T9

Cognitive Systems

2020 edition

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PSI 3560 – COGNITIVE SYSTEMS

class T9

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ARTIFICIAL LIFE, GENETIC ALGORITHM CELLULAR AUTOMATA

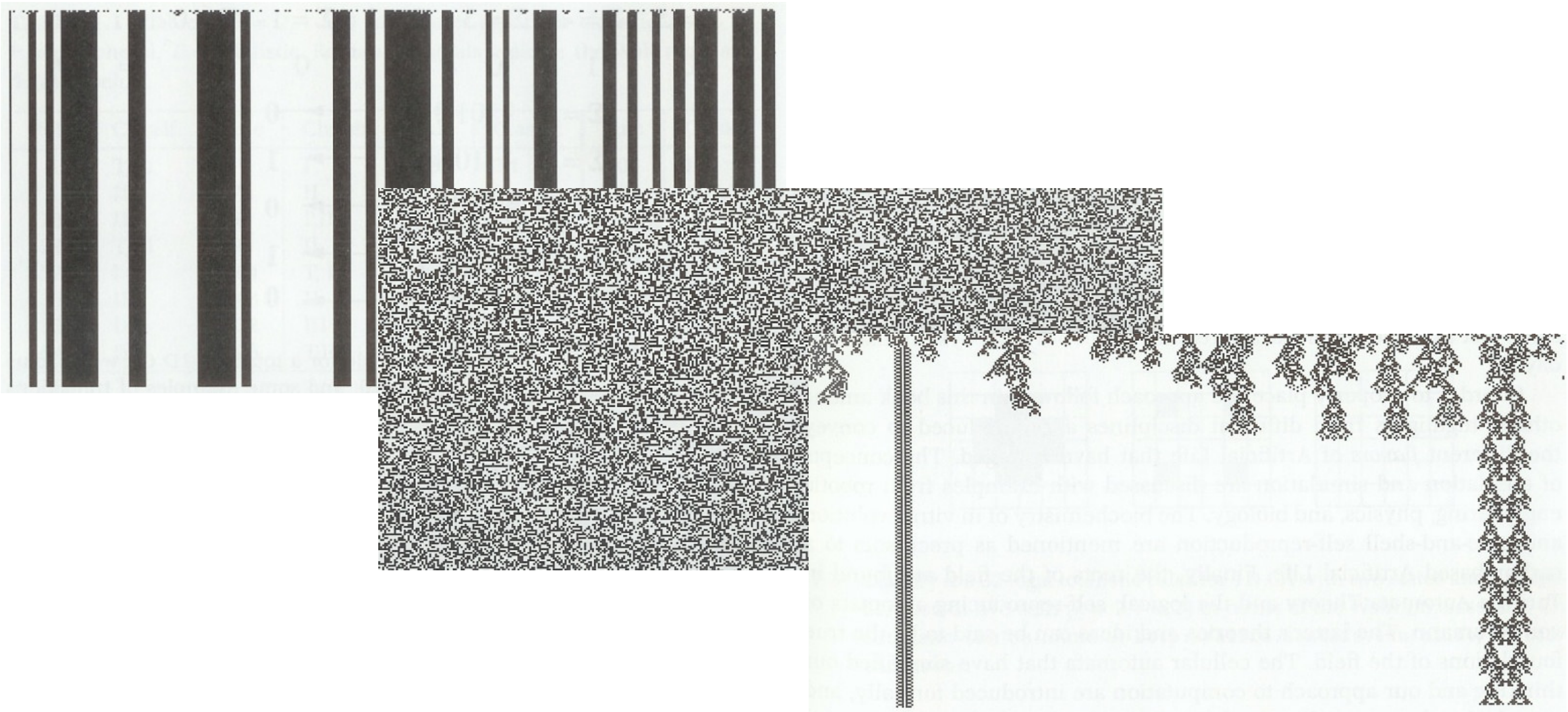
Artificial Life, Genetic Algorithm, Cellular Automata

Session T9

Section 1

- Cellular Automata

ARTIFICIAL LIFE, GENETIC ALGORITHM CELLULAR AUTOMATA



Complex Systems

- Complex structure
- Complex behavior

- Exist on many different levels
  - from nano (molecules) to macro (cosmic) scales
- Mathematical theories and tools helps modeling and assessing them
  - Assistance to their understanding

Complex Systems - Cellular Automata

- How do dynamic systems behave and evolve?
- Are there any background laws?

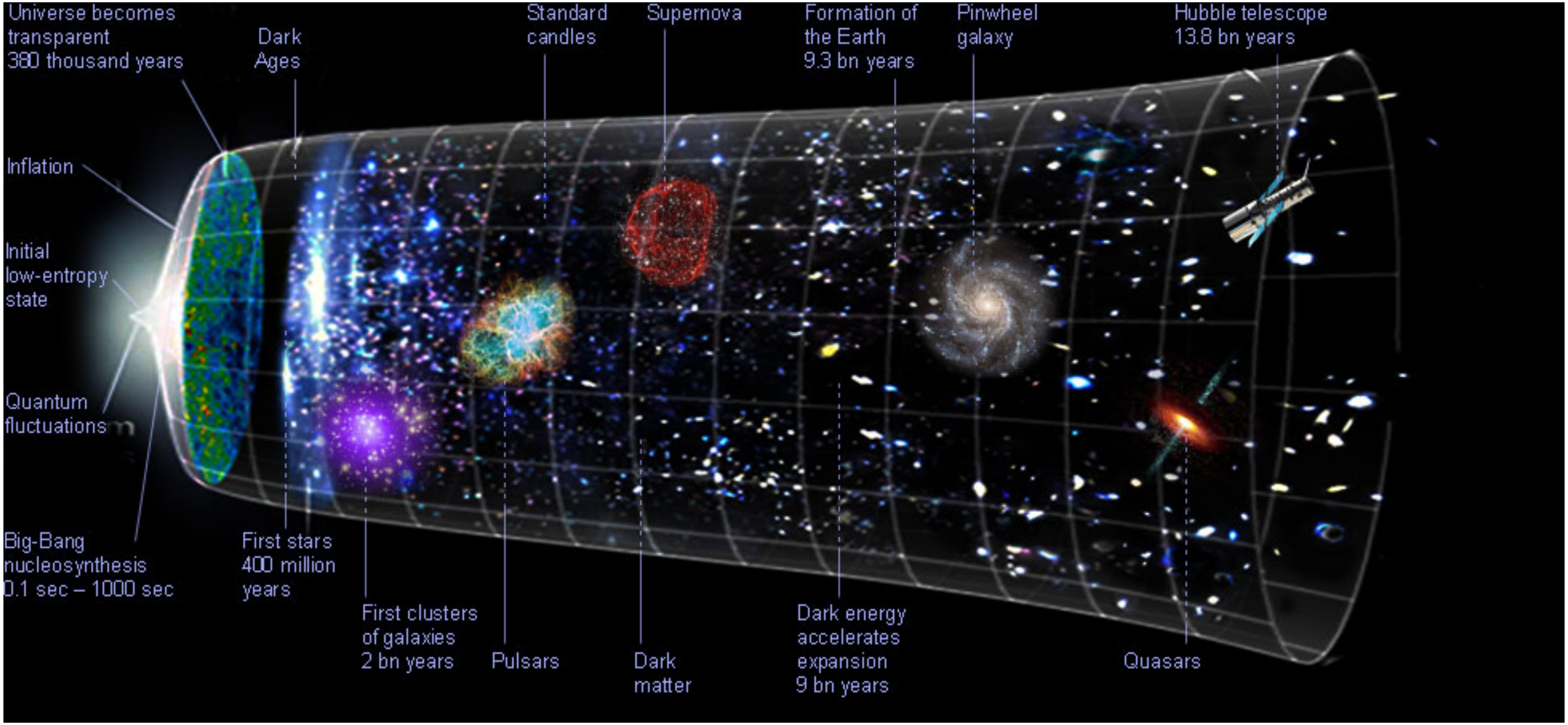
- Cellular Automata
  - Controlled by rules
  - Dependence on initial conditions
    - Very sensitive in some cases
      - Easily changing from regular, to chaotic conditions

Cellular Automata

- Cellular Automata
  - States are assigned to cells
  - Each cell state depends on
    - Neighbor cell states (spatial dependence)
    - Past states (temporal dependence)

- $s^n(t+1) = f[s^{n-1}(t), s^n(t), s^{n+1}(t)]$
  - s: state   n: cell   t: time

Cellular Automata



Source: //philosophy-of-cosmology.ox.ac.uk/cosmos.html

The number of atoms in the universe are estimated to be around 10^{78} to 10^{83}

A cellular automata with 100 cells and 10 states for each cell has 10^{100} combinations!!

Cellular Automata

- $s^n(t+1) = f[s^{n-1}(t), s^n(t), s^{n+1}(t)]$
  - Huge diversity of collective states (state map)
  - Huge diversity of possible changes (trajectories)
    - But finite: Cyclic Systems with large periodicity (typically)
      - D(s) = 4: {00, 01, 10, 11} possible states
      - V(e) = 3 set (central cell and neighbors)
      - $4^3 = 64$ => 4^{64} automata or functions
  - State Map Dimension – assigned by the initial vector
    - Ex:
      - D(e) = 128: {00, 11, 01, 00, ... 10}
        - » 128 elements

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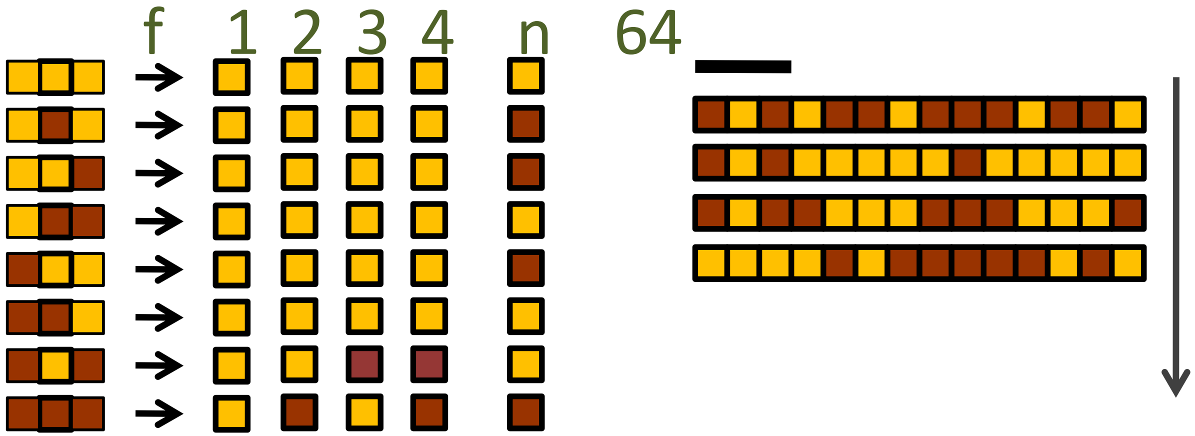
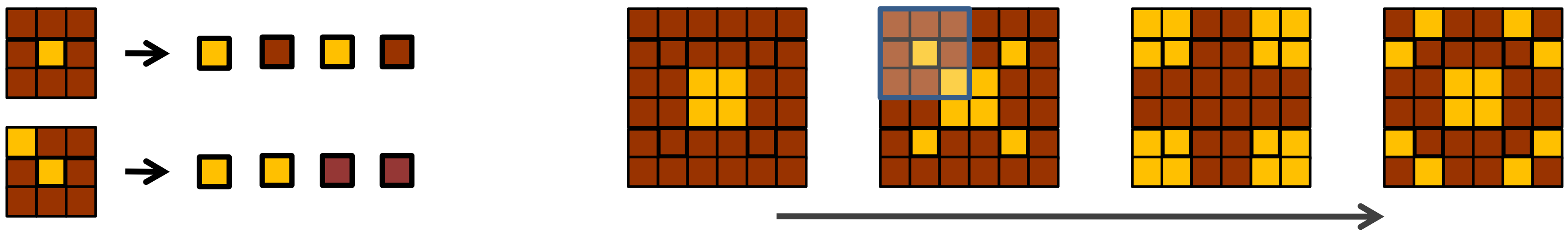
Cellular Automata

– 1D rule temporal evolution (vertical)

D = 2; V = 3; $2^3 = 8$ combinations; $2^8 = 64$ functions

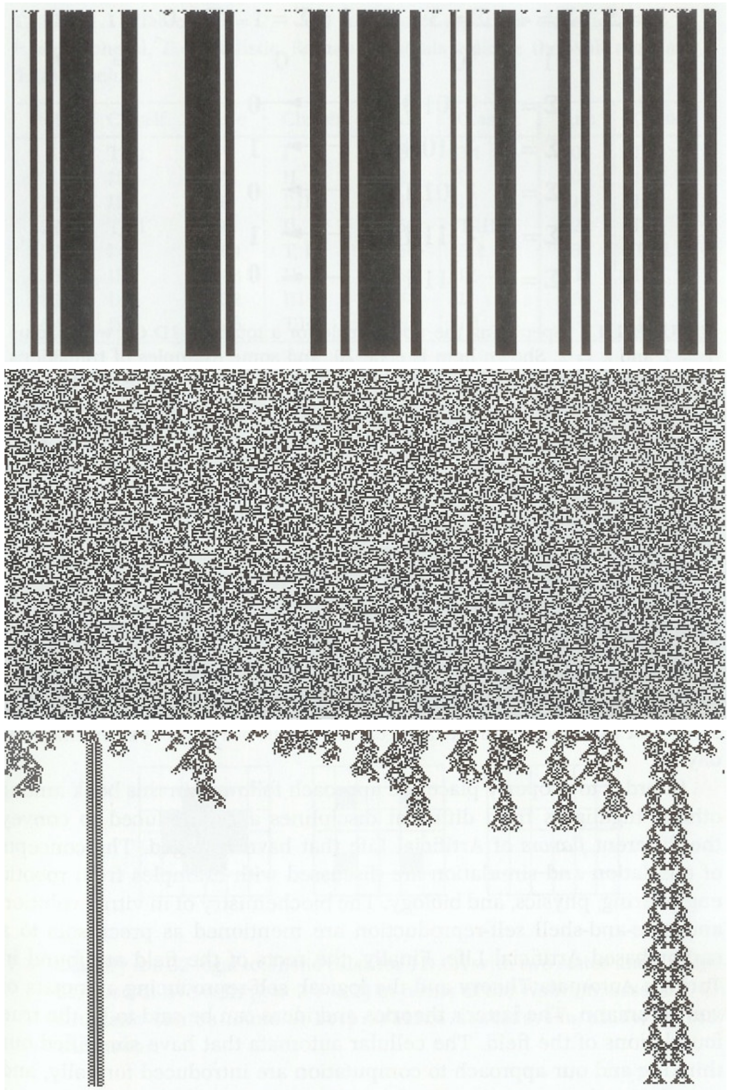


– 2D rule temporal evolution (frame sequence)



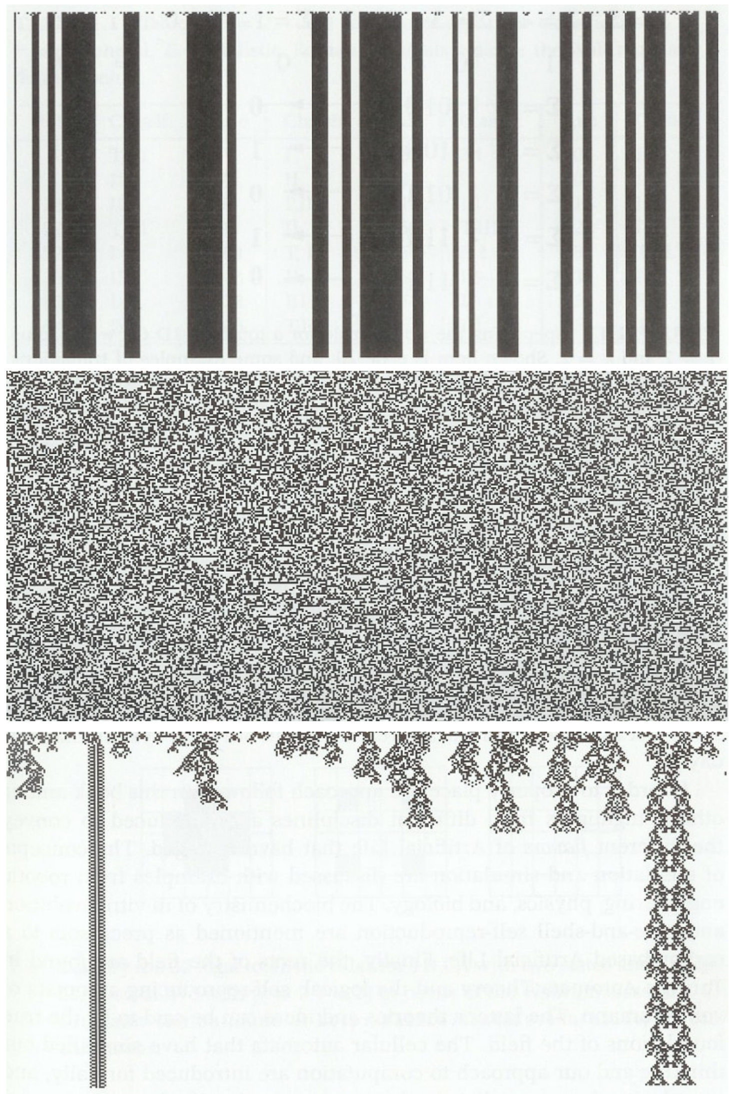
Cellular Automata

- Classes
  - Class I: Death
    - Asymptotically Stables
    - Not so interesting (no changes)
  - Class II: Regular
    - Limit Cycle (bouncing around an attractor)
    - Not so interesting (too regular)
  - Class III: Chaos
    - Chaotic Attractor
    - Richness of states and paths
  - Class IV: Auto-Organized (Life)
    - Richness of states and paths
    - Robustness ensuring the perpetuation of this condition



Cellular Automata

- Classes
  - Class I and II: Death and Regular
    - Low diversity - static
  - Class III: Chaotic
    - High diversity
      - good conditions to start life
      - But not to keep it
  - Class IV: Auto-Organized (Life)
    - Sustainable life



Section 2

- Life & Artificial Life

Life

- Artificial Life
  - Tools to model and simulate different aspects of life
  - Schrödinger, 1943
    - Life from a thermodynamic perspective (entropy)
      - Order from disorder (emergence of life)
      - Order from order (maintenance of life)
        - » DNA (1953)

Life

- What is Life?
  - Historical Facts
    - Miller Experiment (1939)
      - Aminoacidic – fundamental part to the emergence of life
    - Schrödinger Book (1945)
      - Physical thoughts about Life – Book: What is Life?
    - Discovery of DNA (1953)
      - Life Molecule – Life code (material registration of information)
    - Symposia from Christoph Langton (1980)
      - Computational Considerations about Life Principles

Life

"Life is a property of an ensemble whose unities share information coded on a physic substrate, keeping its entropy significantly lower than the one in the surroundings, on time scales that supersede by many orders of magnitude that one expected due to its natural decay"
Christoph Adami

Adami, C. (1998) Introduction to Artificial Life

Life

I would then rephrase it as:

Live beings keep in their DNA (information coded in a molecule) the instructions to build their own body, able to survive for a longer period of time, than the one required to its natural decomposition after death. And even more to keep life going on as these beings procreate, transferring the DNA to further generations. Keeping life alive.

Life

- Life Definitions
  - Physiologic — organs
  - Metabolic — cells
  - Biomechanical
  - Genetic — molecules caring information
  - Entropic — physics

Artificial Life

- Biologic Context
  - Tempt to create life Frankenstein
    - literature & movie

  - Miller Experiment (incomplete – shows just one step - aminoacidic)

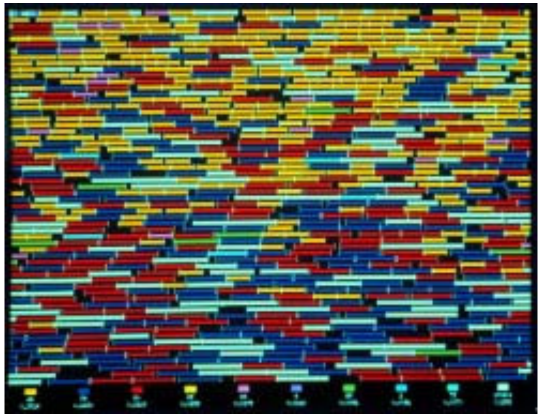
Section 3

- Computational Artificial Life

Artificial Life

- Computational Context
  - Life simulation
  - Proposition and assessment of fundamental concepts and principles of life

Does not look like, but works on some main life features

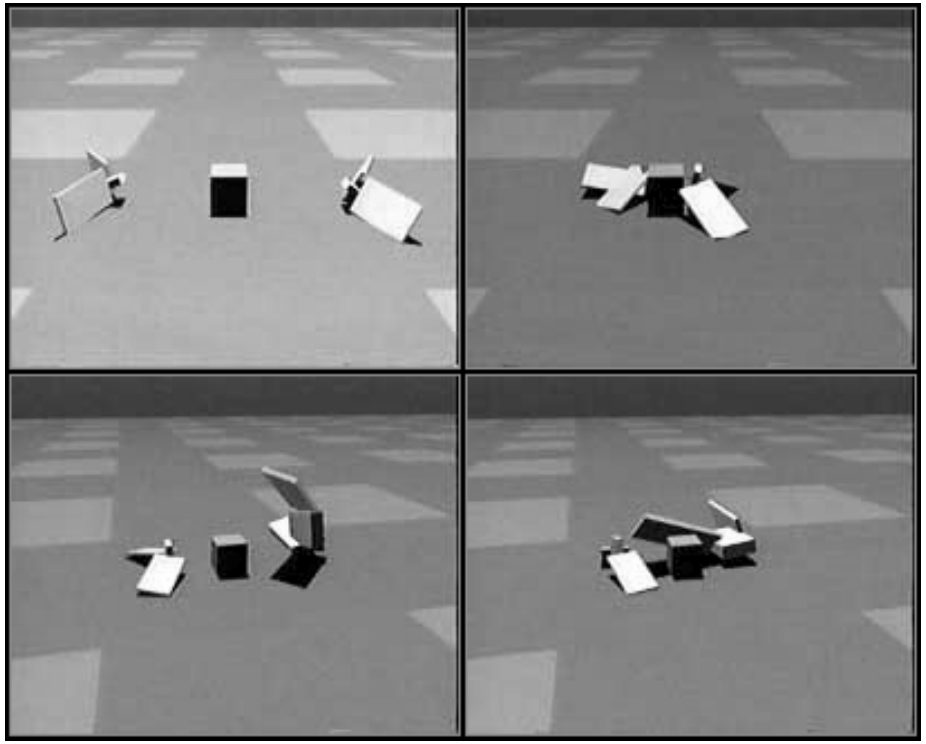


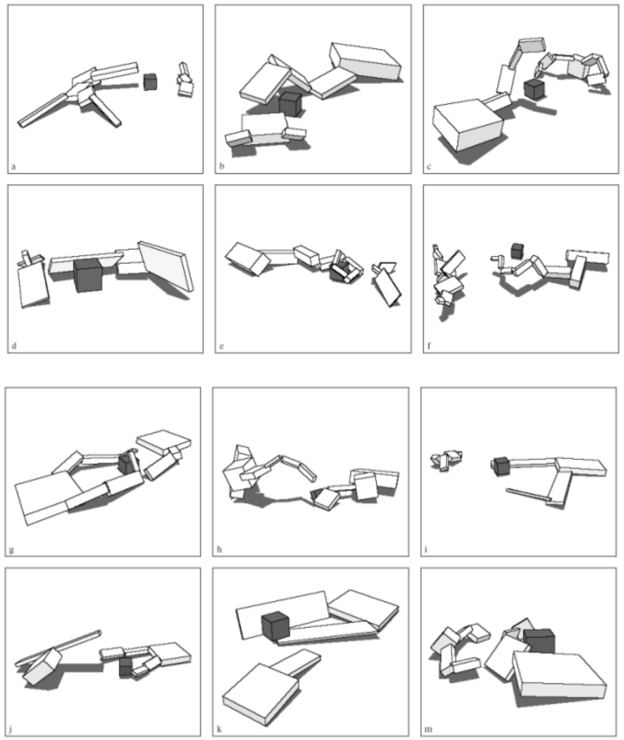
Huge set of opportunities

Looks like, but too artificial – for games

Artificial Life

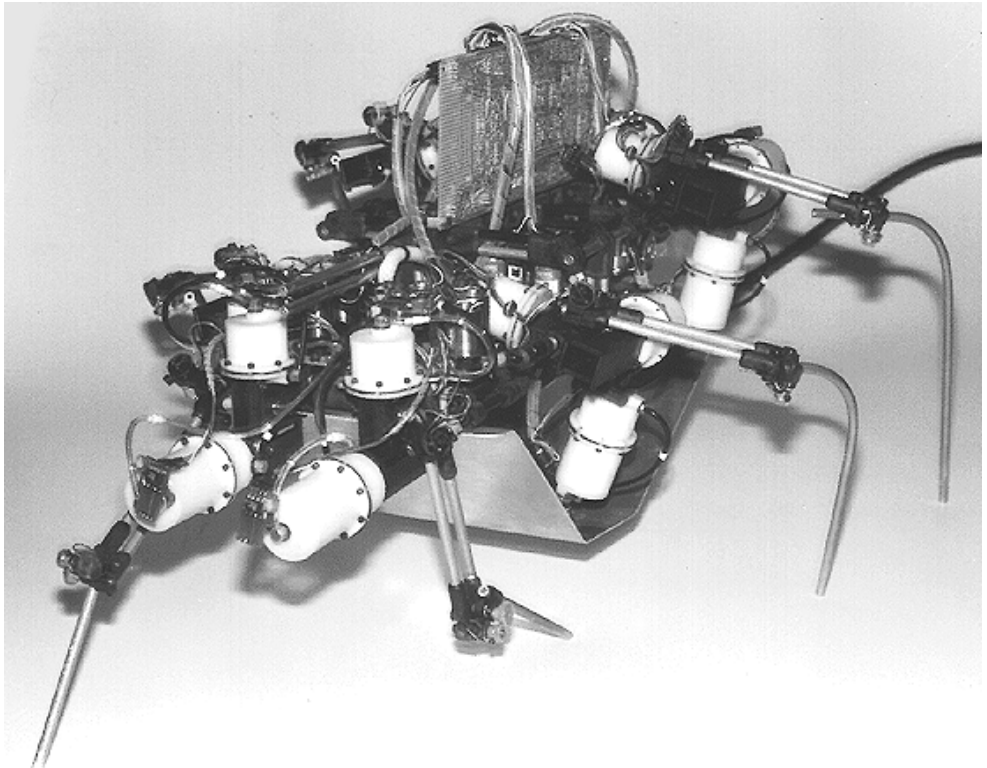
- Creatures (Karl Sims)
  - https://www.youtube.com/watch?v=JBgG_VSP7f8





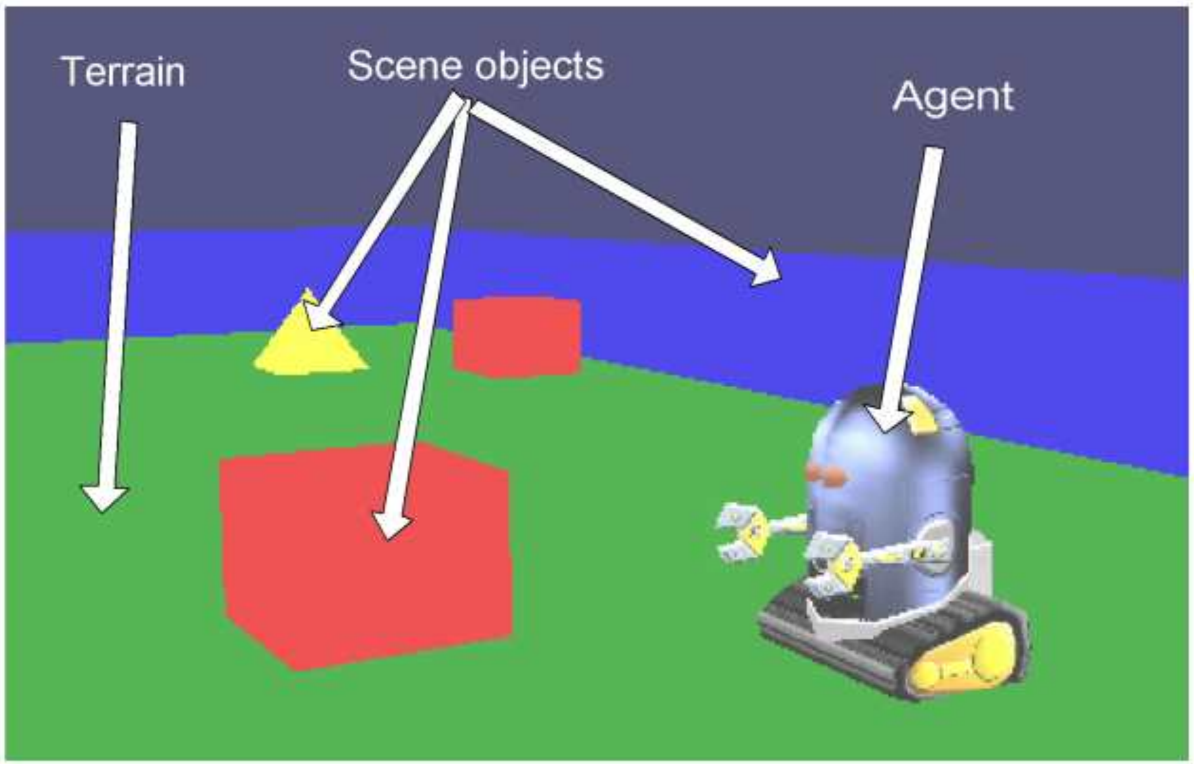
Artificial Life

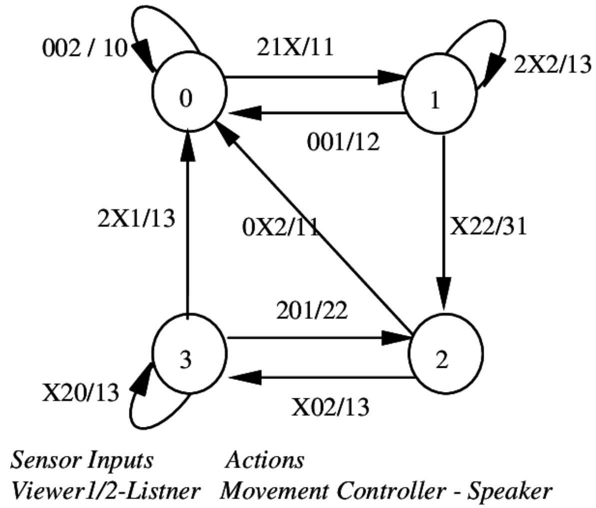
- Artificial Insects (Brooks)
  - Artificial Life Principles
  - Mini-robots
    - Autonomous Learning (by experience)

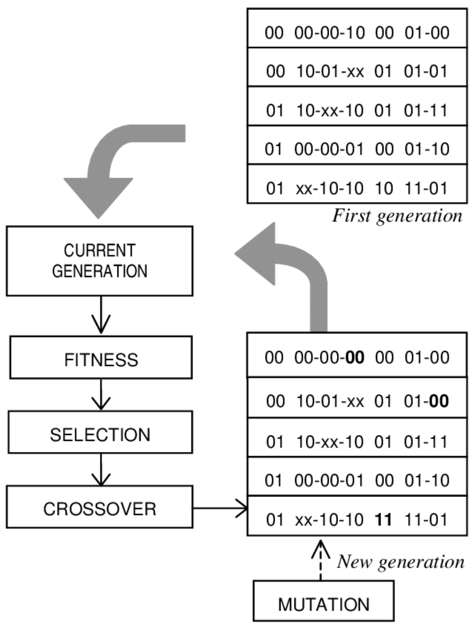


Artificial Life

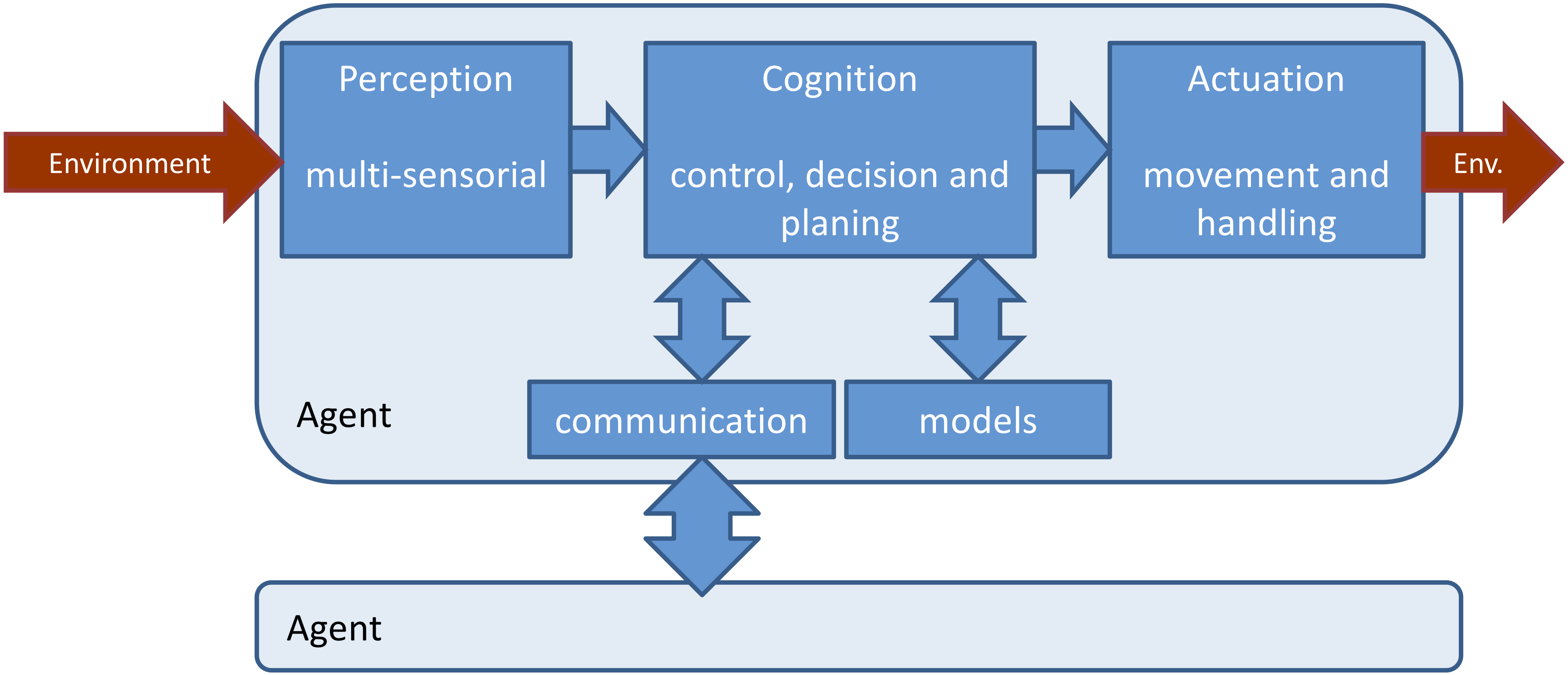
- Woxbot





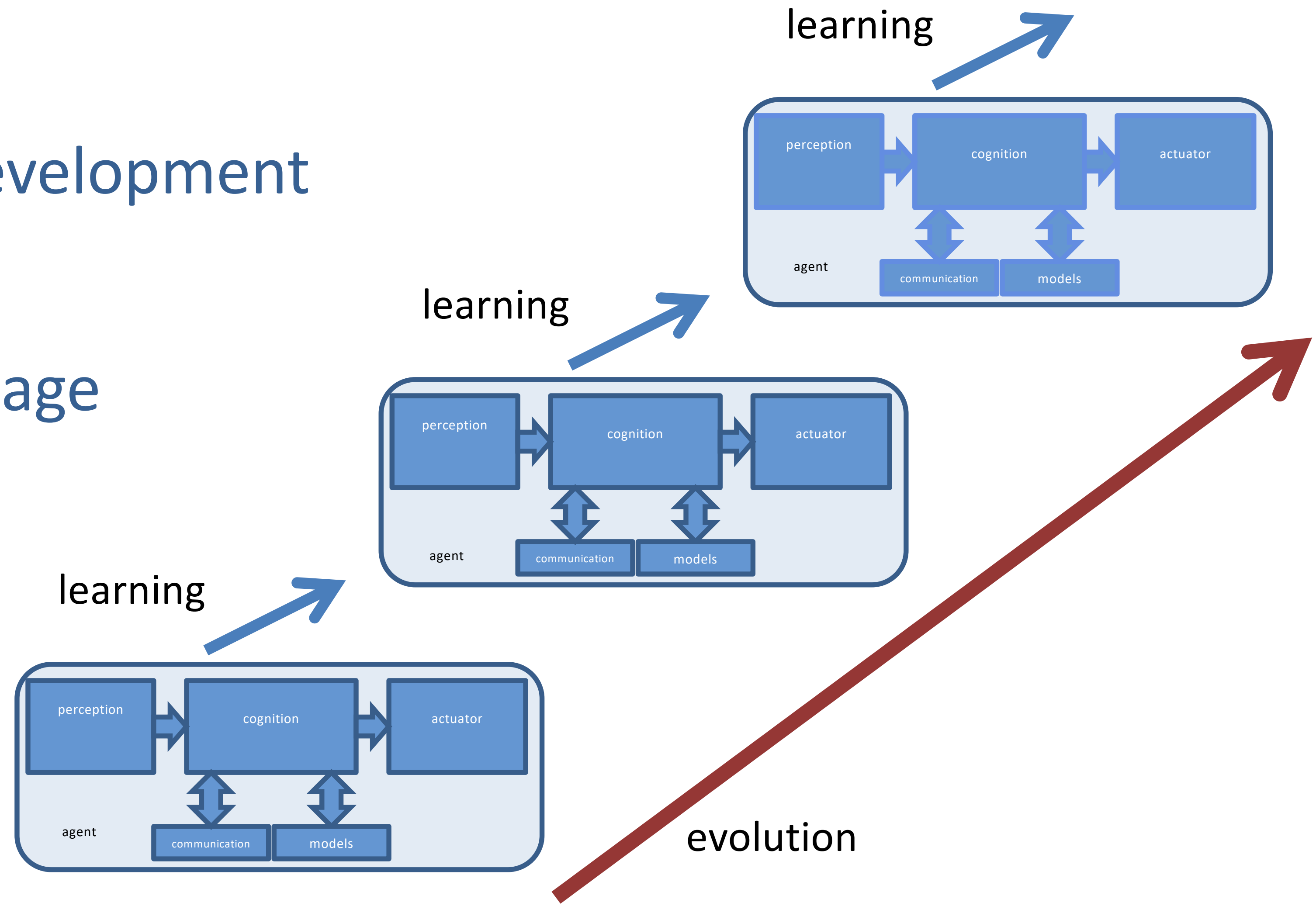


Artificial Life



Artificial Life

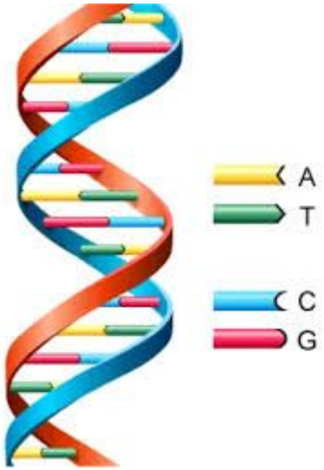
- Evolution
  - System Development
- Learning
  - System Usage



Section 4

- Genetic Algorithms & Evolutionary Strategies

Genetic Algorithms



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Genetic Algorithms

- Inspired by genetic principles
  - Coded Beings
    - Phenotype (beings)
    - Genotype (code)
  - Reproduction: Operations with codes lead to changes in beings
    - Cross over (parents)
    - Mutation (self)
  - Selection: Better adapted beings survive, keeping their codes for further reproduction

Genetic Algorithms

- Reproduction (cross-over)
- Mutation

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- Coding may be trick
  - Depends on the nature of the problem

- The idea behind reproduction is to produce off-springs that combine attribute from their parents
  - And so, being able to be better (or worst) than the parents

Genetic Algorithms

- Selection (fitness)
  - Simple Ranking
    - Elitism (keeping the best by force)
  - Tournament
- Survivors
  - the best on each generation
- Reproducers
  - by chance among survivors (or any other strategies)

Evolutionary Algorithms

- Evolutionary Algorithms
  - Evolutionary Strategies
    - Rechenberg, 1965
    - Methods to evolve solutions of problems
  - Evolutionary Programming
    - Fogel, 1966
    - When applied to computer program development
  - Genetic Algorithms
    - Holland, 1975
    - Methods using genetic coding
  - Genetic Programming
    - Koza, 1992
    - When applied to computer program development

Evolutionary Computing

- Successive adjustments (refinement)
  - Shape
  - Function

- In search of better solutions
  - As performed by nature

This is all for today.

See you next week !