Evolving and Breeding Robots

Henrik Hautop Lund

Orazio Miglino

Presented by
Lingqiang Ge

Introduction

- Henrik Hautop Lund is a robotic researcher at The Danish National Center For IT research, University of Aarhus. www.daimi.aau.dk/~hhl
- Orazio Miglino is a psychology professor at II University of Naples. gracco.irmkant.rm.cnr.it/orazio/

Abstract

- Investigate simulation-reality relationship.
- Study evolutionary robots' biological hypotheses about animal behaviors by using the same experimental set-ups used by animal psychologists.
- Breeding Robotics: Children, as breeders, evolve LEGO robots through an interactive genetic algorithm, then download the evolved behaviors to the physical robots.

Significances

- Showed how evolutionary robotics can be a powerful biological tool.
- Suggested that incremental learning might be useful for achieving complex robot behavior in an evolutionary context.

Backgrounds

- Artificial Neural Network [1]
- Evolutionary Computation [1]
  - o Genetic Algorithm
  - o Genetic Programming
  - o Evolutionary strategies
- What need to be done? To achieve truly complex robot behaviors.
- Why it has not yet been done? We have no clue how to adequately describe the right fitness function. Yet.

Simulation VS. Reality

- Cost of genetic algorithms directly applied to real robot:

  T=[(500 actions * 3 epochs * 100mSec) * 100population * 100Generations] * 10 initial random seeds = ½ year
- Alterative is to make part of the evolutionary process in a simulated environment and a part in physical environment.
  a) Build an efficient simulator
  b) Develop genotype that produces plastic phenotype (from simulator to real environment).

Investigation

- Few actions and epochs (still physical)

  disadvantage: heavily biased by the initial starting position of the robot.
- Mathematical description of motor and sensor responses of the robot. (simulator)

  Motor response is decided by differential equations.

  disadvantage: assume that the response of all sensor of a robot have the same characteristics.
- Build lookup tables. Sampling the real world through the sensors and the actuators of the robot itself.

  disadvantage: how to sample the data is critical. Must not be biased. Very time consuming for a complicated environment.

Evolving Neurocontrollers

- Having the Khepera robot to perform an obstacle avoidance behavior by moving forward as fast as possible, moving in as straight a line as possible and keeping as far away from objects as possible. Fitness function is:

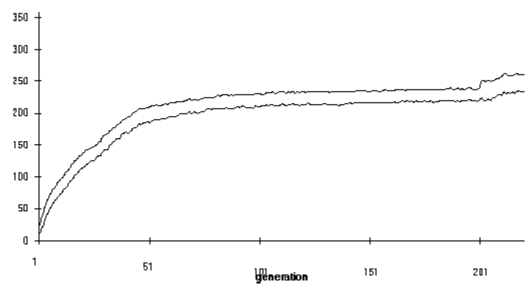
$$F = \sum_{i=1}^{500} V_i (1 - DV_i^2)(1 - I_i)$$

V_i is the average rotation speed of the 2 wheels

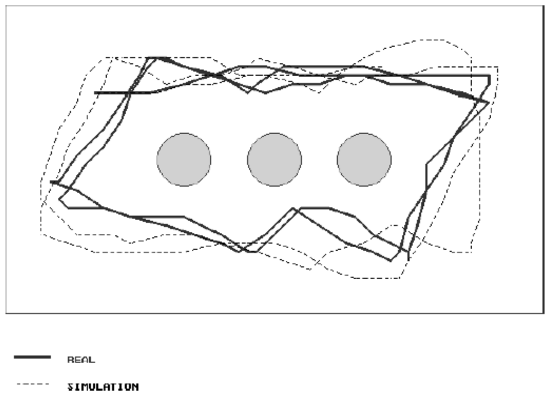
DV_i is the algebraic difference between signed speed values of the wheels.

I_i is the activation values of the proximity sensor with the highest activity at time i.

- Physical environment: 65*35cm walled rectangle with 3 round obstacles of 5.5cm placed in the center.
- The simulator took account the "noises", unpredictable, uncertain effects.(decrease in performance takes place when transferring the control systems developed in a simulator to a real robot in the real environment if noise is not considered.)



- The evolutionary development of the neural network control system takes place for 200 generations in the simulator, and the NNCS is transferred to the real Khepera in the real environment.
- The graph showed no decrease in fitness score. Further, if the evolution continues for 20 generations in the real world, there will be a slight increment in fitness score.



Trajectories of the best individuals of generation 200 of a simulation in the simulated (dashed line) and real (solid line) environment.

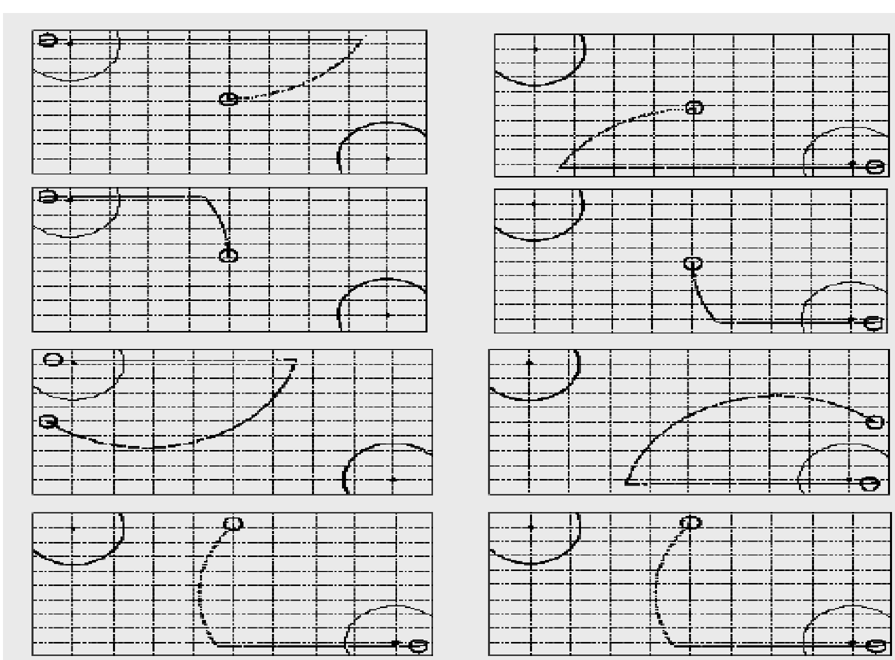
Complex Behaviors

- Rats open field box experiment.[2]
  - ➢Animal psychologists believe that rats use a cognitive map of the environmental shape.
  - ➢A Khepera robot has no capability of constructing internal maps of the surrounding environments' geometrical shape, performed as well as the rats in the same experiment.
  - ➢OFB experiments are not sufficient to conclude a construction of cognitive maps by the rats.

➢ Details of the experiment:

- Our “rat” is a Khepera robot with 8 sensors and 2 motors. Its brain is a a traditional ANN.
- The evolution process is as same as above.
- The best performing neural Network of the last generation was considered as the final control system for he robot rat.

	% Correct	% Rotational Errors	% Misses
Rats	35	31	33
Robots	41	41	18



Suggestions

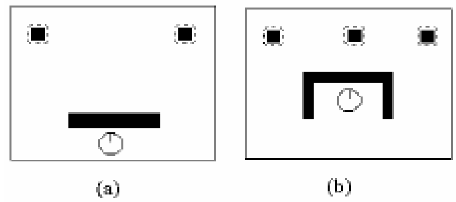
- Animal psychologists should not only report behavioral indexes but also analyze the behavioral trajectories of the animals.

Incremental Learning

- The chick detour experiment.

  implication: Organism is in possession of a spatial representation of the environment that tells the organism where the target is even if the target is currently not visually accessible. Maybe.
- Why 2 day old chicks performed quite well?

  Answer is inconclusive in animal psychology field.



- Robot chick: ANN with a hidden layer (Elman memory unit). equipped a linear camera.
- Fitness function:
  a) How much time the robot spent near the target (< 12cm).
  b) F computed by
$$F = \sum_{i=1}^{500} V_i (1 - DV_i^2)(1 - I_i)$$

Reward if : fast and straight
Punish if: too close barrier or wall
Ignore F if: close to target.

- Robot was not able to learn the task if being put directly under the environment with a U shaped barrier.
- Strategy of incremental learning:
  - During the first 200 generation, robot live in environment (a). 2epochs*120cycles.
  - Generation 201 began to live in environment (b).
  - In the end, the robot performed the detour task in a similar way to the chicks.

Suggestions:

- Incremental learning is fruitful in achieving complex behavior under careful design of the evolutionary environmental conditions.

Breeding Robots [3]

- EHW: evolvable hardware. An evolvable electro-biochemical system.Body plan should co-evolve with the control system.
- Interactive Evolutionary Robotics:
  - Children, as breeders, pick the robots they like from the population, based on robots behaviors.

- Survived robots copies themselves with applied mutation (less than 10% of the connection weight).
- Repeat until the child satisfy with the behaviors of the LEGO robot.

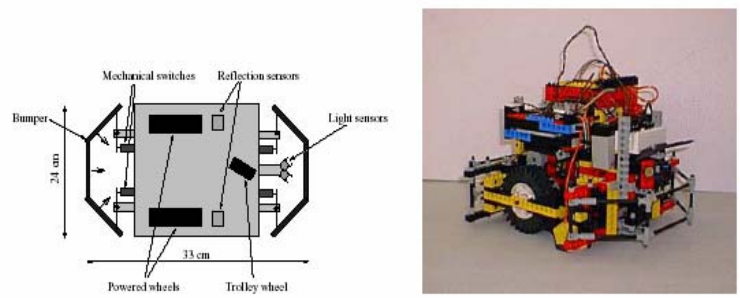


Figure6. Left: Schematic (upper) view of the jeep-like LEGO robot. The robot had three wheels: two powered wheels for locomotion and steering and one passive trolley wheel. The robot received sensory information from 4 mechanical switches mounted within two bumpers, 2 ambient light sensors at its front, and 2 reflection detectors under the chassis. Right: Photo of the LEGO robot. © Lund et al. 1997.

Conclusion

- Carefully designed simulator allows us to test animal behavioral hypotheses directly by evolving robots to perform in identical experiments.
- Incremental learning seems to be necessary when evolving complex animal behaviors.
- Truly complex behavior can emerge from breeding robots. THAT"S THE FUTURE WORK NEEDED TO BE DONE.

References

1. Tom Mitchell ,“Machine Learning”, WCB McGraw-Hill, Boston, 1997, 414 pages.
2. K. Cheng, A purely geometric module in the rat’s spatial representation. Cognition, 23:149-178, 1986.
3. H. H. Lund, O. Miglino, L. Pagliarini, A. Billard, and A. Ijspeert. Evolutionary Robotics ---- A children’s game. In Proceedings of IEEE Fifth conference on Evolutionary Computation, NJ, 1998. IEEE press.