Genetic Algorithms

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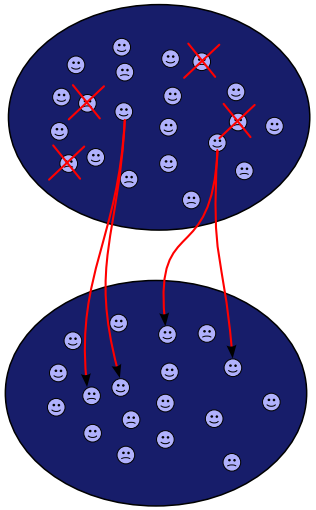
Parallel optimization inspired by biological evolution

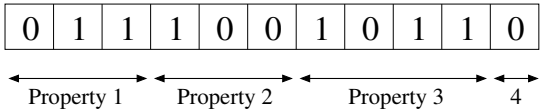
- Populations of Hypotheses
- Selection Process
- Local Variation



- Population of Individuals
- Selection of the best individuals
- Variation creates new individuals
- New Generations created iteratively

How are different hypotheses stored?

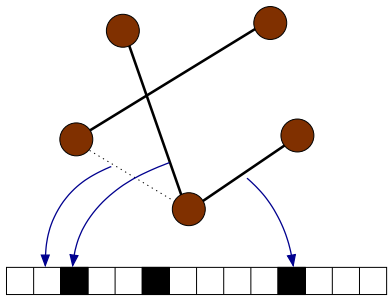
Chromosomes — Binary Strings



- Genotype
  The actual representation (the chromosome)
- Fenotype
  Properties of the individual (interpretation)

Example: Optimal choice of edges in a graph

The edges are encoded as a bit string



Do we *have* to use bit strings?

Variants:
- Other integers than only 0/1
- Real numbers
- Variable length
- Tree structures

Fitness Function

Measure of how good the hypothesis is

$$f : \text{chromosome} \mapsto \Re$$

Example:

- Total path length in a graph
- Error in a function approximation
- Performance of a simulated robot
- Number of games won

Evaluating the fitness functions is normally the *most time consuming* part of a genetic algorithm

Selection

Basic idea: Preserve individuals with a high fitness

- Roulette selection
  Probability of survival proportional to f
- Ranking selection
  Selection based on order instead of the actual fitness value
- Tournament selection
  Random pairs are formed and the one with highest fitness survives
- Elitism
  The best individuals in a generation are guaranteed to survive

Variation

- Mutations
  Small random modifications
- Crossovers
  Mixing of individuals content

Mutations

- Make random changes to the contents of the chromosome
- Choice of coding makes a big difference

Crossovers

- Select two individuals with high fitness
- Exchange parts of the chromosome with each other

One-point crossover
Multi-point crossover

Application on ordinary optimization problems

Assume that we are looking for $\max f(x, y)$

Encoding: chromosome consisting of two real numbers

Each individual corresponds to a point in the plane

- Mutations
  Redistribution parallel to the x and y axis
- Crossovers
  New points with x from one parent and y from the other

Example: Optimized code generation from a compiler

ACOVEA — Analysis of Compiler Options via Evolutionary Algorithms

Software for finding the optimal compiler options for a given C program

Genetic Programming

The use of GA to automatically create programs

- How are programs represented?
- How can one measure fitness?
- How are mutations done?
- How are crossovers done?

Representation of Programs

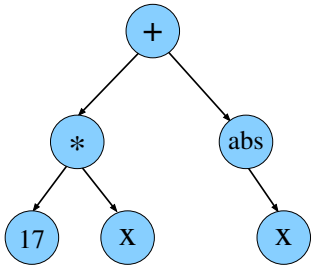
Ordinary programming languages are not suitable

- Tree with operators
- List of instructions

Example

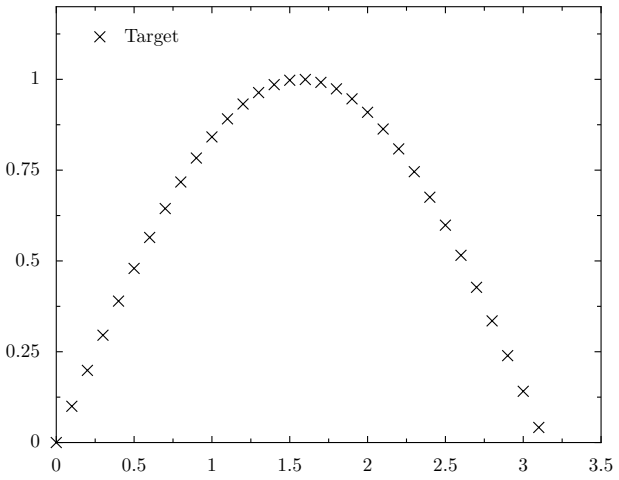
Function Approximation

Representation of the program

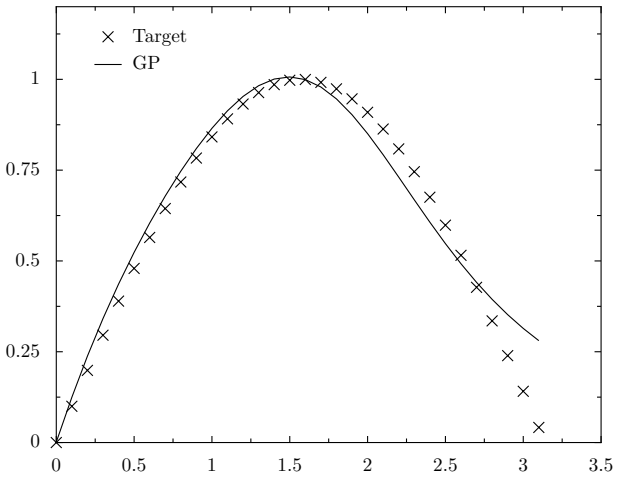


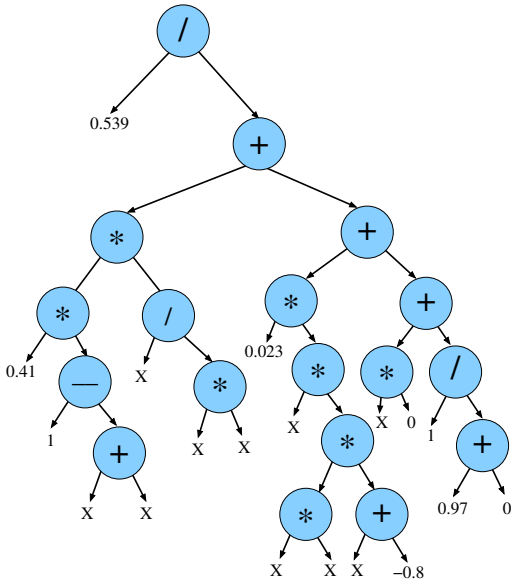
- Mutations
- Crossovers

Goal Function



Solution found by the algorithm





Bloating

Accumulation of unnecessary parts in chromosomes with variable length