Let's build a modular snake robot!

Dr. Juan González-Gómez
July-2nd-2013

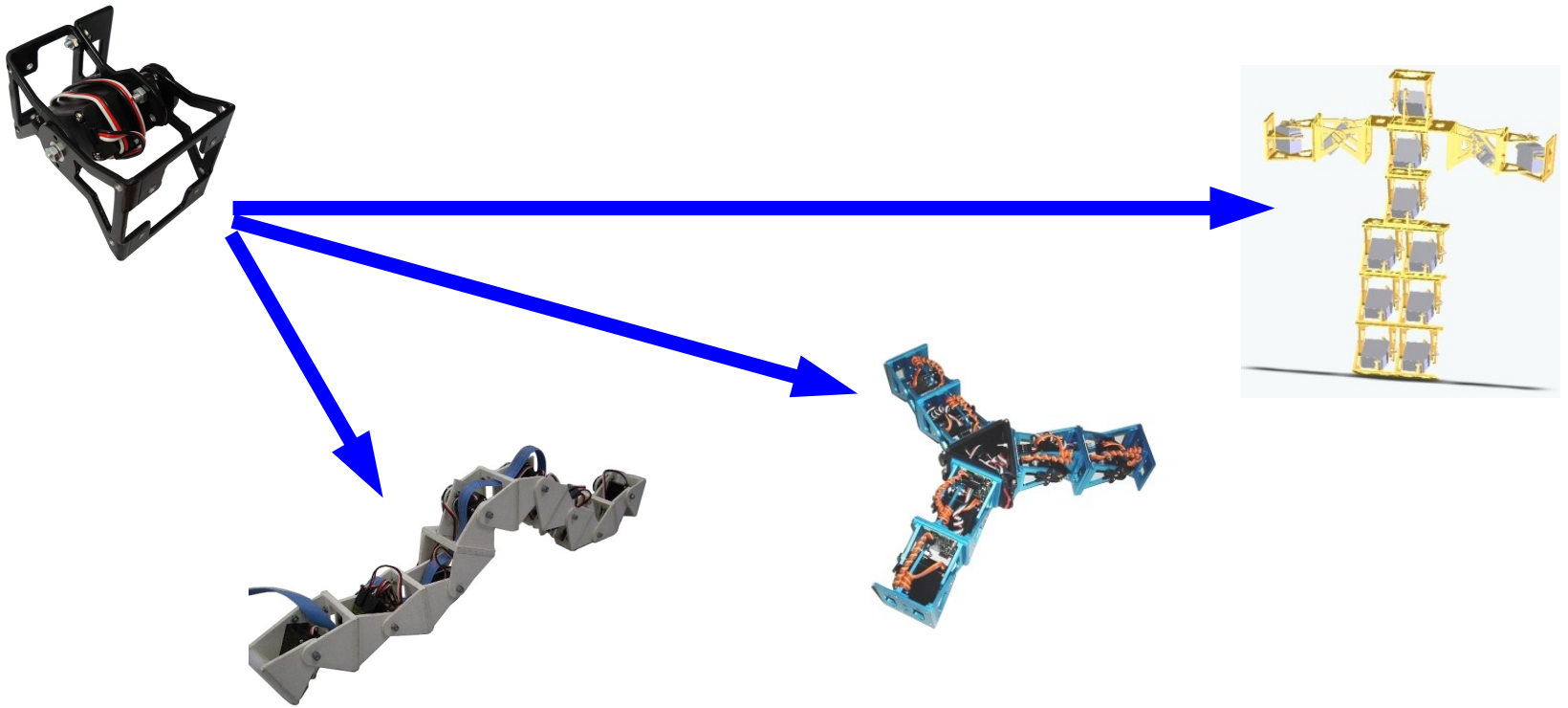
TE Tecnología Electrónica
Universidad de Málaga

Agenda

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

Modular robots

One module to rule them all!!



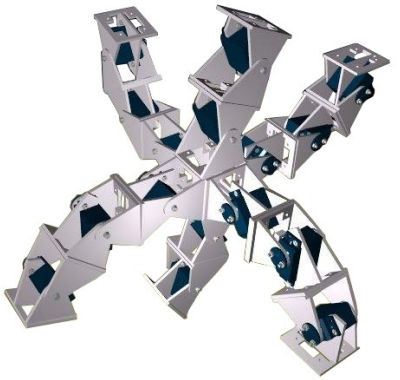
Multiple configurations

Morphology

1D topology

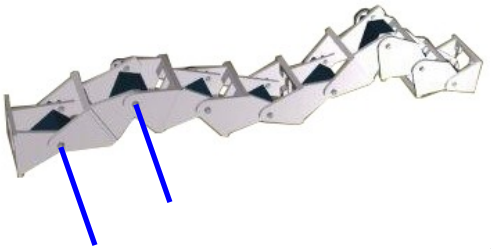
2D topology

3D topology



Snake robots

Pitch-pitch



Yaw-yaw

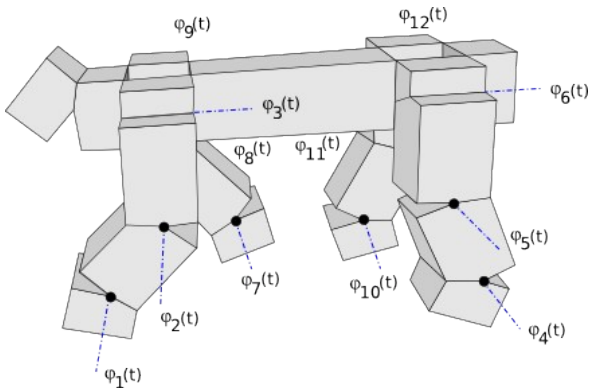
Pitch-yaw

Controller

How to generate the snake motion?

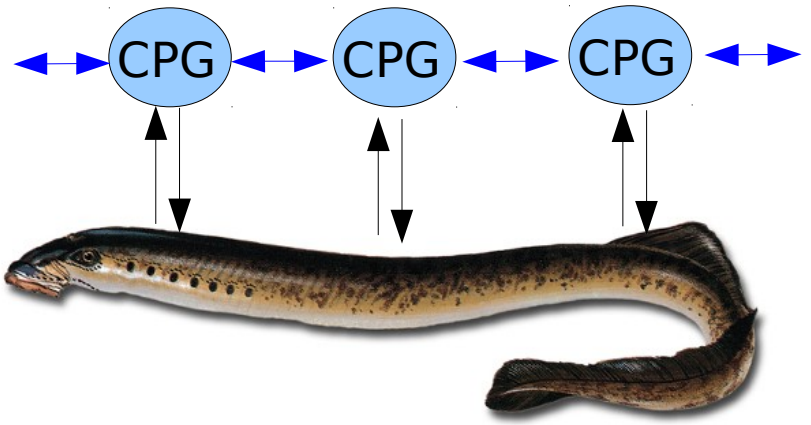
Classic

- Mathematical models
- Inverse kinematics
- Depend on the morphology



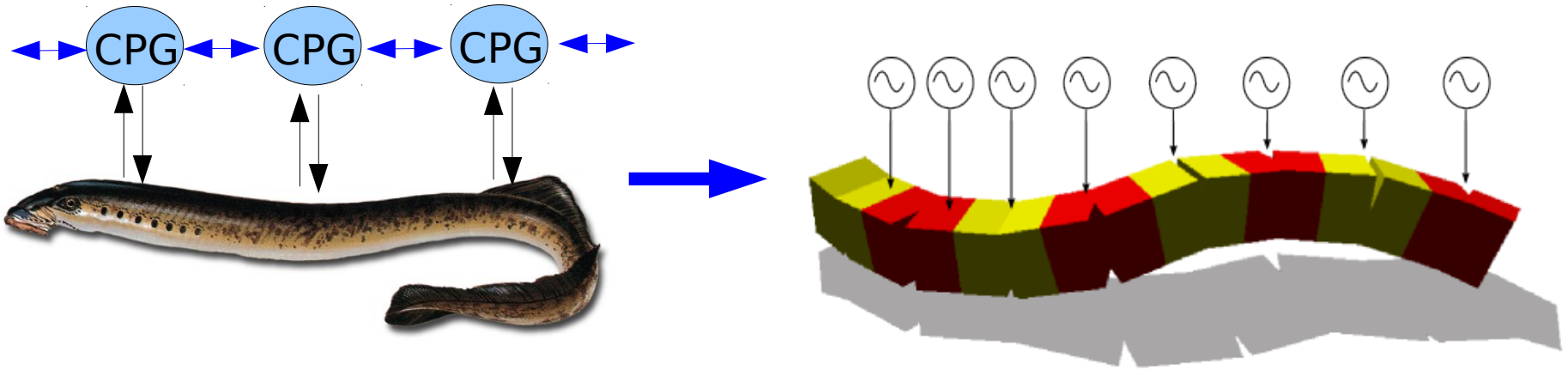
Bio-inspired

- Nature imitation
- Central pattern generators (CPG)

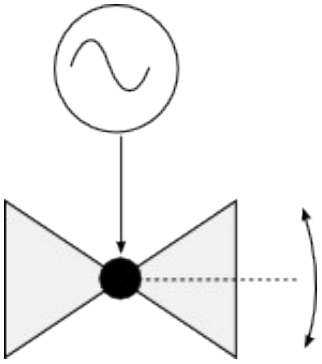


Controller for snake robots

- Replace the CPGs by **sinusoidal oscillators**



- Sinusoidal oscillators:

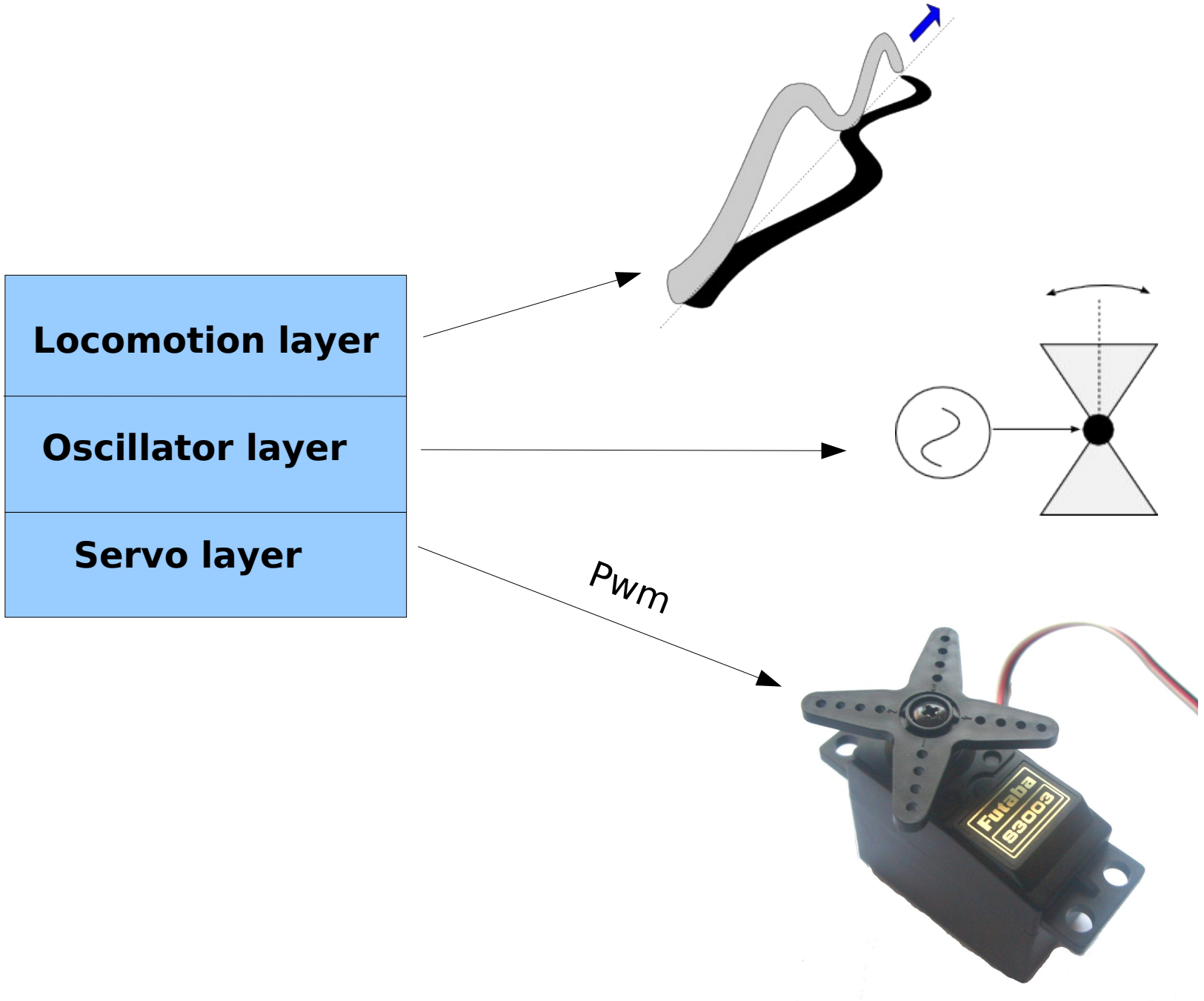


$$\phi_i(t) = A_i \sin\left(\frac{2\pi}{T} t + \psi_i\right) + O_i$$

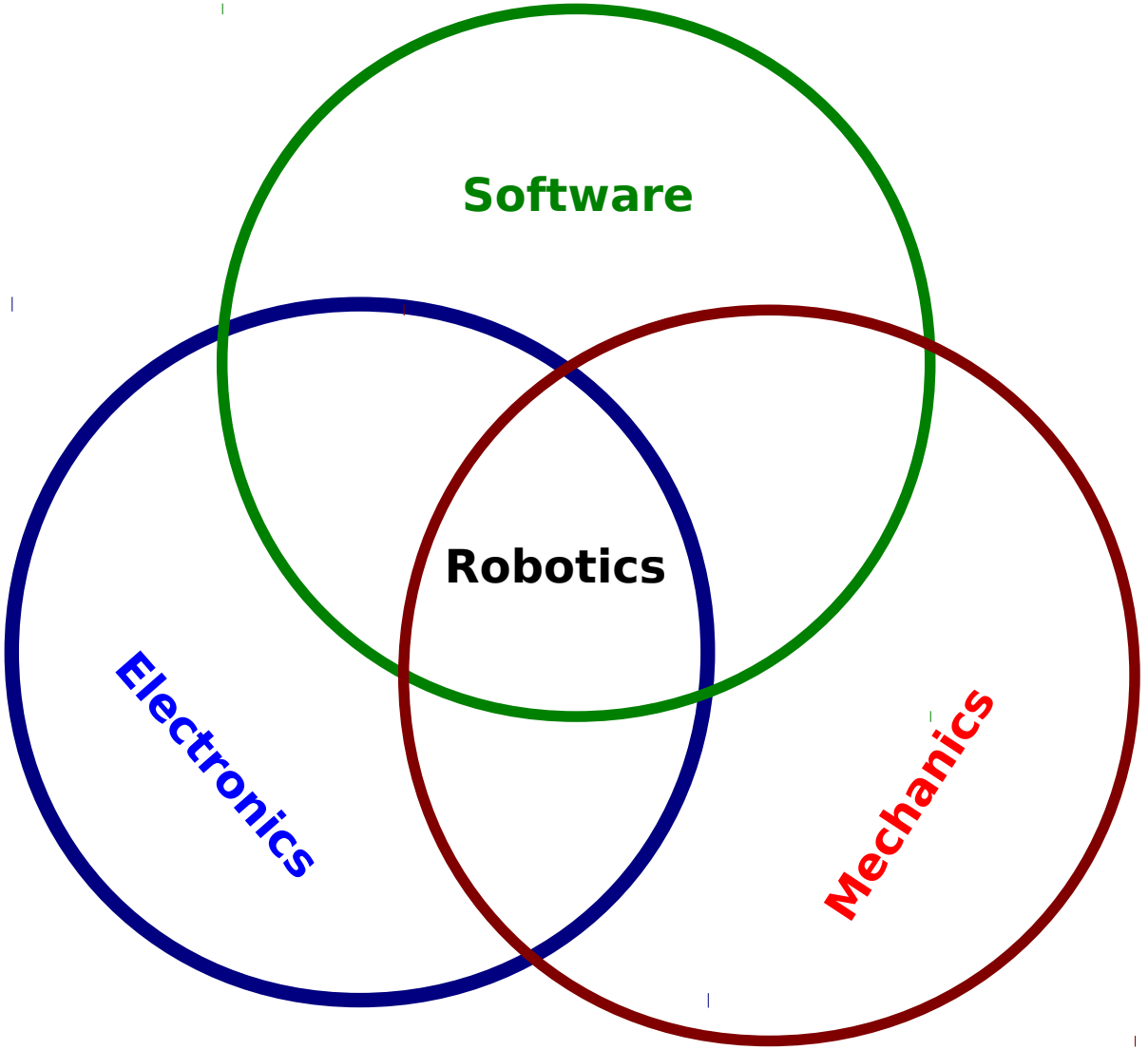
Advantages:

- Very few resources are needed for their implementation

Software architecture



Robotics is interdisciplinary

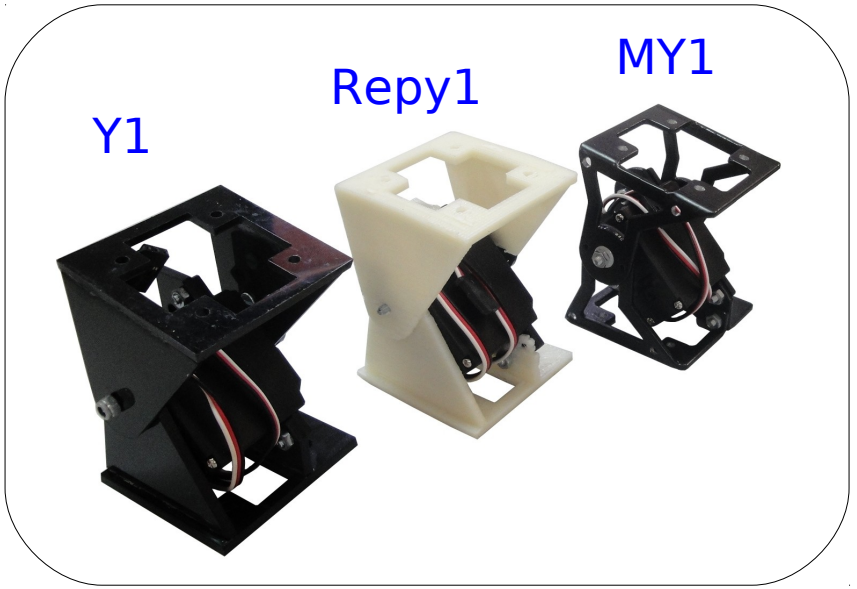


Agenda

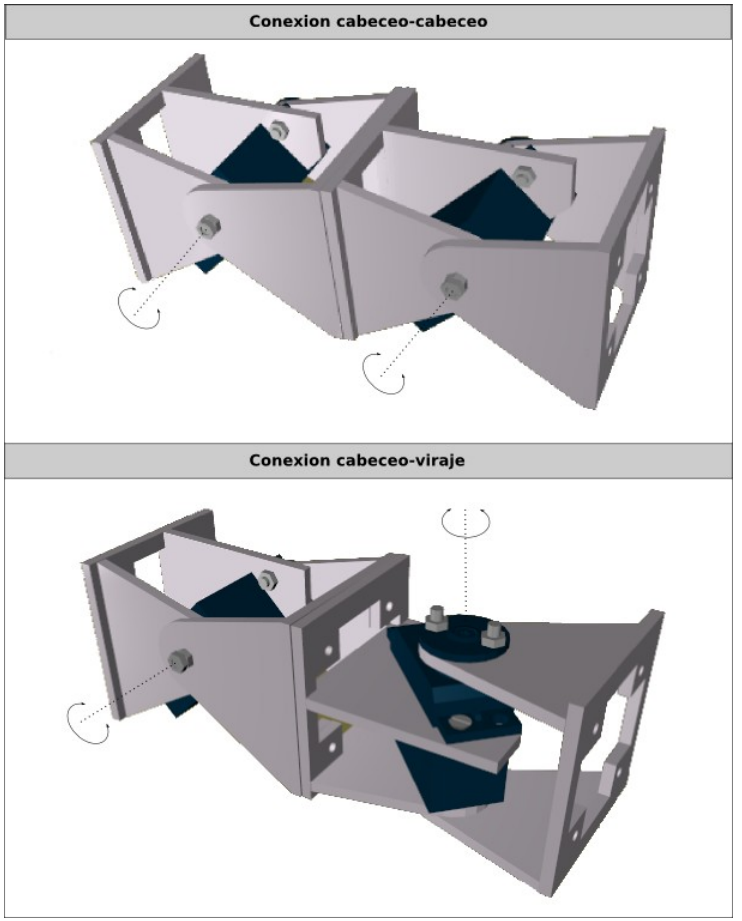
1. Introduction
2. **Modules**
3. Locomotion in 1D
4. Locomotion in 2D

Y1 modules family

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

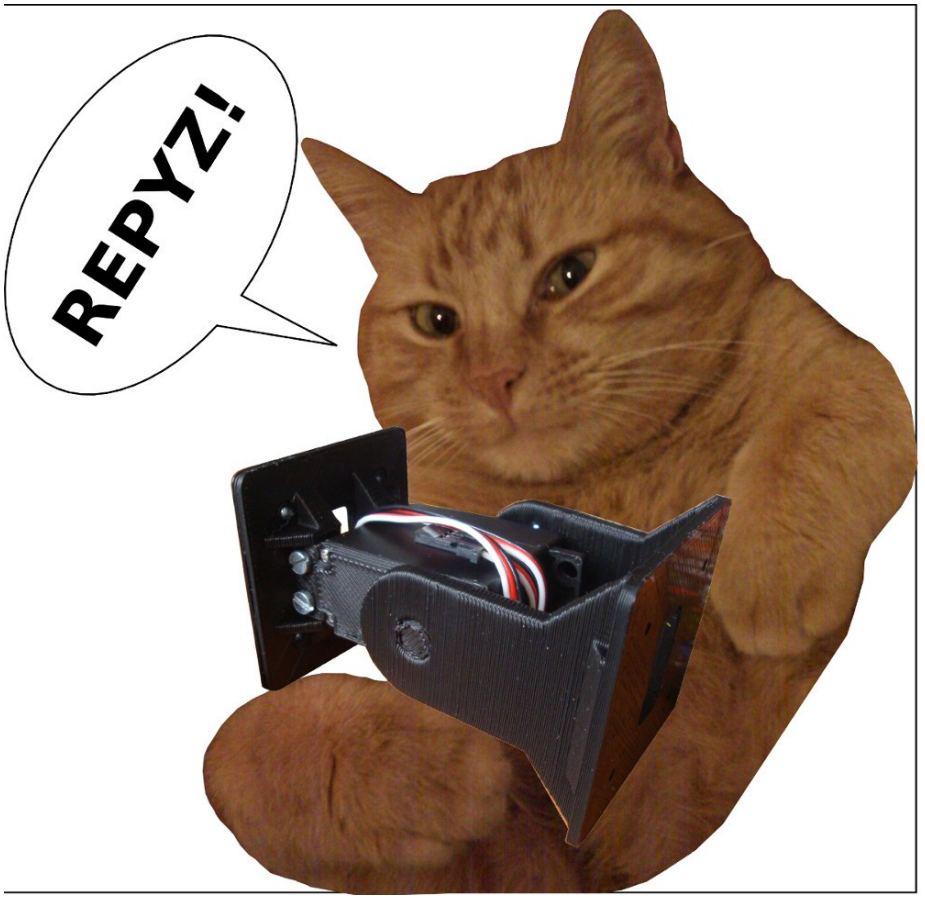


Types of connection

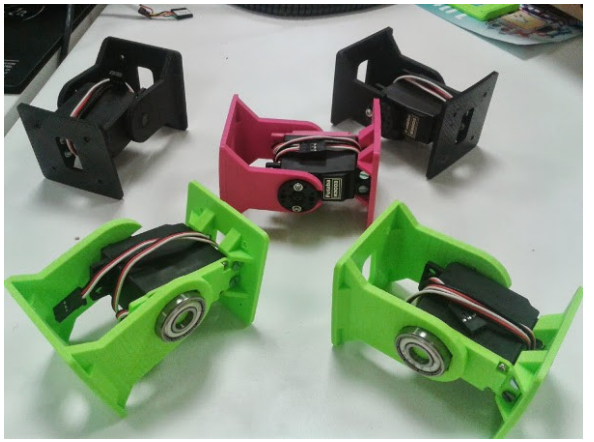


REPYZ modules

- The latest version



- 3D Printed
- Easy to clone
- Easy to modify
- Designed in Openscad
- **Open source**



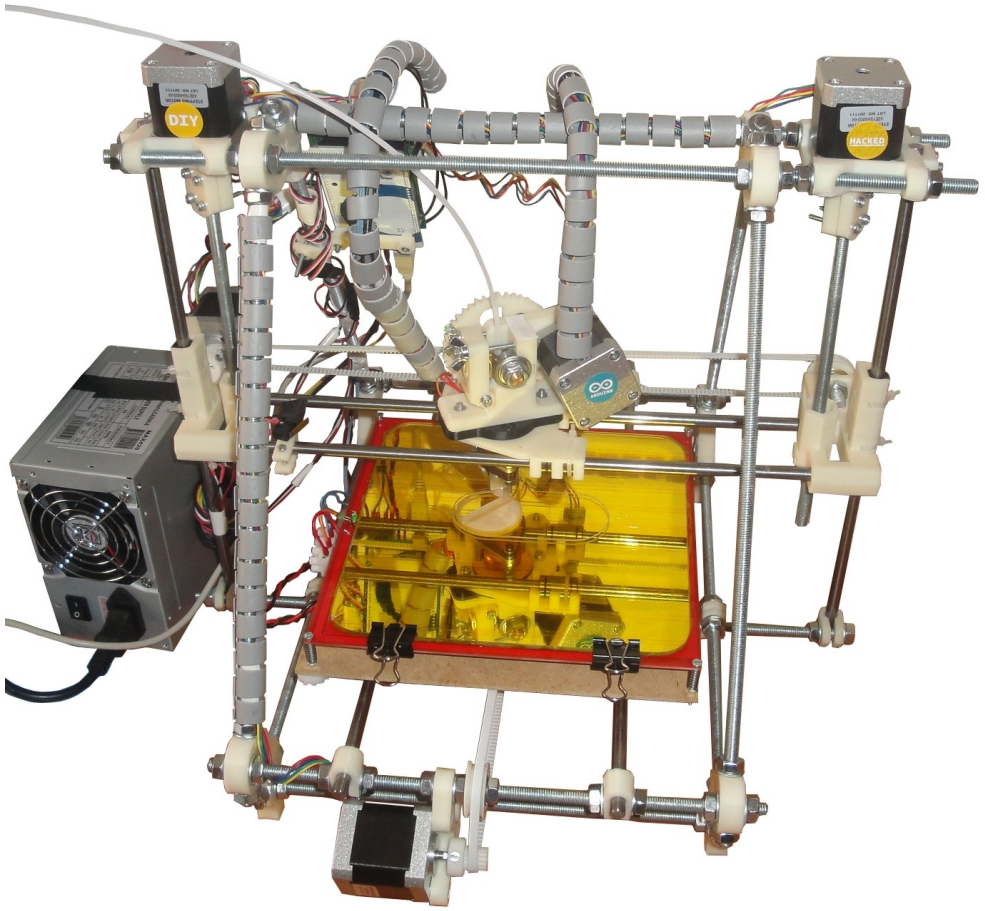
New age: 3D printing!

You can convert ideas into real objects!!

- **EASY**
- **FAST**
- **CHEAP**

RepRap: Open source 3D printers

Demo



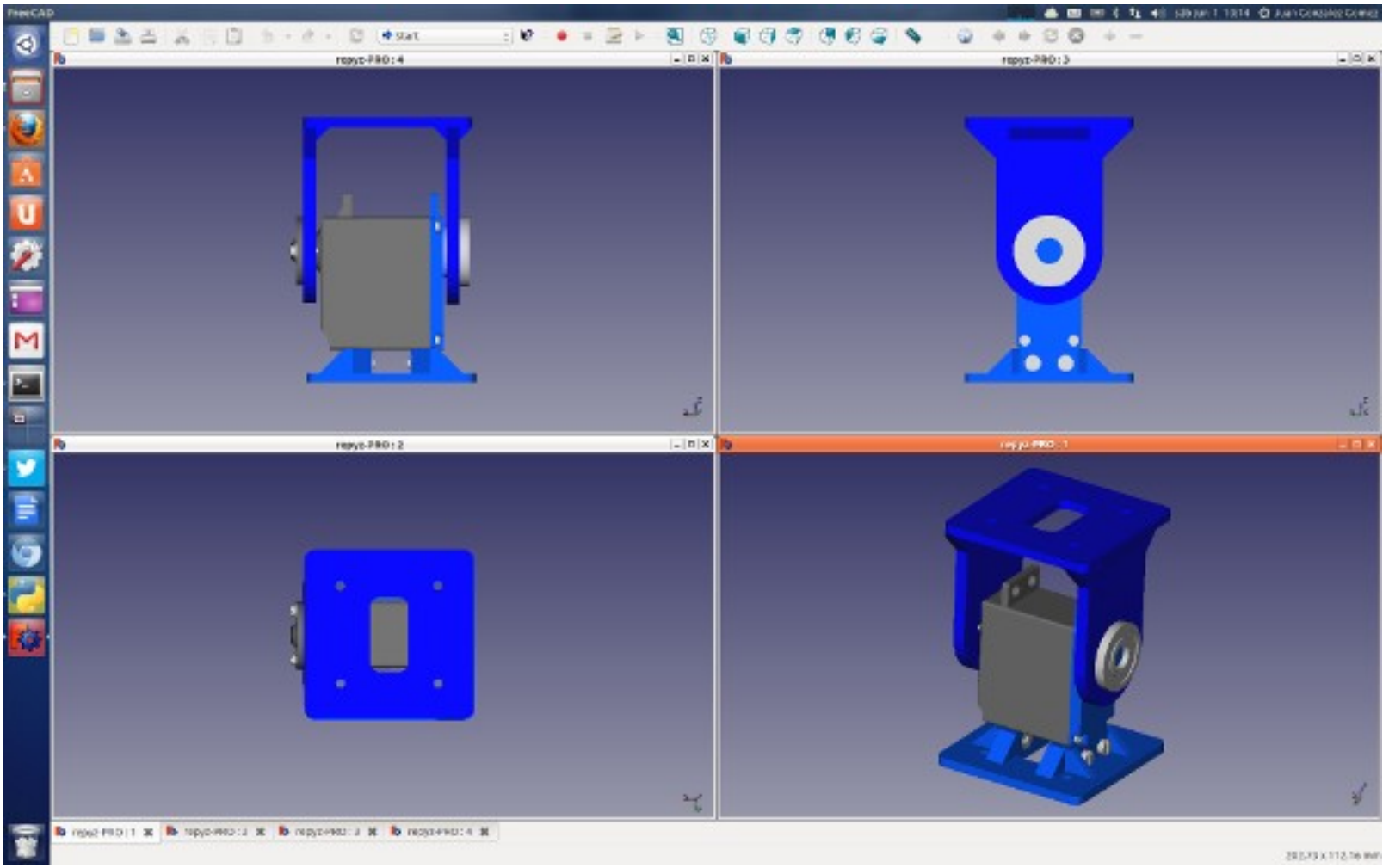
RepRap

Clone wars

REPYZ (II)

Freecad

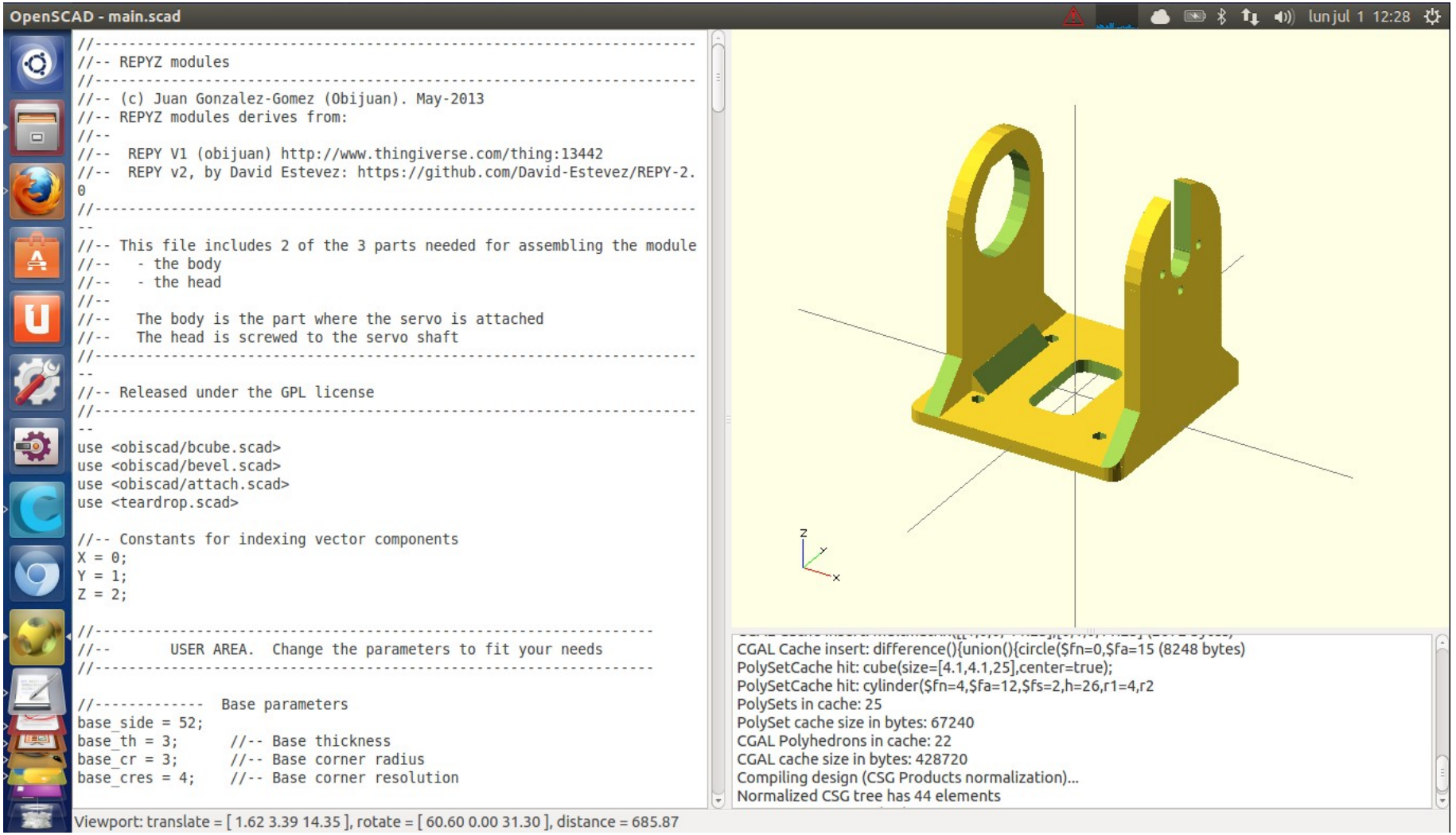
- Module in Freecad (an open source CAD tool)



REPYZ (III)

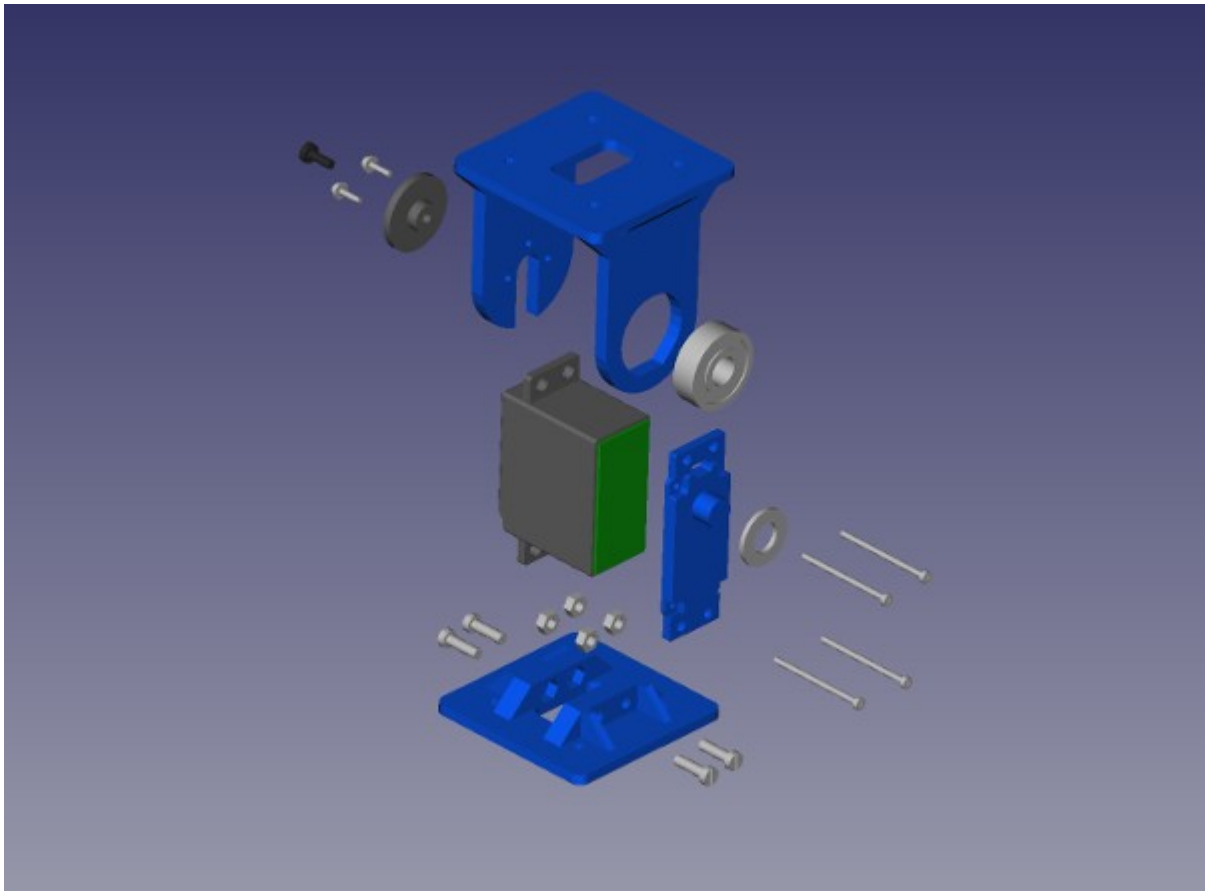
Openscad

- Designed in Openscad (Another open source tool)
- The module is code! Like programming!



REPYZ. Assembling (I)

- REPYZ exploded view

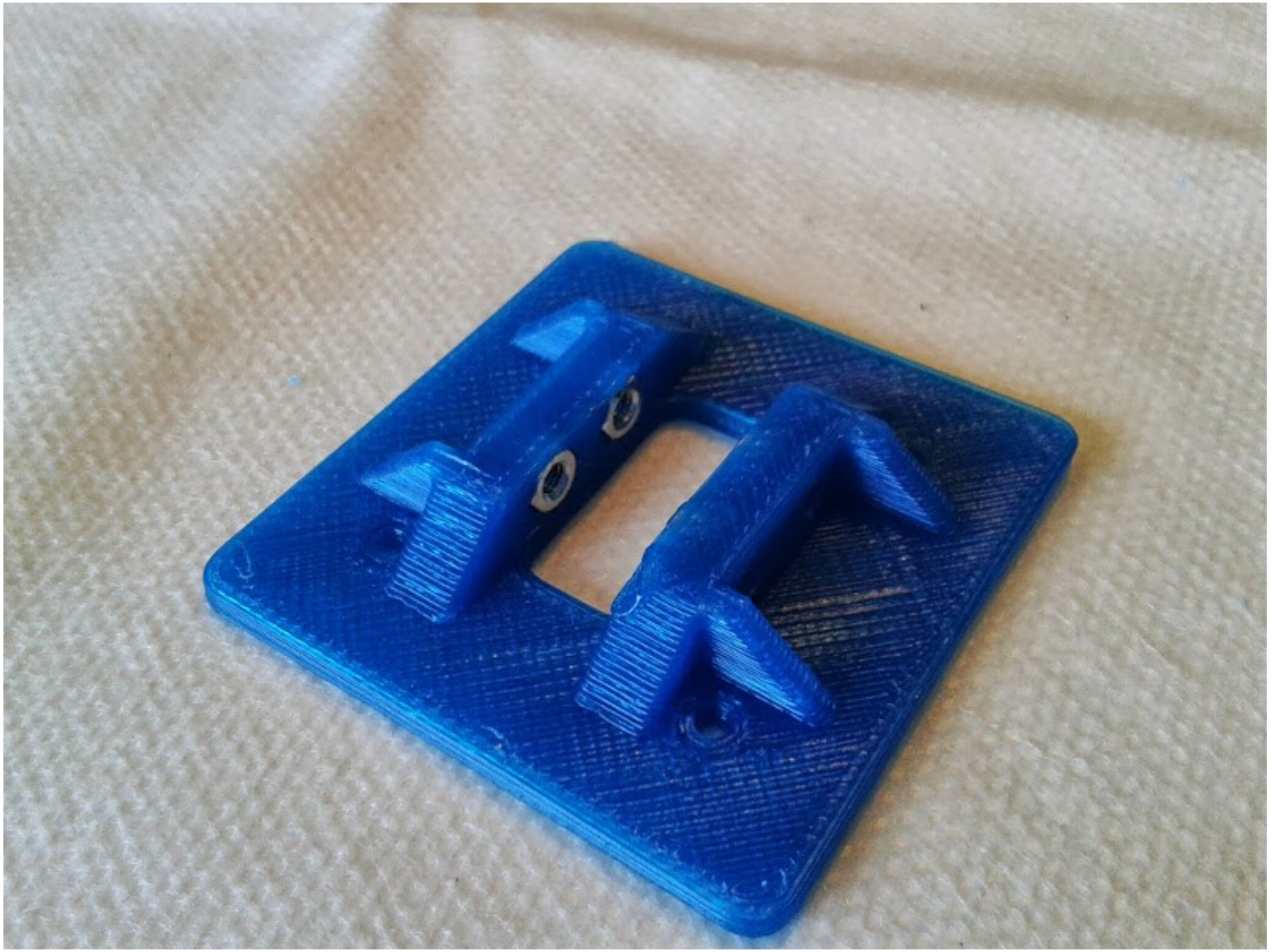


REPYZ. Assembling (II)

- REPYZ: Bill of materials

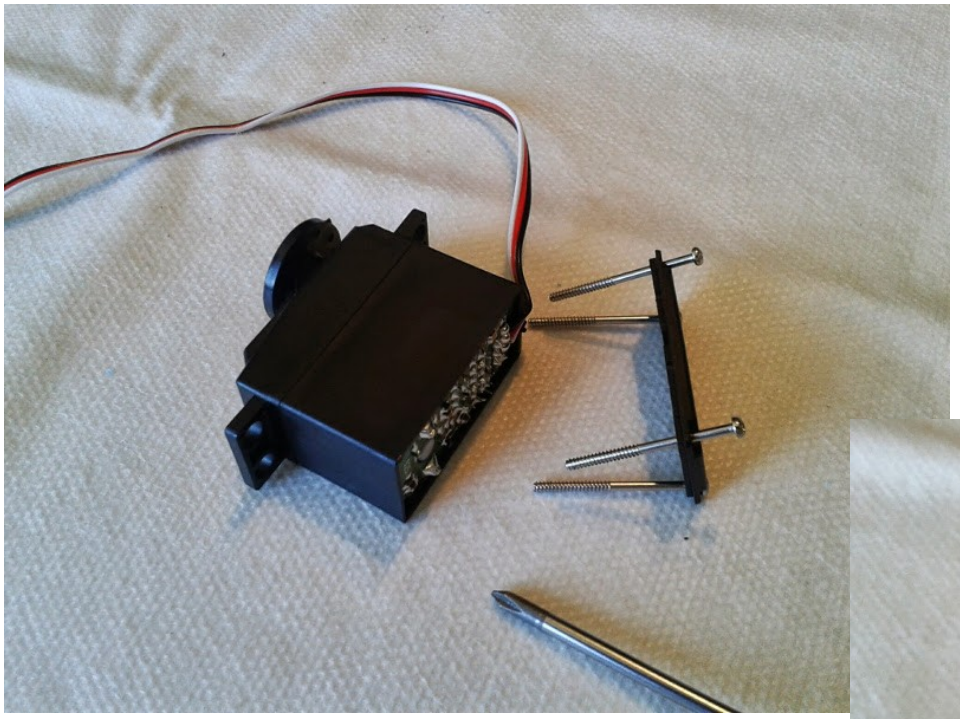
REPYZ. Assembling (III)

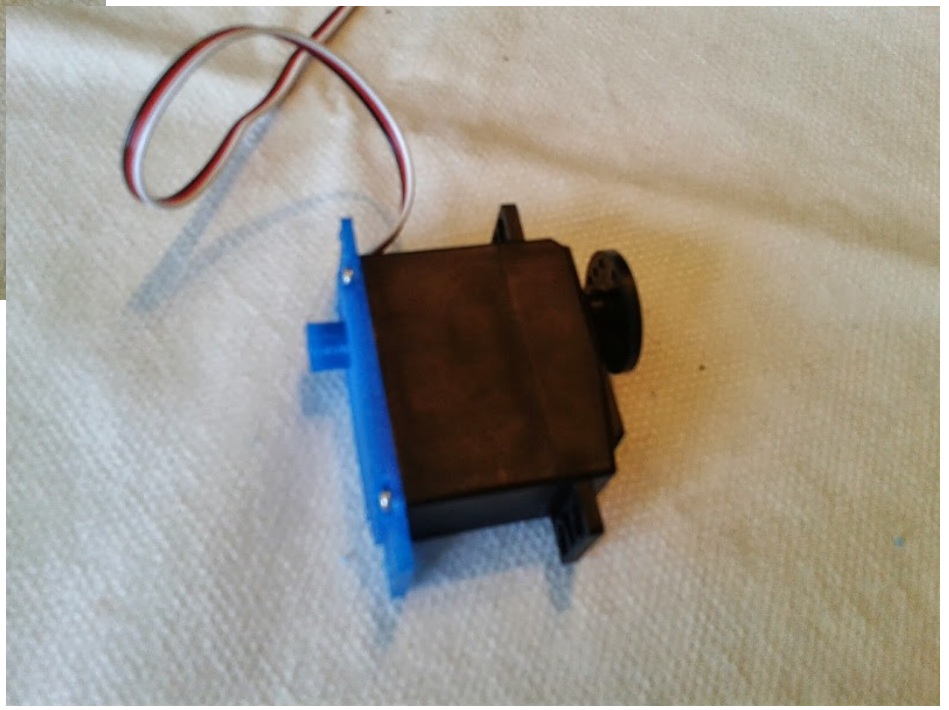
- Embed four M3 nuts



REPYZ. Assembling (IV)

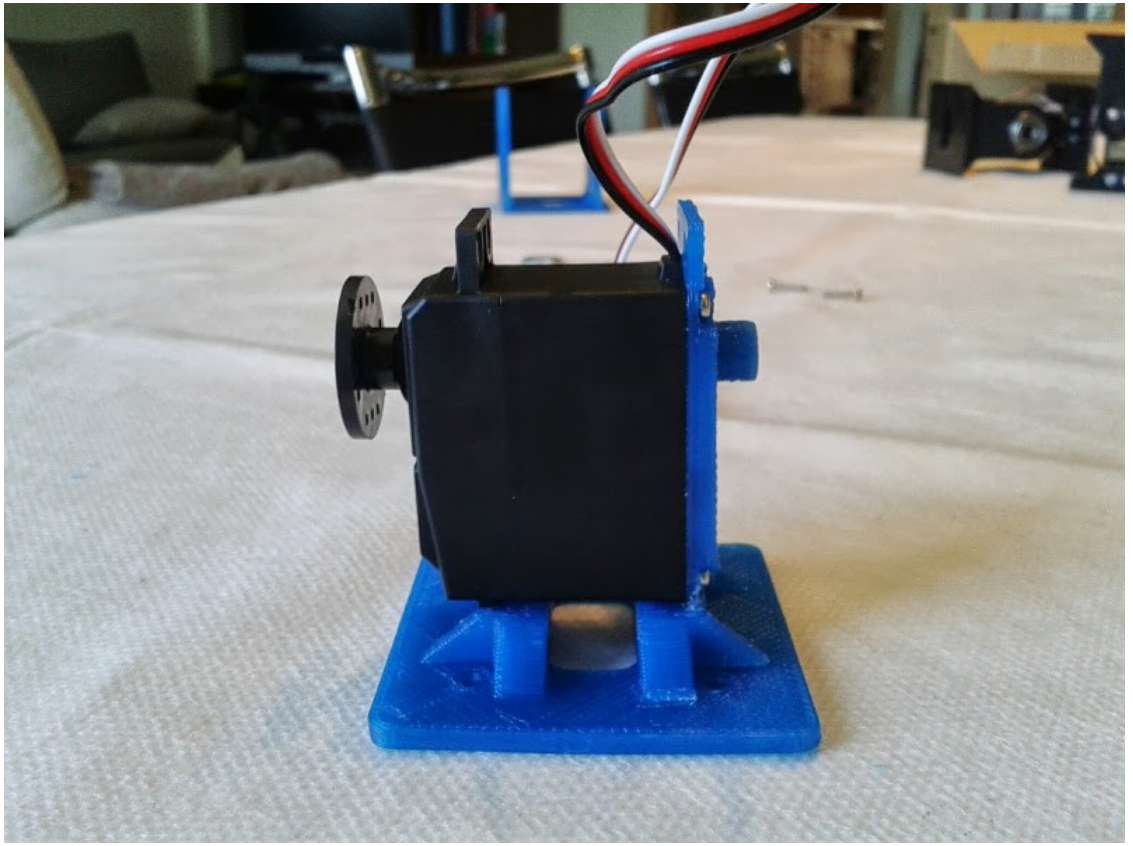
- Change the servo lower cover by the new one





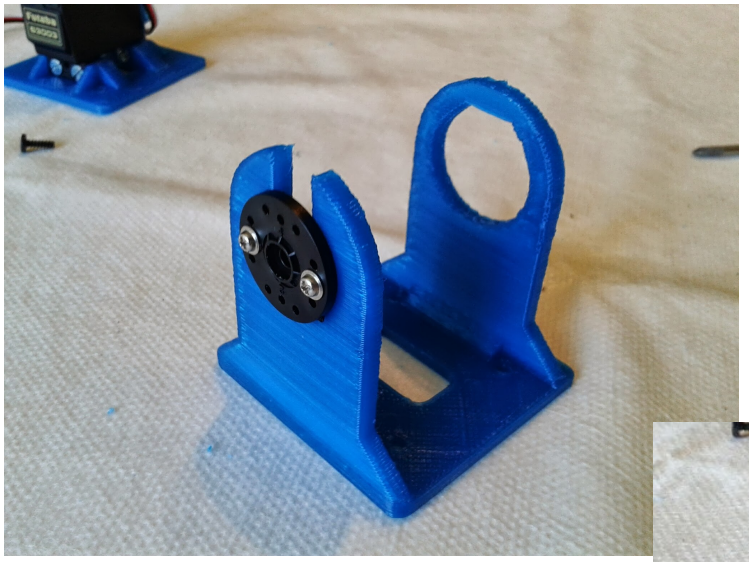
REPYZ. Assembling (VI)

- Screw the servo to the body part



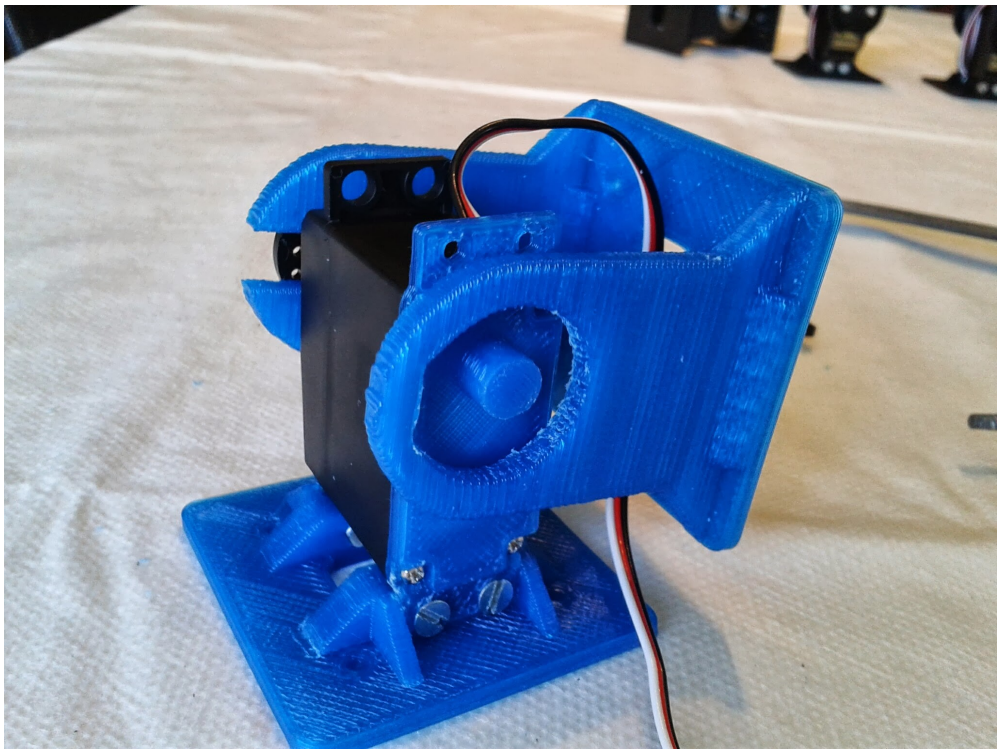
REPYZ. Assembling (VI)

- Prepare the module head



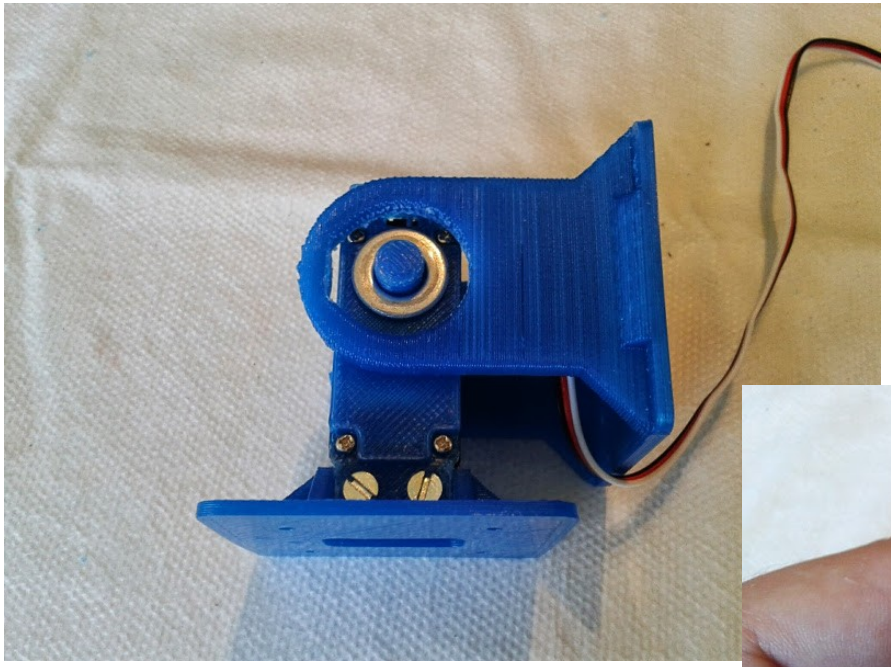
REPYZ. Assembling (VII)

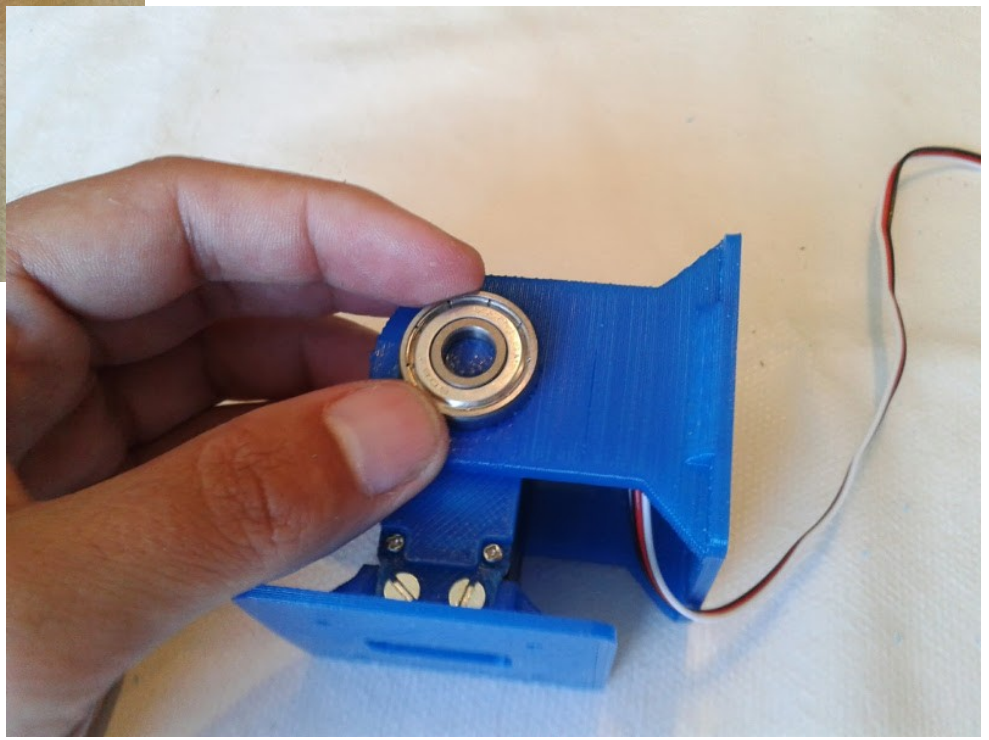
- Join the body and the head



REPYZ. Assembling (VIII)

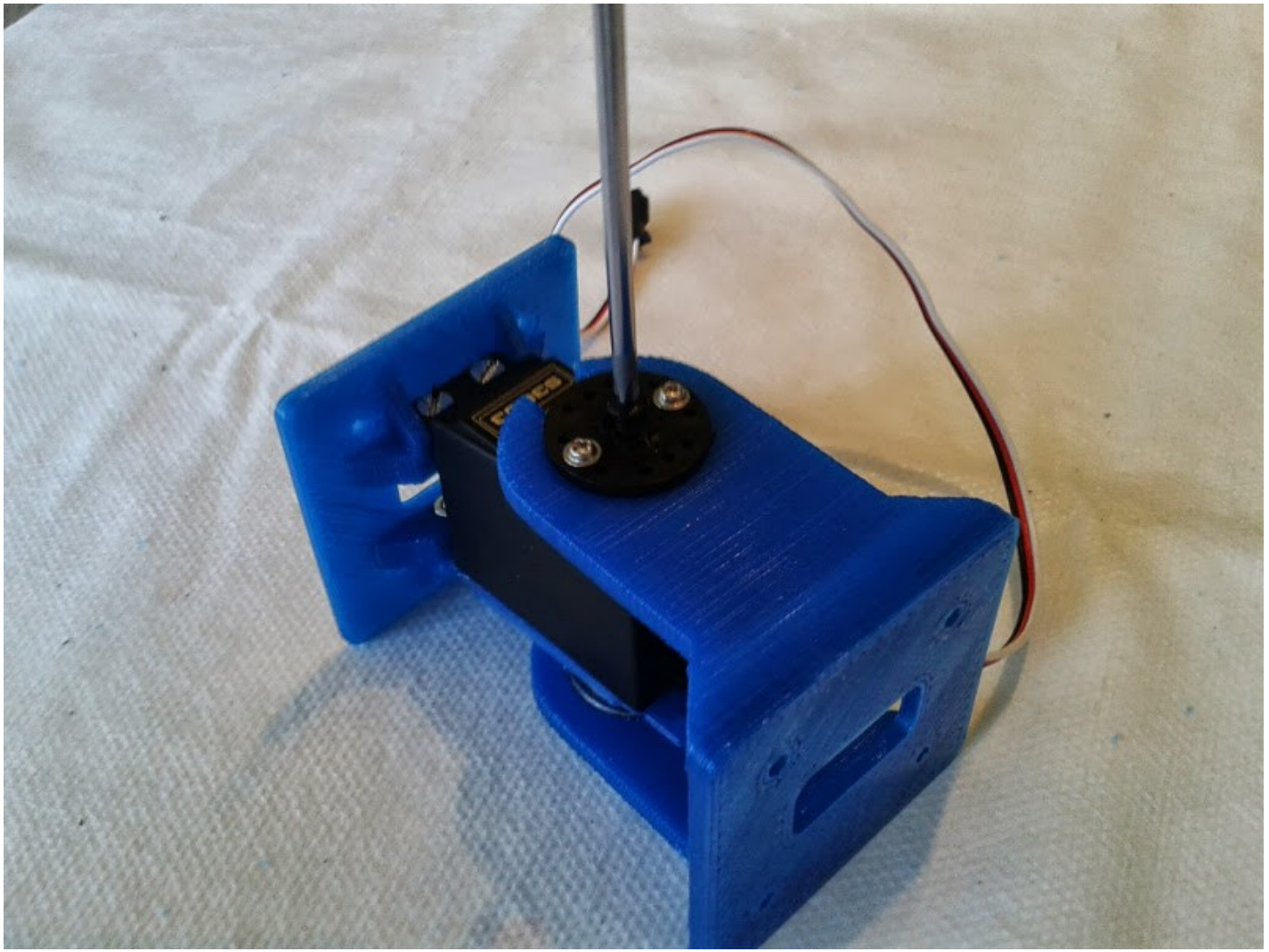
- Add the 608 bearing





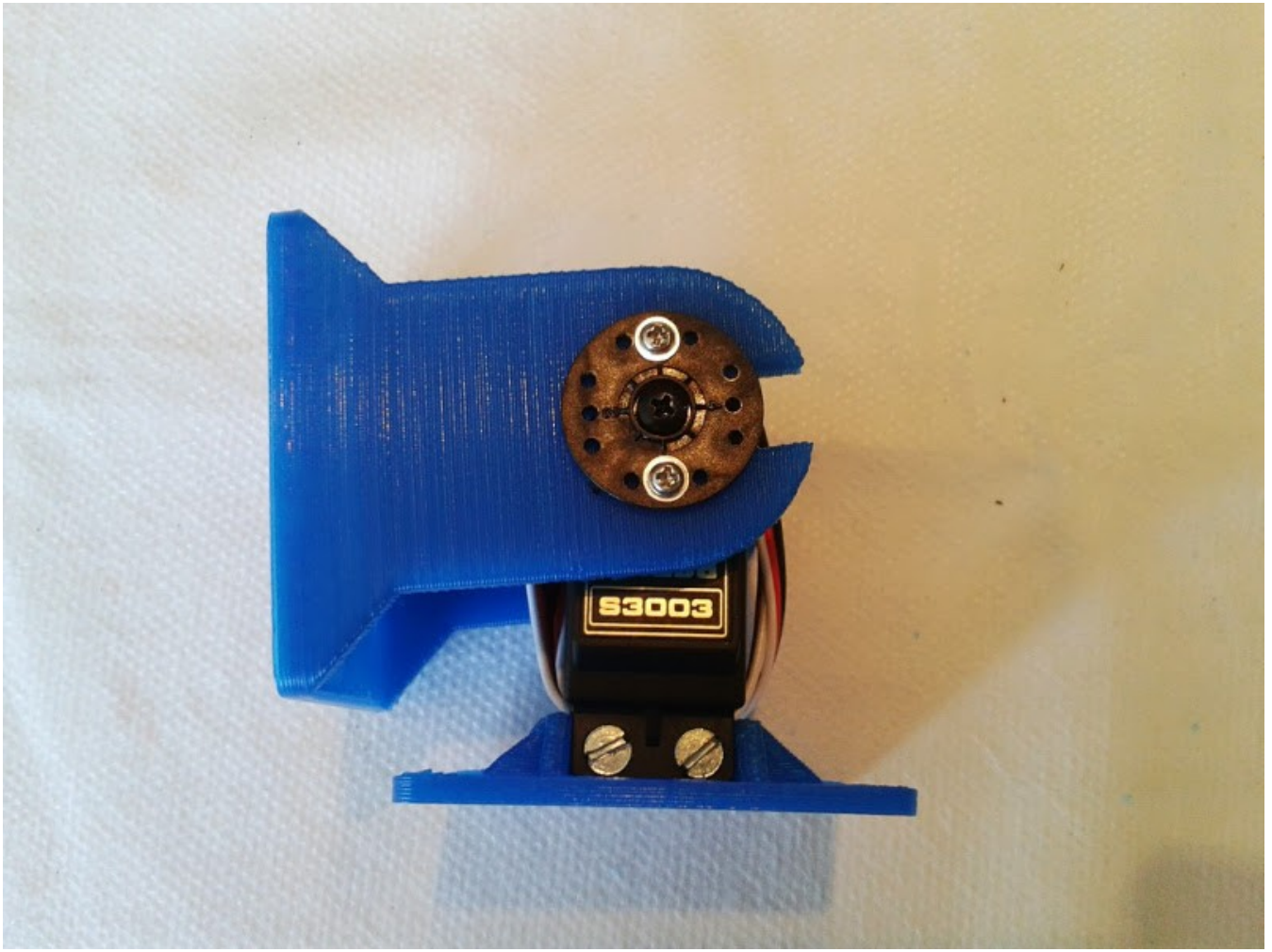
REPYZ. Assembling (XI)

- Tighten the servo horn



REPYZ (X)

- The module is ready!



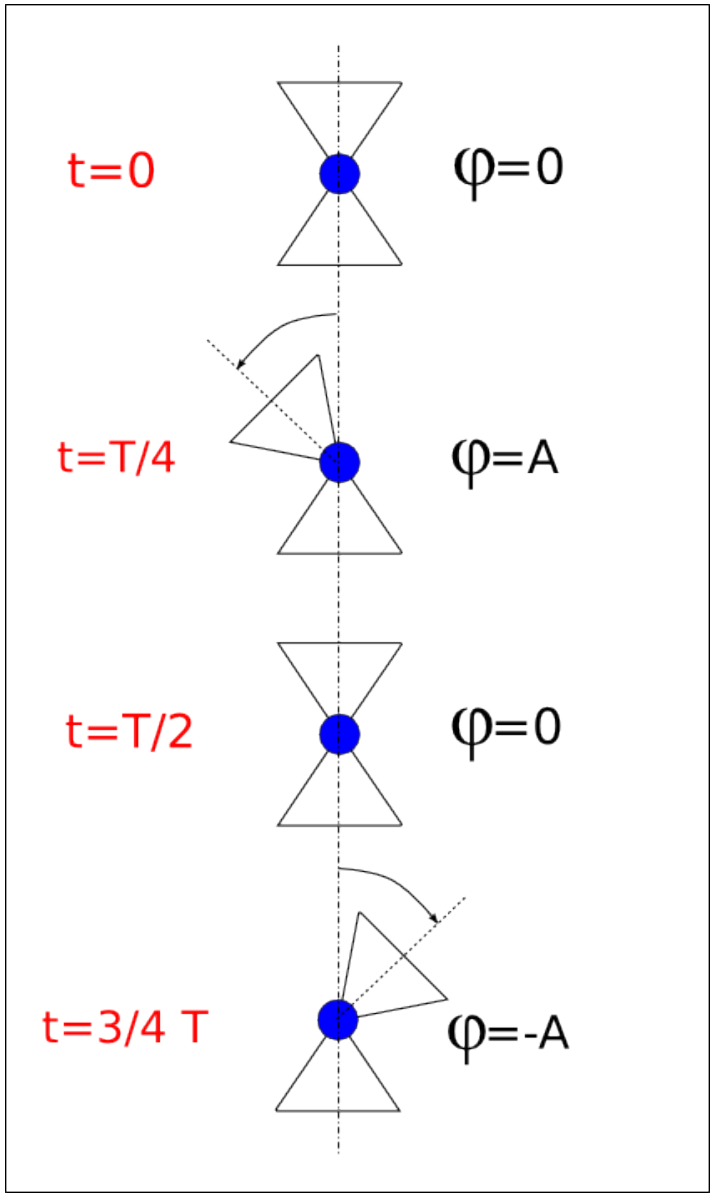
Oscillations (I)

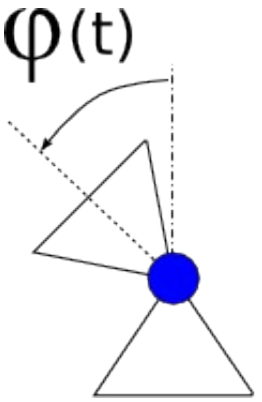
TASK:

- Insert the battery packs into the holders
- Screws the electronics with 20mm in length spacers
- Connect one servo to the SERVO 2 connector

Module oscillation

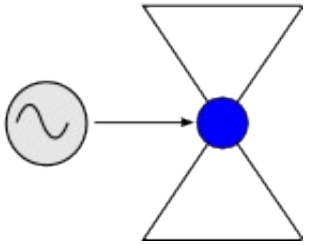
Demo





Bending angle

$$\phi(t) = A\sin\left(\frac{2\pi}{T}t + \Phi\right) + O$$



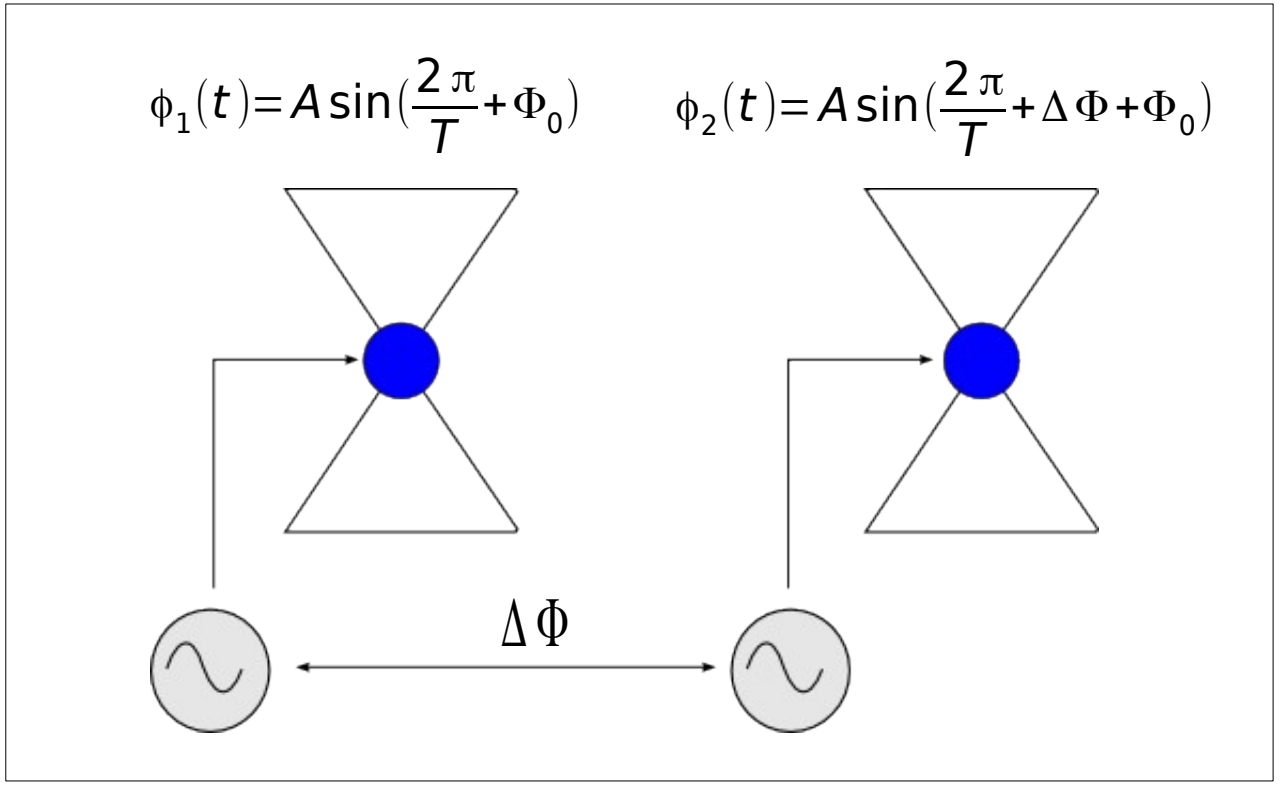
Sinusoidal oscillator

Parameters:

- **Amplitude**: A
- **Period**: T
- **Offset**: O

Oscillation of two modules

Demo



New parameter:

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

It determines how a module oscillates in relation to other

Experiment I: the wave

Demo

TASK:

- Create “the wave” using 9 REPYZ modules
- Amplitude, offset and period are fixed
- See what happens for different phase differences

- Fundamental equation:

$$\Delta\Phi = \frac{360}{M}k \quad \text{Degrees}$$

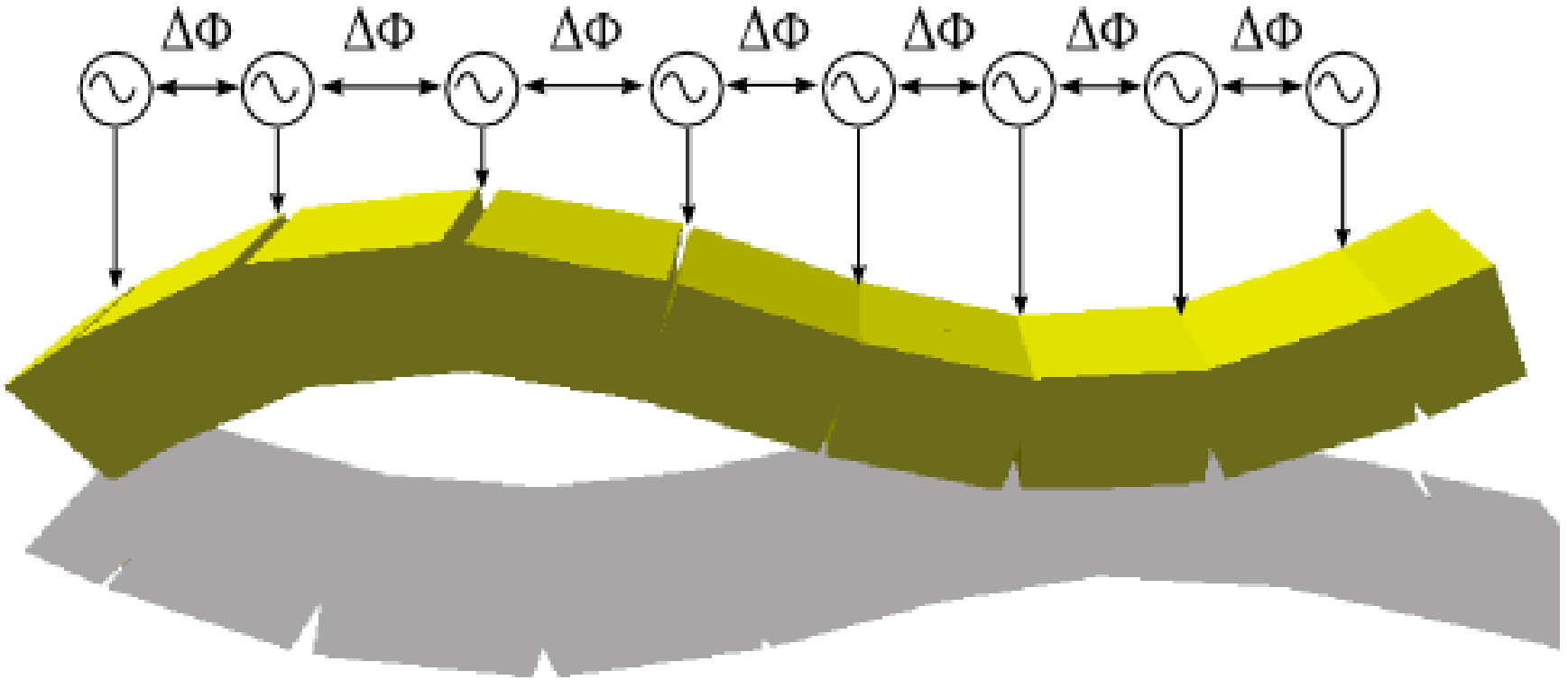
- K number of waves
- M number of modules

- M = 9, k = 1 ===> 40
- M = 9, k = 2 ===> 80
- M = 9, k = 3 ===> 120

Agenda

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

Control model



Minimal configuration

TASK:

- Build 3 minimal configuration
- Each one consist of 2 modules
- Test the locomotion for different oscillator parameters

3 module configuration

TASK:

- Build 3 configurations composed of 3 modules each
- Test the locomotion for different oscillator parameters

6 modules configuration

TASK:

- Build 1 configurations composed of 6 modules
- Test the locomotion for different oscillator parameters

9 modules configuration

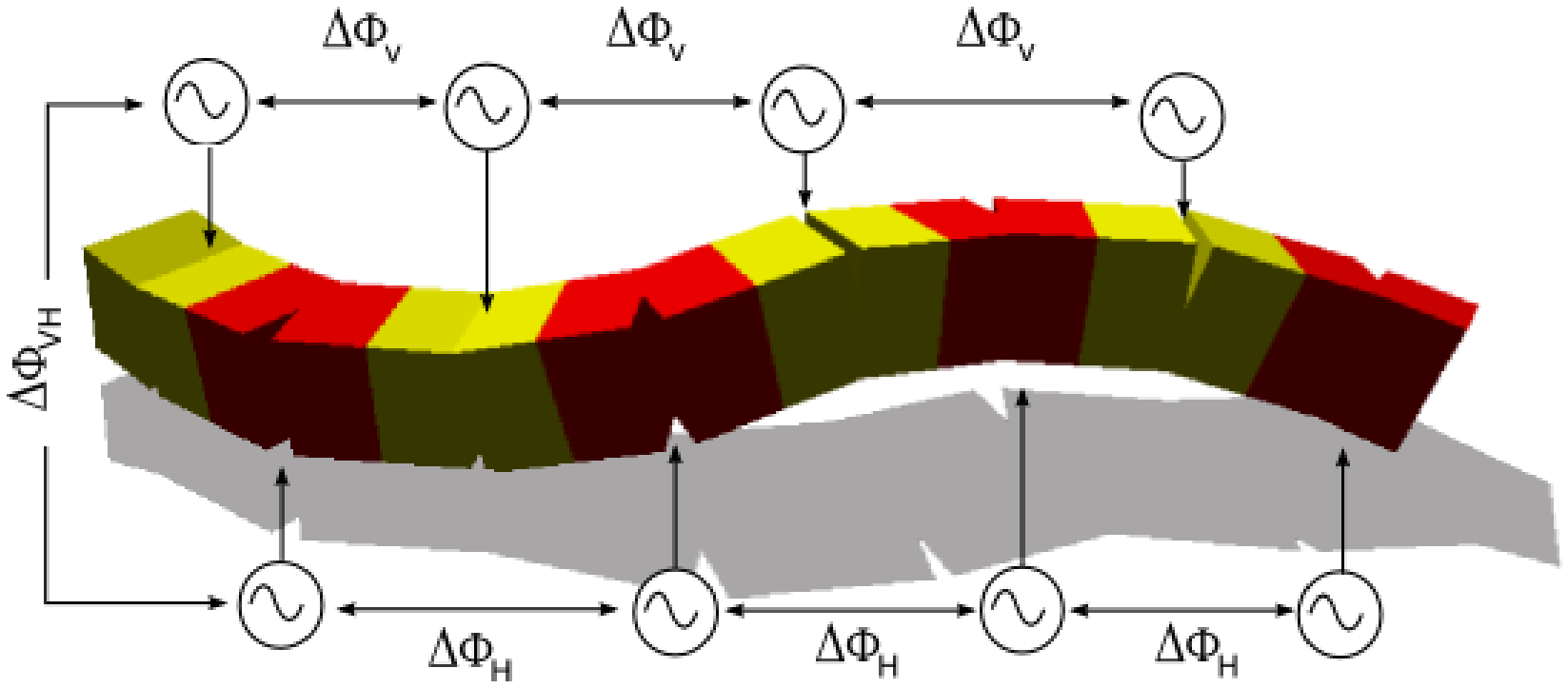
TASK:

- Build 1 configurations composed of 9 modules
- Test the locomotion for different oscillator parameters

Agenda

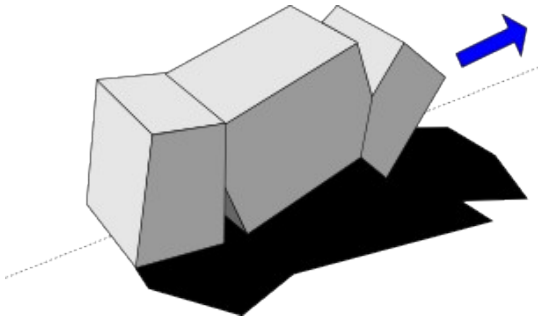
1. Introduction
2. Modules
3. Locomotion in 1D
4. **Locomotion in 2D**

Control model



Locomotion gaits

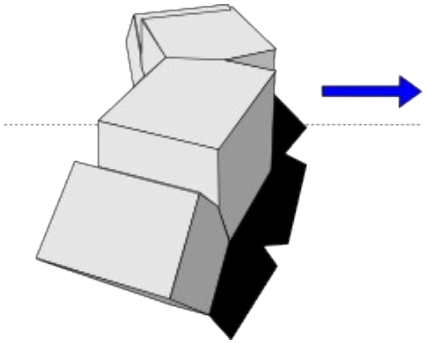
Straight



$A_v = 40, A_h = 0$

$\Delta\Phi_v = 120$

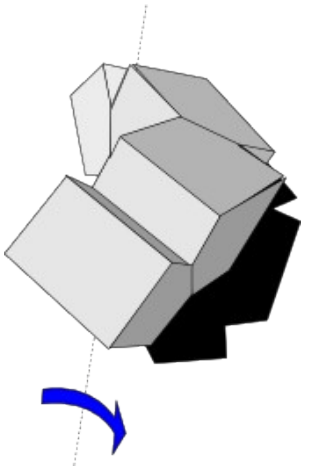
Sideways



$A_v = A_h < 40$

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

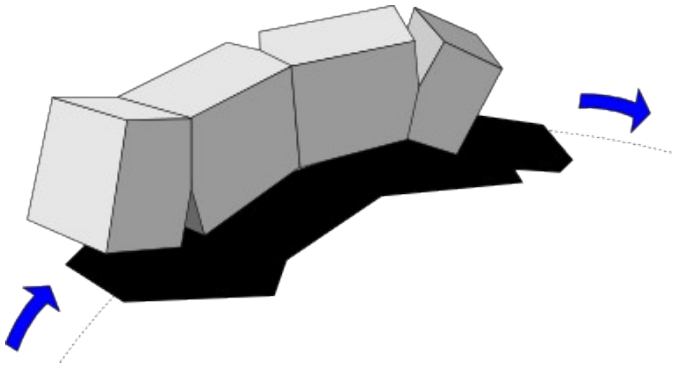
Rolling



$A_v = A_h > 60$

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

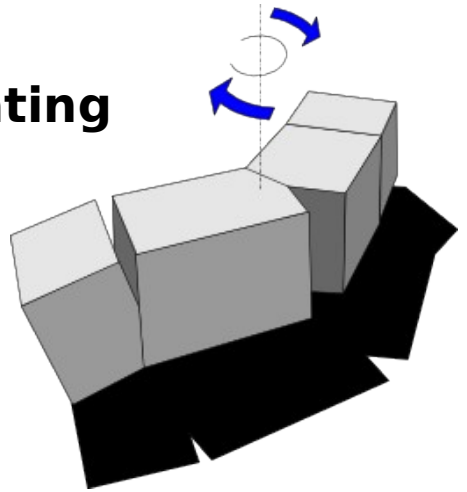
turning



$A_v = 40, A_h = 0$

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

Rotating



$A_v = 10, A_h = 40$

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

Minimal configuration

TASK:

- Build 3 PYP configurations composed of 3 modules
- Test the different locomotion gaits

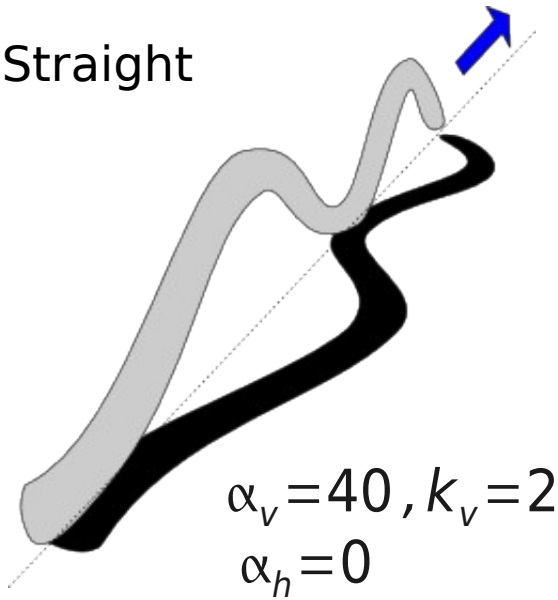
6 module configuration

TASK:

- Build 1 pith-yaw configuration composed of 6 modules
- Test the different locomotion gaits

Locomotion gaits

Straight



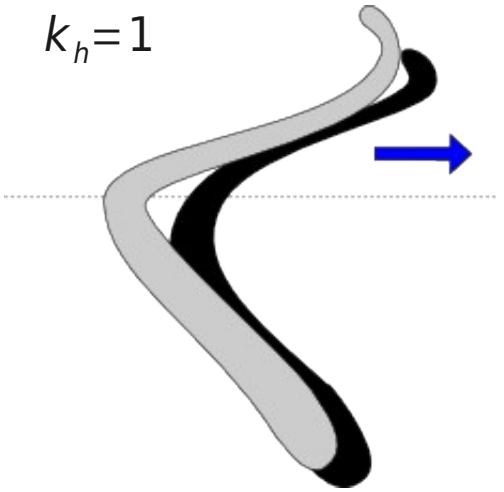
$\alpha_v = 40, k_v = 2$

$\alpha_h = 0$

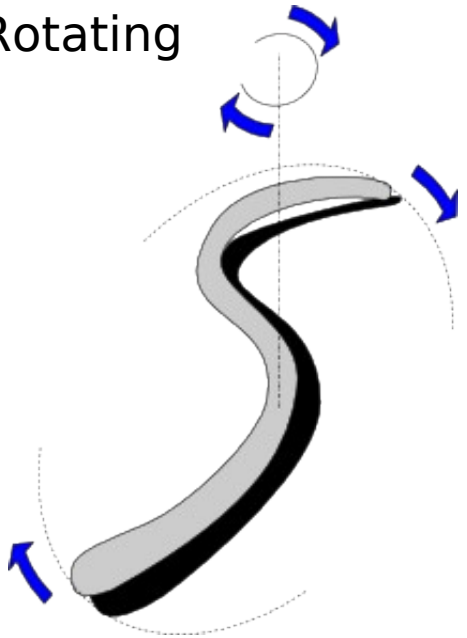
Sidewinding

$\alpha_v \to 0, k_v = k_h, \Delta\Phi_{vh} = 90$

$k_h = 1$

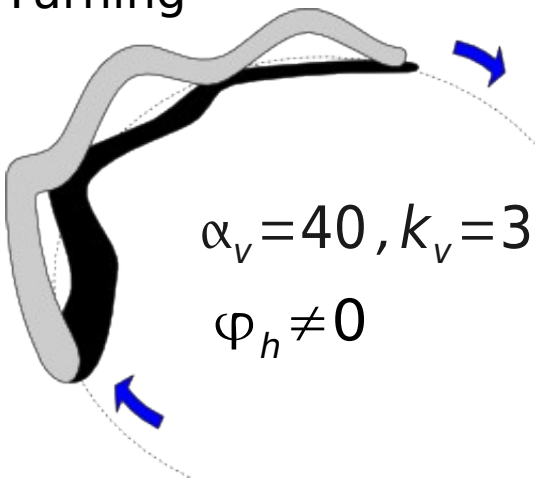


Rotating



$\alpha_v \to 0, k_v = 2k_h, \Delta\Phi_{vh} = 0$

Turning

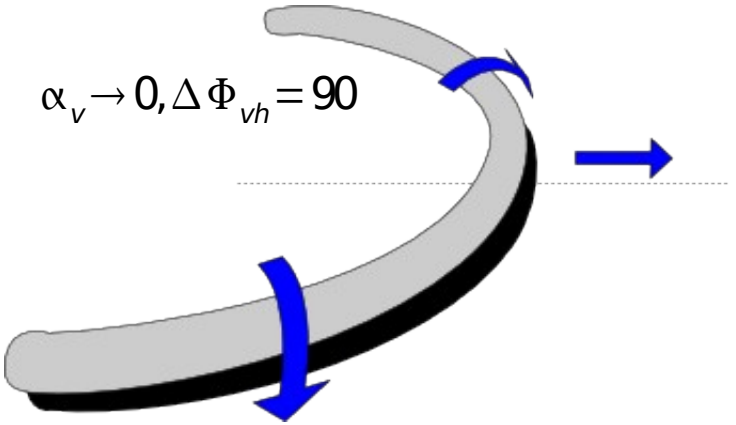


$\alpha_v = 40, k_v = 3$

$\varphi_h \neq 0$

Rolling

$\alpha_v \to 0, \Delta\Phi_{vh} = 90$



Let's build a modular snake robot!

Dr. Juan González-Gómez
July-2nd-2013