“Graduated Embodiment for Sophisticated Agent Evolution and Optimization”

Position Paper on Scalability of Evolutionary Computation

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Graduated Embodiment for Sophisticated Agent Evolution and Optimization

Goal: *To develop methods for graduated evolution for embodied agent optimization.*

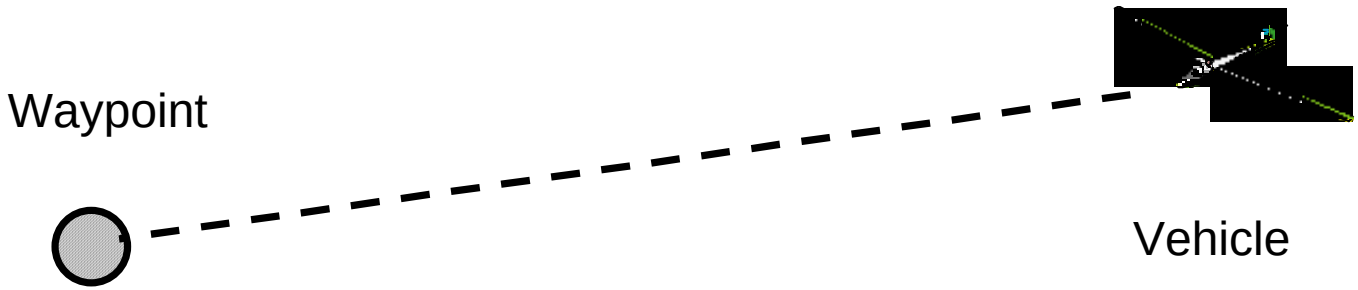
Method: *Evolve agent behaviors in a hierarchical fashion by staging fitness through multiple levels of fidelity.*

Project Accomplishments

- *Implemented Staged Optimization*
  - *Showed that staged methods exhibit improved scaling (as expected).*
- *Implemented Pruning*
  - *Pruned trees demonstrated reduced computational load (as expected).*
- *Combined hand-coded and machine-generated behaviors*
  - *Can build algorithms that are truly human-machine collaborations.*
- *Converted GP code to C++*
  - *Allows for improved modularization; shifts burden off user.*
- *Incorporated GP behaviors into UMBRA*
  - *High fidelity environment for high fidelity behaviors.*

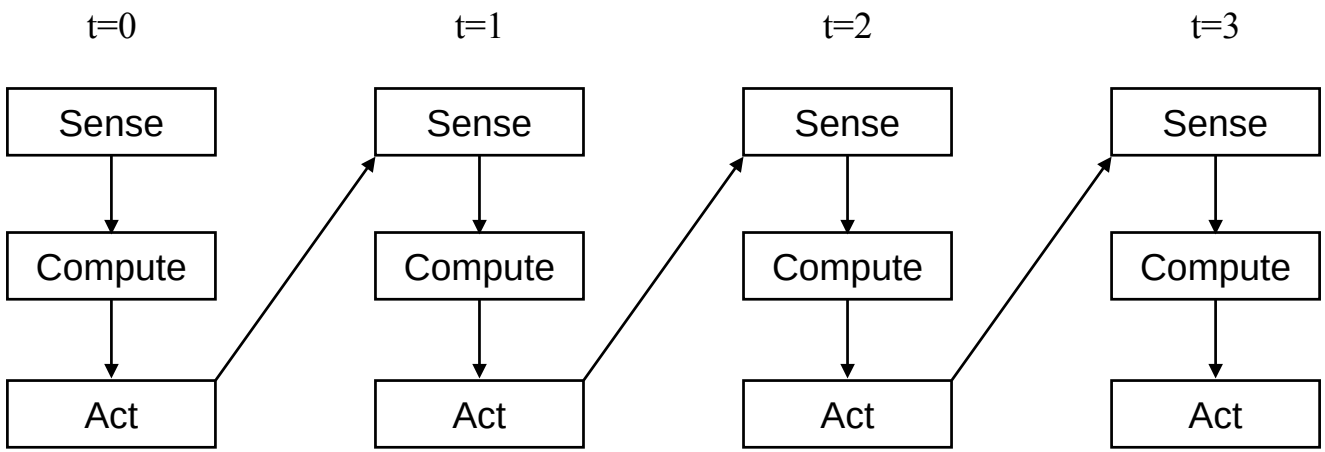
Adaptive Waypoints

This encapsulation is intended to bridge the gap between toy problems and real problems



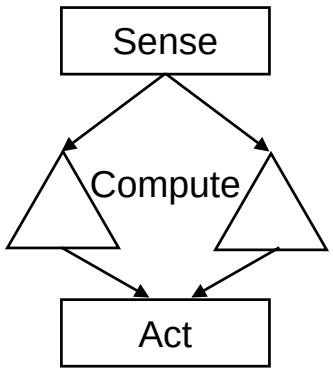
Our method to develop levels of integration:
Vertical, Horizontal, Co-Evolution, Collective Behavior

General implementation concept: Use GP to design “compute” step

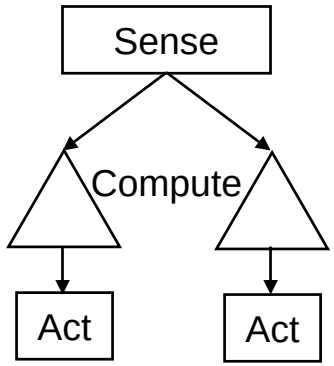


Classification of Building Blocks

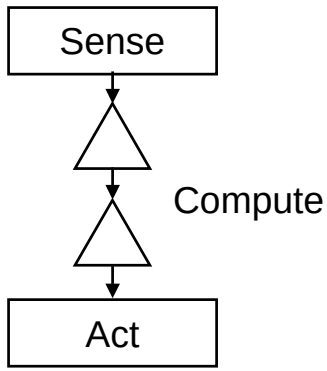
Horizontal Sequential



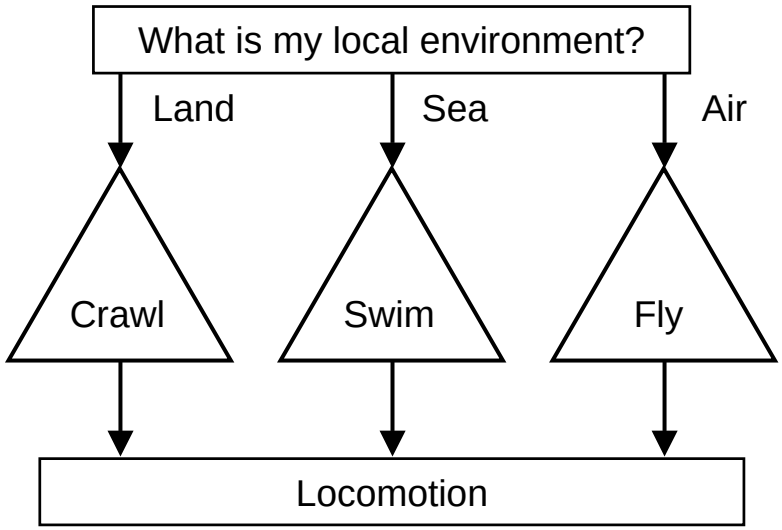
Horizontal Parallel



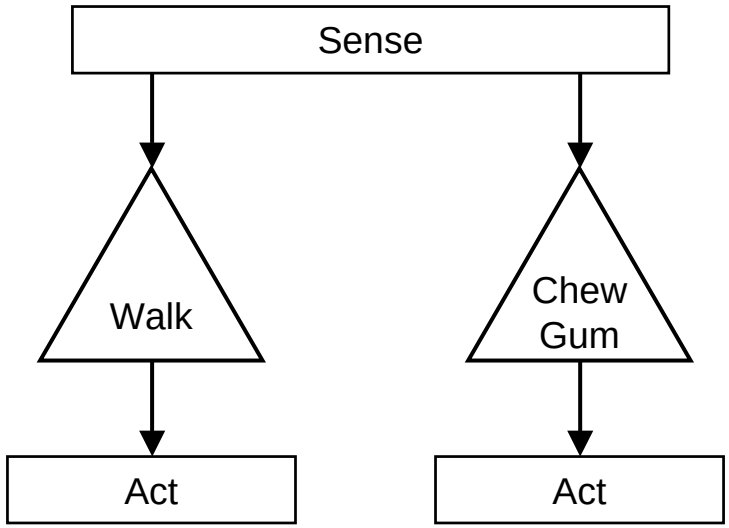
Vertical



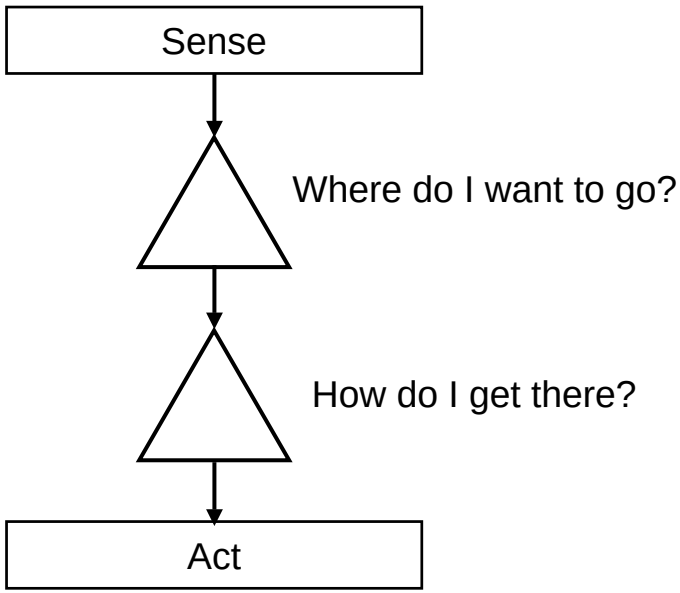
Example: Horizontal Sequential



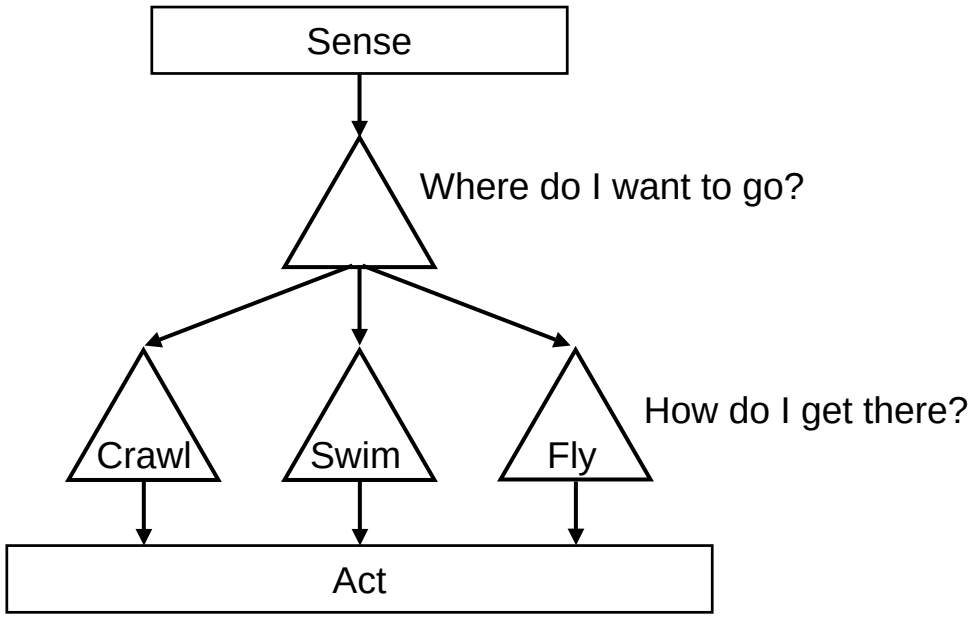
Example: Horizontal Parallel



Example: Vertical

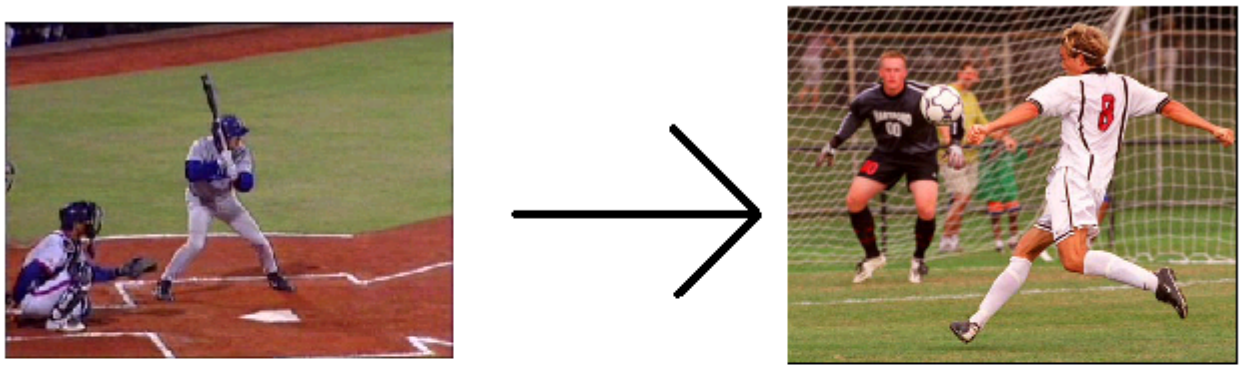


Example: Combined

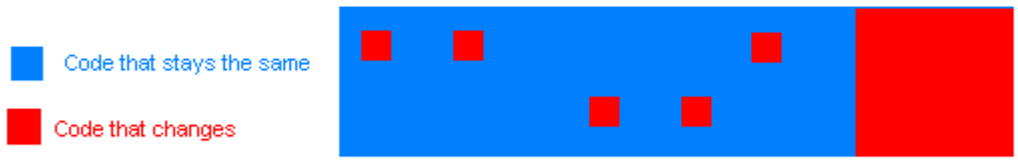


Benefits of Converting code from C to C++: Modularization

C++ reduces and modularizes changes in code



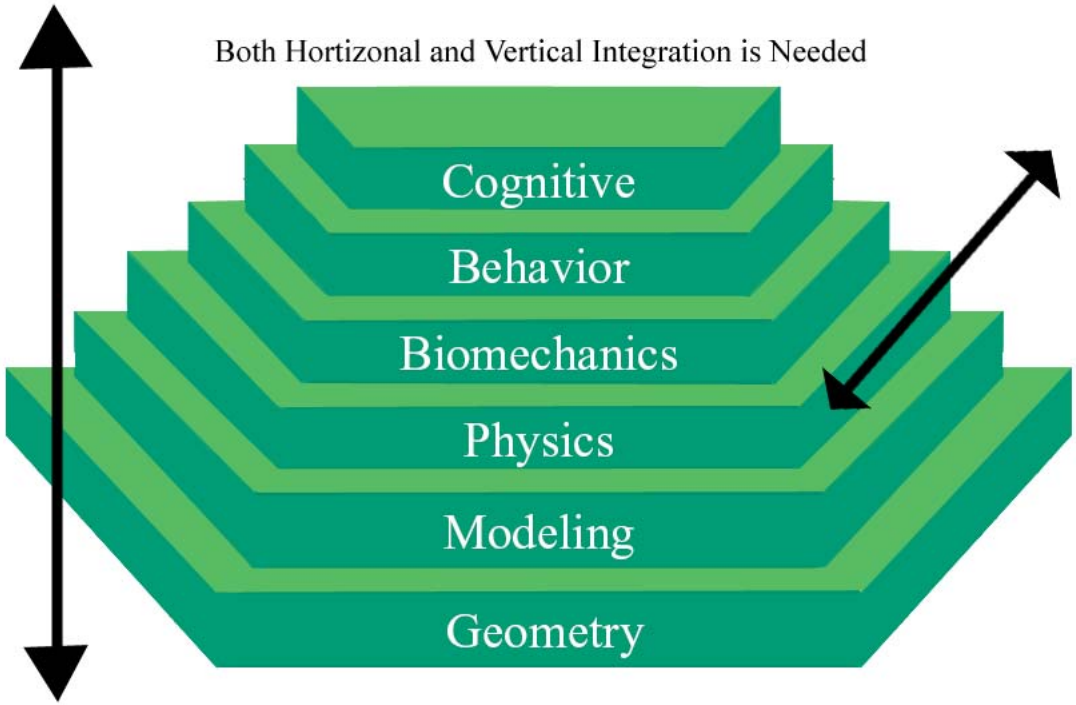
Change optimization in C code



More changes in more places mean more bugs and longer development time

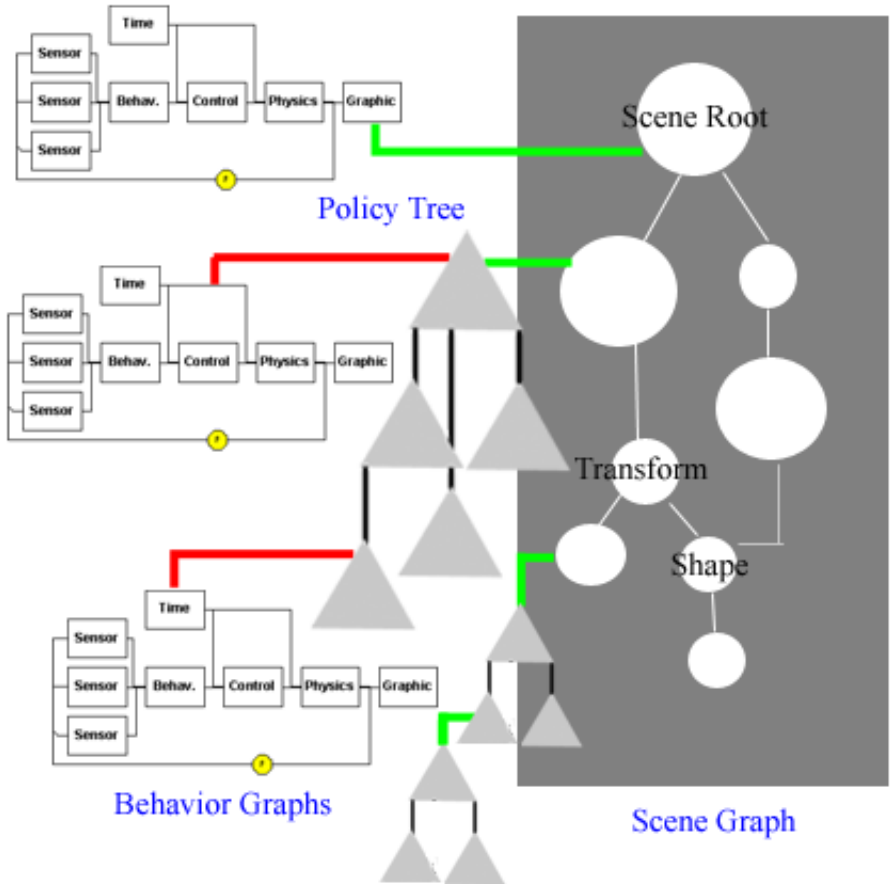
Change optimization in C++ code

Multiple levels are needed: both horizontal and vertical



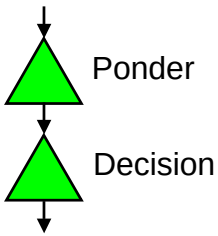
*Modeling Building Blocks according to Funge, Terzopoulos, 1999

We are developing tools to visualize evolved behaviors

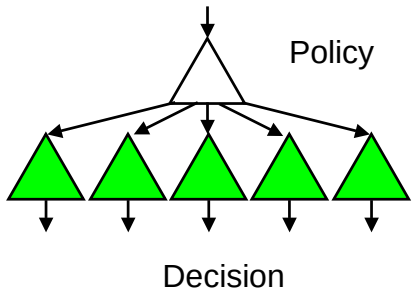


Benchmark problem optimization approaches

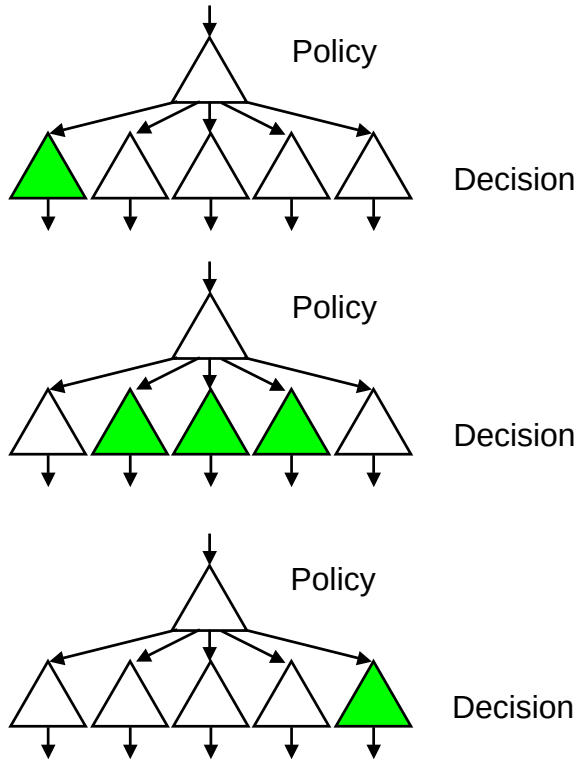
Single Tree Ponder



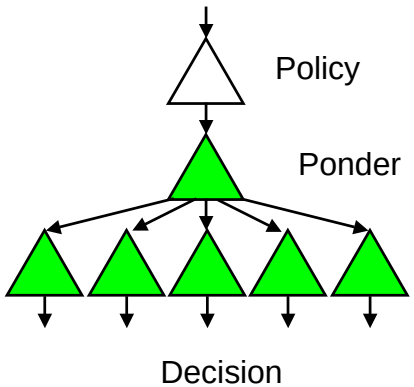
Five Tree No-Ponder



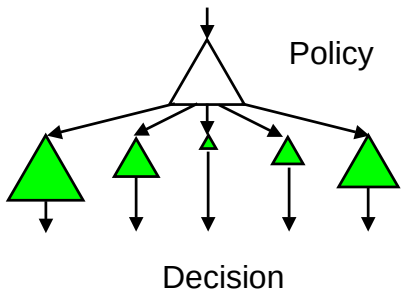
Staged Optimization



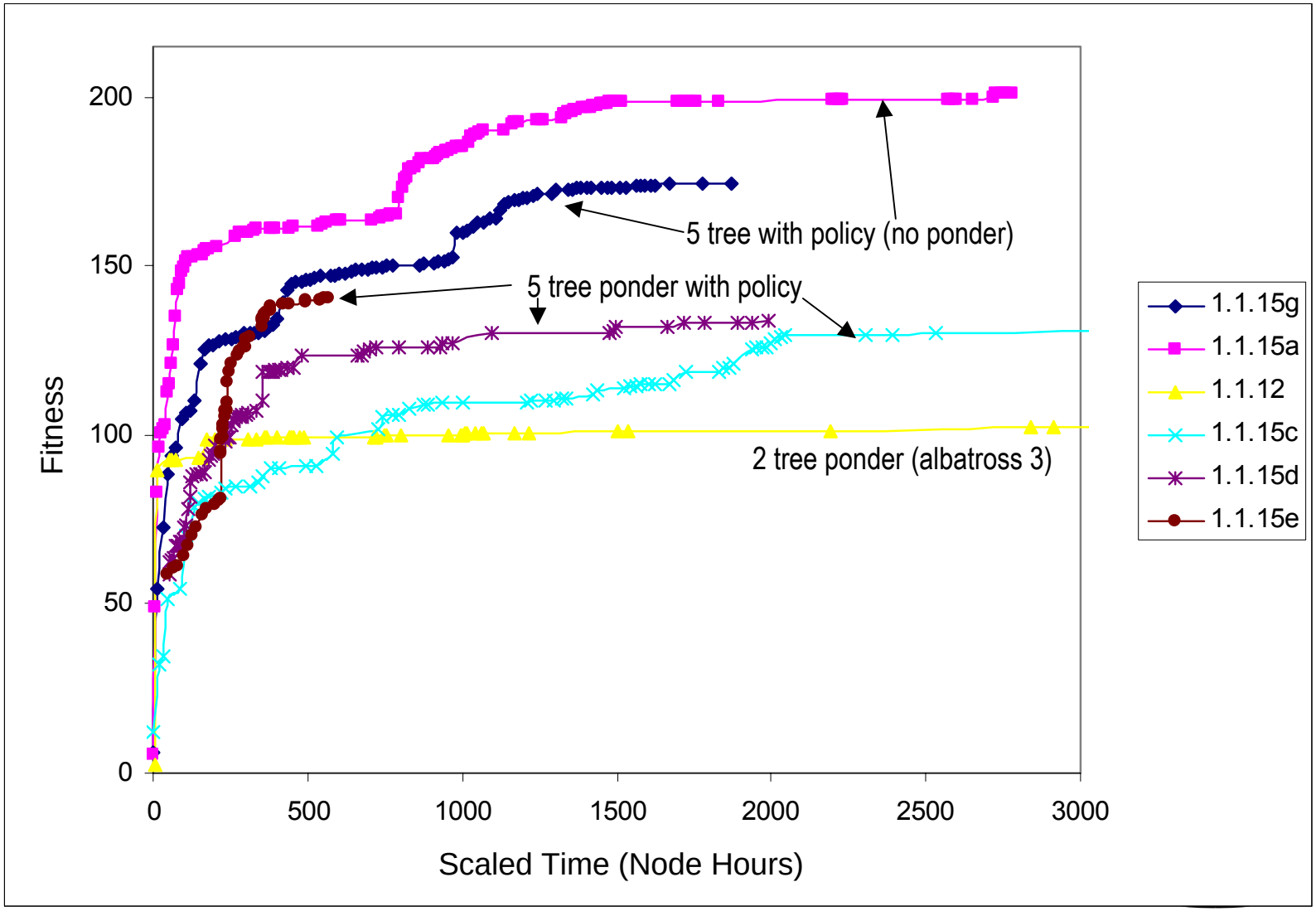
Five Tree Ponder



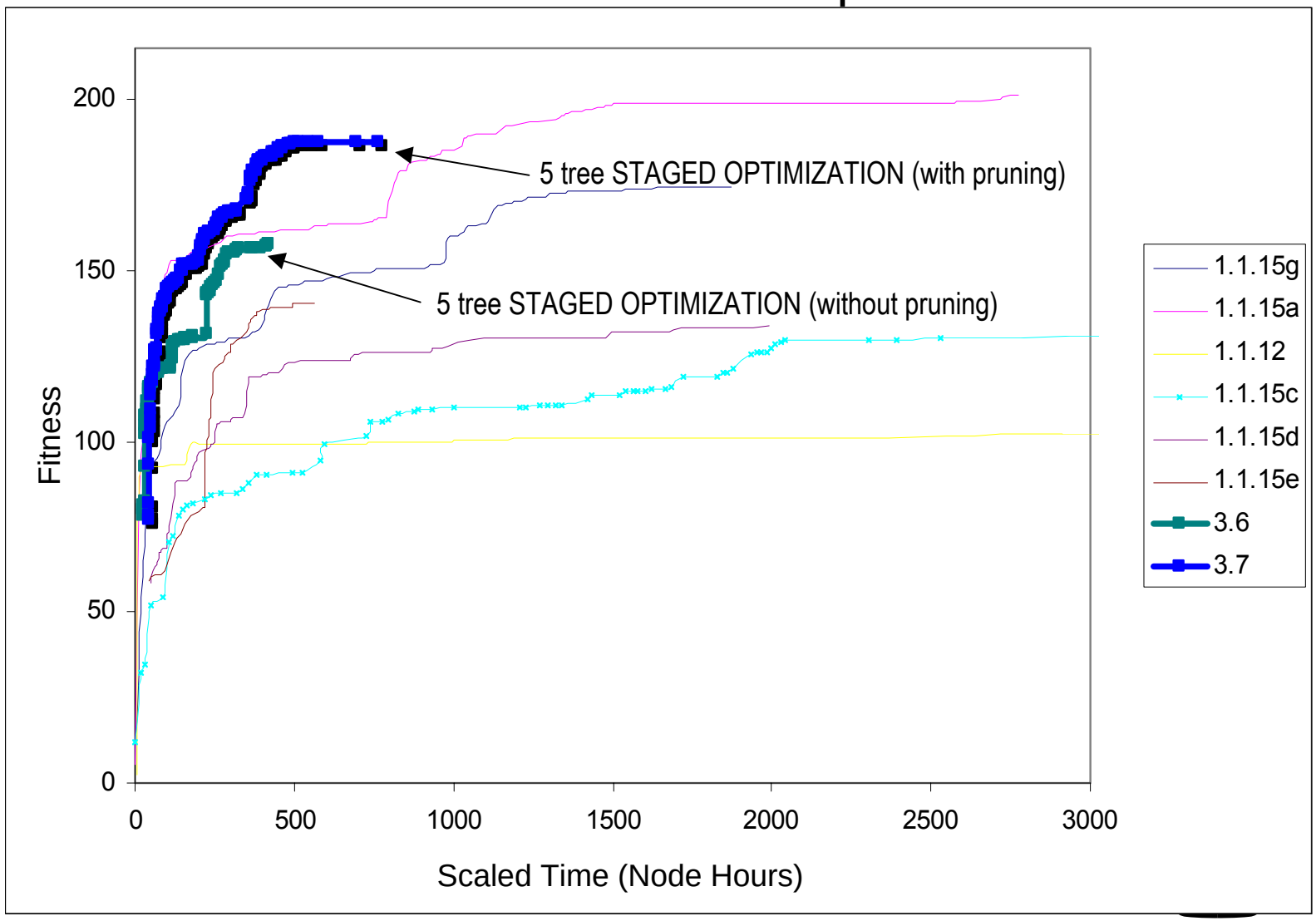
With Tree Pruning



Results for benchmark problem



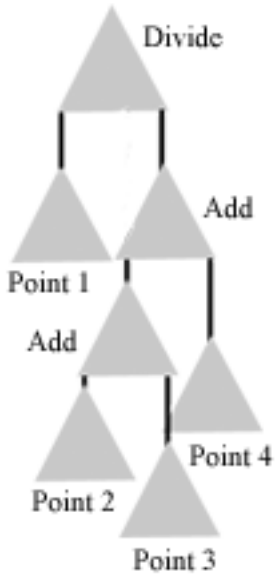
Results for benchmark problem



Real-world example: Image data collection

Sense Compute Act (Machines)

Pixel Neighborhood

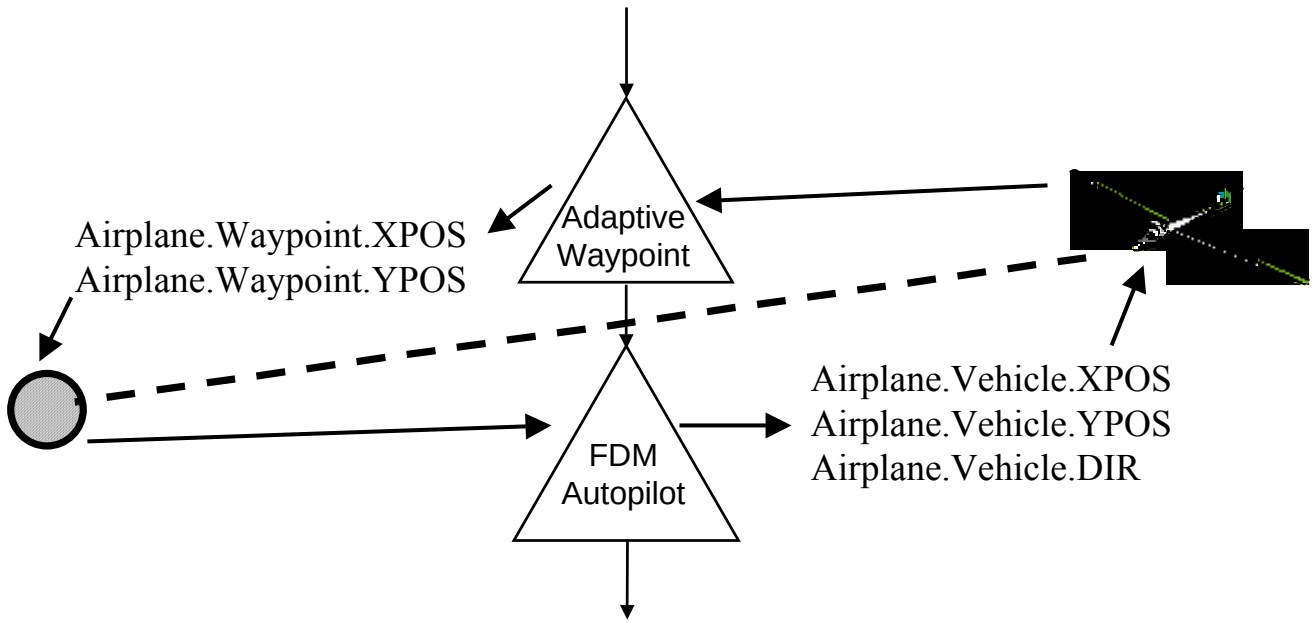


If Value < Target Value

MOVE (C)

Pereceptual Cognitive Behavorial (Humans)

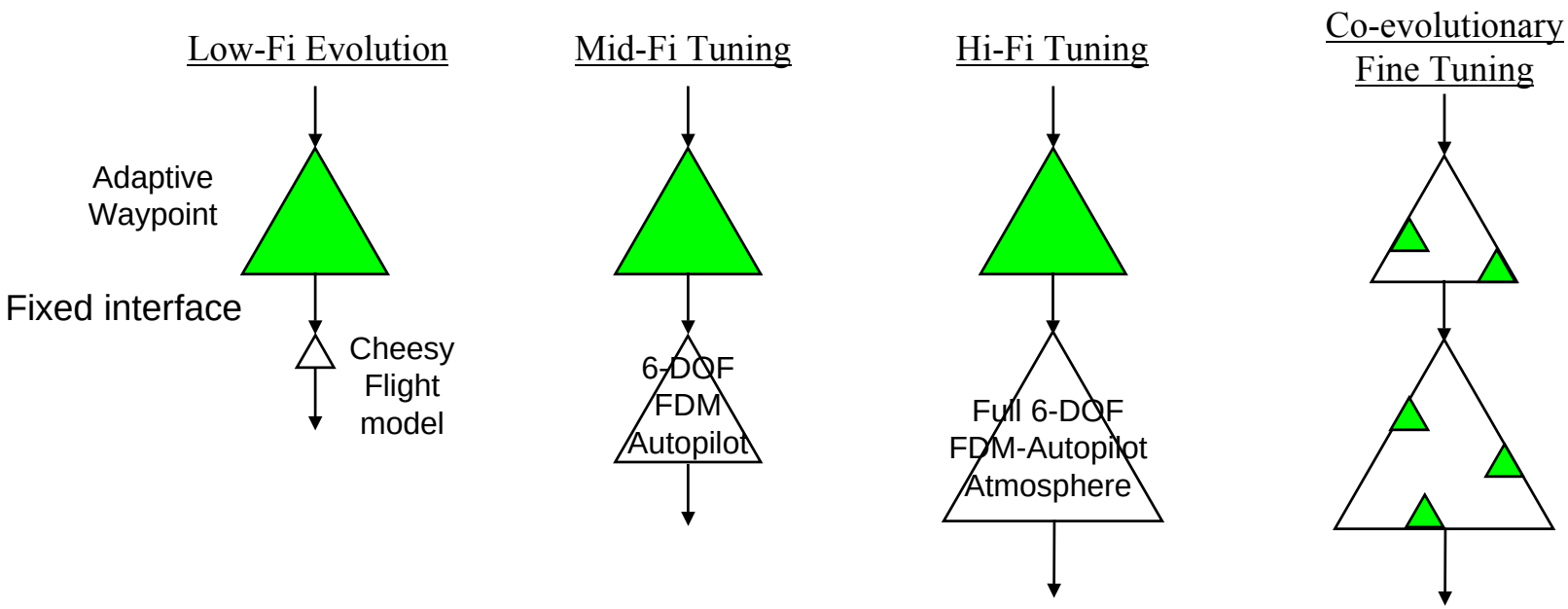
Graduated Embodiment example: adaptive waypoint



Allows Vertical, Horizontal, Co-Evolutionary, Collective Behavior

Graduated Embodiment example: adaptive waypoint

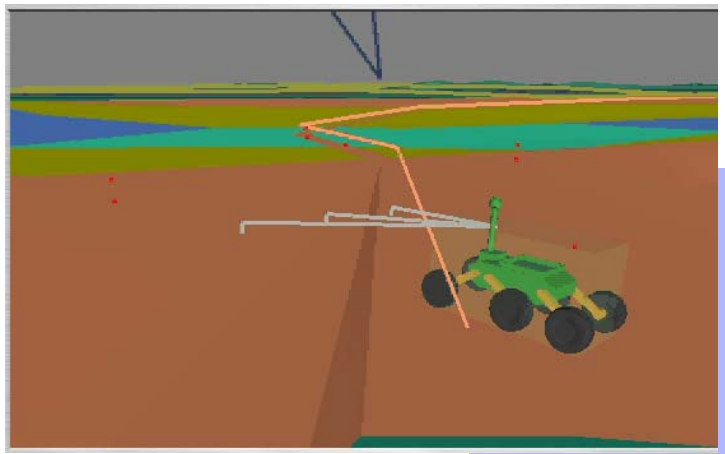
We have chosen this method to develop usable behaviors



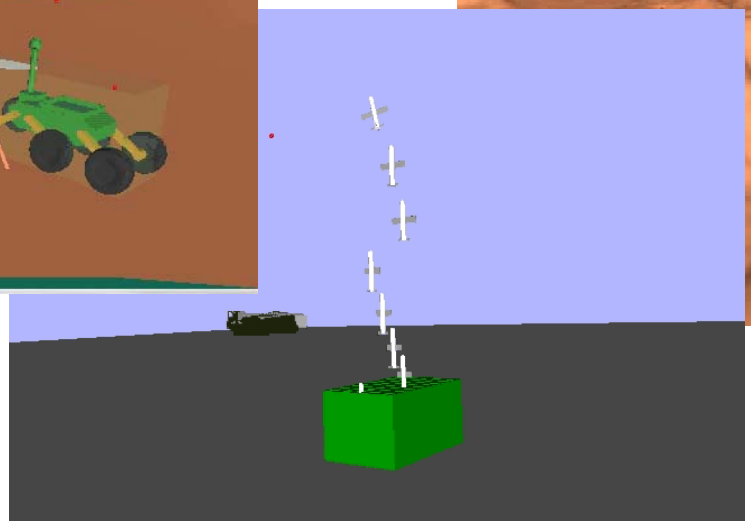
This is the essence of Graduated Embodiment

Next: Apply GP to Umbra's hard engineering

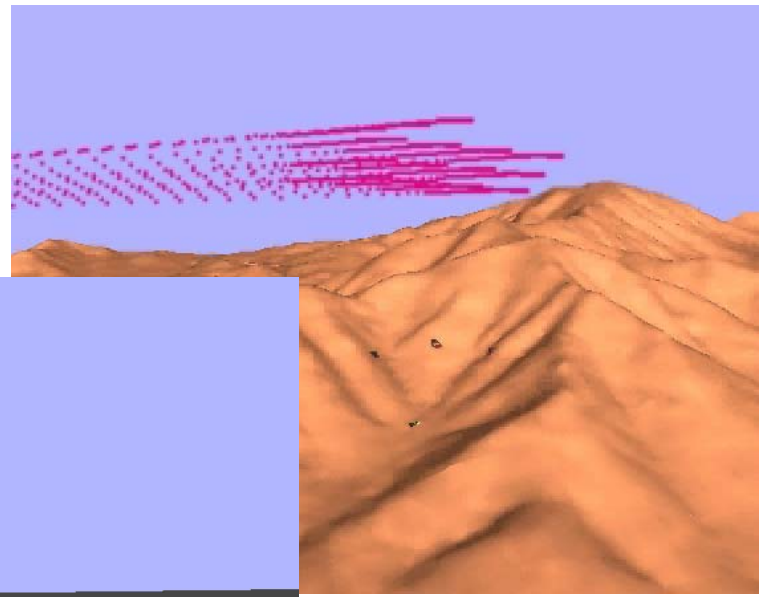
Can the adaptive waypoint concept be generalized to n-demensional parameter space??



Simple target on terrain



Netfires at launch

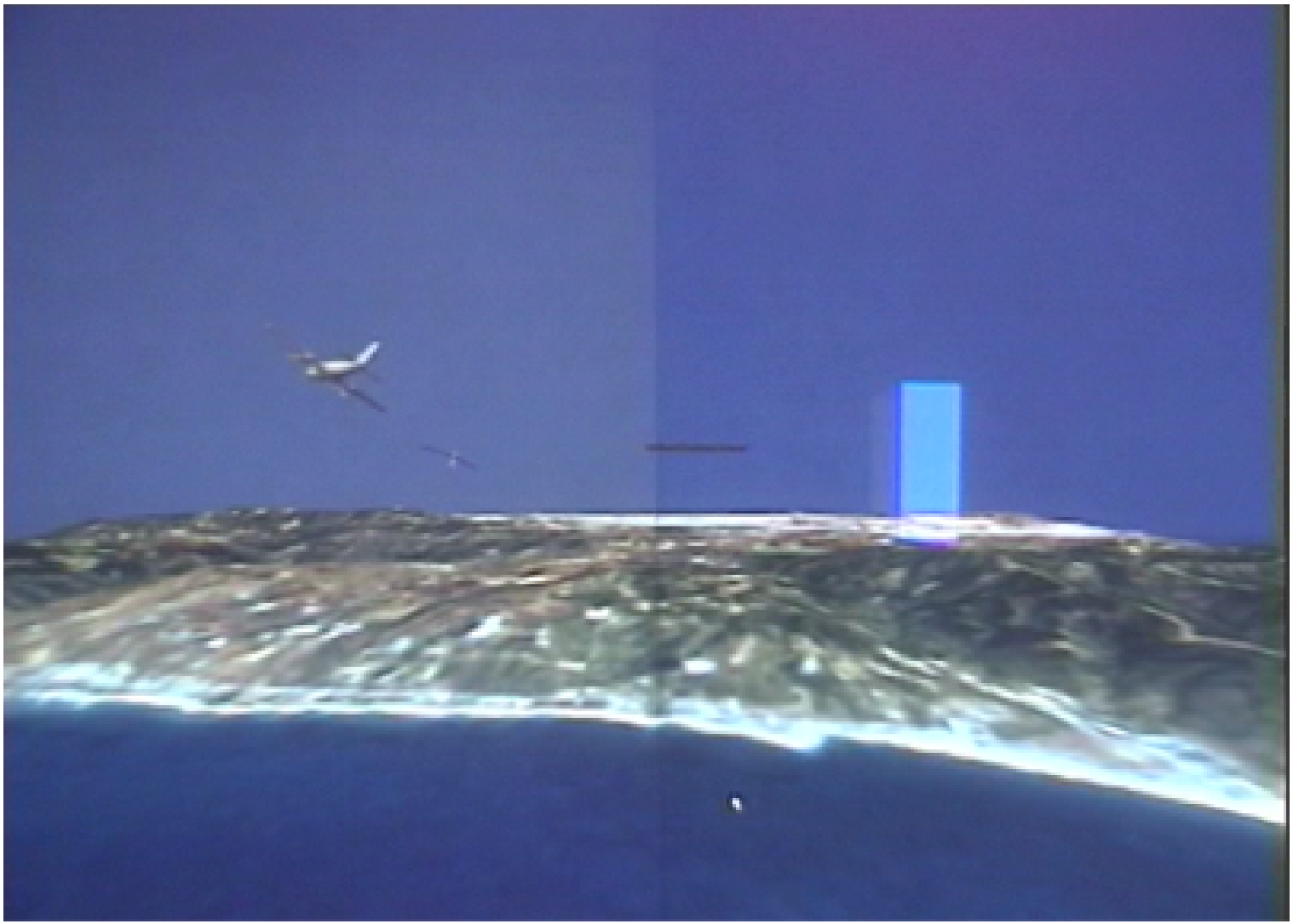


Netfires target seeking

Why are we developing evolutionary computing technology?

- *Well-suited for robotics applications.*
- *Simulation pushes Umbra "multiple-fidelity" capability.*
- *Provides context for intelligent machine systems.*
- *Likely to provide insight into cognition processes.*
- *Uses* behavioral biomimetics *to derive insight from nature.*

Umbra Application of Genetic Programming
Running on 2X2 Tile in VIEWS Corridor Building 880/A1



2056 X 2048 Resolution taken with 720X 480 Camera