**Evolution of Brain and Body**

Our koan’s group goal is to select a robot and make it evolve. We will change the parameters that controls the evolution for getting a robot able to perform the task it is programmed to in the better way. In order to do that, we will make different robots, in different stages of evolution, compete among them in several trials, each one of them will test a different capability of the robots. Once we have the results of the trials, we will give a final valuation about what kind of evolution is better. With that objective in mind, we started with a brainstorming about our project and two ideas came out.

The first one was to evolve a Braitenberg vehicle, a robot with the simplest form of behaviour based AI. It 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, as the body of the robot, 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. The idea to evolve the brain and the body of a braitenberg vehicle concurrently 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.

We would then address our research question, that is the benefits co-evolution of brain and body, by designing several vehicles that evolve in different ways, some of them giving priority to the body, others giving priority to the mind and others in which body and mind would evolve together. Then the robots would compete among them in some trials to see which form of evolution is better.

The second idea was to evolve a walking robot, the simplest walking robot we could think of. Evolving the body would mean to change 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. Like the Braitenberg vehicles, several robots would evolve in different ways and then they would compete among them.

(For taking this ideas to the practice, we have chosen Ludobots over Webots as the software we will use. Ludobots was designed for education in evolutionary robotics, so it will be perfect for our work. We considered using Webots because it is a more flexible program and would be easier to find help with any problem because there is more people working with it, but in the end, we rejected that software because is more complex to evolve the morphology of the robot, which is half our work.)

Finally we discussed in which software environment to put these ideas into practice. The first two options we discussed were webots and ludobots. We considered using webots because it is a flexible program and it would be easy to find help with any problem as many people are working with it, but in the end, we rejected that software because it would be very complex to evolve the morphology of the robot, which is half our work. We then looked at ludobots, a software designed for education in evolutionary robotics, which we thought would be perfect for our project. However, it turned out that the software provides only limited support to evolve the morphology of the robot.

We then started discussing the possibilty to use the Open Dynamics Engine (ODE) directly to implement a brain-body-coevolution. This would require 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 see it as challenging way to go given the limited amount of time for our project. Luckily, we also found another alternative, which is the RoboGen software. This software is specifically designed for co-evolution of the brain and body 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.

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 behavior from the start. The other robot model is a legged robot, where it would be more difficult to evolve a moving behavior. We will use either 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.