Example of design
UE Rehab Robot

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Example of design- UE Rehab Robot

INTRODUCTION

R. Morales Vidal, F.J. Badesa, N. Garcia-Aracil, J.M. Sabater, C. Perez. "*Pneumatic robotic system for upper limb rehabilitation*". Medical and Biological Engineering and Computing, 2011, vol. 4, no.10, pp.1145-1156,2011, ISSN: 140-0118. Grupo B, segundo quintil (25/99) en la categoría COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS.

Introduction

After stroke: Bobath, Brunnstrom, Proprioceptive Neuromuscular Facilitation (PNF), Motor Relearning Program (MRP), constraint-induced movement therapy (CIMT), task-related training and bilateral training.

Proprioceptive Neuromuscular Facilitation method(PNF)

The movement patterns which will be assisted by the robotic device are D1 flexion, D1 extension, D2 flexion, and D2 extension patterns.








Introduction

- The physiotherapist moves the patient through the range of motion initially, to allow the patient to understand how the limb will be moving before adding resistance; this is the same for all diagonal patterns.
- Once the patient understands the movement, the clinician applies manual resistance to the patient
- Simple, one word verbal cues from the clinician are important to achieve maximal results from the patient.

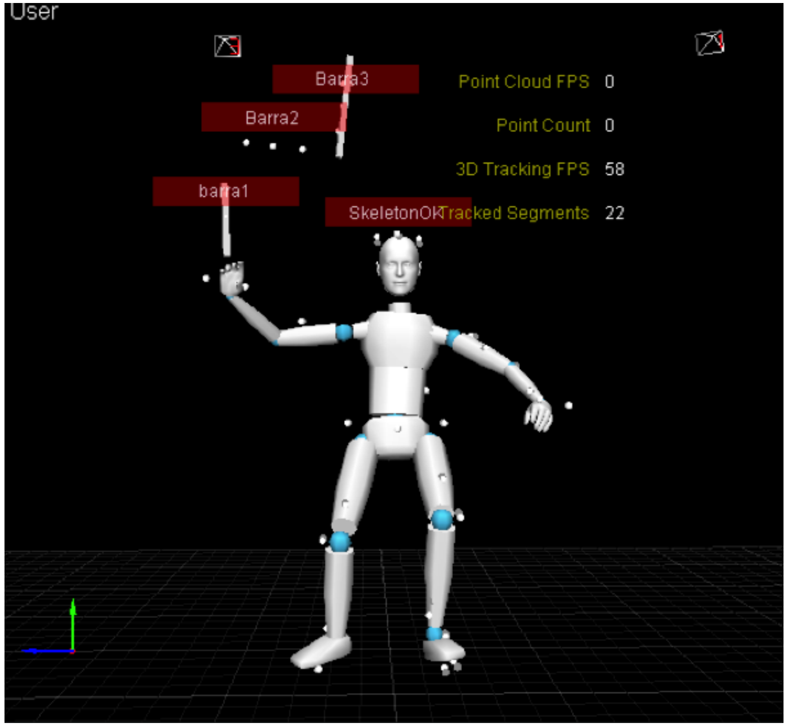
Example of design - UE Rehab Robot

SYSTEM DEVELOPMENT PROCESS

R. Morales Vidal, F.J. Badesa, N. Garcia-Aracil, J.M. Sabater, C. Perez. "*Pneumatic robotic system for upper limb rehabilitation*". Medical and Biological Engineering and Computing, 2011, vol. 4, no.10, pp.1145-1156,2011, ISSN: 140-0118. Grupo B, segundo quintil (25/99) en la categoría COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS.

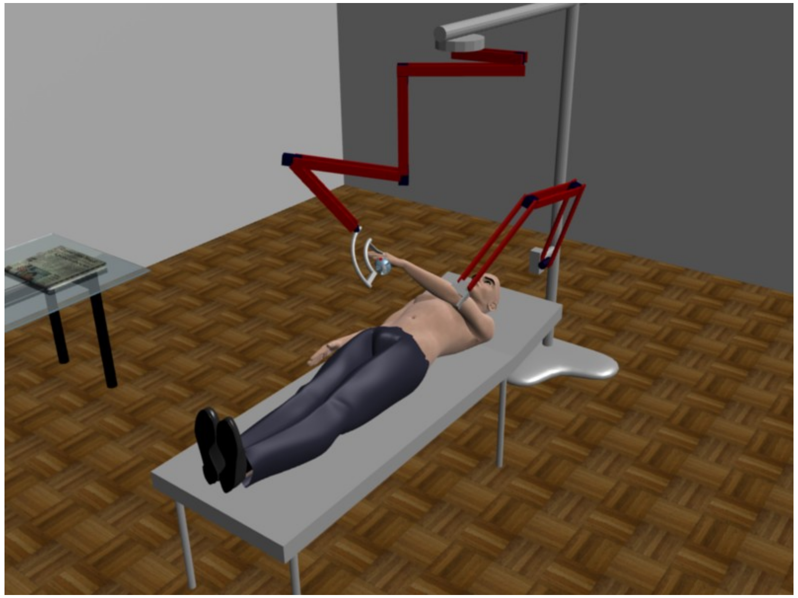
System development process

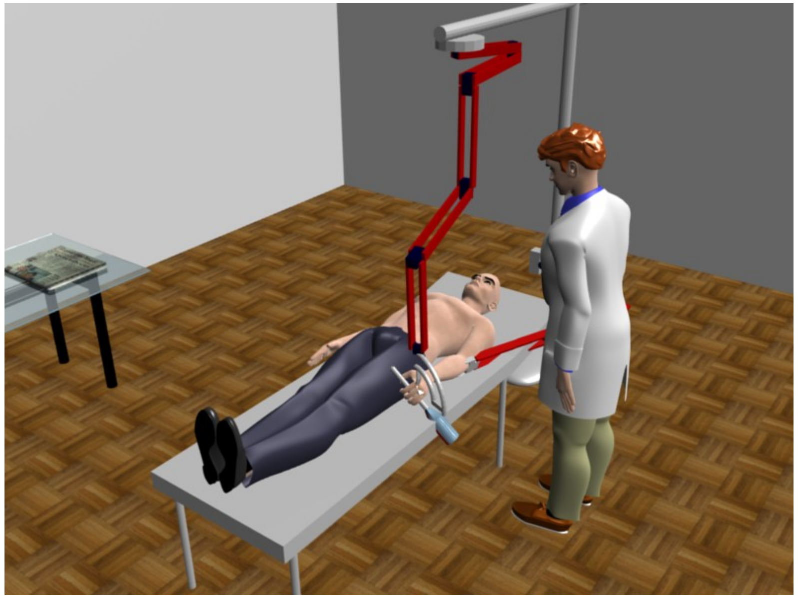
The philosophy of the development process was to involve health care professionals and people with stroke during the development process with the objective of maximizing the acceptation of the system by the end-user and the physiotherapists.



System development process

Design and preliminary evaluation in simulation environments of different robotic solutions for the application of PNF method





The designed robot solution comprises two arm robots:

1. three active degrees of freedom to control the patients' hand (Robotic Arm 1)
2. three active degrees of freedom to control the movements of the patients' elbow (Robotic Arm 2)

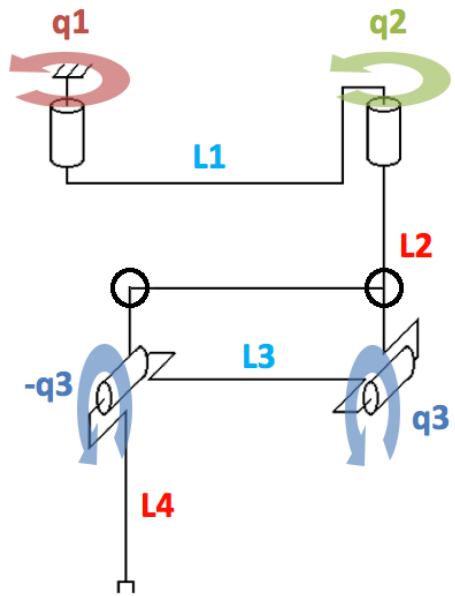
This configuration tries to mimic the way that the physiotherapists do the manual PNF movements.

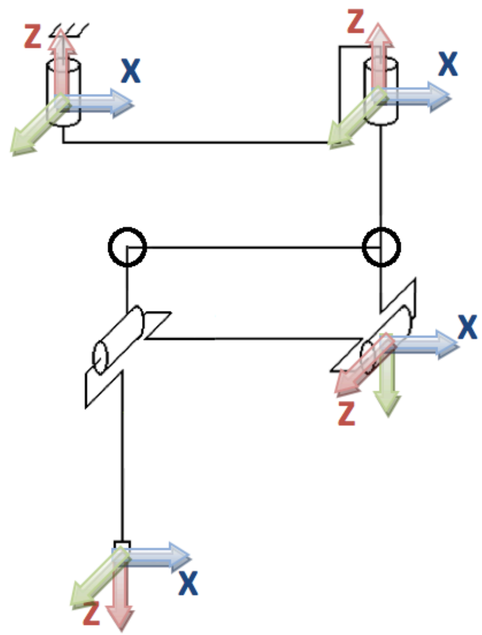
System development process

Direct Kinematic (Robotic Arm 1)

- SCARA configuration
- 3 active dof
- Vertical movement (parallelogram)

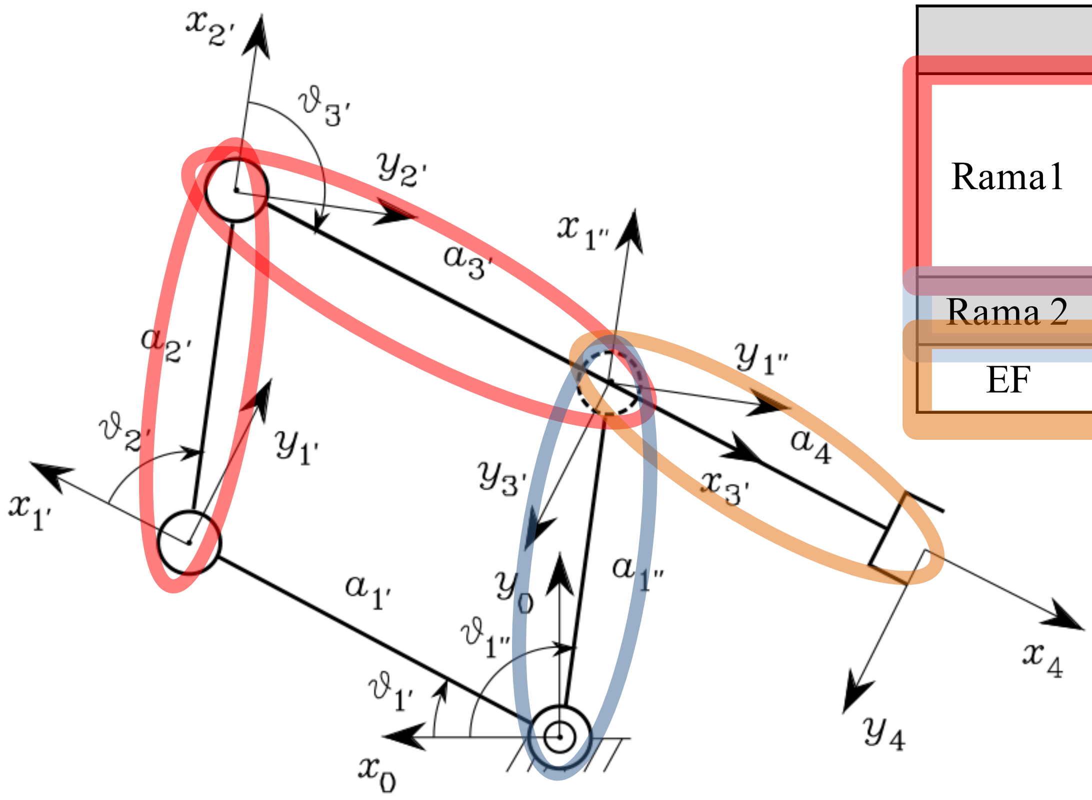
	θ	d	a	α
1	q_1	0	L_1	0
2	$q_2+\pi/2$	$-L_2$	0	$\pi/2$





System development process

Direct Kinematic (Robotic Arm 1)



		θ	**d**	**a**	**α**
Rama1	1’	$q_{1'}$	0	$a_{1'}$	0
	2’	$q_{2'}$	0	$a_{2'}$	0
	3’	$q_{3'}$	0	$a_{3'}$	0
Rama 2	1’’	$q_{1''}$	0	$a_{1''}$	0
EF	4	π/2	0	a_4	π/2

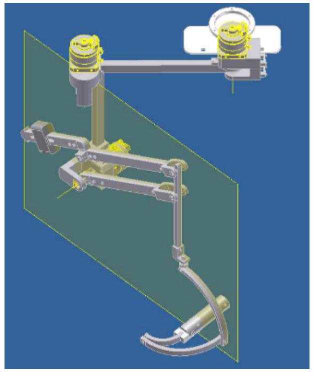
$$x = L_3 \cos(q_3)\,[\sin(q_1)\sin(q_2) - \cos(q_1)\cos(q_2)] + \cos(q_1)L_1$$

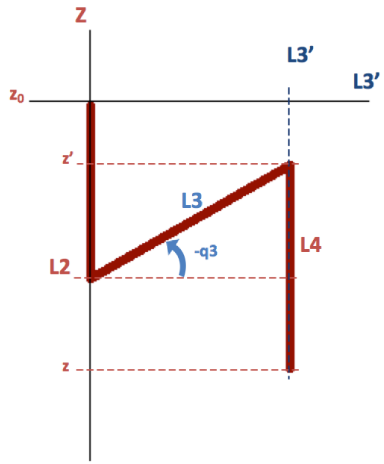
$$y = L_3 \cos(q_3)\,[\cos(q_1)\sin(q_2) + \sin(q_1)\cos(q_2)] + \sin(q_1)L_1$$

$$z = -L_3 \sin(q_3)\; - L_4 - L_2$$

System development process

Inverse Kinematic (Robotic Arm 1)





$$z = z' - L_4 \rightarrow z' = z + L_4$$

$$z' = -L_2 + L_3 \sin(-q_3)$$

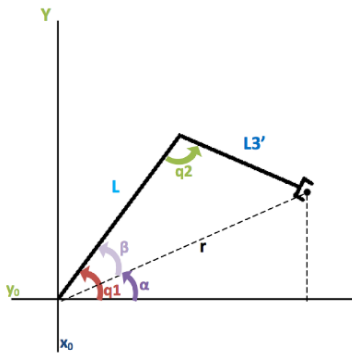
$$\sin(q_3) = -\frac{z + L_4 + L_2}{L_3}$$

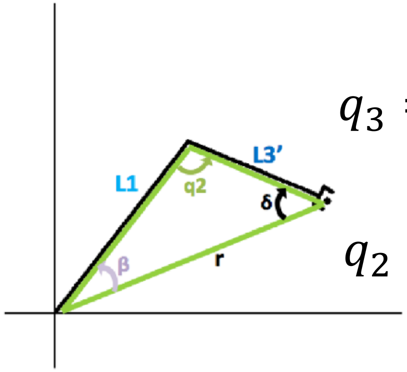
$$q_3 = arcsin\left(-\frac{z+L_4+L_2}{L_3}\right)$$ para z>=L_2

$$q_3 = -arcsin\left(-\frac{z+L_4+L_2}{L_3}\right)$$ para z<L_2

$$q_2 = arccos\left(\frac{r^2 - L_1^2 + L'^2_3}{-2L_1 L'_3}\right)$$

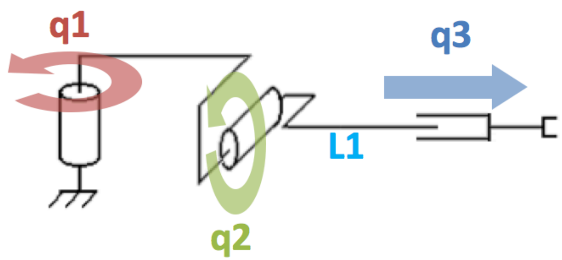
$$q_1 = arctan\left(\frac{y-y_0}{x-x_0}\right) + arcsin\left(\frac{L'_3 \sin(q_2)}{r}\right)$$

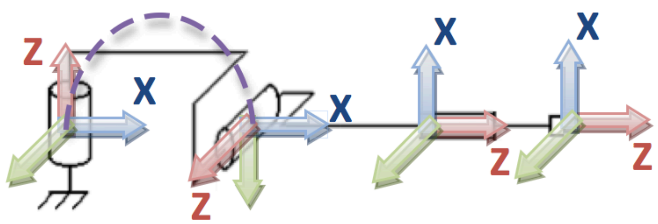




System development process

Direct Kinematic (Robotic Arm 2)





	θ	d	a	α
1	q_1	0	0	$\pi/2$
2	$q_2+\pi/2$	0	0	$\pi/2$
3	0	L_1+q_3	0	0

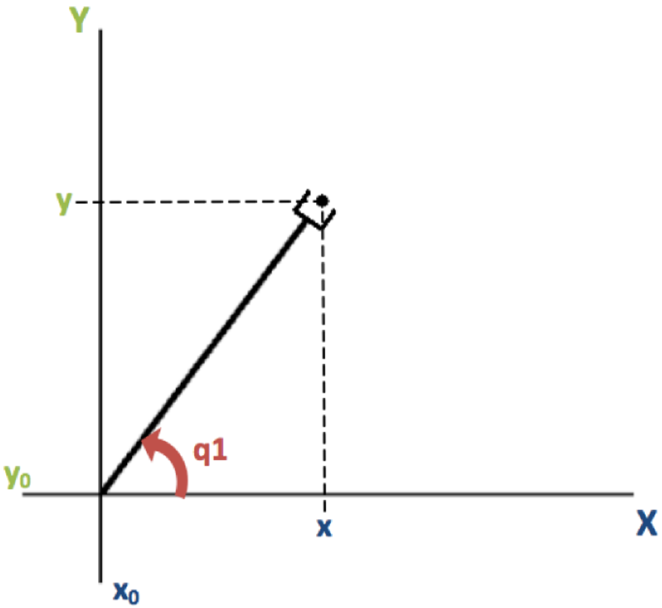
$$x = (L_1 + q_3)cos(q_1)cos(q_2)$$

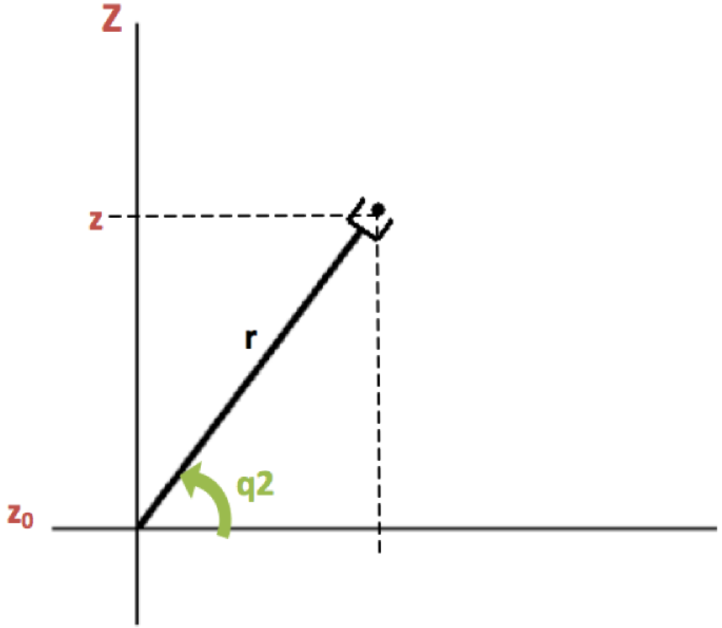
$$y = (L_1 + q_3)sin(q_1)cos(q_2)$$

$$z = (L_1 + q_3)sin(q_2)$$

System development process

Inverse Kinematic (Robotic Arm 2)





$$q_1 = arctan\left(\frac{y-y_0}{x+x_0}\right) \text{ para } y \geq y_0; -q_1 \text{ para } y < y_0$$

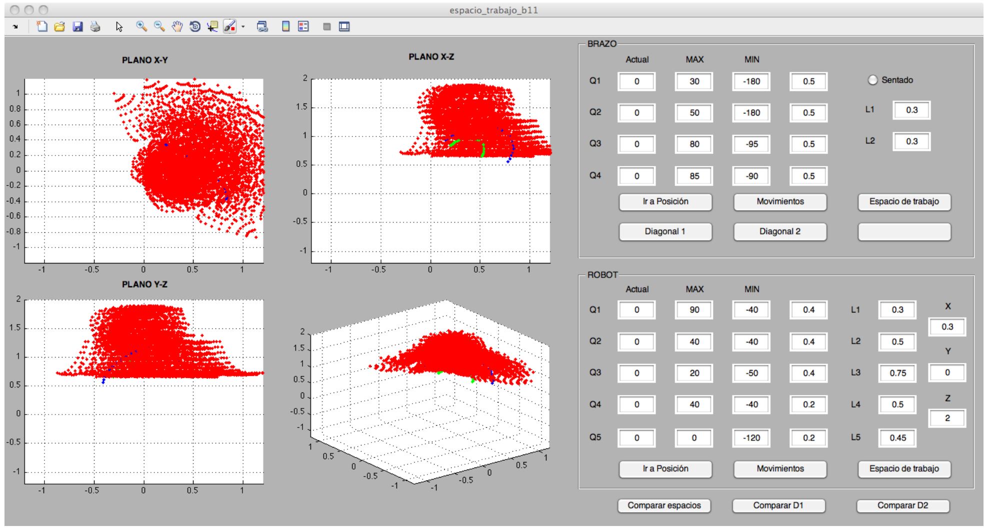
$$q_2 = arcsin\left(\frac{z-z_0}{L_1+q_3}\right) \text{ para } z \geq 0; -q_2 \text{ para } z < 0$$

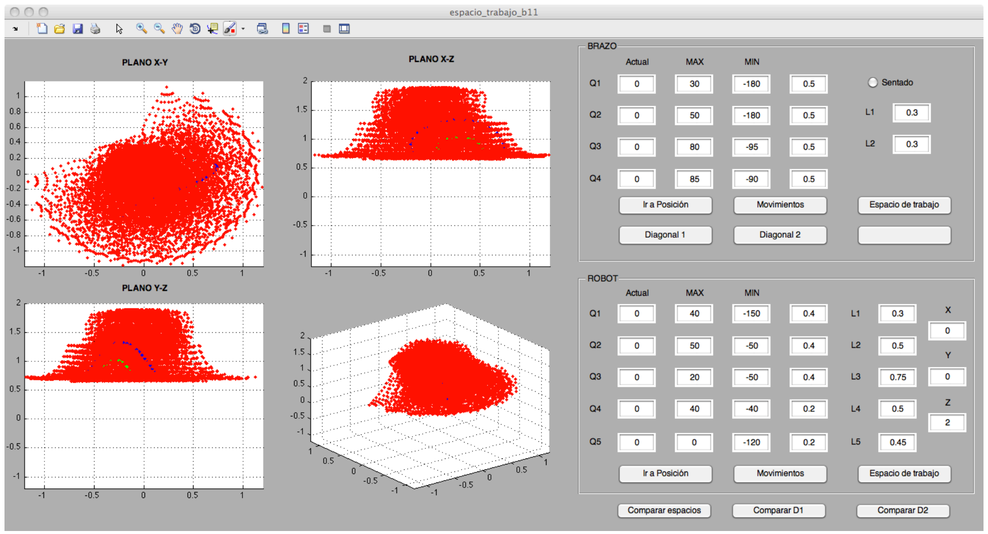
$$q_3 = \sqrt{(x-x_0)^2 + (y-y_0)^2 + (z-z_0)^2} - L_1$$

System development process

Workspace

Length adjustment(links).
Joint range
Point cloud from the motion capture system
Matlab® software.

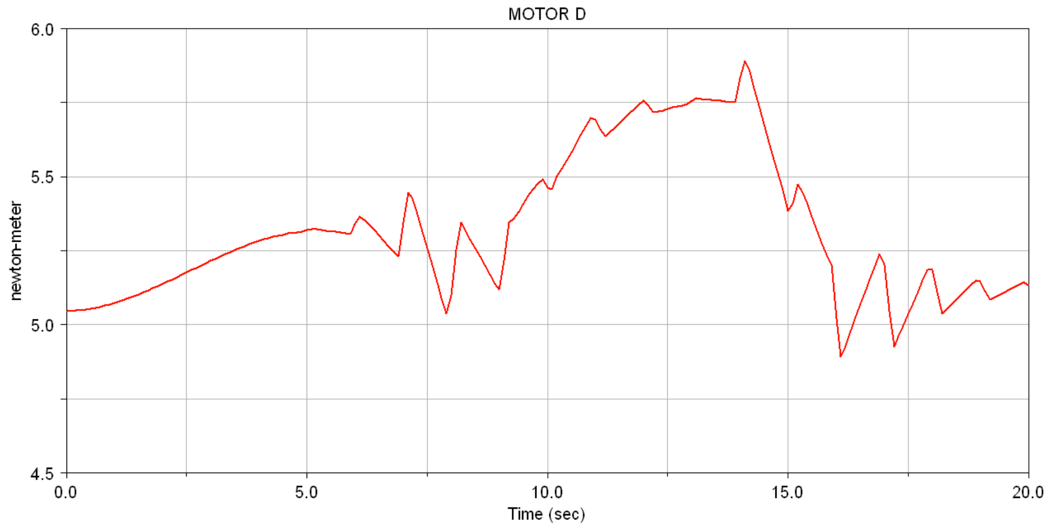


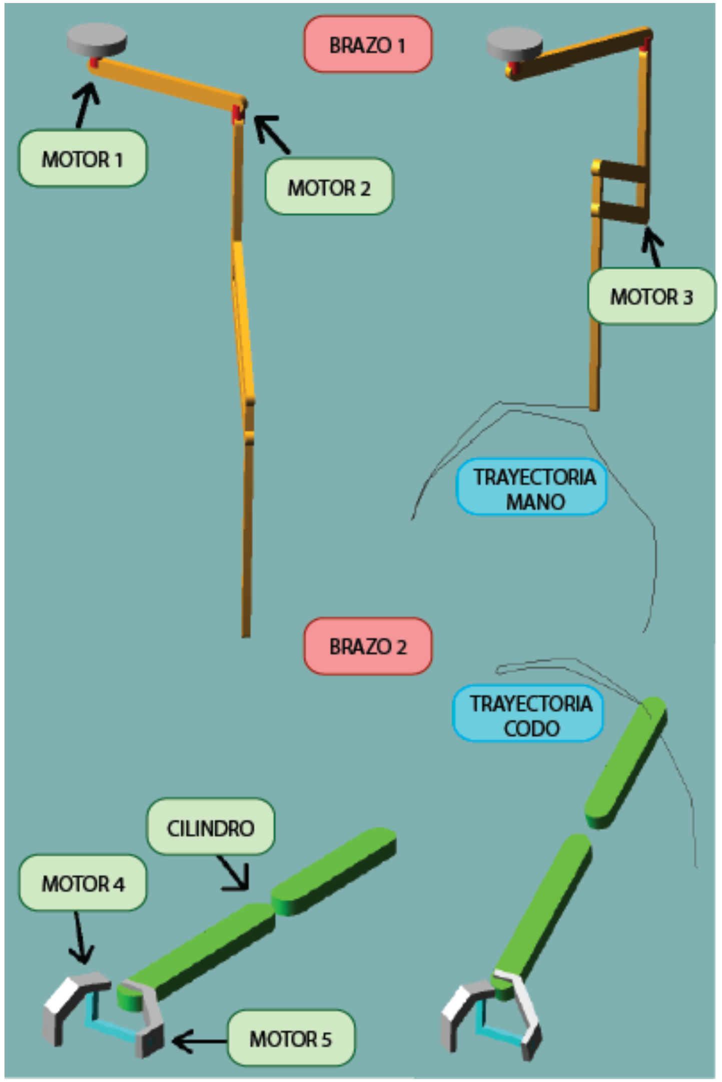


System development process

Dynamic analysis of the robotic device

Dynamic requirements of the actuators
ADAMS® software
Preliminary analysis.





The results allow the selection of the actuators

System development process

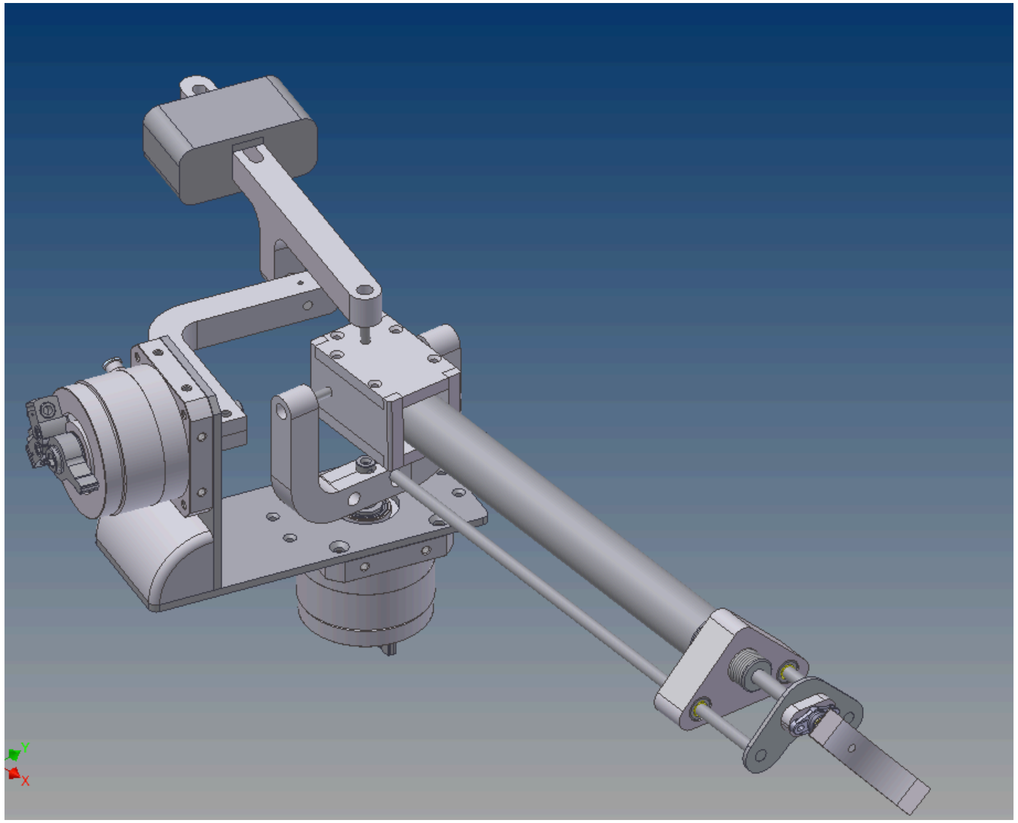
Festo DSMI	25	40	63
Construcción	Aleta pivotante. Eje de accionamiento, rodamiento de bolas.		
Funcionamiento	Doble efecto.		
Detección de posiciones	Analógico, con potenciómetro de plástico conductor.		
Vel. máx. de maniobra [º/s]	2000		
Ángulo de giro [º]	0…270		
Momento de giro [Nm]	5 (6 bares)	20 (6 bares)	40 (6 bares)
Fuerza radial máxima [N]	120	50	500
Fuerza axial máxima [N]	50	120	500
Frecuencia máx. de giro [Hz]	2		1

[redacted]

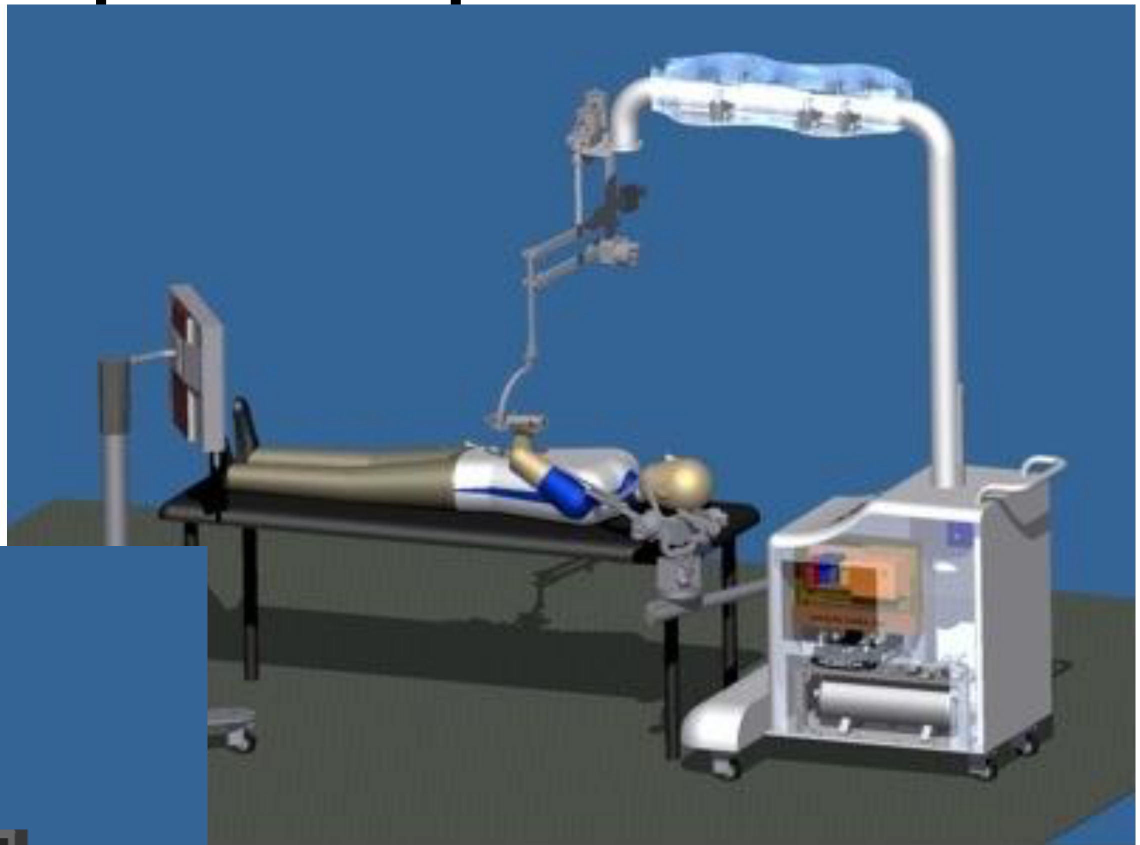
System development process

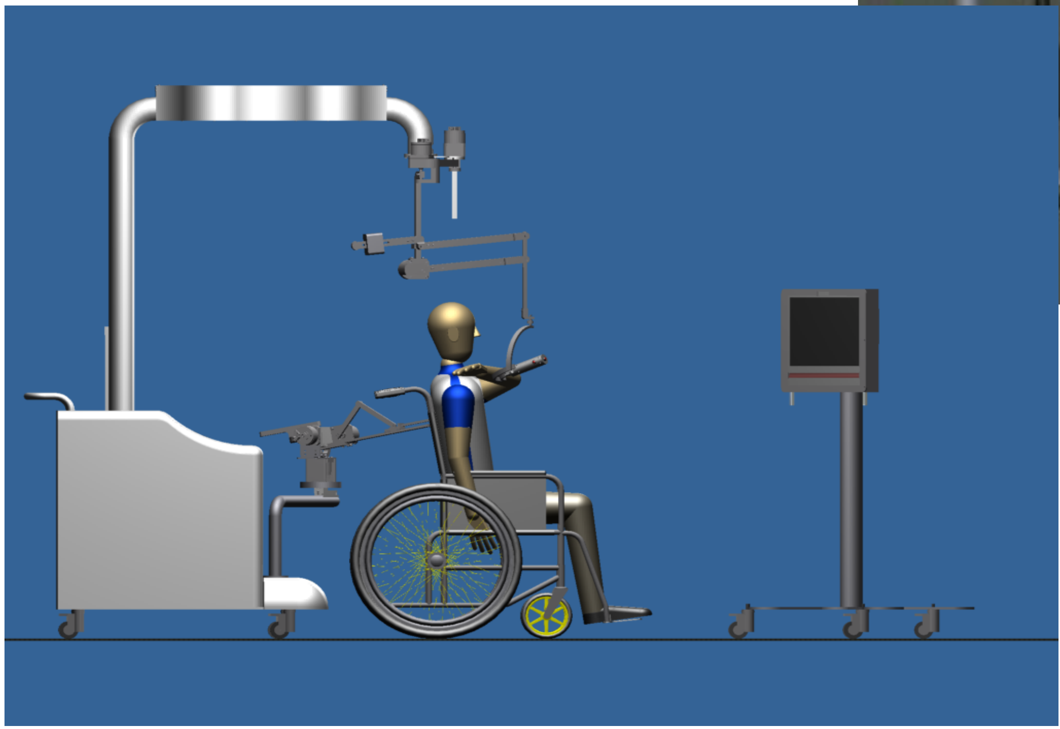
ARM 1

ARM 2



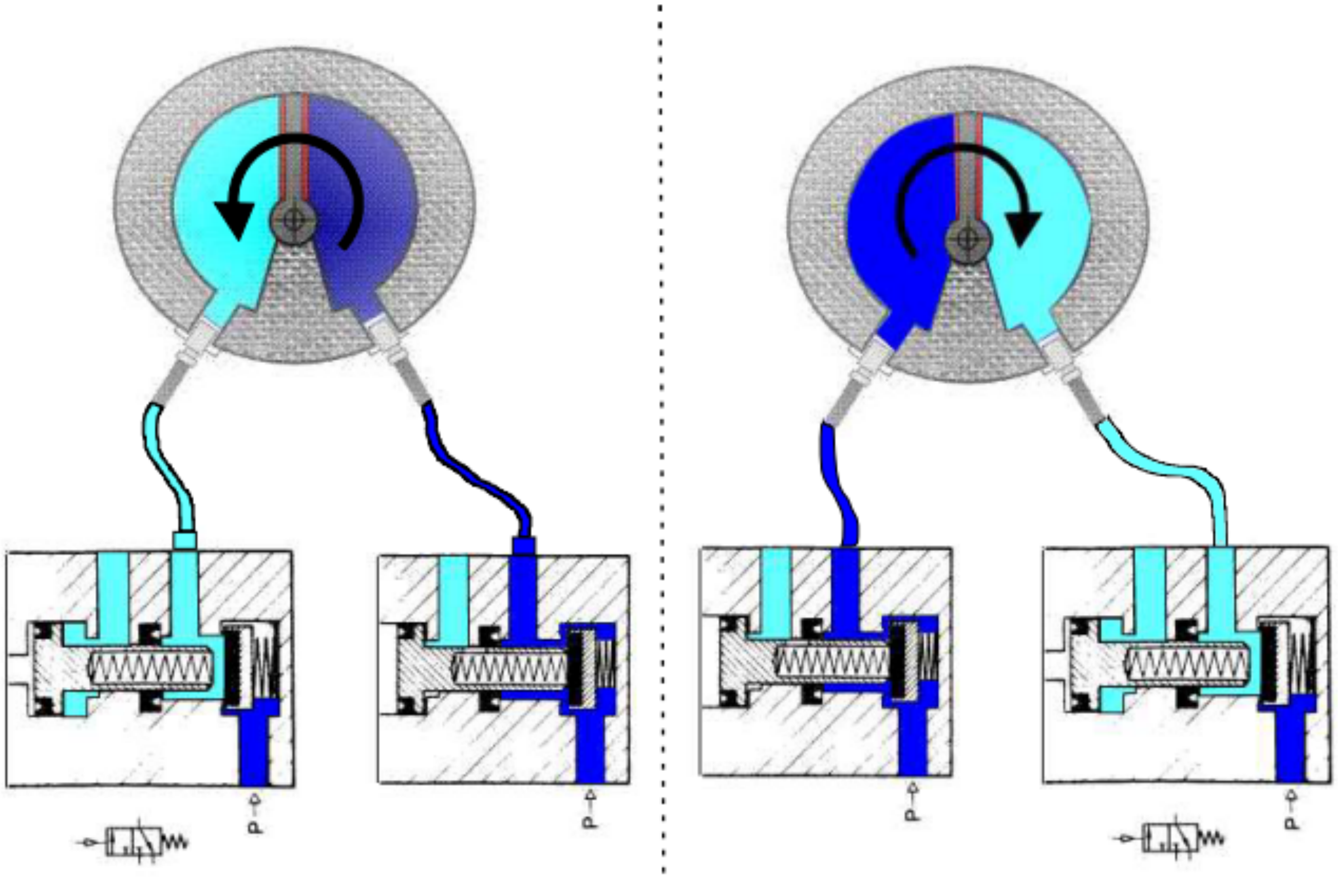
System development process





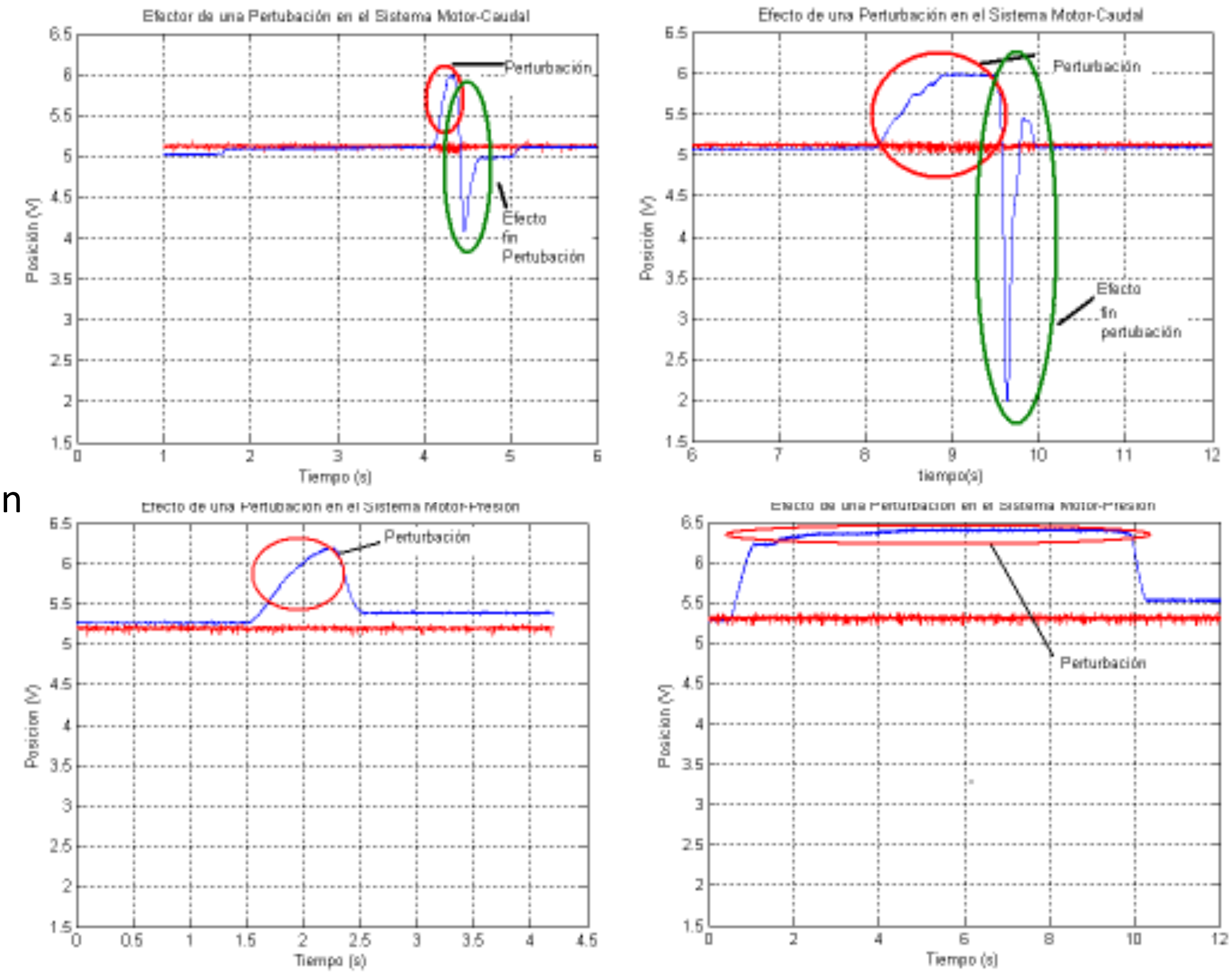
System development process

Each joint of the robotic device is actuated by a pneumatic swivel module with angular displacement encoder (DSMI) and two proportional pressure valves (MPPES).

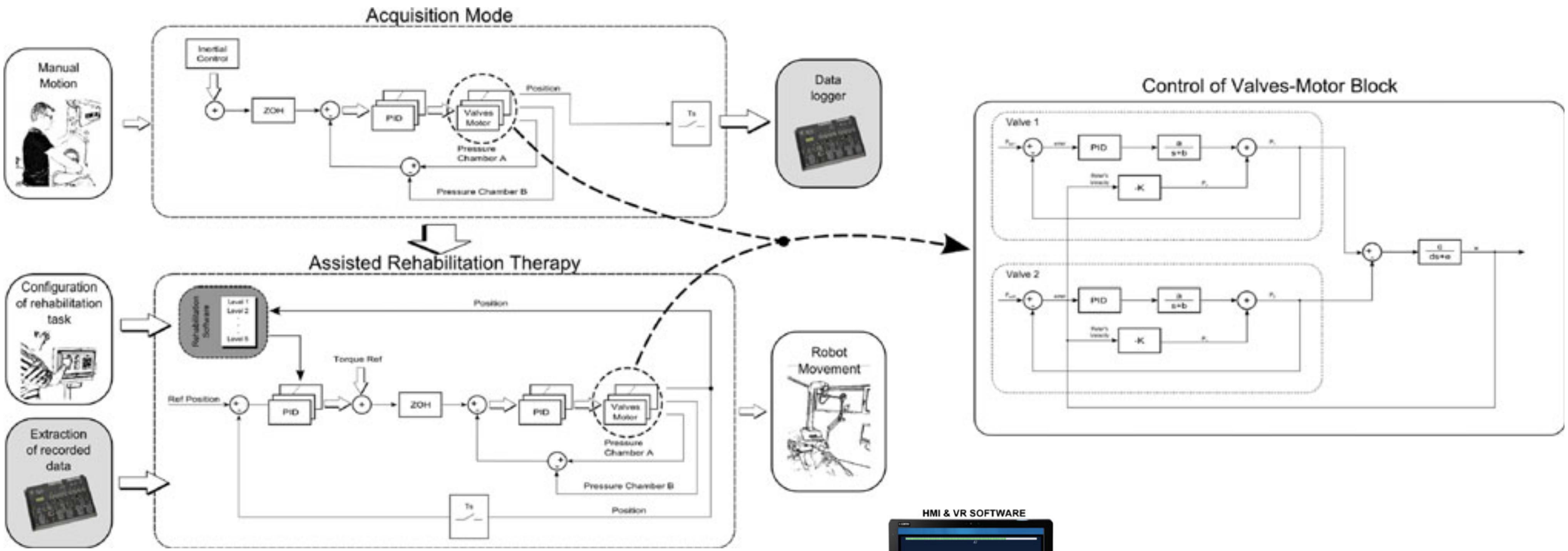


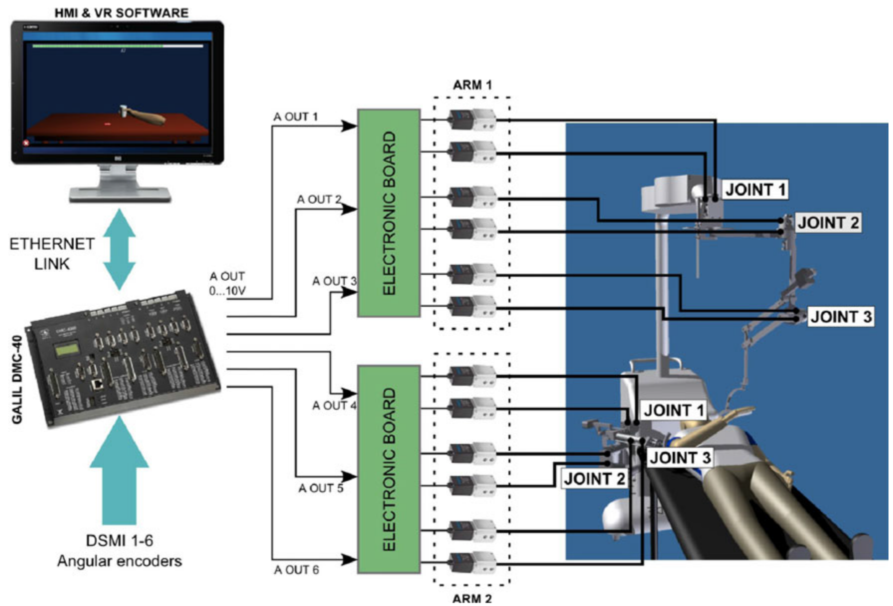
System development process

Why proportional pressure valves?? Proportional flow valves- Perturbation

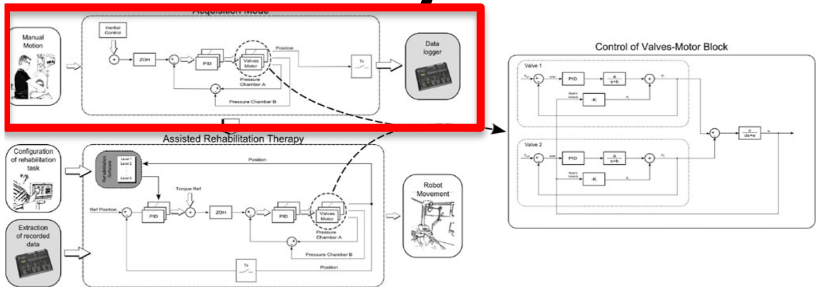


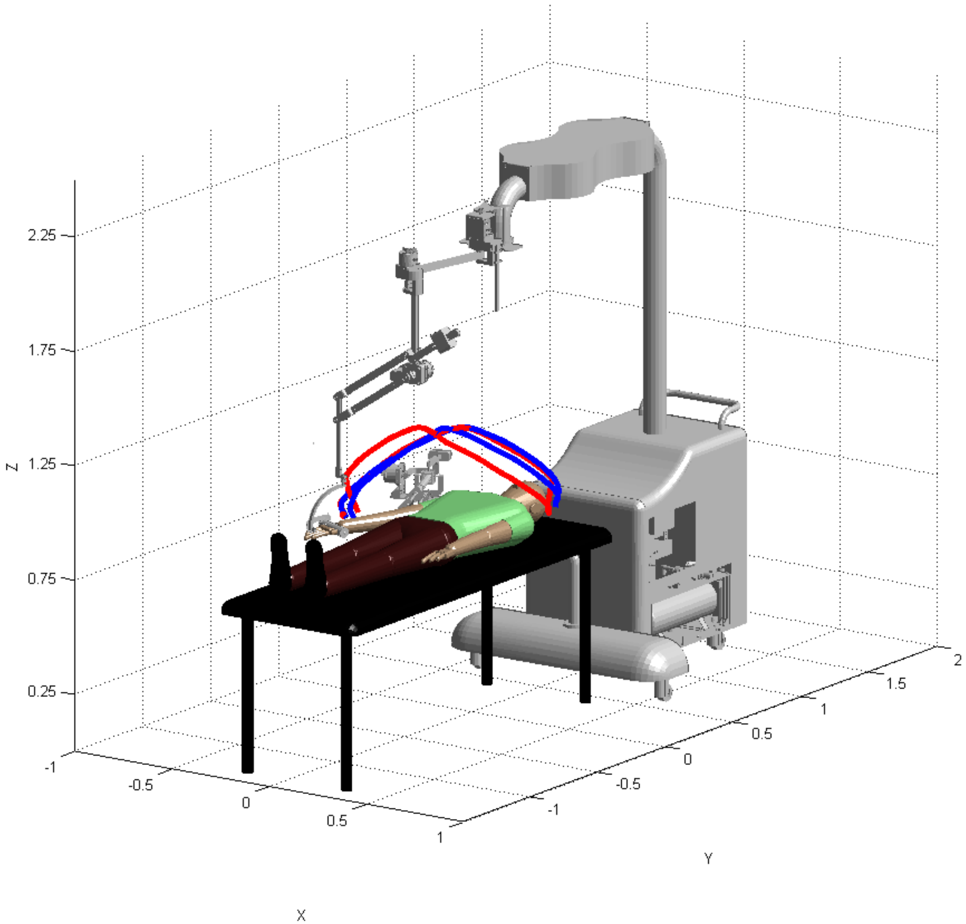
System development process

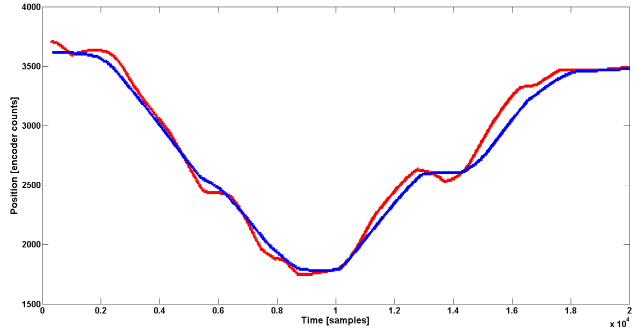


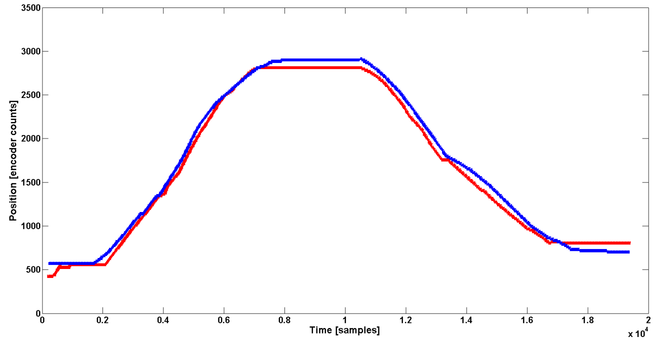


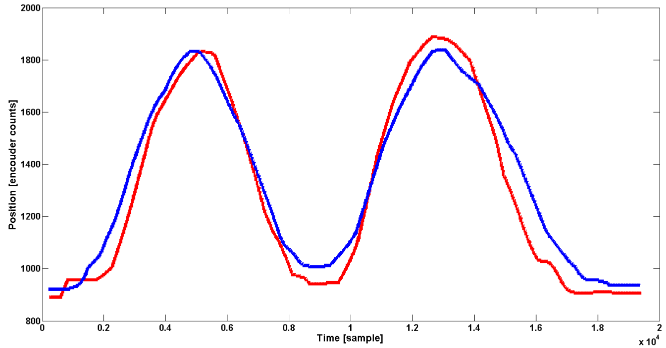
System development process







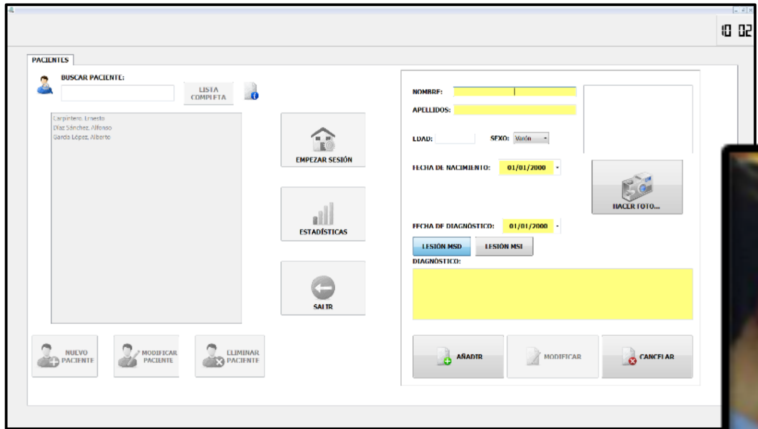


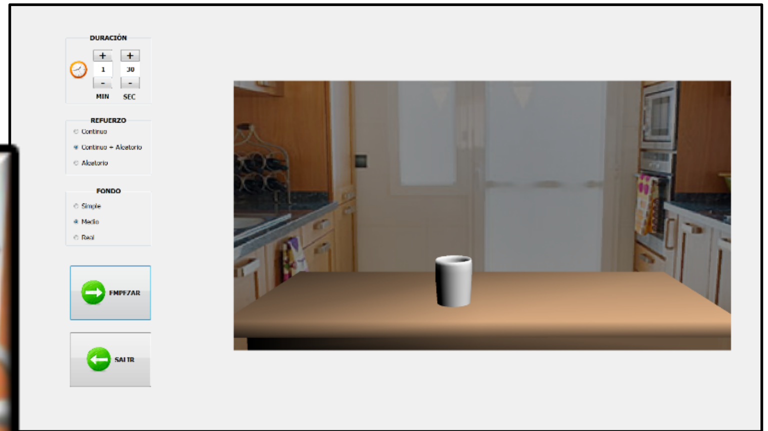


System development process

The virtual activities implemented on the control software for the rehabilitation robot can be classified as ADL and activities for therapies based on PNF.

- In the first phases of PNF therapy, where the patient is fully assisted by the robot, the patient is motivated by his or her own image (like a mirror), through the use of an integrated webcam, to stimulate the mirror neurons. In the phase where the robot offers resistance, the software displays visual activities in coordination with the robots movement to motivate the patient. The start and end positions of the movement and the path of the movement are highlights to be made by the patient
- ADL: the patient is immersed in the virtual environment where he or she performs activities such as taking a glass from the table and drink or placing an object on the shelf.



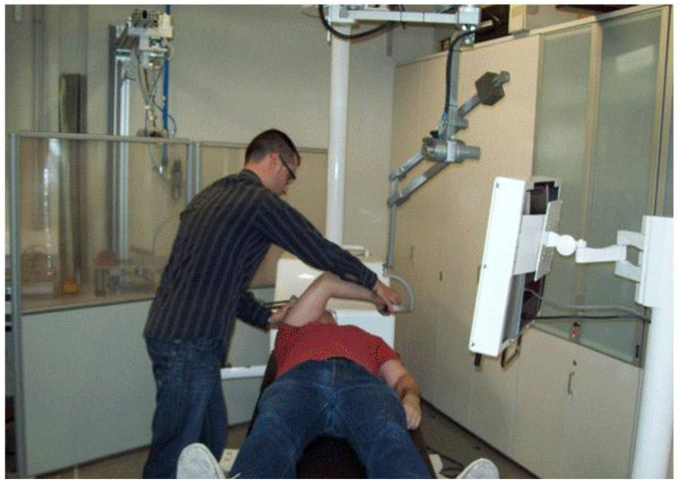


Example of design- UE Rehab Robot

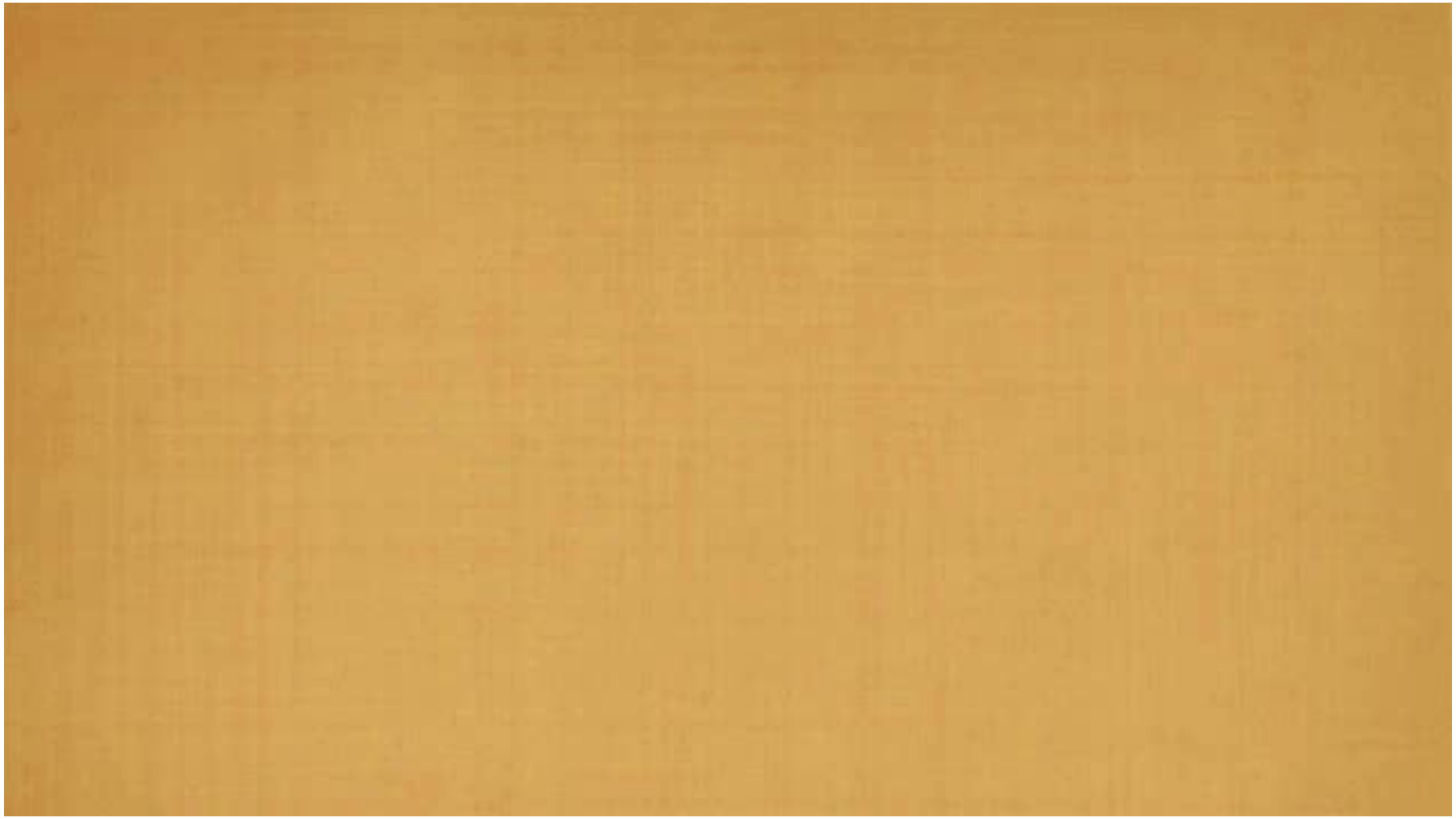
EXPERIMENTAL TESTS

R. Morales Vidal, F.J. Badesa, N. Garcia-Aracil, J.M. Sabater, C. Perez. "*Pneumatic robotic system for upper limb rehabilitation*". Medical and Biological Engineering and Computing, 2011, vol. 4, no.10, pp.1145-1156,2011, ISSN: 140-0118. Grupo B, segundo quintil (25/99) en la categoría COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS.

Experimental tests



Experimental tests



Example of design- UE Rehab Robot

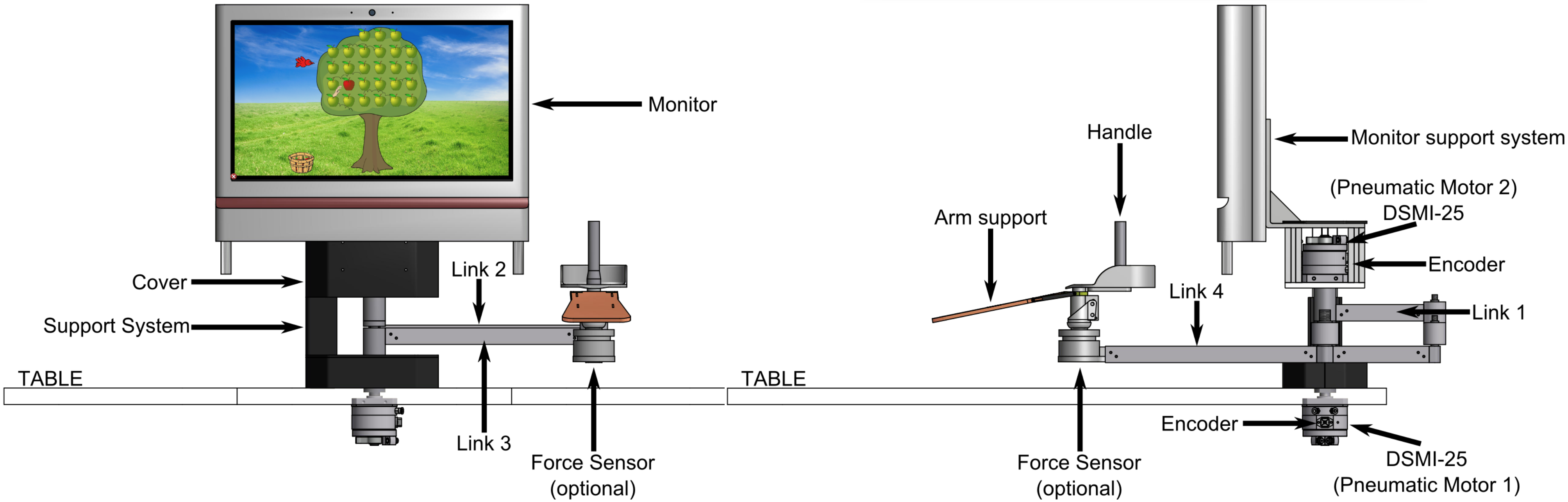
PUPARM

F. Javier Badesa, Ana Llinares, Ricardo Morales, Nicolas Garcia-Aracil, Jose M. Sabater, Carlos Perez-Vidal, **“Pneumatic planar rehabilitation robot for chronic stroke patients”**, Biomedical Engineering: Applications, Basis and Communications

PupArm

The pneumatic rehabilitation robot based on a four bar mechanism similar to the MIT-MANUS rehabilitation robot.

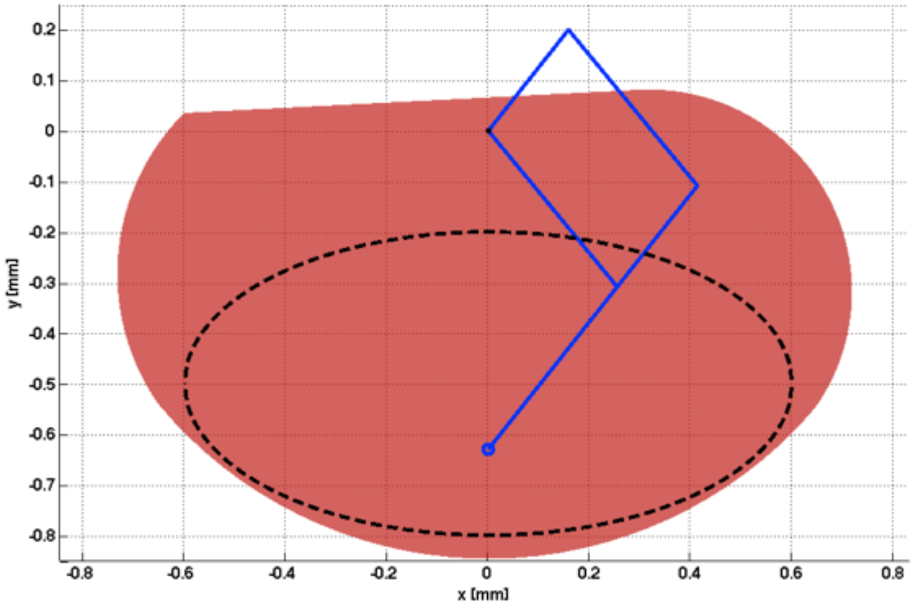
- The mechanism is configured as a generic planar two-dimensional manipulator



PupArm

The four bar mechanism has been designed using the information provided by a previous analysis of reaching activities and a simple model of human arm reachable workspace (ARW).

- The kinematic data of the human arm during different reaching tasks were collected using two wireless inertial measurement units (IMUs) attached to subject's arm and forearm.
- Using the simplified kinematic model of human arm and the information provided by the IMUs, 2D trajectories for each reaching task in the worst case were computed.
- The final conclusion of this analysis was that desired workspace that can be reached by an adult arm is an ellipse with its major and minor axis equal to 1200mm and 600 mm



PupArm

Dynamics analysis of the four bar mechanism: a right selection of link lengths produces the possibility of obtaining a configuration-independent and decoupled inertia matrix.

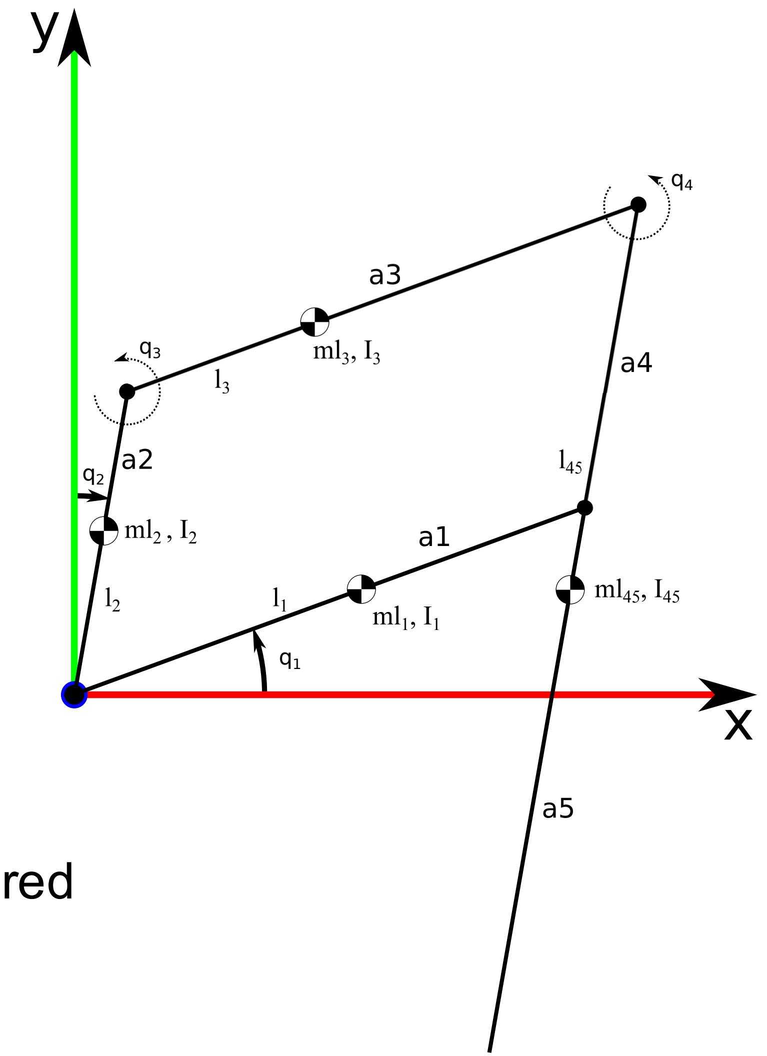
$$\boldsymbol{\tau} = \mathbf{B}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{C}(\mathbf{q}, \dot{\mathbf{q}})\dot{\mathbf{q}} + \mathbf{g}(\mathbf{q})$$

$$\mathbf{B}_a = \begin{bmatrix} b_{a11} & b_{a12} \\ b_{a21} & b_{a22} \end{bmatrix},$$ inertia matrix

$$\begin{aligned} b_{a11} &= I_{l_1} + I_{l_3} + m_{l_1} l_1^2 + m_{l_3} l_3^2 + m_{l_{45}} a_1^2, \\ b_{a12} &= b_{a21} = (a_1 m_{l_{45}} (l_{45} - a_2) \\ &\quad - a_2 l_3 m_{l_3}) \sin(q_1 + q_2), \\ b_{a22} &= I_{l_2} + I_{l_{45}} + m_{l_2} l_2^2 + m_{l_3} a_2^2 \\ &\quad + m_{l_{45}} (a_2^2 + l_{45}^2 - 2 a_2 l_{45}). \end{aligned}$$

$$\frac{m_{l_{45}} \bar{l}_{45}}{m_{l_3} l_3} = \frac{a_2}{a_1}, \longrightarrow (b_{a12} = b_{a21} = 0)$$

inertia matrix is diagonal

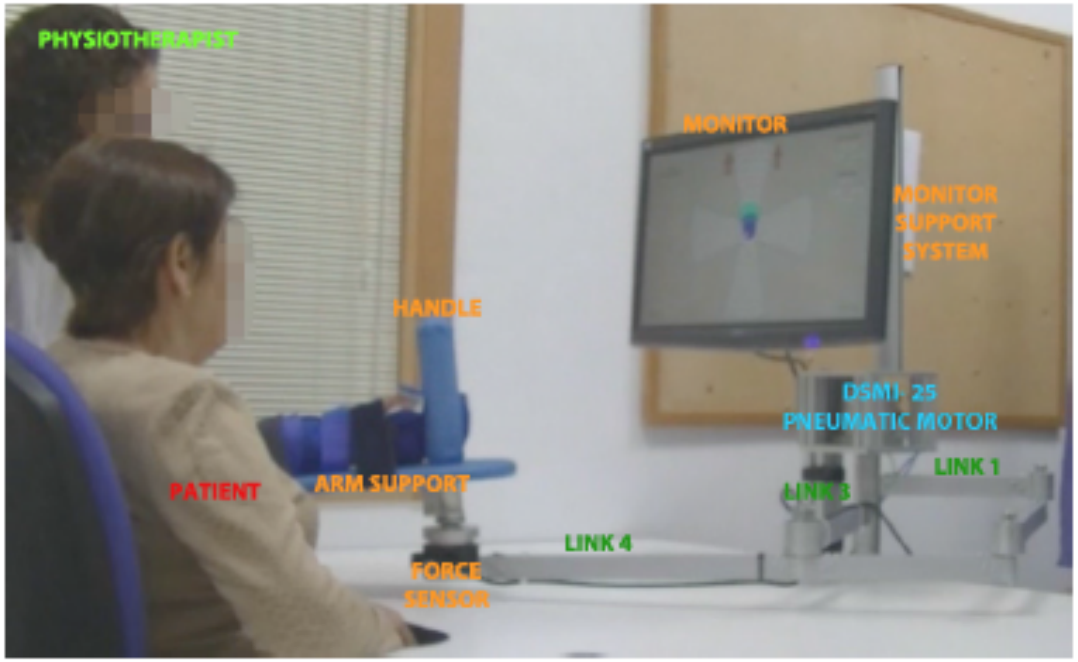


As a consequence the dynamic model can be considered decoupled from the control point of view

PupArm

An extensive clinical trial with post-stroke patients are being carried out at a dedicated room at Histology and Anatomy Department of Miguel Hernandez University of Elche. Two people were present: a patient and a specialized physiotherapist

The clinical study has the ultimate goal of determining the efficacy of upper extremity robot therapy (from now, robot group) compared to the classical therapy (from now, control group) in patients with hemiplegia secondary due to stroke.



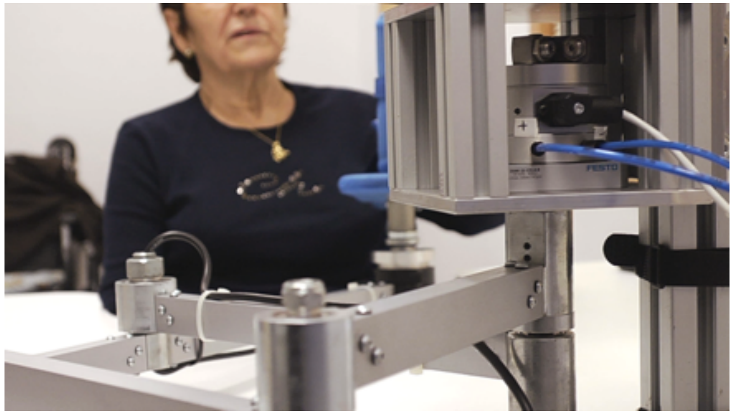
Over a three month period, both groups are receiving 36 sessions of robot-assisted or manual therapy plus 36 sessions of their classical therapy treatment.

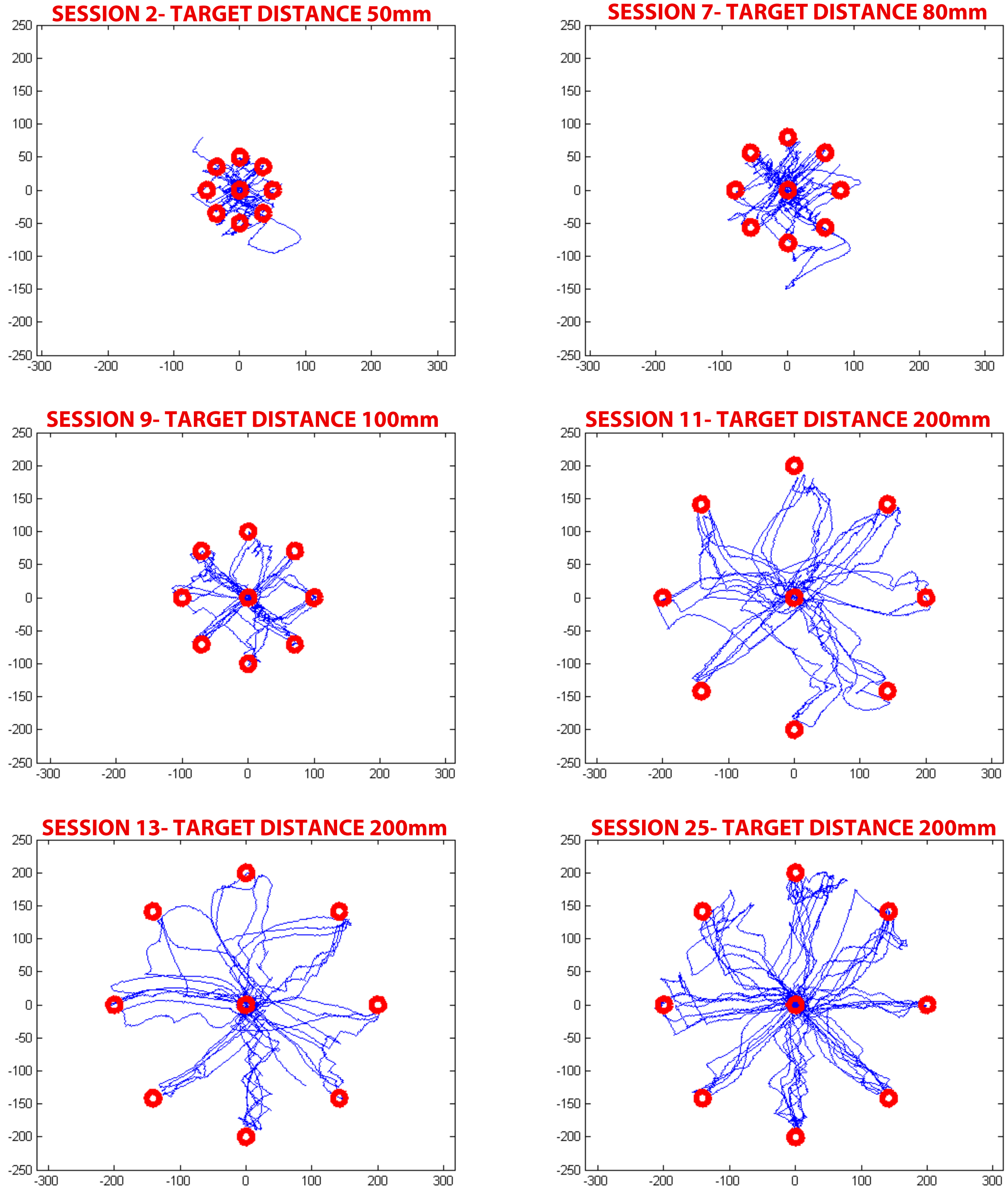
PupArm

Session 2

Session 10

PupArm



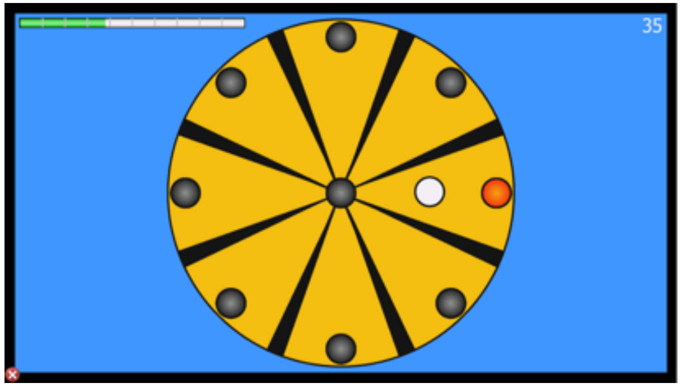

SESSION 2- TARGET DISTANCE 50mm
SESSION 7- TARGET DISTANCE 80mm
SESSION 9- TARGET DISTANCE 100mm
SESSION 11- TARGET DISTANCE 200mm
SESSION 13- TARGET DISTANCE 200mm
SESSION 25- TARGET DISTANCE 200mm

PupArm

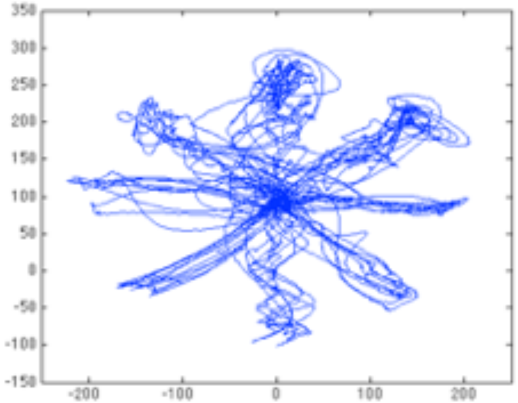
Session 1

Session 7

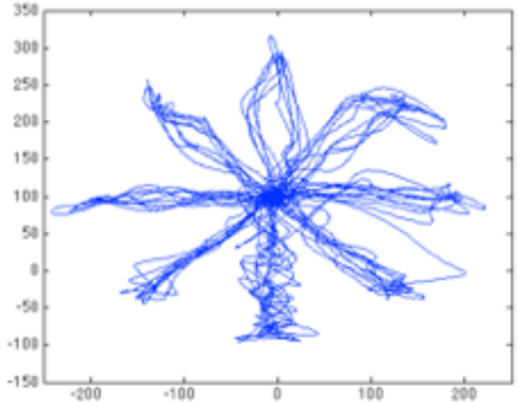
PupArm



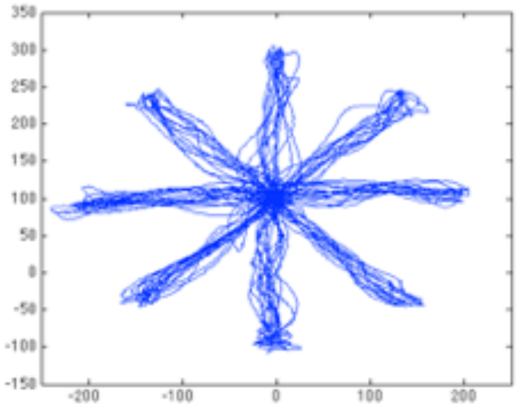
Session 3



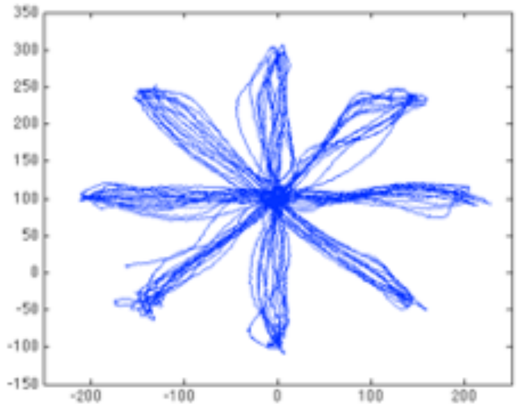
Session 12



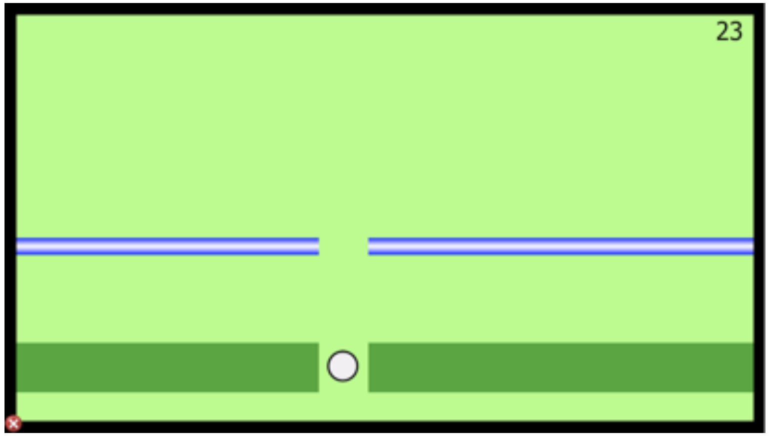
Session 22



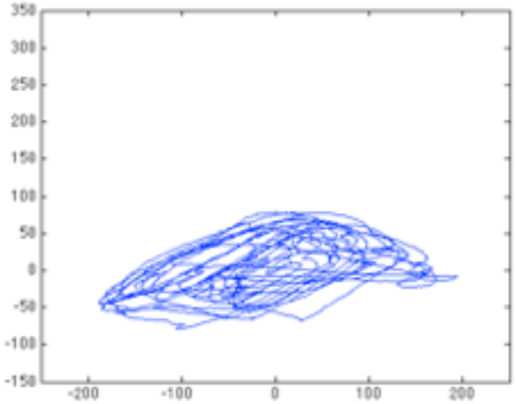
Session 36



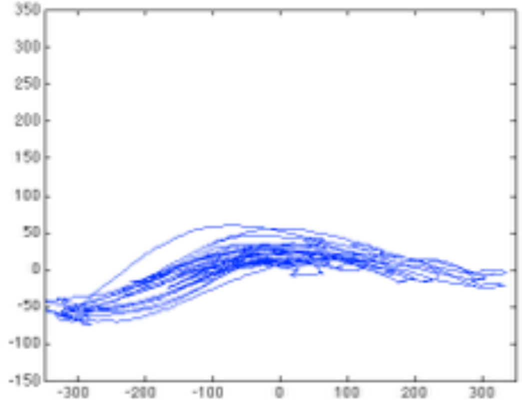
PupArm



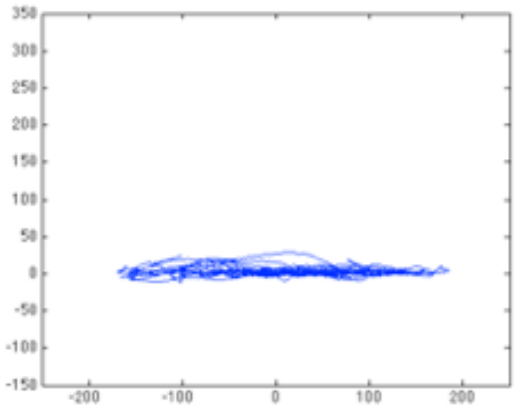
Session 3



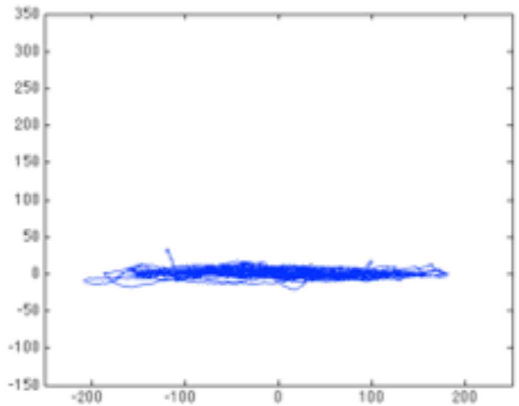
Session 12



Session 22



Session 36

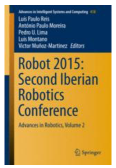


PupArm

PupArm

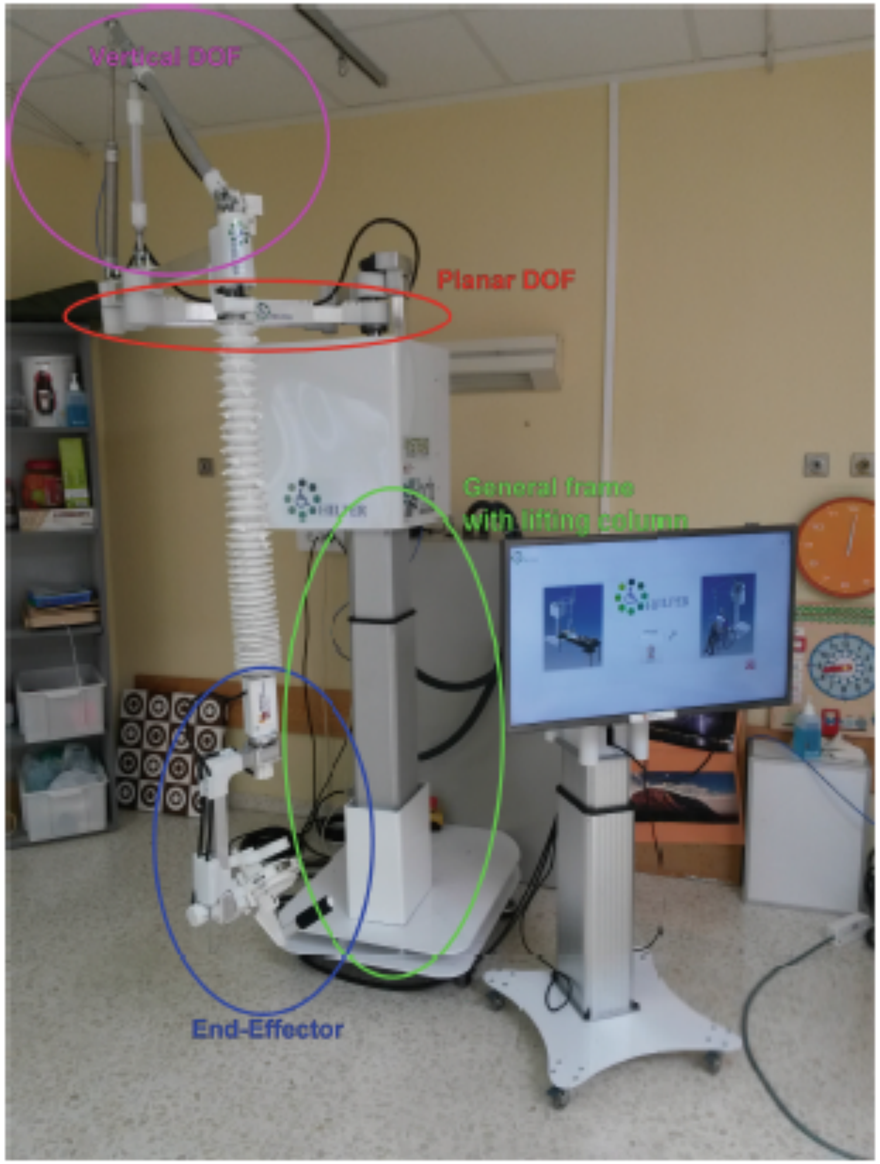
Example of design- UE Rehab Robot

HELPER

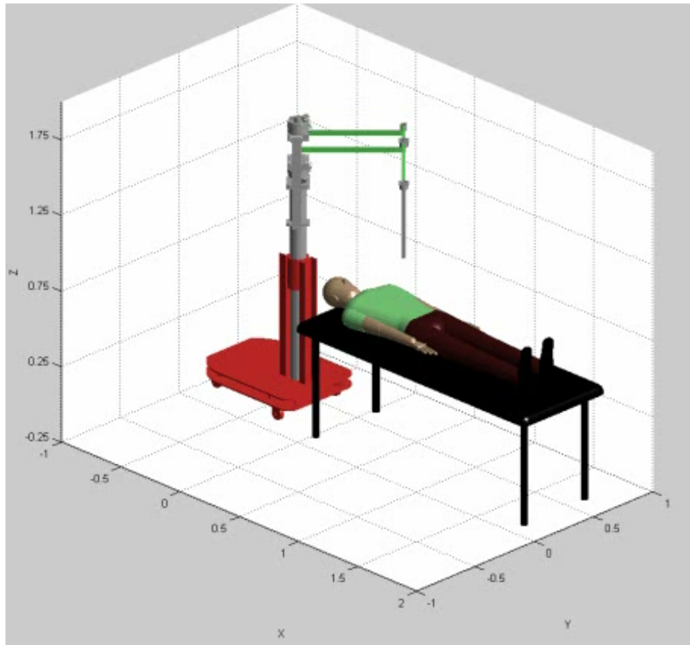


Díez J.A. et al. (2016) Design and Development of a Pneumatic Robot for Neurorehabilitation Therapies. In: Reis L., Moreira A., Lima P., Montano L., Muñoz-Martinez V. (eds) Robot 2015: Second Iberian Robotics Conference. Advances in Intelligent Systems and Computing, vol 418. Springer, Cham

Helper



The device which is being designed must have 6 DOFs in all: 3 of them will be active so the robot can position the patient's wrist inside its workspace, and the 3 remaining will be passive to allow the upper limb to orientate freely.



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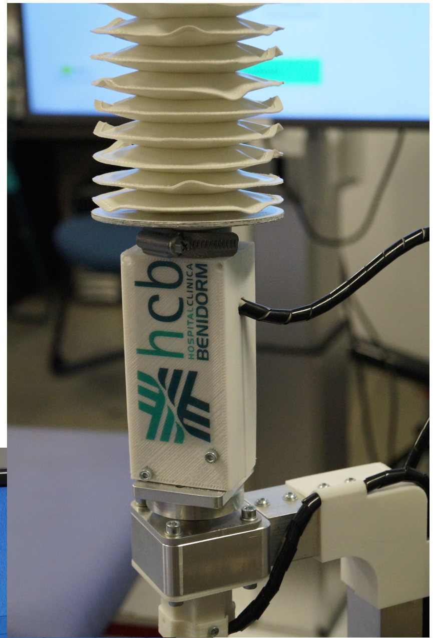

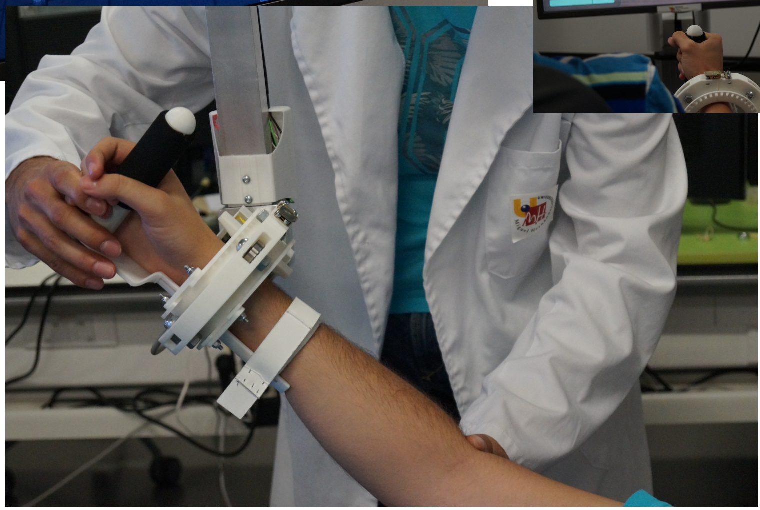

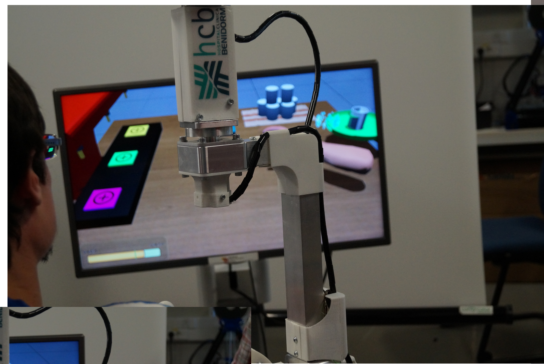

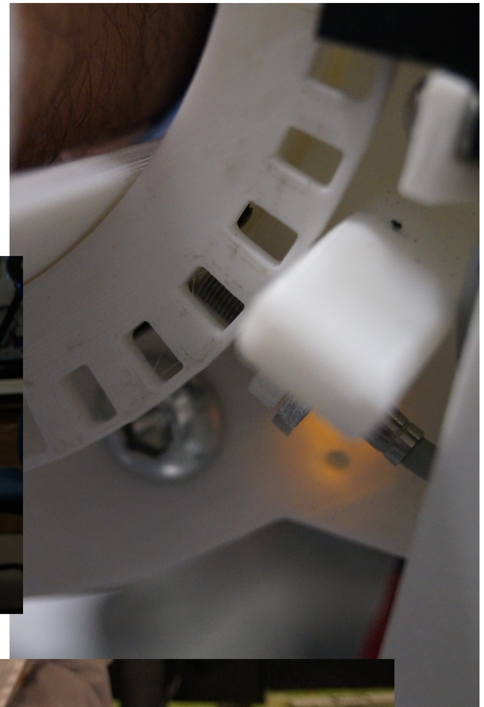

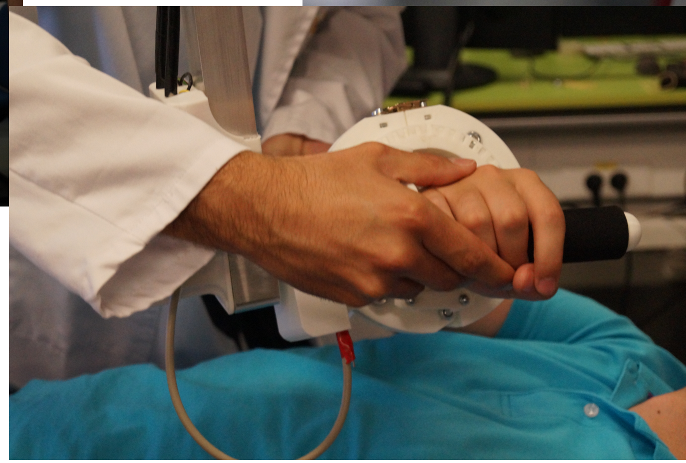

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