Modular snake robots

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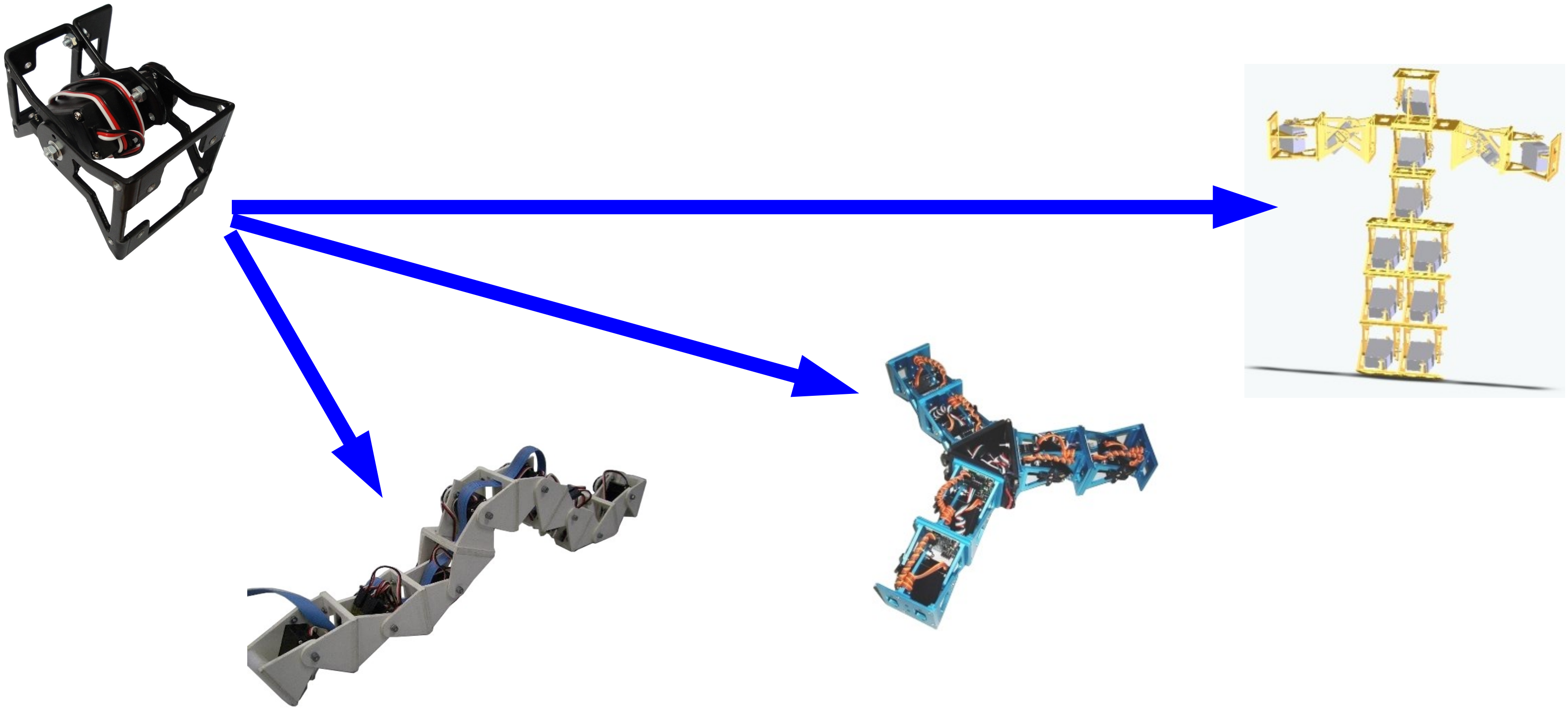
Agenda

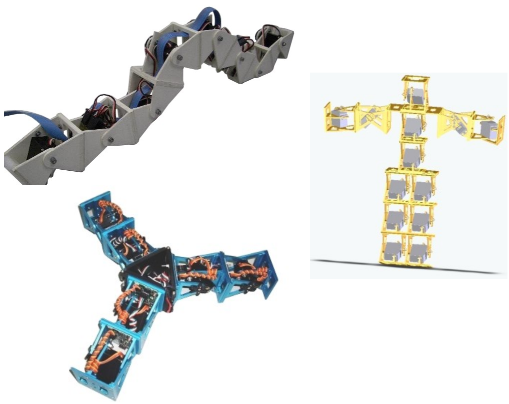
Modular robots

One module, multiple configurations



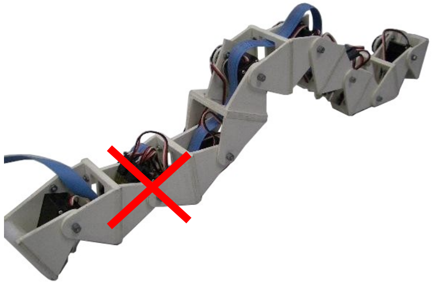
Modular robots: advantages

Versatility

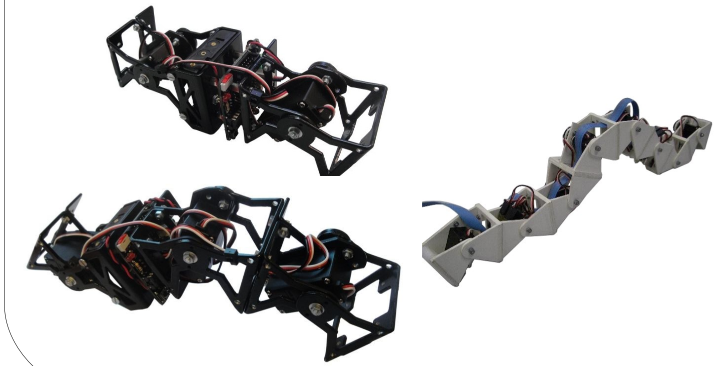


Lower cost

Fault tolerance



Rapid prototiping

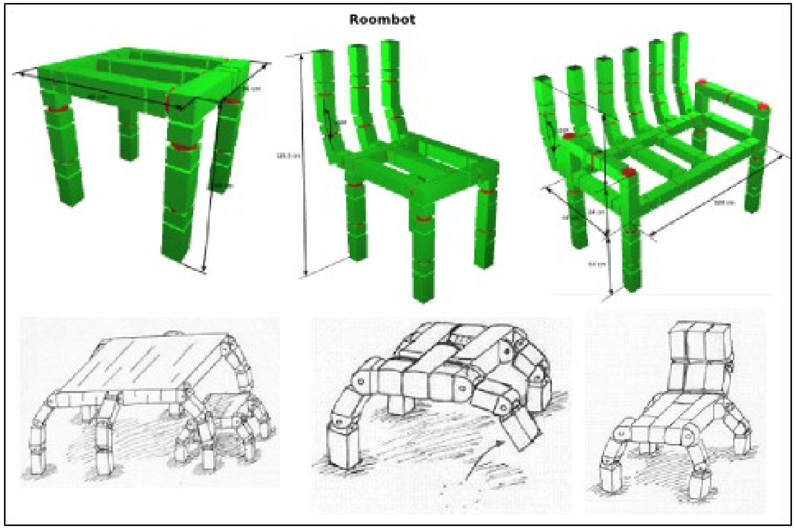


New capabilities

- Self-reconfiguration
- Self-repair
- Self-duplication

New capabilities

Building solid object!



(*RoomBot*, Arredondo et al.)

Bioinspired Robotics Lab at EPFL

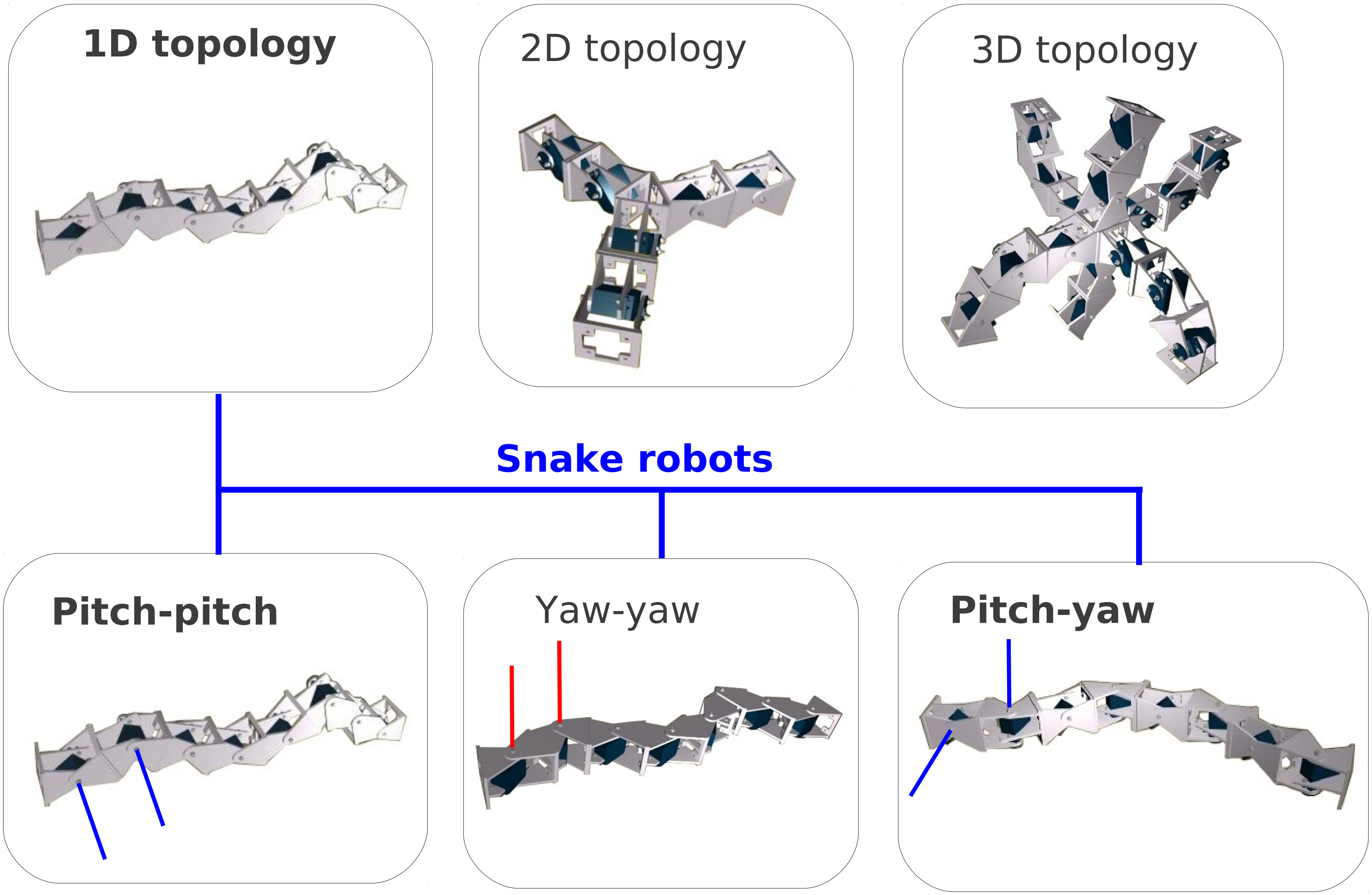
Modular flying robots

(*Distributed flight array*, Oung et al.)

ETH Zurich

- Modular robotic furnitures, capable of moving :-)

Morphology

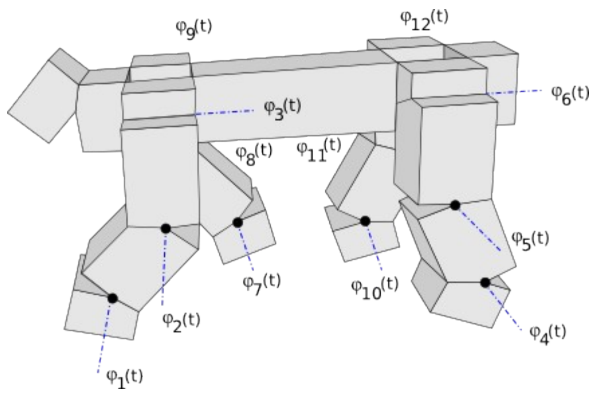

1D topology
2D topology
3D topology
Snake robots
Pitch-pitch
Yaw-yaw
Pitch-yaw

Controller

Unit in charge of moving the joints for achieving the robot locomotion

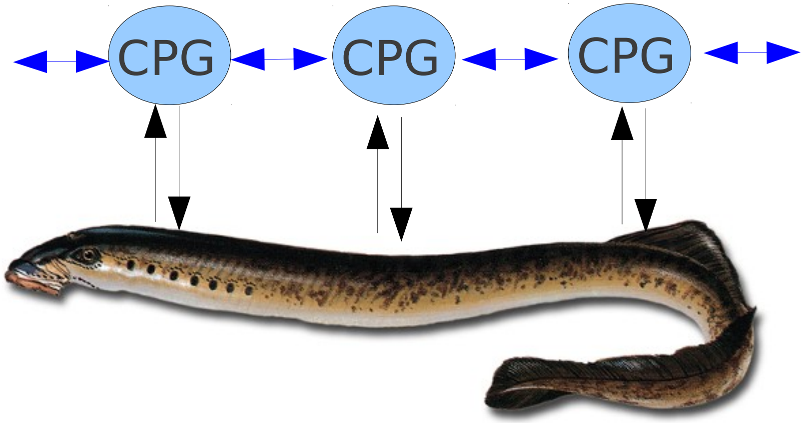
Classic

- Mathematical models
- Inverse kinematics
- Depend on the morphology



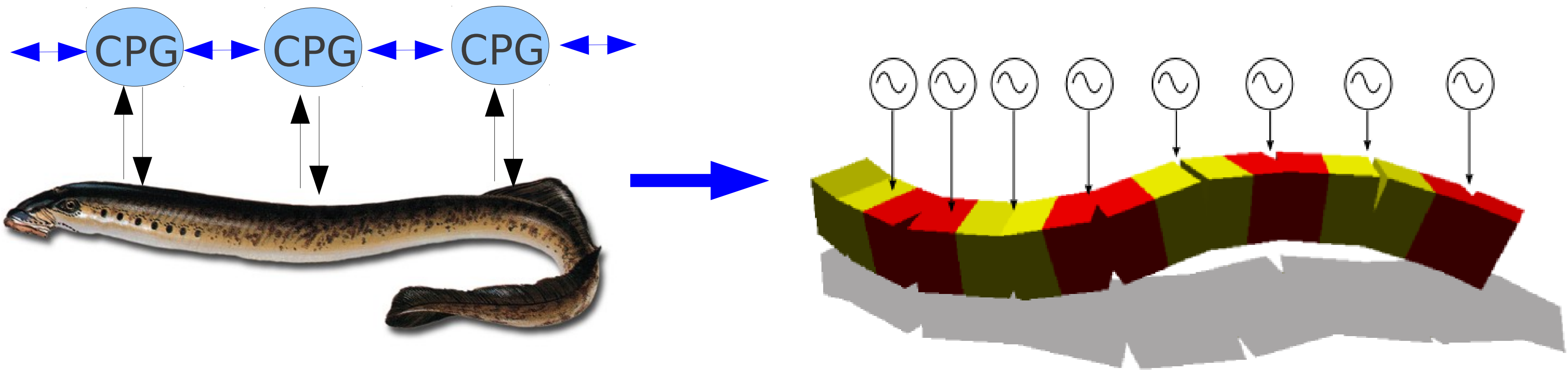
Bio-inspired

- Nature imitation
- Central pattern generators (CPG)

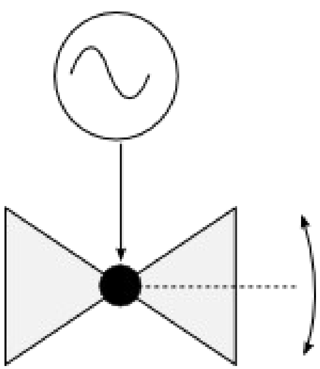


Controller for snake robots

- Replace the CPGs by **sinusoidal oscillators**



- Sinusoidal oscillators:



$$\varphi_i(t) = A_i \sin\left(\frac{2\pi}{T} t + \psi_i\right) + O_i$$

Advantages:

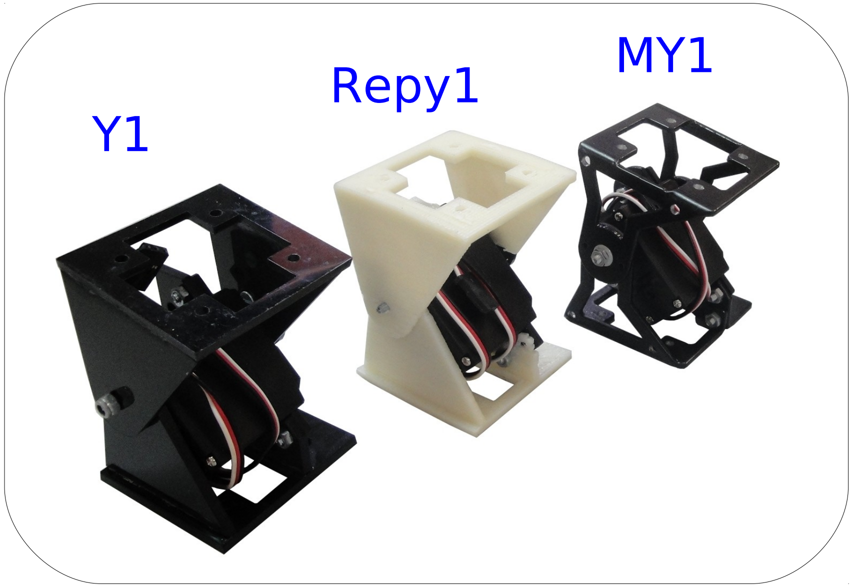
- Very few resources are needed for their implementation

Agenda

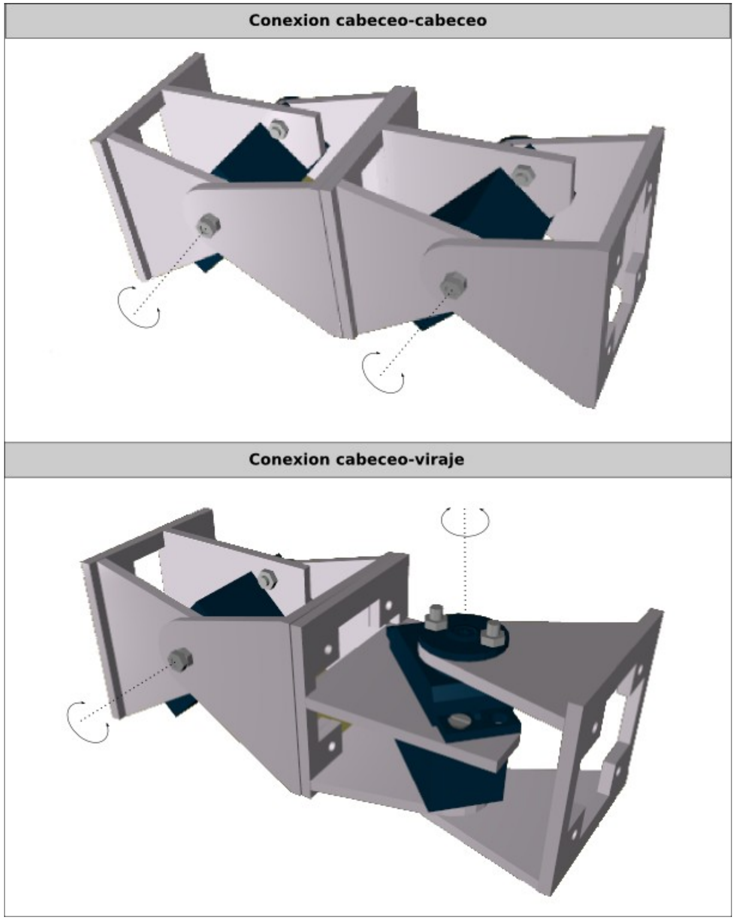
1. Introduction
2. **Modules**
3. Locomotion in 1D
4. Locomotion in 2D
5. Conclusions

Y1 modules family

- One degree of freedom
- Easy to build
- Servo: Futaba 3003
- Size: 52x52x72mm
- Open source

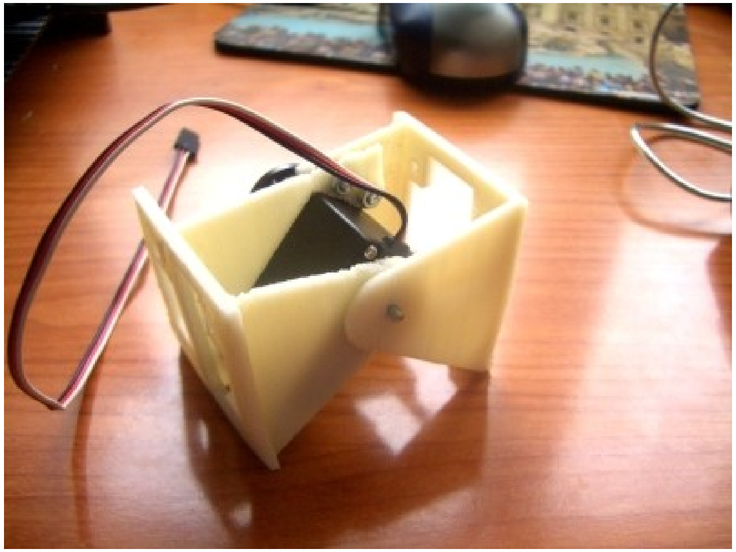


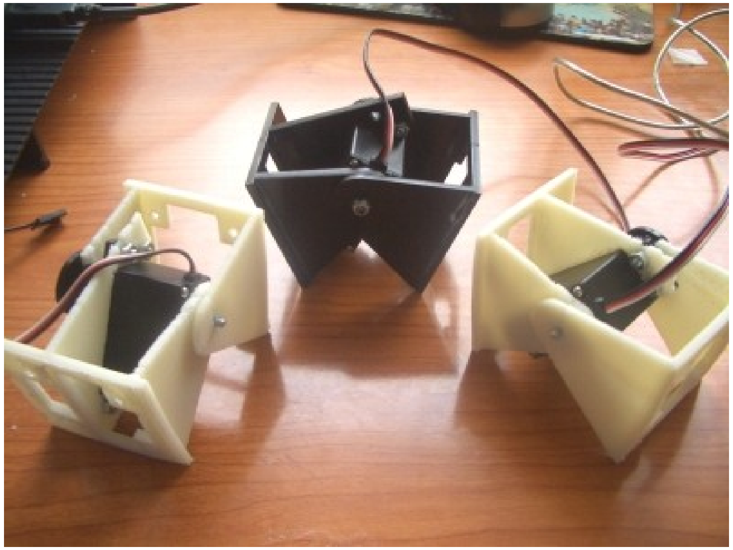
Types of connection



REPY-1: 3D printables

- Printables on an Open source 3d printers (Reprap)
- Material: ABS plastic (the same material than Lego)
- rough
- Print time: 1h 30 min (45 min each part)

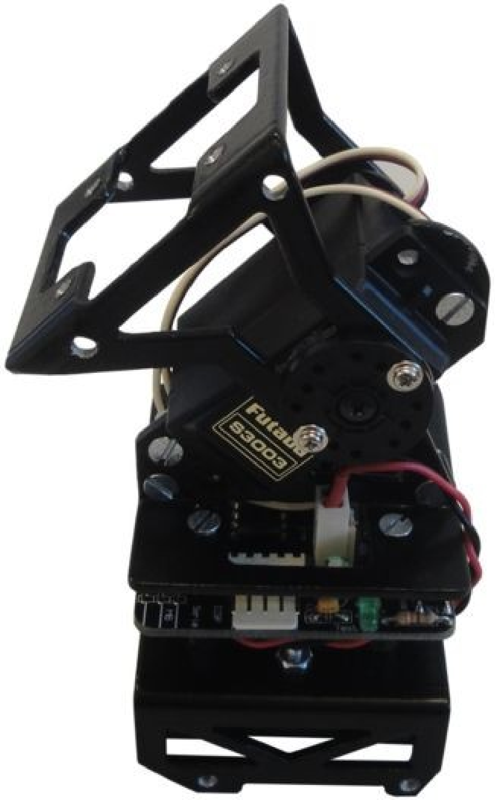


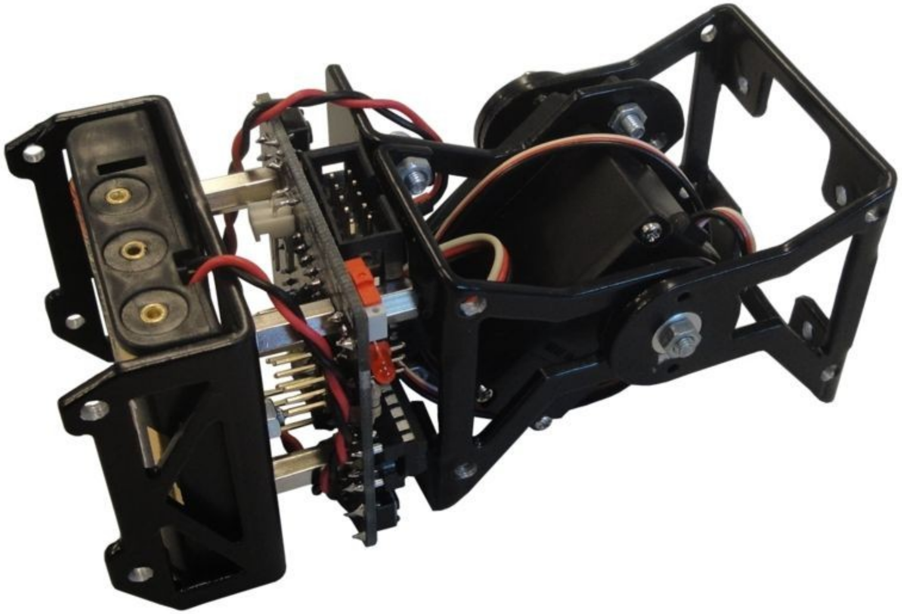


MY1 modules

- Material: Aluminium 2mm wide
- Consist of three screwed parts
- Designed mainly for Educational purposes

Unimod

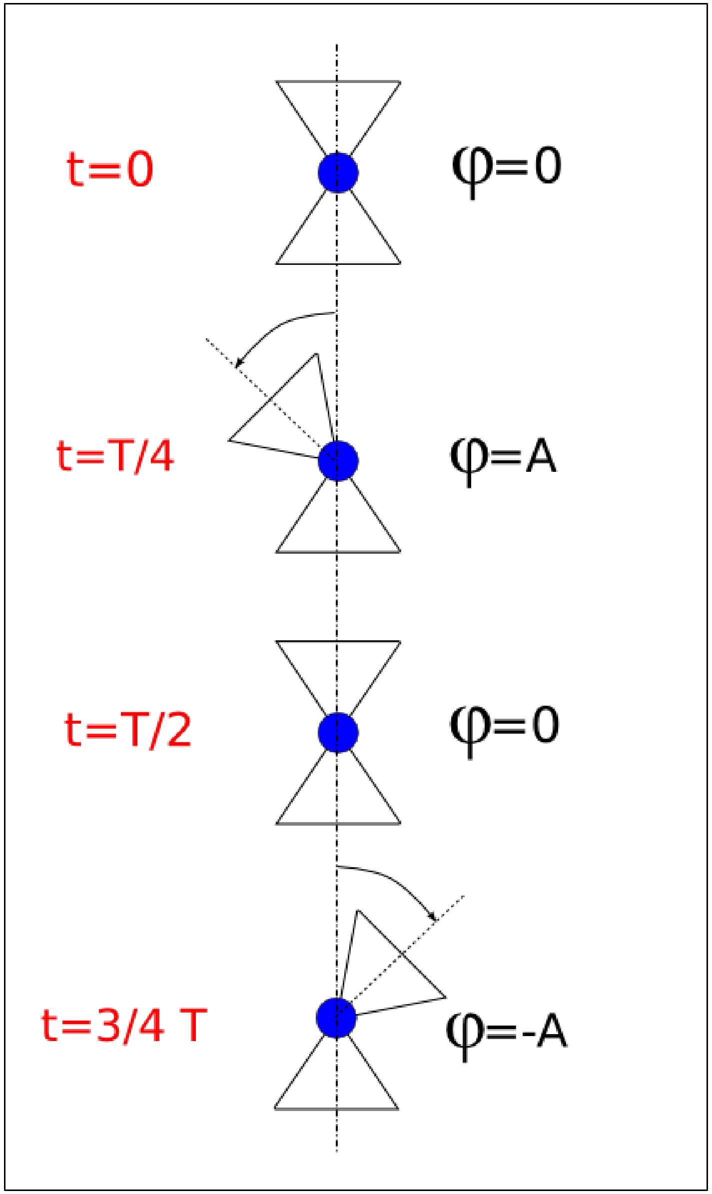


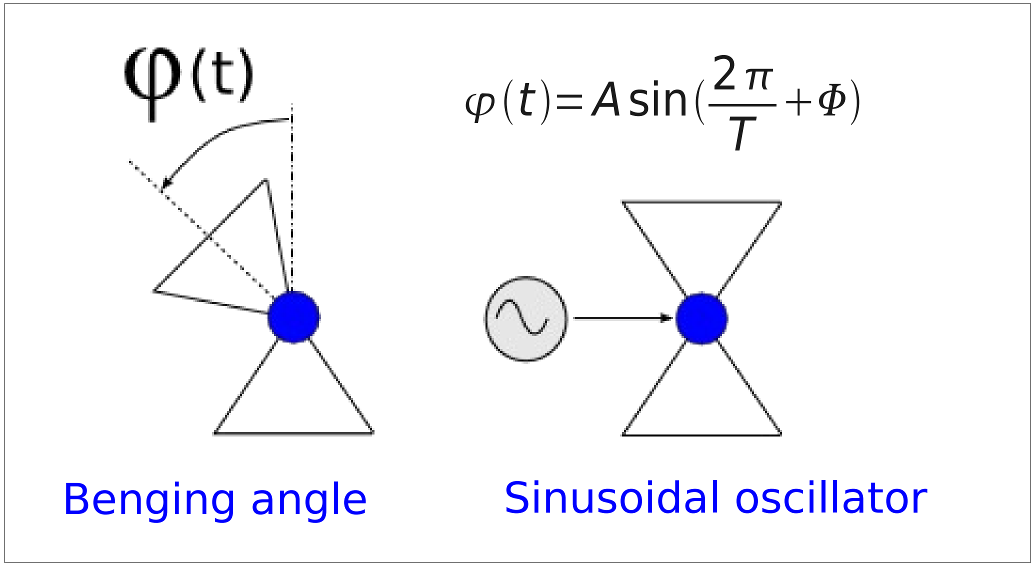


- Module capable of oscillating autonomously
- 1D topology robots are built from them

Module oscillation

Demo





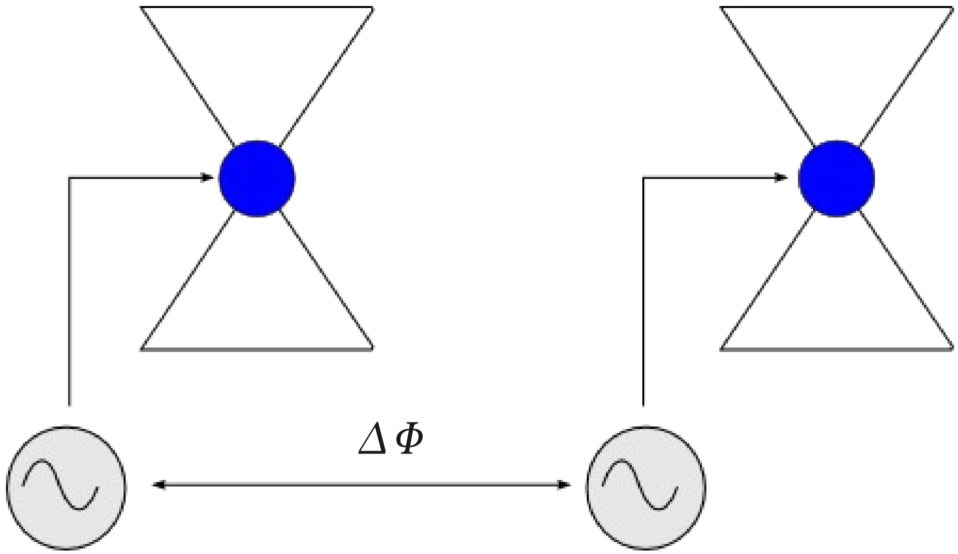
Parameters:

- **Amplitude**: A
- **Period**: T

Oscillation of two modules

Demo

$$\varphi_1(t) = A\sin\left(\frac{2\pi}{T} + \Phi_0\right) \qquad \varphi_2(t) = A\sin\left(\frac{2\pi}{T} + \Delta\Phi + \Phi_0\right)$$



New parameter:

- **Phase difference**: $\Delta\Phi$

It determines how a module oscillates in relation to other

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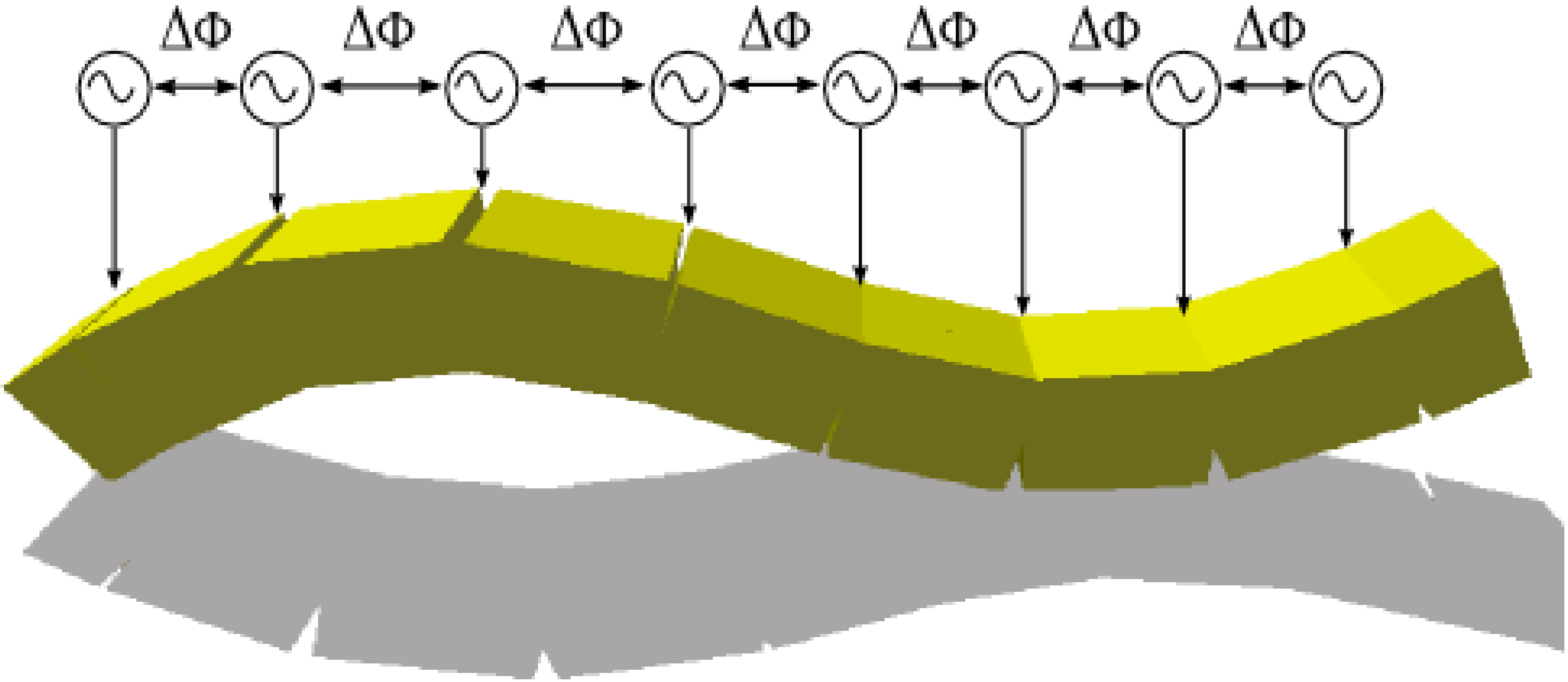
Control model



Minicube-I robot

Demo Video

Minimal configuration

Minimal modular robot capable of moving straight

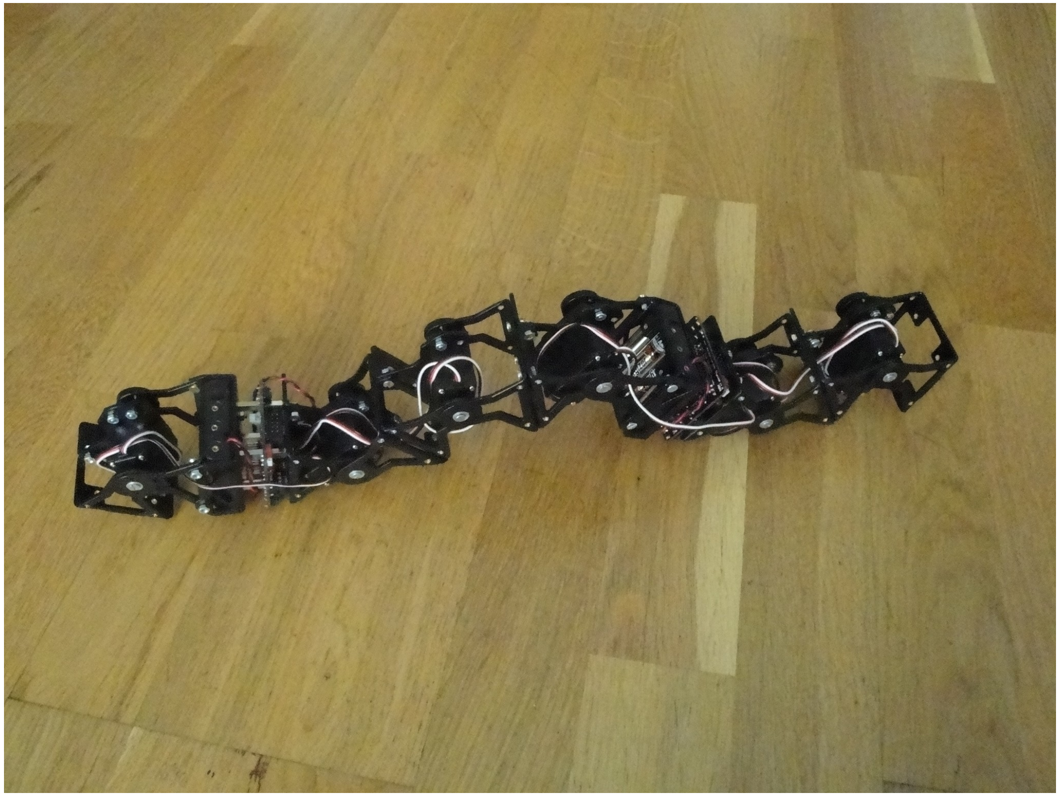
Cube3

Demo

- **Morphology**: 3 pitch modules
- **Controller**: 3 equal oscillators

Cube 6

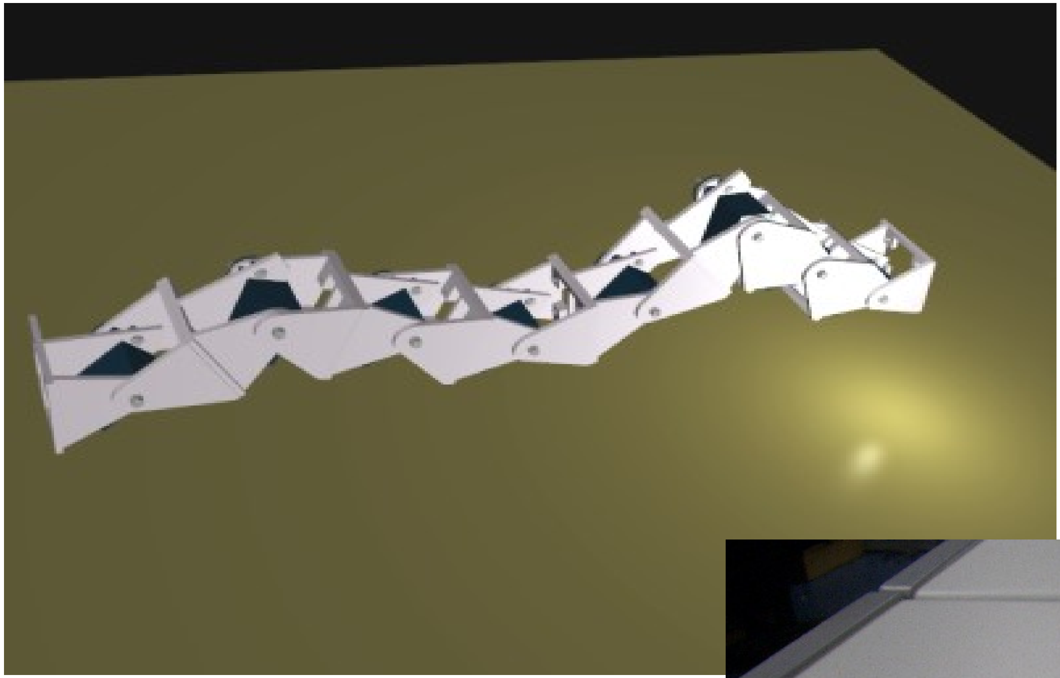
Demo

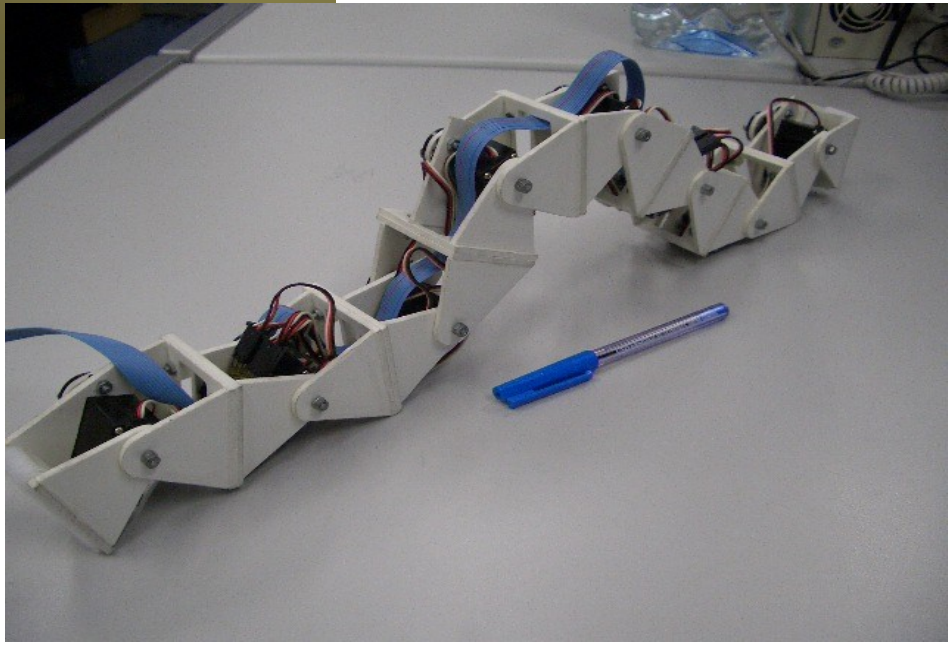


- **Morphology**: 6 pitch modules
- **Controller**: 6 equal oscillators

Cube 8

Video





CUBE 12

- Built by the students
- Consist of 4 Cube3 independents robots
- No communication between the segments

CUBE 18

Video

Spanish record

- 18 módulos
- Length: 1.5 m
- Date: 22/July/2010

CUBE 30

- 30 modules
- Length: 2.5 m
- Date: 07/March/2011

European record

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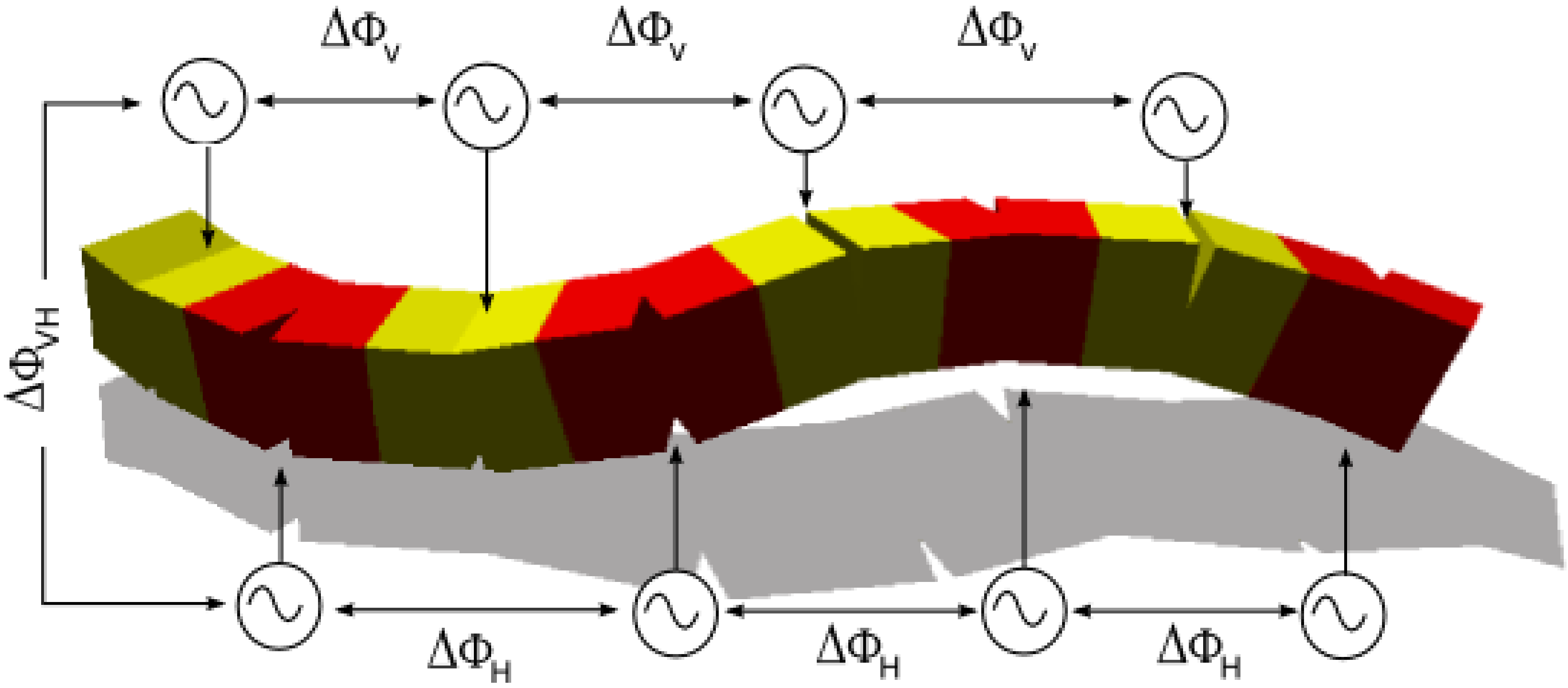
Control model



Minicube-II Robot

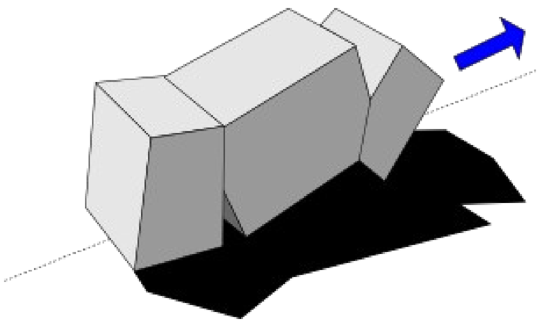
Demo

Minimal configuration

Minimal robot capable of reaching any point in a plane with any orientation

Locomotion gaits

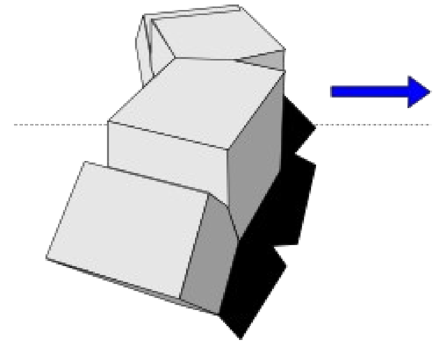
Straight



$A_v = 40, A_h = 0$

$\Delta\Phi_v = 120$

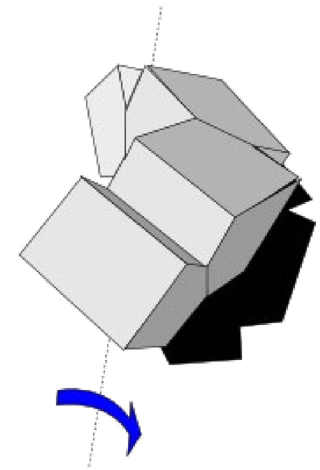
Sideways



$A_v = A_h < 40$

$\Delta\Phi_{vh} = 90, \Delta\Phi_v = 0$

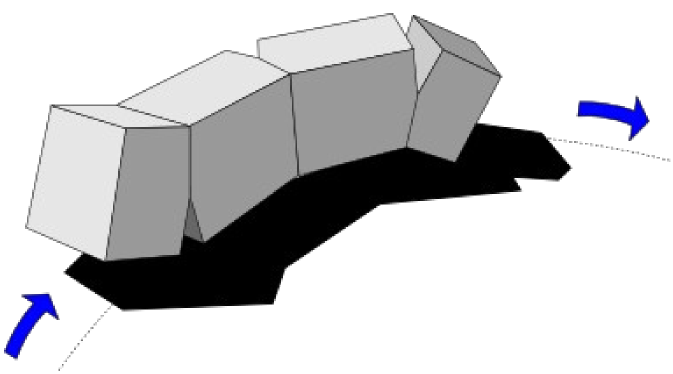
Rolling



$A_v = A_h > 60$

$\Delta\Phi_{vh} = 90, \Delta\Phi_v = 0$

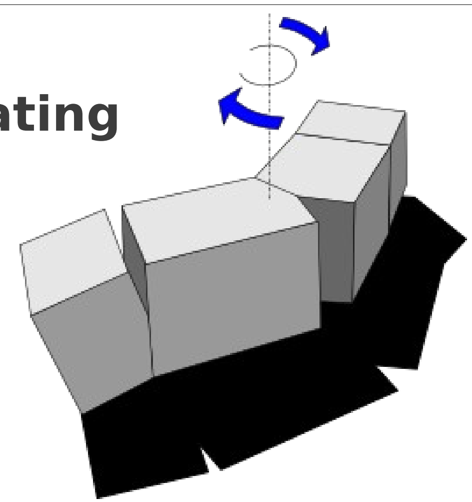
turning



$A_v = 40, A_h = 0$

$O_h = 30, \Delta\Phi_v = 120$

Rotating



$A_v = 10, A_h = 40$

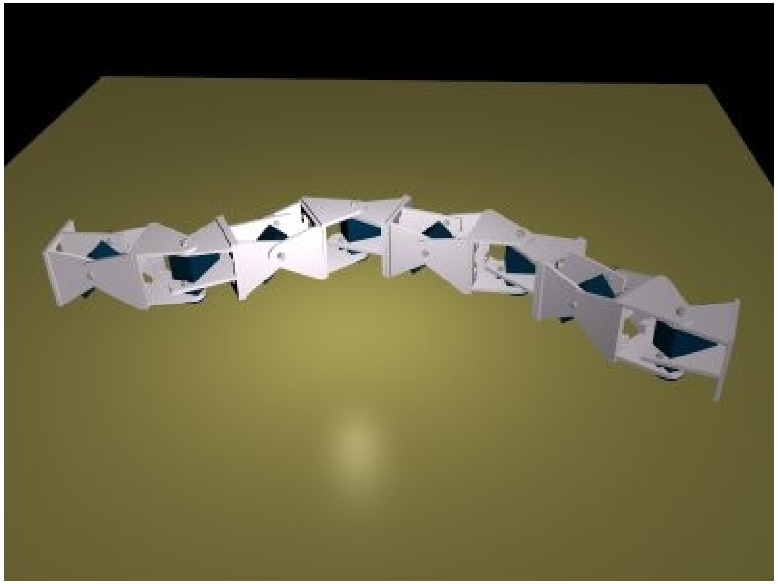
$\Delta\Phi_{vh} = 90, \Delta\Phi_v = 180$

Cube 6 - 2D

Demo

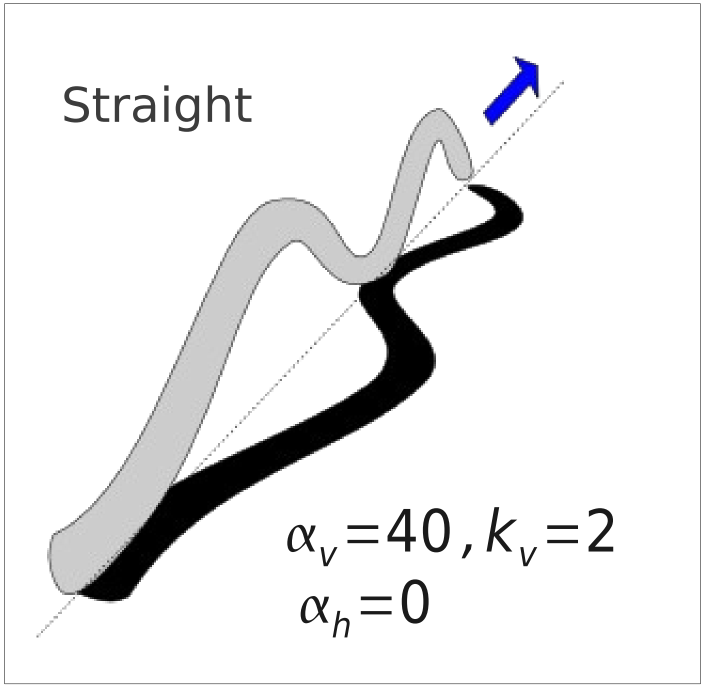
Cube 8-2D

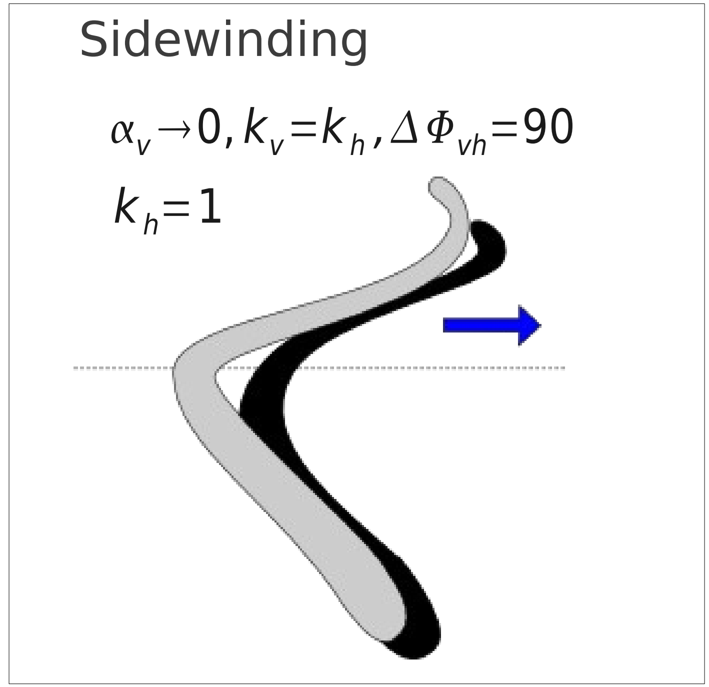
Video

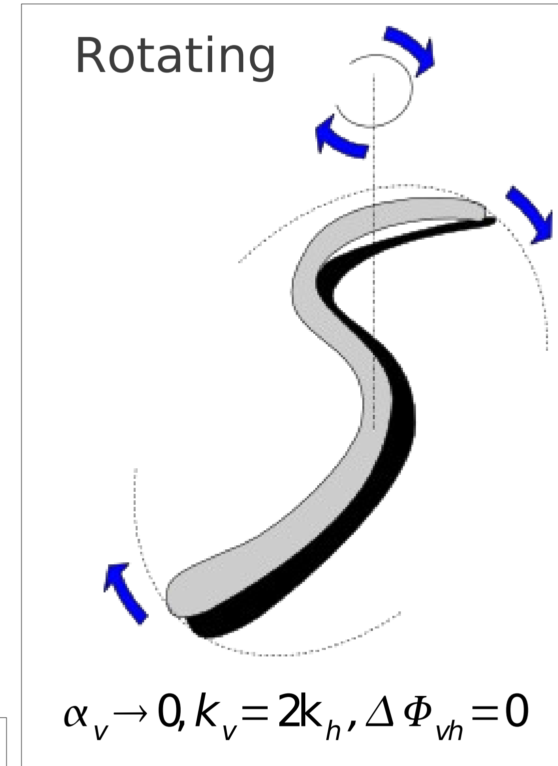


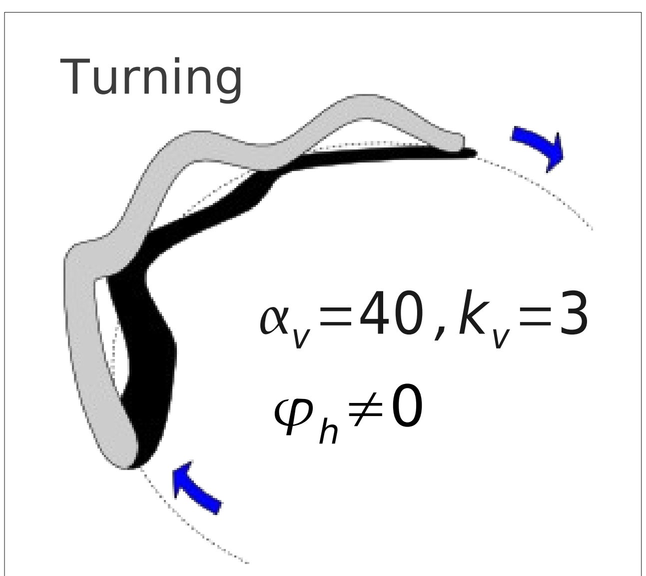
Spanish record

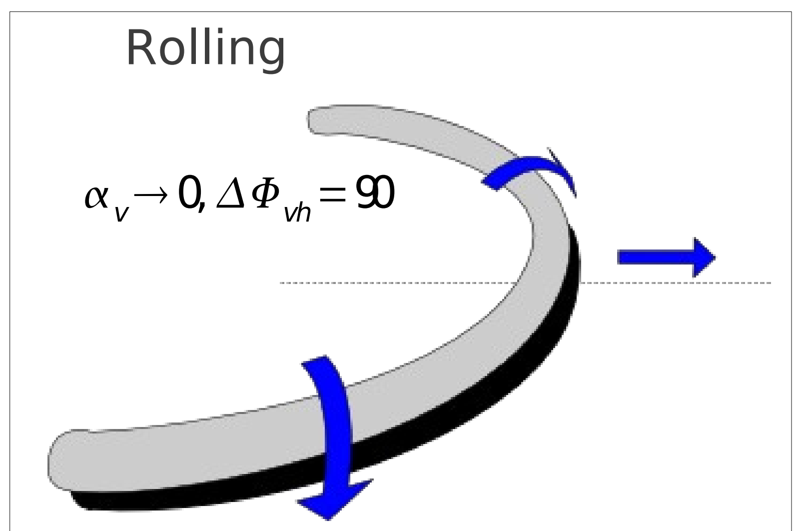
Locomotion gaits











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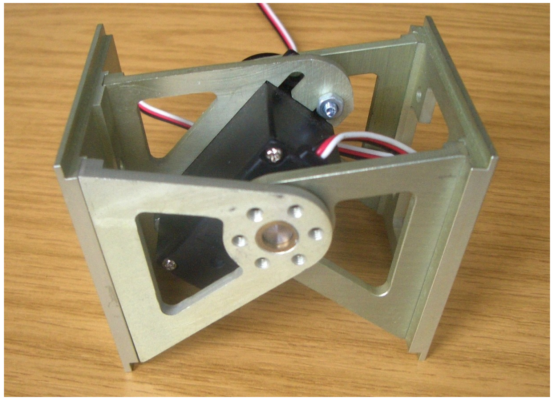
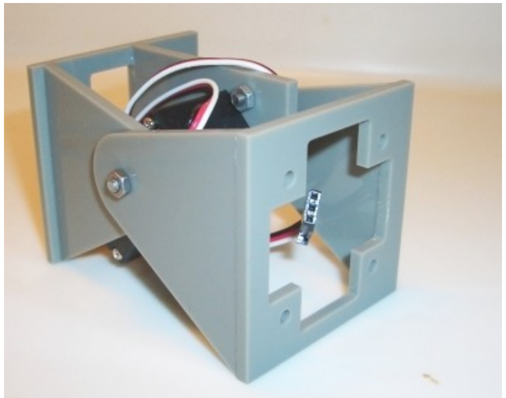
5. **Conclusions**

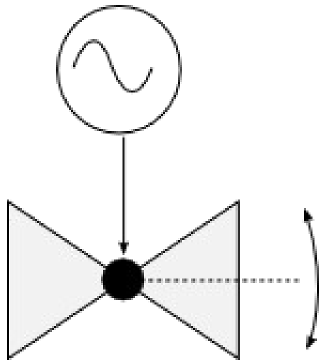
Conclusions

The controller based on sinusoidal generators is valid for the locomotion of 1D topology modular robots

- Very few computational resources required
- Very smooth and natural movements
- Minimal configurations of 2 and 3 modules



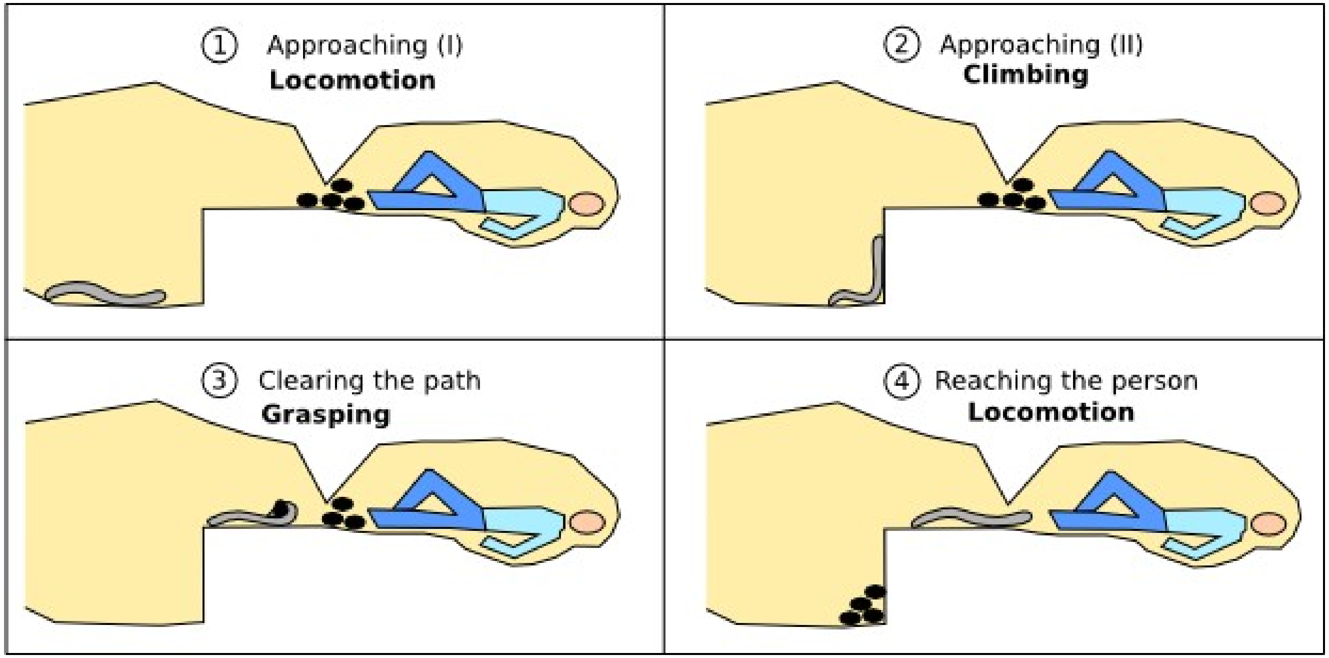




$$\varphi_i(t) = A_i \sin\left(\frac{2\pi}{T} + \psi_i\right) + O_i$$

Future work

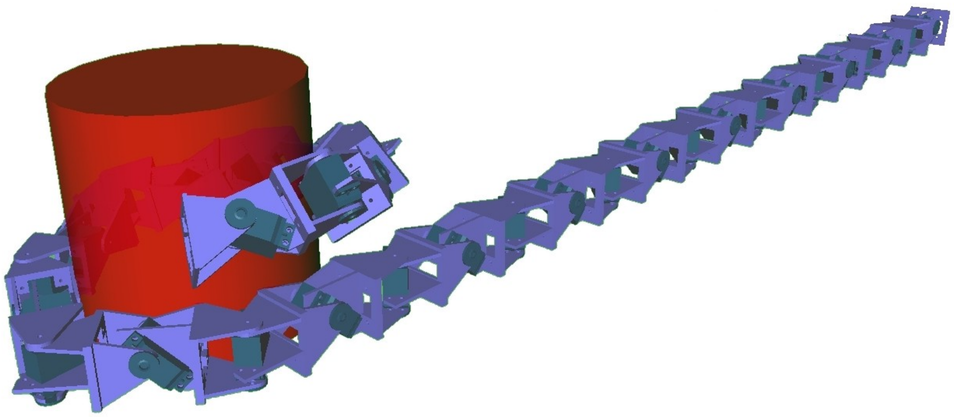
Snake robots for urban search and rescue operations:

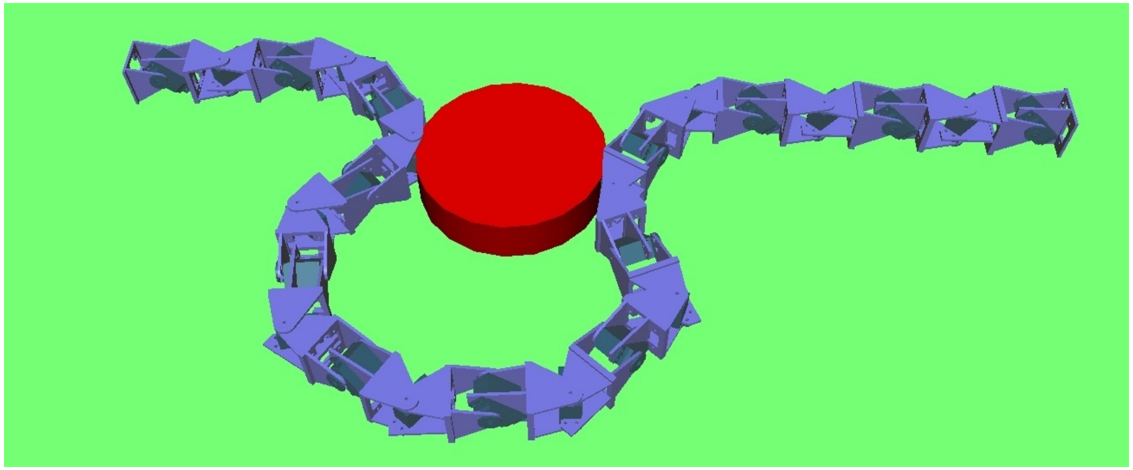


- Capabilities needed (at least): Locomotion, climbing and grasping

Future work (II)

Modular grasping:





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