Framsticks – Artificial Life

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Tutorial helpful for Kōan 4 and 6:
http://www.framsticks.com/common/tutorial/index.html

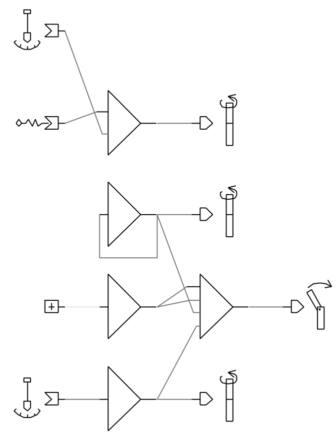
Youtube channel with videos:
https://www.youtube.com/user/Framsticks

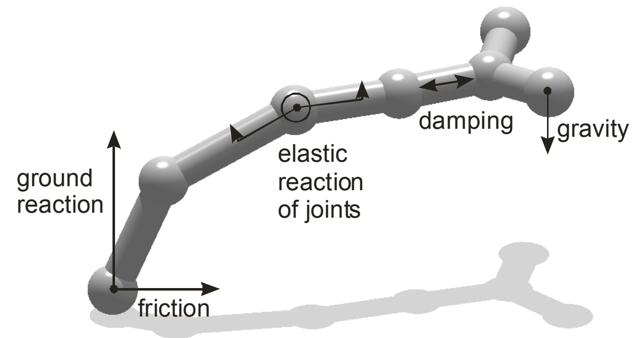
General information

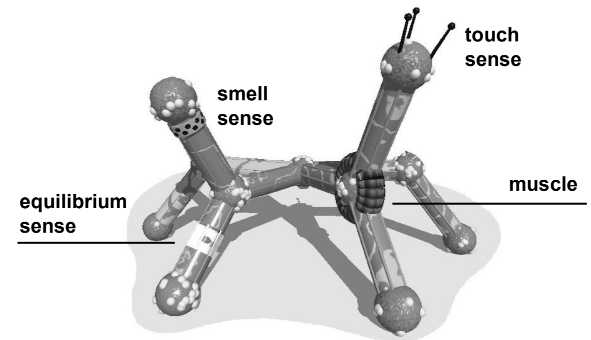
- developed since 1996
- authors and main developers: Maciej Komosinski (CS dept. at PUT) and Szymon Ulatowski
- other people involved in technical support, development, and experiments

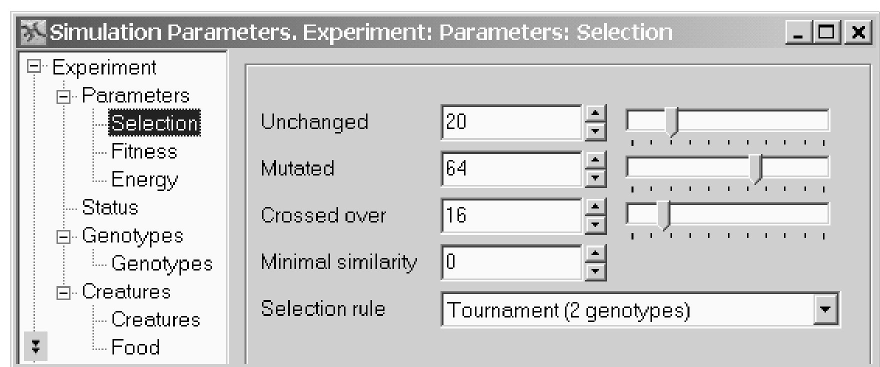
Main points of users' interest

- simulation
- biology, evolution
- robotics
- neuroscience
- cognitive science
- computer science
- visualization
- education and understanding
- simplicity / complexity
- entertainment
- versatility





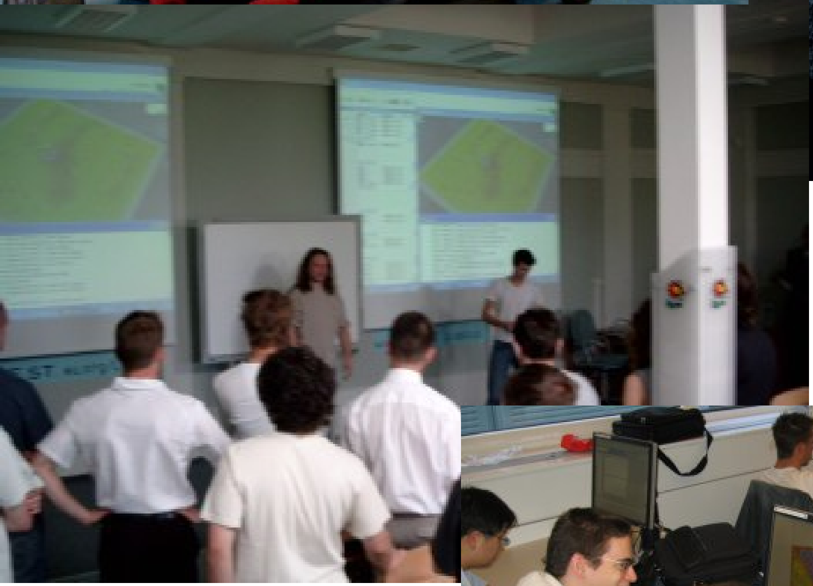




Users

- regular users
- students
- teachers and scientists:
  - Virtual Life laboratory, Utrecht University, Netherlands
  - Bio-inspired Adaptive Machines Course at Autonomous Systems Lab, Lausanne, Switzerland
  - Cognitive Science Lab., Dept. of Philosophy, William Paterson University of New Jersey, USA
  - ...
- advanced users from all over the world

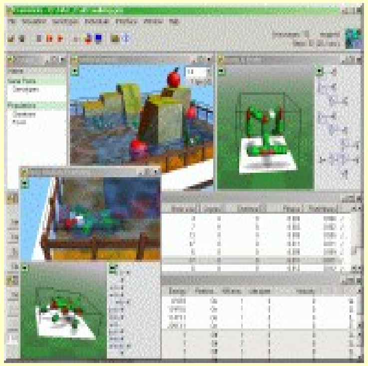
Users



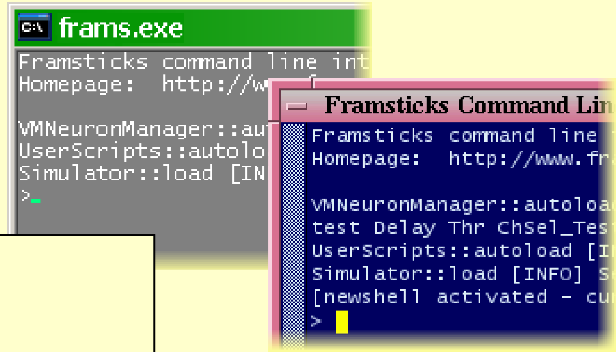
Framsticks

Software

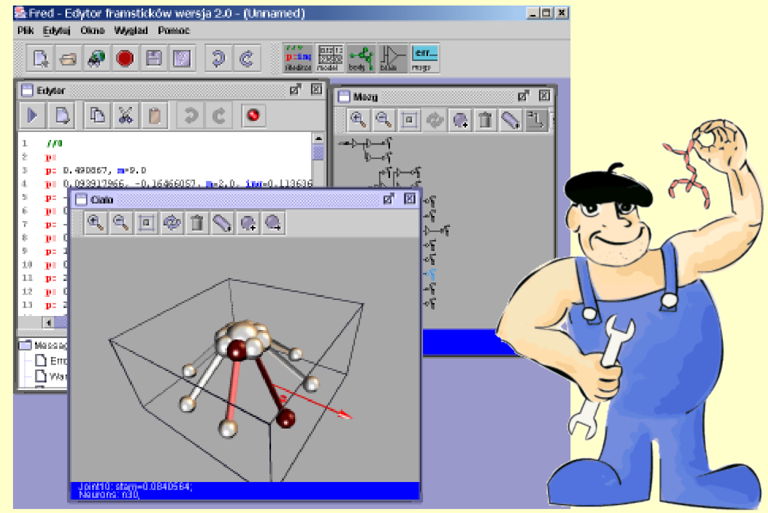
Simulator GUI



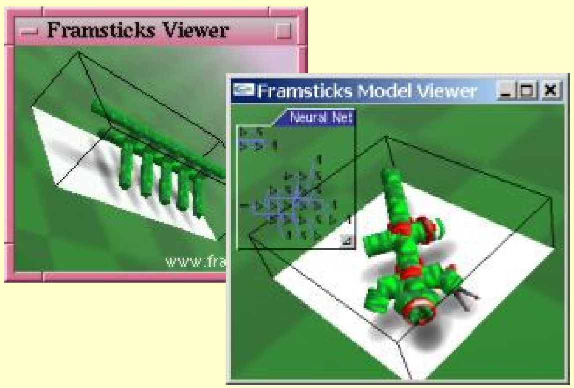
Simulator command-line



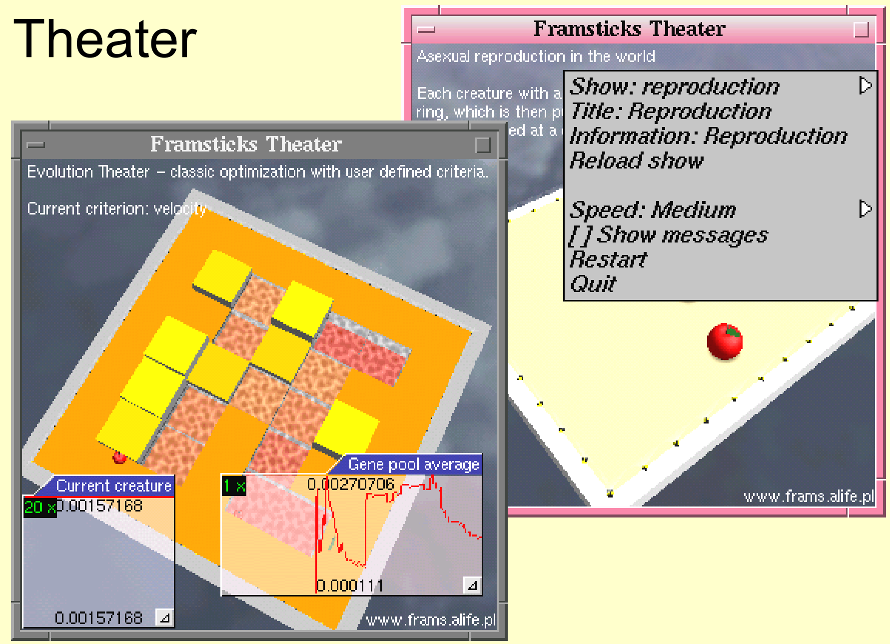
Visual Editor – FRED



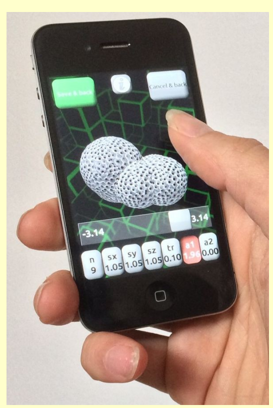
Viewer



Theater



Artificial Life Lab



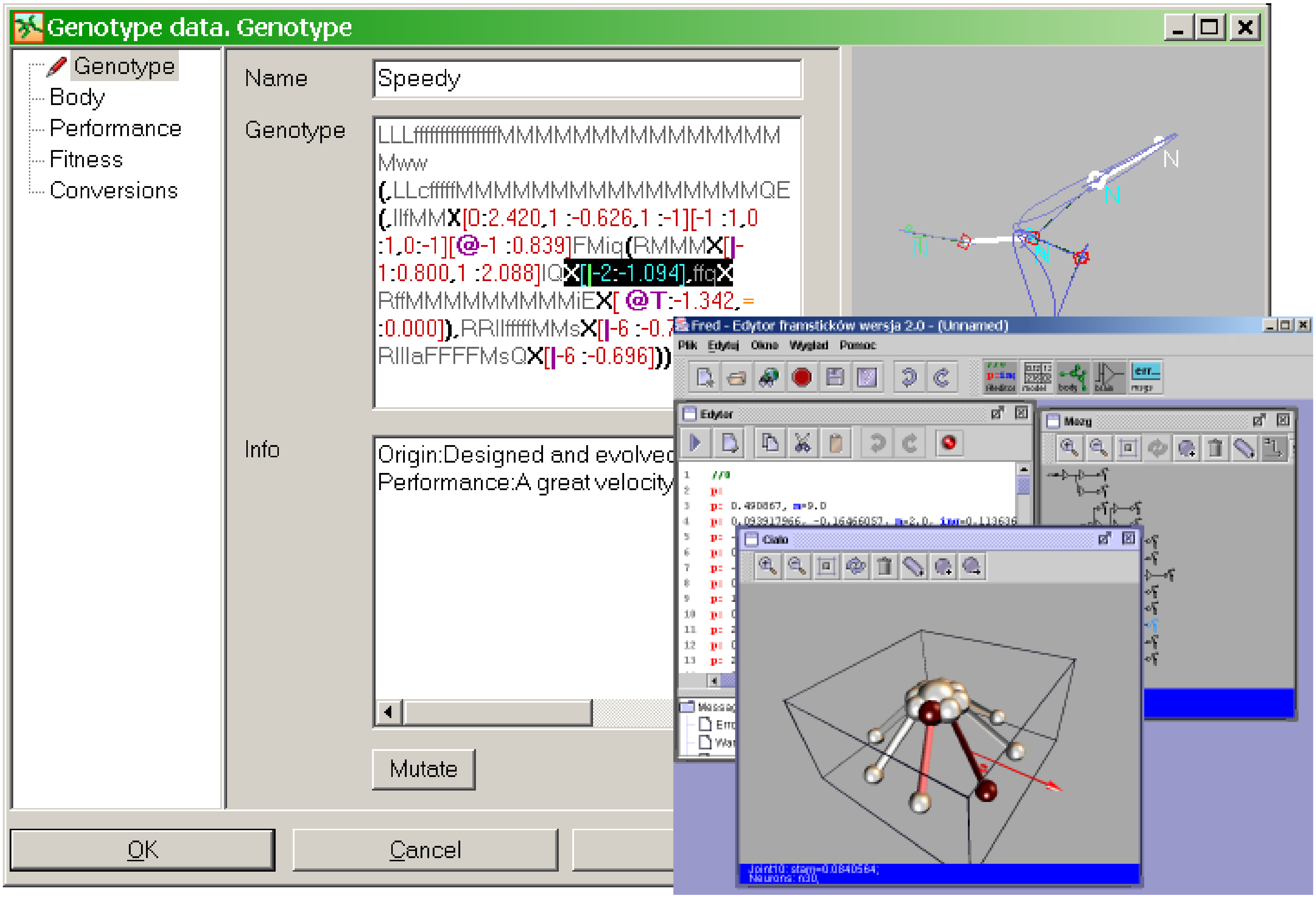
Sample uses and experiments

- synthesizing (building) agents
- studying agents' behaviors
- optimizing agents
- designing genetic representations
- studying evolutionary dynamics, coevolution, migration, etc.
- evolving neural and fuzzy controllers
- understanding evolved brains
- evolution of communication
- designing custom user experiments

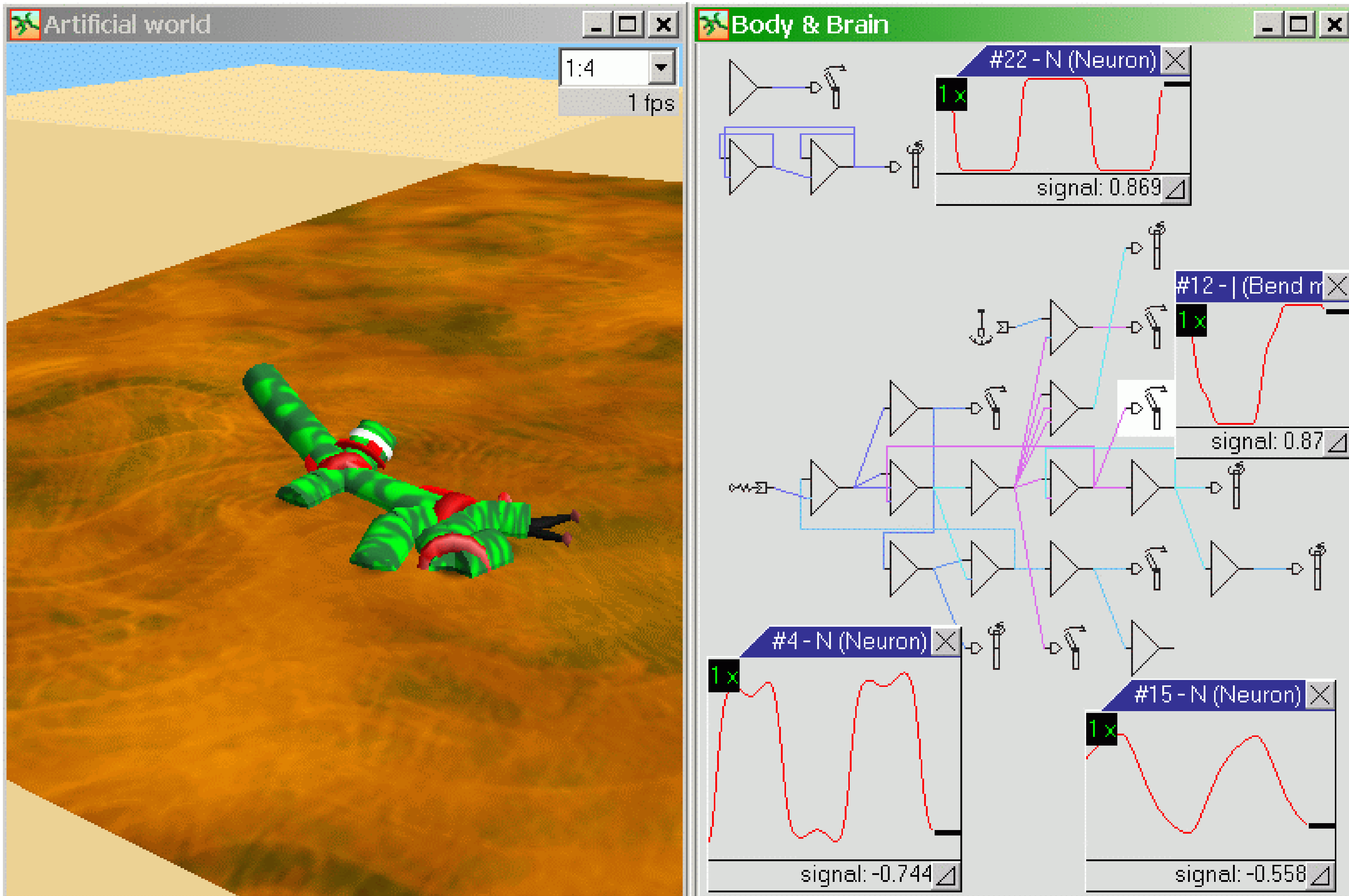
- publications available from the web site

Synthesizing agents

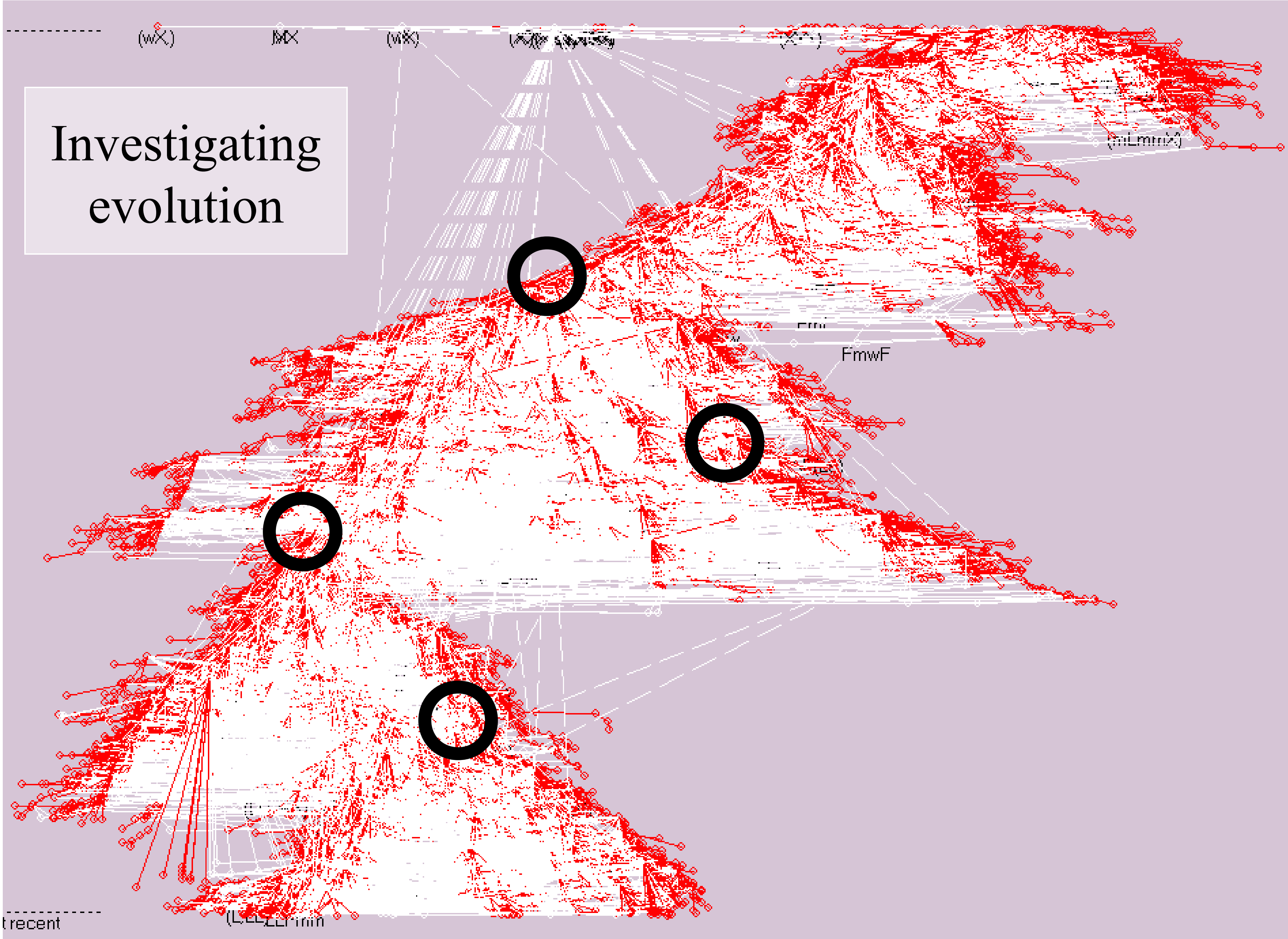
Framsticks



Studying agents' behavior



Investigating evolution



Potential behaviors

- walking/swimming/jumping/rolling/...
- memory
- predation, prey
- symbiosis, cooperation
- mutual identification and location
- preferences, group/social behaviors
- communication
- feelings, consciousness, ...?
- ...they discover, learn and utilize simulator imperfections!

Framsticks
body & brain coevolution

(Kōan 4 and 6)

Reading:

Maciej Komosinski and Adam Rotaru-Varga. Comparison of different genotype encodings for simulated 3D agents. *Artificial Life Journal*, 7(4):395-418, Fall 2001. **[view pdf]**

Goals

- co-evolve bodies and brains
- design various methods of description of body and brain
- study and compare the effectiveness of evolution using these methods
- <u>in a single system.</u>

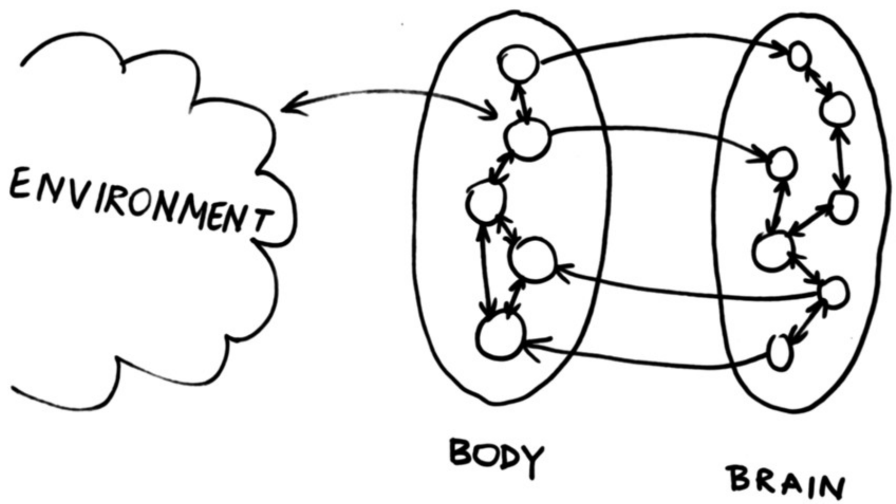
Why to co-evolve brains and bodies?

- because it yields better results than with body separated from brain
- because it is natural

- embodiment: physical interactions (between body parts, signal processing) perform computations, a part of overall behavior
- brain and body strongly connected
  - evolution of body changes the cognitive space of the brain (e.g.: an eye placed on a limb, new senses)
  - evolution of brain changes usage of the body
- co-evolution: can cause change even in the absence of environmental change

What is the trouble?

- the ‘matching’ problem
  - parts of brain (neurons, nodes) must be connected to parts of body (sensors, actuators)
  - if matching is explicit, it can be disrupted by the change of either side, which can be catastrophic
- both are variable size
- crossover on complex representations



General problems in optimization of realistic autonomous agents

- Infinite search space
- Discrete-continuous space
- Hard to define neighborhood
- Solutions contain varying amount of information
- Hard to choose representation
- Very strong dependencies and connections between parts of a solution
- Evaluation function with many local optima
- Many non-feasible solutions and diverse constraints
- Non-determinism and complexity of evaluation
- Multi-criteria evaluation, complex definition of criteria, evaluation delayed to action
- Hard to estimate the time needed for evaluation and optimization

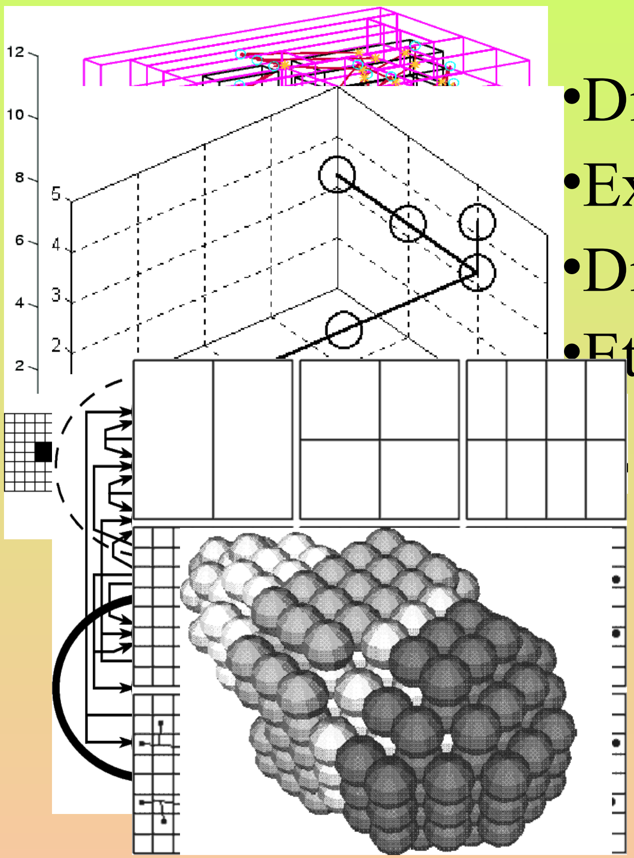
...the big problem is size and nature of the search space

Genetics is important because each representation and its operators

- establishes different structure and order in the search space
- defines important information and ‘building blocks’ in another way
- is scalable in a different degree
- introduces different bias which leads to finding qualitatively different solutions
- imposes diverse local optima and displays various levels of robustness against being trapped into them
- can limit the space of valid solutions in a particular way
- has a specific degree of coherency, redundancy, easiness of interpretation, etc.

Current artificial genomes – very diverse

Simple (direct)



Complex (biologically inspired)

- Different base
- Explicit / implicit
- Different systems
- Etc…

No comparison possible!

What is the best representation?

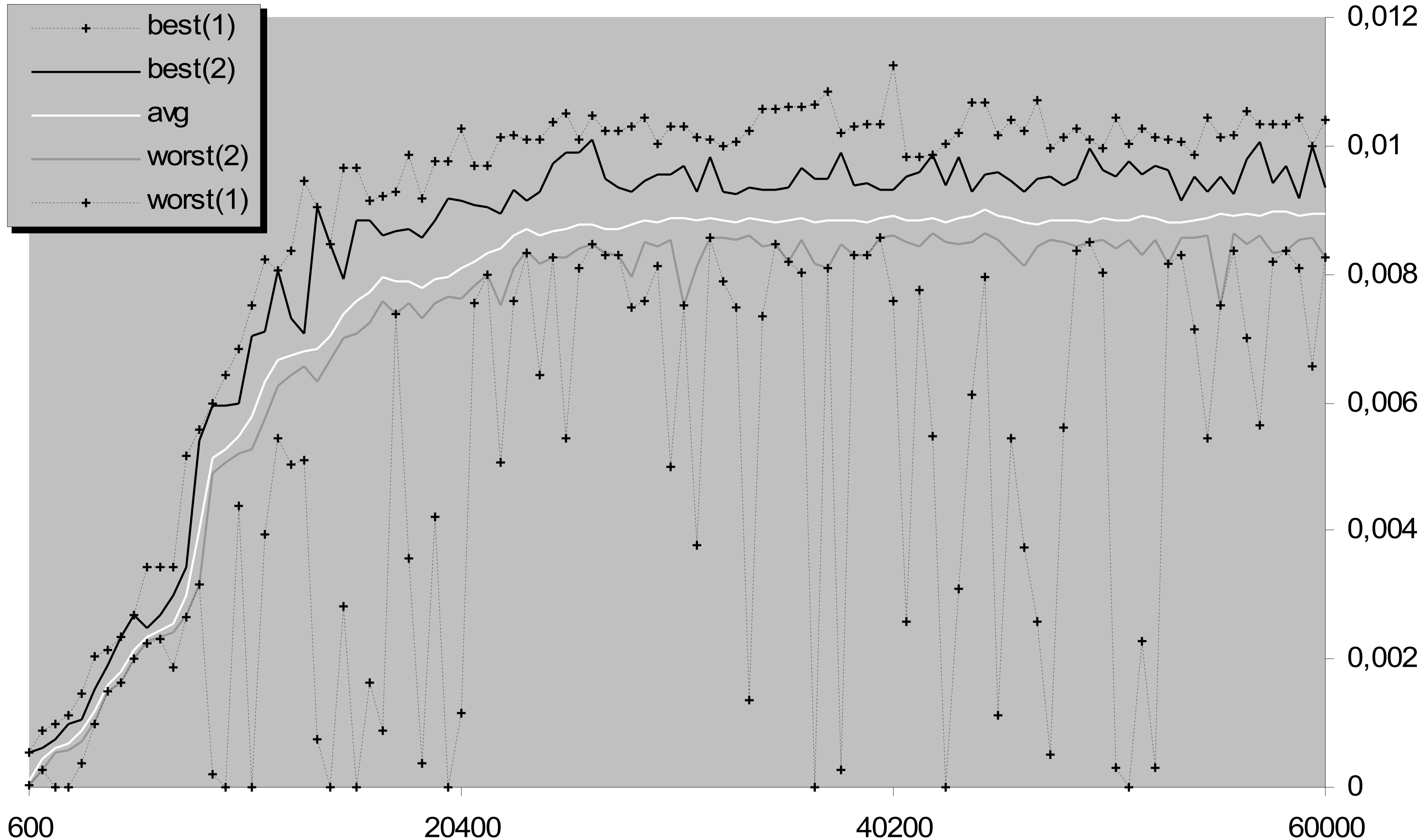
- Fitness values
- Nature of solutions
- Simplicity
- Understandability

Experiments

- 3 one-criterion tasks
  - Average height of agent center (maximize; NN turned off)
  - Average height of agent center (maximize; NN turned on)
  - Average velocity (maximize)
- 10 runs for each task and each genotype format (***simul***, ***recur***, ***devel***)
- 90 runs in total
- System main parameters
  - Steady-state
  - Population size: 200
  - Cloning probability: 20%
  - Crossing over prob.: 16%
  - Mutation prob.: 64%
  - Stabilization period

Show

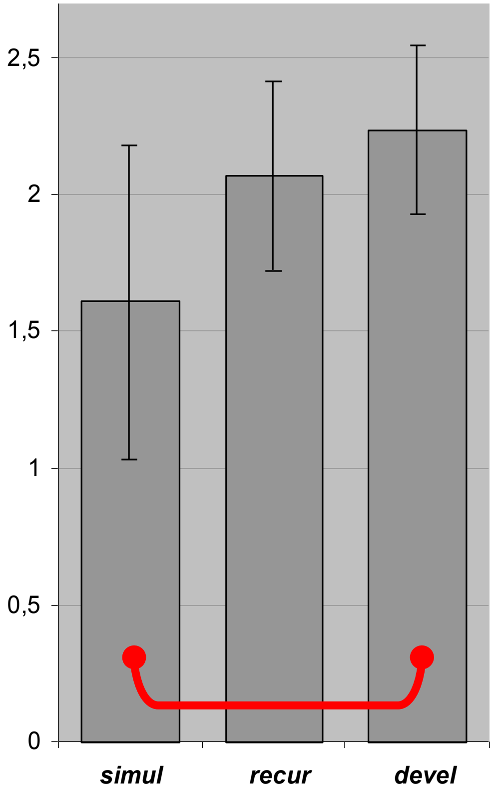
Non-deterministic evaluation



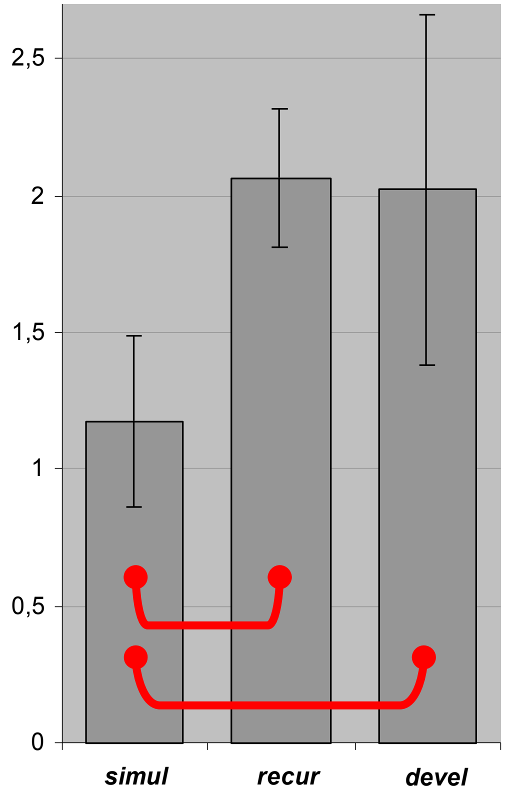
Results (Quantitative)

Genetics experiment

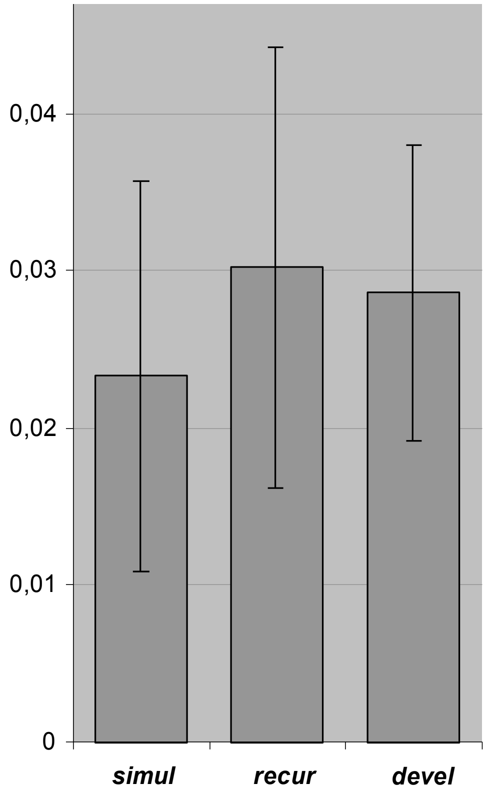
Height passive



Height active

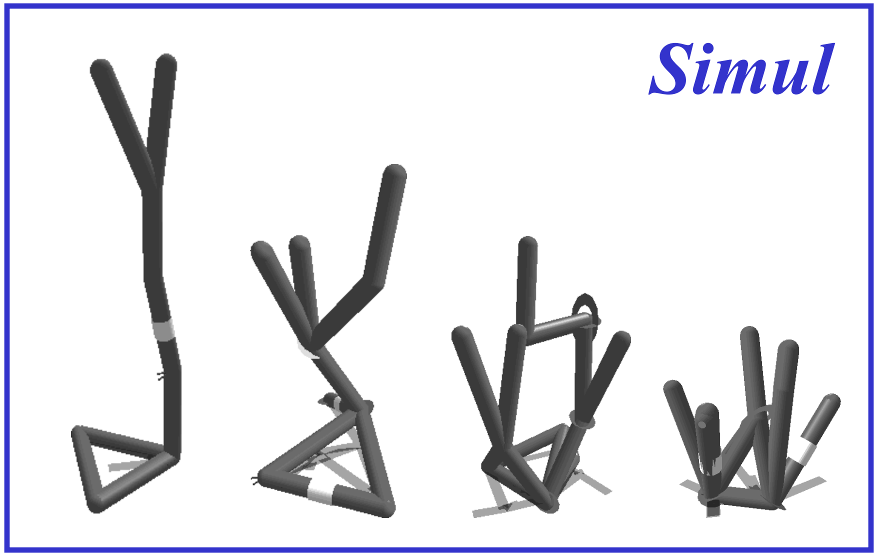


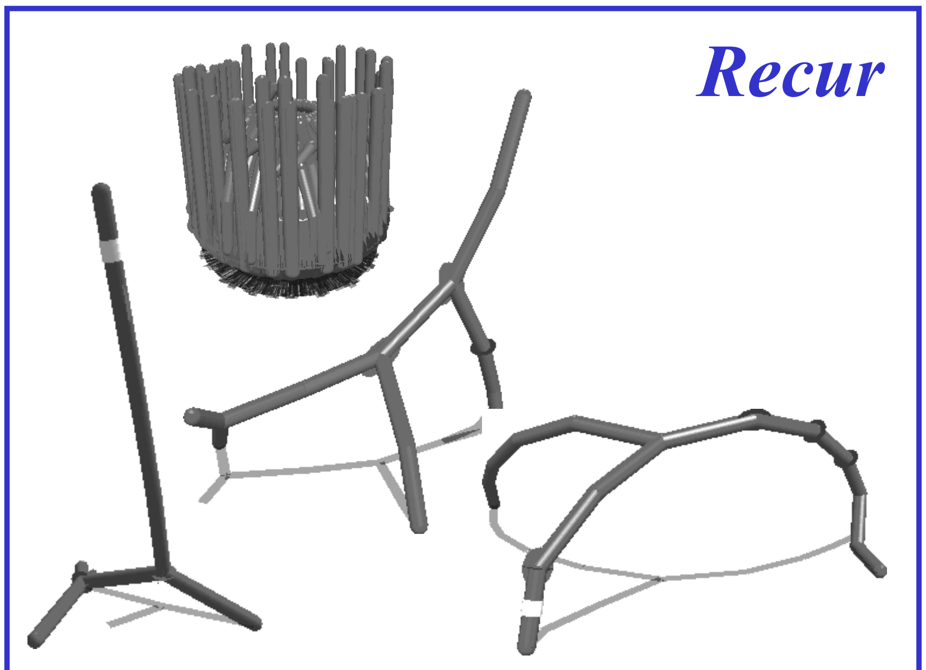
Speed

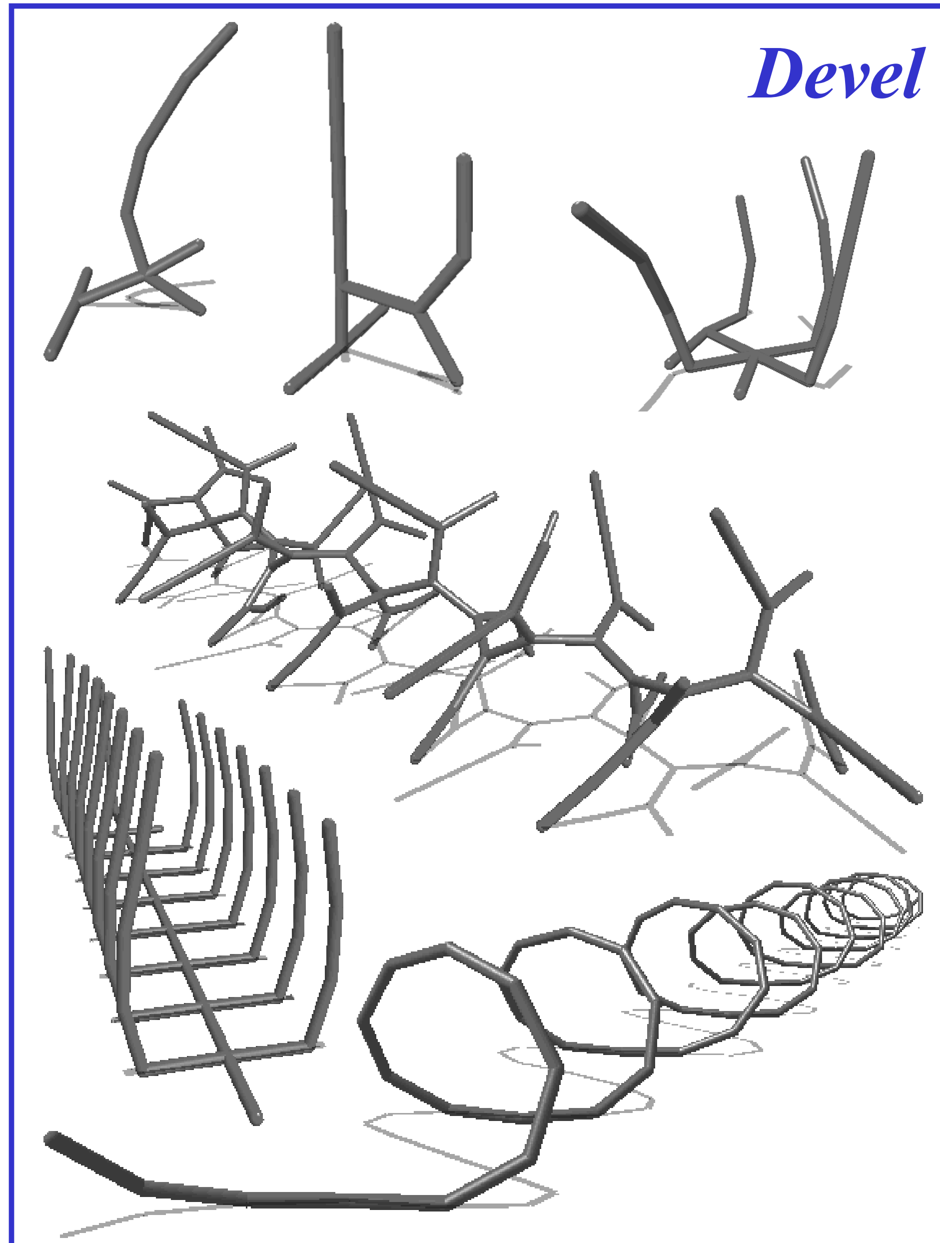


Genetics experiment

Results (Qualitative; height passive)







Conclusions

- ***Simul*** representation with full abilities of expressing agents was the worst one
- The limitation of the search space by higher level representations has not deteriorate results, but has improved them
- The most advanced ***devel*** encoding was not significantly better than ***recur***
- Each higher-level representation introduces a specific bias and new quality (characteristics) into solutions
- For all representations, the best individuals were successful in terms of fitness value. It was difficult or impossible to construct better agents by hand, mainly because of high time costs
- It may be sometimes worthwhile to introduce advanced mechanisms into a representation, in order to obtain different nature of solutions, even when they are not improved in terms of fitness

Genetics experiment

Conclusions, cont.

- punctuated equilibria
- convergence
- exploitation of simulator imperfections
- redundancy, randomness
- many strong (implicit) dependencies inside agents