Bio-Inspired Optimization and Design

FS2009

http://www.tik.ee.ethz.ch/sop/education/lectures/BOD/
http://www.cse-lab.ethz.ch/teaching.html

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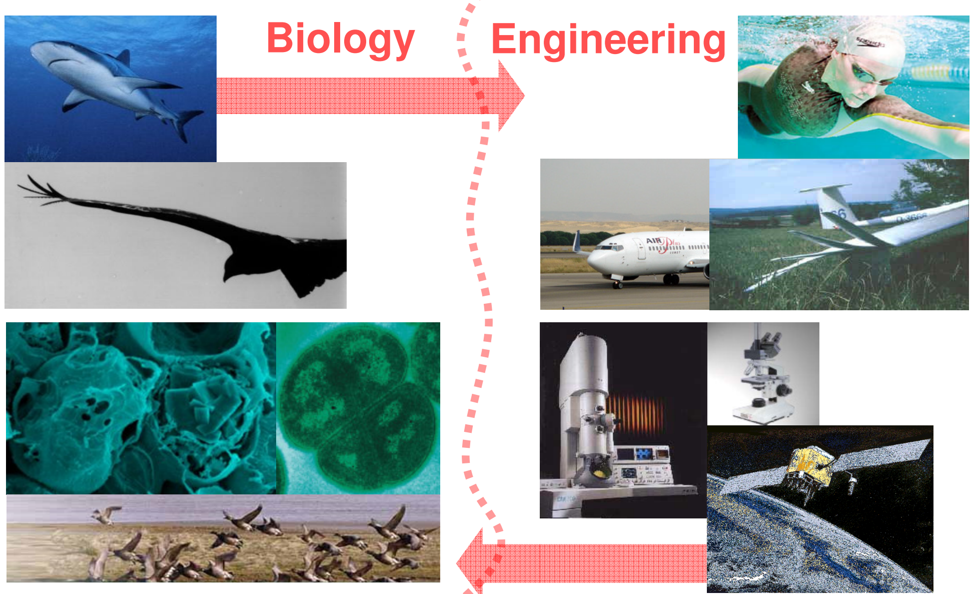
Bio-inspired Optimization and Design

Eckart Zitzler

0. Introduction and Overview

A Natural Link: Biology and Engineering



Research Areas: Biology and Engineering

Biology Engineering

Computational Biology

DNA Computing
Neural Networks
Swarm Optimization

Bio-inspired Computation

Genetic Programming
Membrane Computing
Bioimaging

Bioengineering
Bioelectronics

Biocomputing
Bioinformatics

Evolutionary Algorithms
Ant Colony Optimization

Bio-inspired Computation

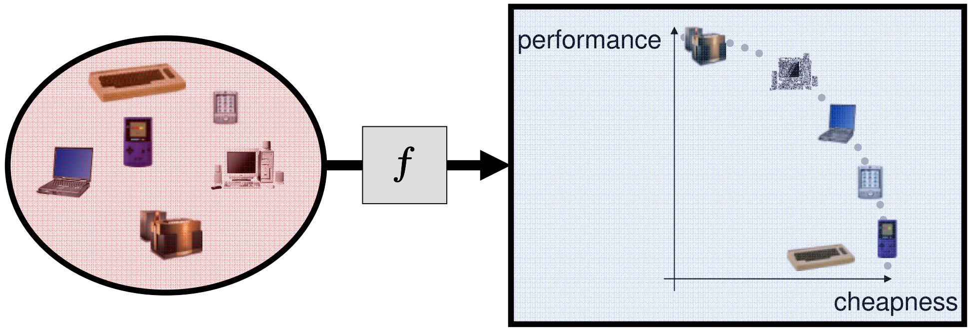
Biology → **Computation**

Biology	Computation
Evolution	Evolutionary Algorithms
Ants	Ant Colony Optimization
Swarms	Particle Swarm Optimization
Immune Systems	Artificial Immune Systems
Brain	Neural Networks
DNA	DNA Computing
Cells	Cellular Automata
Biological Membranes	Membrane Computing

Most of the bio-inspired computational approaches resulted from mathematical models designed to better understand natural systems, e.g., by means of simulation.

Focus: Optimization

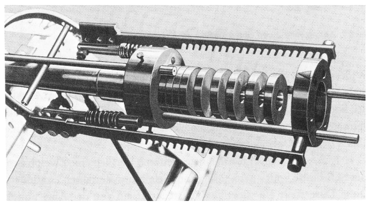
set of potential solutions — optimization criteria — evaluation space

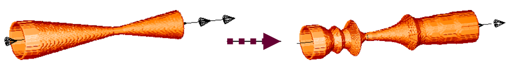


Goal: identify best solution(s) w.r.t. optimization criteria

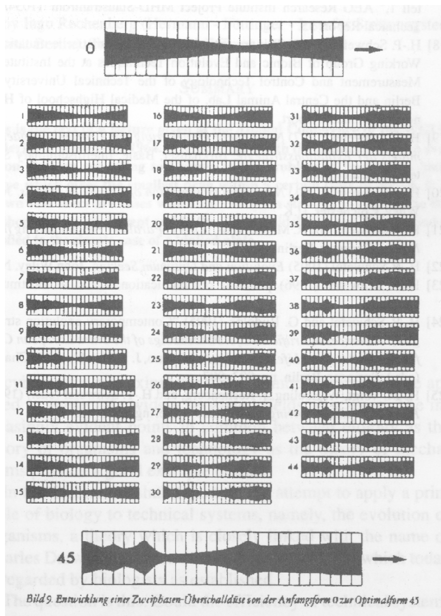
Success Story I: Two-Phase Flashing Noozle Design

Ingo Rechenberg
Hans-Paul Schwefel

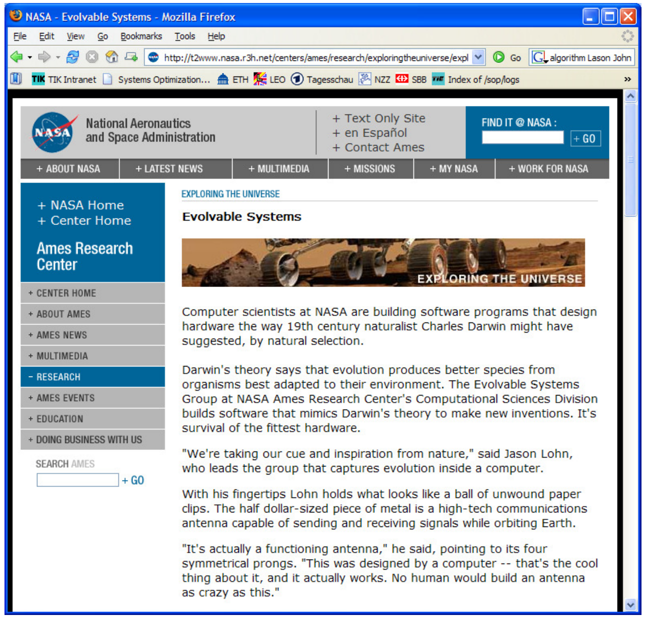


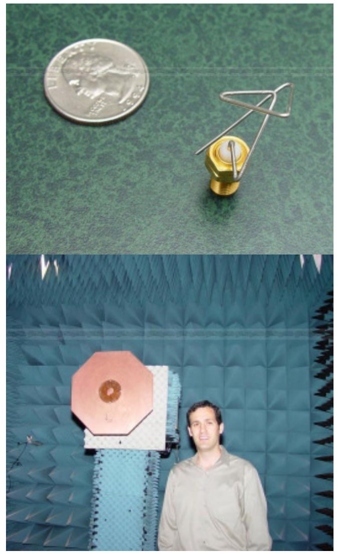


[Rechenberg (1965)]



Success Story II: Satellite Antenna Design





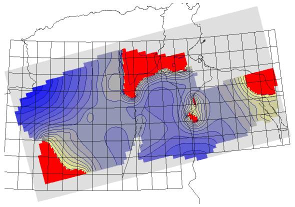
[Lohn et al. (2004)]

Application Domains: Selected Examples

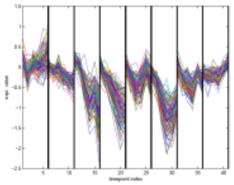
Time tabling

Packing

Placement



Design



Grouping

Teaching Objectives

- You are familiar with the foundations of optimization and with different randomized search algorithms, in particular bio-inspired ones.
- You will be able to design, implement, and tune basic and advanced bio-inspired optimization techniques for tackling complex, large-scale design applications.
- You will be able to evaluate different search algorithms and implementations.
- You are aware of the theoretical foundations of bio-inspired optimization, know the limitations as well as potential advantages and disadvantages of specific design concepts.

Lecture Outline

PART I

0. Introduction and Overview

1. Optimization and Search

2. Randomized Search Algorithms
2.1 Black-Box Optimization
2.2 Local Search
2.3 Metropolis Algorithm
2.4 Simulated Annealing
2.5 Tabu Search
2.6 Evolutionary Algorithms

3. Basic Design Issues
3.1 Representation
3.2 Fitness Assignment
3.3 Selection
3.4 Variation
3.5 Example Application: Clustering

4. Advanced Design Issues
4.1 Multiobjective Optimization
4.2 Constraint Handling
4.3 Implementation Tools
4.4 Example Application: Network Processor Design

5. Performance Assessment
5.1 General Aspects
5.2 The No-Free-Lunch Theorem
5.3 Running Time Analysis

(the order of the topics may change)

PART II

6. Estimation of Distribution Algorithms
6.1 Population Based Incremental Learning
6.2 Estimation of Multivariate Normal Algorithm

7. Parameter Control
7.1 General Concepts – Learning
7.2 Step-size Adaptation
7.3 Covariance Matrix Adaptation

Lecture Organization

Exercises:

- Overall, there are four projects, two for each lecture part, that accompany and extend the lectures. Each project contains several tasks geared towards practical aspects of bioinspired computation.
- Groups of 1-3 students work on the projects and submit their solutions to the teaching assistants. Feedback is given one week later.
- The weekly exercise lessons serve to answer general questions and to discuss the projects.

Testat requirements:

- 200 out of 400 maximally possible points for all projects together.
- At least 40 points per project.

Credit points:

- For regular students (not PhD students), an oral exam of 15-30 minutes needs to be passed in order to earn the credits points (5).
- PhD students obtain 3 credit points for the course, provided the Testat conditions are fulfilled.

Organization of the Lecture Notes (Part I)

The lecture focuses on illustrating the basic concepts and ideas, while the lecture notes comprise further details and additional information.

The lecture notes contain

- the slides of the lecture plus further slides not shown during the lecture containing more detailed explanations;
- some material for background reading with respect to basic concepts that are regarded as known and will not be treated in detail in the lecture;
- questions on the basis of which you can test and deepen your understanding;
- references to publications and books that treat specific aspects of the lecture in more detail.

The lecture notes as a whole represent the material relevant for the exam.

References

- I. Rechenberg (1965): Evolutionary Experimentation. In: D. Fogel (1998): Evolutionary Computation – The Fossil Record. IEEE Press, Piscataway, NJ.
- J. D. Lohn, D. S. Linden, G. D. Hornby, W. F. Kraus, A. Rodriguez, S. Seufert (2004): Evolutionary Design of an X-Band Antenna for NASA's Space Technology 5 Mission. Proc. 2004 IEEE Antenna and Propagation Society International Symposium and USNC/URSI National Radio Science Meeting, Vol. 3, pp. 2313-2316.