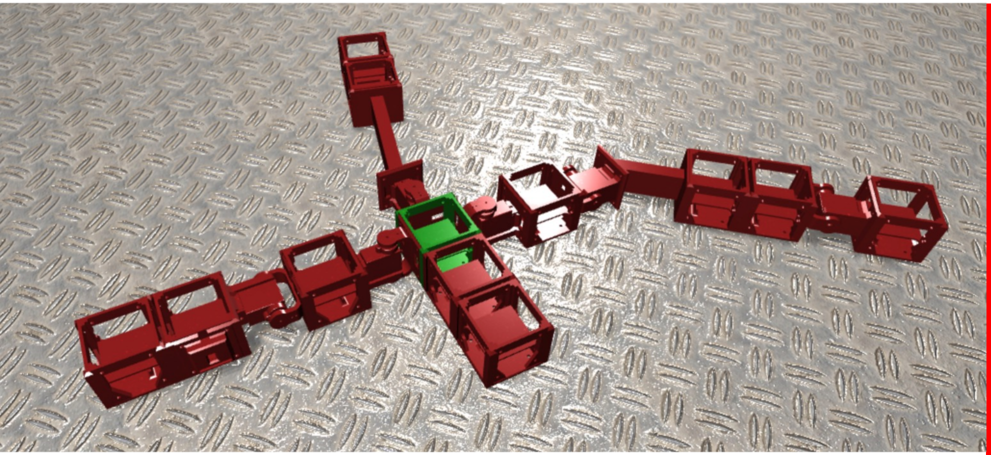

Figure 1: Final image of robot body

RoboGen Project: Group 10

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MICRO-515 Evolutionary robotics

Date : 30.05.2024

Introduction

Goal : Evolve a robot capable of passing over trenches

Requirements: The robot should be

- As quick as possible
- Not disturbed by various size trenches
- Stable
- The robot should move in a straight line

Constraints: The robot should

- Have no more than 6 servos
- Avoid jittery behaviors
- Use legged locomotion
- 25 components maximum
- Noise in the sensors between 0.02 and 0.1

EPFL

Experimental Method

	Hip1	Hip2	Hip4	Knee1	Knee2	Ankle2
IMU 0	-2.614	2.154	1.521	0.505	1.745	2.612
IMU 1	-2.283	3.000	1.361	3.000	3.000	2.372
IMU 2	0.265	-1.465	-2.812	-2.271	-1.272	-2.010
IMU 3	-2.350	3.000	1.788	0.355	0.148	0.919
IMU 4	-2.050	0.555	-1.498	1.197	-1.439	-0.526
IMU 5	-1.493	1.815	2.197	3.000	3.000	2.529
IR2	1.213	0.306	-0.492	0.129	-1.660	1.182
Hip1	2.447	-3.000	-2.165	-0.313	1.626	-1.423
Hip2	-1.372	2.208	-0.857	-2.472	-3.000	0.164
Hip4	3.000	2.332	0.029	-1.193	-2.284	1.597
Knee1	-1.593	2.913	-1.871	1.136	1.645	-0.092
Knee2	2.265	1.644	-1.474	-3.000	0.927	-0.724
Ankle2	-3.000	2.521	-0.035	-0.277	0.730	1.660

Table 1: Final robot neural network (input neuron red, output neuron green)

Multi-step Evolution :

1. **Learn how to walk**
   - Body-brain evolution
2. **Learn how to walk with obstacles**
   - Brain only evolution
3. **Learn how to pass trenches**
   - Body-brain evolution
4. **Learn a stable behaviour in the trenches with obstacles**
   - Brain only evolution

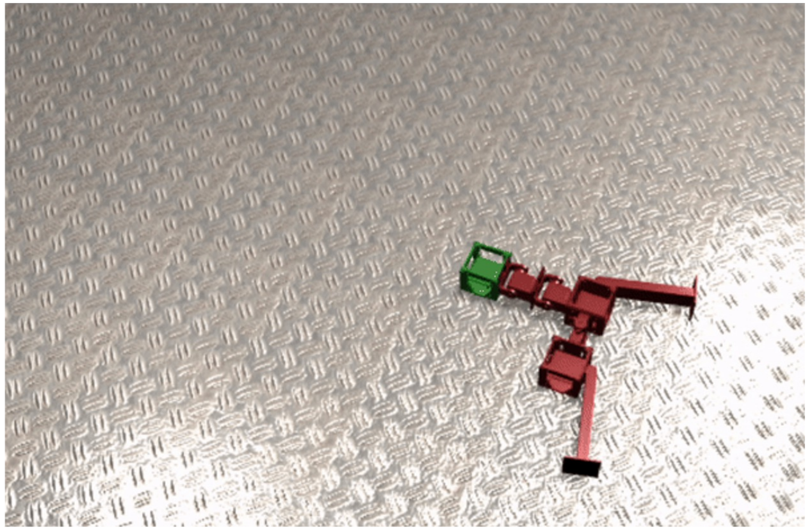
	Bias
Hip1	3.0
Hip2	0.778
Hip4	0.001
Knee1	0.403
Knee2	-2.022
Ankle2	-0.564

Table 2: Final robot bias

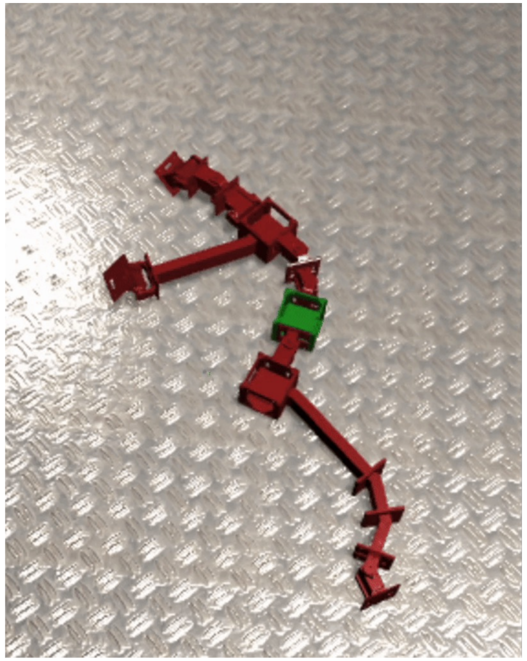
Body from Scratch

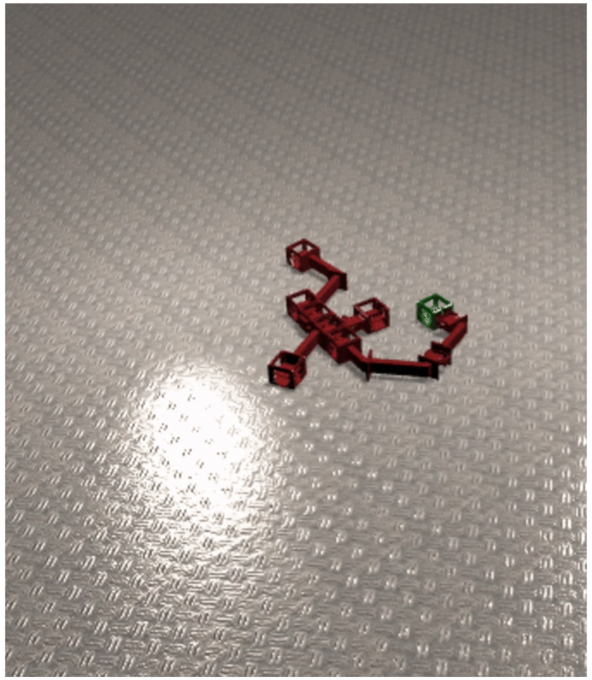
At first we try to evolve a robot body from scratch

<u>Problems :</u> it is hard for the evolution algorithm to produce a satisfying solution. Below you can see some example of robots resulting from the evolution of the step1 without initial bodies :



<u>Figure 1,2,3:</u> Diverse evoluted robot from scratch (the freak show)





With an Initial Morphology

Solution: Evolve from an initial morphology !

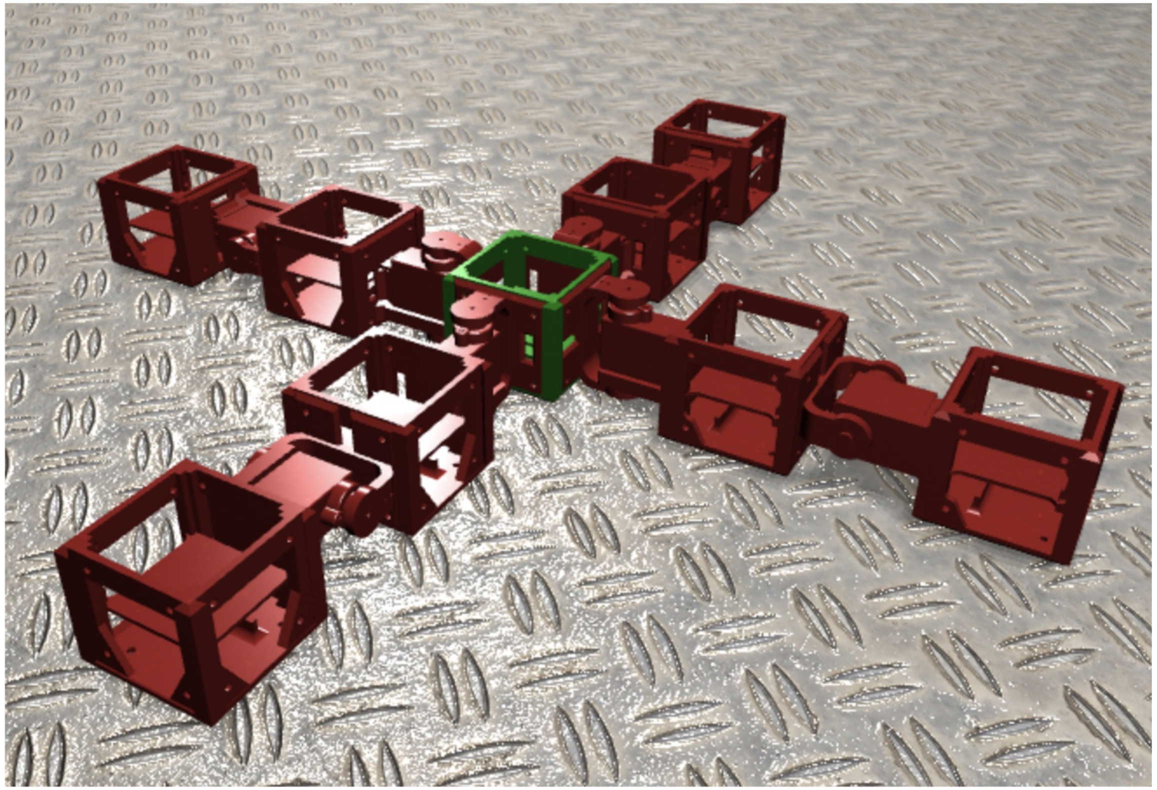


Figure 4: Starfish robot morphology

In order to help the algorithm to find more efficient solutions we decided to start from the initial body of the starfish robot which is has a four-legged simple morphology. The idea is to give directly to the robot a body that is able to learn a more robust way to walk.

Experimental Method

Step 1: Learning how to walk

Arena: Empty

Fitness: DistCoreComponent

- DistCoreComponent: Distance of the core component from the starting point

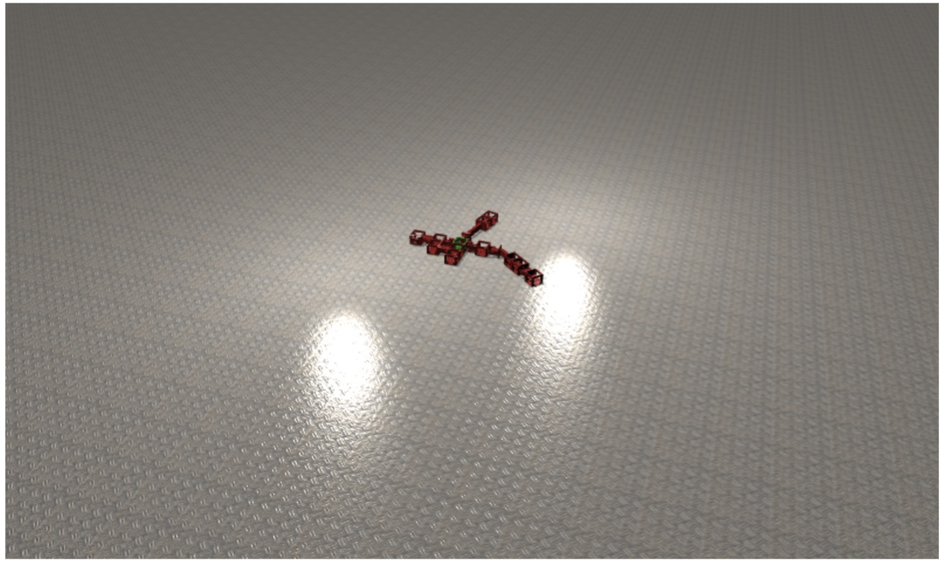


Figure 5: Arena of evolutionary step 1

Friction	Sensor/Motor noise	Simulation time	maxDirectionShiftsPerSecond
1.0	0.03	10	16

Table 3 : Simulation parameters step1

Evolution Mode	Generation	mu	lambda	Replacement strategy	Tournament size	pBrainMutate	pNodeInsert pSubtreeRemove pNodeRemove	pSubtreeDuplicate pParameterModify	pSubtreeSwap
fully	250	150	150	plus	2	0.3	0.3	0.2	0.1

Table 4: Evolution parameters step1

Experimental Method

Step 2: Learn how to walk with obstacles

Arena: Flat with simple fixed obstacles

Fitness: DistCoreComponent

- DistCoreComponent: Distance of the core component from the starting point

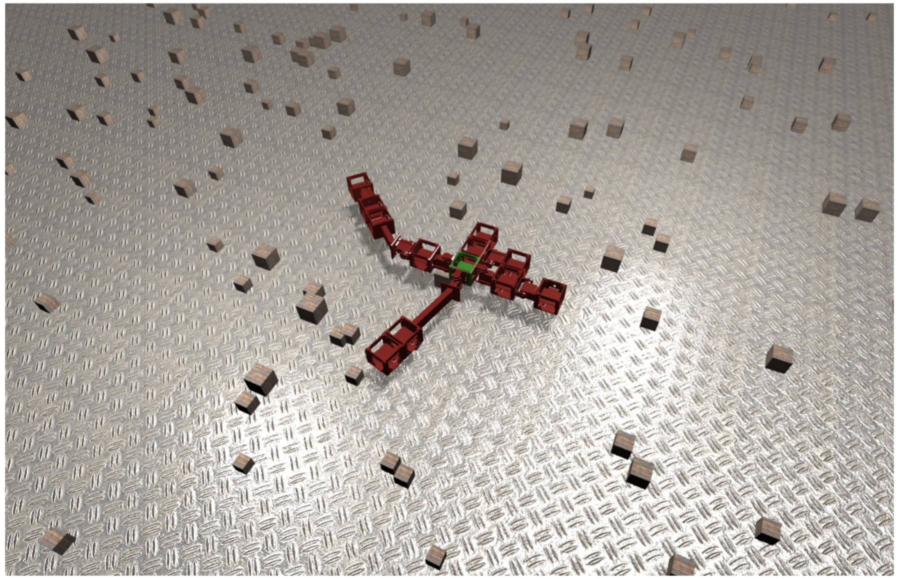


Figure 6: Arena of evolutionary step 2

Friction	Sensor/Motor noise	Simulation time	maxDirectionShiftsPerSecond
1.0	0.03	10	16

Table 5 : Simulation parameters step2

Evolution Mode	Generation	mu	lambda	Replacement strategy	Tournament size	pBrainMutate	pAddHiddenNeuron pOscillatorNeuron
brain	300	100	100	plus	2	0.3	0.1

Table 6: Evolution parameters step2

Experimental Method

Step 3: Learn how to pass a trenche

Arena: Custom Trenches

Fitness: exp(DistCoreComponent) * NumIRSensor

- DistCoreComponent: Distance of the core component from the starting point
- NumIrSensor: Number of IR sensor

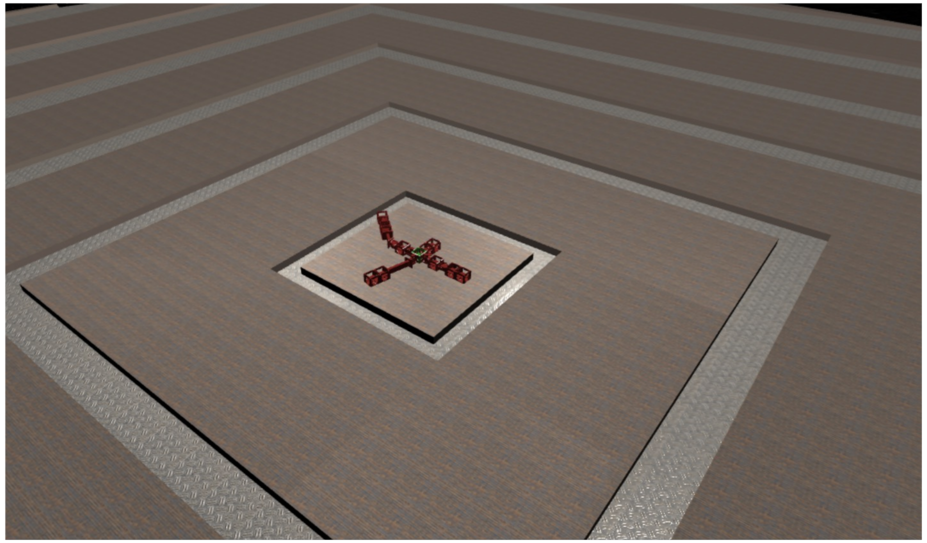


Figure 7: Arena of evolutionary step 3

Friction	Sensor/Motor noise	Simulation time	maxDirectionShiftsPerSecond
1.0	0.03	20	16

Table 7 : Simulation parameters step3

Evolution Mode	Generation	mu	lambda	Replacement strategy	Tournament size	pBrainMutate	pNodeInsert pSubtreeRemove pNodeRemove	pSubtreeDuplicate pParameterModify	pSubtreeSwap
full	100	100	100	plus	3	0.3	0.3	0.2	0.1

Table 8: Evolution parameters step3

Experimental Method

Step 4: Learn a stable behaviour in the trenches with obstacles

Arena: Custom Trench with little fixed obstacle
Fitness: exp(DCCy) * NumIR / maxNDS / (|MR|+|MP|+|MY|)

- DCCY: Distance of the core component from the starting point on the y axes
- NumIR: Number of IR sensor
- maxNDS: max number of direction shift
- MR/MP/MY: Max Roll, Max Pitch, Max Yaw

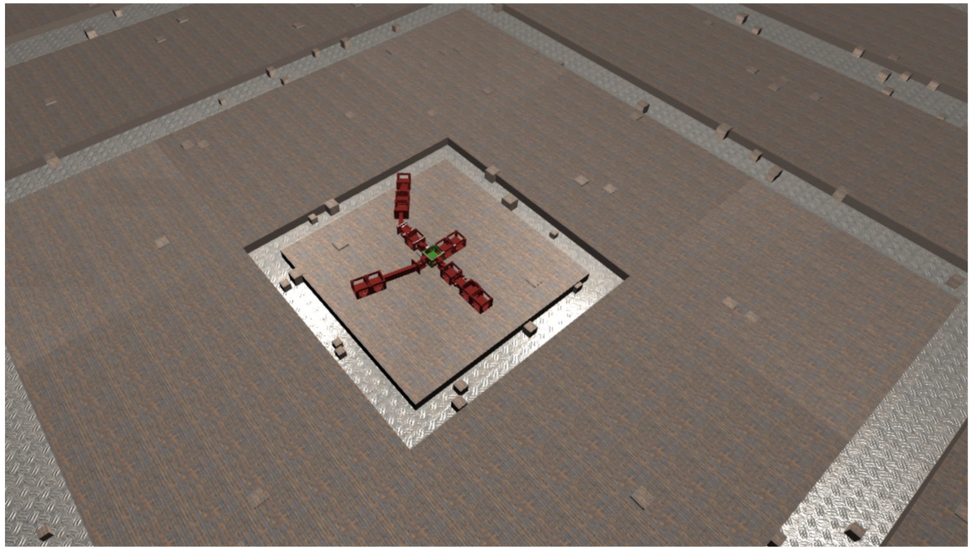


Figure 8: Arena of evolutionary step 1

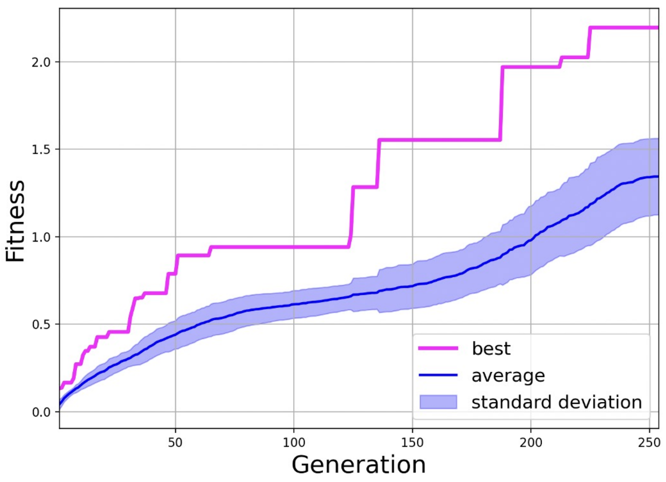
Friction	Sensor/Motor noise	Simulation time	maxDirectionShiftsPerSecond
1.0	0.07	20	-

Table 9 : Simulation parameters step4

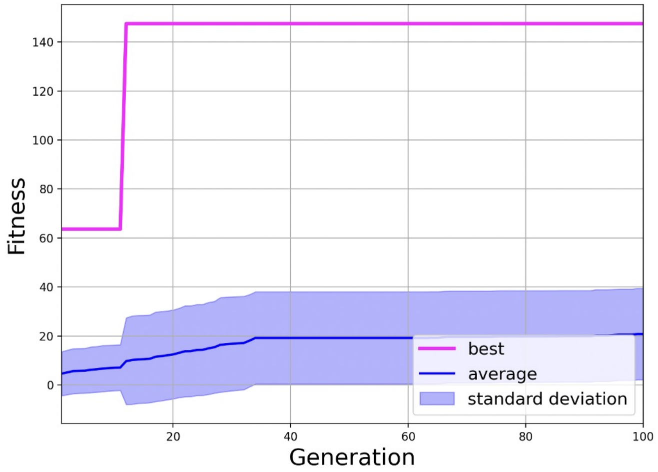
Evolution Mode	Generation	mu	lambda	Replacement strategy	Tournament size	pBrainMutate	pAddHiddenNeuron pOscillatorNeuron
brain	50	100	100	plus	3	0.3	0.1

Table 10: Evolution parameters step4

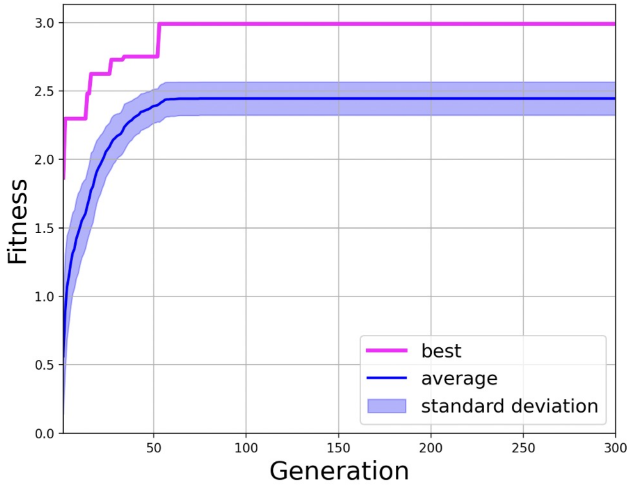
Results



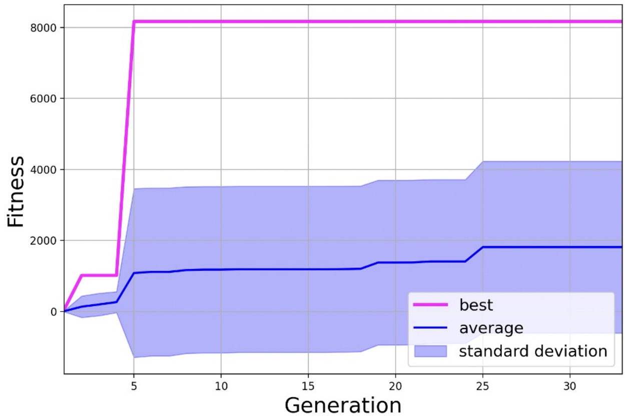
Graph 1 : Evolution of the fitness during step 1



Graph 3 : Evolution of the fitness during step 3



Graph 2 : Evolution of the fitness during step 2



Graph 4 : Evolution of the fitness during step 4

EPFL

Prototyping

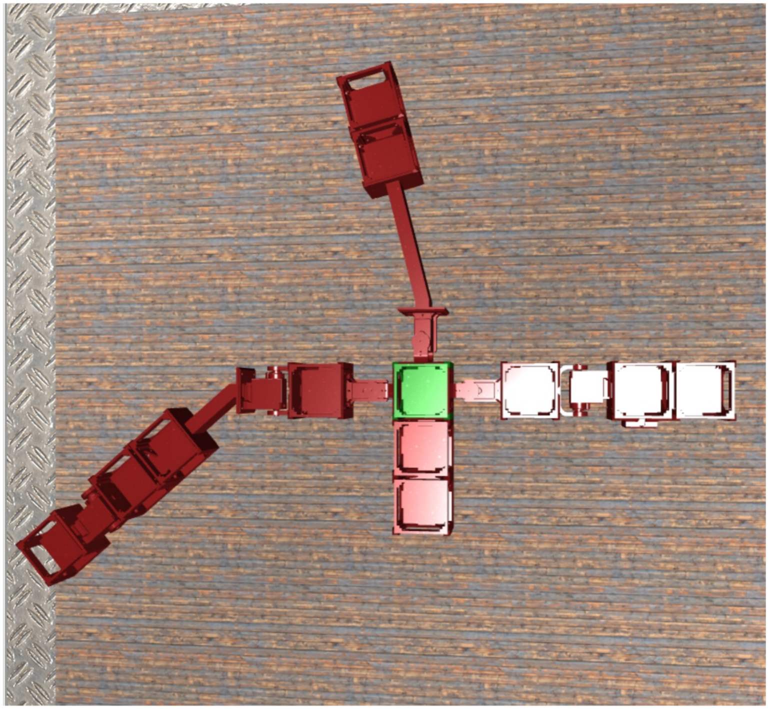


Figure 9: Final robot morphology

21 Blocks total
6 Servo Motors
1 IR Sensor
1 IMU

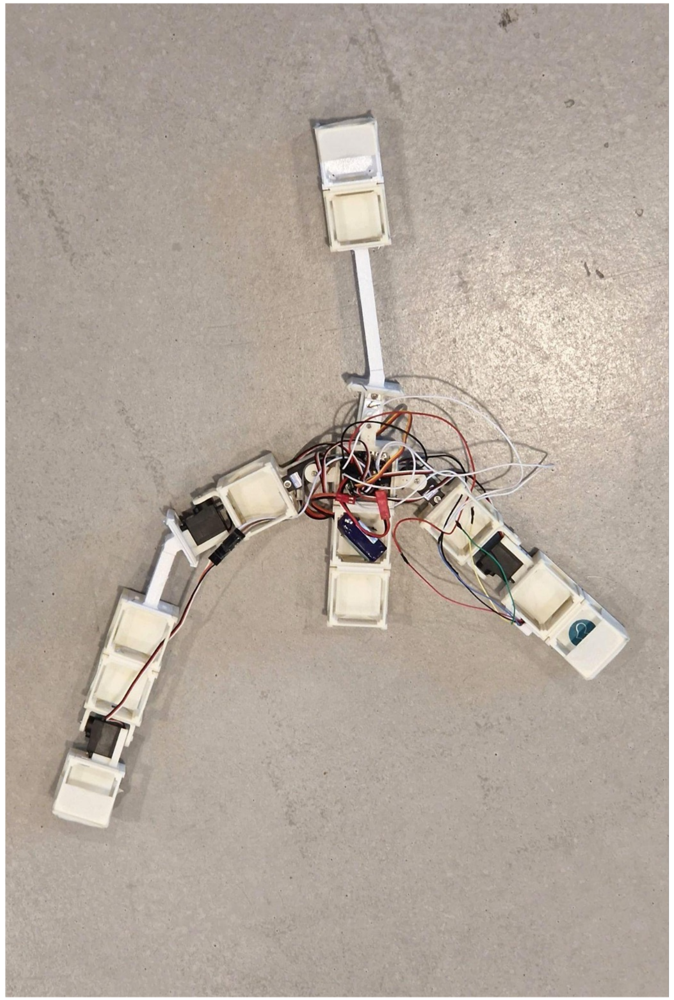
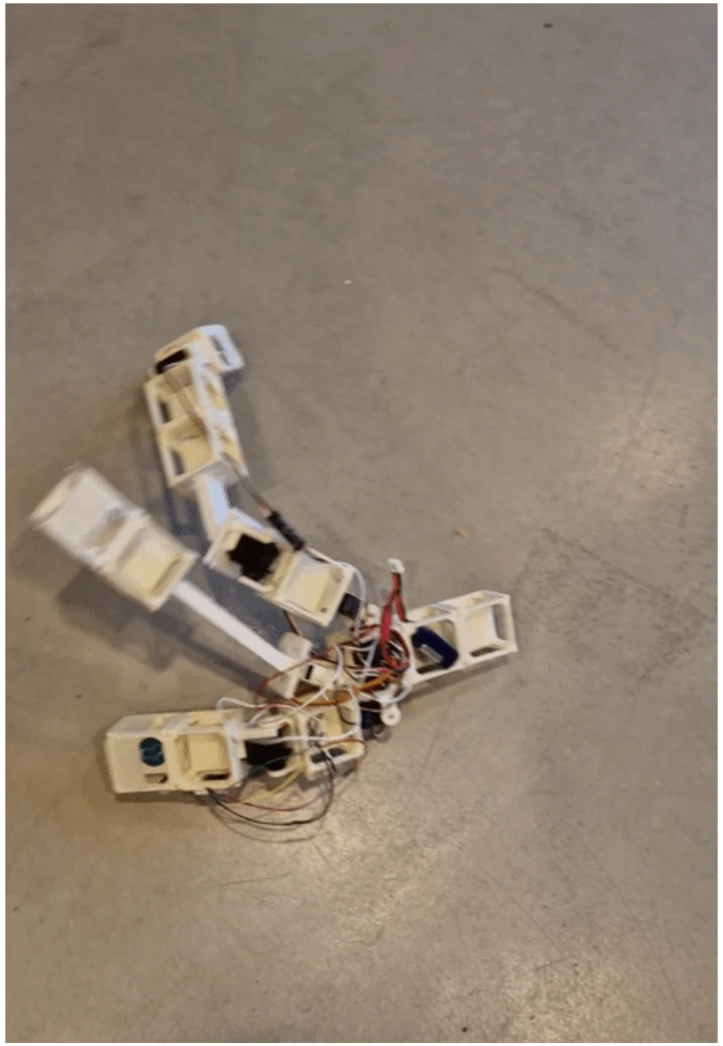


Figure 10: Robot prototype in real life

Figure 11: Final design ?

https://noaateacheratsea.blog/tag/lobsters/

Prototype performances

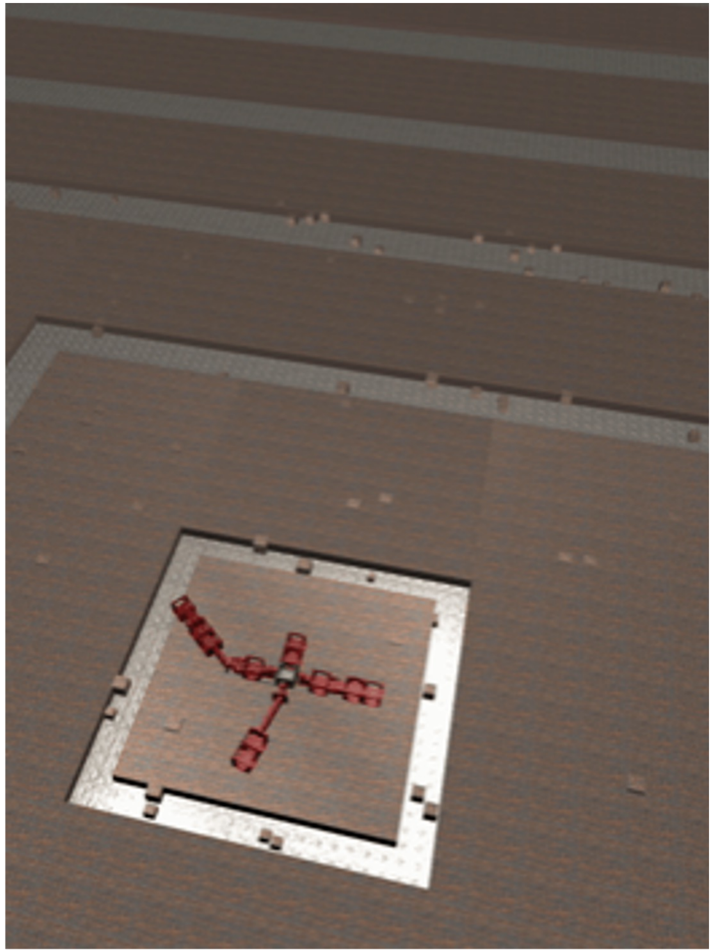


Video 1: Crawling gait

- Big sim-to-real gap
- Unable to climb trenches
- Able to walk with various gaits
- Surprisingly natural looking movements

Video 2: Dragging gait

Sim-to-Real Gap



Video 3: Simulation of step 4

Due to:

- Inaccurate sensor and actuator simulation
- IMU orientation
- Friction with the floor
- Unpredictable neural network behaviors

Video 4: Rotational gait

Conclusion

Multistep evolution helps to find a solution tailored to our needs

A good planning for the scientific approach is necessary to optimize time and results

Evolution takes time and a lot of simulation

→ We need a lot of computational resources

Even with a simulation close to reality, we still observe a big simulation to reality gap

Body-brain at specific stages helps to discover new ways to solve a defined problem, even if after some time the algorithm struggle to find new good solutions (step3-4).

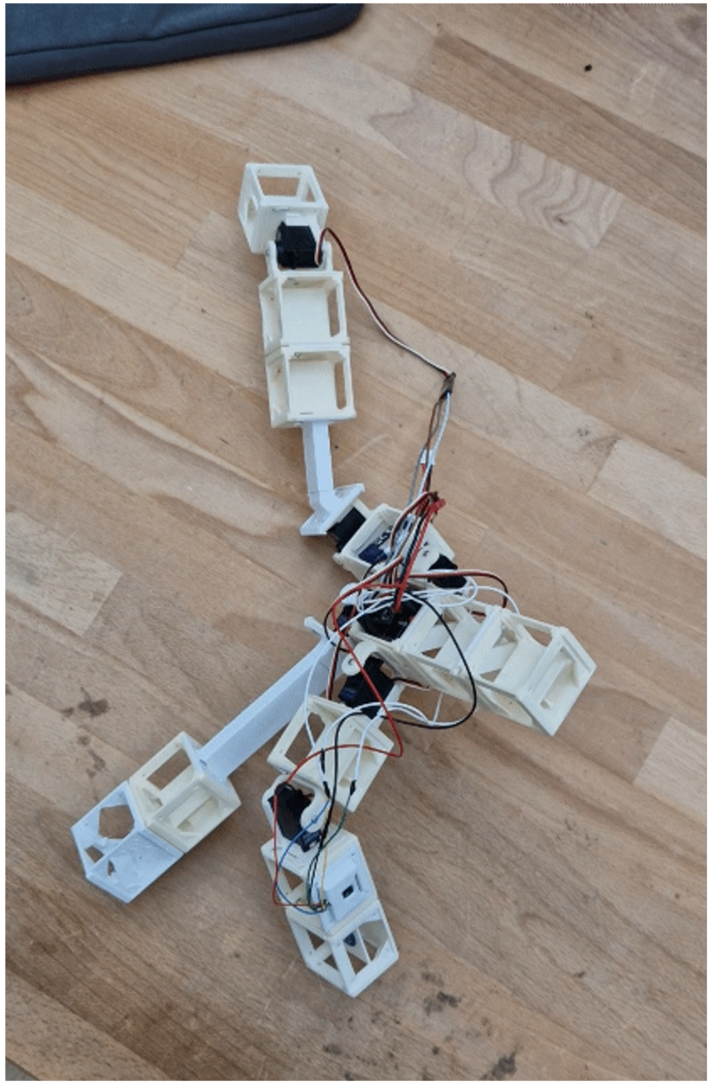
Workload distribution

	Rémi Oddon	Erik Mortensen	Killian Hinard
Evolution	Step 1-2-3-4	-	Step 1-2-3-4
Construction	-	Construction/ Soldering/ 3D-printing	-
Report	Powerpoint	Powerpoint	Powerpoint

Table 11: Workload distribution

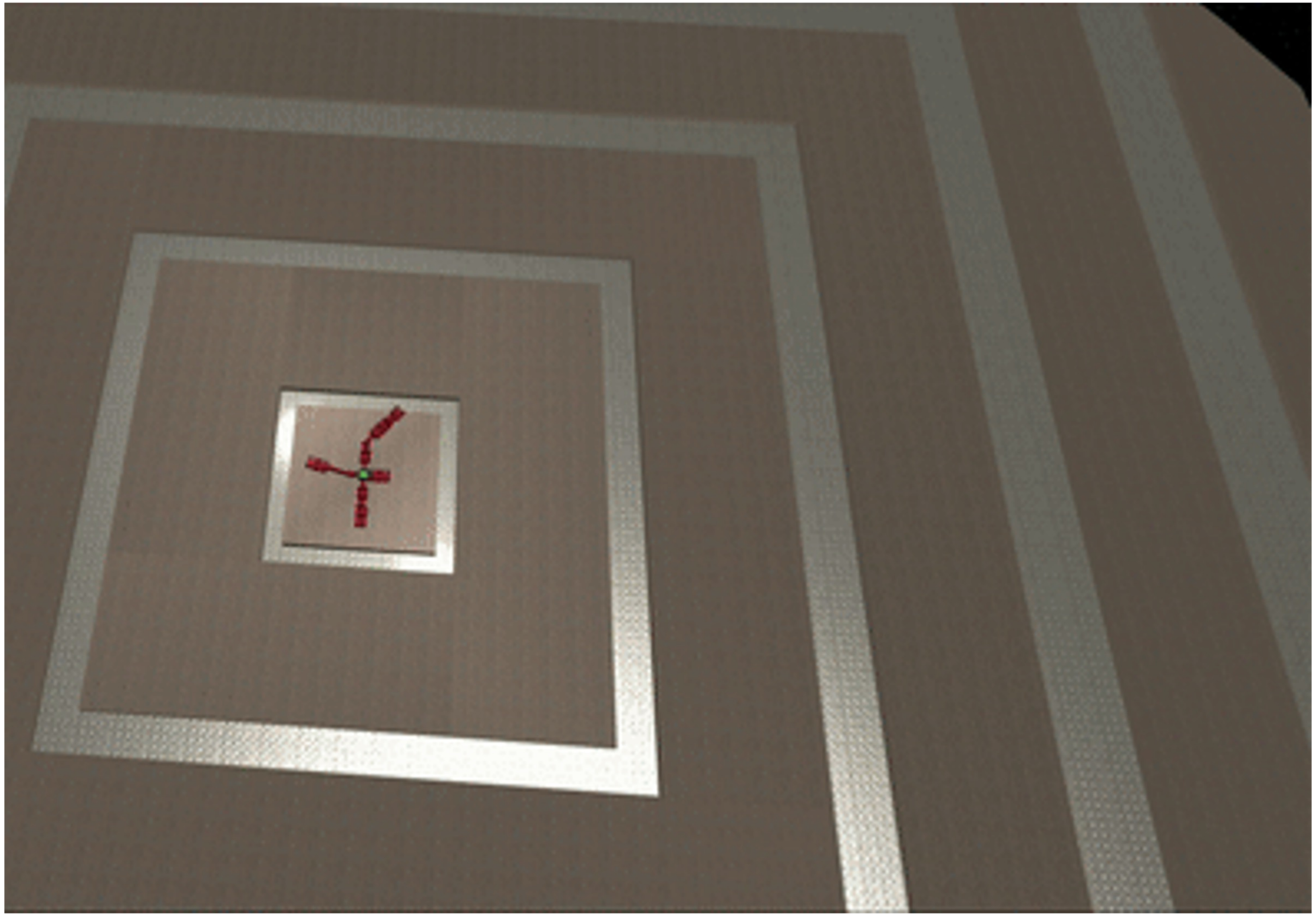
Thank you for your attention !

Any questions ?



Video 5: Farewell gait

Appendix



Video 6: Simulation step 3