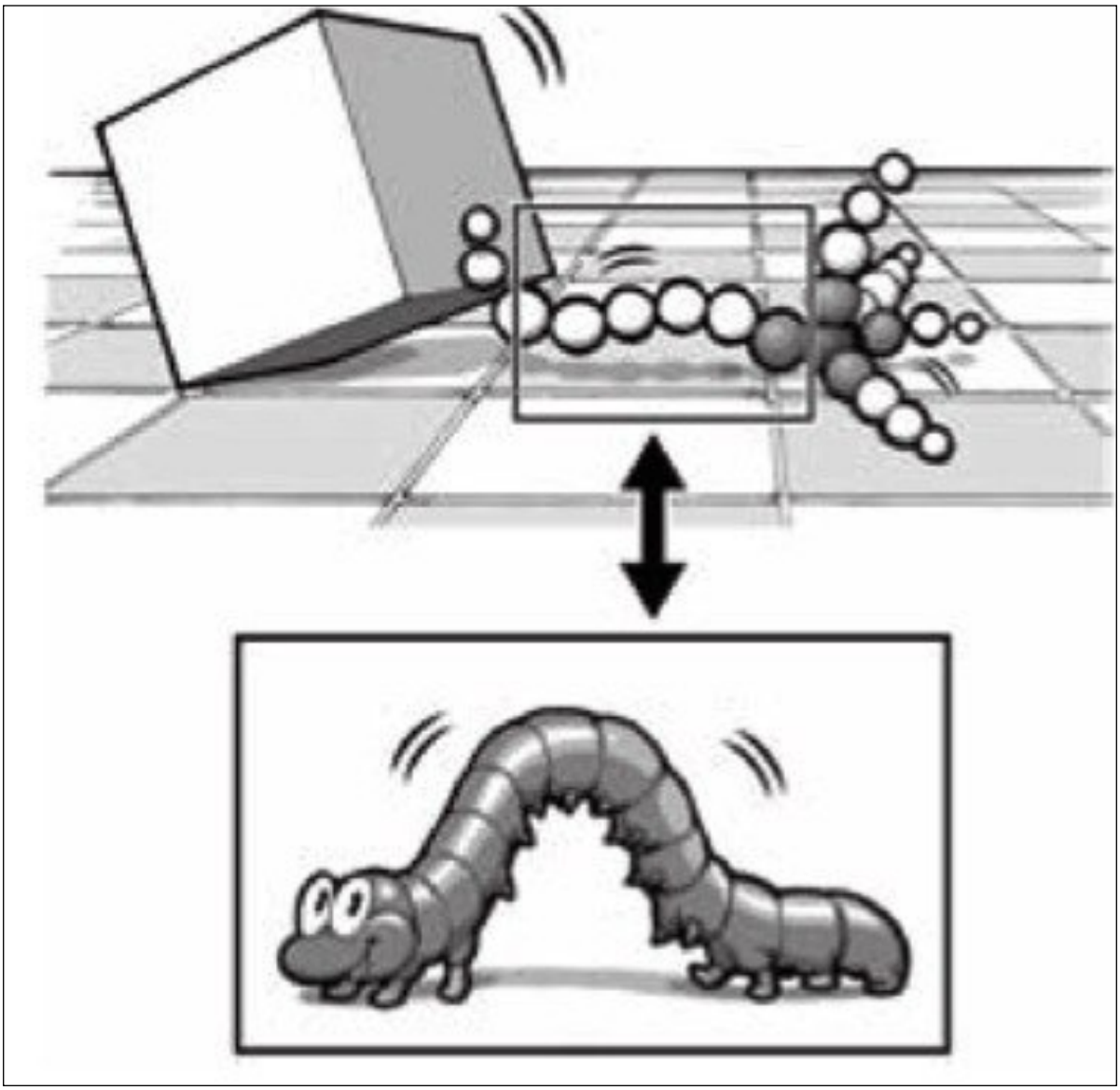
Evolution of brain and body

Shanghai lectures Kōan 6 preliminary design report

Iulia Lungu, Guo Mantang, Enrique Fernández Rodicio, Mathias Schmerling, Ping Xu

December 2014



Introduction

Our Kōan's group goal is to select a robot and explore the evolution of its brain (the control algorithms) and its body (the sensor, actuator and structural embodiment), in a fashion that resembles the natural evolution.

The predicted benefit of jointly evolving the controller and the body of a robot is the better match between the brain and the capabilities of the body this brain controls. As such, the controller will be perfectly adapted to the particularities of the body, taking full advantage of it, while the body will be able to change to better suit the task at hand.

Current status

When deciding what type of robot to choose for our task, the first idea we had was to evolve a Braitenberg vehicle, a robot with the simplest form of behaviour-based AI.
A Braitenberg vehicle is an autonomous robot with basic sensors and wheels controlled by independent motors. Depending on how you connect the information received by the sensors with the movement of the wheels, you can change the behaviour of the vehicle.
Our idea was to evolve the type and position of the sensors and the motors and the control algorithm that would receive the information of the sensors and activate the corresponding motors, so the behaviour of the vehicle would be evolving along with its body.
The idea to evolve the brain and the body of such a vehicle has been inspired by the student presentation on Braitenberg vehicles during the lectures. There it became evident that while the control algorithm is important for the emerging behavior, the position of the sensors is equally important, as small changes to the position can already greatly impact the vehicle's behavior. Another argument to use Braitenberg vehicles is the fact that they can be implemented as wheeled robots, which usually makes it more simple to construct a moving robot.

The second idea was to evolve a walking robot. Evolving the body would mean changing the number and position of the legs and also the type and position of the different sensors, while the mind would be the control algorithm. In order to evolve it, we were thinking of exposing it to different environments, such as a flat surface, a rugged terrain and teach it how to climb steps or avoid obstacles.

The initial proposed platforms we considered to use for the concurrent evolution of brain and body were Webots[1] and Ludobots[2].

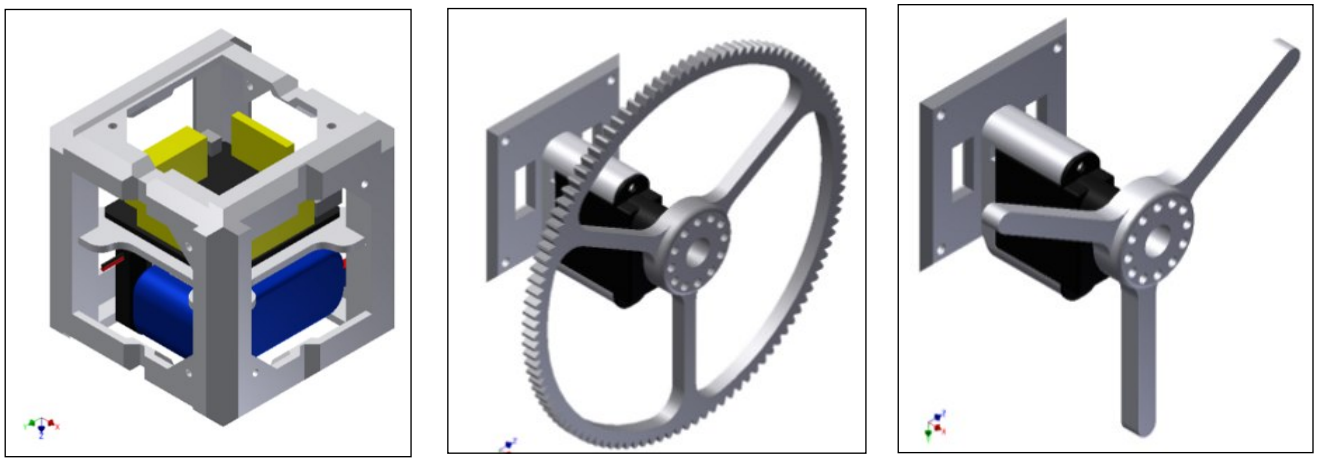
Webots is a flexible program, well documented, providing easy access to multiple examples. It is also being used by a significant fraction of the scientific community, which

can come in handy when troubleshooting. Webots also offers the possibility to implement the Yamor model of modular robots, which could have turned out to be useful when evolving a body.
The most notable shortcoming of Webots is its inability to easily implement the body evolution. In order to change the morphology of the robot, we had to modify XML files, a process which turned out to be difficult and very time consuming.

Due to this problem, we decided to turn to **Ludobots,** which is a software designed for education in evolutionary robotics, created by Josh Bongard, who pioneered in the field on which our Kōan project is based. We therefore thought that the software designed in his lab would be the perfect tool for our project.
However, it turned out that this platform also provides only limited support for body evolution, therefore we started discussing the possibilty of using the **Open Dynamics Engine** (ODE) directly to implement a brain-body-coevolution.

This requires us to implement basic building parts, sensors and actuators, flexible connections between them, and a simple control program like a neural network. While we think this would be possible in principle, we believe this is a challenging way to go given the limited amount of time for our project.

Luckily, we discovered what seems like a viable alternative, which is the **RoboGen** project. This software is specifically designed for co-evolution of the brain and body of a Braitenberg vehicle and runs on the ODE. It already provides some of the elements we would otherwise have to implement from scratch, namely building parts, sensors, actuators (wheels, whegs and joints) and a fully connected recurrent neural network. The morphology of the robot is then encoded in a tree-like structure, which represents the genome of the body, while the weights and biases of the neural network represent the genome of the brain. This software would also perfectly resonate with our idea to evolve Braitenberg vehicles, as all the required elements are provided.



Examples of body parts provided by RoboGen

Planned workflow

To sum up, we have discussed two robot models and two possible software solutions to approach the co-evolution of brain and body. The first robot model is a Braitenberg vehicle, equipped with sensors and wheels to ensure simple movement behaviour from the start. The other robot model is a legged robot, which would be more difficult to implement.

We are planning on either using the ODE directly, which would be the more ambitious and challenging alternative, or we will use the RoboGen software on top of it, which would simplify implementation a great deal. In the latter case, we will definitely focus on Braitenberg vehicles, as this resonates perfectly with what the software offers.

After deciding on the platform to use and the type of robot to evolve, the following methods will be applied in order to explore our research question and to come up with optimal results:

- we will create different robots with various initial conditions (i.e. different initial morphologies or starting positions)
- we will embed these robots in multiple environments with different obstacles and terrains
- we will explore the importance of evolving either mind or body by designing several vehicles that either give priority to the body, or to the mind and others in which body and mind will evolve together
- we will evaluate each robot in order to assess how different bodies, evolved along with their controllers, would perform in a given environment, through multiple trials