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Basics of Modern Computer Science

Evolutionary Algorithms
Motivation

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MBCS CIPT, www.bcs.org/
http://www.springer.com/series/10624

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Topics

- What kinds of disasters can wrong engineering (even software) design cause?
  - Collapse of technological structures.
  - Airplane crash of Spanair flight 5022.
  - "Wind Up" and jet fighter crash.
  - Blackout.
  - Space Shuttle.
  - Nuclear war.
  - …
- Sophisticated algorithms for high-quality design of engineering solution exist today.
- Selected examples of sophisticated engineering design.

Objectives

The objectives of the lesson are:

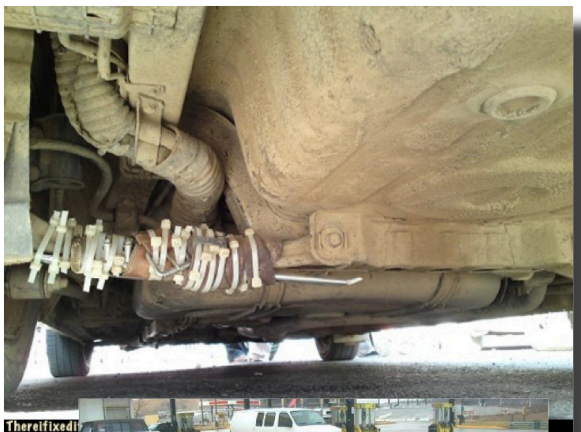
- Explain what disasters can be caused by wrong and/or nonprofessional engineering design.
- Demonstrate that sophisticated algorithms for high-quality design of engineering solution exist today and are based on nature inspired algorithms.
- Discuss selected examples of sophisticated engineering design from wide spectra of applications.

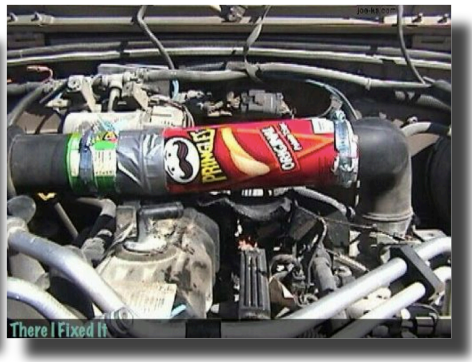
Real Disasters Caused by Bad Engineering Design

http://www5.in.tum.de/~huckle/bugse.html

Non-Engineering Solutions

☺





Disaster No. 1

The Explosion of the Rocket Ariane 5

http://www.ima.umn.edu/~arnold/disasters/ariane.html

- On June 4, 1996 after decade of development costing **$7 billion** the Rocket Ariane 5 exploded.
- The destroyed rocket and its cargo were valued at **$500** million.
- Specifically a **64 bit floating point** number relating to the horizontal velocity of the rocket with respect to the platform **was converted to a 16 bit signed integer**. The number was larger than 32,767, the largest integer storable in a 16 bit signed integer, and thus the conversion failed.
- The result was …

Disaster No. 2

Wrong Intervention of Patriot Missiles

http://www.ima.umn.edu/~arnold/disasters/patriot.html
http://sydney.edu.au/engineering/it/~alum/patriot_bug.html

- On February 25, 1991, during the Gulf War, an American Patriot Missile battery in Dharan, Saudi Arabia, failed to track and intercept an incoming Iraqi Scud missile. The Scud struck an American Army barracks, **killing 28** soldiers and **injuring around 100** other people.
- It was caused by time error difference of 0.34s
- A Scud travels at about 1,676 meters per second, and so travels more than half a kilometer in this time.

Disaster No. 3

Sleipner A Platform

http://www.ima.umn.edu/~arnold/disasters/sleipner.html

- The first concrete base structure for Sleipner A sprang a leak and sank under a controlled ballasting operation during preparation for deck mating in Gandsfjorden outside Stavanger, Norway on 23 August 1991.
- The conclusion of the investigation was that the loss was caused by a **failure** in a cell wall, resulting in a serious crack and a leakage that the pumps were not able to cope with. The **wall failed as a result of a combination** of a serious error in the finite element analysis and insufficient anchorage of the reinforcement in a critical zone.
- Thus disaster was based on bad engineering design.

Disaster No. 4
Collapse of Stock Exchange in Vancouver

- In 1982, the Vancouver Stock Exchange introduced a new index with a nominal value of 1000.000. The index was updated after each transaction.
- Twenty-two months later it dropped to 520. The reason was that the updated value is **not rounded** (Round) **but shortened** (Truncated).
- Rounding the calculation gave a value of 1098.892. (*The Wall Street Journal November 8, 1983, p.37.2. The Toronto Star, November 19, 1983.3. BD McCullough and H. D. Vinod Journal of Economic Literature Vol XXXVII (June 1999), pp. 633-665.*)
- Another cases: Black Friday 1929 Wall Street,…


The Philadelphia Inquirer

Dow Dives 508.32 Points In Panic on Wall Street

Famous Blogger Loses Fortune

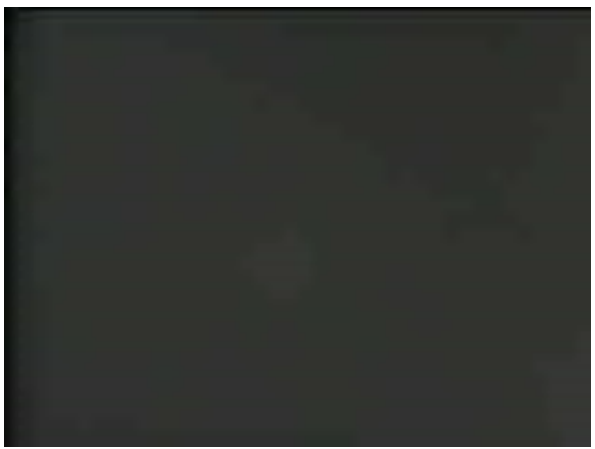
Billions lost in trading

Disaster No. 5

Tacoma Bridge Collapse, 1940

http://www5.in.tum.de/~huckle/bugse.html

- On 7 November 1940, at approximately 11:00 am, the first suspension bridge collapsed Tacoma Narrows due to vibration caused by light winds. The place is located on the Tacoma Narrows in Puget Sound, near Tacoma, Washington, **the bridge was opened for traffic a few months only.**



Disaster No. 6
Air Crash of the Spanair MD-82, Madrid, 2008

- Spanair Flight 5022 was a scheduled passenger flight from Madrid-Barajas Airport to Gran Canaria Airport.
- Spain that crashed just after take off from runway 36L of Barajas Airport at 14:24 CEST (12:24 UTC) on 20 August 2008.
- **Only 18 people survived**.
- Investigation has shown that it was caused by malfunction of the central computer **control system that has been infected by malware** kind of Trojan Horse.

Disaster No. 7
Mars - American Mars Climate Orbiter

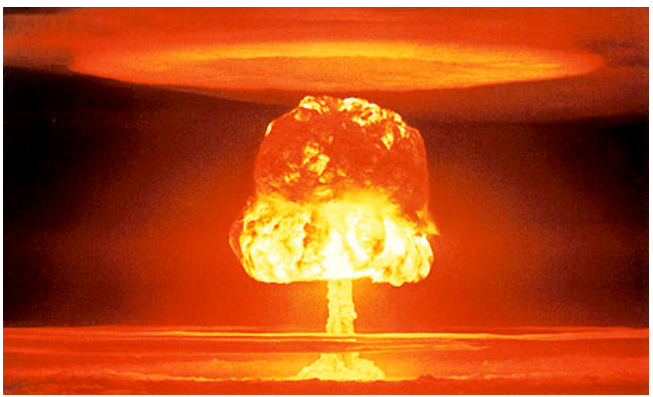
- American Mars Climate Orbiter paid for the fact that during its training one of the teams worked with the Anglo-Saxon units, while the second one with the metric system.
- Attitude of atmosphere was calculated incorrectly.
- When motors went off, the probe was in that moment a dozens of meters above the surface of the red planet.

Disaster No. 8
Space Shuttle Challenger

- The first of two U.S. space shuttle accidents (the other was the crash landing of Space Shuttle Columbia in 2003) in January 1986 over Cape Canaveral, Florida.
- There was a defective seal on one of the thrusters that withstood the heat during the start. The fire blown thrusters holder and it crashed into the main fuel tank. Following explosion shattered the space shuttle. Cabin crew rose to a height of 20 km for a while and then crashed into the ocean. The explosion occurred just 73 seconds after launch.
- All seven crew members (the same number as the later Columbia) were killed.

Disaster No. 9
Nuclear War

- On September 26, 1983 Stanislav Yevgrafovich Petrov was the duty officer at the command center for the nuclear early-warning system of USSR.
- The system reported that a missile was being launched from the United States.
- Petrov judged the report to be a false alarm, later he said "***I had very strange feeling that no one will start nuclear war with 5 missiles only***!"
- Reason: wrong computer interpretation of the Sun light reflection from the clouds.



Disaster No. 10
Blackout

The results of studying the causes of blackouts

- High-energy limit of the carrying capacity.
- Uncontrolled situations when interconnection of neighboring countries.
- Because of market liberalization traditional production scheduling transmission of electricity disappeared.
- The year 1998 was not the happiest for the city of Auckland in New Zealand, because the 19th February of that year the electricity to 1,700 households and businesses was cut due to interruption of 4 energy cables. Losses reached **156 million** dollars!
- The longest blackout lasted whopping **66 days** !

Disaster No. 10

Blackout

- 20th February 1998 Auckland, New Zealand.
- 14th August 2003 Northeast USA and Canada.
- 23rd September 2003 Denmark and Sweden.
- 28th September 2003 Italy.
- 12th July 2004 Greece.
- 18th August 2005, Bali, Indonesia.
- 27th April 2007 Colombia.

Disaster No. 11

WindUp - Hidden Oscillation / Attractors

- An oscillation in a dynamical system can be easily localized numerically if initial conditions from its open neighborhood lead to long-time behavior that approaches the oscillation.
- Such oscillation (or a set of oscillations) is called an attractor, and its attracting set is called the basin of attraction.
- Thus, from a computational point of view in applied problems of nonlinear analysis of dynamical models, it is essential to regard attractors as self-excited attractors or hidden attractors depending on the simplicity of finding its basin of attraction in the phase space.

Disaster No. 11

WindUp - Hidden Oscilation - Attractors

Disasters

The Biggest Software Disasters – an Overview

- July 22, 1962 at 9 pm 26 minutes the security specialist team at Cape Canaveral pressed red button and destroyed rocket Mariner.
- This **act was the first of many** future large software disasters.
- Mariner 1 rocket should have been the first interplanetary probe to explore Venus. Instead, the debris after flight lasting 293 seconds crashed into the Caribbean.
- The programmer forgot to write down the upper underscore sign **(”-”)** of handwritten formulas for the control program.
- Lessons learned "from the accident Programming" later appeared in an internal challenge NASA: “**No detail is too small to be overlooked**."

Disasters

The Biggest Software Disasters – an Overview

- 1962 Mariner 1: Immediately after launch the rocket began to deviate from the course and had to be destroyed. **Reason**: Programmers forgot the formula for single sign.
- 1971 Eole 1: French satellite caused the destruction of 71 weather balloons. **Reason**: Software incorrectly interpreted the request for transfer of measured data as a command to self-destruct.
- 1978 Nimbus 7: Satellite failed in the examination of the ozone hole over Antarctica. **Reason**: Program for the analysis of the obtained values marked unusual readings as errors.

Disasters

The Biggest Software Disasters – an Overview

- 1979 nuclear reactor. Five U.S. nuclear reactors have been turned off when their software checked the stability in the quake adding bad data. **Reason**: Program counted instead of the sum of the square roots the sum of the squares.
- 1982 cruiser HMS Sheffield. During the Falklands War the ship was hit and sunk by a missile. **Reason**: Software switch weapons systems into "safe" mode.
- 1983 Third World War. Soviet satellite detected five intercontinental missiles. Colonel Petrov evaluated the data as a false alarm. **Reason**: Software interpreted light reflections as hostile missiles.

Disasters

The Biggest Software Disasters – an Overview

- 1985-1987 Therac 25. Irradiation equipment to kill a wide range of patients with overdose of radiation. **Reason**: Software device able to accurately control multiple processes only if the commands were entered slowly.
- 1988 USS Vincennes. U.S. cruiser shot down an Iranian Airbus - the result was **290 dead. Reason**: According to the survey assessed the Aegis system (for approximately $ 400 million) Airbus as " supposedly hostile". Crew believed that it is the attacking fighter aircraft.

Disasters

The Most Common Errors

Source: SCAN.COVERTY.COM

- The software errors can be encountered even in well-tested, and frequently used programs.
- Within few years of testing software "provider" Coverity more than **150** large open-source projects using their own tools based on static analysis of the code base.
- The mentioned projects were designed primarily for Linux and Apache server.
- In total software analyzed more than 55 million lines of code. Three years ago it revealed one error in 3300 lines, currently this limit is shifted up to 4000 lines. The most commonly detected errors were as follows: …

Disasters

The Most Common Errors

Source: SCAN.COVERTY.COM

Errors in %

- The pointer is set to null references in memory **27.95**%.
- How to Use a non-memory **25.73**%.
- Inaccessible program code **9.76**%.
- How to Use the untested variables **8.30**%.
- Overflow statically addressed memory area is **6.14**%.
- How to Use the already freed memory is **6.46**%.
- Unauthorized counting with zero (e.g. division) **5.85**%.
- Variables are assigned values of **5.50**%.
- The calculated negative values are used without checking the **3.72**%.
- The pointer refers to memory that is not accessible to **0.62**%.
- Overflow Dynamic addressing memory areas in **0.31**%.

Dizasters

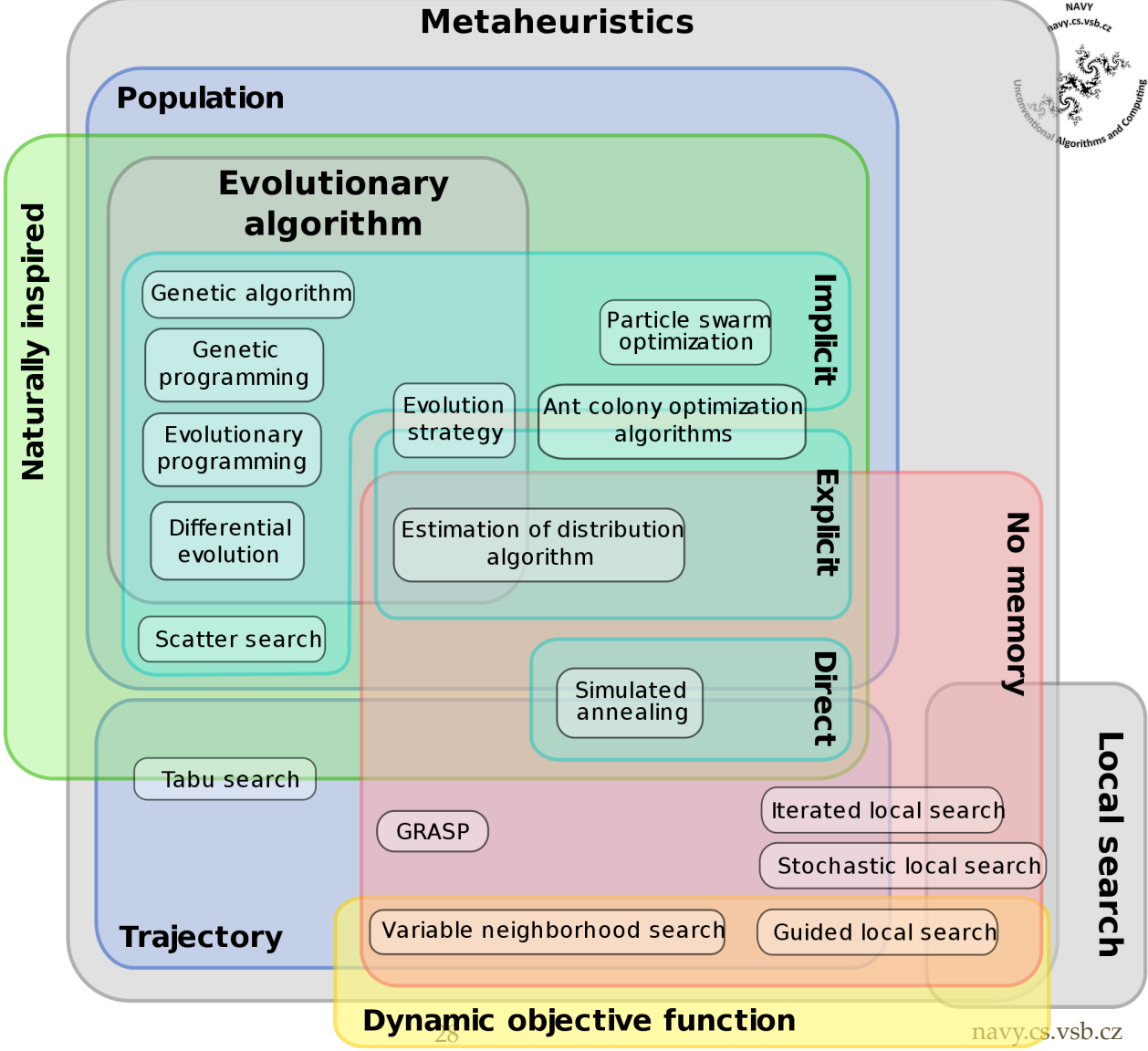
What can we do?

Modern Methods of Solving Engineering Problems

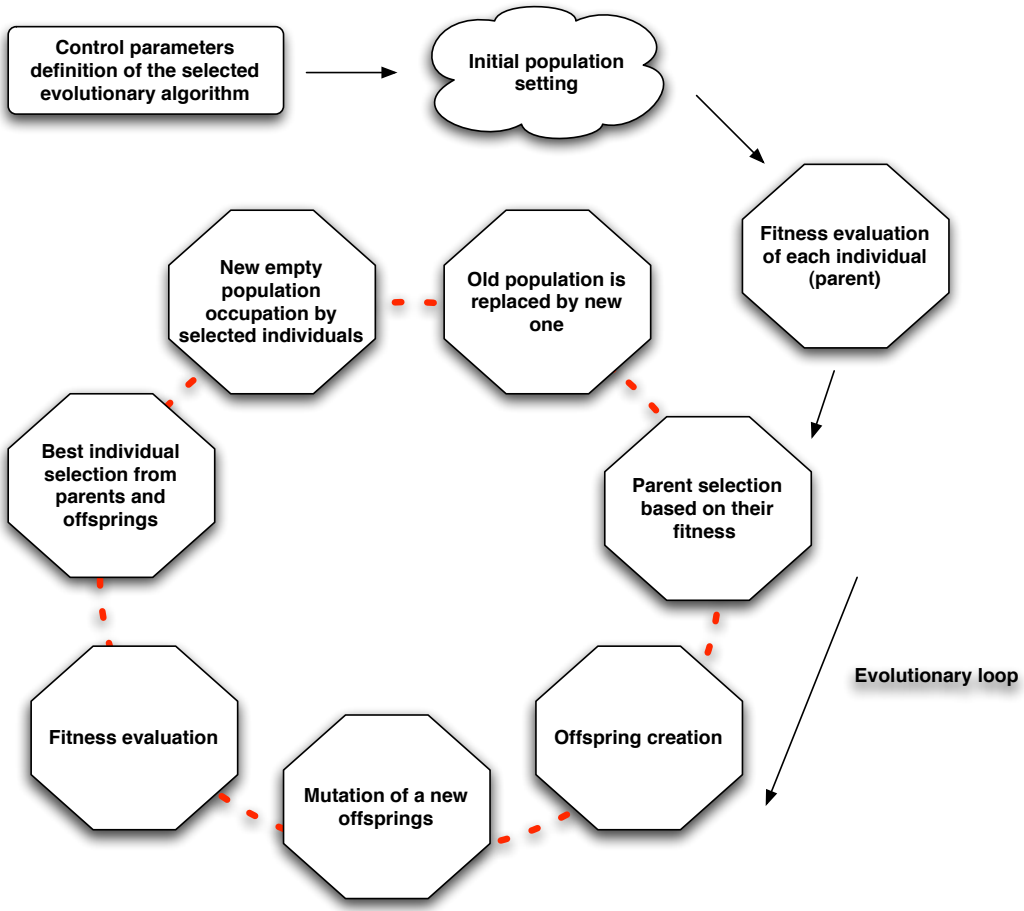
Unconventional Computation

- **Unconventional computation** is computing by a wide range of new or unusual methods. It is also known as **alternative** computing. Including:
  - optical computing
  - quantum computing
  - chemical computing
  - natural computing
  - **biologically-inspired computing** (metaheuristic)
  - wetware computing, DNA computing, molecular computing
  - amorphous computing
  - nanocomputing, reversible computing
  - analogue computing …

Nature Inspired Computation



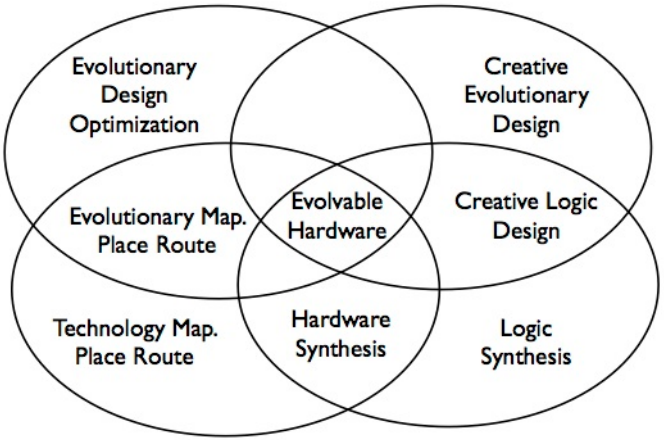
Evolution – the Central Dogma



From the above mentioned main ideas of Darwin and Mendel theory of evolution, ECT uses some building blocks, see the diagram.

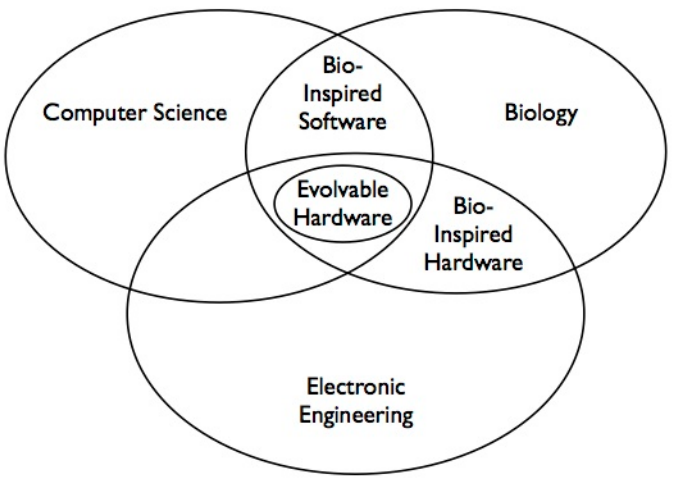
The evolutionary principles are transferred into computational methods in a simplified form that will be outlined now.

Evolvable Hardware



Inter-relational aspects of evolvable hardware

Evolvable hardware and sciences of computer, biology and electrical engineering

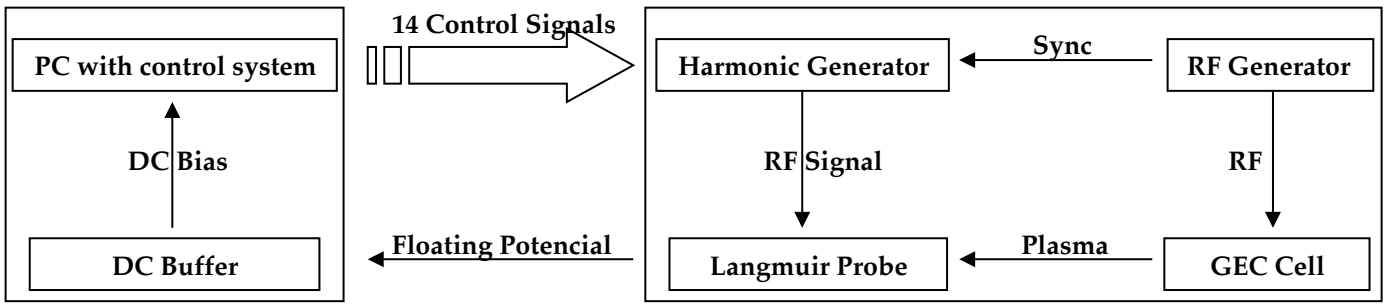


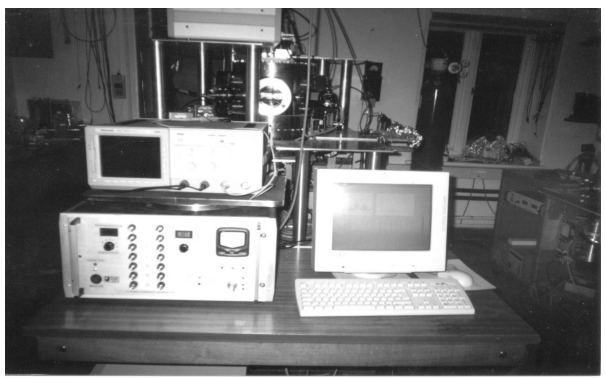
Evolvable Hardware
Hummies Competition

Applications	Number of Awards
Analog circuits	25
Quantum circuits	8
Physics - optical systems	7
Logical circuits	5
Optimization problems	5
Game strategies	4
Chemistry - molecular design	3
Antenna design	2
Applied mathematics	1

Examples

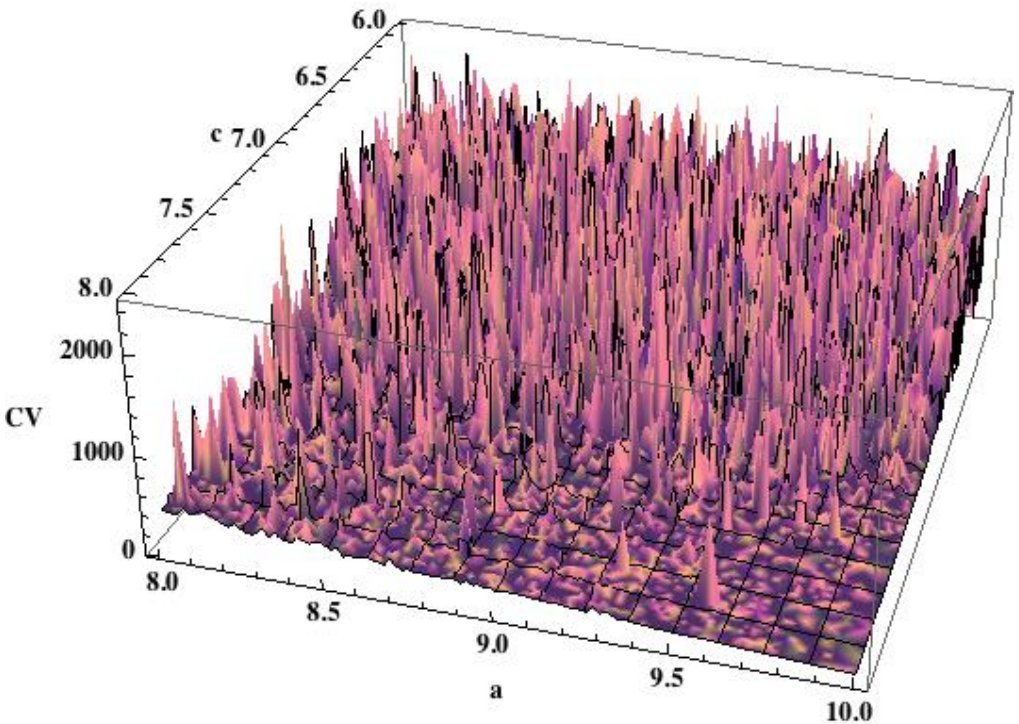
Plasma Reactor Control



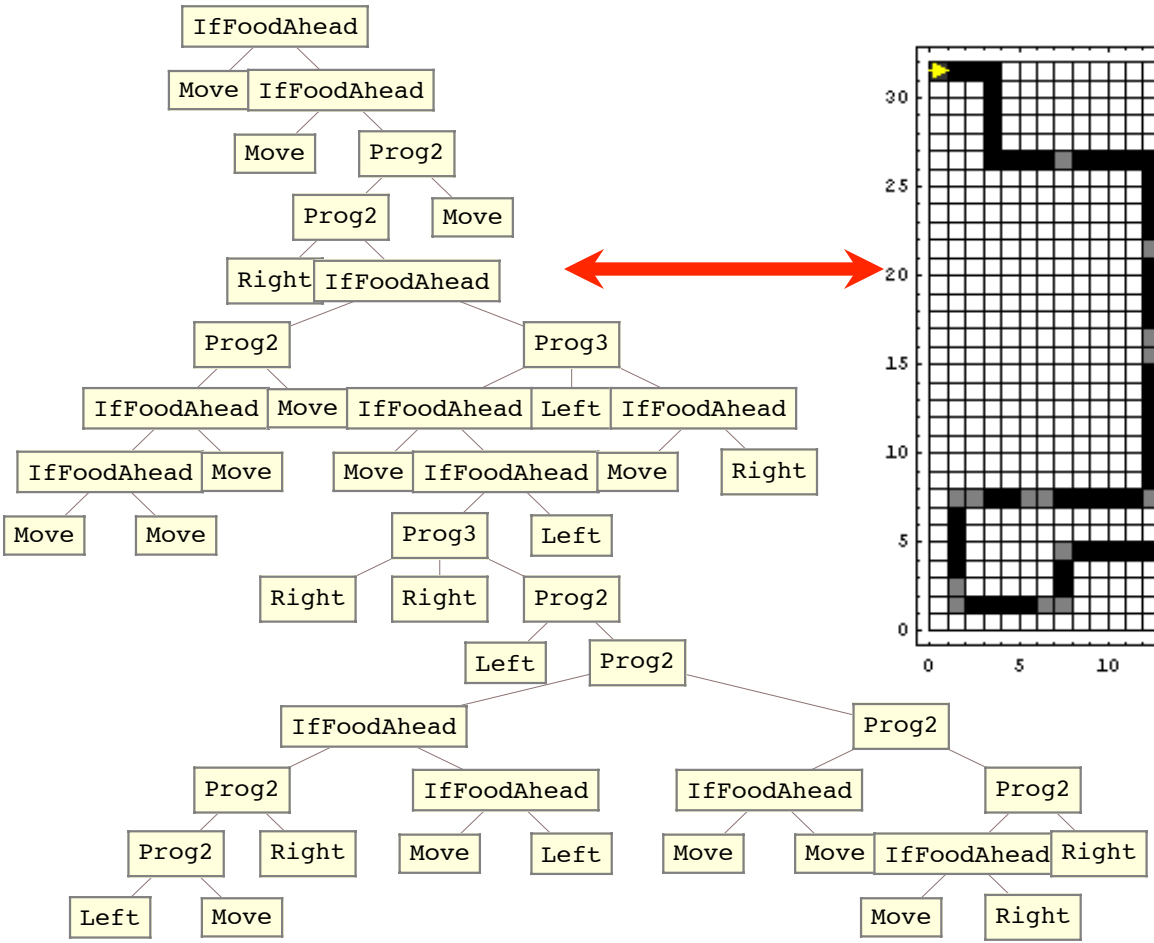


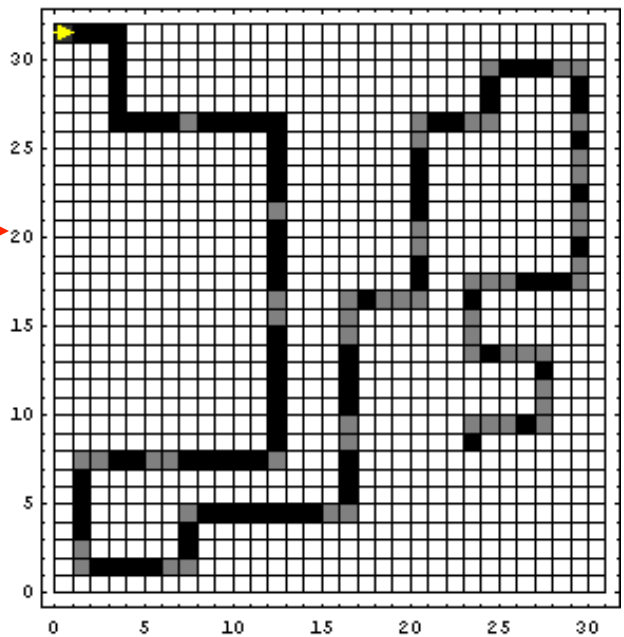
Computer with control software (right), wave synthesizer (bottom left) and oscilloscope (top left)

Multimodal Surface of Chaos Control



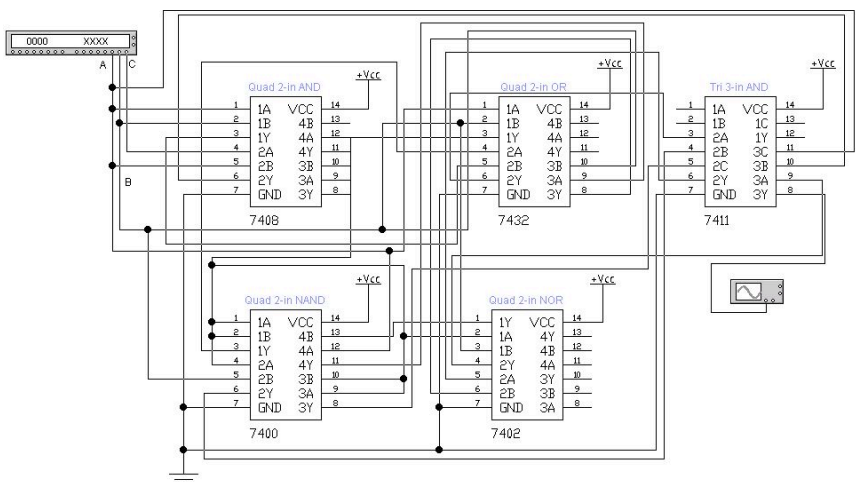
Robot Control Program Synthesis

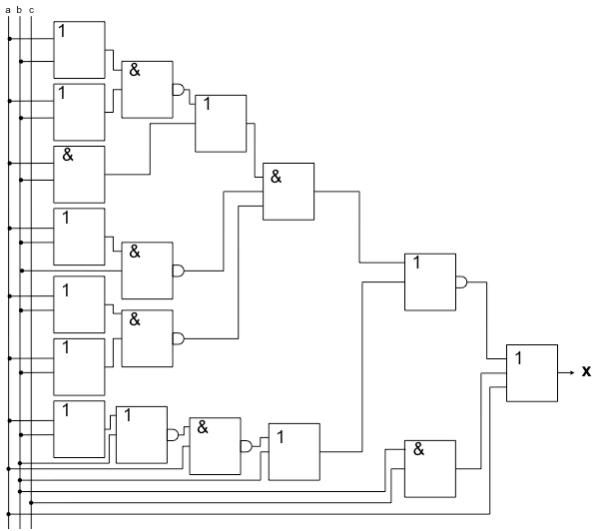




Logic (Electronics) Circuits Synthesis
Heat Control

Input 1	Input 2	Input 3	Output
False	False	False	False
False	False	True	False
False	True	False	False
False	True	True	True
True	False	False	True
True	False	True	True
True	True	False	True





Optimization of Wing Geometry

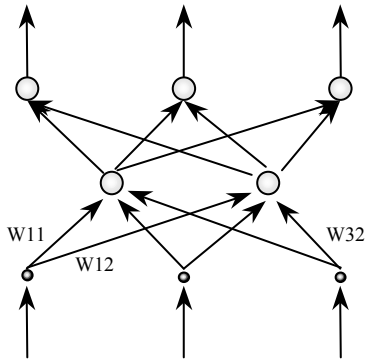
Problem Description

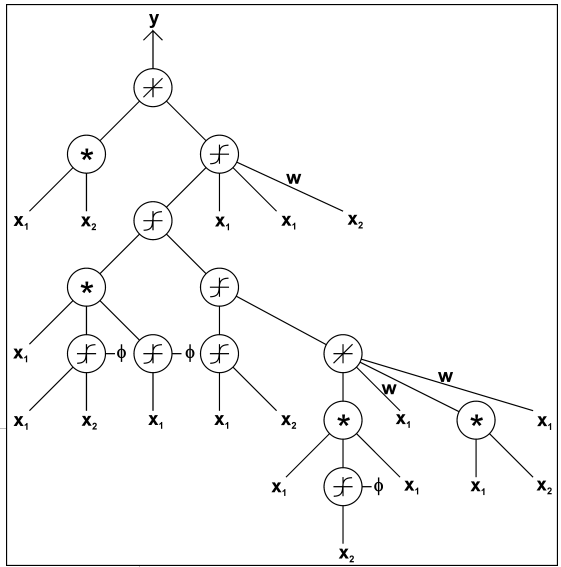
- Aerodynamic wing geometry optimization was performed on two different planes.
- The first set of results represents a modification proposal of wing of ultralight aircraft Harmony.
- The second group of simulations was performed for the purpose of modifying an aircraft wing BUT-100 Cobra in order to improve its aerodynamic characteristics.
- A third set of optimization tasks was to develop a completely new wing for the Cobra without any constraints used in the previous optimization.

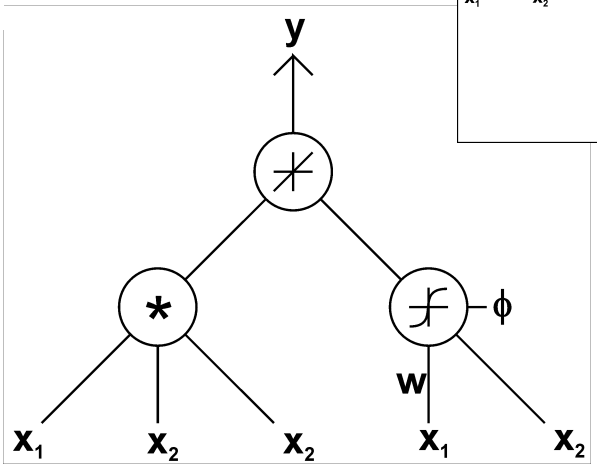
Harmony

Cobra

Artificial Neural Networks Synthesis

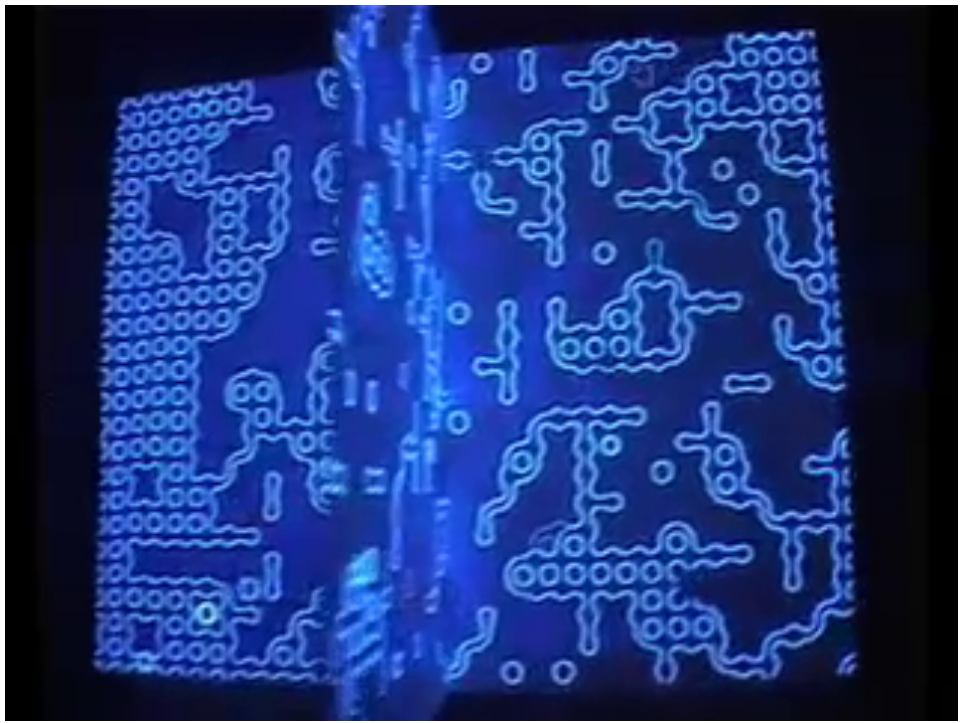






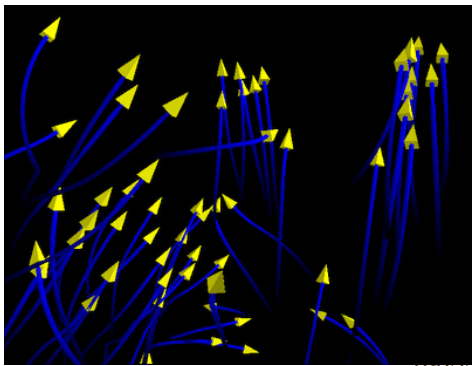
Eden: an Evolutionary Sonic Ecosystem

http://www.csse.monash.edu.au/~jonmc/projects/eden/edenImages.html



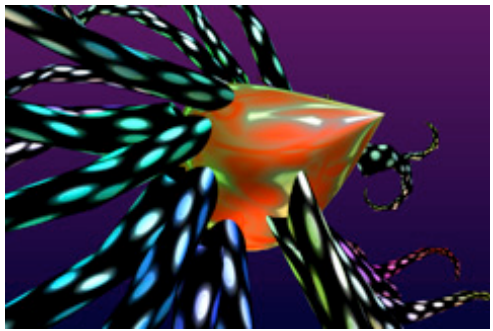
Boids

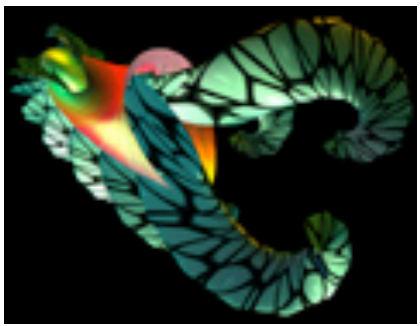
http://www.red3d.com/cwr/boids/

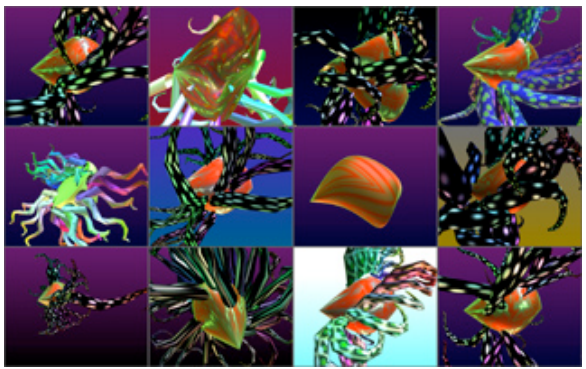


Galapagos

http://www.genarts.com/galapagos/index.html

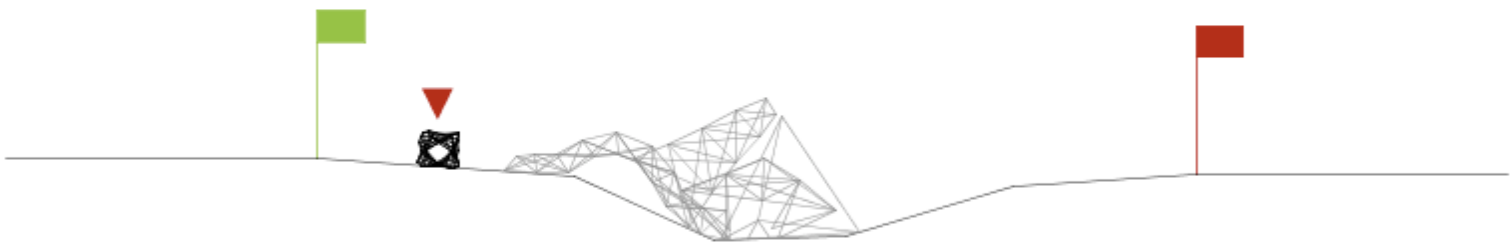






Sodarace – Robotic Evolution

http://sodarace.net



Sodarace is an online system in which a human athlete can try to success with a robotic competitor against computer-controlled oponents. Your competitor is selected after a competition and evolutionary advances may again participate in the race.

Swimboot

http://www.swimbots.com/

Swimboots are artificial, evolutionarily prepared digital organisms. The environment is water. In this environment, their offspring compete for food, etc. The success of the competition can be influenced also by artificial intervention of a human operator.sw

Conclusions

- Various technological problems and collapses of technical devices arecaused by imprecisions in device design.
- Possibilities of nature inspired algorithms.
- Examples of sophisticated engineering design from wide spectra of applications.

THANK YOU FOR YOUR ATTENTION

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