ed.), *Advances in Neural Information Processing Systems 1*, 748-760. San Mateo, CA: Morgan Kaufmann.

F. Rosenblatt (1962). *Principles of Neurodynamics*. Washington, DC: Spartan Books.

G. Tesauro (1989). Neurogammon wins computer Olympiad. *Neural Computation* **1**(3):321-323.