Introduction to Natural Computation

Lecture 14

Examples and Design of Evolutionary Algorithms

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Evolutionary Algorithm

1. Generate the initial population *P(0)* and set $i = 1$; **(Initialisation)**

2. Evaluate the fitness of each individual in *P(0)*;

REPEAT **(Generation)**

(a) Generate offspring from the parents using *variation operators* to form *P(i)*; **(Variation)**

(b) Evaluate the fitness of each individual in *P(i)*; **(Evaluation)**

(c) Select parents from *P(i)* and *P(i-1)* based on their fitness; **(Selection)**

(d) $i = i + 1$;

3. UNTIL halting criteria are satisfied

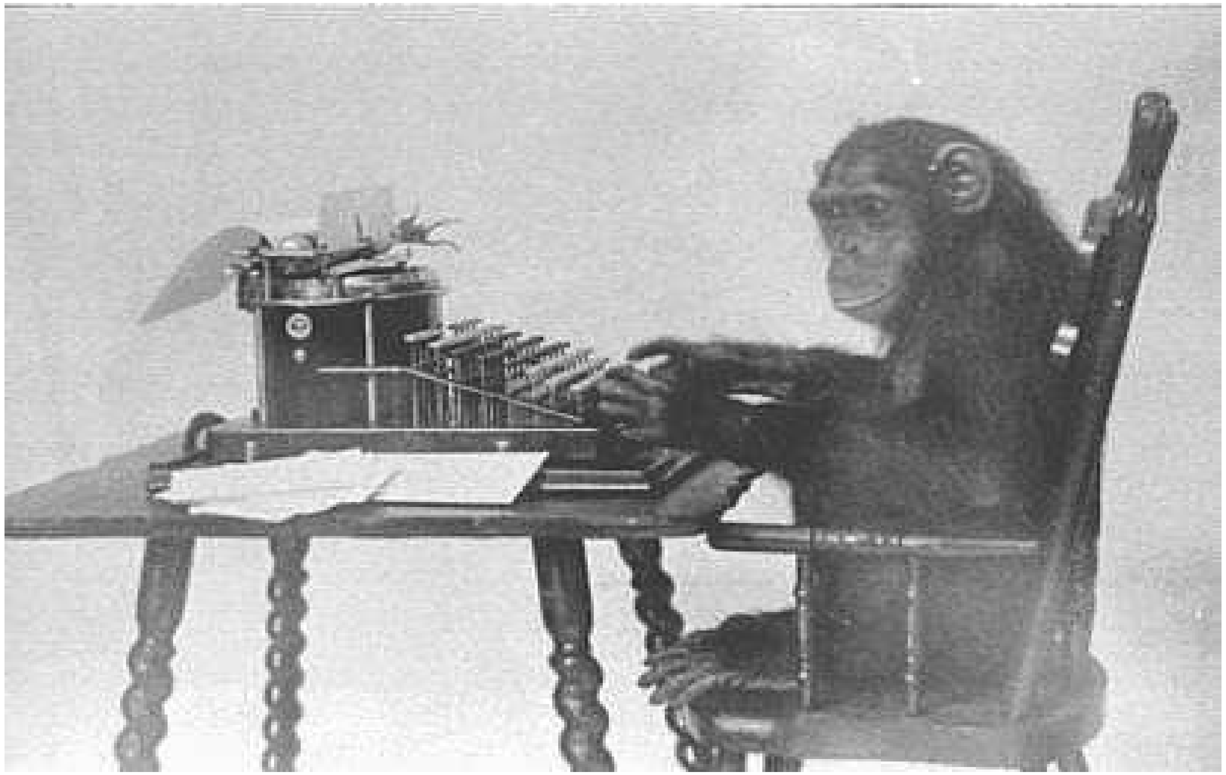
Characteristics of EAs

1. **Flexible:** applicable to different problems
2. **Robust:** can deal with noise and uncertainty
3. **Adaptive:** can deal with dynamic environments
4. **Autonomous:** without human intervention
5. **Decentralised:** without a central authority

Application Areas

- **Planning**
  - Routing, Scheduling, Packing
- **Design**
  - Electronic Circuits, Neural Networks, Structure Design
- **Simulation**
  - Model economic interactions of competing firms in a market
- **Identification**
  - Fit a function to medical data to predict future values
- **Control**
  - Design a controller for gas turbine engine, design control system for mobile robots
- **Classification**
  - Game playing, Diagnosis of heart disease, Detecting SPAM

Infinite Monkey Theorem



Given enough time, a hypothetical chimpanzee typing at random would, as part of its output, almost surely produce all of Shakespeare's plays.

Practical Theorem?

- The probability of a monkey exactly typing a complete work such as Shakespeare's *Hamlet* is so tiny that the chance of it occurring during a period of time of the order of the age of the universe is minuscule, but not zero.
- Example: typing ‘banana’
  - the typewriter has 50 keys
  - probability of each letter to be typed right is 1/50
  - probability of that ‘banana’ is typed right is (1/50)^6 = less than 1 in 15 billion
  - Expected of number of trials to write ‘banana’ = 15 billion

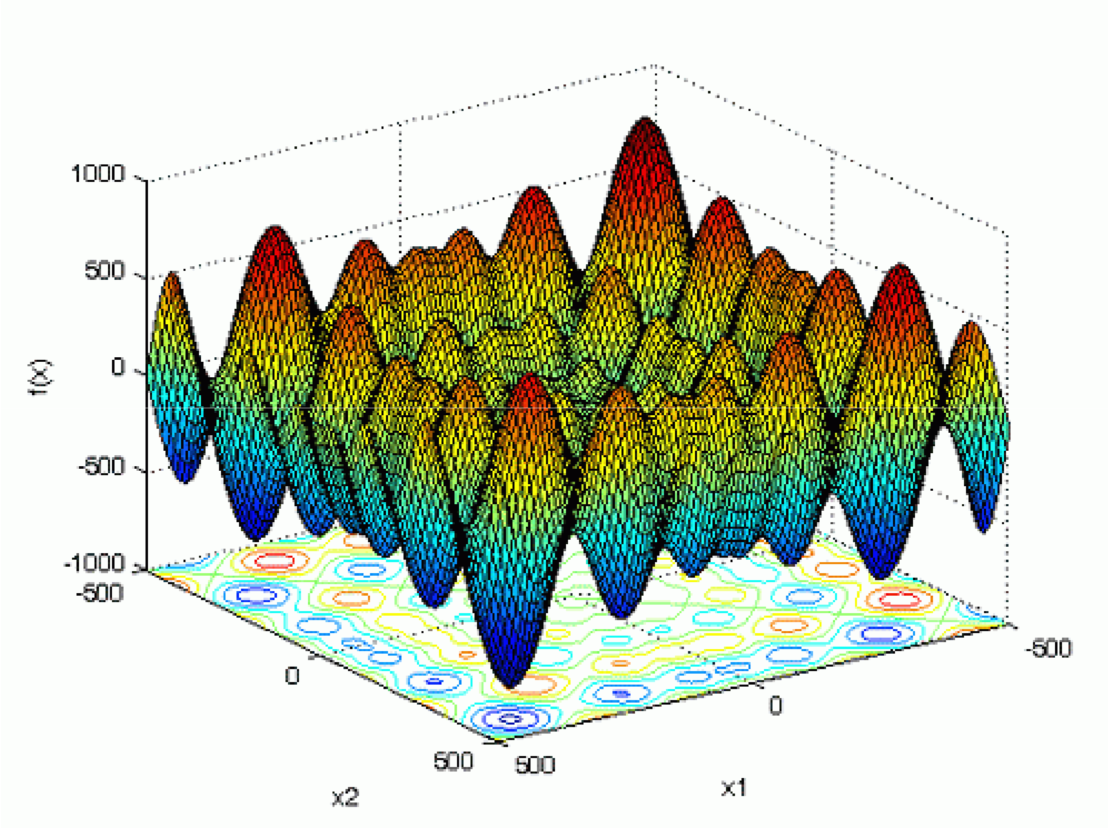
Monkeys, Typewriters and Evolution

- Evolution being a randomized generate-and-test process present some similarities to the monkey- with-typewriter process.
- However, natural selection can produce unlikely results. Could a monkey accidentally type the Hamlet line “methinks it is like a weasel”? The chances are virtually zero.
- How does an evolutionary algorithm do?

Richard Dawkin’s Weasel

- Search space:
  - Set of strings of characters of fixed length
- Fitness (to minimise):
  - Number of errors in the string
- Stochastic Hill-climber Algorithm:
  - Generate an initial string of characters at random
  - Repeat until the target string has been found:
    - Generate an offspring string by mutating a character in the current string
    - If the offspring string is better that the current string then it becomes the current string
- Demo: http://vlab.infotech.monash.edu.au/simulations/evolution/richard-dawkin-weasel/

Function Maximisation



Evolutionary approaches suitable for not well-behaved functions (non-linear, non-convex, non-differentiable, discontinuous)

Function Maximisation

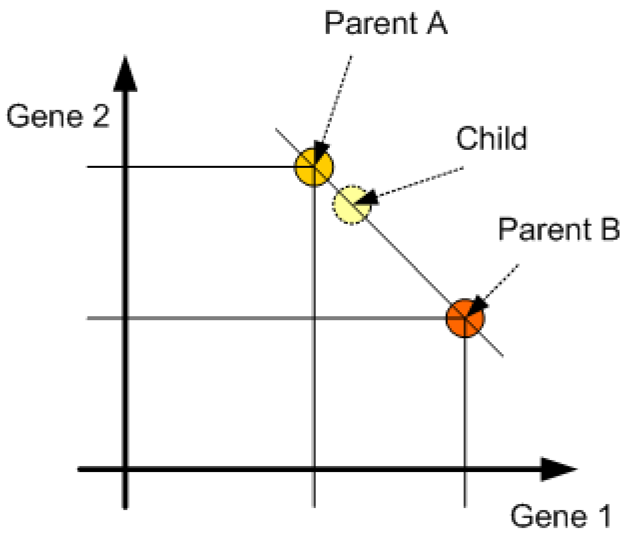
- Approach 1:
  - Represent candidate solutions (real numbers) using a binary encoding
  - Fitness: the function value
  - Use mutation and crossover for binary strings (e.g., bit-flip mutation and one-point crossover)

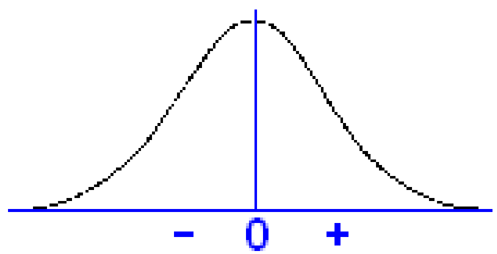
    P1: 1001|011 O1: 1001110 M1: 0001110
    P2: 1100|110 O2: 1100011 M2: 1100111

- Demo: http://www.obitko.com/tutorials/genetic-algorithms/example-function-minimum.php

Function Maximisation

- Approach 2:
  - Represent candidate solution directly as real numbers
  - Use mutation and crossover on real numbers
    - Crossover: randomised average of parents
    - Mutation: small random perturbation





Travelling Salesman Problem

Given a list of cities and their pair-wise distances, the task is to find a shortest possible tour that visits each city exactly once.

Travelling Salesman Problem

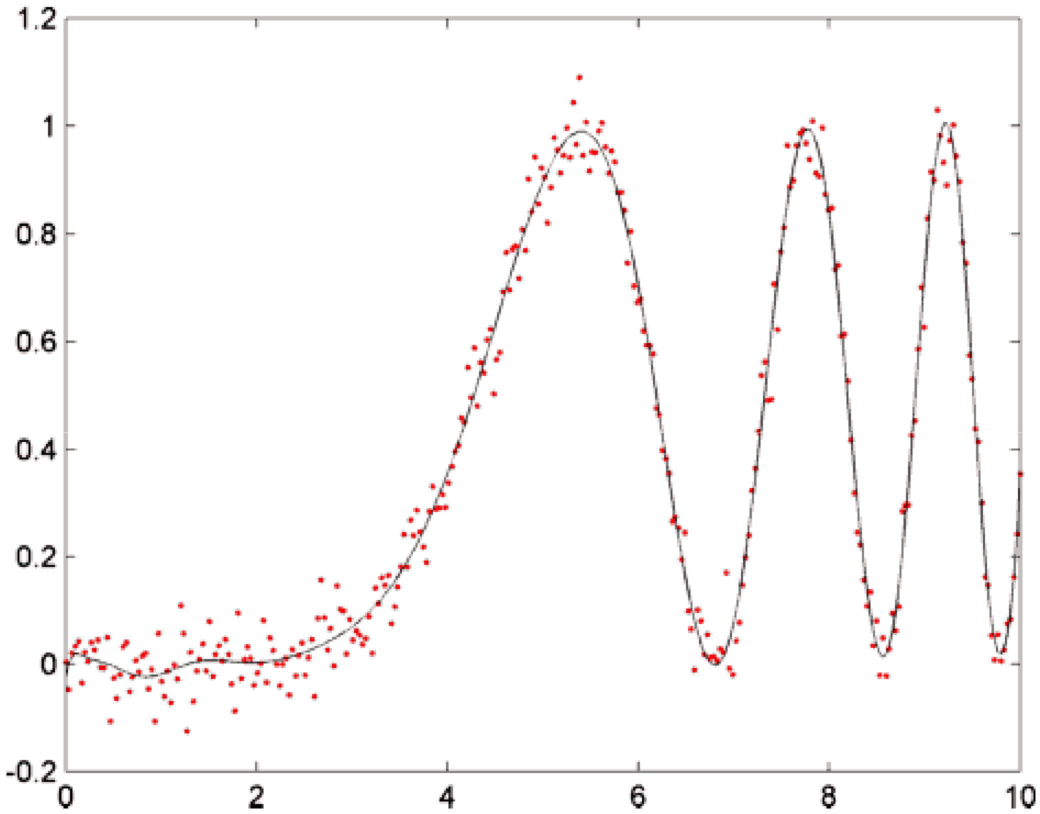
- A solution is tour passing through all cities
- Represent tours as permutations: list of integers without repetitions (e.g., 25143 for a tour of 5 cities)
- Fitness (to minimise): the tour length
- Search operators:
  - one-point crossover for permutations: part of the first parent is copied and the rest is taken in the same order as in the second parent
  - swap mutation: two elements are swapped at random)
  - the offspring is a VALID permutation

P1: 123|45   O: 12354   M: 14352

P2: 25143

DEMO: http://www.obitko.com/tutorials/genetic-algorithms/tsp-example.php

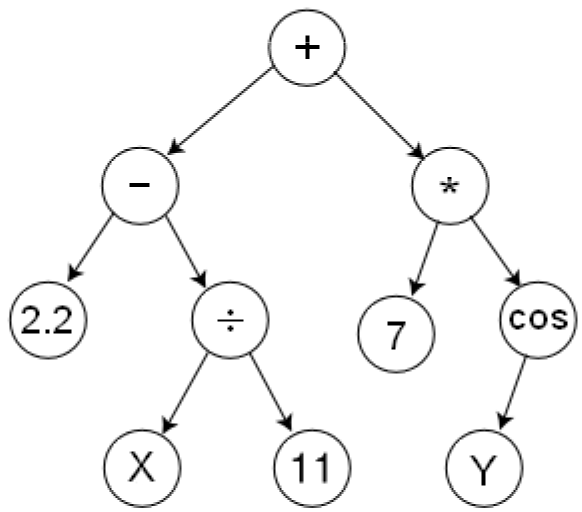
Symbolic Regression



Find a curve that best fits given noisy data-points

Symbolic Regression

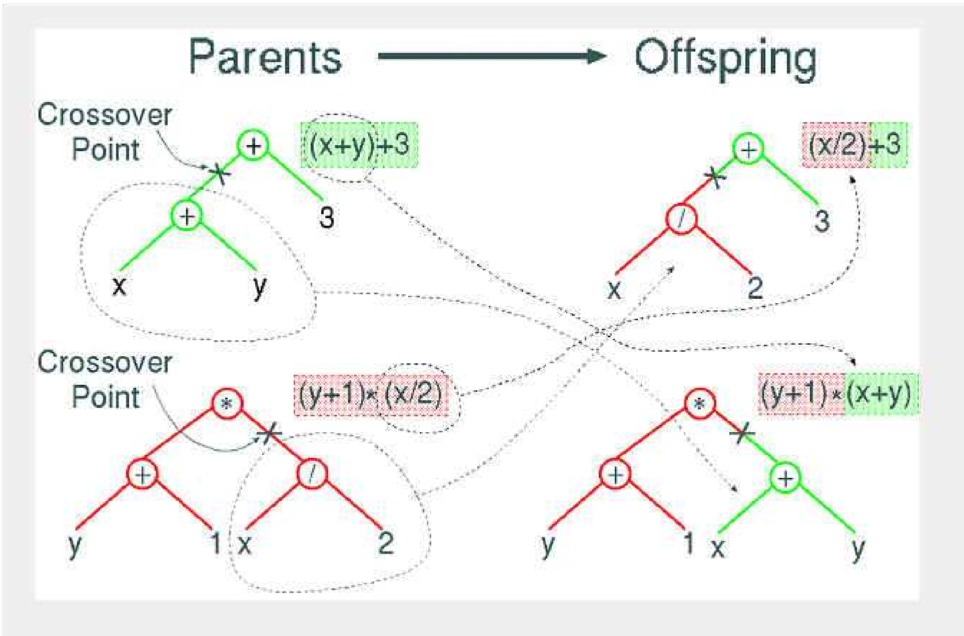
- Candidate solutions are curves (i.e., functions like y=sin(x)*2+1)
- Fitness (to minimise): sum of errors at each data point
- Functions can be represented using a tree encoding



$$\left(2.2 - \left(\frac{X}{11}\right)\right) + \left(7 * \cos(Y)\right)$$

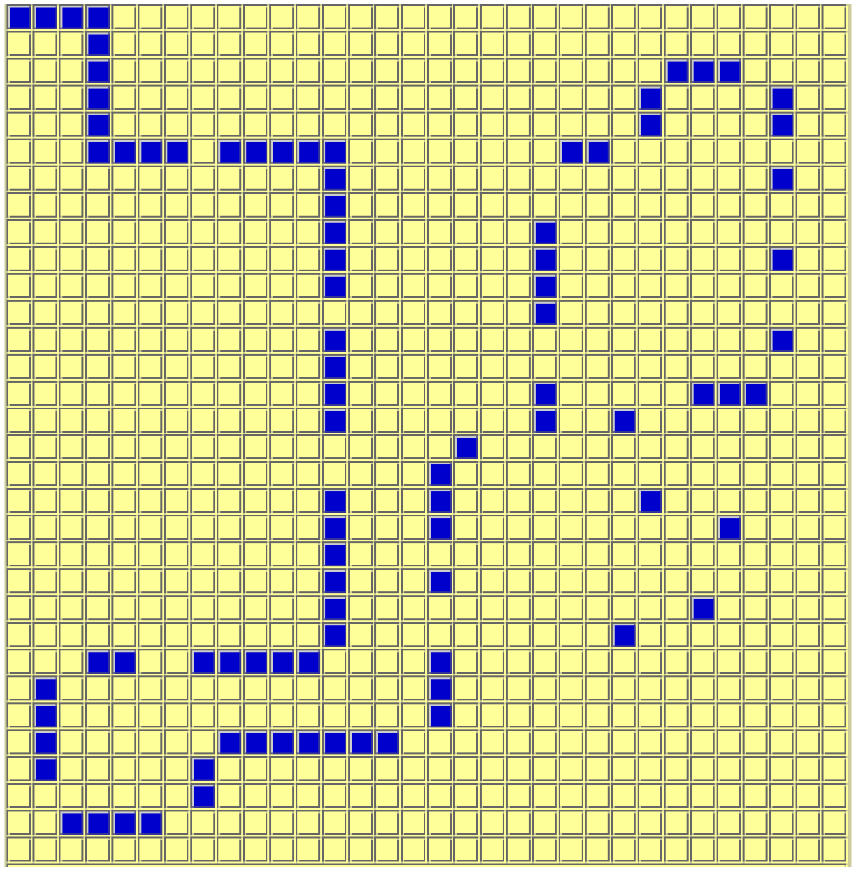
Symbolic Regression

- Search Operators:
  - Sub-tree swap crossover: swap two sub-trees in the parents
  - Sub-tree mutation: replace a sub-tree with a randomly generated sub-tree
  - The offspring is a VALID function



Demo: http://alphard.ethz.ch/gerber/approx/default.html

Ant Controller

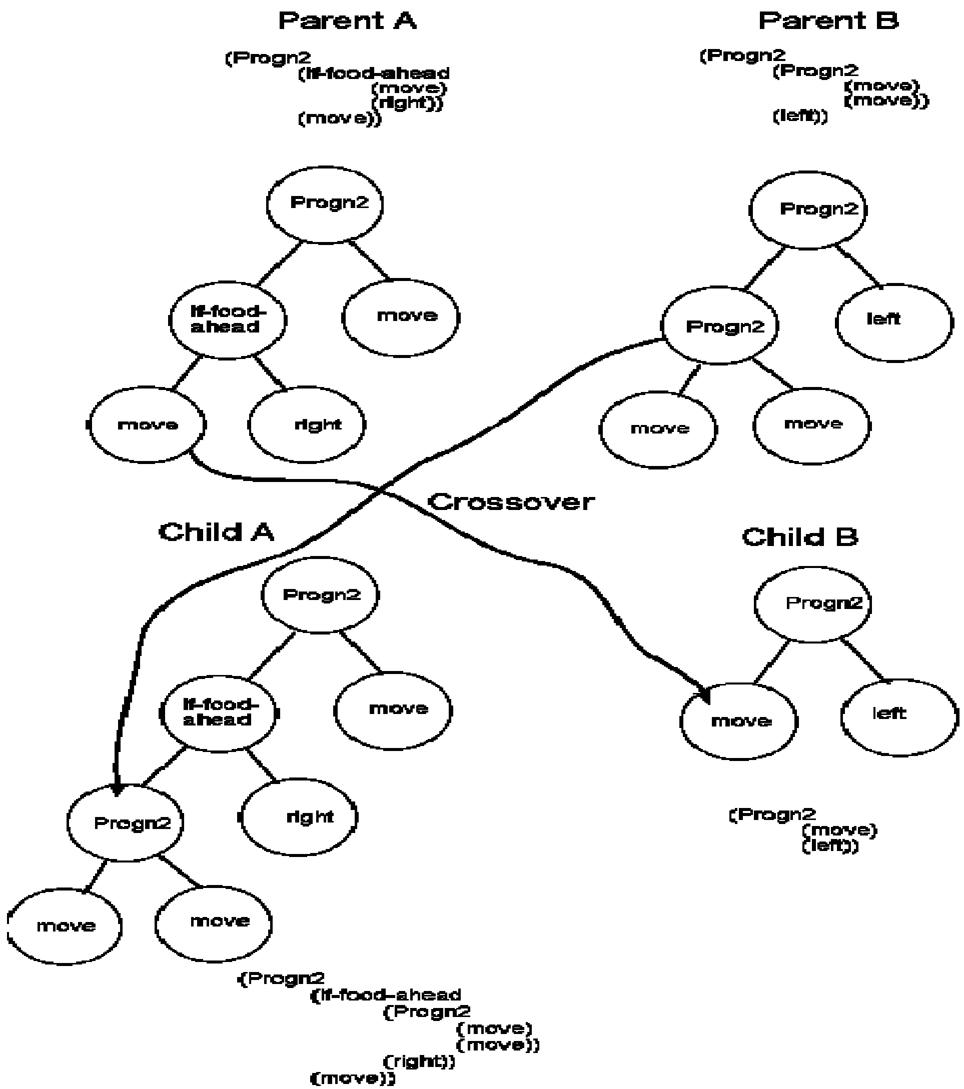


SANTA FE TRAIL PROBLEM: find a program that controls an ant able to eat all food pellets on the trail

Ant Controller

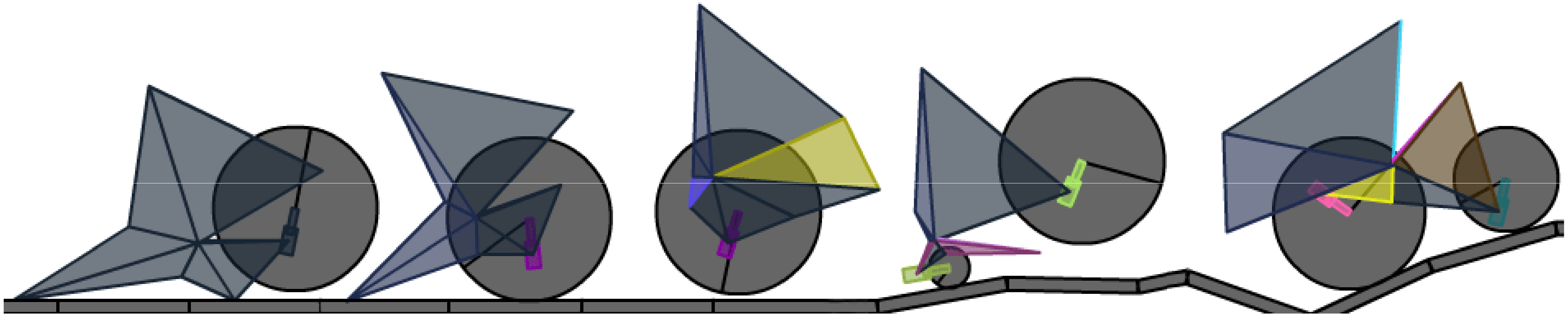
- Candidate solutions: set of instructions (left, right, move, if-food-ahead, prog2, prog3)
- Fitness (to maximise): food eaten
- Control programs can be represented as trees
- Mutation and Crossover acting on trees

Ant Controller



Video: http://www.youtube.com/watch?v=rx9tTUpZ5B8

Structure Design: Car Evolution



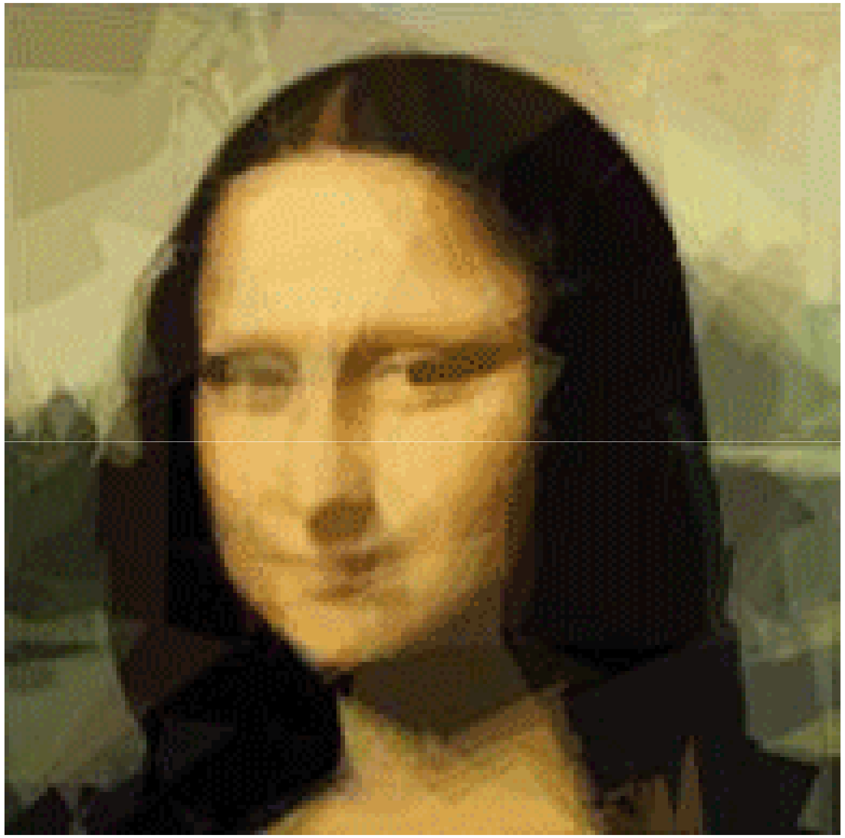
Problem: design a car using polygons and wheels able to run on a terrain

Structure Design: Car Evolution

- A candidate solution is a set of polygons connected in a central point, and wheels attached to them.
- Representation: for each polygon there is a real vector (a “gene”) describing the shape of the polygon. For each wheel there is a value specifying its radius and it’s the location of its centre.
- Fitness: how far the car goes on the terrain when run
- Mutation and crossover: variations on mutation and crossover for real vectors

DEMO: http://boxcar2d.com/

Evolutionary Art: Mona Lisa Evolution



Problem: paint a replica of the Mona Lisa using only 50 semi transparent polygons

Evolutionary Art: Mona Lisa Evolution

- A candidate solution is a set of 50 transparent polygons of various colours on the canvas
- Representation: for each polygon there is a real vector describing the shape, the location and the colour of the polygon
- Fitness (to minimise): sum of the differences in colour components (RGB) on each pixel between the phenotype and the target image
- Standard crossover and mutation on real vectors

DEMO: http://www.nihilogic.dk/labs/evolving-images/