

Evolutionary Algorithms

a short introduction

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Outline

- 1 Evolution
- 2 Evolutionary Computation
- 3 Evolutionary Algorithms
- 4 EAs applications
- 5 Advantages of EAs
- 6 Disadvantages of EAs

Evolution

- *What is Evolution ?*
- You may wish to treat this as an abstract idea only.
- It does not matter (in the context of Evolutionary Computation)!

Darwinian Evolution

Four Postulates:

- Individuals within species are variable.
- Some of the variations are passed on to offspring.
- In every generation, more offspring are produced than can survive.
- The survival and reproduction of individuals are not random: The individuals who survive and go on to reproduce, or who reproduce the most, are those with the most favorable variations. They are *naturally selected*.

On the Origin of Species by Means of Natural Selection
(Darwin 1859).

Nature of Natural Selection

Natural Evolution acts...

- on individuals, but the consequences occur in the population.
- on individuals, not groups.
- on phenotypes, but evolution consist of changes in the Genotype.
- on existing traits, but can produce new traits.

Evolution...

- Is backward looking.
- Is not perfect.
- Is non (totally) random.
- Is not progressive.

Why are we Interested ?

- Results of Evolution are...
 - Creative, Surprising, Unexpected
 - Highly adapted to Environmental Niches
- God or Evolution ?
- Natural Evolution had an extremely long time (3.7 Billion Years!).
- Natural Evolution acts in parallel.
- *Can a program create things like this ?*

Evolutionary Computation

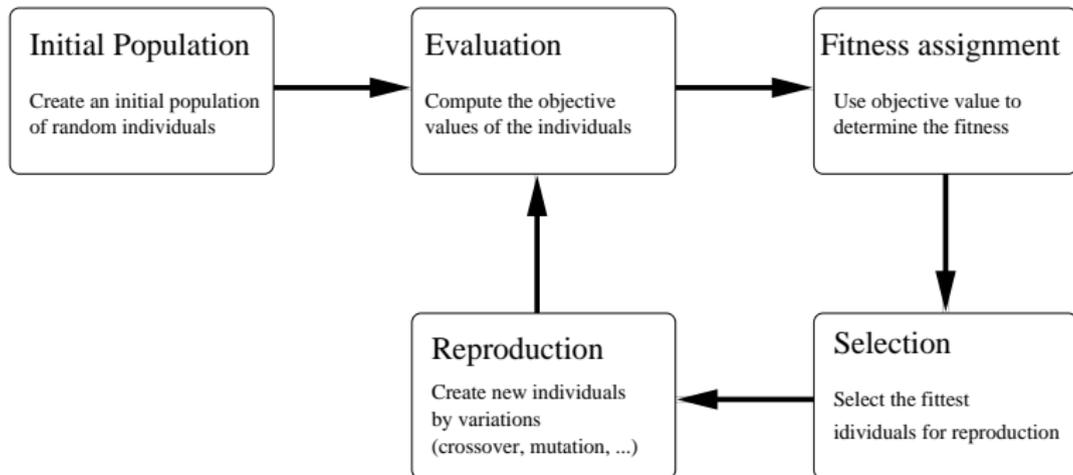
- ...is the study of computational systems which use ideas and get inspirations from natural evolution and other biological systems.
- Evolutionary Computation (EC) techniques are used in optimization, machine learning and automatic design.

Evolutionary Algorithms

- Algorithms that are inspired by natural evolution.
- Closely linked to AI techniques, especially search techniques.
- Can be regarded as *population-based stochastic generate-and-test* algorithms.
- Four Main Elements:
 - Group of Individuals - *Population*.
 - Source of Variation - *Genetic Operators*.
 - Reproductive Fitness - *Fitness*.
 - Survival of the Fittest - *Selection*.
- Search Process
 - Trial and Error.
 - Recipe for choosing next trial.

Evolutionary Algorithm

The basic cycle

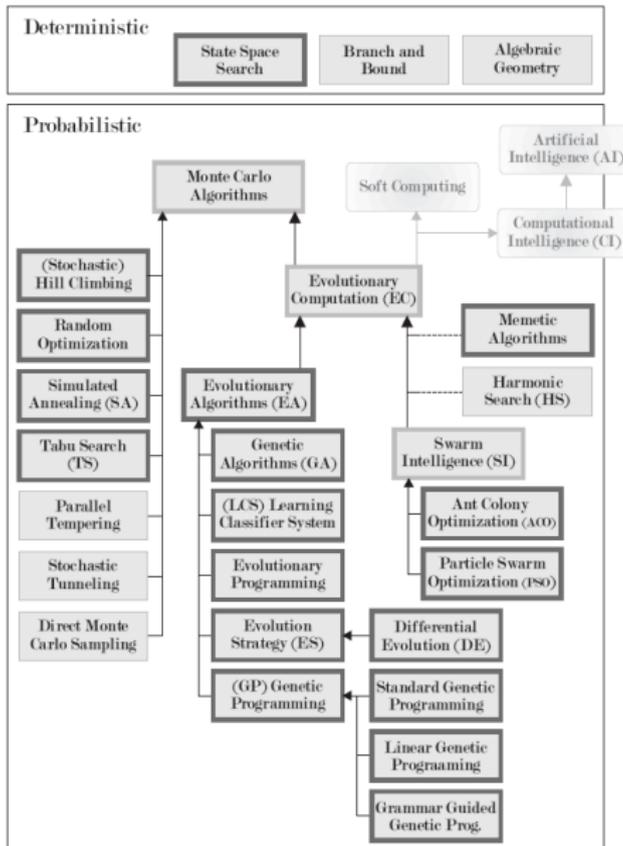


EAs major building blocks

- Population size:
 - (max) number of individuals used.
- Selection strategy:
 - method of selecting the individuals for reproduction.
- The representations of the individuals:
 - they may be represented in their natural form or in the form of chromosomes of a given genotype.
- Replacement operator:
 - way offsprings are selected and included into the new population(s).

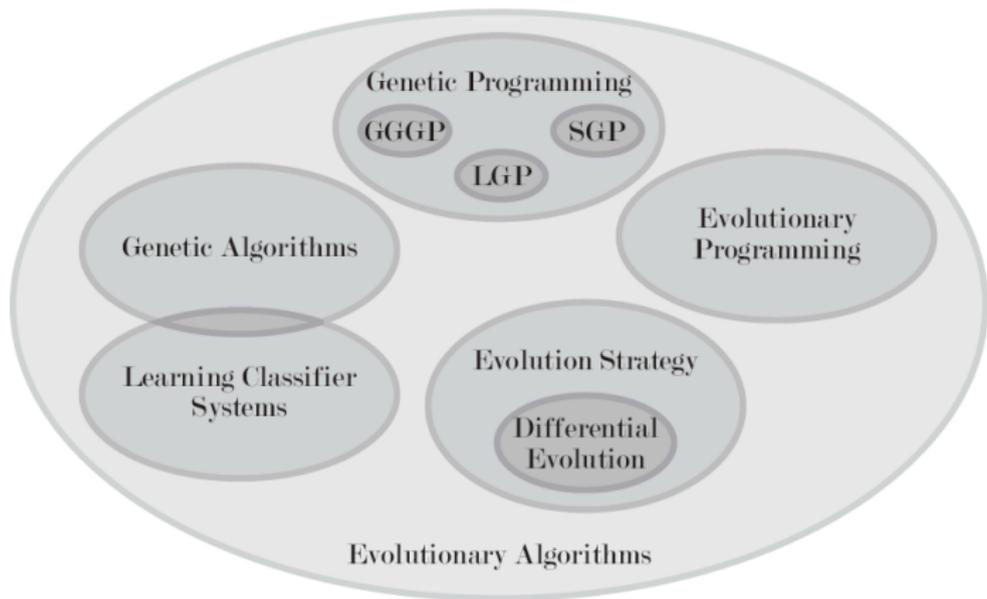
Optimization Algorithms

Taxonomy

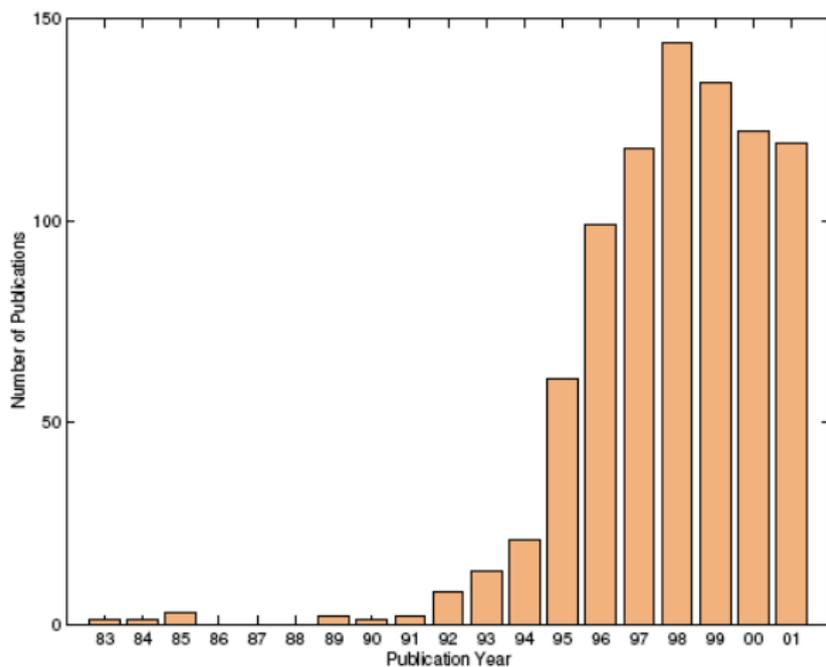


Evolutionary Algorithms

Family



How popular are EAs in Multi-Objective Optimization



EAs applications

- Optimization (scheduling, function optimization, chemical process optimization, etc...)
- Exploration (Evolutionary Art).
- Electronic Hardware Design.
- Robot Control.
- An much more...

Advantages of EAs

- Applicable in problems where no (good) method is available:
 - Discontinuities, non-linear constraints, multi-modalities.
 - Discrete variable space.
 - Implicitly defined models (if-then-else constructs).
 - Noisy problems.
- Most suitable in problems where multiple solutions are required:
 - Multi-modal optimization problems.
 - Multi-objective optimization problems.
- Parallel implementation is easier.

Disadvantages of EAs

- No guarantee for finding optimal solutions in a finite amount of time:
 - However, asymptotic convergence proofs are available
 - For specific problems, computational complexity worked out.
- Parameter tuning mostly by trial-and-error:
 - Self-adaptation is a remedy.
- Population approach may be expensive:
 - Parallel implementation is a remedy.

For Further Reading



Kalyanmoy Deb

Multi-Objective Optimization Using Evolutionary Algorithms.

John Wiley & Sons, Inc, New York, NY, USA, 2001.



Thomas Weise

Global Optimization Algorithms - Theory and Application.

<http://www.it-weise.de/projects/book.pdf>