

Evolutionary Robotics

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Ecole Polytechnique Fédérale de Lausanne (EPFL)

Laboratory of Intelligent Systems (LIS) – Prof. Floreano





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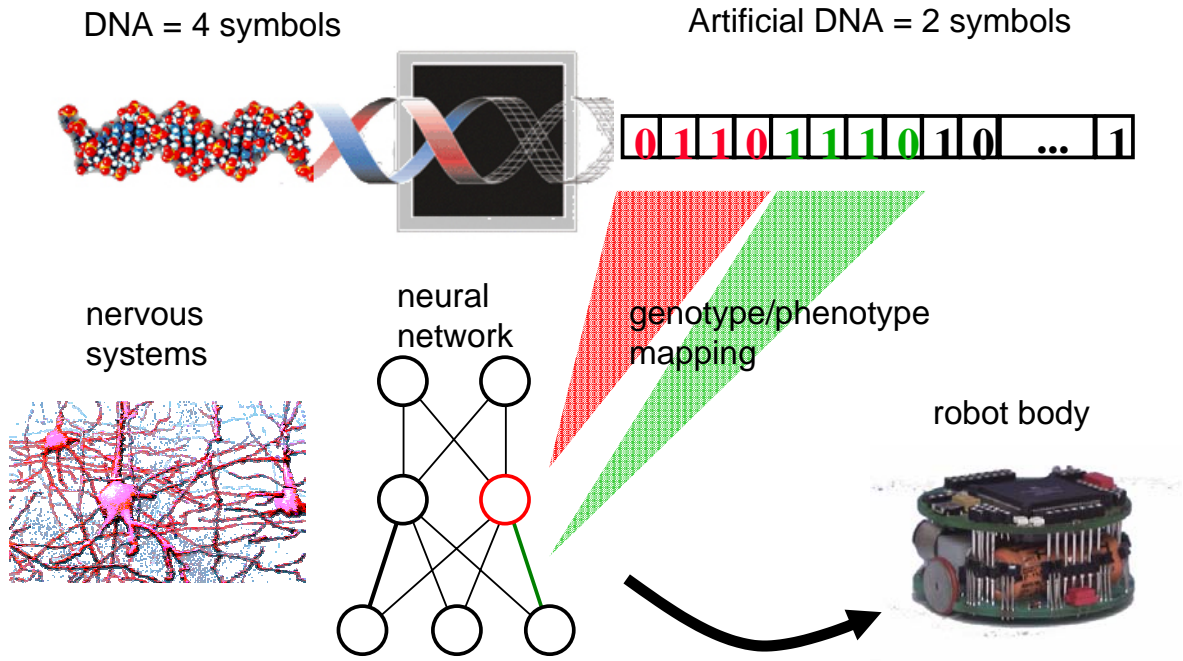
Evolutionary Robotics

- Evolutionary Robotics (ER) is **automatic generation of control systems** (and/or morphologies) for **autonomous robots** based on the **Darwinian principle** of selective reproduction of the fittest.

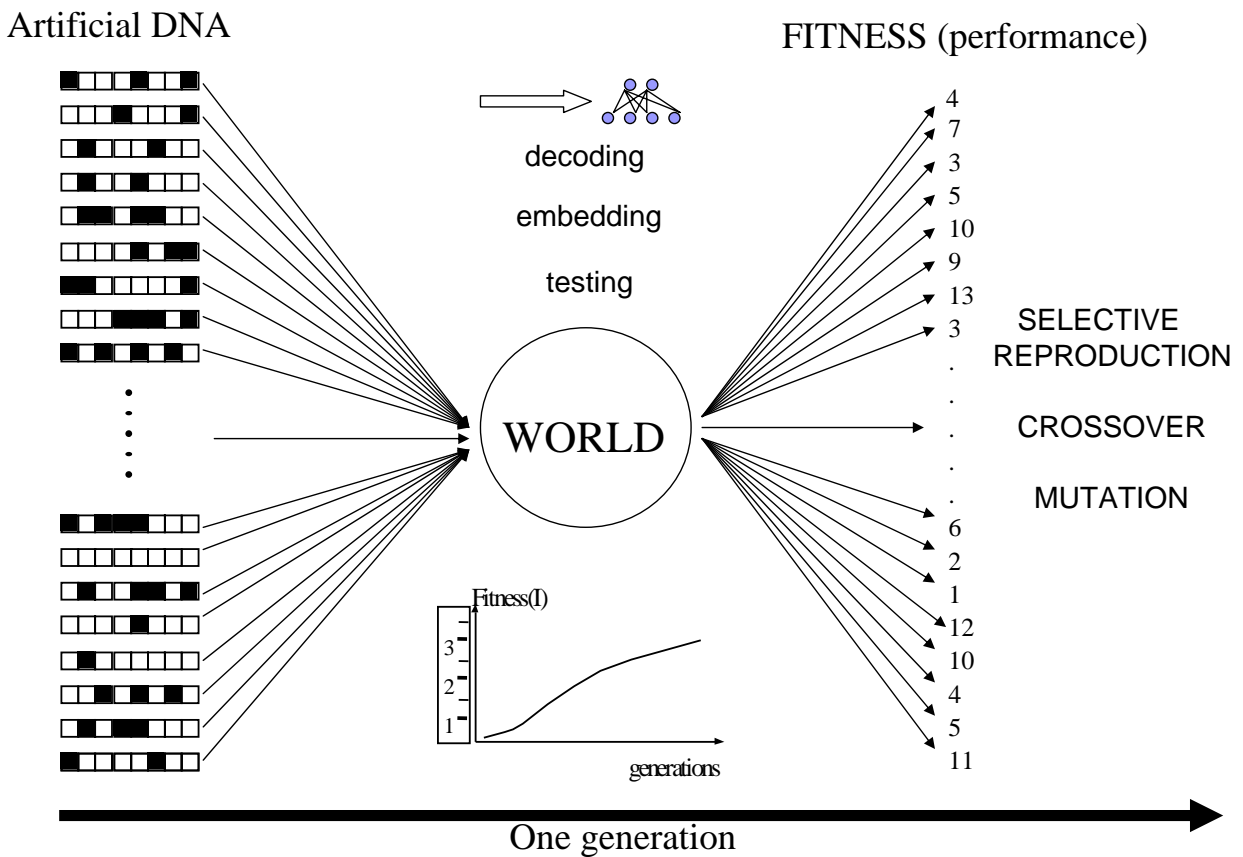
- Motivation: it is difficult to design autonomous systems using a purely top-down engineering process because the interaction between an autonomous robot and its environment is very complex and hard to predict.

- In ER the engineer defines the components of the control system and a selection criterion and lets artificial evolution discover the most suitable combinations while the robot interacts with the environment.

Evolutionary Robotics Toolbox

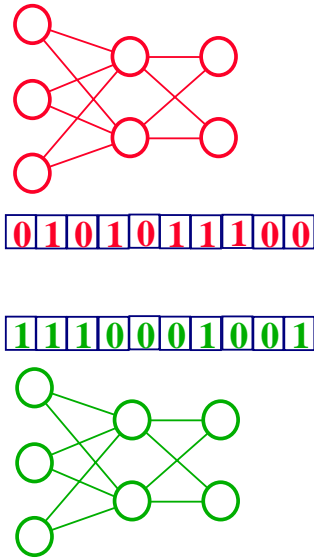


Artificial Evolution

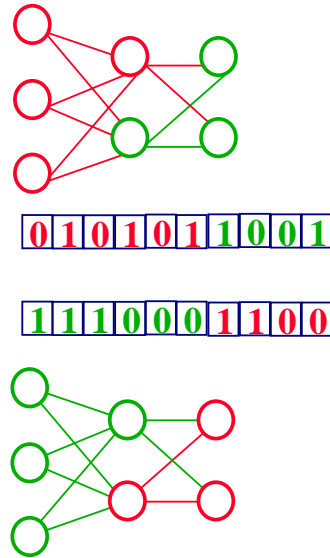


Genetic Operators

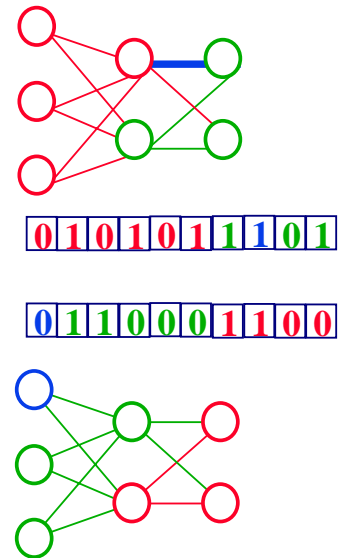
SELECTION



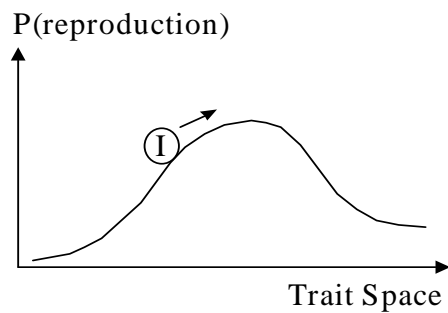
CROSSOVER



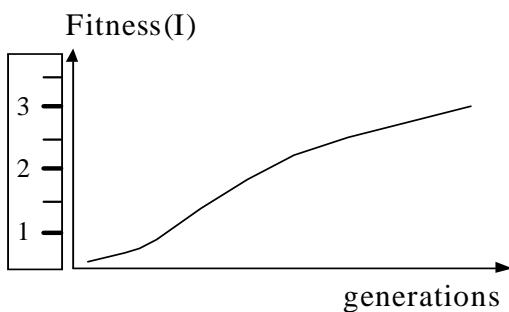
MUTATION



Fitness Landscape & Fitness Graph

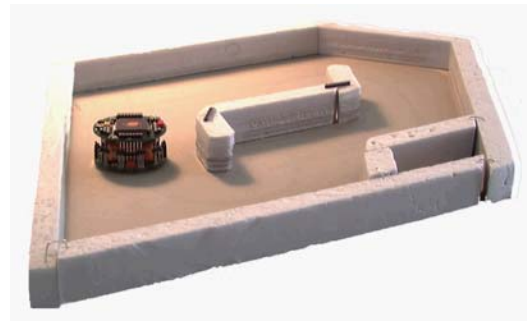
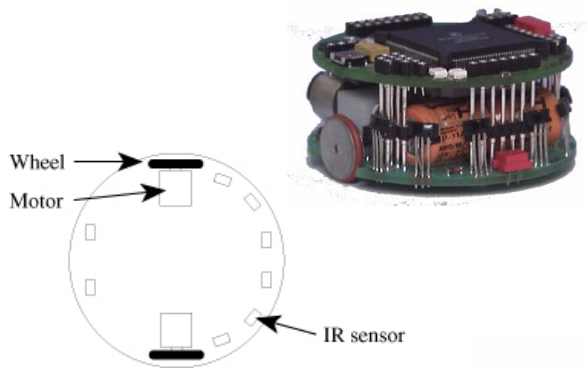


The **fitness landscape** shows the performance of all the possible phenotypes (neural networks) in genetic space. In most cases, it cannot be visualized but indirectly explored by the process of artificial evolution.

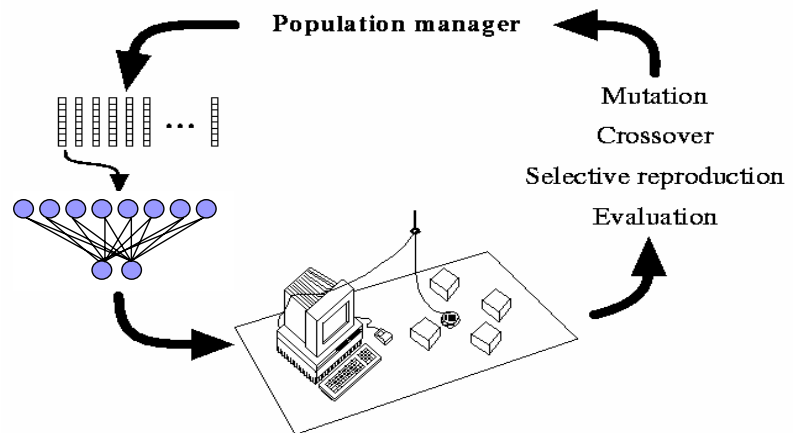
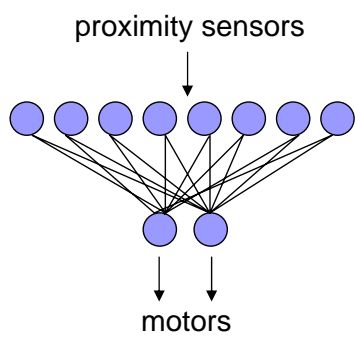


The **fitness graphs** are a measure of performance during an evolutionary run.

Simple Navigation

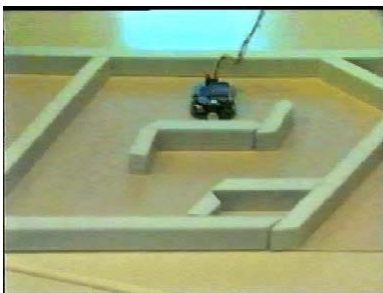


$$\text{Fitness} = V \times (1 - \Delta v) \times (1 - s)$$

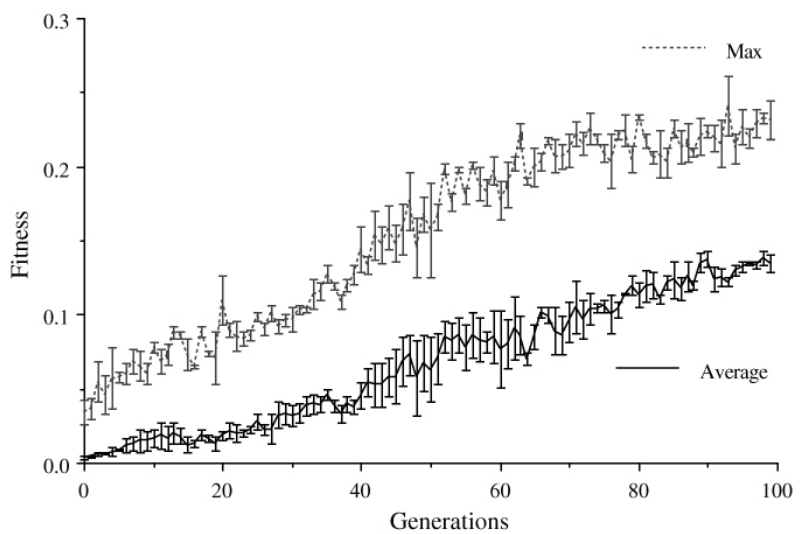
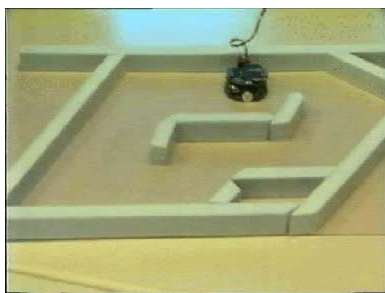


Results

Initial generation



After 100 generations



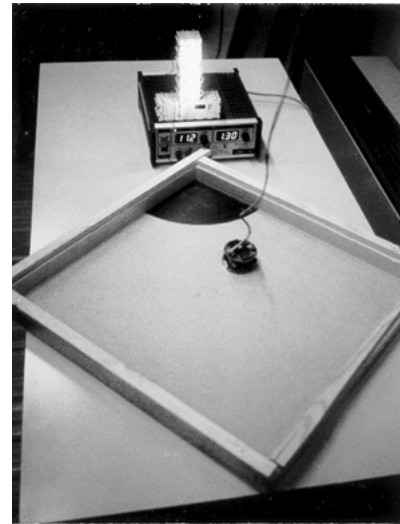
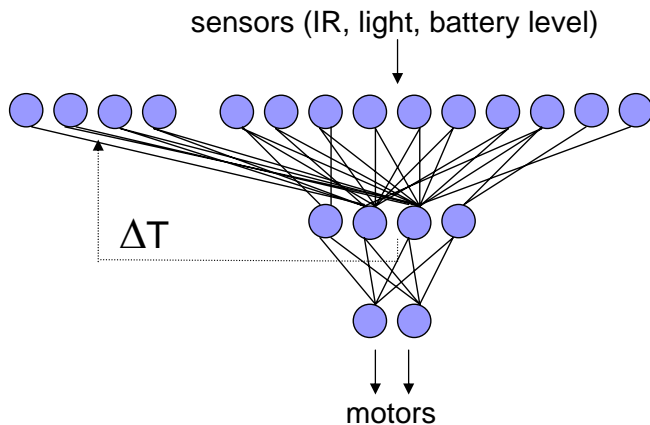
Video clips available at

<http://lis.epfl.ch/resources/documentation/EvolutionaryRobotics>

Homing and Energy Management

■ Robot

- Virtual battery lasting only 20 sec
- Maximum life time of 60 sec
- Even simpler fitness function



■ Environment

- Virtual charger in a corner (no fitness)

$$\text{Fitness} = V \times (1-s)$$

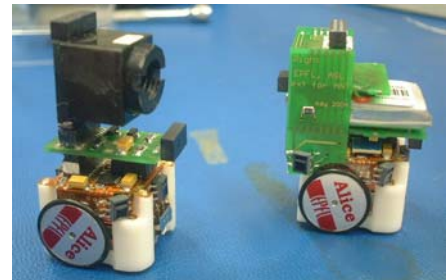
Results

After 240 generations, we find a robot capable of moving around and going to recharge 2 seconds before the batteries are completely discharged.



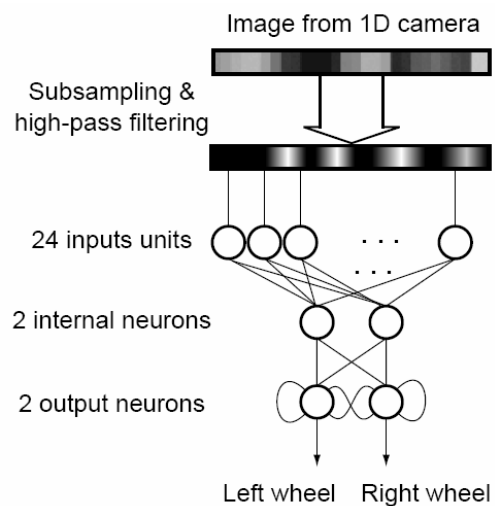
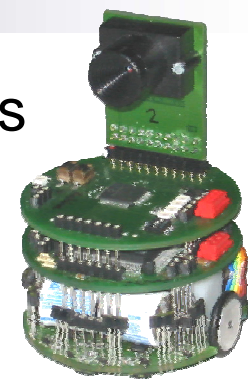
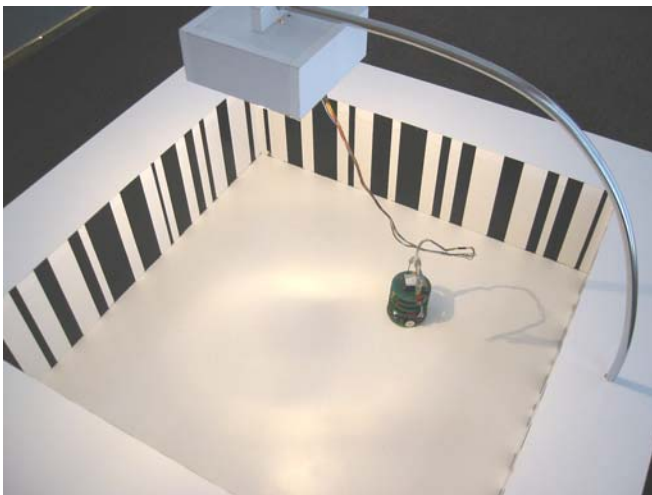
Evolution of Cooperation and Labour Division

- Provide methods for automatic generation of cooperation and labour division
- Investigate the role of relatedness and levels of selection on the evolution of cooperation and labour division in social insects.



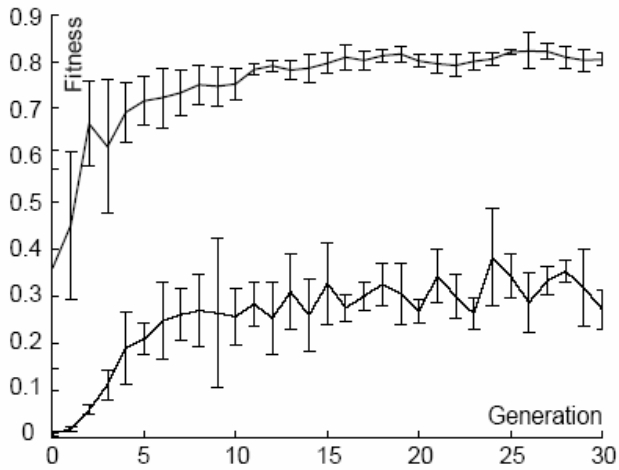
Video clips available at <http://lis.epfl.ch/research/projects/EvoAnts>

Vision-based Navigation on Wheels

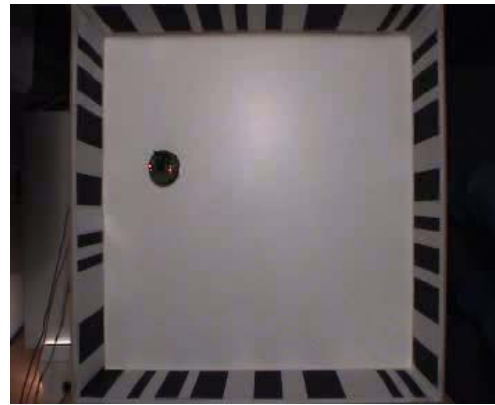


$$\text{Fitness} = V_{\text{forward}}$$

Results

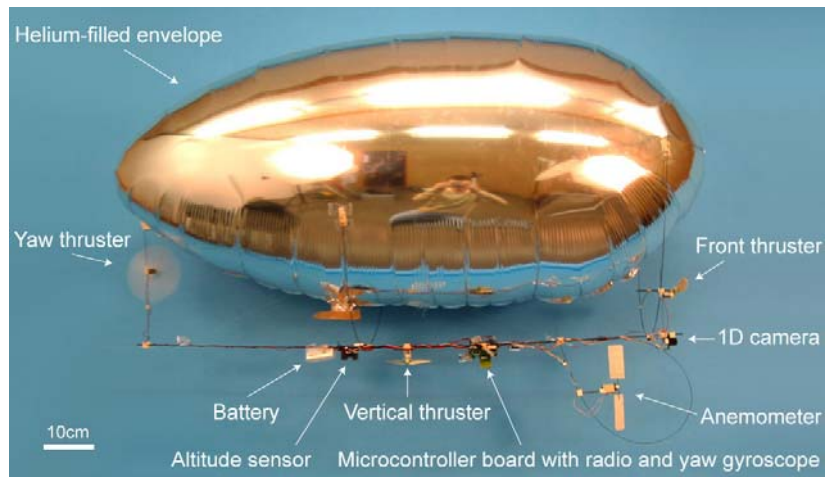


Video clips available at <http://lis.epfl.ch/research/projects/BioinspiredFlyingRobots>

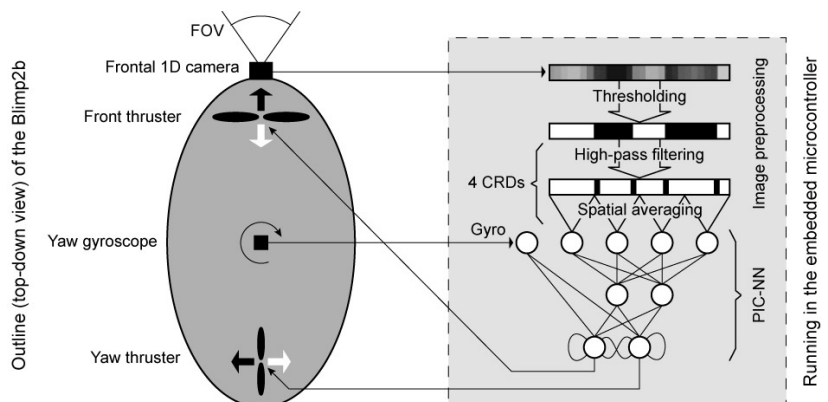


Flying Robot

- Lift capacity: 100g
- 8-bit micro-controller
- Bluetooth radio module
- 1D camera
- Rate gyroscope
- Anemometer



$$\text{Fitness} = V_{\text{anemometer}}$$

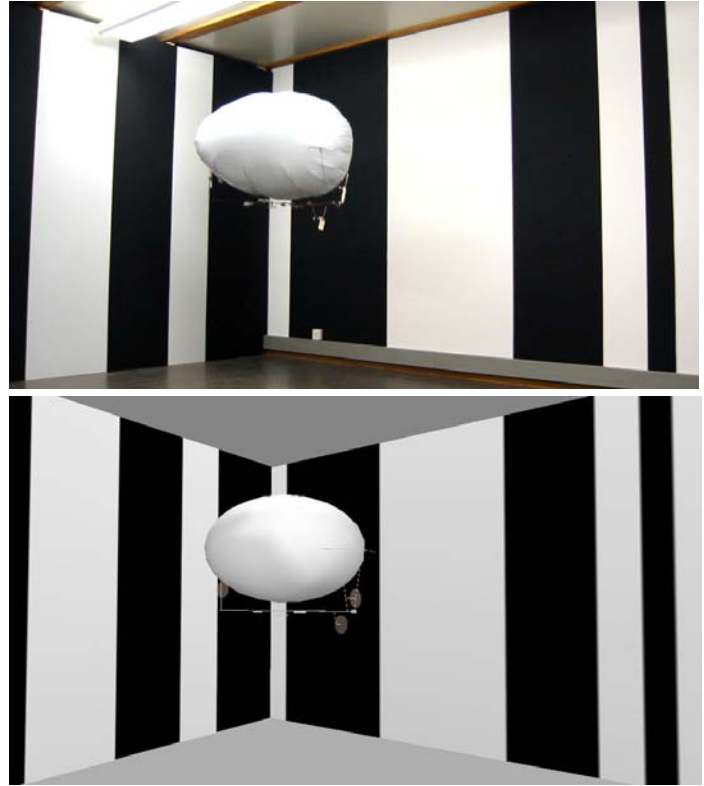


Environment & Simulation

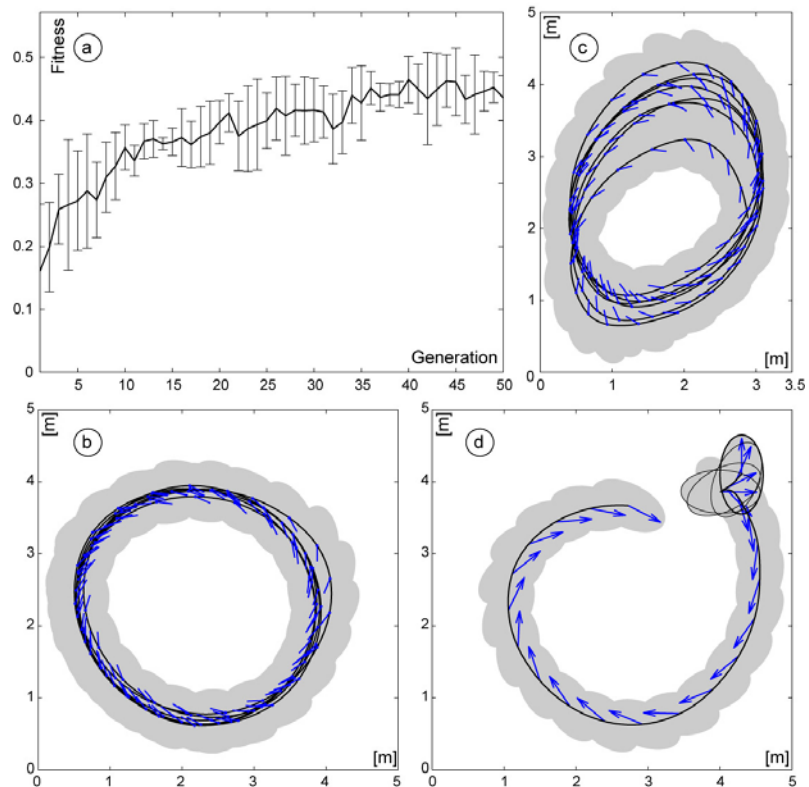
- Square environment with randomly distributed black and white stripes
- An example of what the robot sees:



- Evolutionary robotics applied to flying robots requires
 - robust platforms
 - or
 - realistic simulation

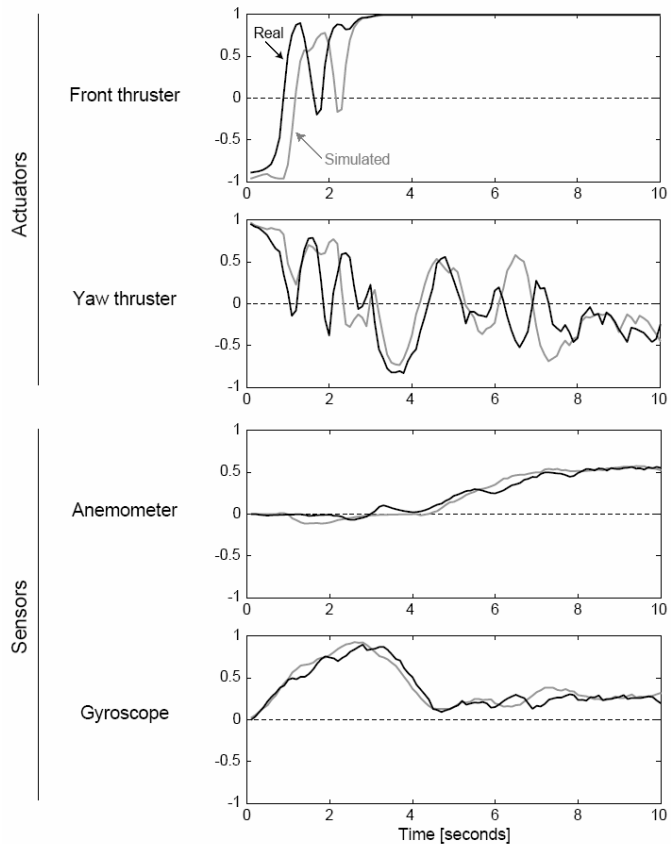
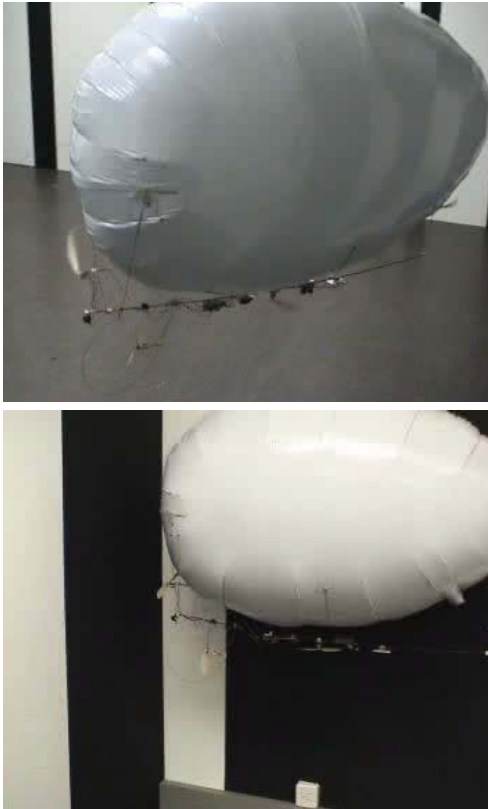


Results in Simulation



Transfer to Reality

Video clips available at <http://lis.epfl.ch/research/projects/BioinspiredFlyingRobots>



What's next?

- Demonstrate the ability of Evolutionary Robotics to cope with
 - uncontrolled environments
 - very limited payload
 - strong energy constraints
 - few processing resources

The *miniCeline* from DIDEL: an example of a 6-gram airplane capable of flying in office-like environments.



Video clips available at <http://lis.epfl.ch/research/projects/BioinspiredFlyingRobots>



Thanks for your attention.

Information, publications & video clips: <http://lis.epfl.ch>