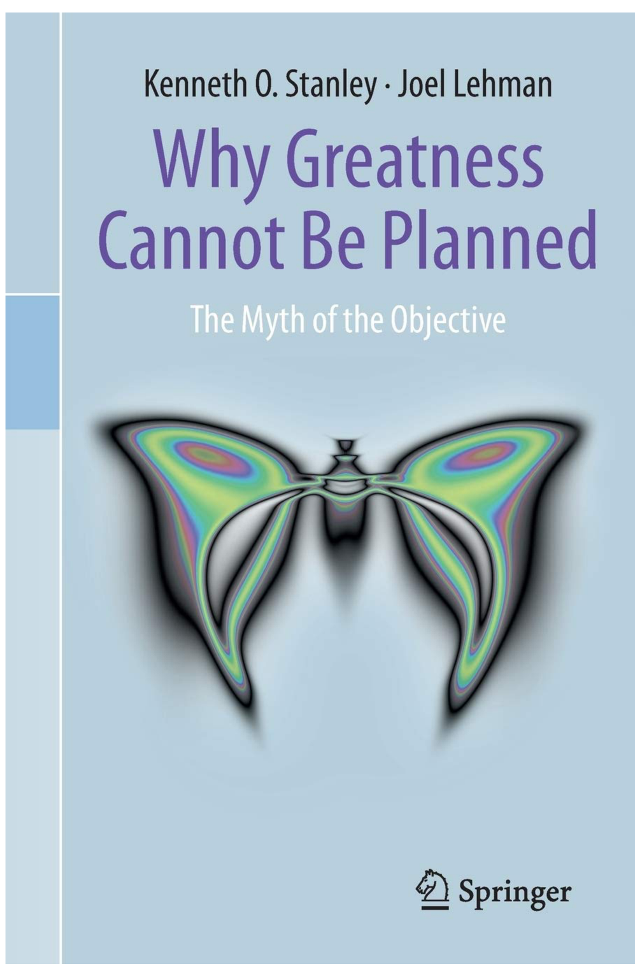
25: Novelty Search



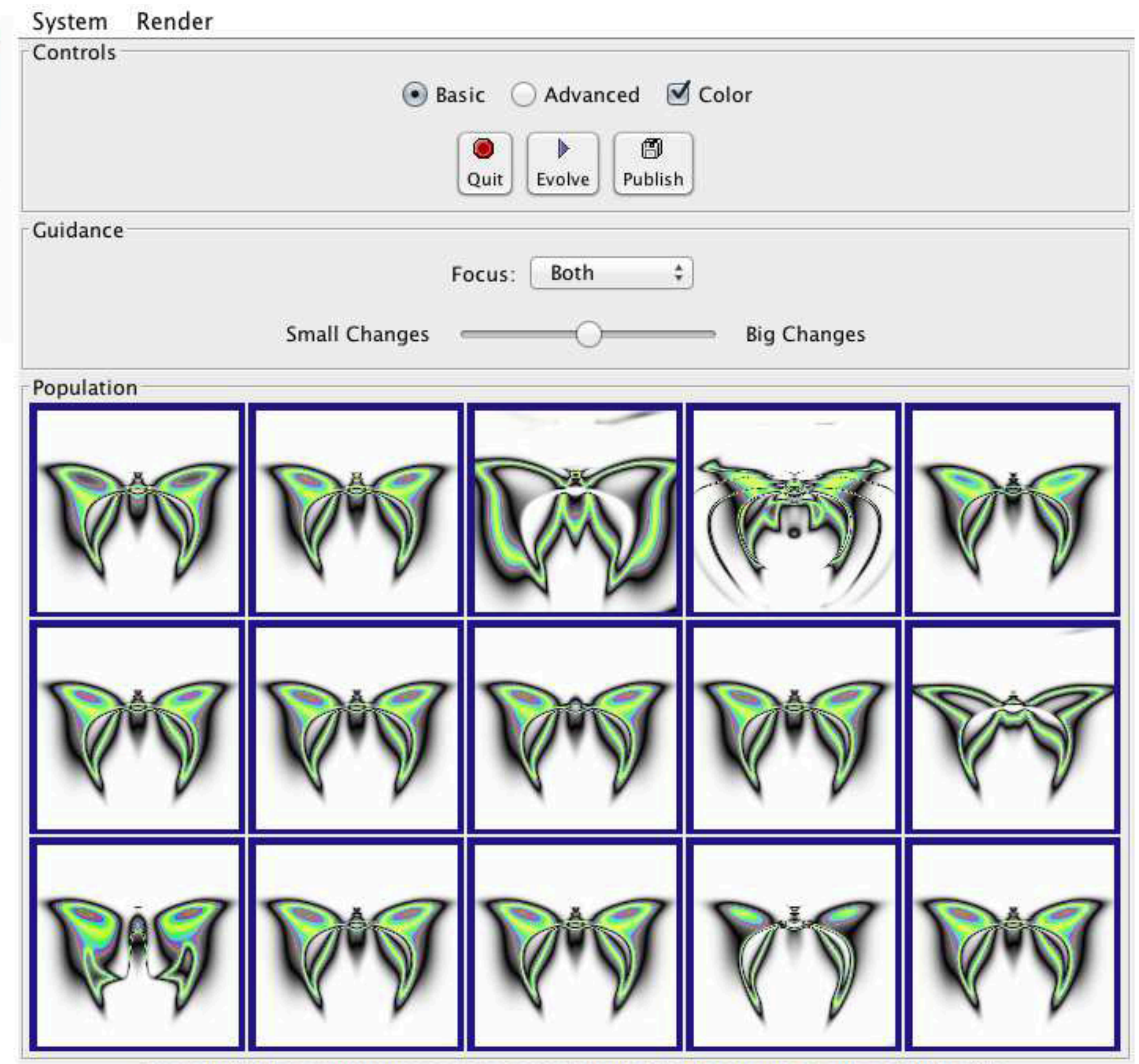
- Objectives for AI
- Story of Picbreeder
- Deception in search
- Novelty search
- Novelty search for GP

Prof. Ting Hu, School of Computing, Queen's University

The myth of the objective

- Almost all current AI systems are trained based on objectives
- Intelligence should be creative, innovative, and collaborative
- Ambitious objectives can block their own achievement
  - An obstacle to creativity and innovation
  - Without protection for individual autonomy, collaboration can become dangerously objective
- We are infatuated with metrics

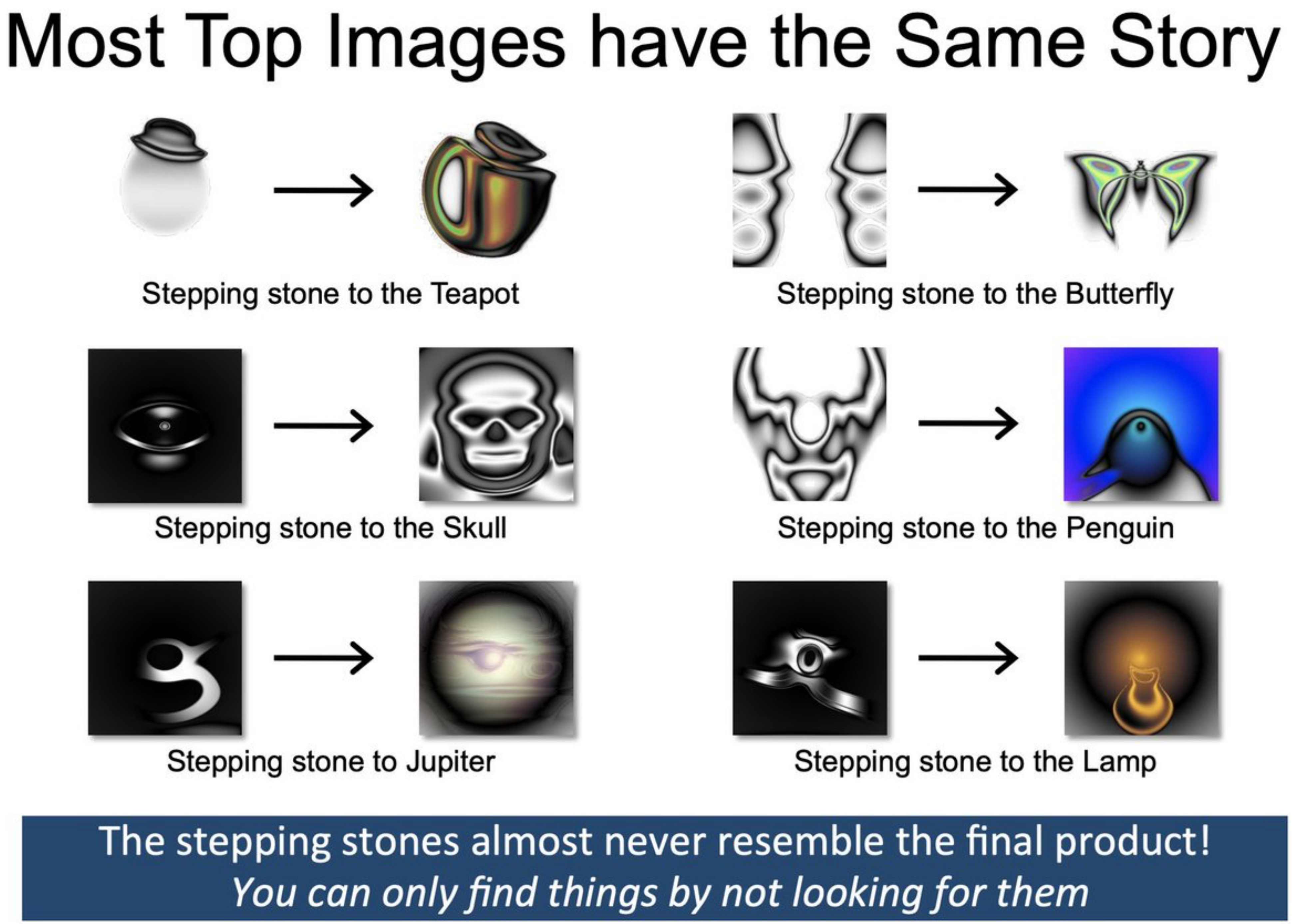
Picbreeder



- Online collaborative evolution of images
- No specific goal
- Users choose what is interesting
- Highly subjective

Secretan, Beato, D'Ambrosio, Rodriguez, Campbell, Folsom-Kovarik, Stanley: Picbreeder: A case study in collaborative evolutionary exploration of design space. *Evolutionary computation.* 2011

Picbreeder

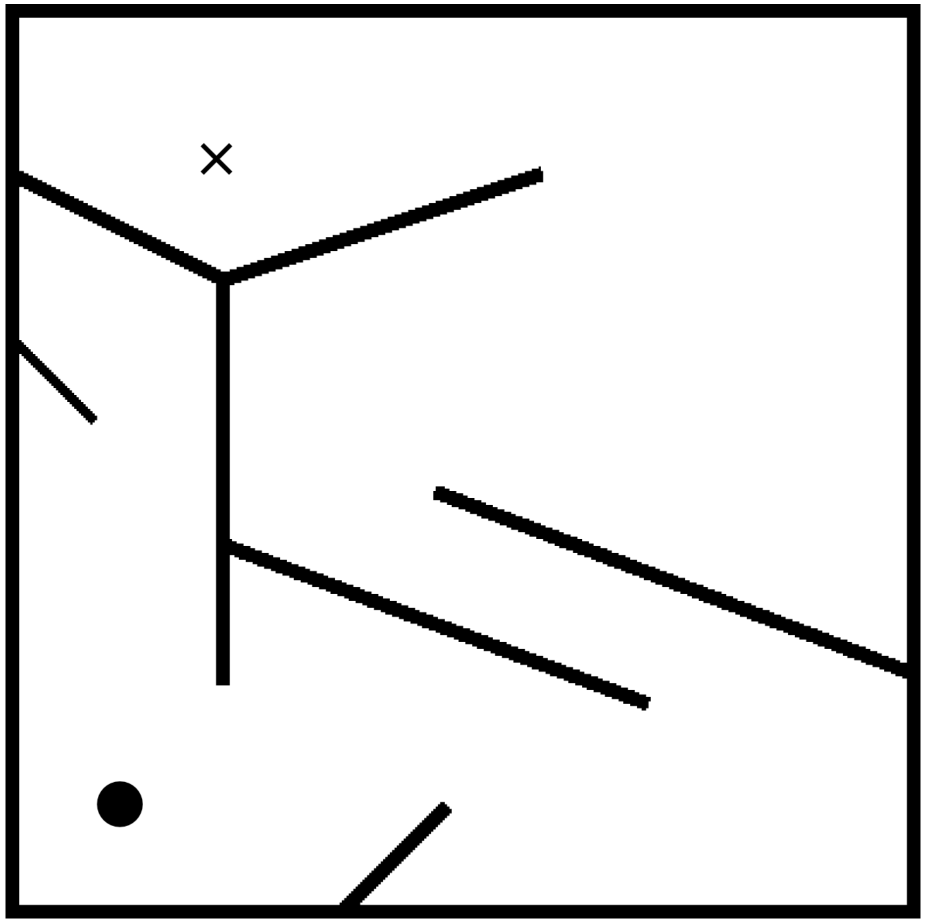


Secretan, Beato, D'Ambrosio, Rodriguez, Campbell, Folsom-Kovarik, Stanley: Picbreeder: A case study in collaborative evolutionary exploration of design space. *Evolutionary computation.* 2011

Implications

- “The path to success is through not trying to succeed”
- “To achieve our highest goals we must be willing to abandon them”
- “It is in your interest that others do not follow the path you think is right”
- “They will lay the stepping stones for your greatest discoveries”
- Convergent consensus vs. divergent treasury hunting

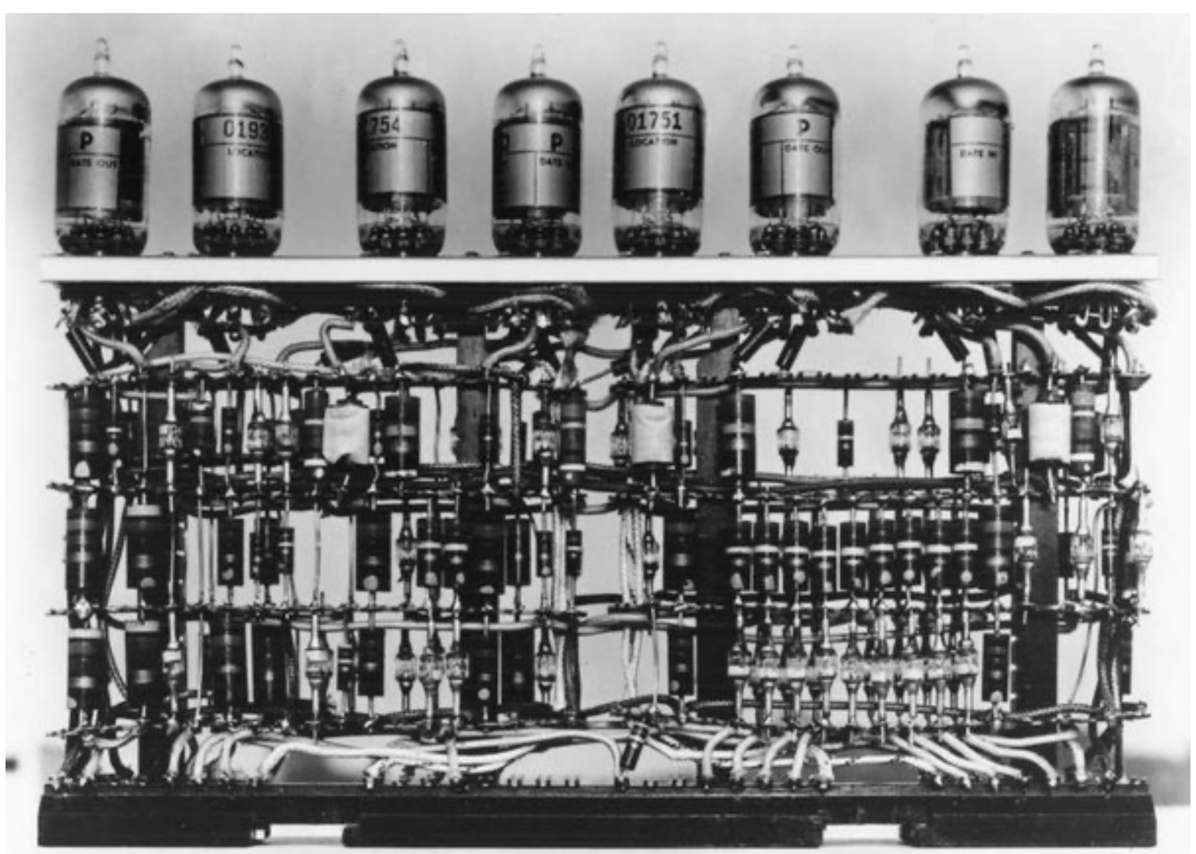
Deception

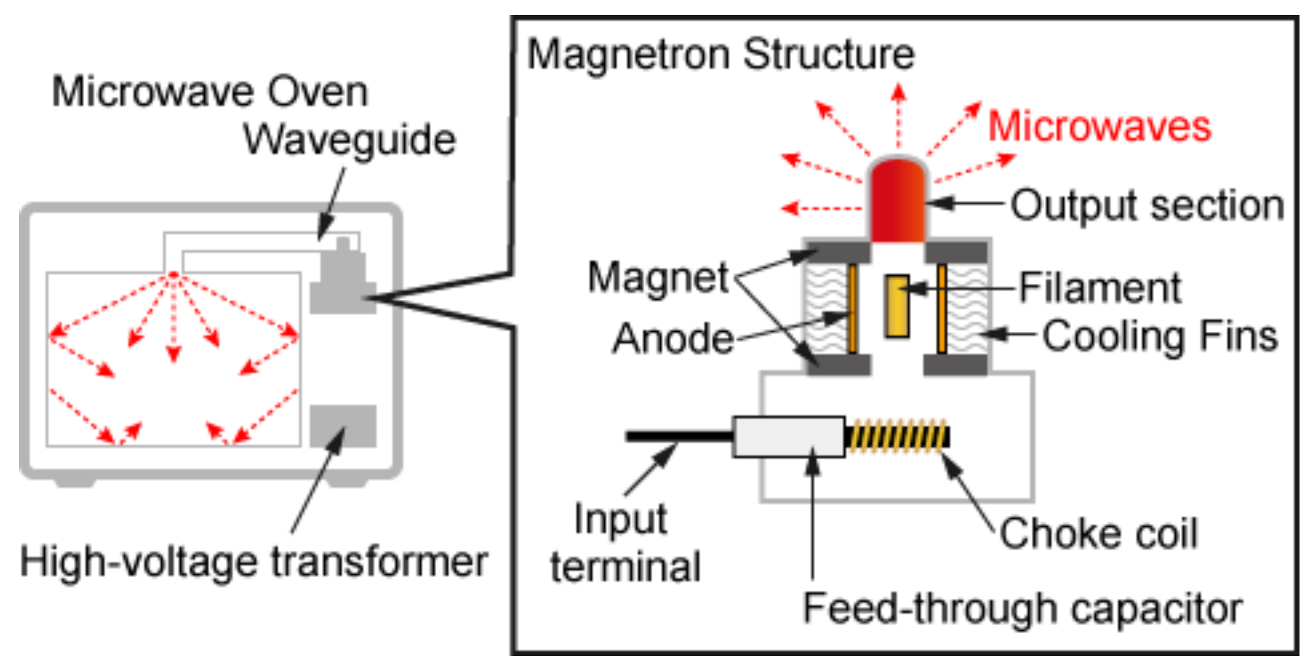


- Deception is the reason one can't find things by looking at them
- The stepping stones to get to the solution are not like the final solution
- Most heuristic base on how close to the goal
- Deceptive search space
- The need for more exploration

Examples of accidental inventions

- The vacuum tube and modern computers
- Magnetron for radar systems and microwave





Images from the Internet

Open-endedness

- Not how to learn something
- But how to learn everything
- Not just a single positive result
- But an ongoing cacophony of surprises
- Natural evolution is the ongoing creation of all the diversity of life

Interestingness and novelty

- Subjectivity of measuring interestingness
- Divergence is creative
- Novelty reflects divergence and can be quantified
- Fitness creates a gradient towards the objective
- Novelty creates a gradient of behavioral differences

Novelty search

- What if we ignore the fitness function?
- And search for novel things (behaviors)
- Characterize behaviors with a vector
- Replace fitness by novelty, computed by the behavioral distance to the archive and population

$$\rho(x) = \frac{1}{k}\sum_{j=0}^{k} d_b(x, \mu_j)$$

Novelty of x

Sum over the k
nearest neighbors
from archive and population

behavioral distance
between x and μ_j

Efficiently Evolving Programs through the Search for Novelty

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“ Abandoning objectives is often the only way to outperform the direct search for the objective.”

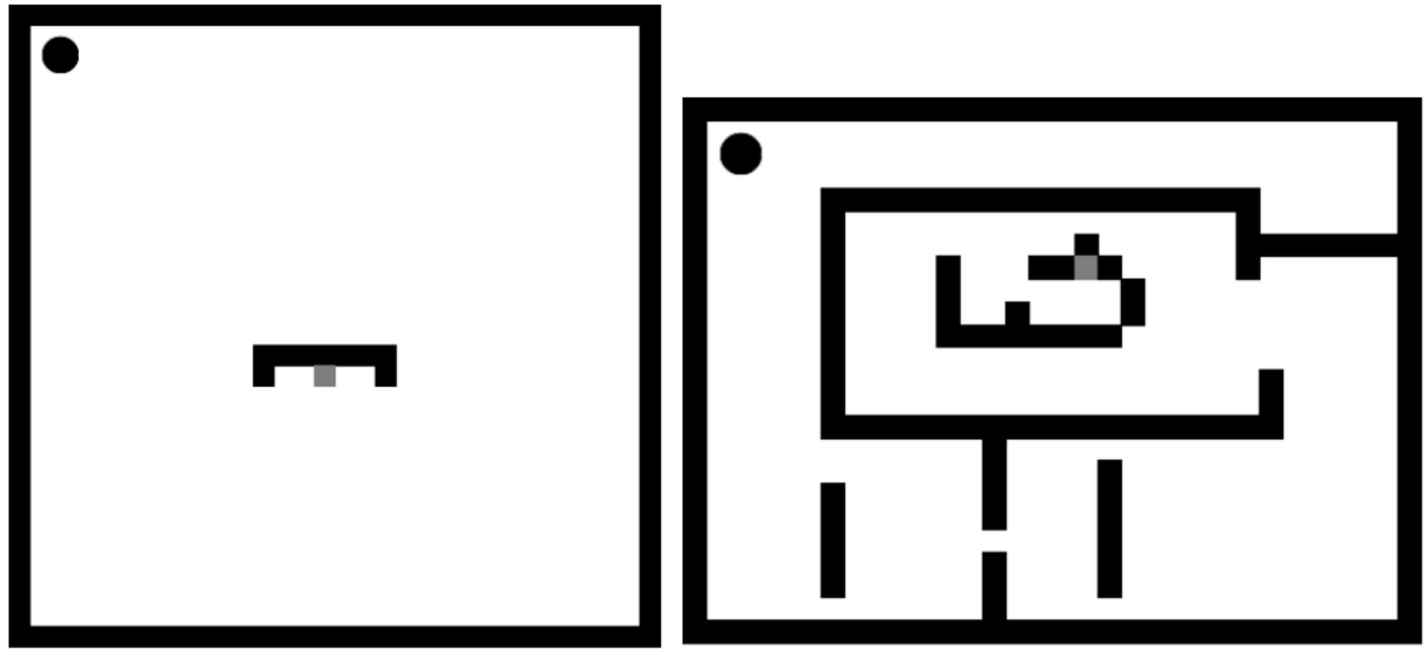
— Kenneth Stanley

Novelty search for genetic programming

- Premature convergence
- Solving deceptive GP problems
- A measure of sparseness at a point: the average distance to the k-nearest neighbors of that point

$$\rho(x) = \frac{1}{k}\sum_{i=0}^{k} \mathrm{dist}(x, \mu_i)$$

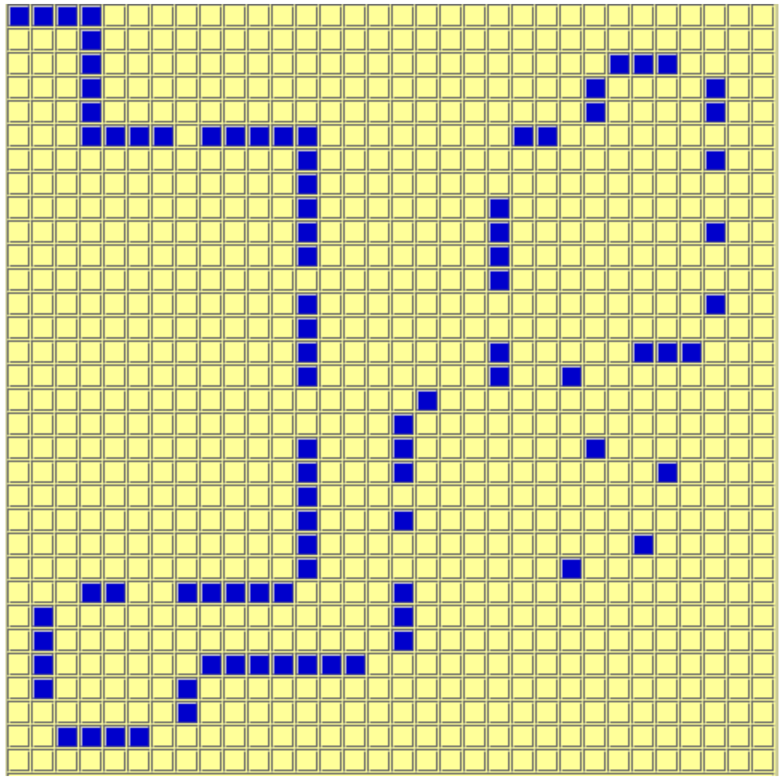
Maze experiment



(a) Medium Map (b) Hard Map

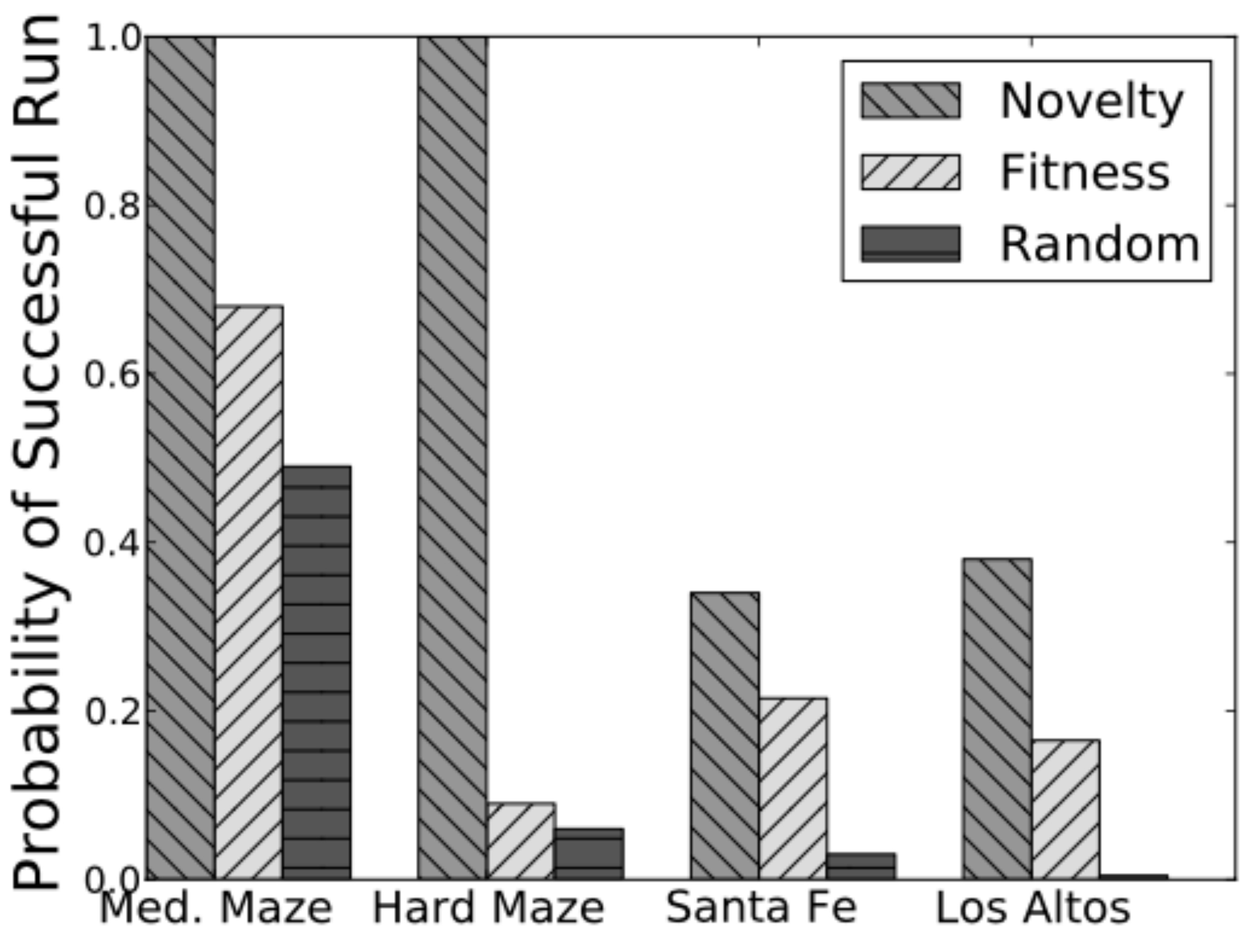
Objective:	Find a robot that navigates the maze
Terminal set:	Left (turn left), Right (turn right), Move (move forward one square)
Functions set:	IfWallAhead (execute one of two child instructions based on whether there is a wall directly ahead), Prog2 (sequentially execute the two child instructions)
Fitness cases:	Medium Maze and Hard Maze
Wrapper:	Program repeatedly executed for 100 time steps for the medium maze or 400 time steps for the hard maze
Population Size:	$1,000$
Termination:	Maximum number of generations $= 1,000$

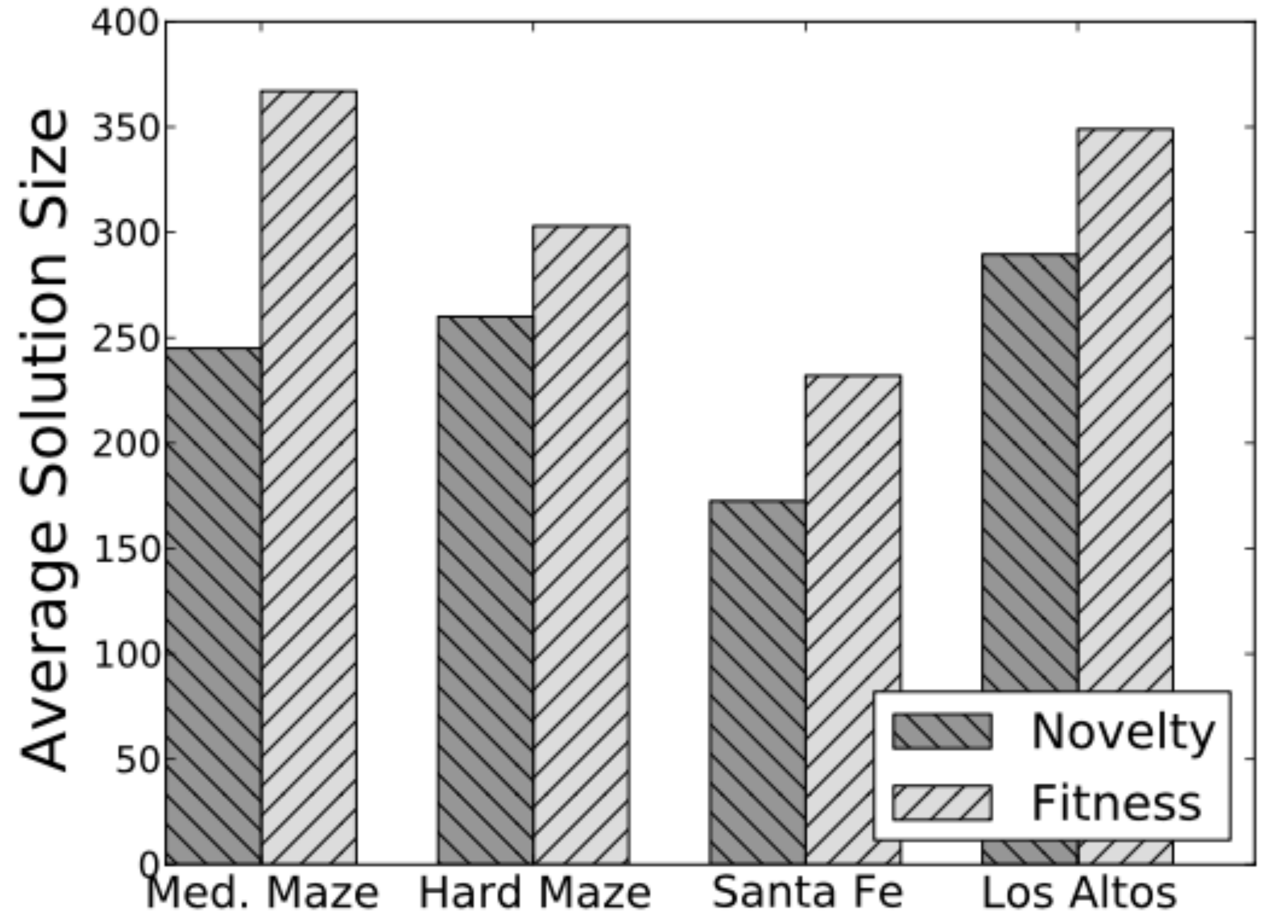
Artificial Ant experiment



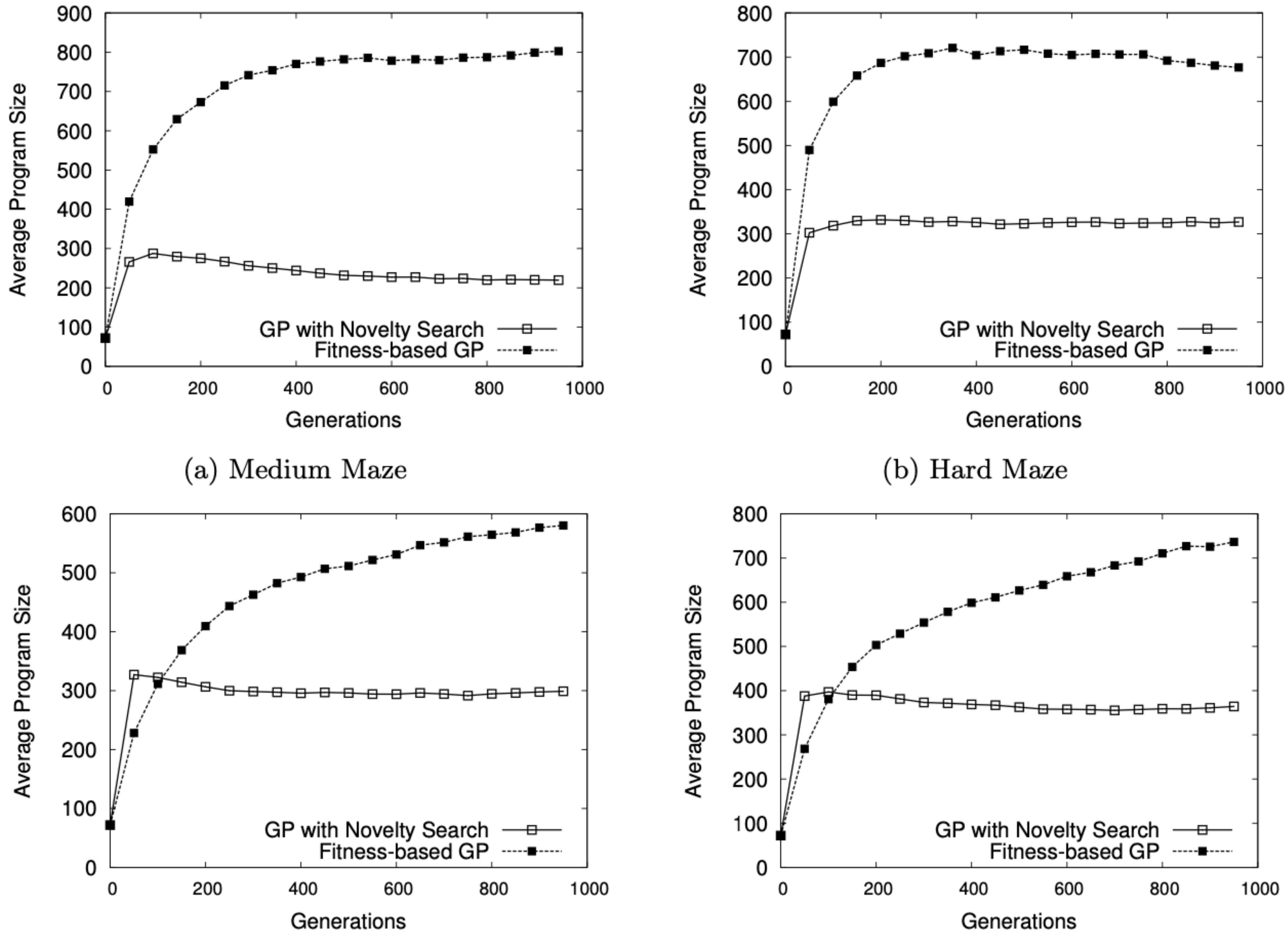
Objective:	Find an ant that follows food trails
Terminal set:	Left (turn left), Right (turn right), Move (move forward one square)
Functions set:	IfFoodAhead (execute one of two child instructions based on if there is food directly ahead), Prog2 (sequentially execute the two children instructions)
Fitness cases:	Santa Fe Trail and Los Altos Trail
Wrapper:	Program repeatedly executed for 400 time steps for Santa Fe Trail or $3,000$ time steps for Los Altos Trail
Population Size:	$1,000$
Termination:	Maximum number of generations $= 1,000$

Results comparison





Results comparison



(a) Medium Maze

(b) Hard Maze

(c) Santa Fe Trail

(d) Los Altos Trail