Heuristic Optimisation

Part 10: Genetic Algorithm Basics

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Overview

1. Introduction
2. The terminology borrowed from Nature
3. Representation, selection, crossover, mutation
4. Evaluation
5. Constraints

Introduction

Traditional optimisation methods fail when

- there are complex, nonlinear relationships between the parameters and the value to be optimized;
- the goal function has many local extrema;
- resources are limited.

Modern heuristic optimisation methods are employed in such cases.

Evolutionary Algorithms

EAs transpose the notions of natural evolution to the world of computers and imitate natural evolution.

EAs evolve solutions to a problem by maintaining a population of potential solutions.

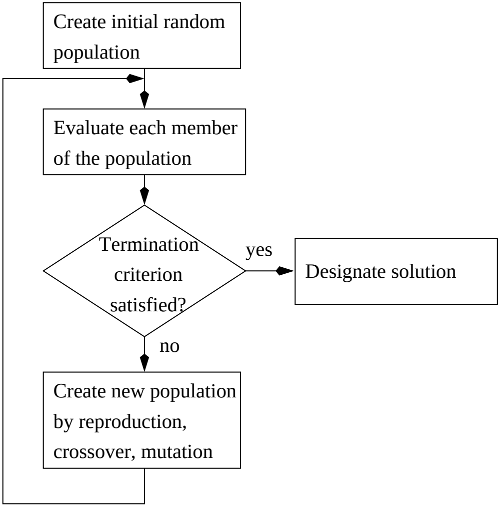
Survival of the fittest: fit individuals live to reproduce, weak individuals die off.

EAs: genetic algorithms, evolutionary programming, genetic programming, evolution strategies

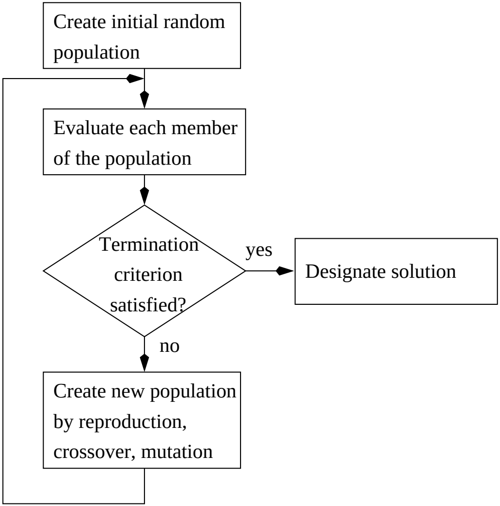
Nature – Evolutionary algorithms

Nature	Evolutionary algorithms
Individual	Solution to a problem
Population	Collection of solutions
Fitness	Quality of a solution
Chromosome	Representation of a solution
Gene	Part of representation of a solution
Crossover	Binary search operator
Mutation	Unary search operator
Reproduction	Reuse of solutions
Selection	Keeping good subsolutions

Genetic Algorithm



Genetic Algorithm



Previously evolved good parts of solutions (schemata) can be transferred to subsequent generations through crossover.

Representation

The first step of designing a GA.

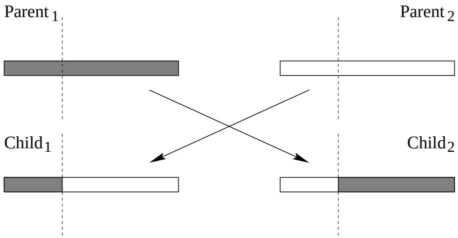
Representation together with the genetic operators bound the exploration of the search space.

Basic representation: fixed length bit string

Incorporating domain knowledge into the representation helps guiding the evolutionary process toward good solutions.

Crossover and Mutation

One-point crossover:



Mutation consists of applying minor changes to one individual (ex. flipping a bit).

Evaluation: Fitness Assignment

Possibilities:

- We define a fitness function and incorporate it in the genetic algorithm.
- Fitness evaluation is performed by separate dedicated analysis software.
- There is no explicit fitness function, but a human evaluator assigns a fitness value to the solutions presented to him.
- Fitness can be assigned by comparing the individuals in the current population.

Selection

Only selected individuals of a population are allowed to have offspring.

Selection is based on fitness.

Selection schemes:

- Fitness proportional selection
- Ranked selection
- Tournament selection

Constraints

In the simplest case, constraints occur as well-defined intervals for design parameters.

Methods for handling constraints in GAs:

- Reject individuals that violate constraints (infeasible individuals).
- Repair infeasible individuals.
- Penalize infeasible individuals.
- Incorporate constraints in the representation.

Advanced Issues

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  Example: good performance at low cost.

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- Diversity
  Premature convergence to a local optimum is a major problem.
  Solutions: niching, speciation, parallelism

GAs in Engineering Design

Engineering design can be seen as the transformation of design specifications into design descriptions.

Modelling design helps building computer programs that assist (if not yet automatise) human design.

Design can be seen as the search for a suitable or optimal construction.

Shape Optimisation

Values of the shape variables have to be determined, which result in an optimal value of some target parameter.

Shapes can be described by a structured set of shape parameters; scalars, vectors, or discrete representations such as pixels.

A general representation might lead to poor results.

One could use a pixel-based representation, when specific genetic operators need to be developed.

Remarks

GAs are considered science by some, craft by others, and art by some others.

The basic notions are very easy to understand.

BUT note that the performance of GAs
depends A LOT on the chosen representation, evaluation, genetic operators.

The more domain knowledge is incorporated, the more likely the GA's success is.