Artificial Intelligence and Evolutionary Computing

Lecture 5-6

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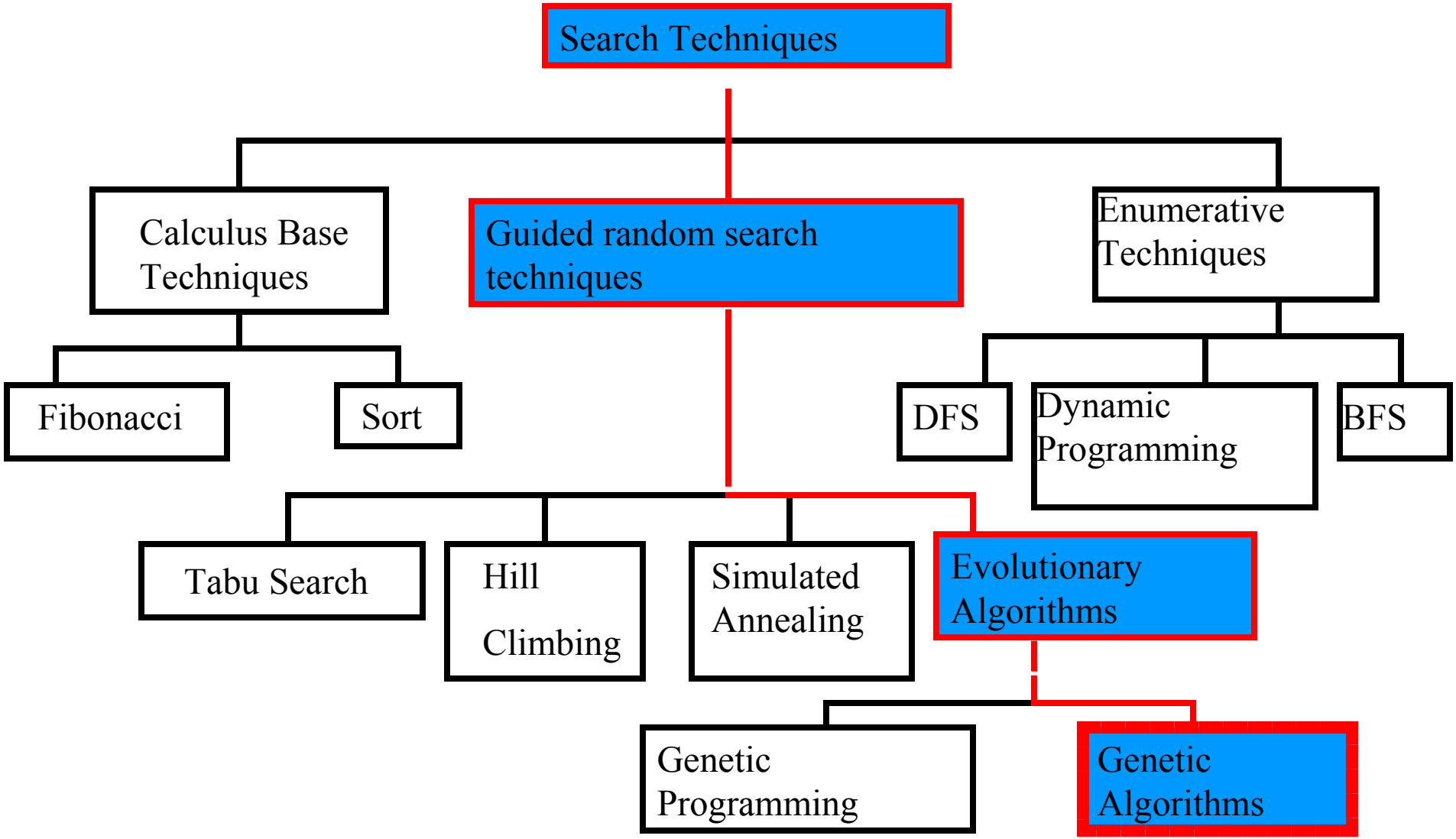
Introduction

- After scientists became disillusioned with classical attempts at modeling intelligence, they looked in other directions.
- Two prominent fields arose, connectionism (neural networking, parallel processing) and evolutionary computing.
- It is the latter that this essay deals with - genetic algorithms and genetic programming.

Classes of Search Techniques



Variants of Evolutionary Algorithms

Different versions appeared independently in mid '60s

- Genetic Algorithms (Holland)
- Genetic Programming (Koza)
- Evolution Strategies (Rechenberg & Schwefel)
- Evolutionary Programming (Fogel)

Evolutionary Computation: A better term

Evolutionary Computation Theory

- Aims to explain
  - What
  - Why
  - When
  - How

  Evolutionary Algorithms work.

What is Evolutionary Computation?

- The study of computational systems that use ideas inspired from natural evolution
  - The principle of survival of the fittest

- Stochastic search procedures in large search spaces
  - General methods for solving 'search for solutions' type of problems
  - Can be used in optimisation, learning and design

Why Evolutionary Computation?

Traditional comp

- Fixed & accurate at exact computation
- Inflexible
- Limited. Can't cope with:
  - Complicated, e.g. non-smooth functions
  - Objectives that change over time

→ Exact solution to simplified problem

Evolutionary comp

- Yield good quality approximate solutions to large real world problems
- Flexible
- Robust
- Time consuming
- Appropriate when traditional methods break down

→Approximate solution to real problem

Major Areas in Evolutionary Computation

- Optimisation
- Learning
- Design
- Theory

Evolutionary Optimisation

1. Numerical (global) optimisation.
2. Combinatorial optimisation (of NP-hard problems).
3. Mixed optimisation.
4. Constrained optimisation.
5. Multiobjective optimisation.
6. Optimisation in a dynamic and/or uncertain environment

Evolutionary Learning

Evolutionary learning can be used in supervised, unsupervised and reinforcement learning.

1. Learning classifier systems (rule-based systems).
2. Evolutionary artificial neural networks.
3. Evolutionary fuzzy logic systems.
4. Co-evolutionary learning.
5. Automatic modularisation of machine learning.

Evolutionary Design

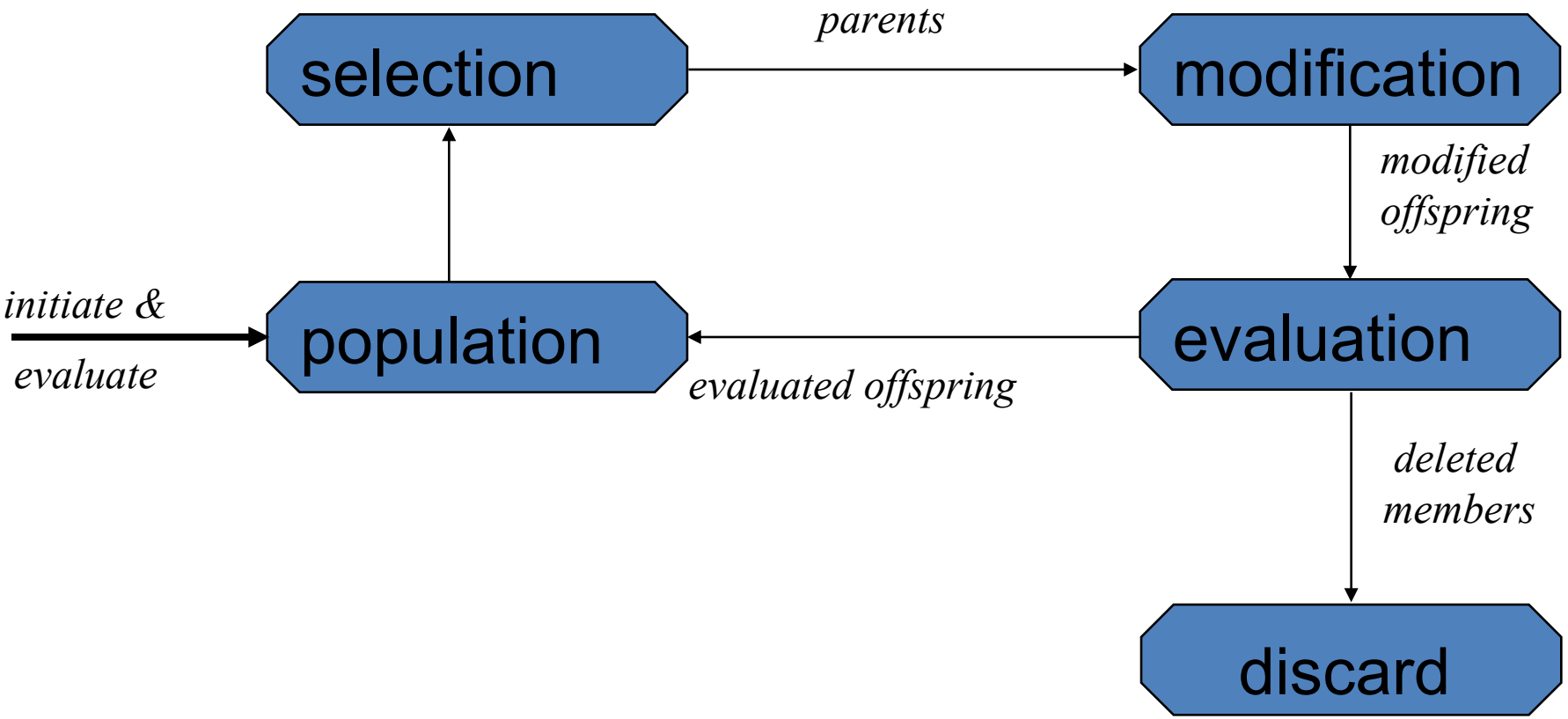
EC techniques are particularly good at exploring unconventional designs which are very difficult to obtain by hand.

1. Evolutionary design of artificial neural networks.
2. Evolutionary design of electronic circuits.
3. Evolvable hardware.
4. Interactive creative design using evolutionary approaches

Machine Learning vs. Evolutionary Computation

- Most Machine Learning is concerned with constructing a hypothesis from examples, which generalises well
  - fast but very biased
- EC is a discovery-search over hypotheses
  - slow and unbiased

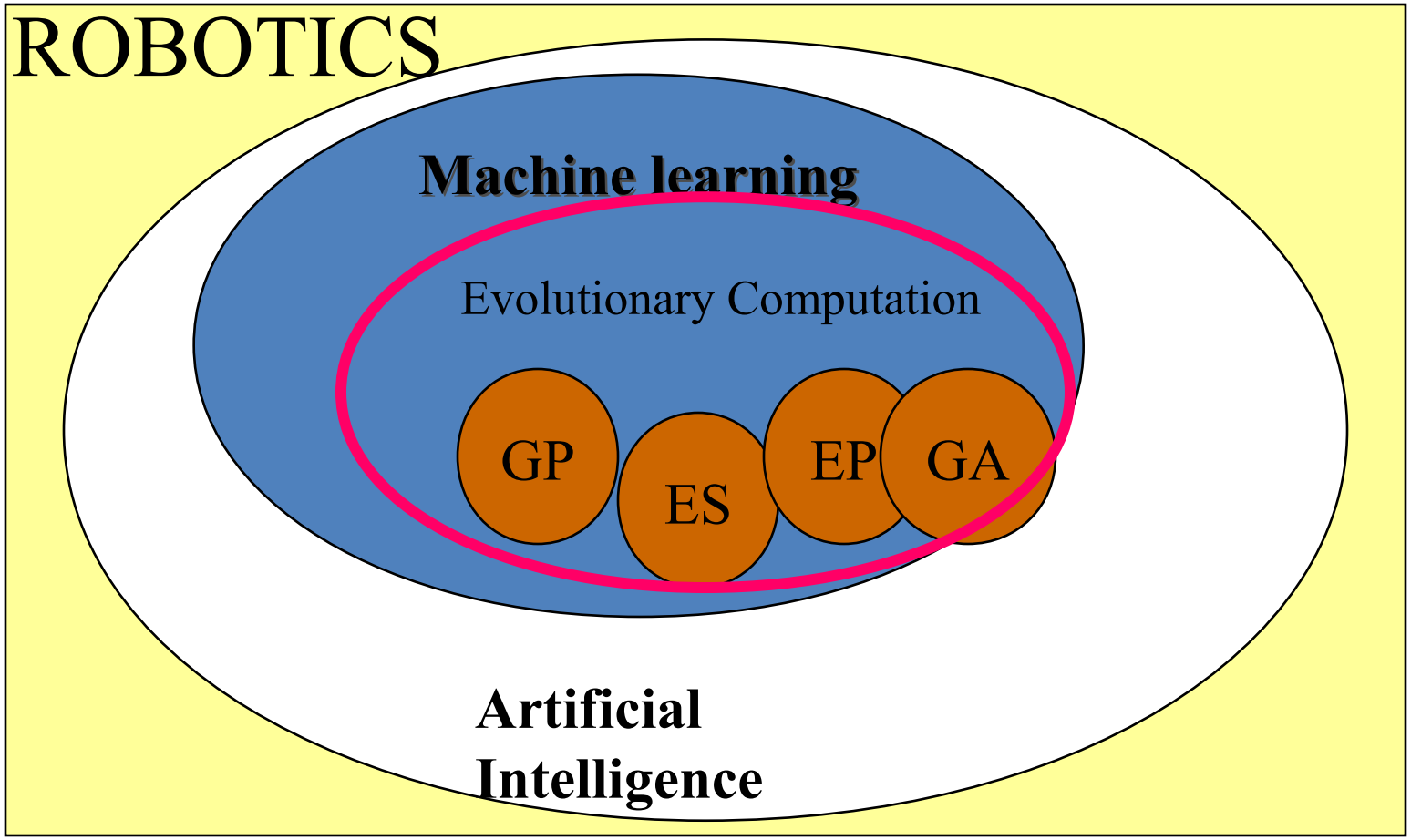
The Evolutionary Cycle



...inspiration from genetics

- DNA (**D**eoxyribo**n**ucleic **A**cid) = the physical carrier of genetic information
- Chromosomes = a single, very long molecule of DNA
- Gene = basic functional block of inheritance (encoding and directing the synthesis of a protein)
- Locus = location of a gene
- Genome = the complete collection of genetic material (all chromosomes together)
- Genotype = the particular set of genes contained in a genome
- Phenotype = the manifested characteristics of the individual; determined by the genotype

What are evolutionary algorithms and Genetic Algorithm (GA)?



Further application areas

- **Optimisation**
  - Combinatorial optimization: circuit layout, job-shop scheduling
- **Automatic programming**
  - Evolving computer programs for specific tasks
  - Designing other computational structures (NNs, cellular automata)
- **Machine Learning**
  - classification: evolving rules for learning classifier systems
  - prediction: predicting protein structure, predicting weather
- **Economics**
  - Modeling of bidding strategies
  - Modeling of the emergence of economic markets
- **Immune systems**
  - Discovery of multi-gene families during evolutionary time
- **Ecology**
  - Modeling host-parasite co-evolution, symbiosis and resource flow
- **Population genetics**
  - Under what conditions will a gene for recombination be evolutionarily viable
- **Evolution and learning**
  - Studying how individual learning & species evolution affect each other
- **Social systems**
  - Evolution of social behavior in insect colonies → evolution of cooperation & communication in multi-agent systems
- **Etc.**

Summary

1. Evolutionary algorithms can be regarded as population-based generate-and-test algorithms.
2. Evolutionary computation techniques can be used in optimisation, learning and design.
3. Evolutionary computation techniques are flexible and robust.
4. Evolutionary computation techniques are definitely useful tools in your toolbox, but there are problems for which other techniques might be more suitable.