Critical Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Mechanical Engineering

Experimental platform: Four-bar mechanism

Workgroup: Universidad de Castilla-La Mancha

This document is the Critical Design Review of the technical competence 'Mechanical Engineering'. Its details the complete design of the four-bar mechanism 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 four-bar mechanism platform developed in the framework of MISCE project.

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

C6. Mechanical Engineering

which related skills are (see Table I):

Table I. Skills of Mechanical Engineering

S6.1.	To understand mechanism fundamentals
S6.2.	To be able to analyse and understand the kinematics of linkages
S6.3.	To be able to synthetize planar mechanism
S6.4.	To know how to model and simulate mechanisms
S6.5.	To be able to apply mechanisms as engineering solutions

1.2 Preliminary definition

This experimental platform has been widely analysed for teaching purposes in mechanical systems and kinematics (e.g. [1,2]). It consists of a four-bar linkage composed of four rigid links connected by rotary joints in a closed kinematic chain. One of the links is actuated by a DC-motor, enabling the study of motion transmission between input and output links (see Figure 1).

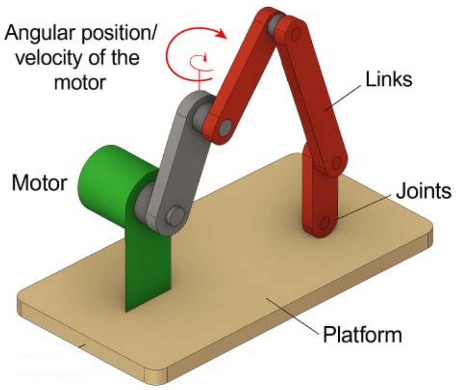

Figure 1. Four-bar mechanism platform

This proposal requires electronics and control systems capable of precisely driving the input link, typically by controlling the angular position or speed of the DC-motor. This enables students to visualize the resulting motion of the coupler and output links in real time.

The main advantage of this platform is that the four-bar mechanism is one of the most fundamental and extensively studied linkages in mechanism theory. It provides a clear and accessible way to introduce concepts such as energy transmission, force and torque distribution, and the influence of geometry on output motion. Its simplicity and versatility make it ideal for academic environments.

On the contrary, the main drawback is that, due to its planar and rigid structure, it may not capture more complex spatial or compliant behaviours found in advanced mechanical systems.

1.3 Technical requirements

The technical requirements to efficiently contribute to the achievement of skills of Table I are:

R1. The platform shall enable experimental analysis of the position, velocity, and acceleration of the nodes of a four-bar mechanism under various configurations, promoting understanding of planar kinematics.

R2. The system shall allow physical modification of the lengths of at least three of the four bars (coupler, rocker, fixed link), using slot-based mechanical systems, in order to study the influence of geometry on kinematic behaviour.

R3. The mechanism must be mounted on a rigid structural base (fixed link) that ensures a stable reference frame and supports revolute joints at points A and D (see Figure 2).

R4. The system shall permit analysis under multiple geometric configurations (e.g., crank-rocker, double-crank), enabling experimental validation of vector closure equations and trajectory properties.

R5. All mechanical components (links, joints, mounting supports) must be designed for quick assembly and adjustability, using modular 3D printed parts and standard fasteners.

R6. The mechanism shall integrate two high-resolution encoders (Hall and optical) placed at key nodes (D and A) to allow precise measurement of angular positions for validation of mechanical models.

R7. The platform shall fit within a maximum volume of 30 cm × 20 cm × 20 cm, supporting usage in academic laboratory environments with limited workspace.

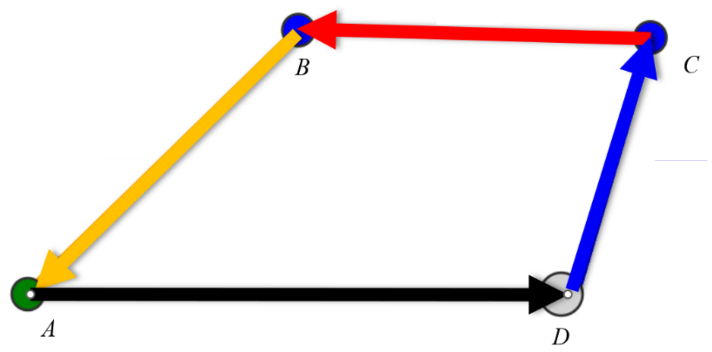

Figure 2. Four-bar mechanism nodes placement

2 Hardware design

2.1 Functional parts

The hardware design includes some functional parts that shall be easy to find and to acquire by the teaching professionals. In this case, the following functional elements have been selected:

- DC Motor/gearbox set 12V and gearbox ratio between 10 and 100 with 64 CPR hall encoder:

Figure 3. DC-motor/gearbox set

- Microcontroller ESP32-WROOM-32E:

Figure 4. ESP32-WROOM-32E

- BreakOutBoard FNK0091:

Figure 5. BreakOut board FNK0091

- Driver module L298N:

Figure 6. Driver module L298N

- Incremental optical encoder LPD3806-360BM:

Figure 7. LPD3806-360BM optical encoder

- External Power Supply 12V-5A:

Figure 8. Generic external power supply 12V (up to 5A)

- Additional elements: This item includes cables, connectors, screws, … see the Mounting Instruction document for more details.

With these functional elements the hardware architecture of the device is shown in Figure 9.

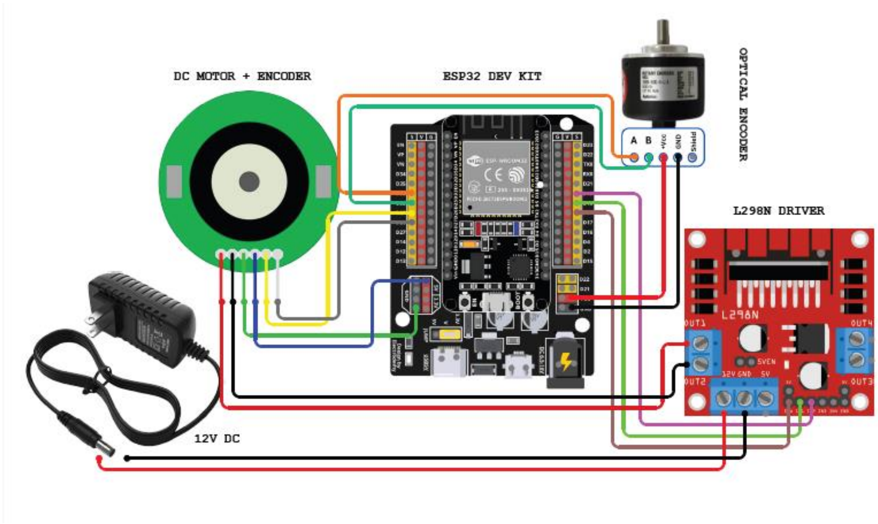

Figure 9. Hardware architecture of the experimental platform

2.2 Mechanical design

The mechanical design of the device has been carried out to be built by a conventional 3D printer. Apart from the 3D printable links of the mechanism, the platform where all is mounted includes the hardware elements aforementioned in the previous section. The design and placement of all the elements allow the experimental platform to be as compact as possible. Figure 10 shows some renders illustrating the designed experimental platform. The .STL files to print the different parts can be downloaded at: www.misceproject.com.

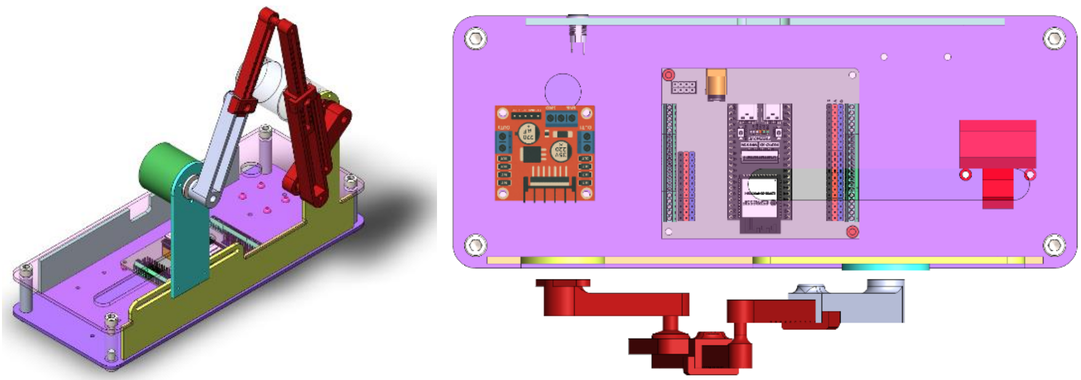

Figure 10. Four-bar mechanism platform renders

The final aspect of the experimental platform is shown in Figure 11.

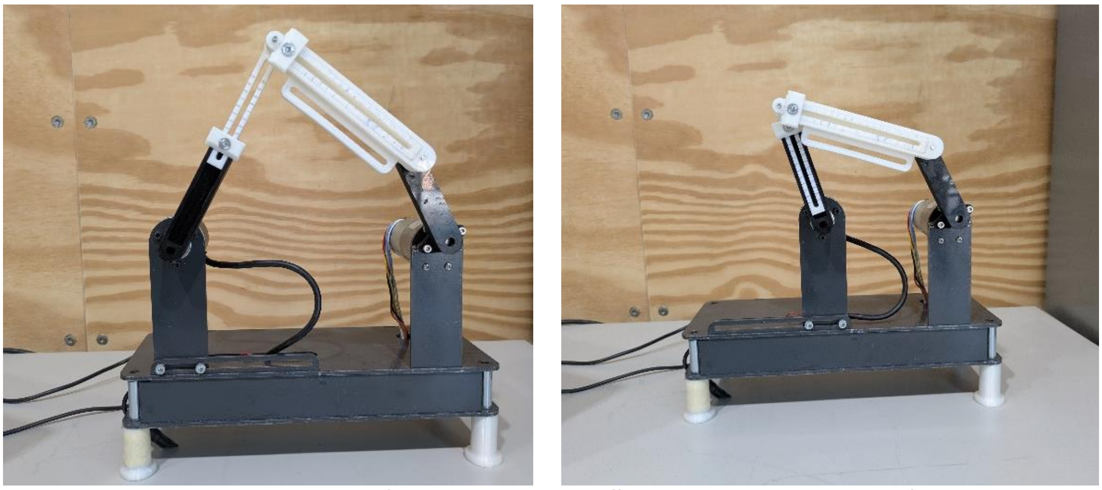

Figure 11. Experimental platform overview with different links lengths and configurations

3 Software design

3.1 Preliminaries

The software architecture developed for the four-bar mechanism platform is designed to facilitate experimental learning of planar mechanism kinematics and to be used by professors and students. The implementation is open and license-free: the embedded control is programmed in the Arduino IDE (https://www.arduino.cc/en/software) for the ESP32 microcontroller, while the graphical user interface (GUI) is developed in MATLAB® App Designer (https://es.mathworks.com/products/matlab/app-designer.html)., ensuring compatibility with commonly used academic tools.

Communication between the embedded system and the GUI is established via USB, which is usually available in any desktop or laptop computer. Figure 12 illustrates the software architecture.

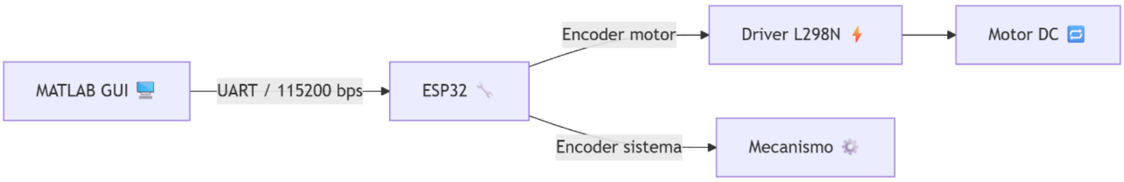

Figure 12. Software architecture of the experimental platform

The end-user of the device only has to download the ESP32 Program from MISCE project webpage and upload it into ESP32-WRROM-32E board and to install the Matlab designed app.

3.2 App design (Matlab®)

The MATLAB® application serves as the main user interface (HMI), enabling students to configure experiments and define input parameters, monitor real-time variables, such as position, velocity or acceleration, visualize and export results.

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

3.3 Embedded Software Design (ESP32/Arduino®)

The embedded control program running on the ESP32 is written in C++ using the Arduino IDE. The programming code is also available, under demand, in MISCE project webpage.

References

[1] Rodríguez-Molina, A., Villarreal-Cervantes, M. G., & Aldape-Pérez, M. (2018). Adaptive control for the four-bar linkage mechanism based on differential evolution. Proceedings of the 2018 International Conference on Robotics and Automation (pp. 31–37).

[2] Ghoghani, M. H., & Pham, V. V. (2024). Flexible modeling and dynamics simulation of four-bar beating-up mechanisms. Journal of Mechanical Sytems Dynamics.