Critical Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Robotics

Experimental platform: Robotic Hand Platform

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Universitat Politècnica de València

This document is the Critical Design Review of the technical competence ‘Robotics’. It details the complete design of the robotic hand platform.

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Visit https://misceproject.eu/ for more information.

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1 Introduction

1.1 Scope

This document presents the detailed design of the robotic hand platform developed in the framework of the MISCE project.

The final objective is to use the developed platform in the practical lectures of engineering degrees to contribute to the technical competence:

C1. Robotics

which related skills are (see Table I):

Table I. Skills of Robotics

S1.1.	To know the different robotic architectures and their main features/applications
S1.2.	To understand the main parameters of robotics system
S1.3.	To understand the inverse kinematic and robot trajectories
S1.4.	To be able to program the robot behaviour
S1.5.	To know security rules to a safety operation

1.2 Preliminary definition

This experimental platform has been developed for teaching purposes, with the objective of improving the acquisition of technical skills related to the 'Robotics' competence. It consists of a five-finger robotic hand with a total of six degrees of freedom, mounted on a custom-designed 3D-printed palm structure. Each finger is actuated by a small electric linear actuator that enables flexion and extension, while the opposable thumb integrates an additional degree of freedom for rotation, implemented with a servomotor (see Figure 1).

The mechanical design includes linkage-based mechanisms (four-bar systems) to convert linear motion into realistic finger movements. The fingers are constructed with laser-cut steel sheets for structural rigidity, while the palm and other support elements are made of PLA using additive manufacturing techniques.

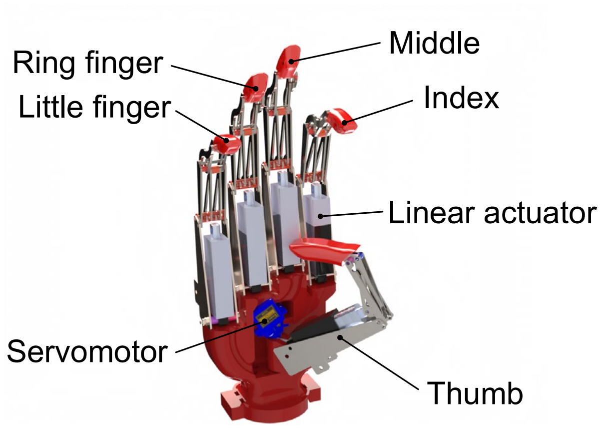

Figure 1. Robotic hand platform

The main advantage of this educational platform is that it introduces key robotics concepts—such as robotic kinematics, actuator control, and behaviour programming—through a compact, hands-on system. It also provides a realistic example of robotic manipulation, including basic grasping actions, which enhances students' understanding of practical robotics applications.

The main limitation is that the platform focuses solely on finger kinematics and does not include mobile or full-arm robotic elements, which may be required for more advanced training scenarios.

1.3 Technical requirements

The technical requirements listed below are defined to ensure that the robotic hand platform efficiently contributes to the acquisition of the skills described in Table I. These requirements aim to promote student understanding of robotic system architecture, motion control, kinematics, programming and safe interaction.

R1. The platform shall allow the individual activation of each finger through the user interface, enabling basic programming of open/close movements.

R2. The platform shall implement pre-programmed coordinated gestures (e.g., grasping, pinching) involving multiple fingers, to illustrate robotic behaviour control.

R3. The thumb rotation shall be independently controlled via a servo motor, allowing students to study the concept of opposability and its role in grasping.

R4. The system shall allow the analysis of forward kinematics, relating the displacement of the actuators to the resulting angular position of the phalanges.

R5. The system shall be able to demonstrate simplified inverse kinematics by controlling the position of fingertips using known actuator displacements and comparing it with expected positions or task goals.

R6. The control software shall be fully accessible and modifiable by students to encourage experimentation with robot programming logic.

R7. The hardware design shall be modular and reproducible, so that students can assemble and test the platform themselves, reinforcing hardware-software integration.

R8. The graphical user interface shall allow intuitive interaction with the robot and include safety features (e.g., emergency stop, current limits).

2 Hardware design

2.1 Functional parts

The hardware design of the robotic hand includes a set of functional components that are easy to acquire and assemble by teaching staff or students. The selected parts are listed below:

- Linear actuators (x5): Miniature 12V DC linear actuators with a 15 mm stroke, used to actuate each of the five fingers (four identical fingers + thumb flexion).

Figure 2. Linear electric actuators

- Servo motor (x1): Tower Pro MG90S micro servo used to rotate the thumb and enable opposable motion. This provides an extra degree of freedom.

Figure 3. Servo motor

- Arduino Mega 2560 board: The main microcontroller that handles the digital control of all actuators and interfaces with the user application.

Figure 4. Arduino Mega 2560 rev 3

- Relay modules (3x 4-channel SPDT): Used to switch polarity and control the direction of the linear actuators (each actuator requires two relays for forward/reverse motion).

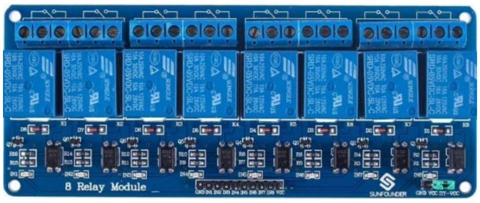

Figure 5. Relay module

- Power supply (12V / 5A): External power source used to drive the actuators independently from the logic circuitry.

Figure 6. Generic external power supply 12V (up to 5A)

- Additional elements: This item includes 3D-printed structural parts, cables, connectors, screws, … see Mounting Instruction document for more details.

With these functional elements the hardware architecture of the device is shown in Figure 7.

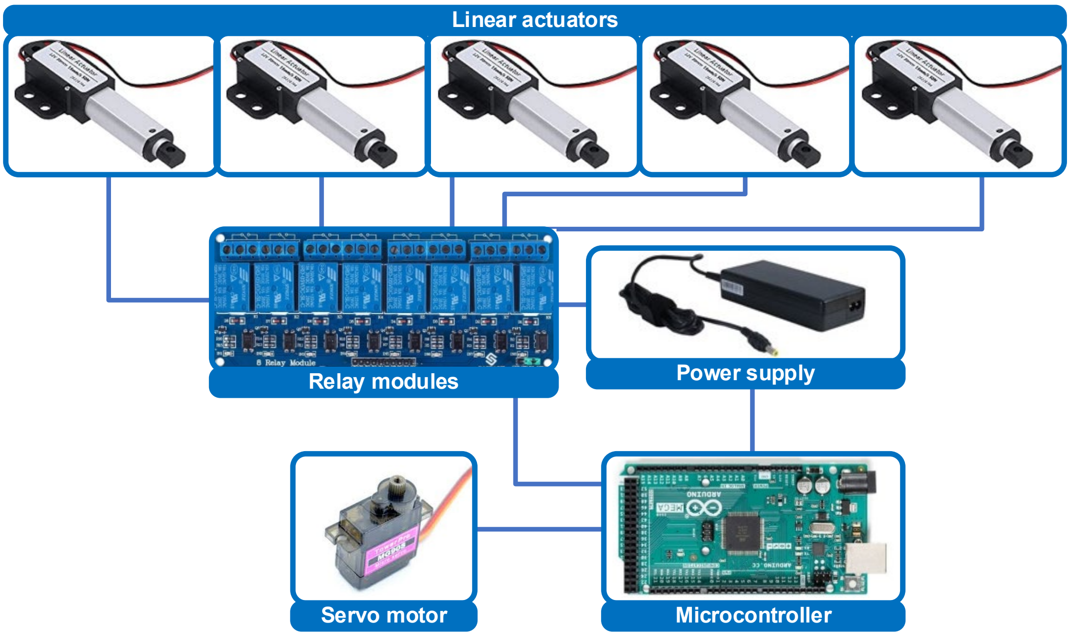

Figure 7. Hardware architecture of the experimental platform

2.2 Mechanical design

The mechanical design of the platform has been developed to ensure easy reproduction and use in educational settings. The structure consists of a 3D-printed palm where five fingers are integrated: four identical ones and an opposable thumb.

Each finger has one degree of freedom that allows it to close using an electric linear actuator. The thumb includes a second degree of freedom enabled by a servomotor, which allows it to rotate and oppose the other fingers.

The overall layout of the components has been designed to allow for easy assembly and a compact structure. Most of the parts are manufactured using PLA and standard 3D printing, which simplifies fabrication and maintenance. The result is a functional and educational platform that can be used for programming exercises as well as for studying basic robotics concepts.

The mechanical design of the device has been carried out to be built by a conventional 3D printer. The platform includes all the necessary functional elements, making it a compact and ready-to-use experimental device. Figure 8 shows some renders illustrating the designed platform. The STL files to print the different parts can be downloaded at: www.misceproject.com

Figure 8. Hand platform rendering

The final aspect of the experimental platform is shown in Figure 9.

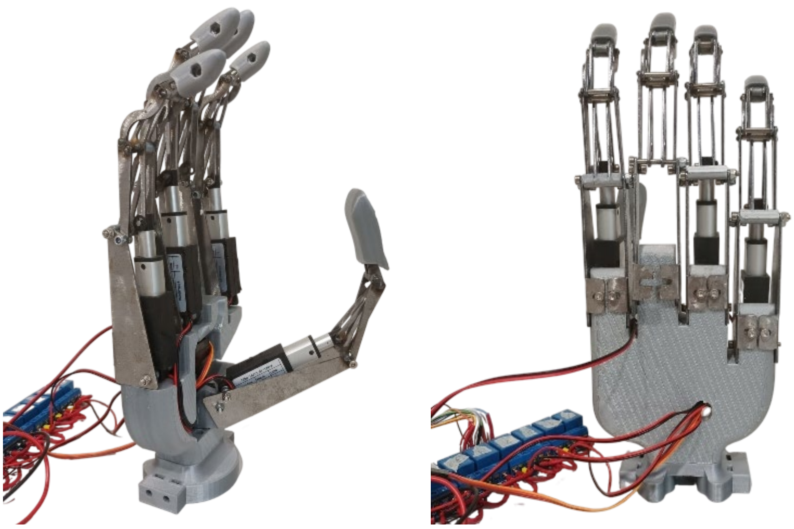

Figure 9. Experimental platform overview

3 Software design

3.1 Preliminaries

The software has been designed to be usable by any user (professors/students) without any licensable software requirements. In this way, the microcontroller Arduino Mega rev 3 has been programmed using its IDE (https://www.arduino.cc/en/software) and a front application has been designed using App Designer of MATLAB® https://es.mathworks.com/products/matlab/app-designer.html).

Both applications are communicated by means of a USB port, usually available in any desktop or laptop computer. Figure 10 illustrates the software architecture.

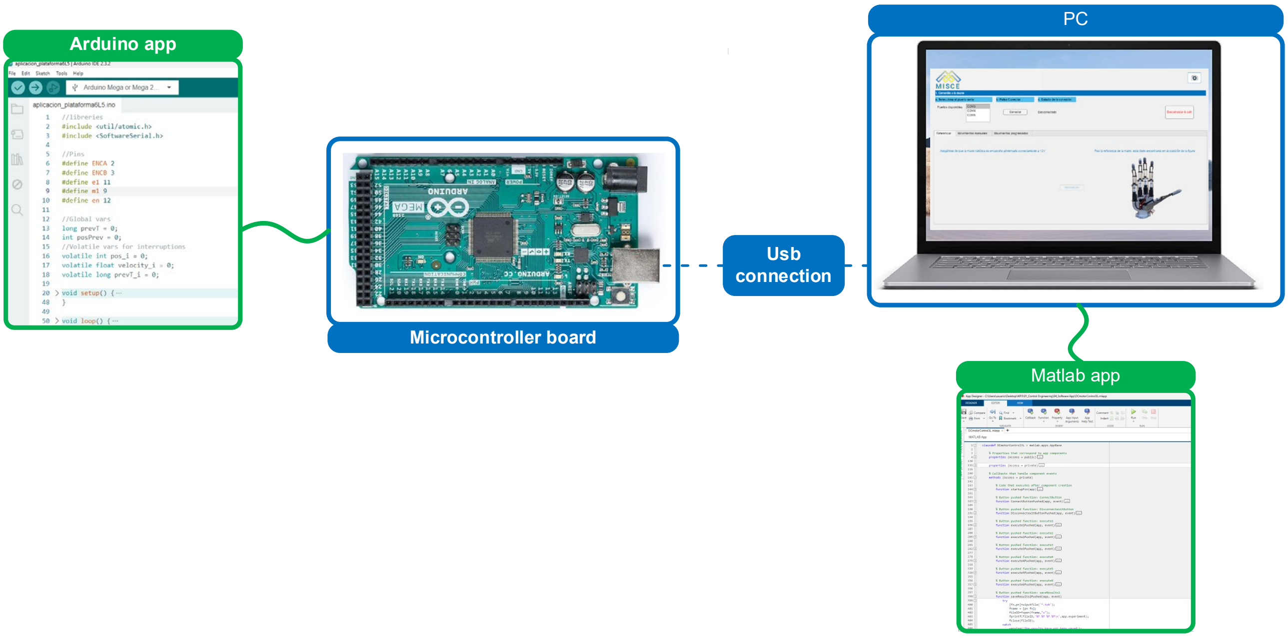

Figure 10. Software architecture of the experimental platform

The end-user only needs to download the Arduino program from MISCE project webpage and upload it into Arduino board and to install the MATLAB designed app.

3.2 App design (MATLAB®)

The code of the MATLAB® app and its corresponding installer file are available, under demand, in MISCE project webpage.

3.3 Software design (Arduino®)

The Arduino code is also available, under demand, in MISCE project webpage.