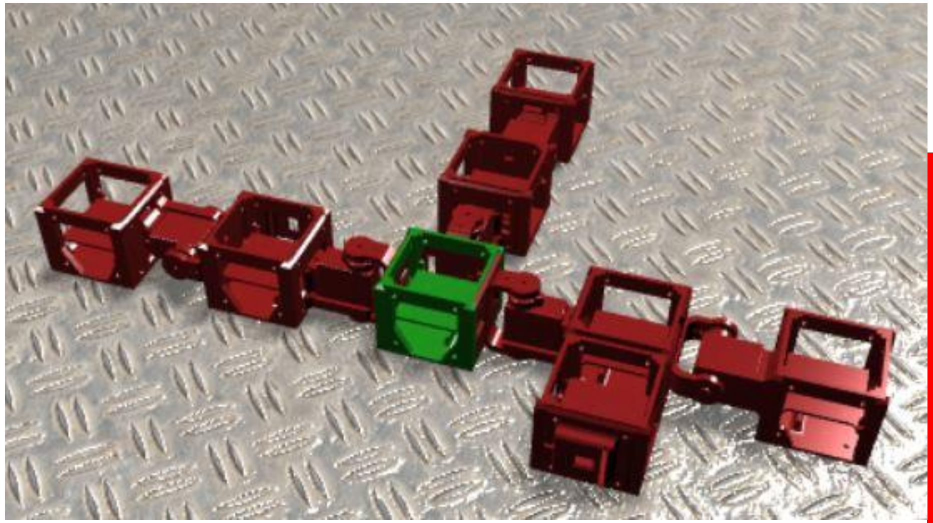

Figure 1: Final image of robot body

RoboGen Project: Group 4

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MICRO-515 Evolutionary robotics

30th of May 2022

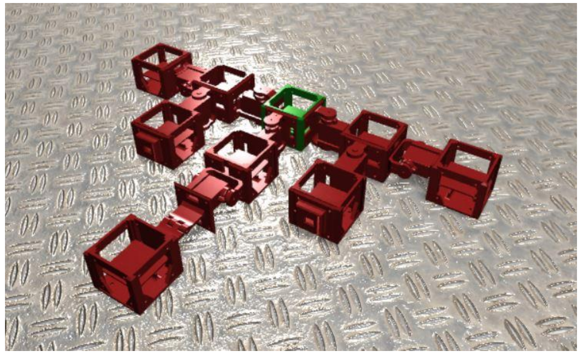
Introduction

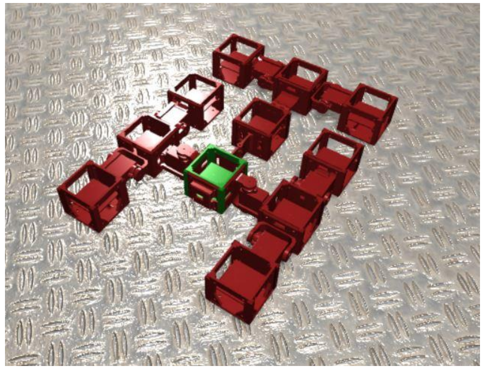
- ➢ In this project, the challenge was to create and evolve a robot for the next Mars exploration rover
- ➢ Its main goal is therefore to be able to locomote as quick as possible on rough terrain
- ➢ It should also be capable of avoiding obstacles
- ➢ Additionally, the core components should be stabilized as mush as possible
- ➢ It cannot have wheels

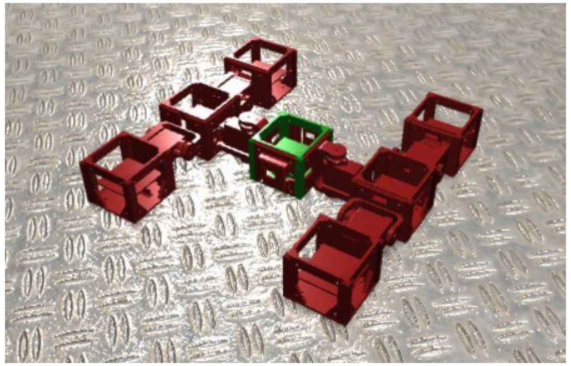
Experimental Method

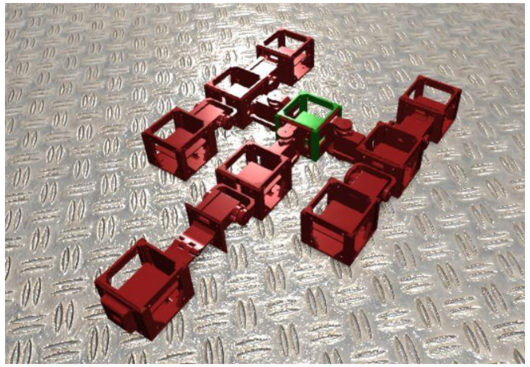
Pre-experimental step

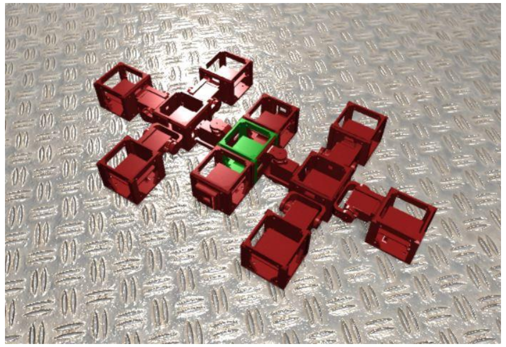
First, we wanted to become familiar with the various body parts, have a better and more concrete first idea of the pros and cons of there dispositions, orientations, … so that we weren’t starting from scratch. It turned out this step was crucial to dive in the evolutions with a much better idea of what to expect. Here are a few examples of robots we tested :

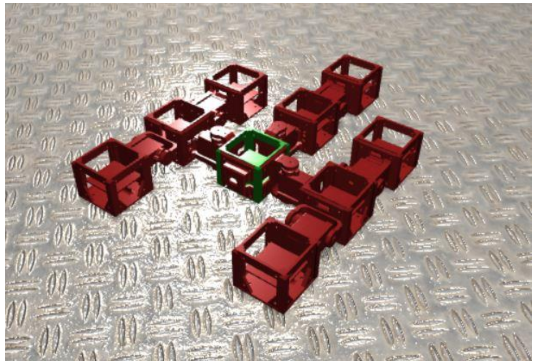


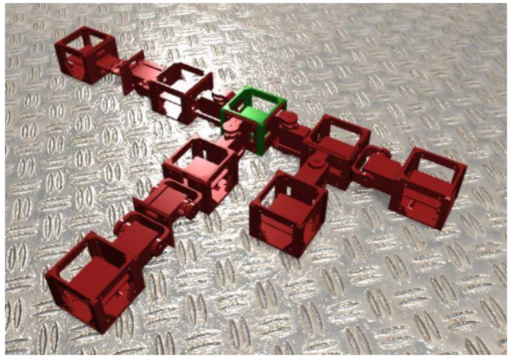


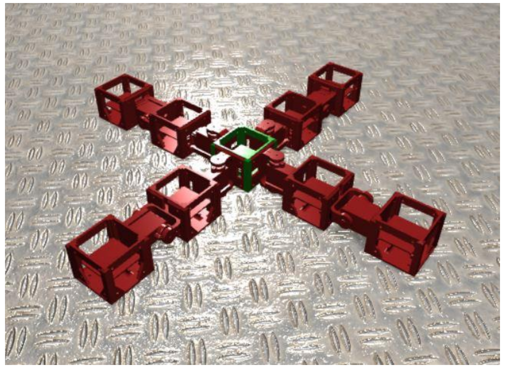












Experimental Method

After the pre-experimental step, we started the real **multi-step** evolution, chosen because the robot has several tasks and conditions to optimize. Our robot was improved through a **5-step** evolution :

- **1 body-brain** evolution, to shape accordingly the robot
- **3 brain** evolutions, to improve the efficiency of the robot and reach the desired features

We started from the **starfish** model, illustrated below on the left, without any brains at first, and evolved it into our final robot, illustrated below on the right :

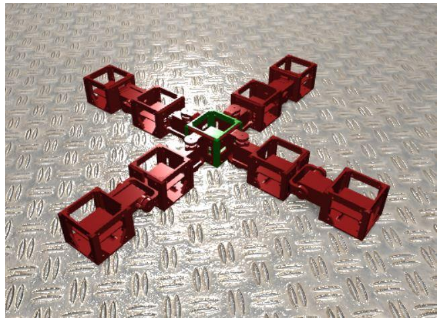


Figure 2: starfish model

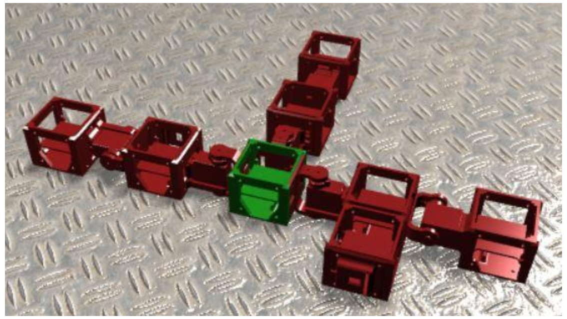


Figure 3: final robot

The reason for that is that the starfish was the **most stable** initial model we could think of, and has already proven to be **very mobile** on numerus videos and even evolutions we performed

Final robot neural network

Outputs Inputs	Hip 1	Hip 2	Hip 3	Knee 1	Knee 2	Knee 3
Core 0	2,93	1,21	1,84	-1,94	-2,66	-1,5
Core 1	3	0,65	-1,7	3	0,27	2,08
Core 2	-0,73	-3	-0,07	1,93	-2,72	-2,15
Core 3	-0,37	-2,14	-1,47	0,72	2,15	-1,48
Core 4	-2,31	2,4	1,25	1,84	0,01	-1,97
Core 5	2,70	0,5	-1,58	1,81	022	2,01
Hip 1	-0,22	1,81	-0,46	1,24	-2,09	0,63
Hip 2	3	-3	-1,47	-1,65	1,72	-1,45
Hip 3	1,63	-0,83	-3	-0,34	0,93	0,06
Knee 1	-2,56	3	1,06	3	-1,7	-2,82
Knee 2	2,67	-2,85	2,52	-1,85	3	2,35
Knee 3	-2,08	-2,13	-0,66	-0,03	0,9	3
LeftSensor	-0,23	3	0,21	-1,12	-1,45	-0,42
RightSensor	-0,03	-0,74	-0,88	-0,89	1,27	-2,35

Table 1 : Neural network of final robot

Experimental Method – Evolution Step 1

- The goal of this first step was to actually **build the body** of the robot

- The arena was chosen to be close to the given arena and do a first simulation of an environment **similar to Mars**

- The evolution started from the starfish model with no brains to reach the final body

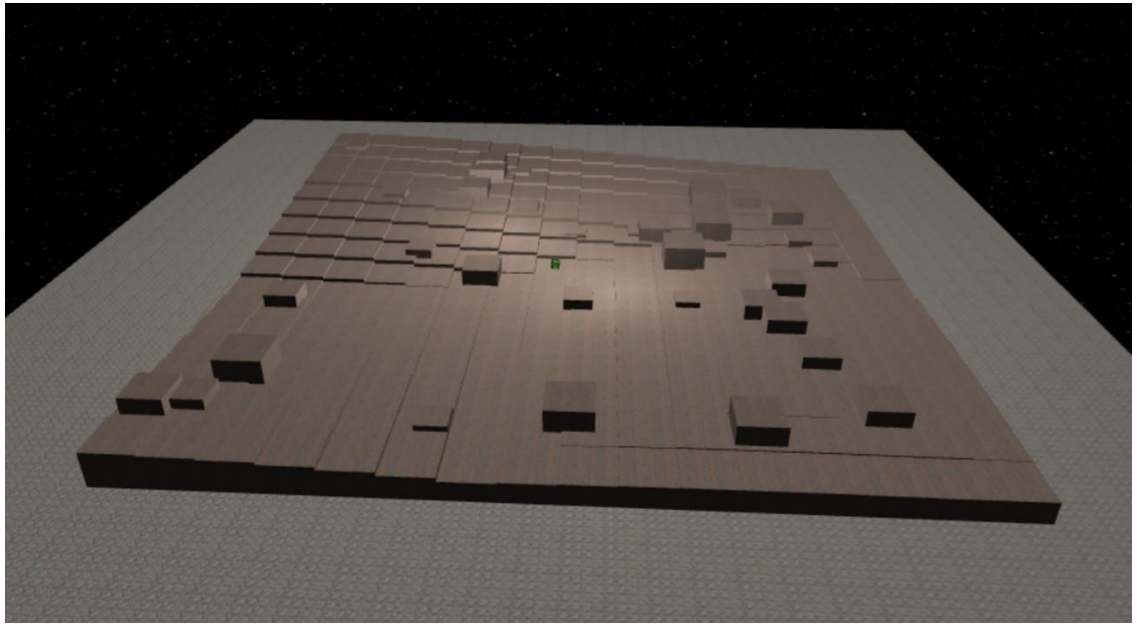


Figure 4: Arena of evolutionary step 1

Friction	Sensor noise	Motor noise	Simulation time	Time-step
1.0	0.02	0.02	16 sec	0.005 sec

Table 2 : Simulation parameters of step 1

μ	λ	Evolution mode	Replacement strategy	Tournament size
20	20	Full	Deterministic-tournament	2

Table 3: Evolution parameters of step 1

Experimental Method – Evolution Step 1

The fitness function had 3 terms :

- Maximize **distance**
- Minimize **instability on the core component**
- Reward the **presence of an IR-sensor**

Conclusion of step 1 :

The resulting robot had an interesting form that we then exploited. It was stable and mobile and had one less leg as the starfish, which meant less components to deal with. We can observe gradually evolving fitness values.

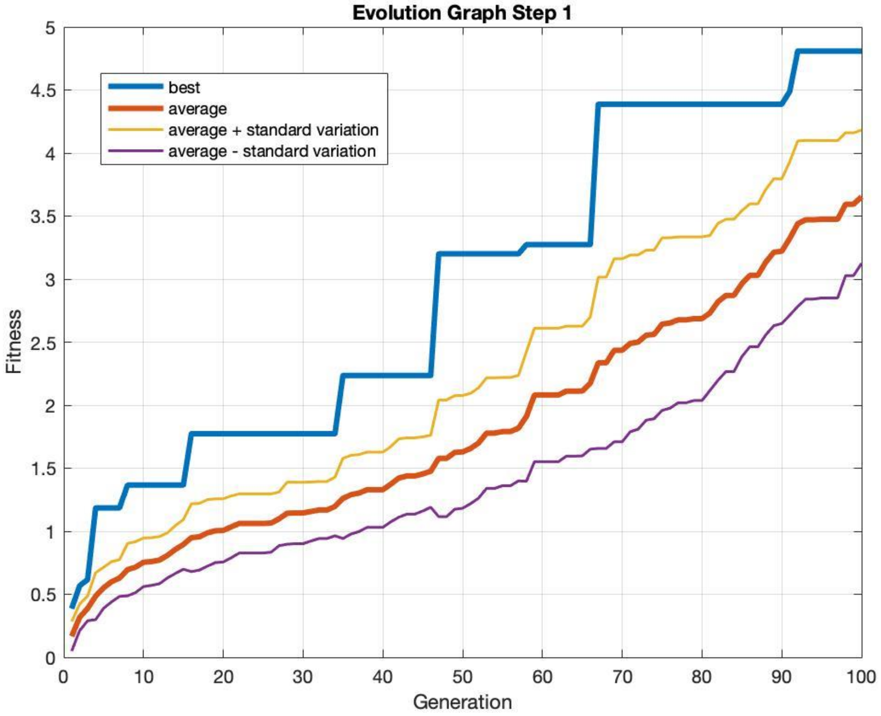


Figure 5: Evolution graph of step 1

Experimental Method – Evolution Step 2

- The goal of this second step was to set the **best position for the IR-sensors**
- This arena provides random obstacles, simulating a **realistic unknown environment**
- We tried different IR-sensor configurations in order to find the most **efficient**

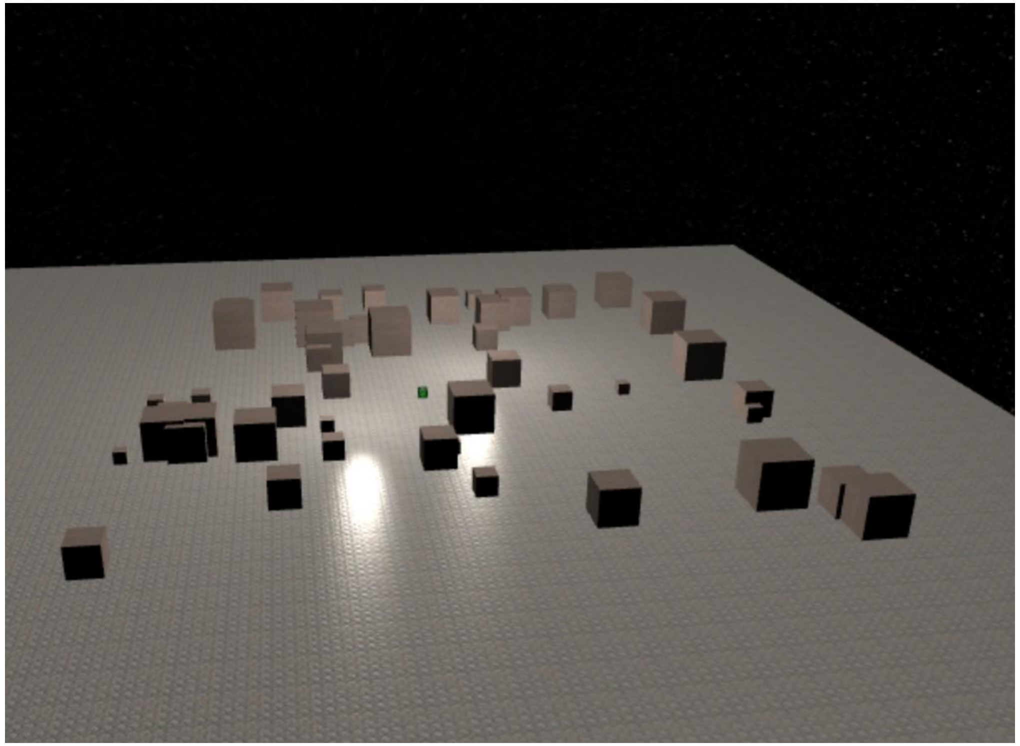


Figure 6: Arena of evolutionary step 2

Friction	Sensor noise	Motor noise	Simulation time	Time-step
1.0	0.02	0.02	16 sec	0.005 sec

Table 4 : Simulation parameters of step 2

μ	λ	Evolution mode	Replacement strategy	Tournament size
20	20	Brain	Deterministic-tournament	2

Table 5: Evolution parameters of step 2

Experimental Method – Evolution Step 2

The fitness function had 3 terms :

- Maximize **distance**
- Minimize **instability on the core component**
- Maximize **IR-sensor values**

Conclusion of step 2:

We found that the best disposition was 1 sensor on each face of the robot (front and back) and ideally also 1 sensor on each side (right and left), forcing the robot to rotate in order to avoid obstacles.

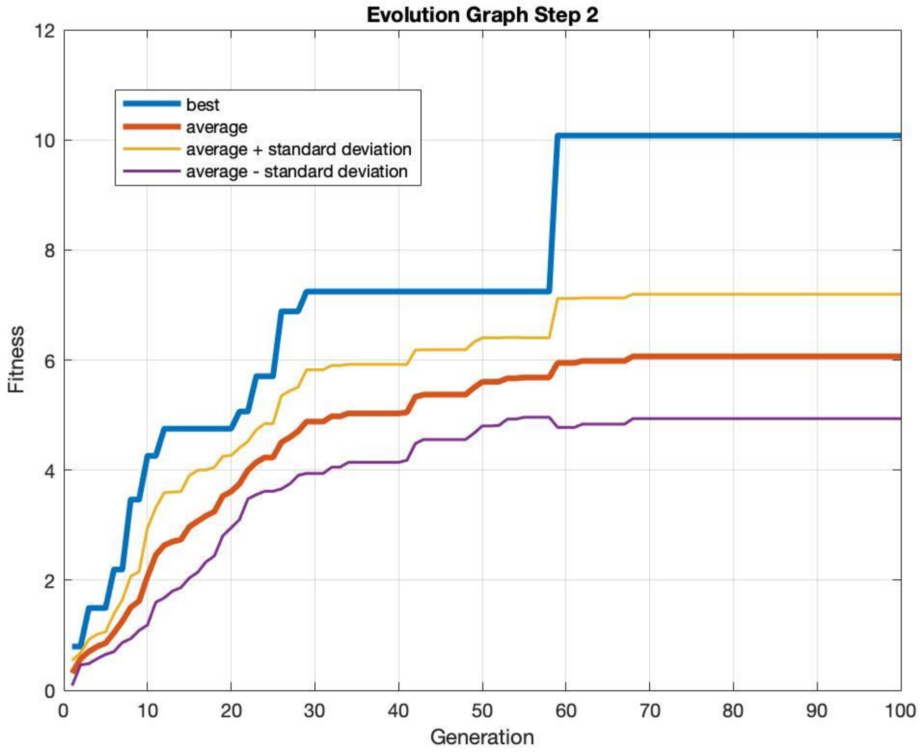


Figure 7: Evolution graph of step 2

Experimental Method – Evolution Step 3

- The goal of this third step was to optimize the ability of the robot to move upwards and downwards on **rough terrain**

- This arena provides a simulation of real world environment, in order to train the robot to be **robust to slopes** while assuring stability on the core component

- We ignored the obstacle avoidance in this step

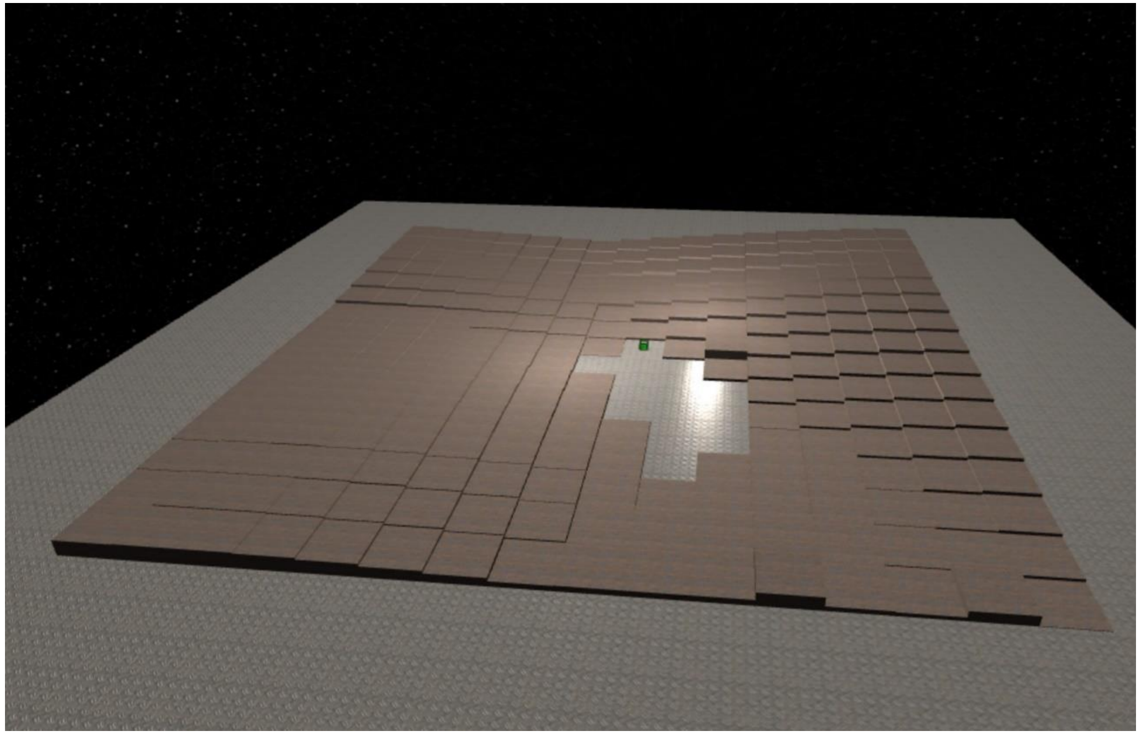


Figure 8: Arena of evolutionary step 3

Friction	Sensor noise	Motor noise	Simulation time	Time-step
1.0	0.02	0.02	16 sec	0.005 sec

Table 6 : Simulation parameters of step 3

μ	λ	Evolution mode	Replacement strategy	Tournament size
20	20	Brain	Deterministic-tournament	2

Table 7: Evolution parameters of step 3

Experimental Method – Evolution Step 3

The fitness function had 3 terms :

- Maximize **distance**
- Maximize **height**
- Minimize **instability on the core component**

Conclusion of step 3:

After a lot of falling and rolling, the robot was capable **slightly climbing uphill**. It wasn’t the most concludin evolution however. The complex arena seemed to disturb a lot this evolution step.

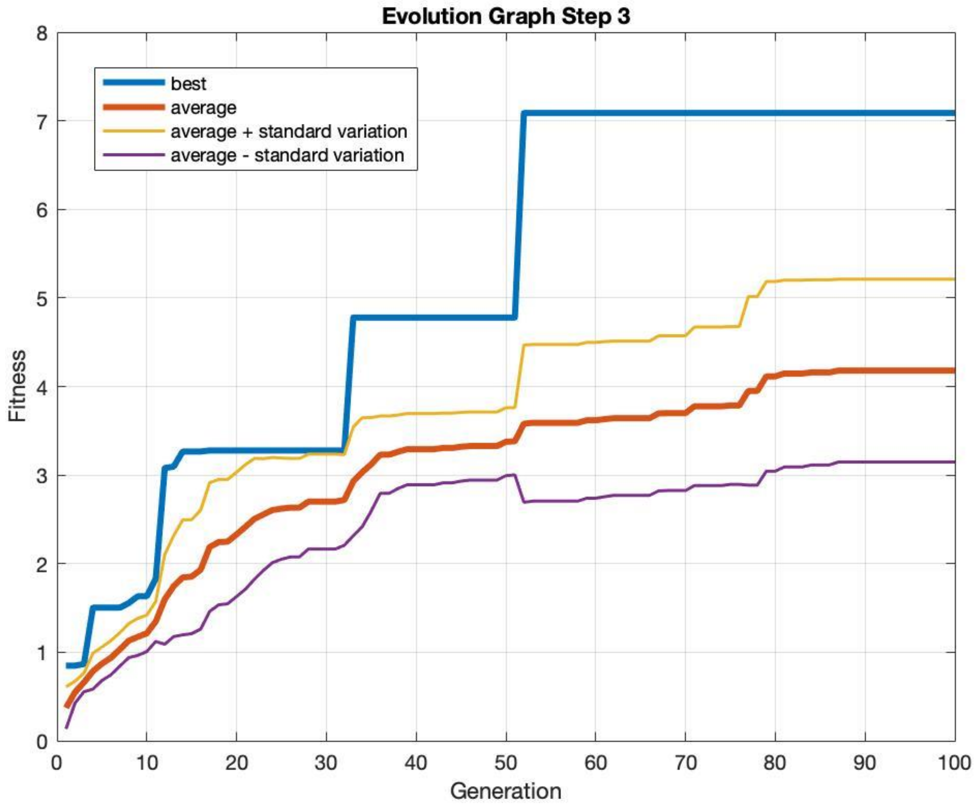


Figure 9: Evolution graph of step 3

Experimental Method – Evolution Step 4

- The goal of this fourth and final step was to optimize the **obstacle avoidance** while putting all the other fitness terms together

- This arena, in the shape of a maze, was the most efficient to train the robot to **avoid obstacles**

- This evolution also added some criteria that were observed in previous steps and seemed to be improving the robot general abilities

Friction	Sensor noise	Motor noise	Simulation time	Time-step
1.0	0.02	0.02	16 sec	0.005 sec

Table 6 : Simulation parameters of step 3

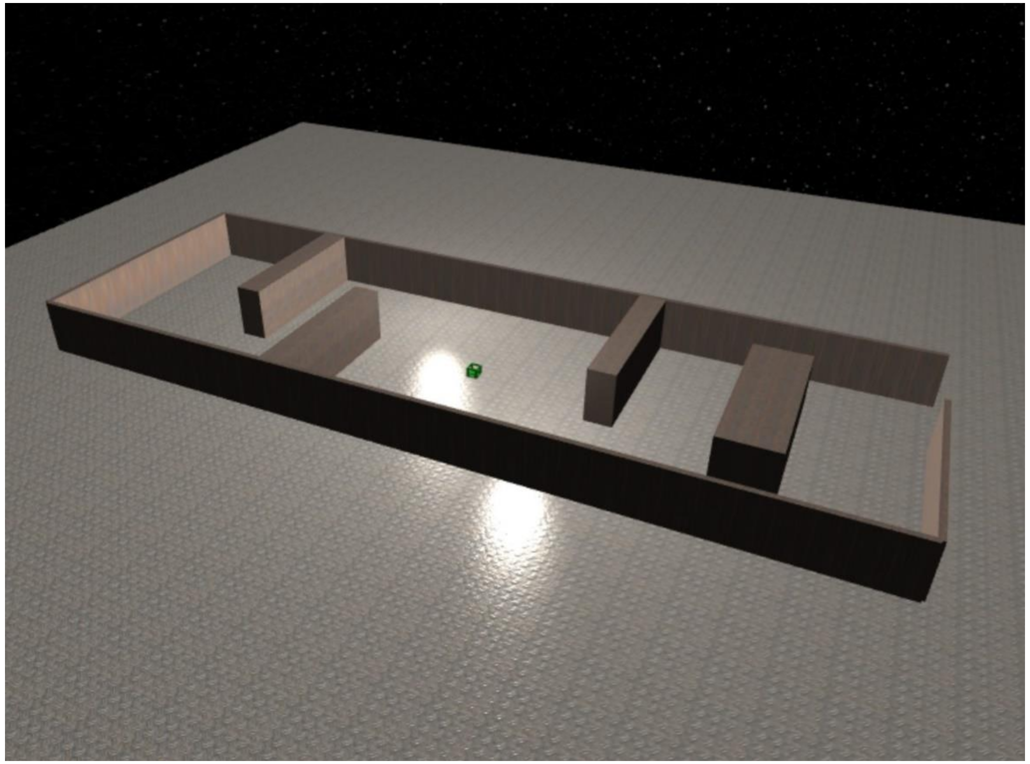


Figure 10: Arena of evolutionary step 4

μ	λ	Evolution mode	Replacement strategy	Tournament size
20	20	Brain	Deterministic-tournament	2

Table 7: Evolution parameters of step 3

Experimental Method – Evolution Step 4

The fitness function had 4 terms :

- Maximize **distance**
- Maximize **IR-sensor values**
- Maximize **torques in the knees**
- Minimize **instability on the core component**

Conclusion of step 4:

This step really **improved the obstacle avoidance**, whilst maintaining a good stability on the core component

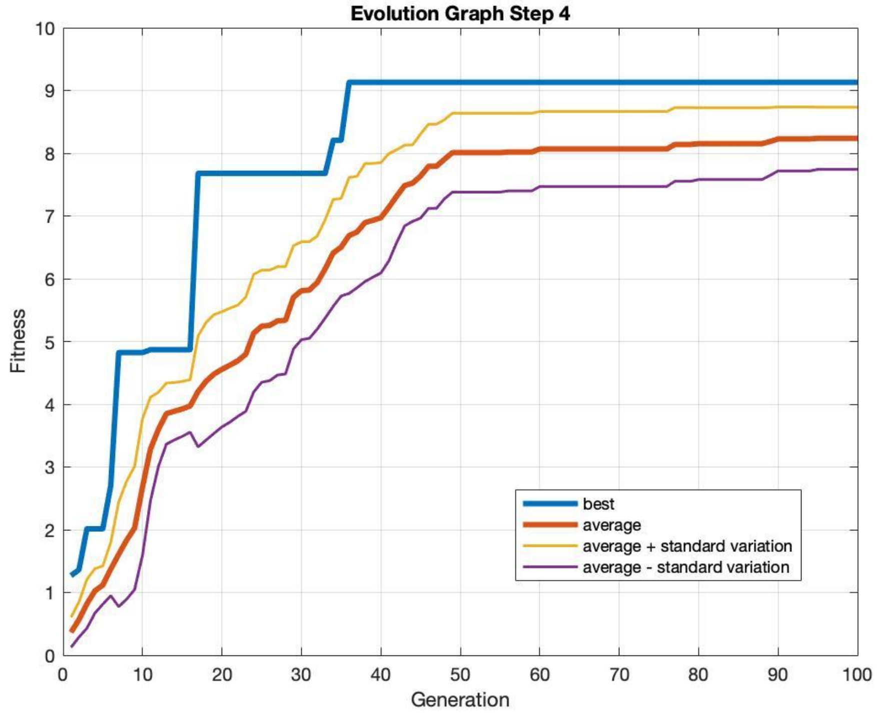


Figure 11: Evolution graph of step 4

Results

The final result was interesting. Indeed, it can climb rough terrain arenas such as the bigarena given for the project, it can also roughly avoid obstacles and the core component is particularly stable on most runs, which was the most satisfying part

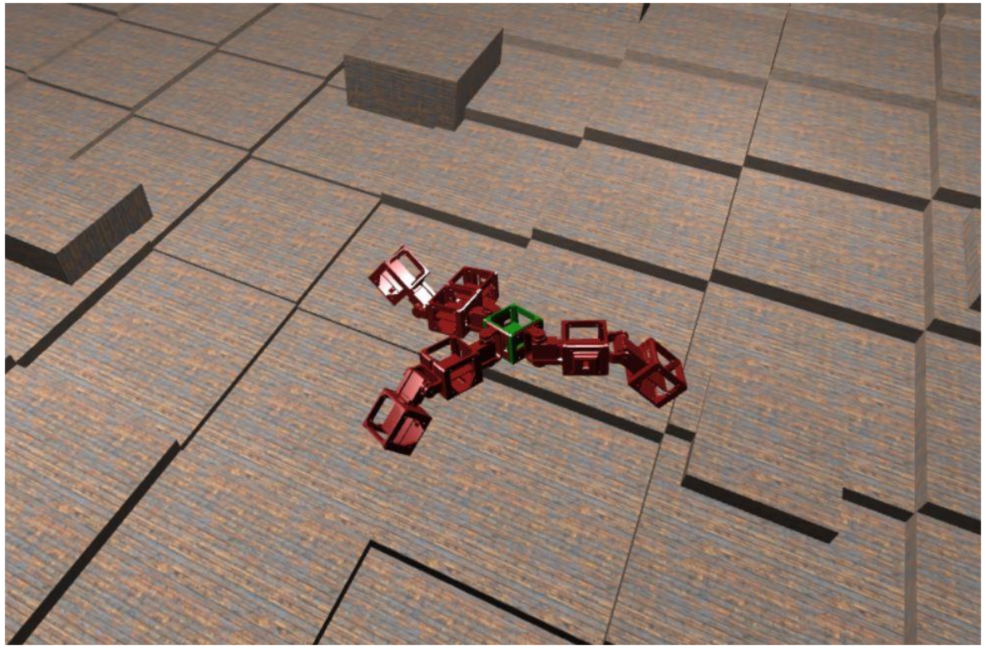
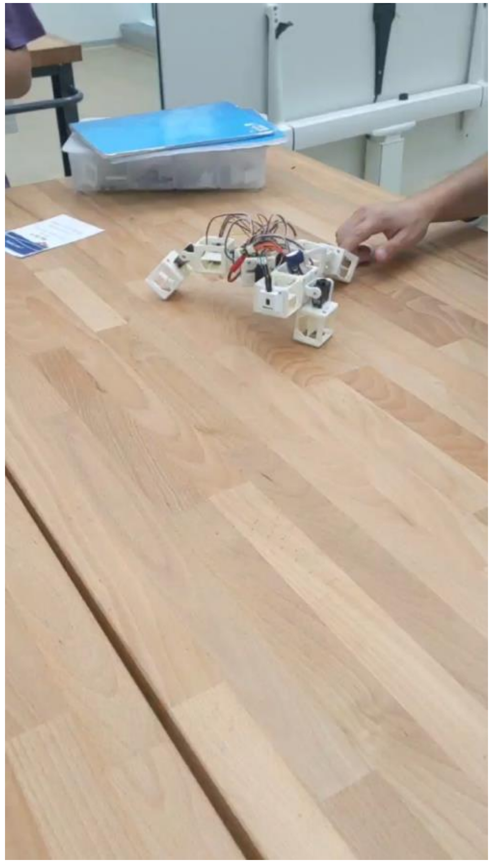


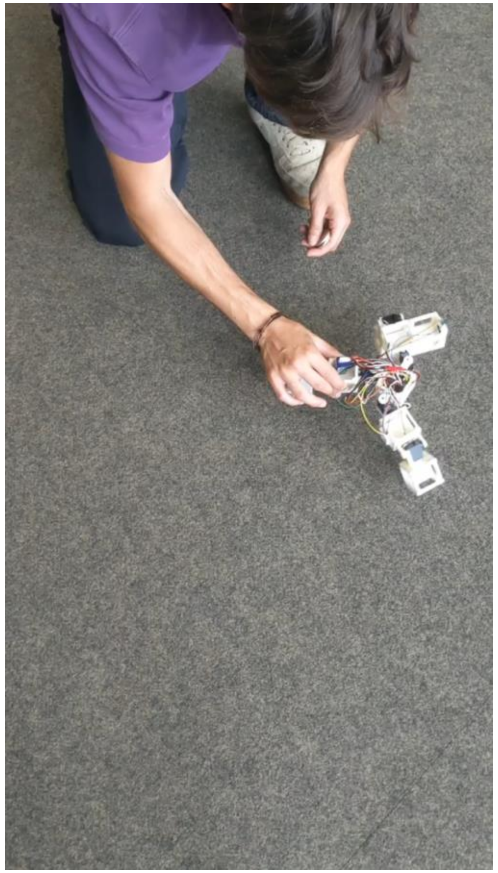
Figure 12: Final robot during simulation on bigarena

Videos of the final robot



Maximize distance

Maximize IR-sensor values



Minimize instability on the core component

Maximize knee torques

Conclusion

- ➢ Overall the project was very interesting
- ➢ We were able to put into practice the notions we saw during the theory of this class, this always helps to understand
- ➢ However, the project was a little frustrating. Indeed, we did a lot of logical reasoning for the fitness function, arena shapes, robot bodies, but it was very hard to see satisfying results on the simulations as well as on the actual built robot
- ➢ We still obtained a robot that could execute what we implemented and the building part was very enriching

Thank you for your attention

Any questions ?