Automatic Programming of Agents via Multi-type, Self-Adaptive Genetic Programming

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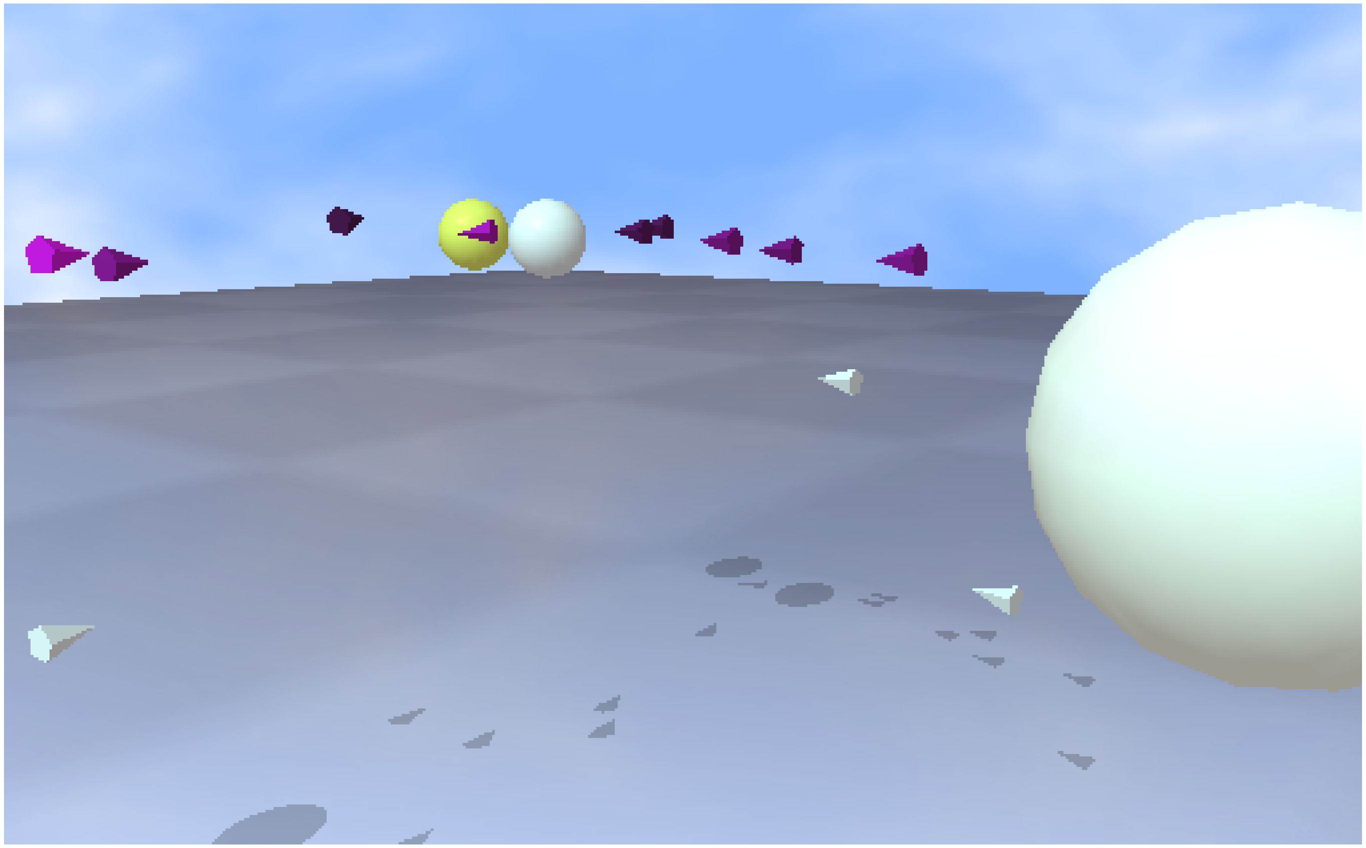
Assistance by Jon Klein



Overview

Approach and Critical Elements

Technologies:
Push, PushGP, Pushpop, Breve, **SwarmEvolve**

Recent Results:
Emergence of collective/multicellular organization
Environmental/genetic stability and adaptation
Push/Breve integration v. 0.1

Demo:
SwarmEvolve 1.5

Next Steps

Approach & Critical Elements

Design Approach: Self-adaptive, multi-type genetic programming for automated or semi-automated agent design.

Critical Elements: Autonomy, coordination, **adaptation**, control, evolution.

Problems: Can agents be automatically generated for complex, dynamic environments? Can agents evolve to become more adaptable to changing environments?

Metrics: Wait time, event response delay, agent lifetime, code parsimony/diversity, evolutionary computational effort, **task completion**.

Toolkit: Push programming language for evolved agent programs, PushGP genetic programming system, Pushpop autoconstructive evolution system.

The Push Programming Language for Evolutionary Computation

Goal: Scale up GP/agents techniques for human-competitive performance in complex, dynamic environments.

Evolve agents that may use:

- multiple data types
- subroutines (any architecture)
- recursion
- evolved control structures
- evolved evolutionary mechanisms

Push supports all of this using simple, mostly standard GP techniques.

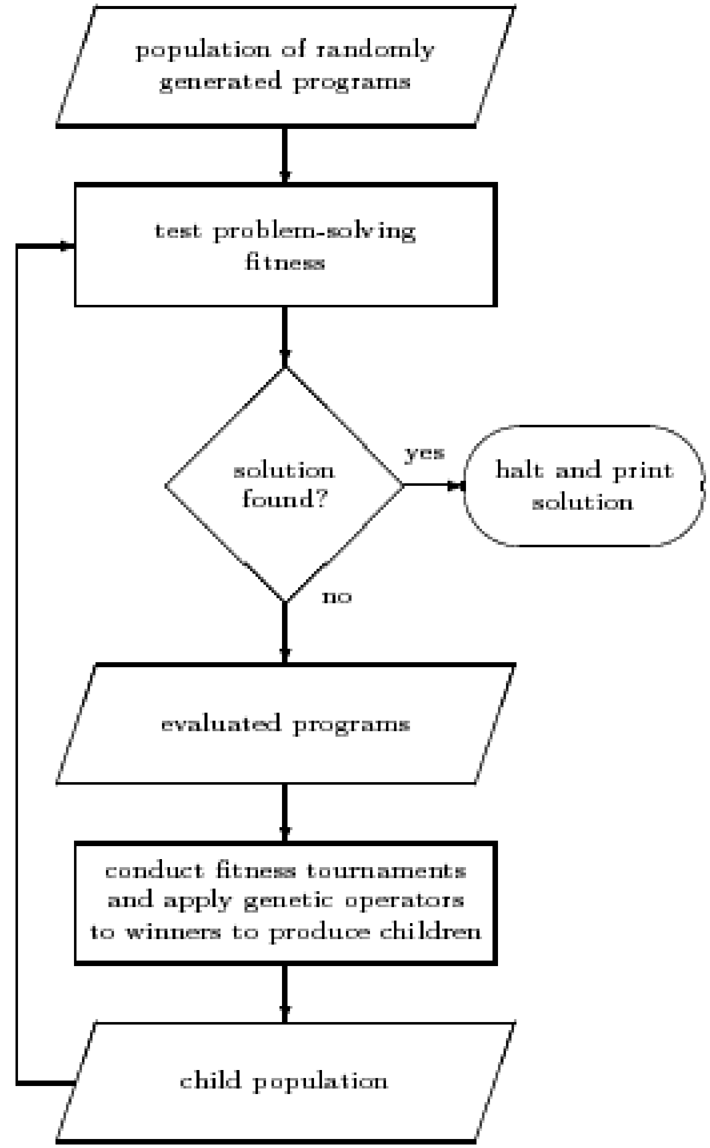
Stack-based language with one stack per type; types include integer, float, Boolean, **code**, child, type, name.

PushGP

Evolves Push programs
using (mostly) standard GP.

Multiple types handled without
syntactic constraints.

Evolves modules and
control structures automatically.

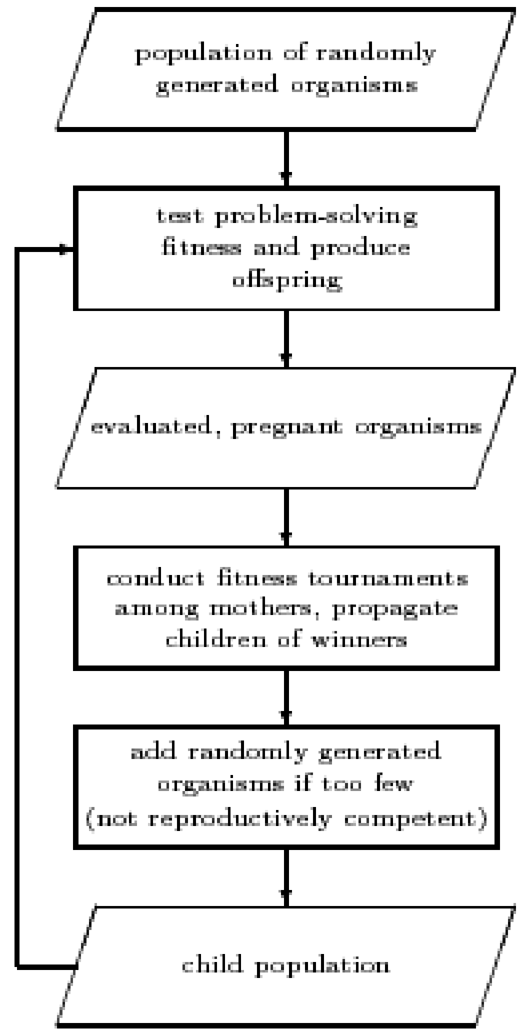


Autoconstructive Evolution: Pushpop

Individuals make their own children.

The machinery of reproduction and diversification (and thereby the machinery of evolution) evolves.

Radical self-adaptation.



Breve: a 3D Environment for the Simulation of Decentralized Systems and Artificial Life

Written by Jon Klein, http://www.spiderland.org/breve

Simplifies the rapid construction of complex 3D simulations.

Object-oriented scripting language with rich pre-defined class hierarchy.

OpenGL 3D graphics with lighting, shadows, and reflection.

Rigid body simulation, collision detection/response, articulated body simulation.

Runge-Kutta 4th order integrator or Runge-Kutta-Fehlman integrator with adaptive step-size control.

Breve Swarm

by Jon Klein, after Craig Reynolds

$$\begin{aligned}\text{acceleration} = \; & p_1 * [\text{away from crowding others vector}] \\ & + p_2 * [\text{towards world center vector}] \\ & + p_3 * [\text{average neighbor velocity vector}] \\ & + p_4 * [\text{towards neighbor center vector}] \\ & + p_5 * [\text{random vector}]\end{aligned}$$

SwarmEvolve

On-Line evolution of goal-directed swarms

Multiple species
    p_6*[away from crowding other species vector]

Randomly moving energy sources:
    p_7*[towards closest energy source vector].

Energy costs:
- Colliding with one another
- Being outnumbered (by species) in neighborhood
- Giving birth
- Surviving (per simulation cycle)

Upon death (energy = 0), parameters replaced with mutated version of fittest of species

Fitness metric = age * energy

SwarmEvolve 1.5

- Food consumption/growth
- Birth near mothers
- Corpses
- Food sensor, inverse square signal strength
- GUI controls and metrics
- Feeders redesigned, increased in number
- OEF correspondence increasing

[view movie]

Emergence of collective/multicellular organization

Observed behavior: a cloud of agents hovers around an energy source. Only the central agents feed, while the others are continually dying and being reborn.

Can be viewed as a form of emergent collective organization or multicellularity.

Facilitated by “birth at death location” implementation.

To appear in proceedings of *Beyond Fitness: Visualising Evolution*, a workshop at ALife 8.

[view movie]

Environmental/Genetic Stability and Adaptation

Food supply as a function of environmental stability and mutation rate:

		MUTATION low	MUTATION med	MUTATION high
STABILITY	low	54%	17%	18%
	med	43%	12%	10%
	high	55%	14%	12%

Preliminary data (2 runs/condition) averaged over first 10,000 time steps of each run.

[Demo: SwarmEvolve 1.5]

Next Steps

Enhance complexity/realism/OEF integration.

Species-specific controls and metrics.

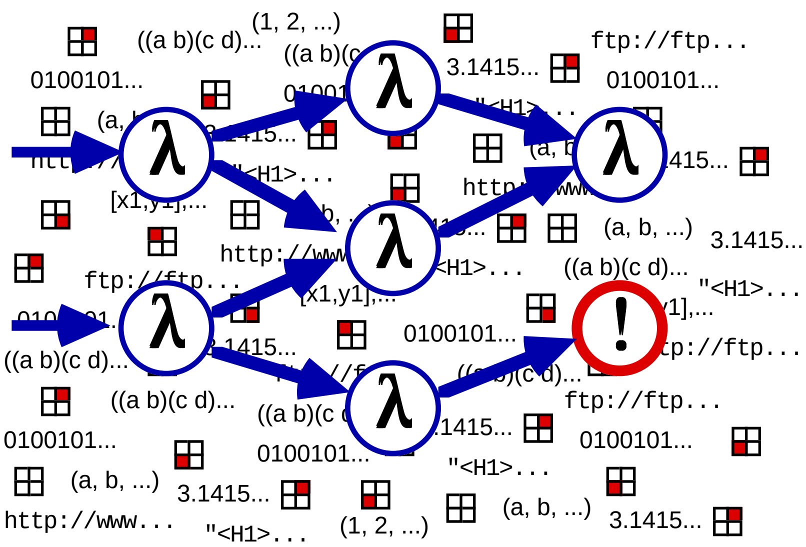
Structured feeder behavior; agent-responsive.

Leverage Push/Breve integration for evolution of arbitrary agent control programs and group (species) distinctions.

Integrate MIT/BBN elementary adaptive modules.

Provide “evolution” components for Taskable Agent Software Kit.

Multi-Type, Self-Adaptive Genetic Programming for Complex Applications



New Ideas

• Richly heterogeneous data can be flexibly integrated in programs produced by stack-based genetic programming.

• Explicit code manipulation allows for automatic emergence of modules and evolved program architecture.

• Self-adaptive construction of evolutionary mechanisms enhances fit to problem environments.

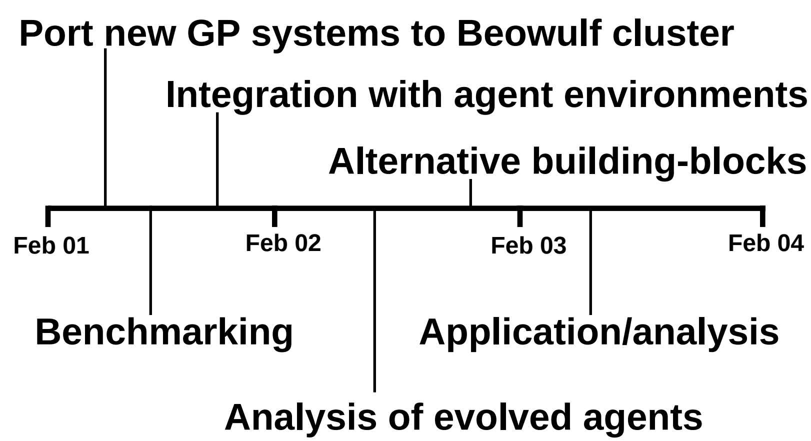
Impact

• Evolved agents for heterogeneous, dynamic environments.

• Broader range of applications for automatic programming technologies.

• Automatic programming with less configuration by users.

Schedule



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