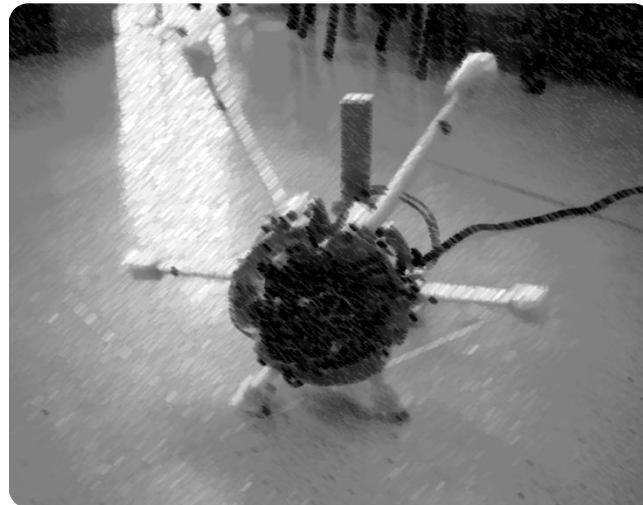UNIVERSIDAD DE MÁLAGA

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Design of a driving module for a hybrid locomotion robot

J. J. CASTILLO, J. A. CABRERA, M. JAIMEZ, F. VIDAL AND A. SIMÓN.

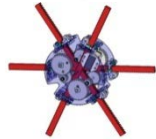DEPARTMENT OF MECHANICAL ENGINEERING. UNIVERSITY OF MÁLAGA.
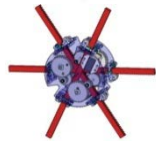
Script

I.   **Introduction**

Script

Script

 I.   Introduction

 II.   Mechanical Design

 III. Electronics and Sensing
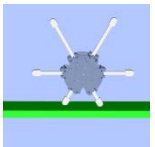
Script

Script

Script

Introduction

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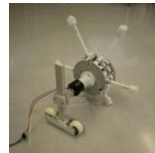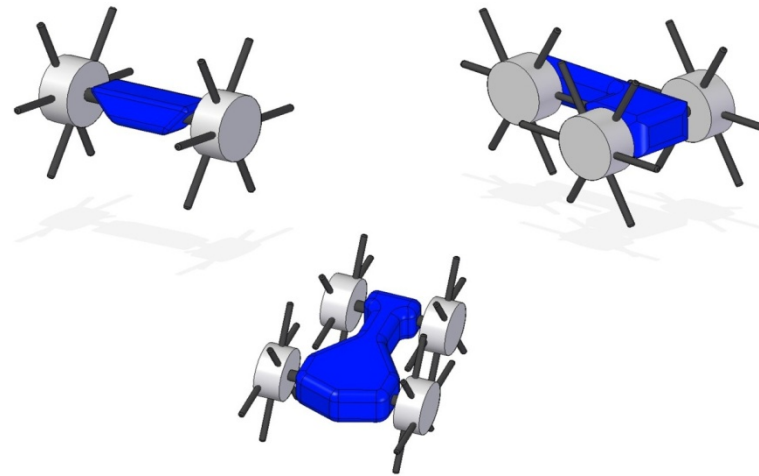
Introduction

Robotics challenges

❖ Energy autonomy

❖ Computational capability

❖ Artifitial intelligence

❖ Sensing capabilities

❖ Locomotion systems

Mobile robotics

Introduction

Evolution

Inspiration
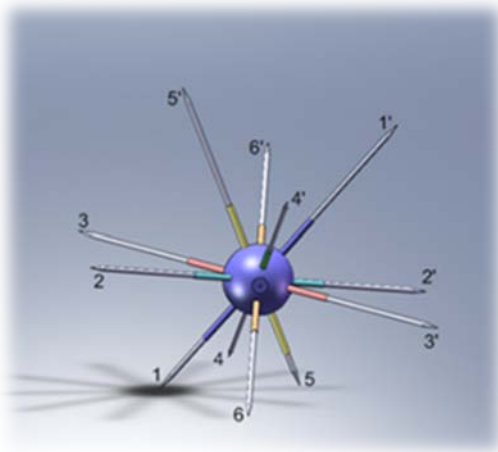
Spherical robot with sliding legs

V. Gheorghe et al
(2008)

Adaptation
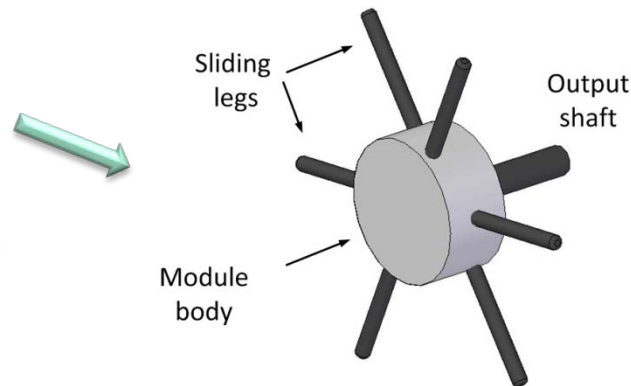
Cilindrical module with sliding legs

Castillo et al ?
(2014)

Objetive

Robot with sliding legs modules

Mechanical Design
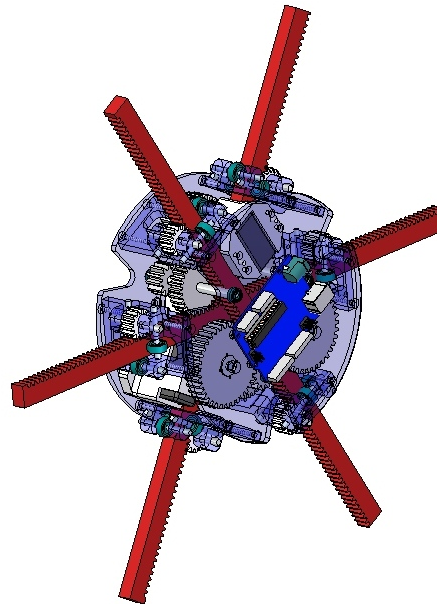
Mechanical Design

4 Feet
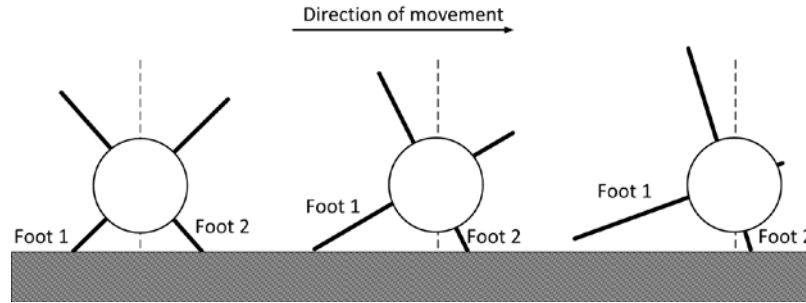
6 Feet
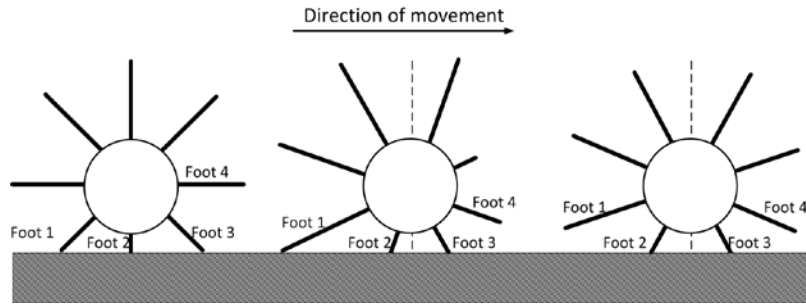
8 Feet
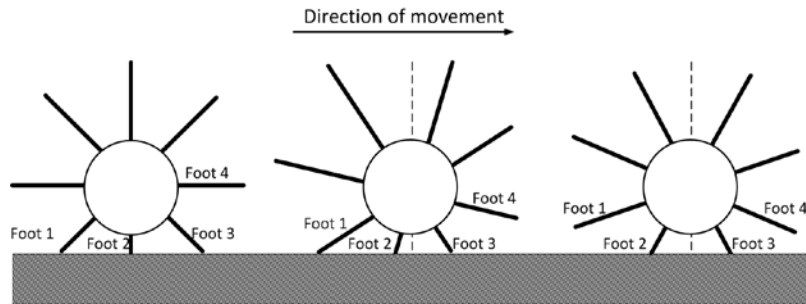
Triple support required
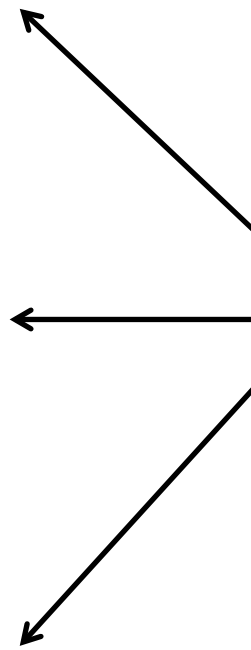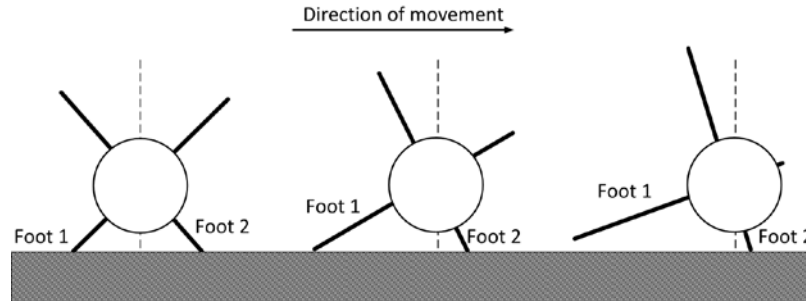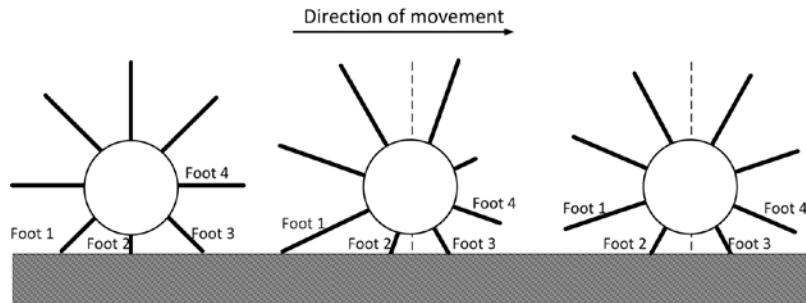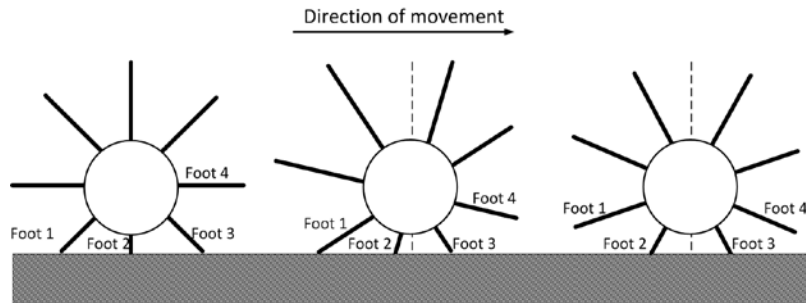
Mechanical Design

4 Foot

6 Feet
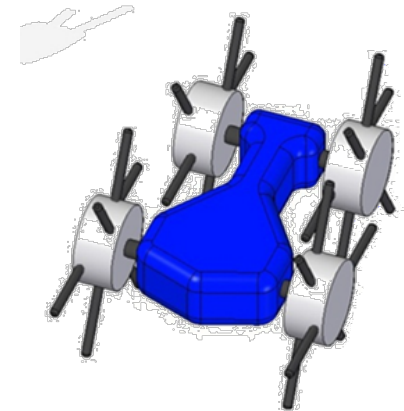
8 Feet

Complete rotation not possible

Triple support required

Mechanical Design

4 Foot
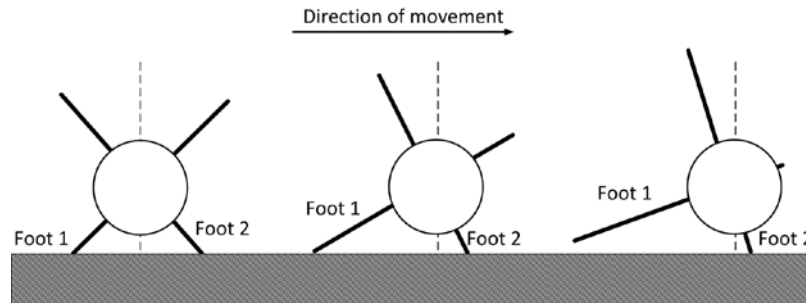
6 Feet
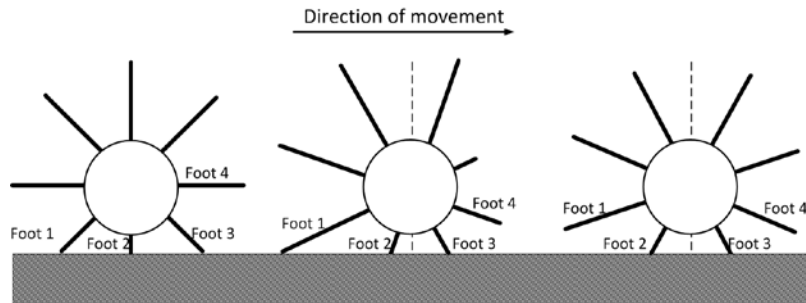
8 Feet
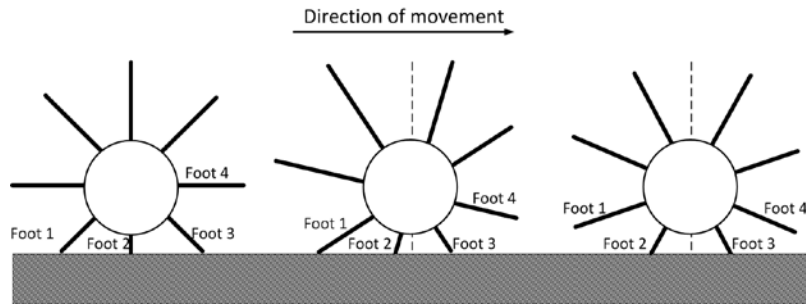
Complete rotation not possible

Triple support required

Complex

Mechanical Design

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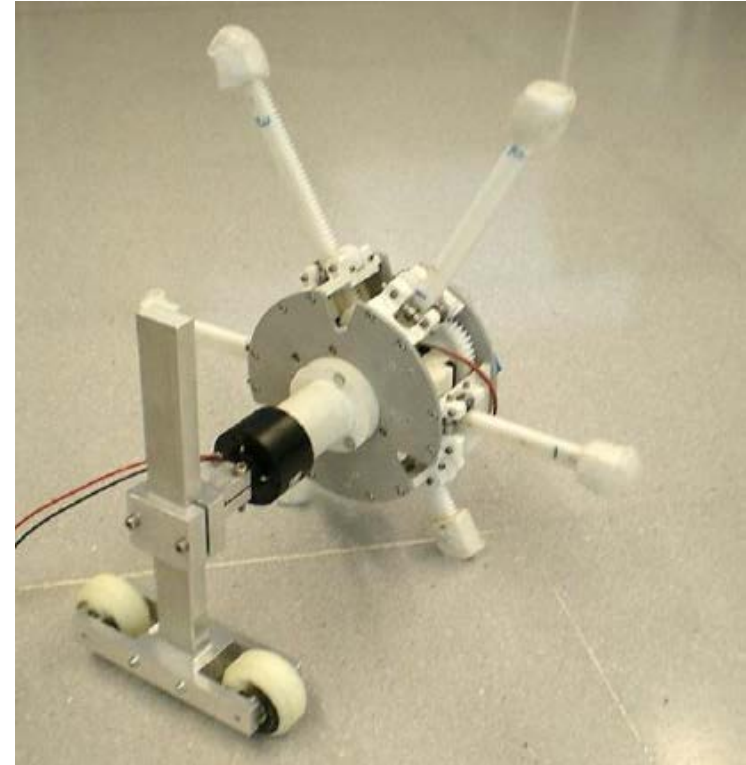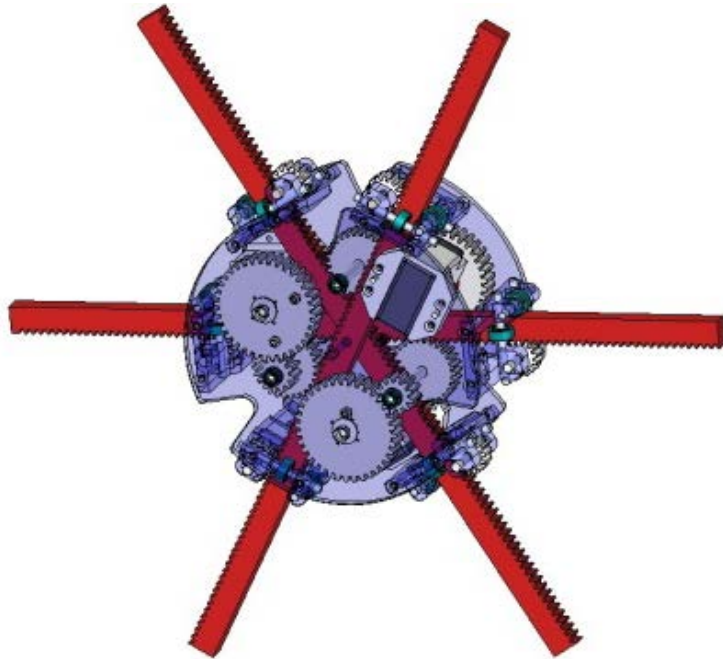
Mechanical Design

Servomotors

Mass – 60 grams

Maximum Torque – 16 kg cm

Maximum speed – 333º/ s

Mechanical Transmission

- **Rotation 180º**

- **Sliding distance > 12.8 cm**

- **Maximum force = 30 N**

- **Low inertia**

Mechanical Design

Servomotor

Servomotor fastening part

Aluminium plate

Gear 1

Gear 2

Gear 3

Rack

Bearings

Servomotor

Connecting part

Gear 1

Bolts

Mechanical Design

Bearings

Gear

Arduino Board

Mechanical Design

Magnet

Angle sensor

Output shaft

Bearings

Fixing ring

Crown

Aluminium plate

Output shaft

Sliding ring
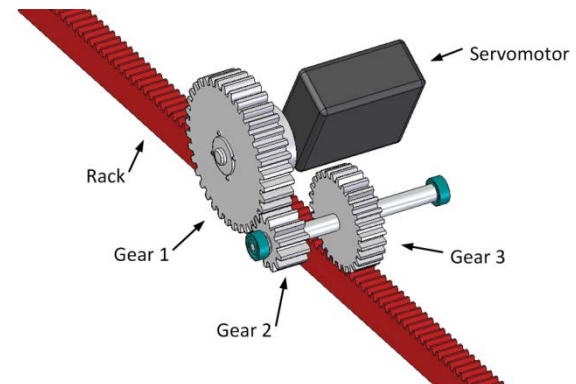
Electronics and Sensing
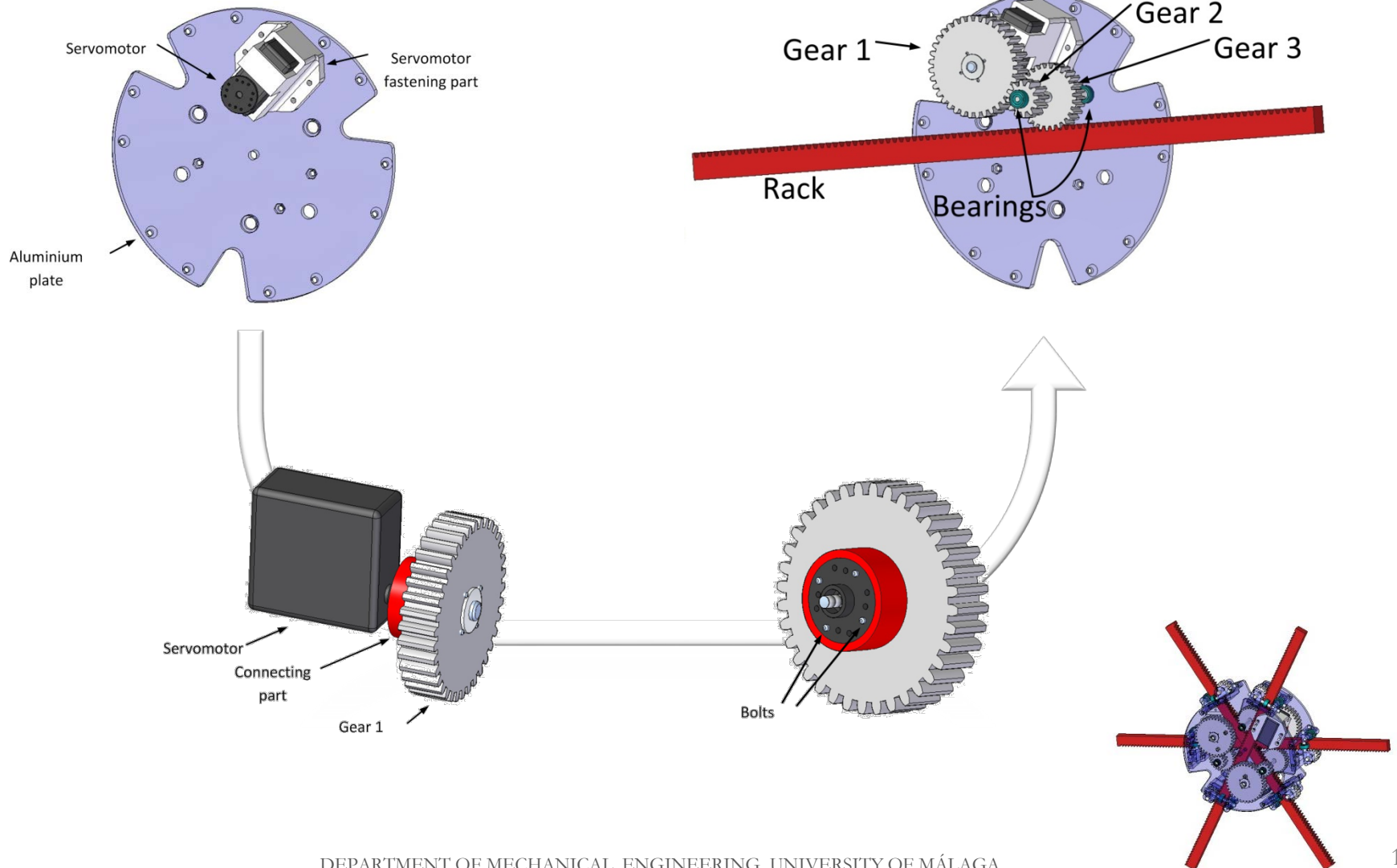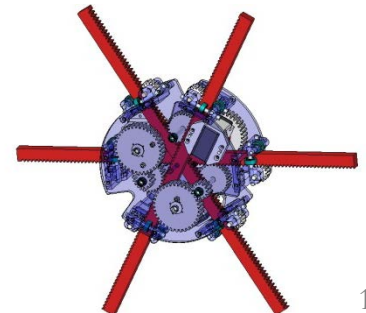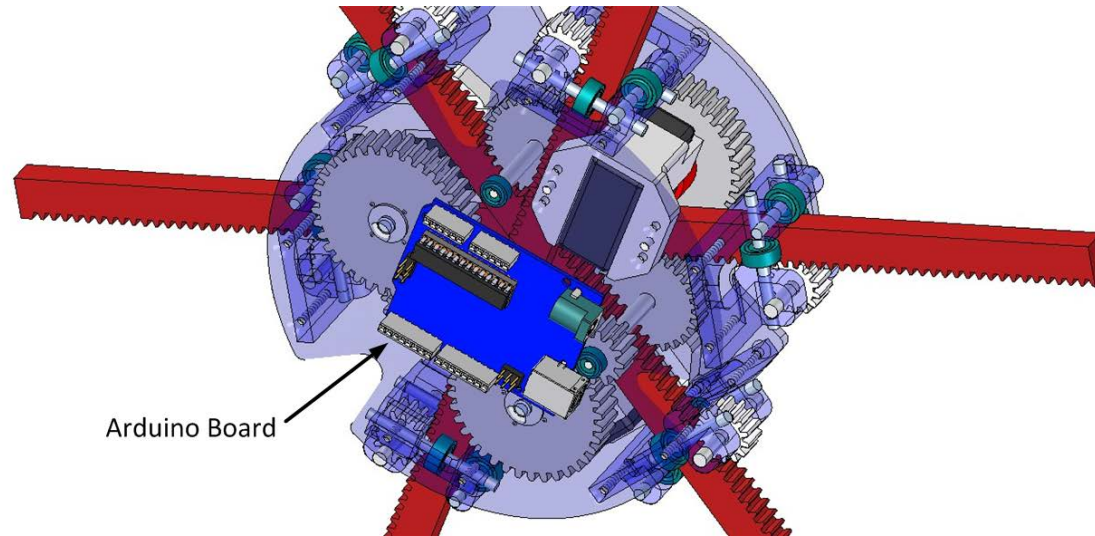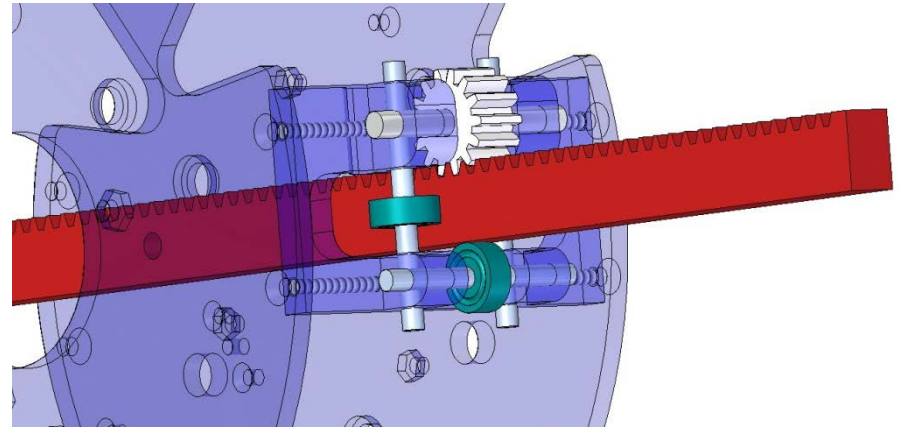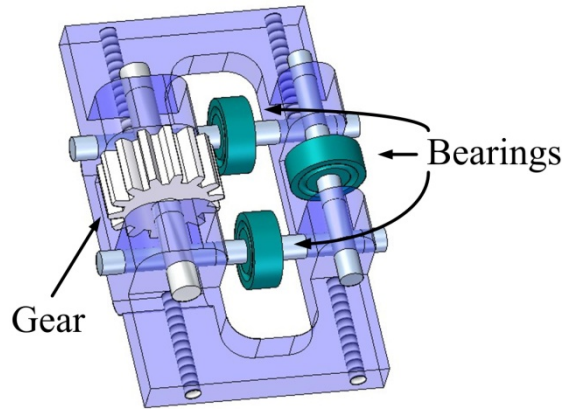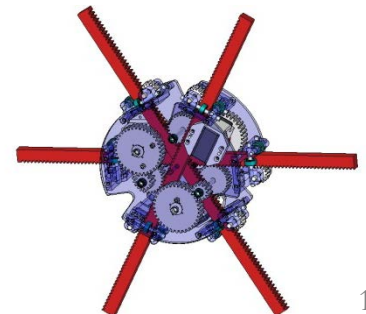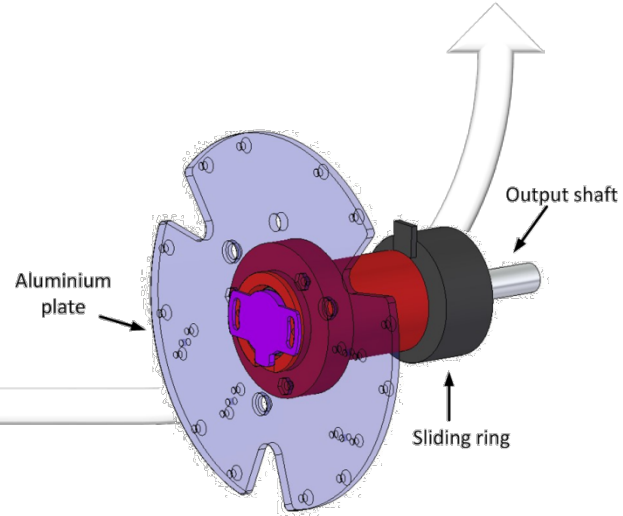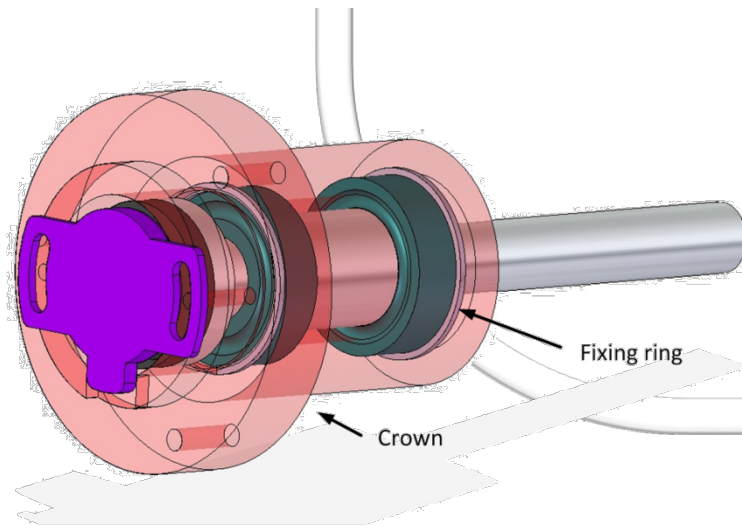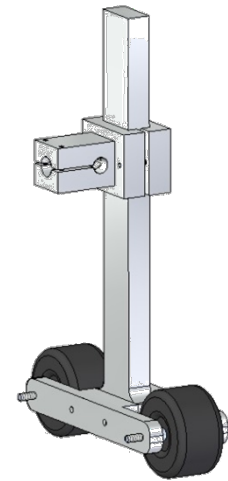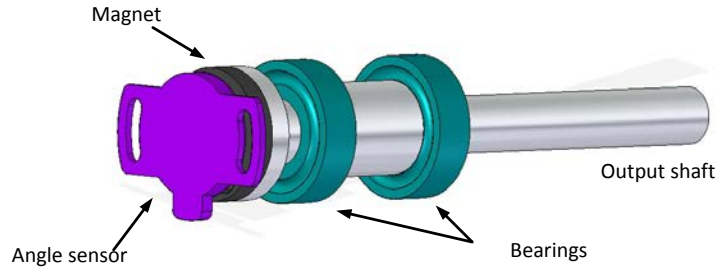
Electronics and sensing

Sensors

Angular sensor

Magnet

Angle sensor

Bearings

Output shaft

Contact sensor

Connection wires

Contact zone

Contact sensor

Connecting part

Contact zone

Connectors

Foot

Electronics and sensing
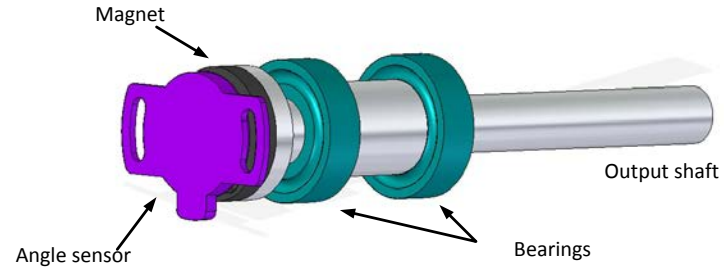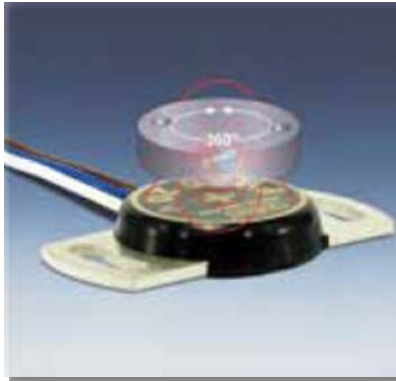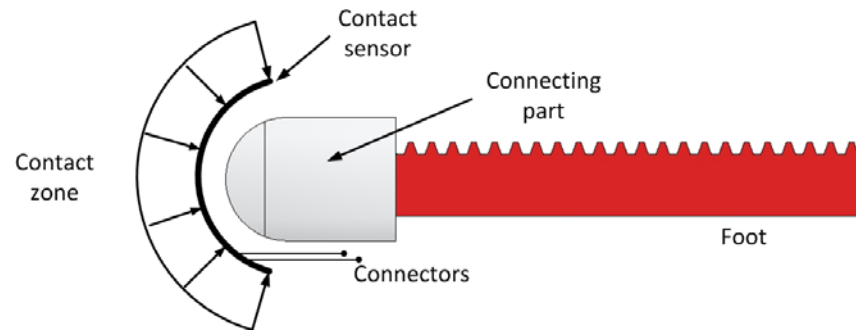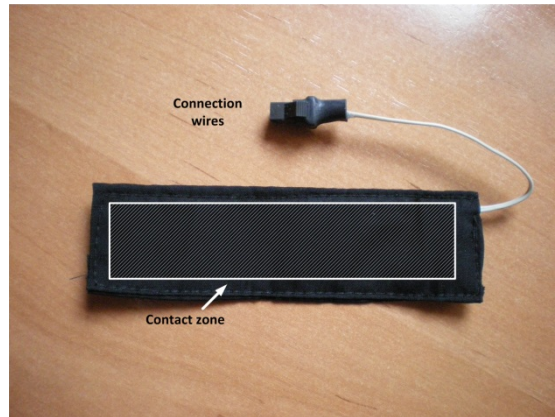
Programming

Arduino UNO
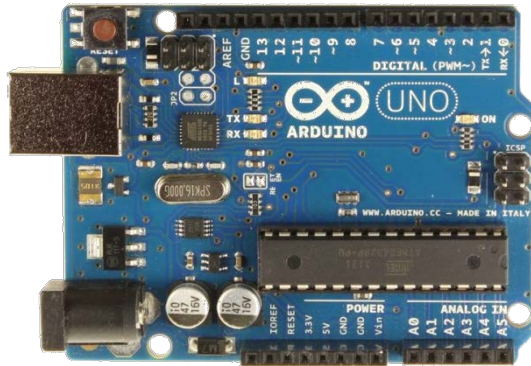
ZigBee module

C++ (programming) ✓

LabVIEW Interface ✓
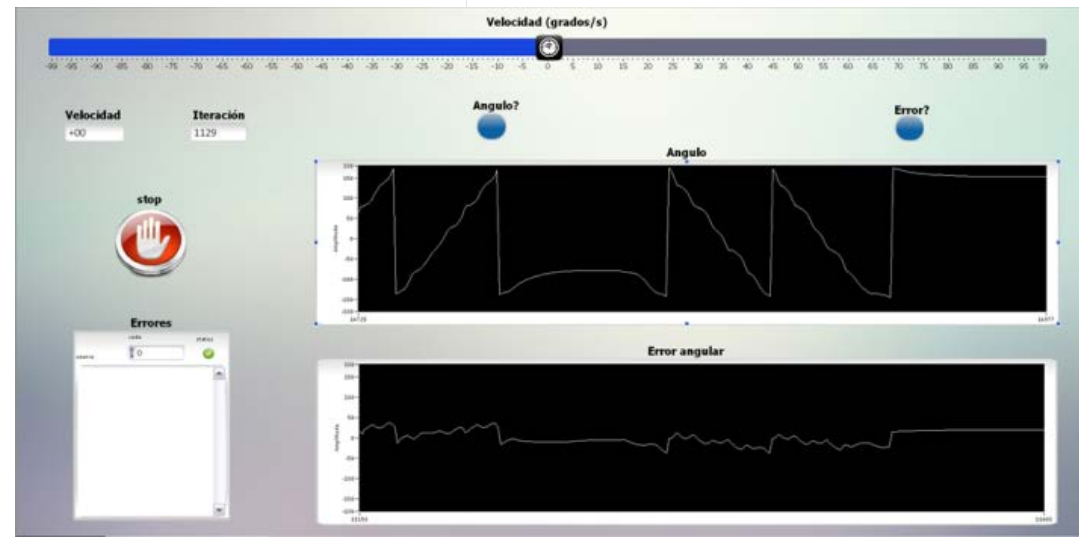
Module Modeling
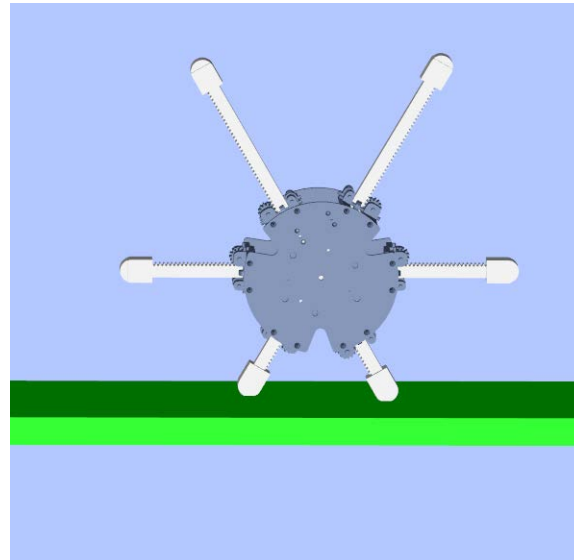
Module Modeling
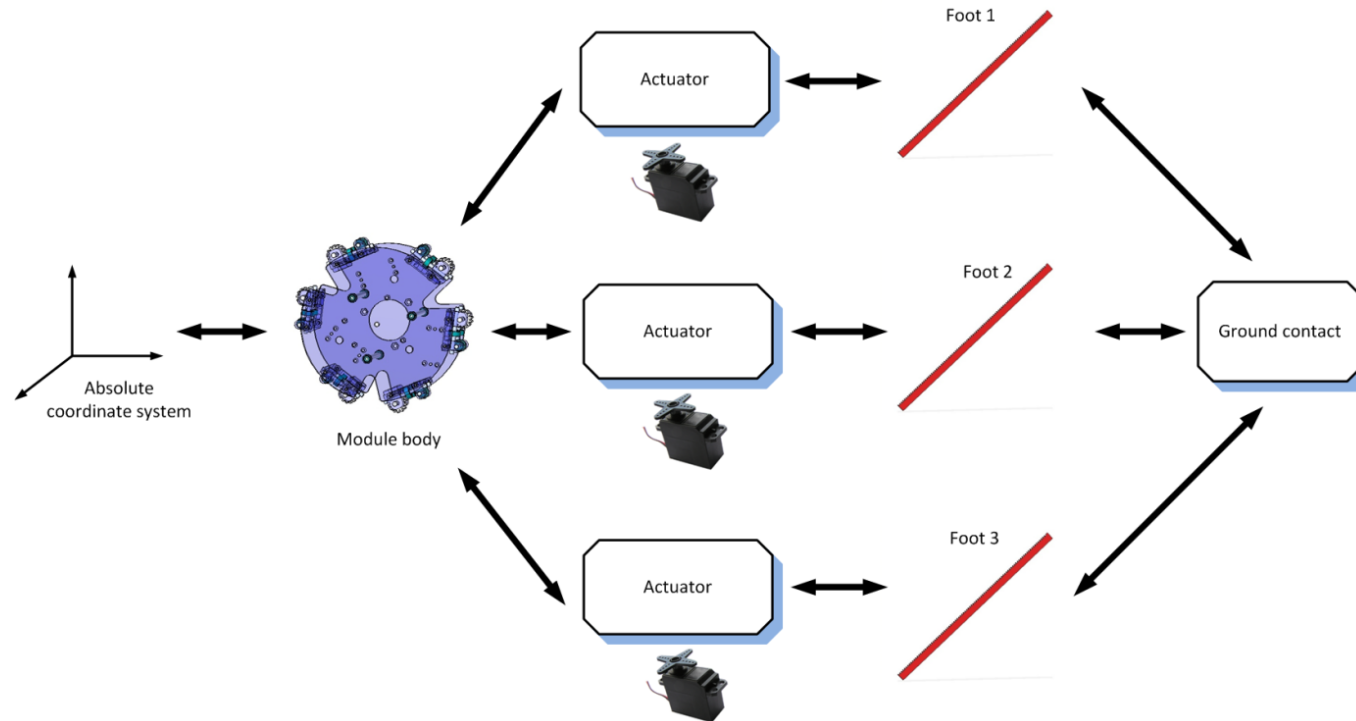
Assumptions

- ❖ **Bidimensional model**
- ❖ **Ground friction is considered**
- ❖ **Flat and smooth surface**

Module Modeling

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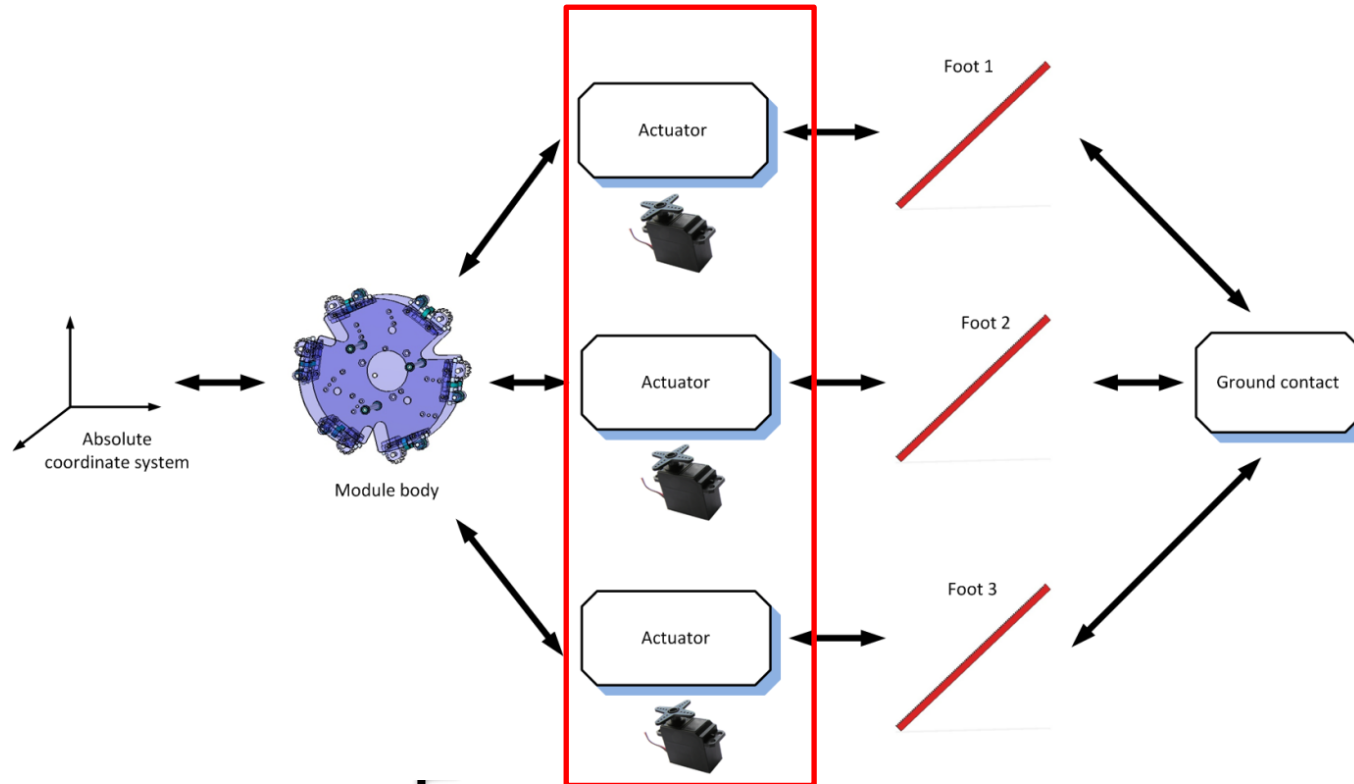
Module Modeling

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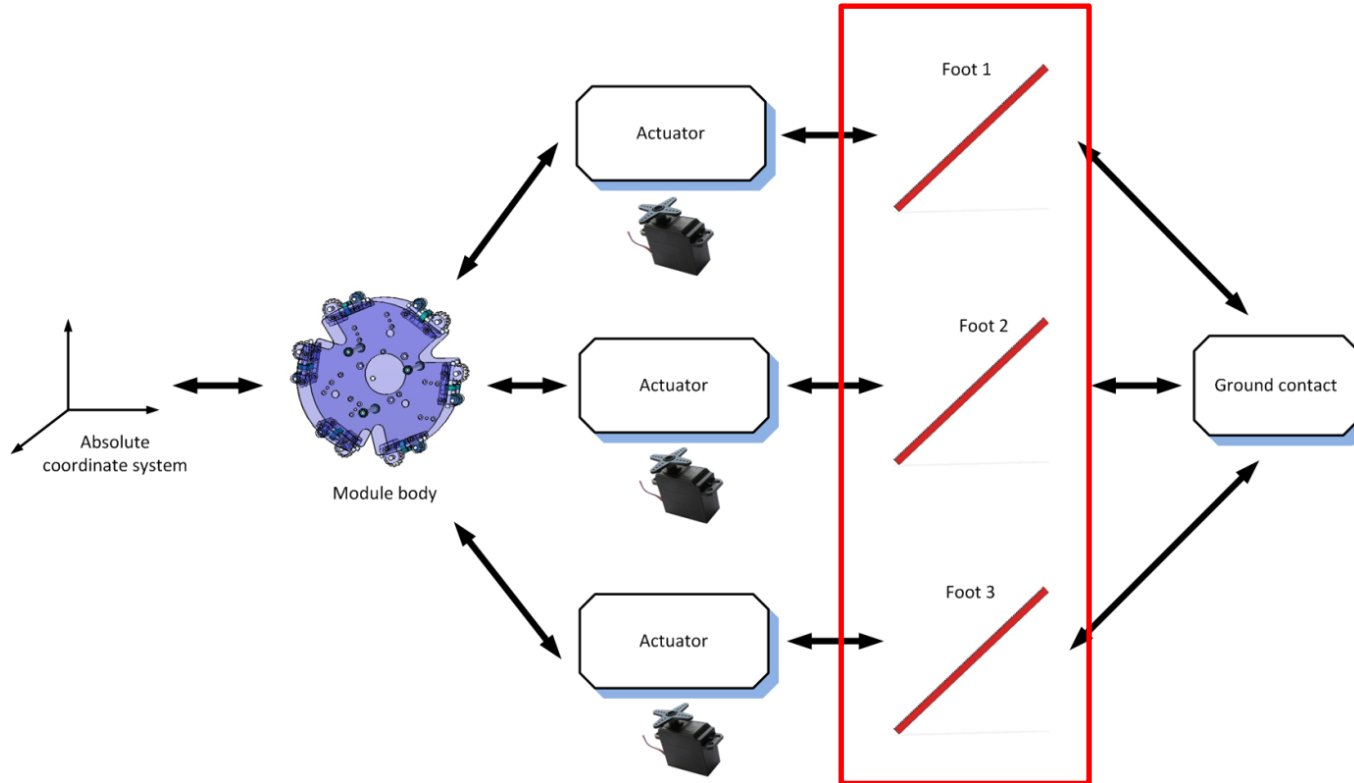
Module Modeling

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Module Modeling

Assumptions

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Motors modeling

Torque & Speed vs voltage
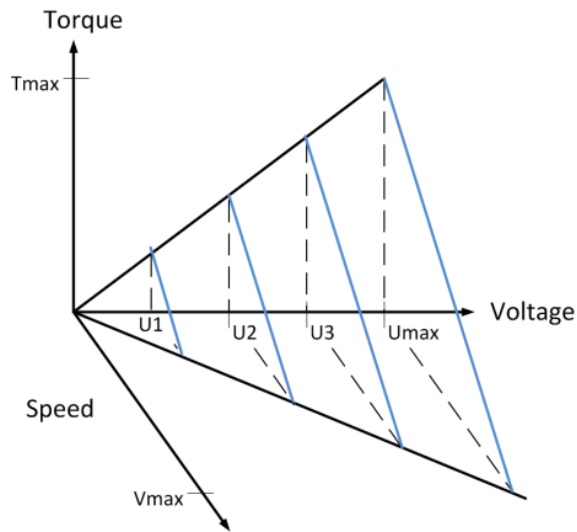
Linear actuator force

$$F(e,v) = \begin{cases} \dfrac{F_{max}}{e_c}\, e - \dfrac{F_{max}}{v_{max}}\, v & |e| < e_c \\[2em] sign(e)F_{max} - \dfrac{F_{max}}{v_{max}}\, v & |e| \geq e_c \end{cases}$$

$e_c = Maximum\ acceptable\ error$

$$Voltage = \begin{cases} \dfrac{U_{max}}{e_c}\, e & si\ e < e_c \\[1.5em] U_{max} & si\ e \geq e_c \end{cases}$$
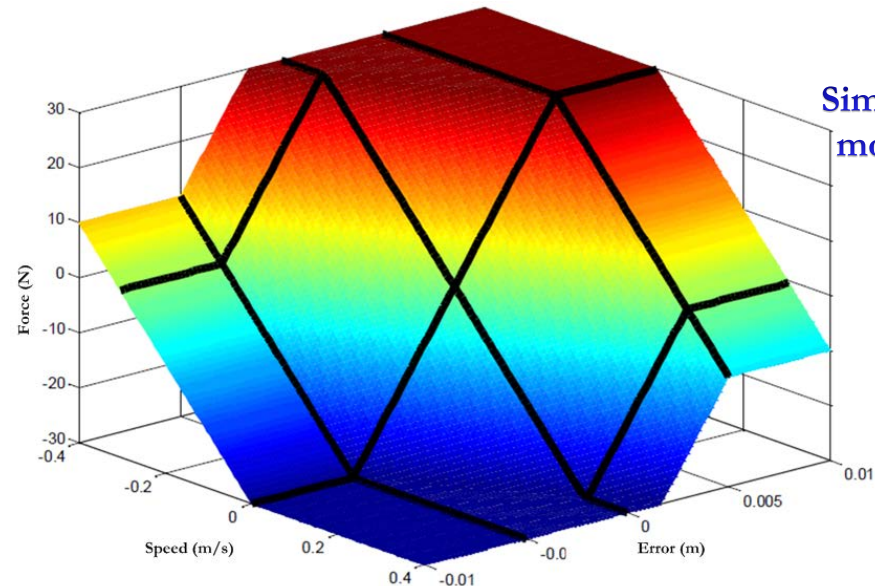
SimMechanics motor model

29

Module Modeling

Feet movement control. Low level control.

Geometric parameters
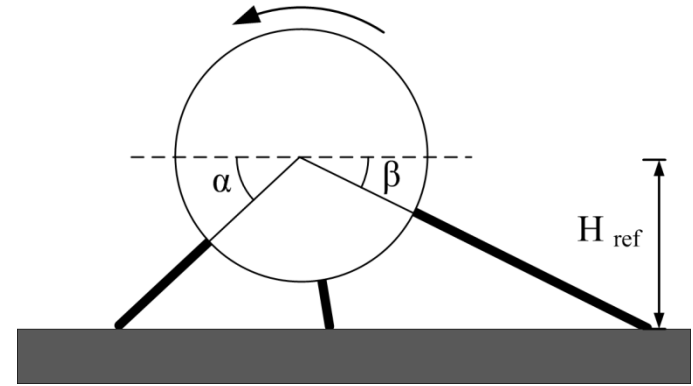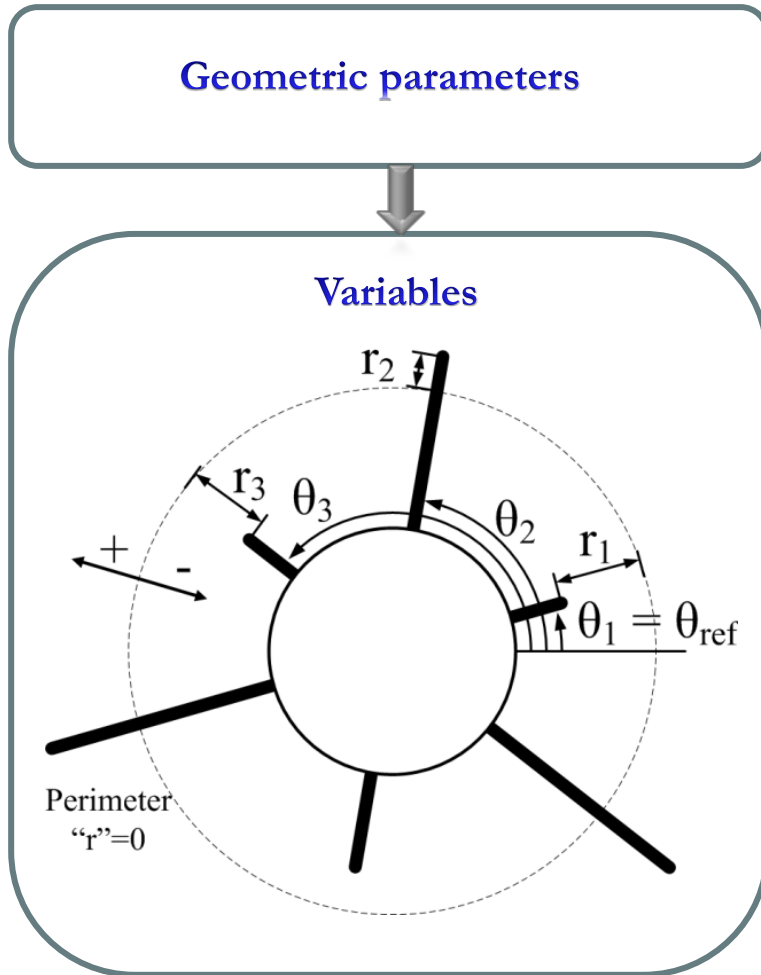
Variables

H_{ref}: desired height during operation

Θ: angular reference of the module

Feet movement control. Low level control.

Geometric parameters

Contact zone
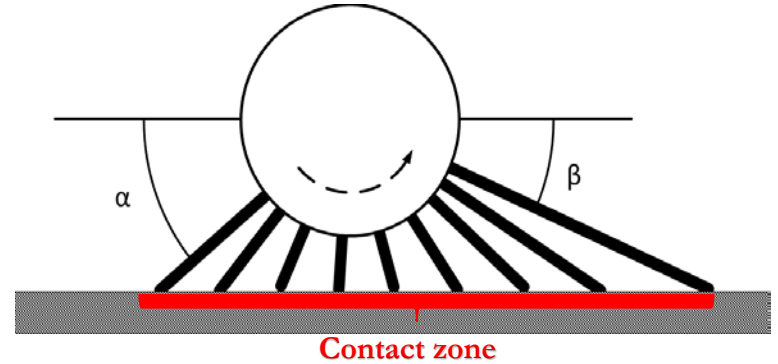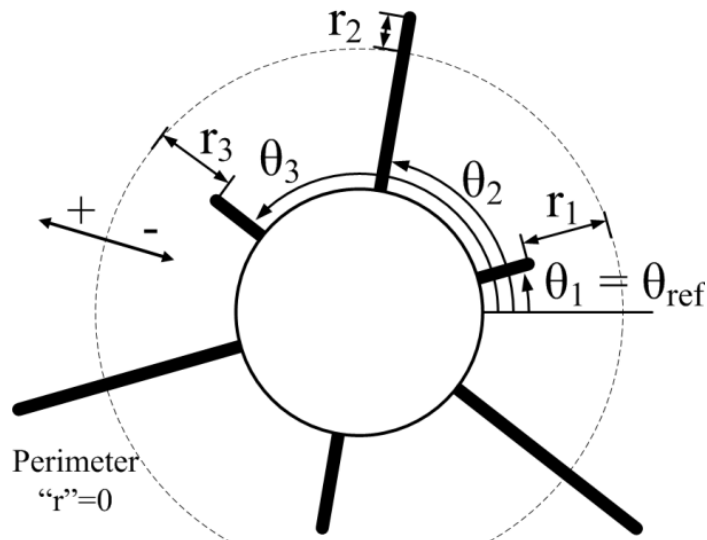
Variables

Control equations

$$r_i^{ref} = signo(\sin(-\theta_i))\left(\left|\frac{H_{ref}}{\sin(-\theta_i)}\right| - \frac{l}{2}\right)$$

Feet movement control. Low level control.

Geometric parameters

No contact (2)   No contact (1)

Variables
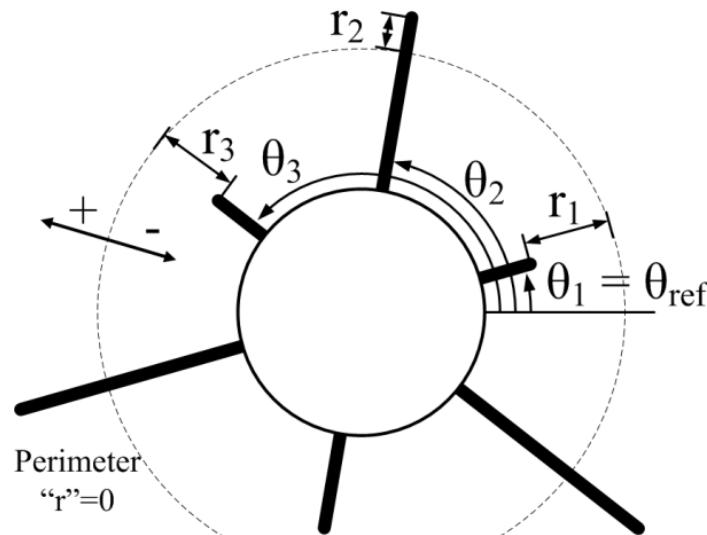
Control equations

$$r_i^{ref} = signo(\sin(-\theta_i))\left(\left|\frac{H_{ref}}{\sin(-\theta_i)}\right| - \frac{l}{2}\right)$$

(1)
$$r_i^{ref} = -\left(\left|\frac{H_{ref}}{\sin(\beta)}\right| - \frac{l}{2}\right)\frac{\sin(\theta_i)}{\sin(\beta)}$$

(2)
$$r_i^{ref} = -\left(\left|\frac{H_{ref}}{\sin(\alpha)}\right| - \frac{l}{2}\right)\frac{\sin(\theta_i)}{\sin(\alpha)}$$

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Module Modeling

Ground contact model

Feet ⟶ **Rigid solid**

Ground ⟶ **Soft solid (high elastic constant, k_e, + dissipation constant, k_d)**

Normal force equation:

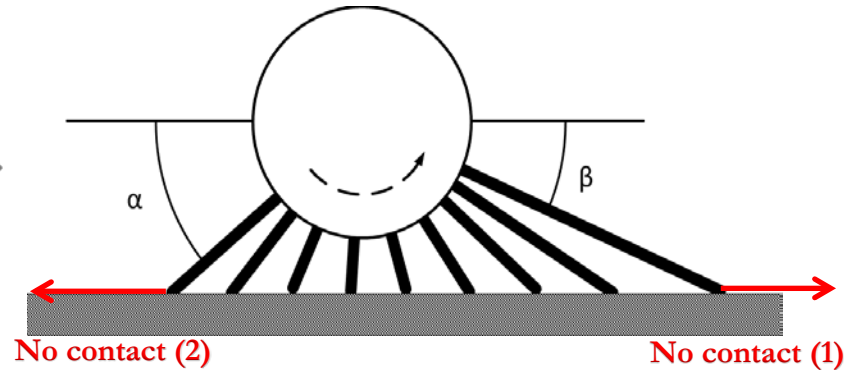$$F_{contact} = \begin{cases} 0 & si\ p > 0\ o\ \left(-k_e\,p - k_d\dfrac{dp}{dt}\right) < 0 \\[4mm] -k_e\,p - k_d\dfrac{dp}{dt} & si\ p \le 0\ y\ \left(-k_e\,p - k_d\dfrac{dp}{dt}\right) \ge 0 \end{cases}$$

$F_{contact}$

p
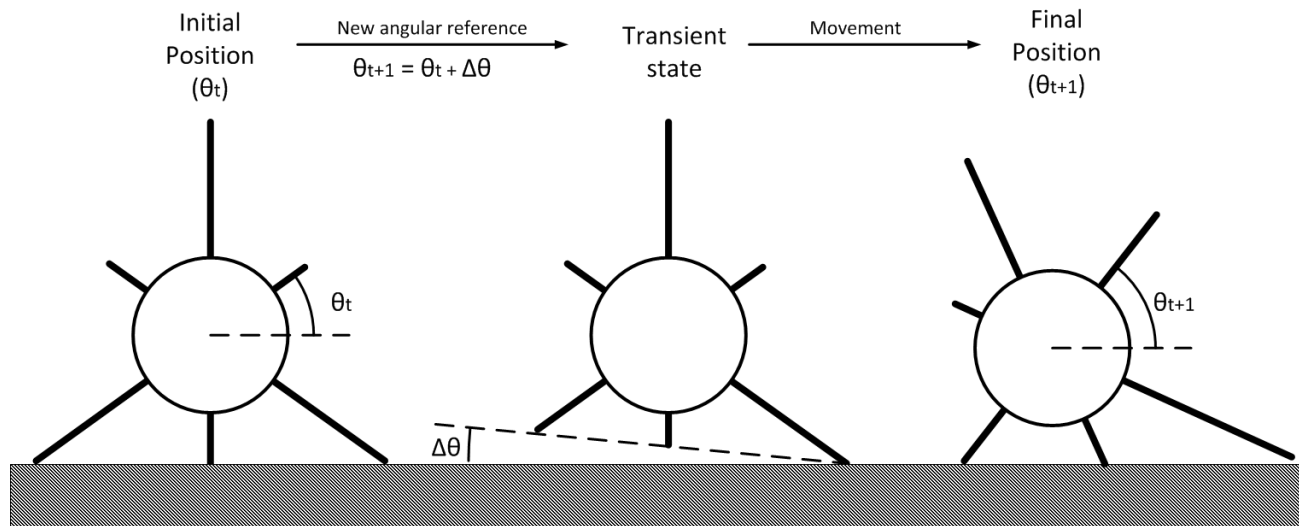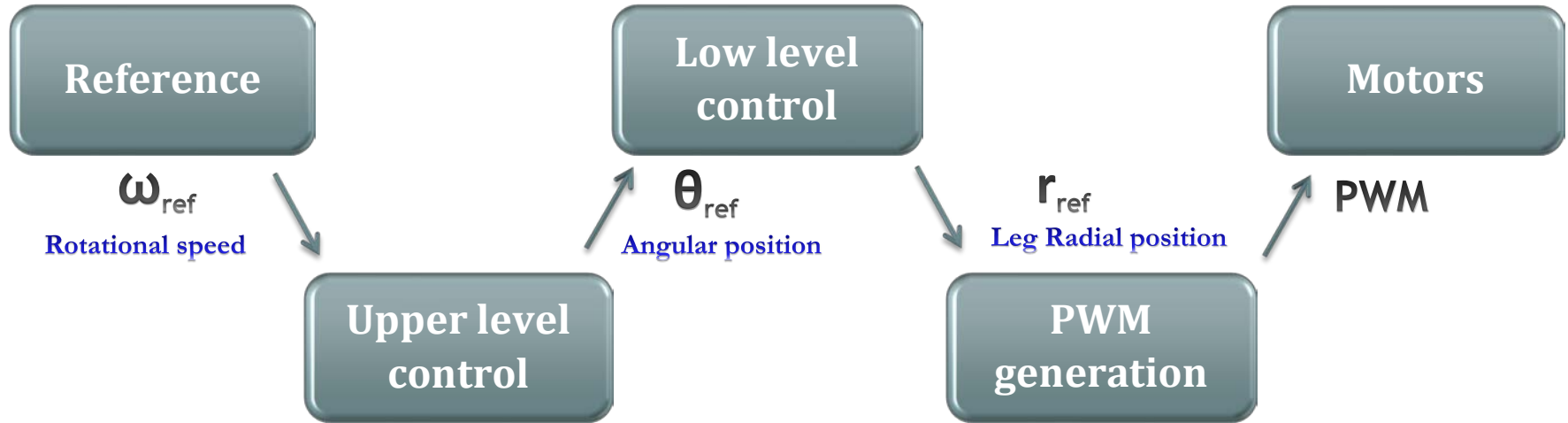
Module Modeling

Simulations

$$\omega_{ref}^1 = 10\,°/s$$

$$\omega_{ref}^1 = 30\,°/s$$

Simulations

$$\omega_{ref}^1 = 90\,°/s$$
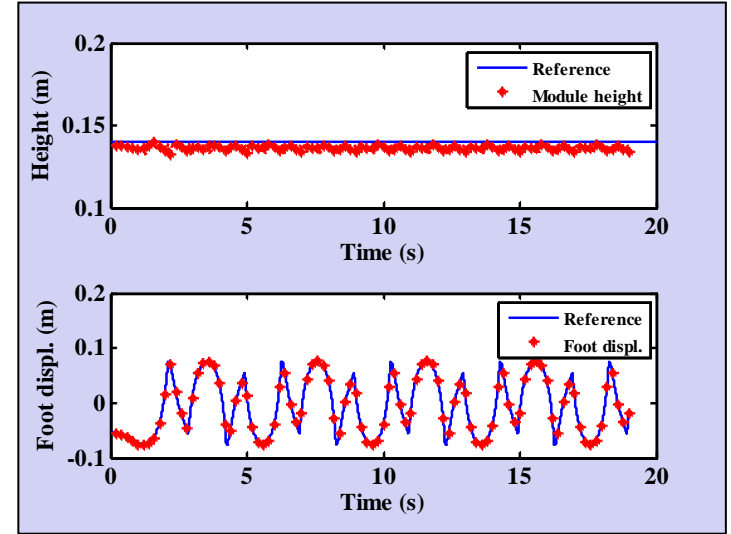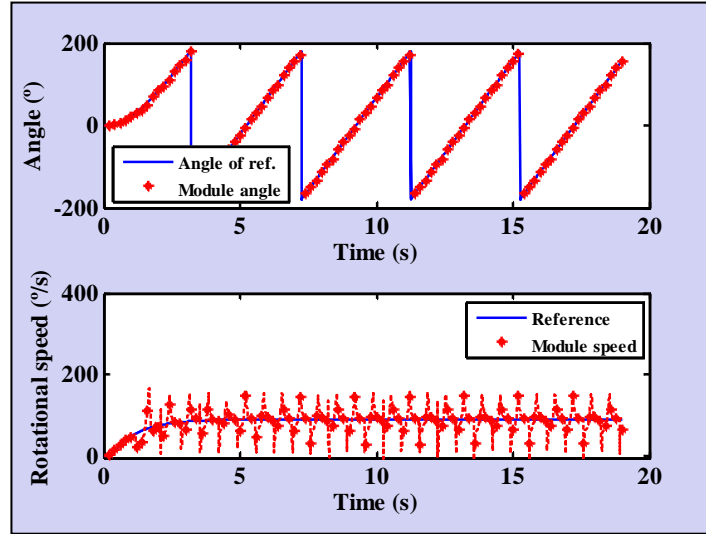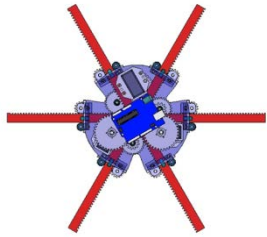
$$\omega_{ref}^1 = 120\,°/s$$
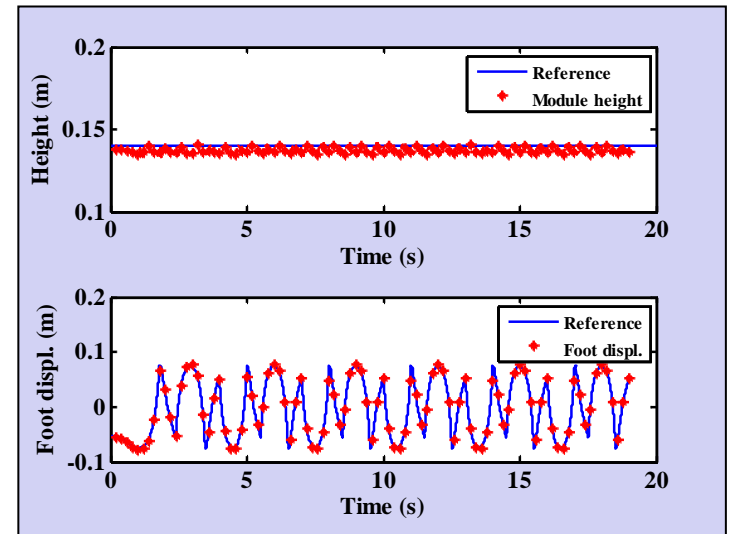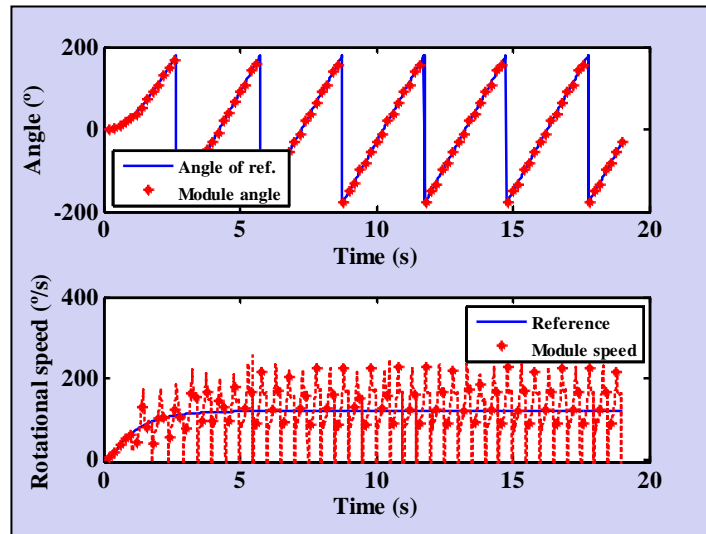
Experimental Results
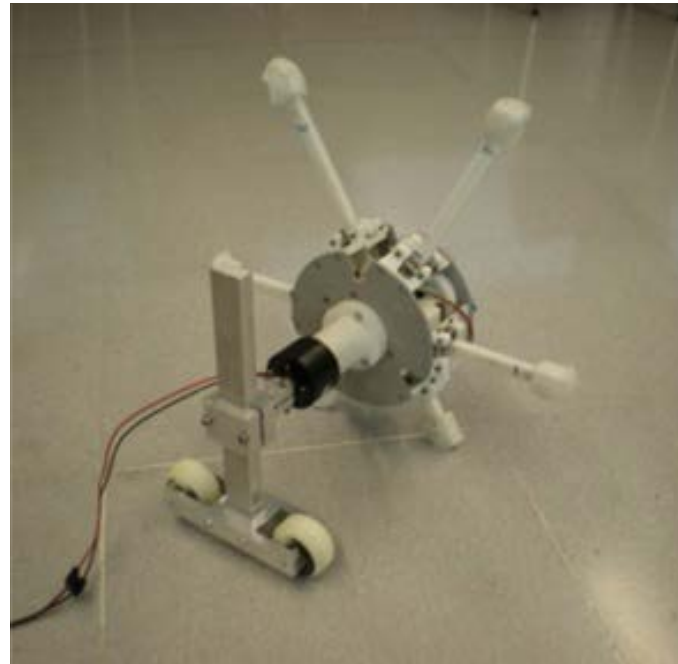
Experimental results

$$\omega_{ref}^1 = 10\,°/s$$
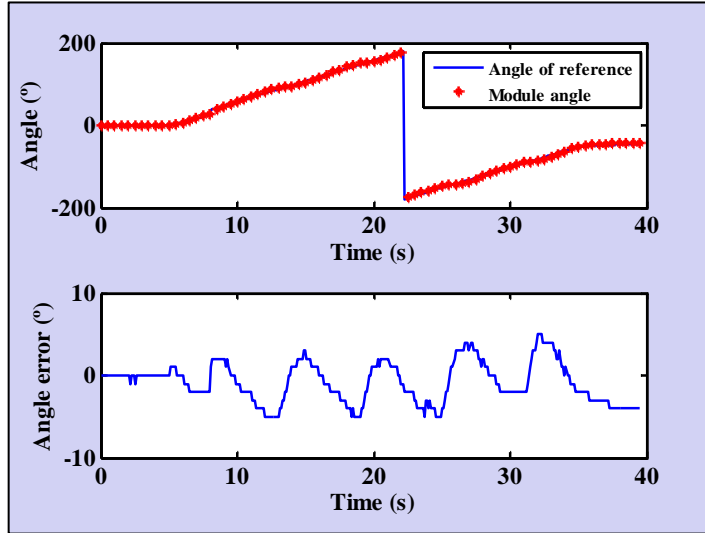
$$\omega_{ref}^2 = 30\,°/s$$
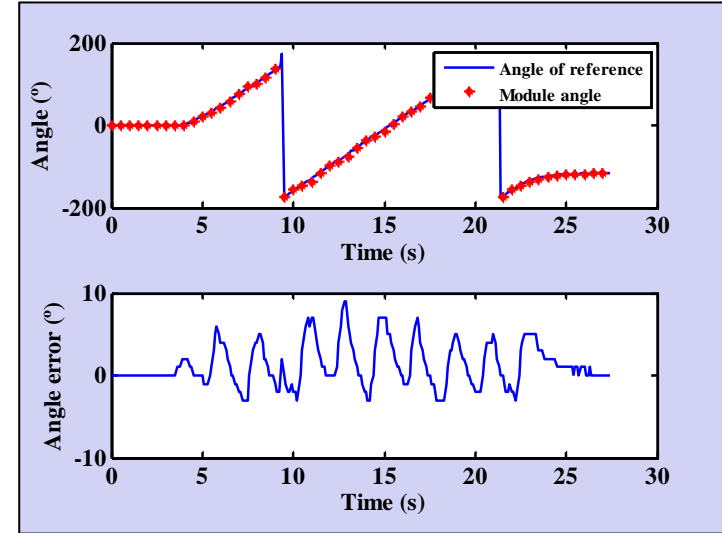
$$\omega_{ref}^3 = 90\,°/s$$
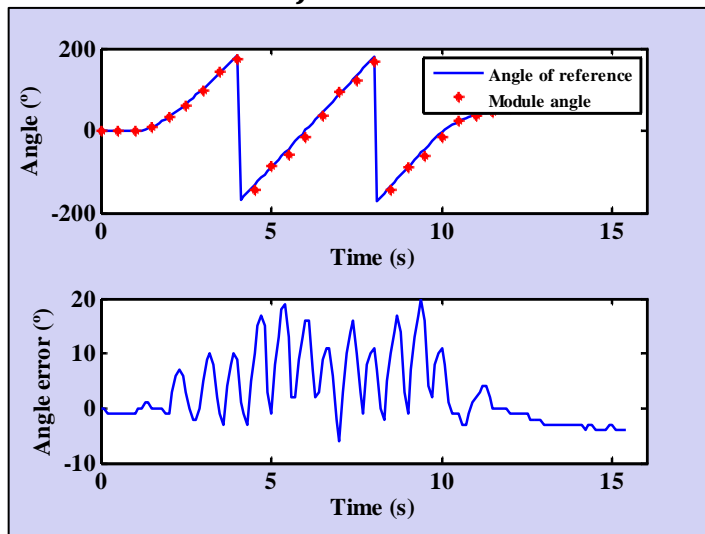
- The module faithfully follows the reference.
- The maximum angle errors are smaller than 9 and 20 degrees respectively.
- The errors increase when moving faster since the movement of the module becomes sharper and less smooth.
- Results are very similar to those obtained in simulations,

Conclusions

Conclusions

- **A new concept of locomotion system for mobile robots has been proposed, designed and built.**

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- A control algorithm has been programmed and tested with the model.

- **Experimental tests demonstrate the correct operation of the module when moving on a flat and smooth surface and without obstacles.**
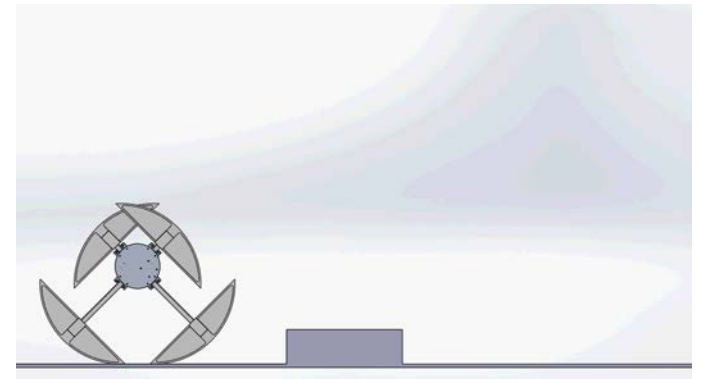
Conclusions
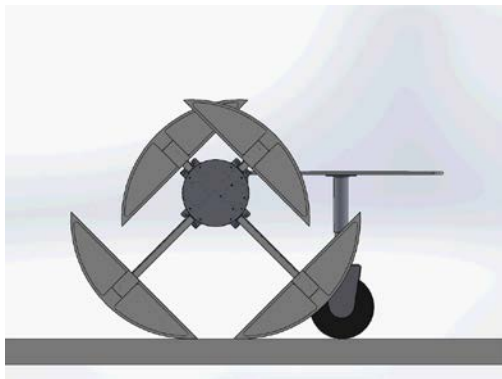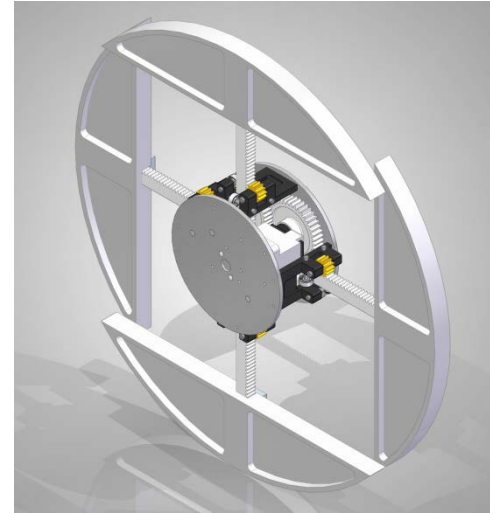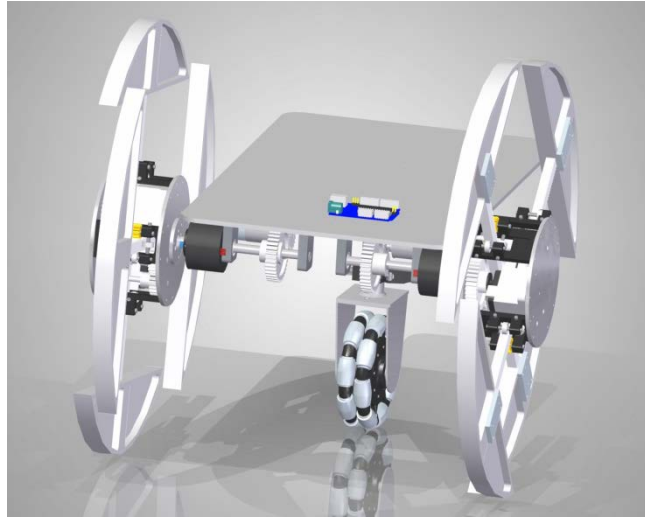
Legs
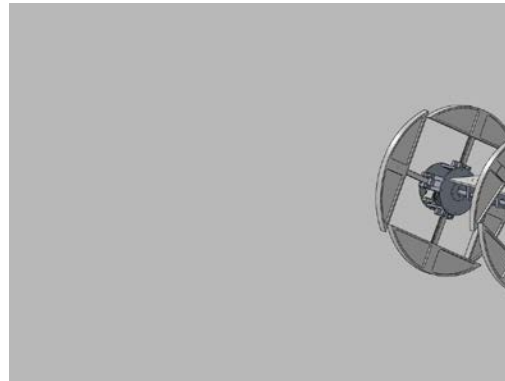
Wheels

Obstacle

Thank you for your attention

J. J. CASTILLO, J. A. CABRERA, M. JAIMEZ , F. VIDAL AND A. SIMÓN

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