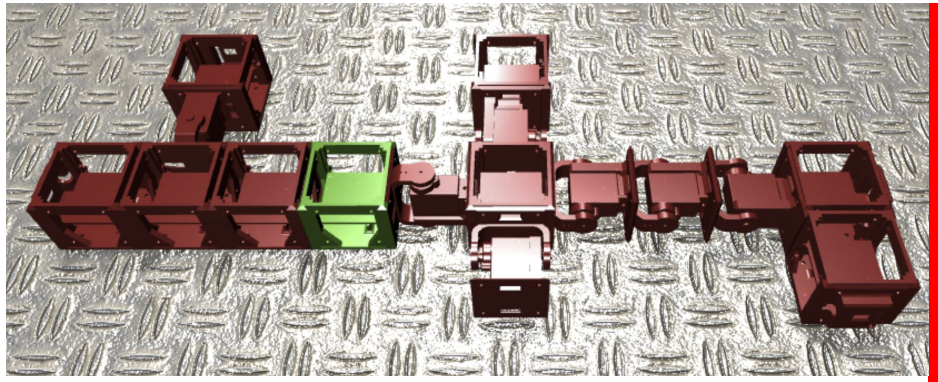


Figure 1: Final image of robot body

RoboGen Project: Group 7

M. Hassan,
L. Zunino,
L. Duggan,
H. Sprumont,
MICRO-515 Evolutionary robotics

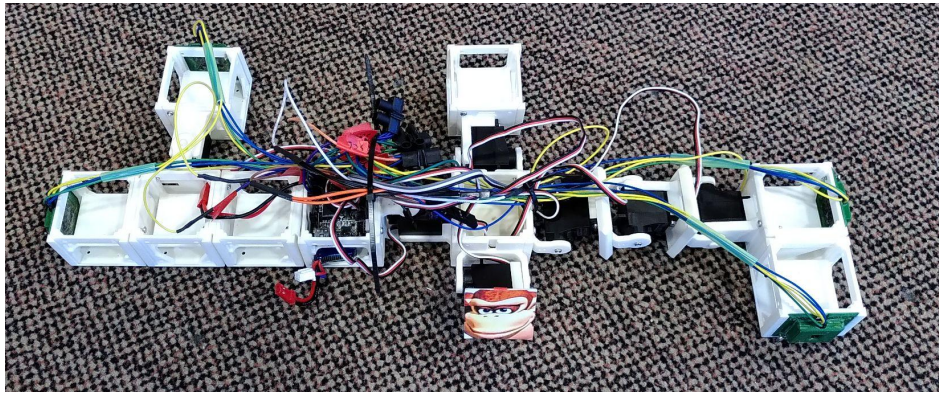


Figure 2: Final image of robot body (real)

29.05.2022

Introduction: **Mars exploration rover**

- Locomotion on uneven terrain
- Stability of the core component → **Scientific approach / Repeatability**
- Obstacle avoidance → **Exploring the parameters of Robogen**

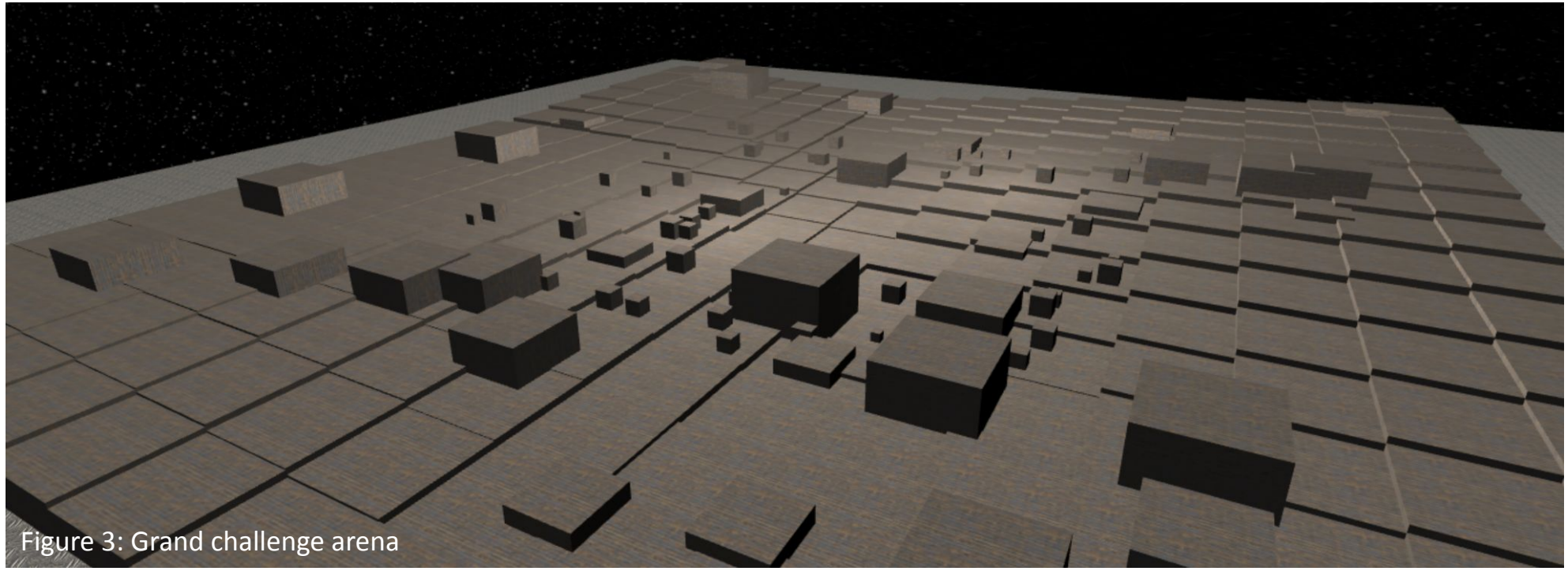


Figure 3: Grand challenge arena

Experimental Method:

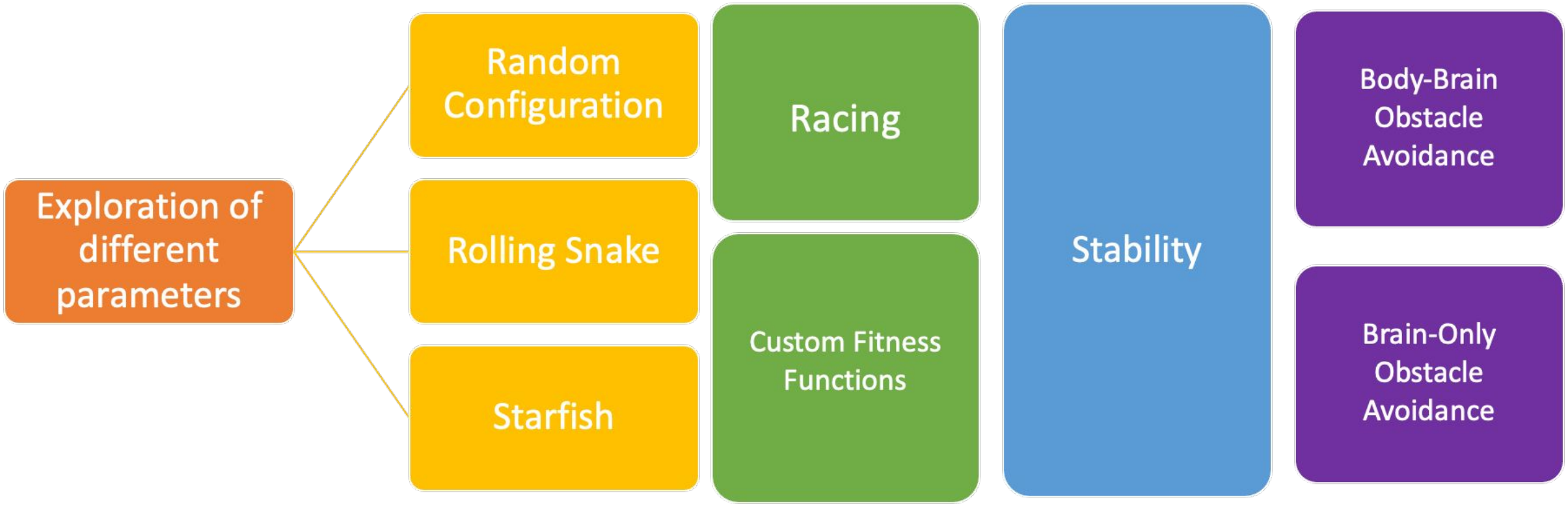


Figure 4 : Project flowchart

Experimental Method: **Starting robot**

2 Random starts:

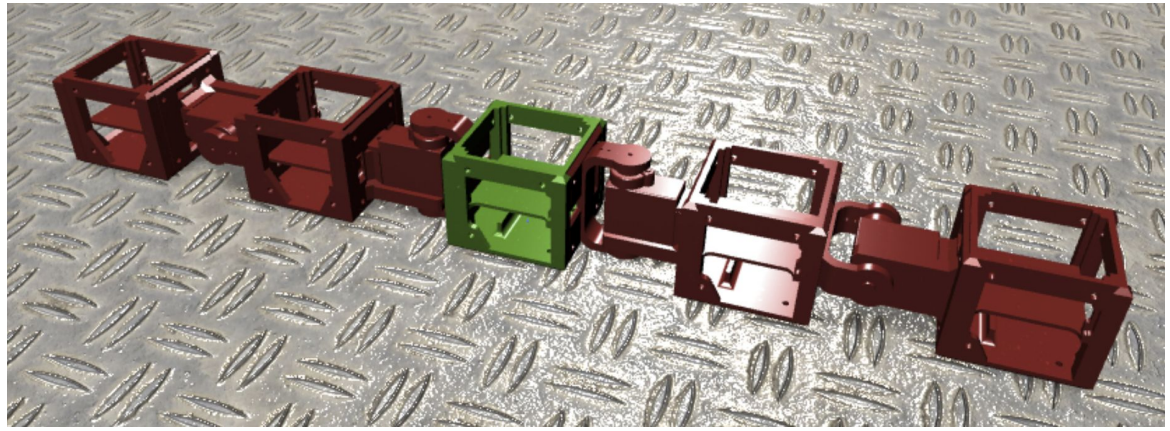
- **More exploration**
- **Surprises !**

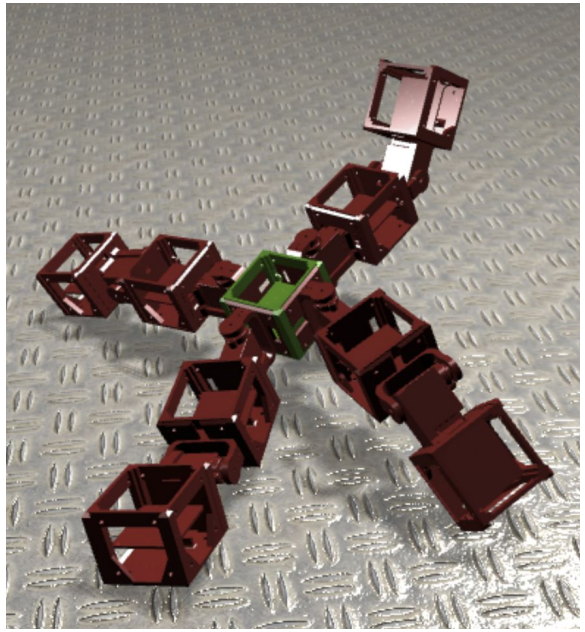
Rolling snake:

- **Oscillators only**
- **Good racing score**
- **Simple geometry**

Starfish:

- **Oscillators only**
- **Good racing score**
- **Advanced geometry**





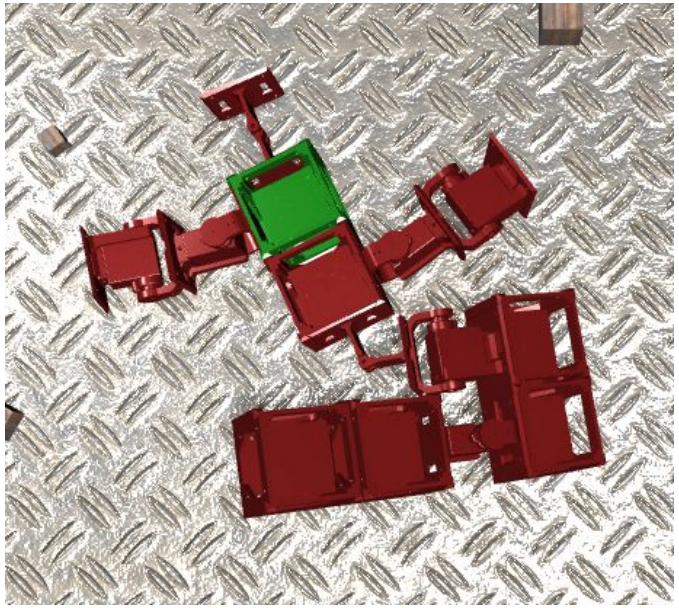


Figure 5 : Starting robots and one of our random results

Experimental Method: **Starting robots (bis)**

2 Random starts:

- **More exploration**
- **Surprises !**

Rolling snake:

- **Oscillators only**
- **Good racing score**
- **Simple geometry**

Starfish:

- **Oscillators only**
- **Good racing score**
- **Advanced geometry**

Oscillators	LowerLeg1	Hip1	Hip2	LowerLeg2
Period	0.8	0.8	0.8	0.8
Offset	0.2	-0.8	-0.95	-1
Amplitude	1	1	1	1

Table 1 : Rolling snake oscillator parameters

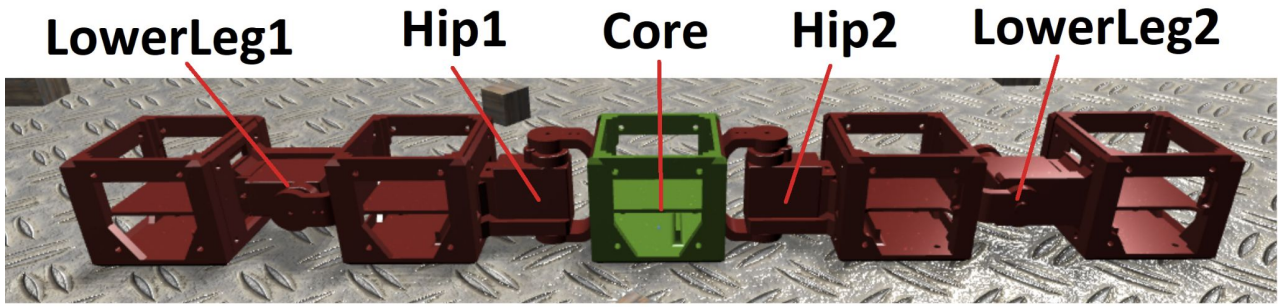


Figure 6 : Rolling snake core and actuators

Experimental Method: **Starting robots (bis)**

2 Random starts:

- **More exploration**
- **Surprises !**

Rolling snake:

- **Oscillators only**
- **Good racing score**
- **Simple geometry**

Starfish:

- **Oscillators only**
- **Good racing score**
- **Advanced geometry**

Oscillators	Hip 1	Hip 2	Hip 3	Hip 4	knee 1	knee 2	knee 3	knee 4
Period	2	2	2	2	2	2	2	2
Offset	0	0	0	0	0	0	0	0
Amplitude	1	1	1	1	1	1	1	1

Table 2 : Starfish starting oscillator parameters

Oscillators	Hip 1	Hip 2	Hip3	Hip 4	knee 1	knee 2	knee 3	knee 4
Period	1.87	2	1.83	2	1.92	1.99	1.61	2
Offset	1	-0.57	-0.89	0.41	0.38	0.17	0.24	0.64
Amplitude	1	0.83	0.78	0.93	1	1	1	1

Table 3 : Brain-only Evolved Starfish

Experimental Method: **Initial parameters**

Number of generations	200
Mu	25
Lambda	100
Replacement strat	plus
Tournament size	3
pBrainMutate	0.5
BrainSigma	0.9

Table 4 : Evolution parameters

Motor noise	Sensor noise	Simulation time (s)	max direction shifts per second
0.03	0.03	12	16

Table 5 : Simulation parameters

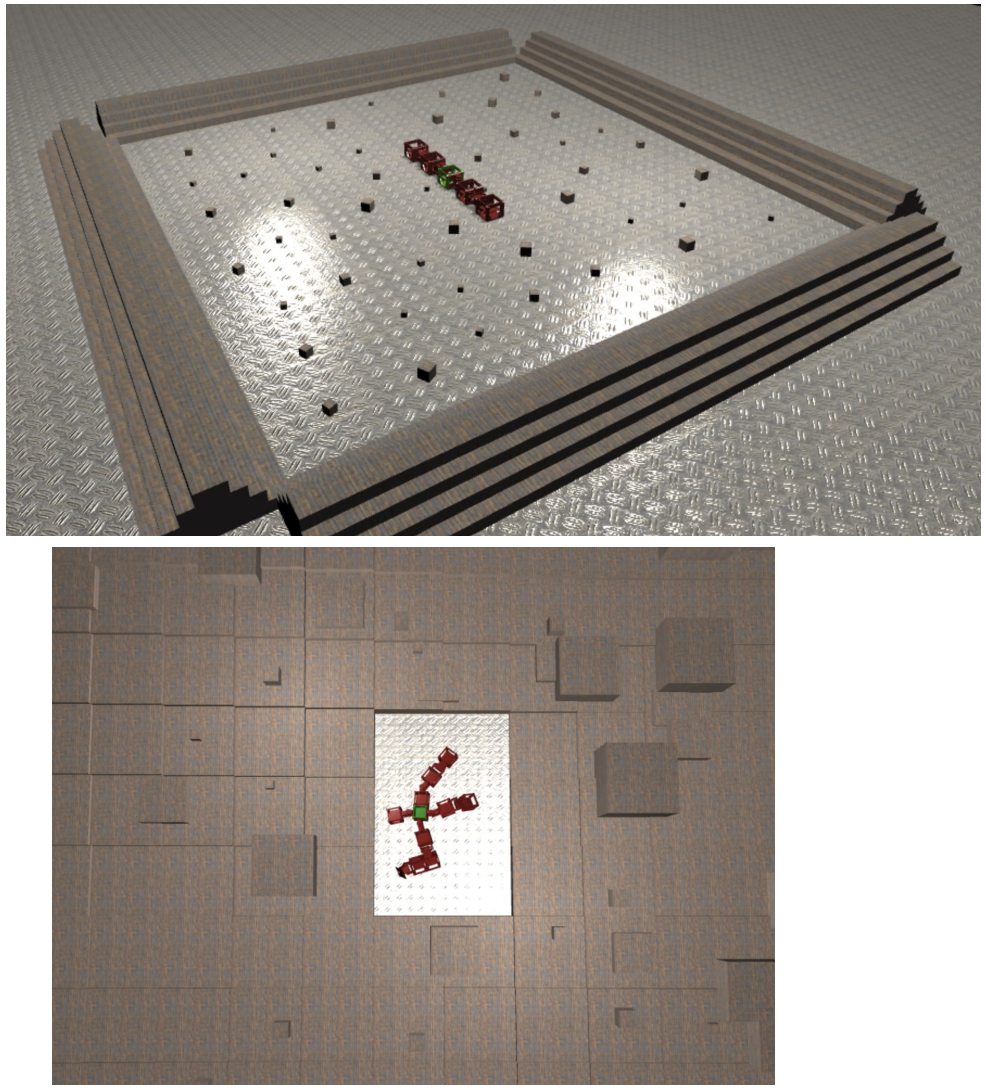


Figure 7 : Arena of evolutionary step 1

Experimental Method: **Locomotion**

A variety of fitness functions:

Racing (Final distance of the closest element)

$$d_{min} = \sqrt{x_{final}^2 + y_{final}^2}$$

Integral of Core position

$$\int \sqrt{x^2 + y^2 + z^2}$$

Final Core position

$$\sqrt{x_{final}^2 + y_{final}^2 + z_{final}^2}$$

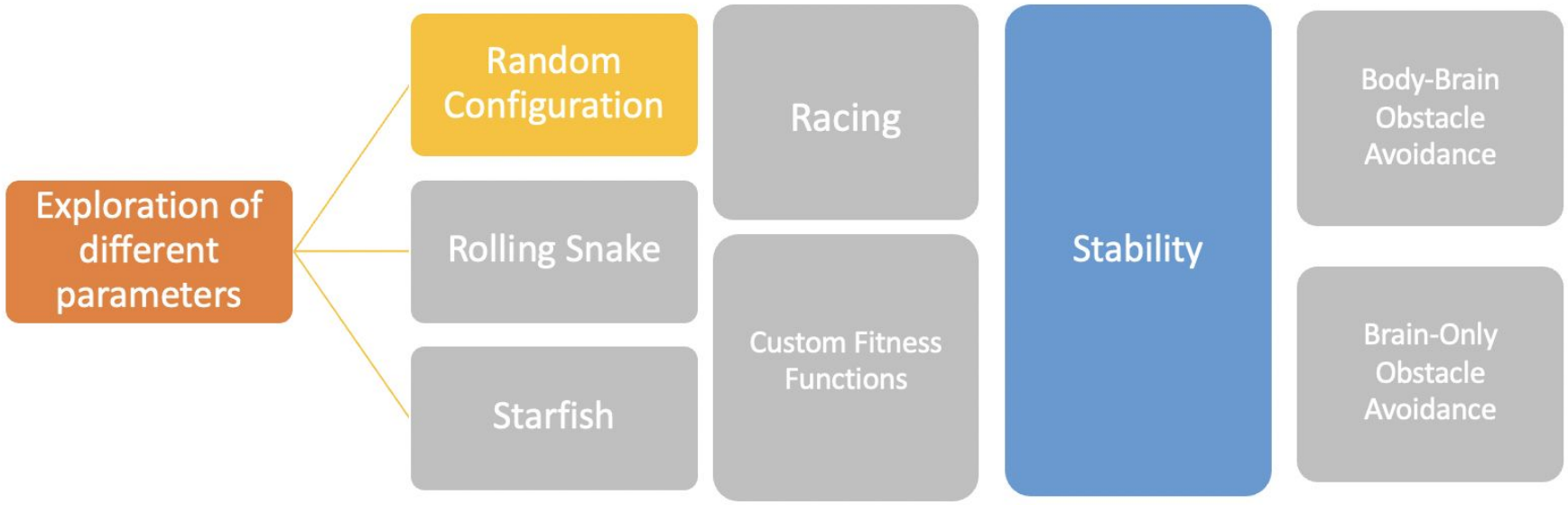
Final Core position + Stability

$$0.7 \cdot \sqrt{x_{final}^2 + y_{final}^2 + z_{final}^2} + 0.3 \cdot \left(\frac{0.5}{max(rate_{pitch}) + 0.5} + \frac{0.5}{max(a_x + a_y + a_z) + 0.5} \right)$$

Minimum distance + Stability

$$2 \cdot d_{min} + 2 \cdot z_{max} - 0.1 \cdot \sqrt{gyro_{max}} - (d_{min} < 0.01) \cdot 1000$$

Intermediate results: **Random configuration**



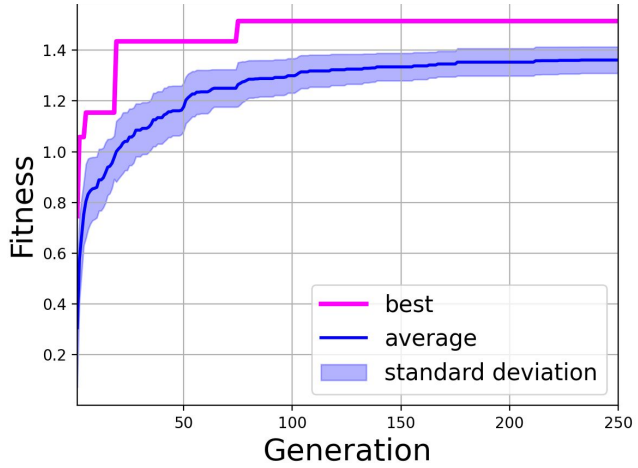


Figure 8: Fitness evolution: Max (x,y) distance + max acceleration, roll, pitch fitness function

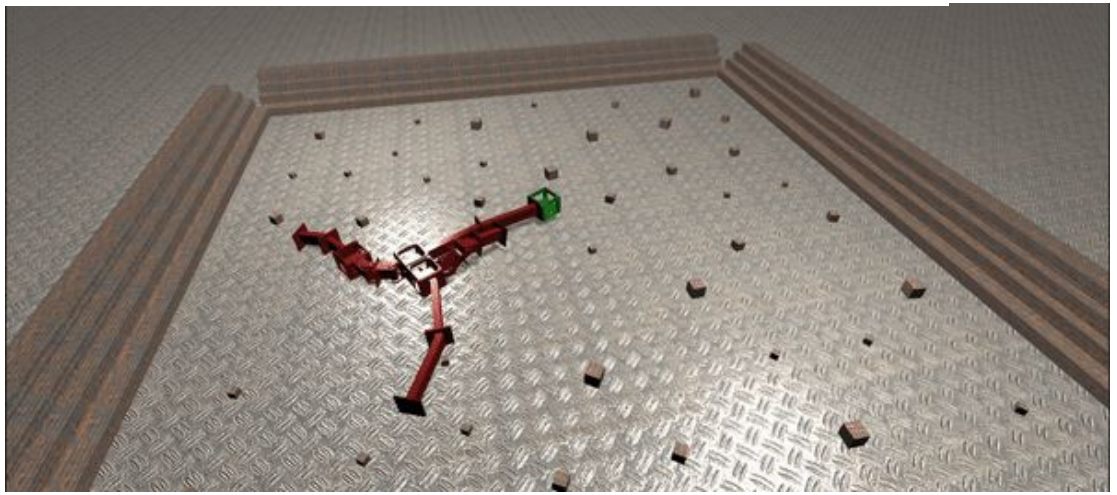
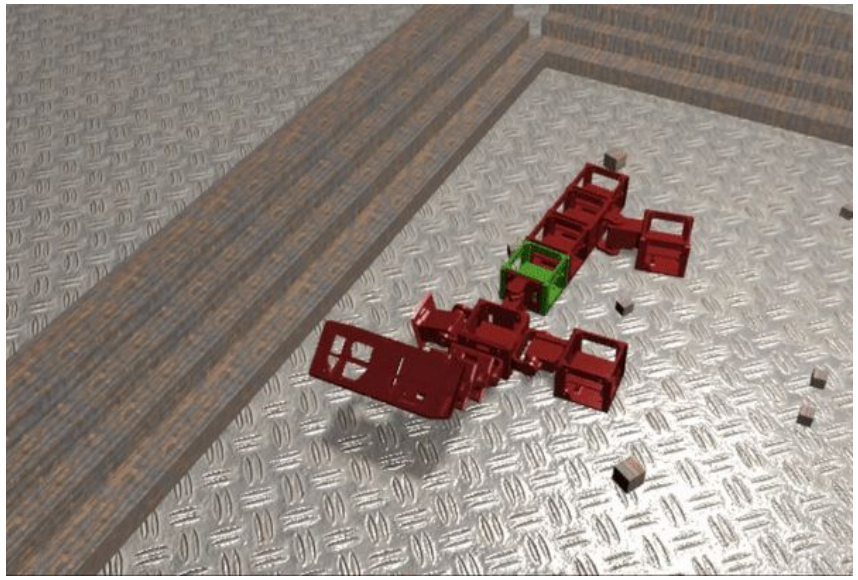


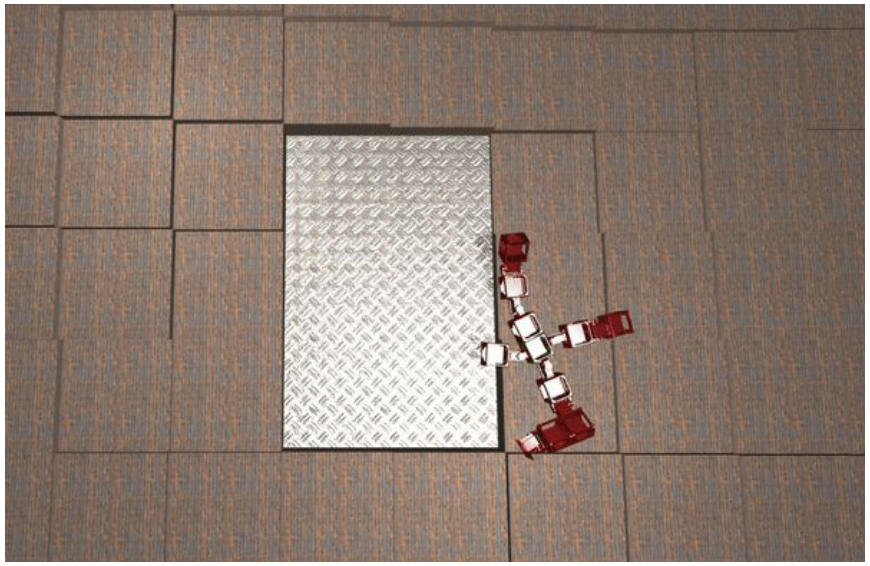
Figure 9 : Robot at the end of the evolution

Intermediate results: **Snake and starfish**

GorillaBot :



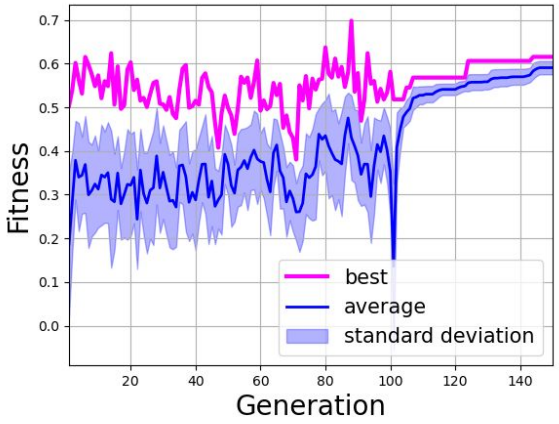
Starfish:



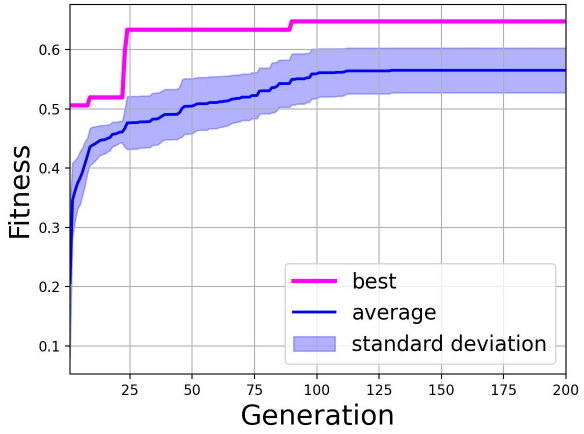
↑ ↑

Figure 10 : GorillaBot and Starfish in simulation

(Don't judge them, they've been through a lot)



← Figure 11 : Fitness evolution for both robots →



Experimental Method: **Obstacle avoidance**

Brain evolution, manual sensor placement:

- **Fitness functions:**

1. $$\sqrt{x_{final}^2 + y_{final}^2} \cdot \int (1 - max(IrSensor))$$

2. $$0.8 \cdot \left(1 - 1.2 \cdot \int (max(IrSensor))\right) + 0.5 \cdot \sqrt{x_{final}^2 + y_{final}^2 + z_{final}^2} + 0.2 \cdot Stability$$

$$Stability = \left(\frac{0.5}{max(rate_{pitch}) + 0.5} + \frac{0.5}{max(a_x + a_y + a_z) + 0.5}\right)$$

Body and brain evolution, implicit OA:

- **Fitness function: Racing** scenario with conditions on **minimum number of sensors** and **no obstacle removal**
- Constant battle with the robot's exploits (no IR sensors on robot, obstacle despawning, lucky starting position, ...)

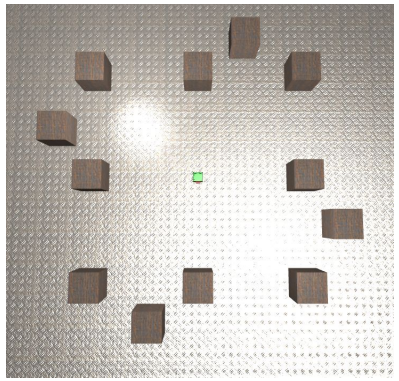


Figure 12 : Arena for implicit obstacle avoidance

Results

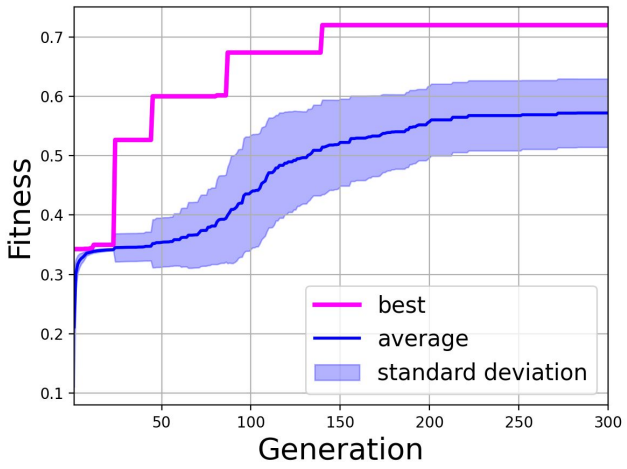


Figure 13 : Fitness evolution : Brain-only OA fitness function

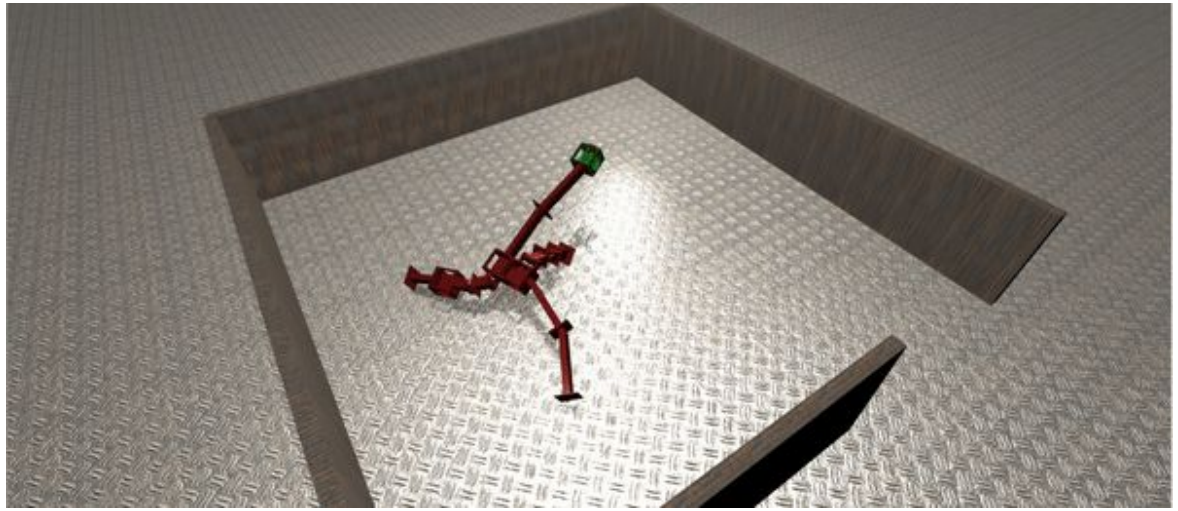
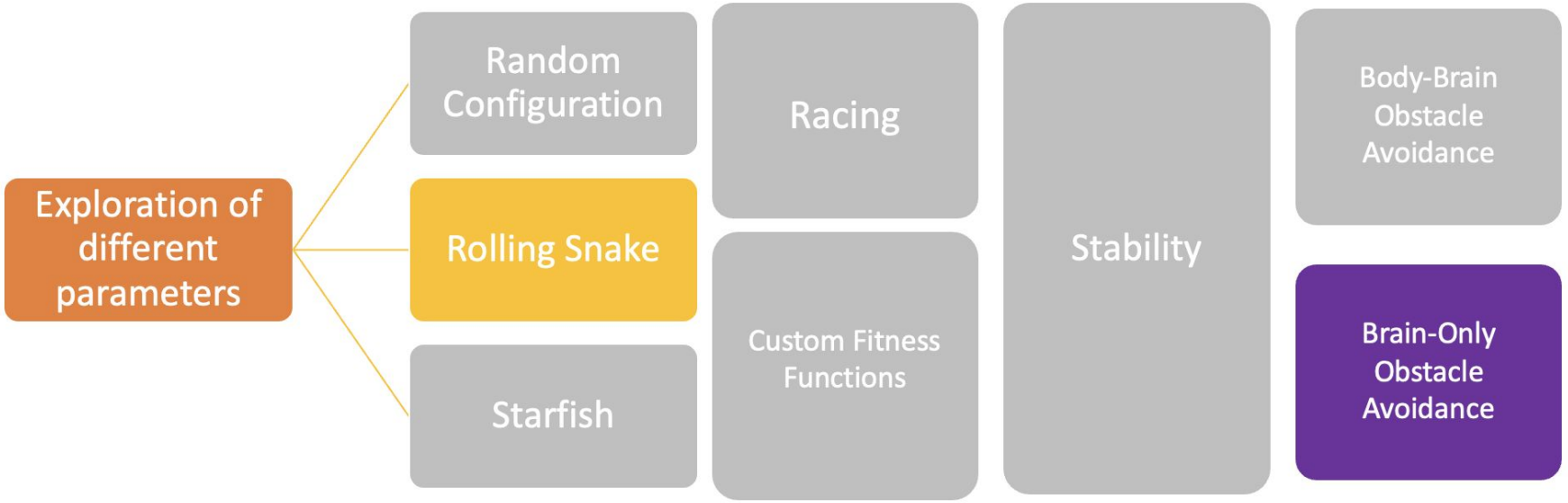


Figure 14 : Robot at the end of the evolution

Results



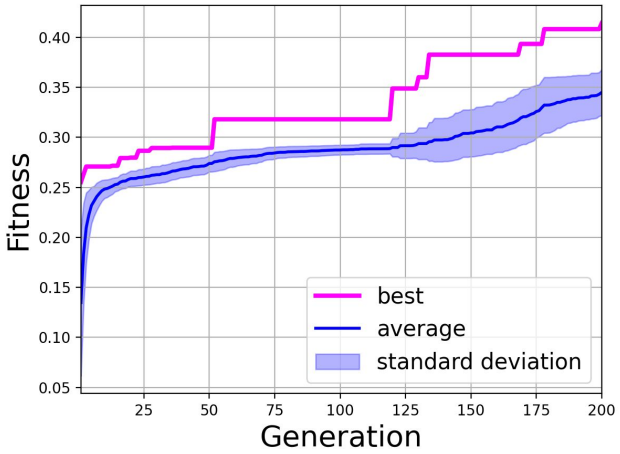


Figure 15 : Fitness evolution : Brain-only OA fitness function

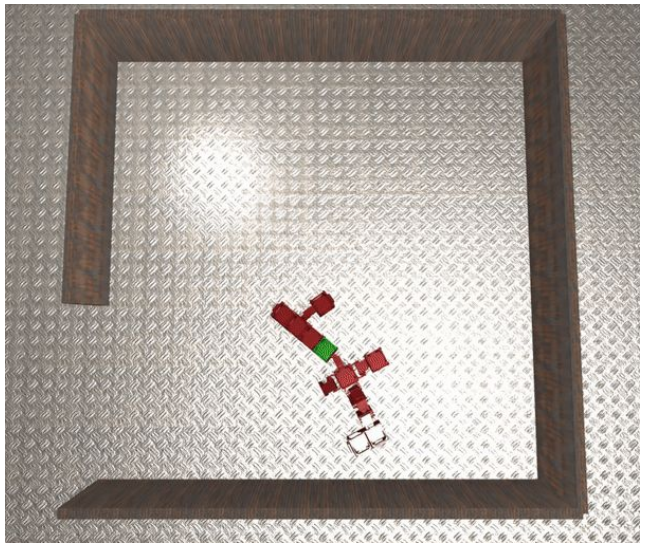


Figure 16 : Robot at the end of the evolution

Results

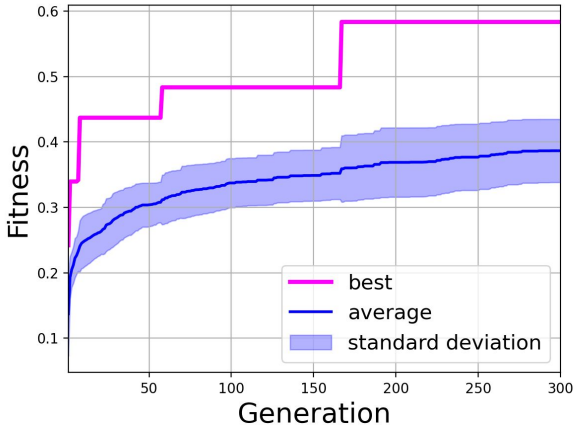


Figure 17 : Fitness evolution : Brain-only OA fitness function

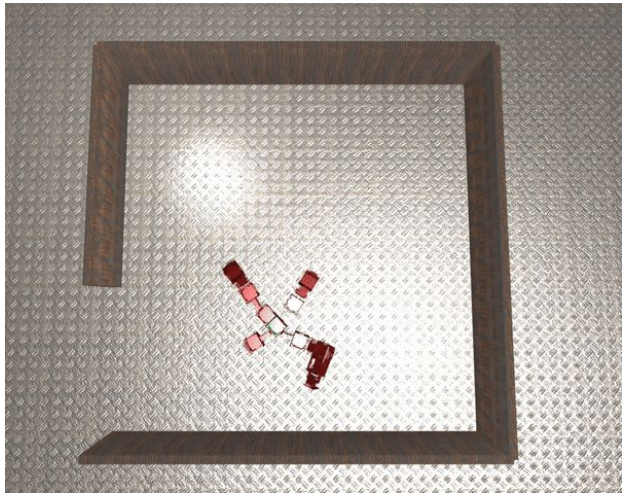
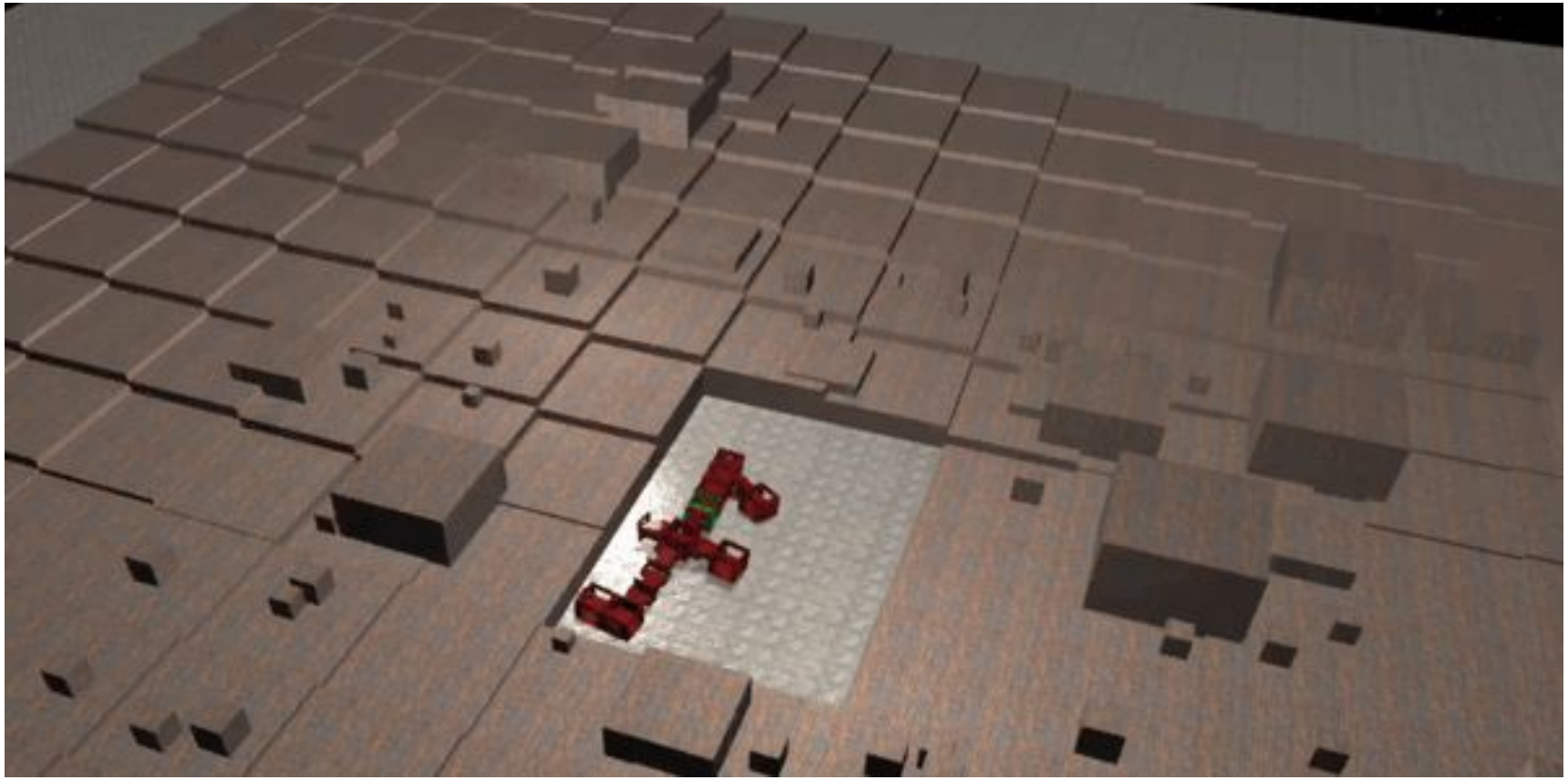
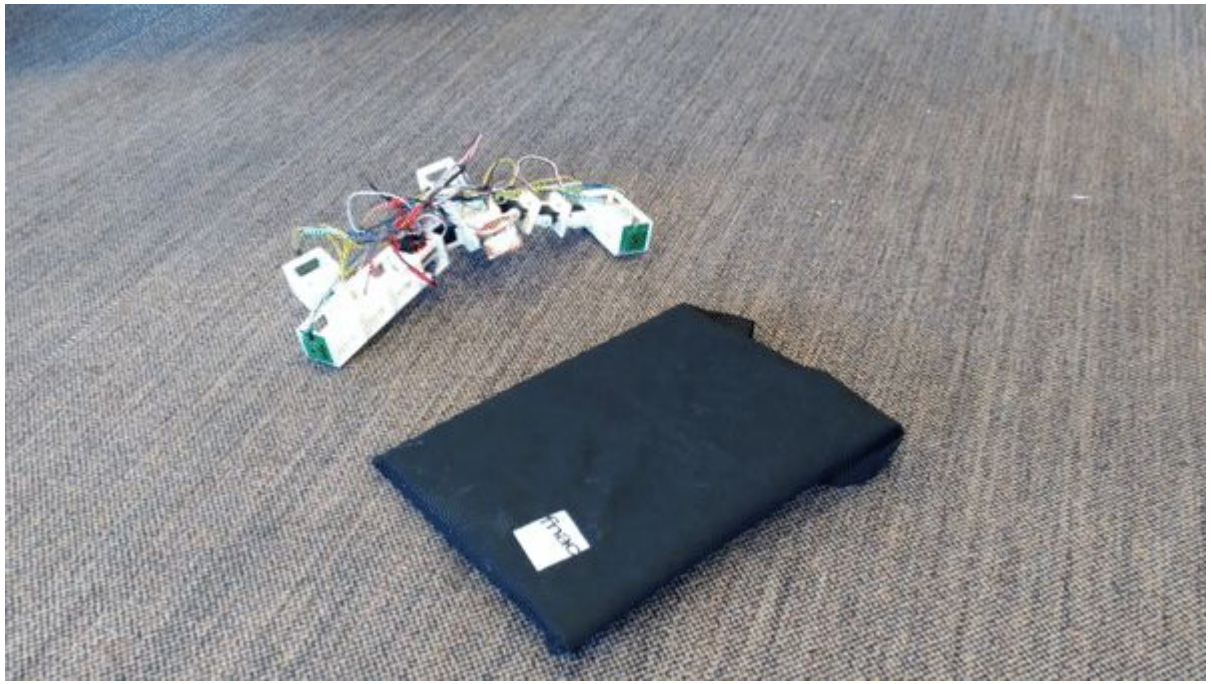


Figure 18 : Robot at the end of the evolution

Video of GorillaBot - Simulation (2x speed)



Video of GorillaBot - Real robot



Conclusion

Observations

- Simpler fitness functions worked better
- Random start has greater variability in results
- Repeatability is more guaranteed with non-random start configurations (GorillaBot: obtained ⅝ times)
- Evolutionary algorithm is opportunistic

Figure 19 : Artistic depiction of GorillaBot

Future works, if we had more time :

- Longer evolution with more starting positions
- Explore more the implicit OA (tweaking arenas, …)
- More random starts (funny results)
- Train on different arena for more general results

Workload distribution

	M. Hassan	L. Zunino	L. Duggan	H. Sprumont
Starting robot	Starfish	Random	Random	Snake
Final OA	Starfish + Gorilla	Random		Gorilla
Robot build			Body + Sensors	Body