Introduction to Evolutionary Computing

Contents

- Positioning of EC and the basic EC metaphor
- Historical perspective
- Biological inspiration:
  - Darwinian evolution theory (simplified!)
  - Genetics (simplified!)
- Motivation for EC
- What can EC do: examples of application areas

Different Views of EC/EA/GA/EP

The techniques and technology that is discussed in this course can be viewed as:

- An approach to *computational intelligence* and for *soft computing*
- A *search* paradigm
- As an approach for *machine learning*
- As a method to *simulate biological systems*
- As a subfield of *artificial life*
- As generators for new ideas, new designs and for music and computer art

EC as Search

Search Techniques

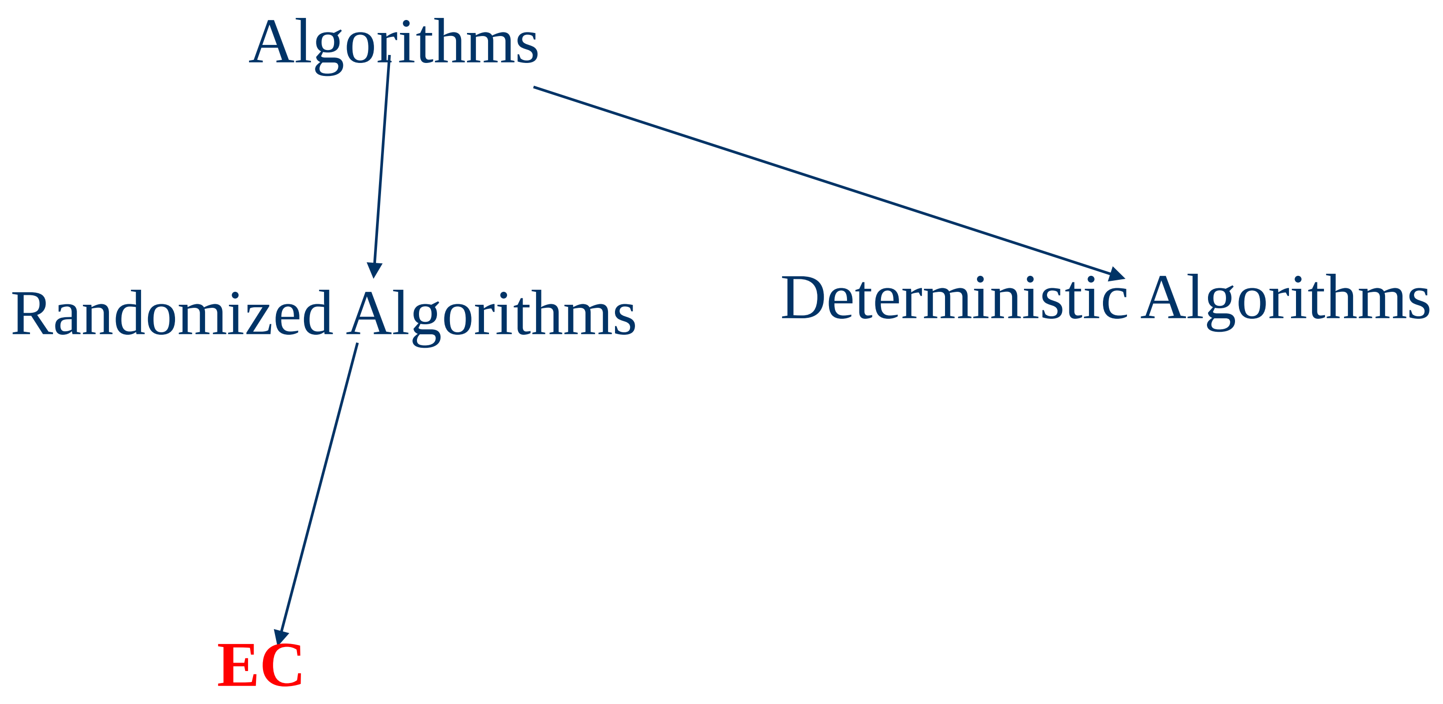
Backtracking Hillclimbing Simulated Annealing A* **EC**

EC as Machine Learning

Machine Learning

Learning from Examples Reinforcement Learning **Classifier Systems**

EC as Randomized Algorithms



Positioning of EC

- EC is part of computer science
- EC is not part of life sciences/biology
- Biology delivered inspiration and terminology
- EC can be applied in biological research

The Main Evolutionary Computing Metaphor

EVOLUTION		PROBLEM SOLVING
Environment	$\longleftrightarrow$	Problem
Individual	$\longleftrightarrow$	Candidate Solution
Fitness	$\longleftrightarrow$	Quality

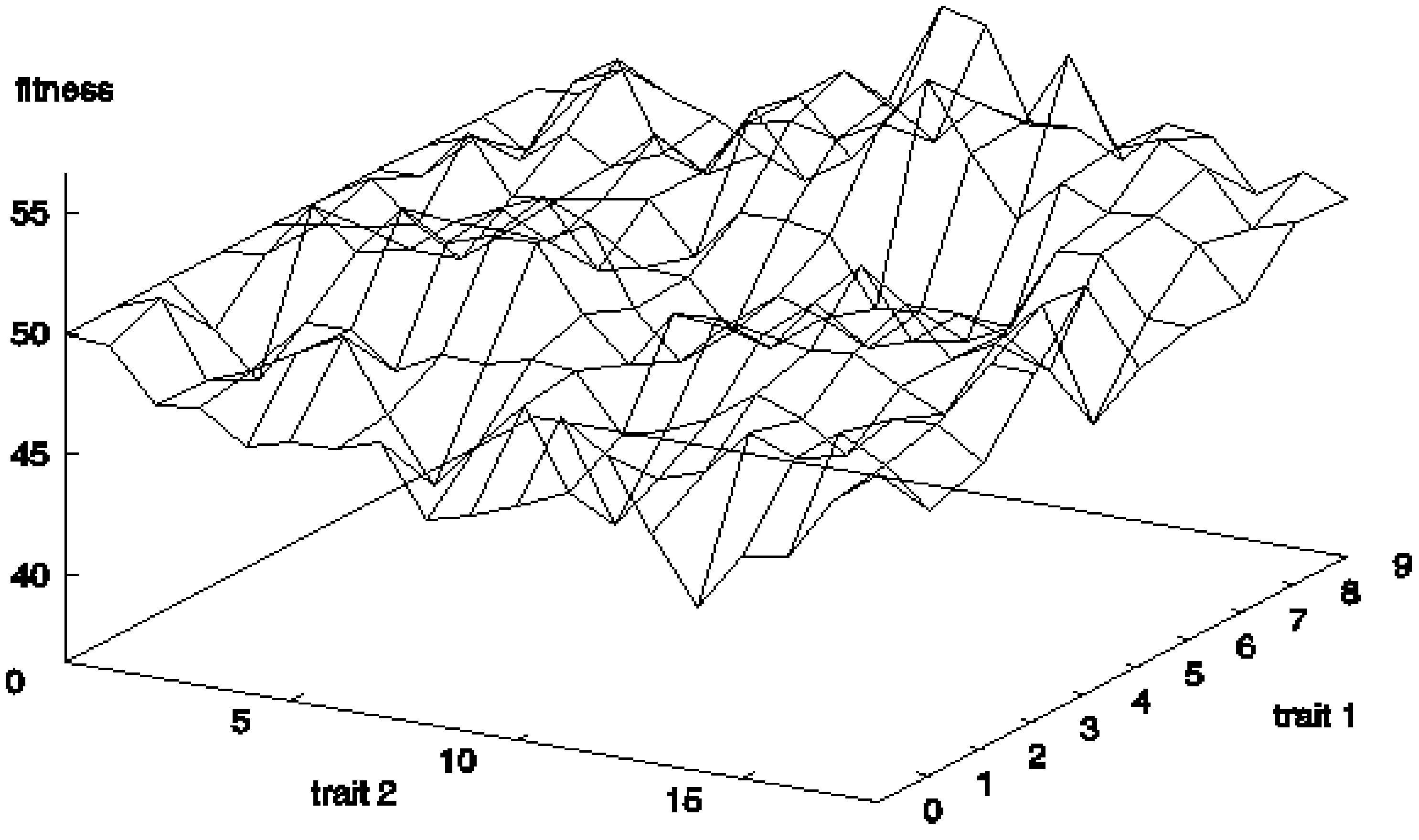
Fitness $\rightarrow$ chances for survival and reproduction

Quality $\rightarrow$ chance for seeding new solutions

Adaptive landscape metaphor (Wright, 1932)

- Can envisage population with *n* traits as existing in a *n+1*-dimensional space (landscape) with height corresponding to fitness
- Each different individual (phenotype) represents a single point on the landscape
- Population is therefore a "cloud" of points, moving on the landscape over time as it evolves - adaptation

Example with two traits

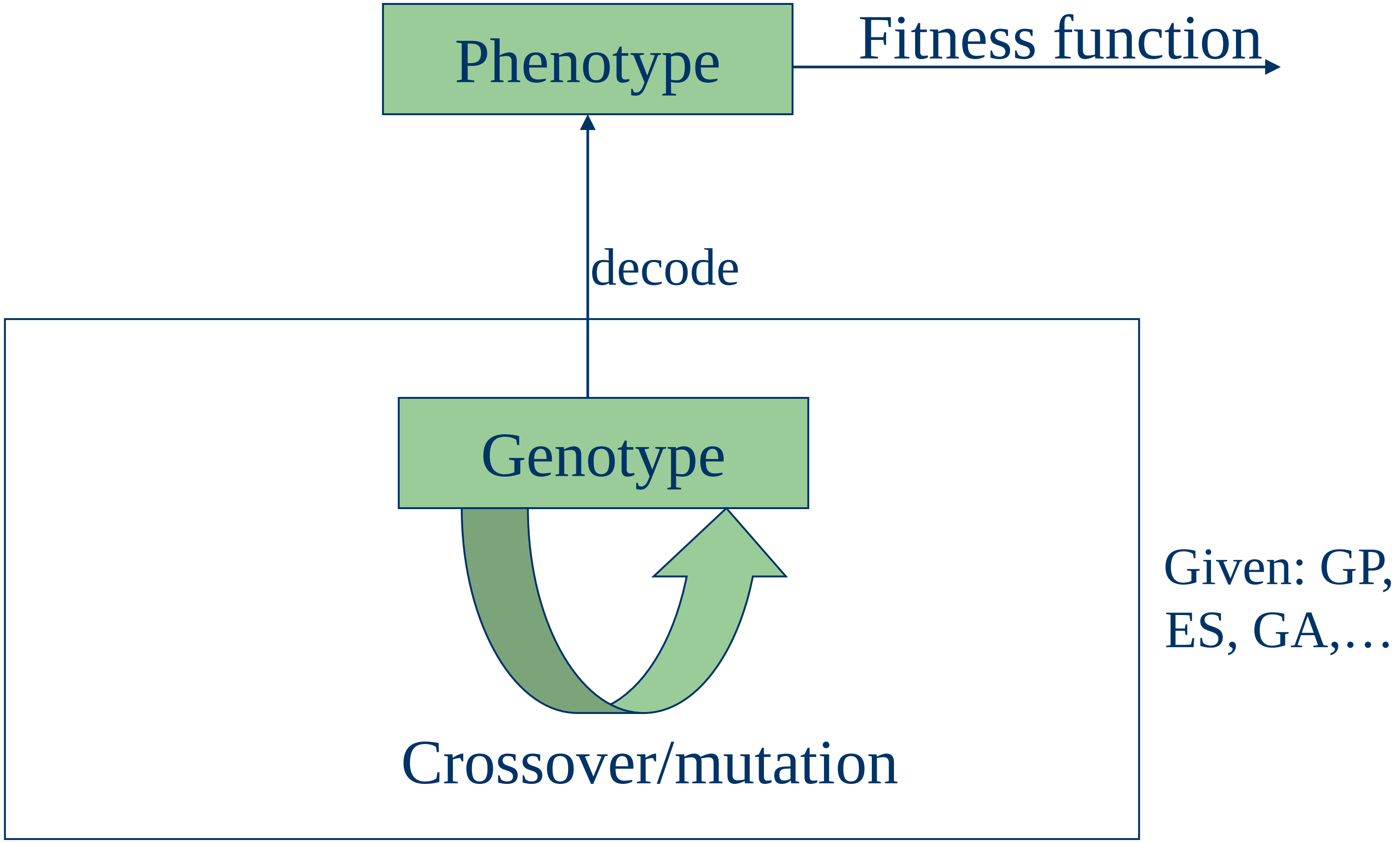


Natural Genetics

- The information required to build a living organism is coded in the DNA of that organism
- Genotype (DNA inside) determines phenotype
- Genes → phenotypic traits is a complex mapping
  - One gene may affect many traits (pleiotropy)
  - Many genes may affect one trait (polygeny)
- Small changes in the genotype lead to small changes in the organism (e.g., height, hair colour)

Evolutionary Computing Systems

Reduce it to an GA, ES, GP,… Problem



Motivations for EC: 1

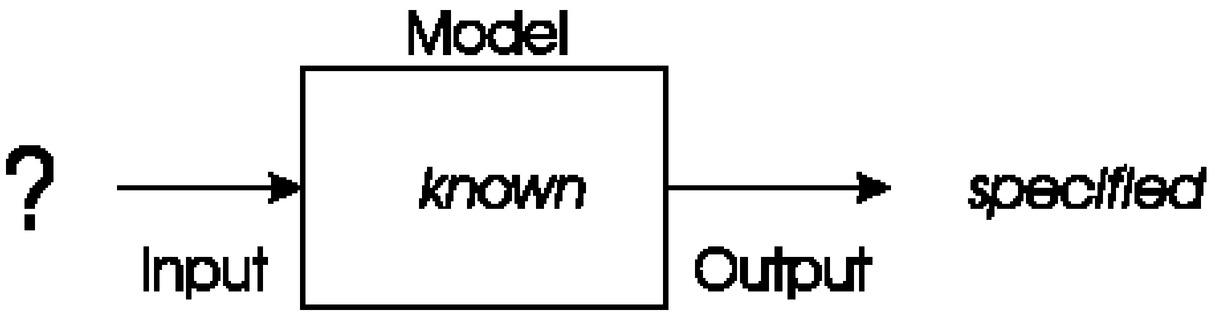
- Nature has always served as a source of inspiration for engineers and scientists
- The best problem solver known in nature is:
  - the (human) brain that created "the wheel, New York, wars and so on" (after Douglas Adams' Hitch-Hikers Guide)
  - the evolution mechanism that created the human brain (after Darwin's Origin of Species)
- Answer 1 → neurocomputing
- Answer 2 → evolutionary computing

Motivations for EC: 2

- Developing, analyzing, applying problem solving methods a.k.a. algorithms is a central theme in mathematics and computer science
- Time for thorough problem analysis decreases
- Complexity of problems to be solved increases
- Consequence:
  Robust problem solving technology needed

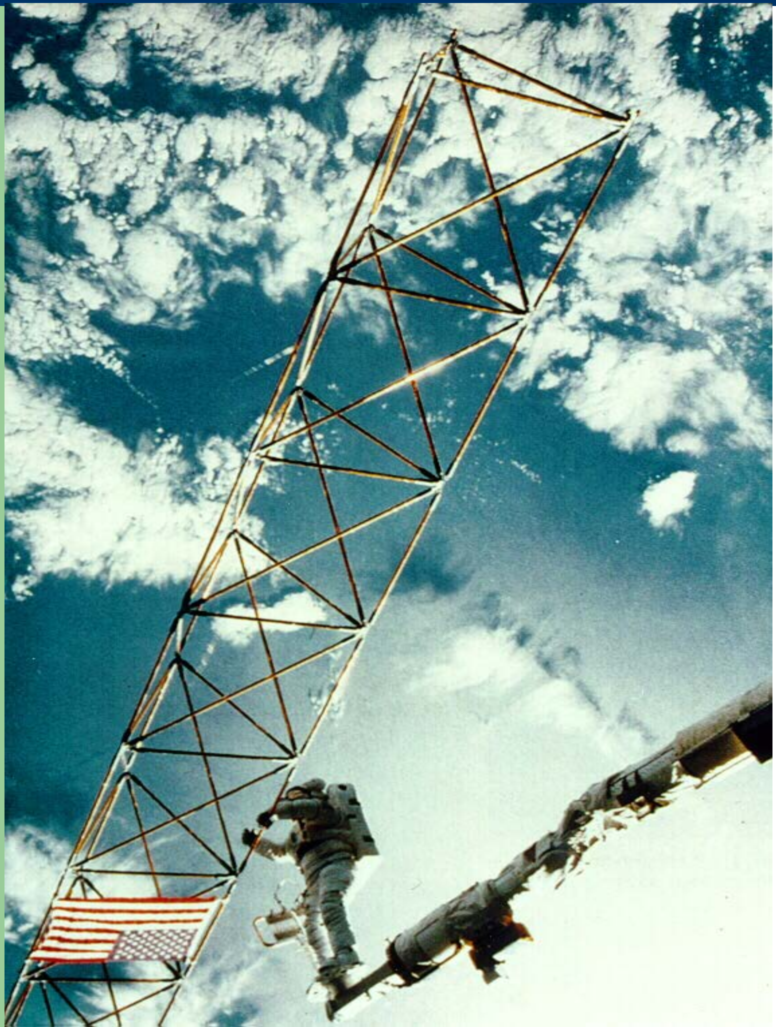
Problem type 1 : Optimization

- We have a model of our system and seek inputs that give us a specified goal



- e.g.
  - time tables for university, call center, or hospital
  - design specifications, etc etc

Optimisation example 2: Satellite structure



Optimized satellite designs for NASA to maximize vibration isolation

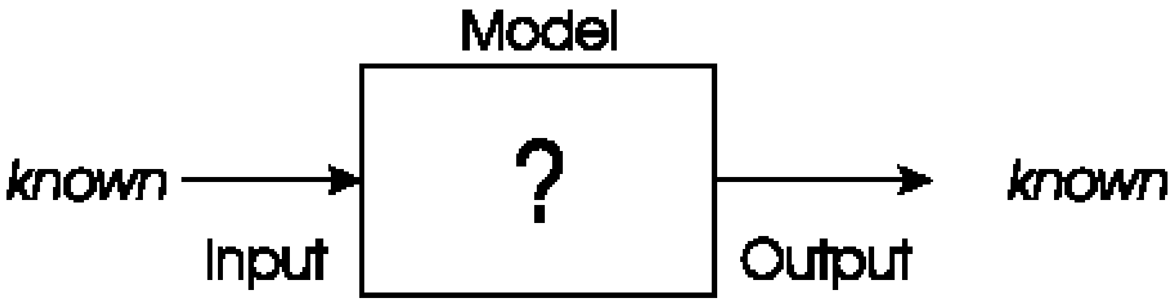
Evolving: design structures

Fitness: vibration resistance

Evolutionary “creativity”

Problem types 2: Modelling

- We have corresponding sets of inputs & outputs and seek model that delivers correct output for every known input



- Evolutionary machine learning

Modelling example: loan applicant creditibility

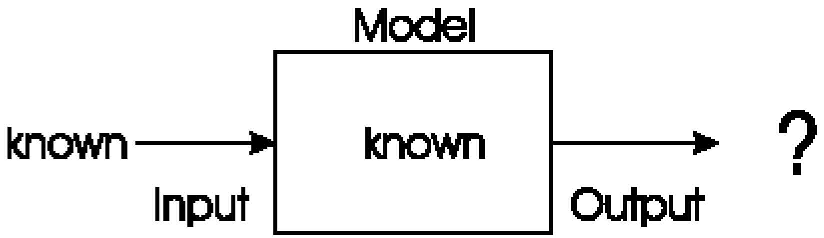
British bank evolved creditability model to predict loan paying behavior of new applicants

Evolving: prediction models

Fitness: model accuracy on historical data

Problem type 3: Simulation

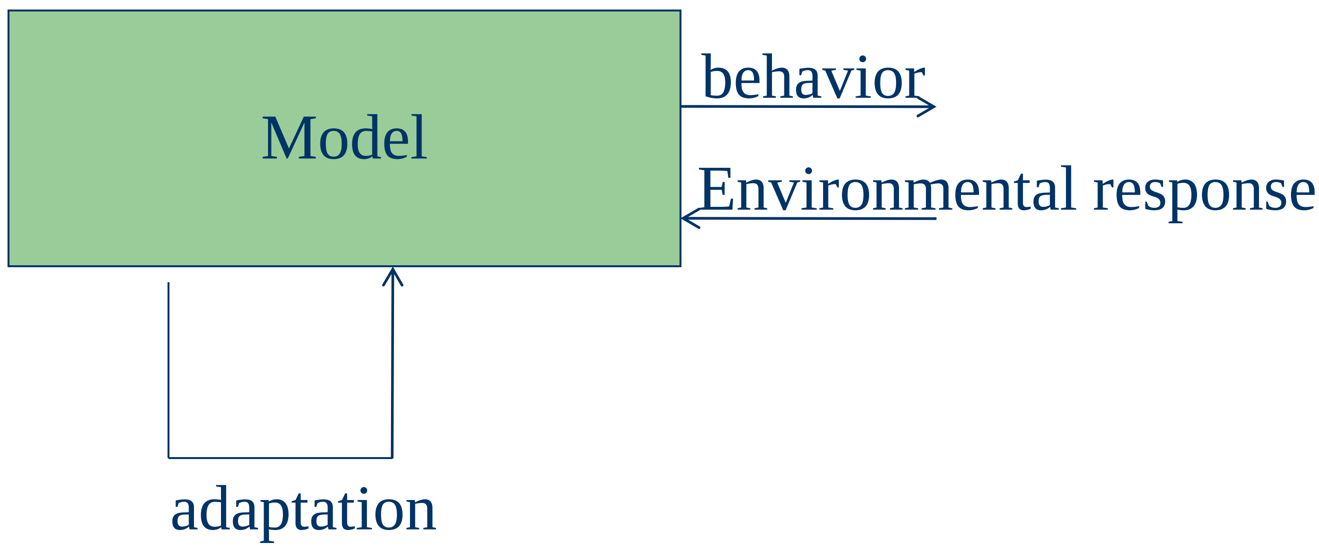
- We have a given model and wish to know the outputs that arise under different input conditions



- Often used to answer “what-if” questions in evolving dynamic environments
- e.g. Evolutionary economics, Artificial Life

Problem type 4: Building Systems that Adapt

- We have a model and want to adapt it based reactions of the environment



Example Problem type 4:

- Poker Systems that Play Poker
- …