Coupled Industrial Robotic System Arm

Zeina Hesham 52-12242, Seif Eldin Refaat 52-1389, Omar Samir 52-25832, Sarah El Shemy 52-4074, Yahia Mohamed 52-6681, Hazem Sherif 52-5272

In this milestone report, we document the development of a functional handling robot for a coupled industrial robotic system. The robot's primary function is to handle and transport cut pieces, including finished products and scrap materials, to optimize the production line workflow. A suction-based end effector was designed to perform these tasks effectively. The robot's design and functionality were analyzed and tested using CoppeliaSim, creating a digital twin based on a URDF model to enable accurate simulation and synchronization with the physical system. Key aspects such as hardware components, frame assignment, DH-Convention analysis, and simulation results are discussed, highlighting the steps taken to achieve efficient control and coordination within the robotic system.

• INTRODUCTION

This report centers on the design of a fully functional handling robot that operates within an industrial robotic system. Its primary task is to pick up and transport cut pieces from a production line. Using a suction-based end effector, the robot efficiently handles both finished products and scrap materials to optimize workflow. The robot's performance is simulated in CoppeliaSim, using a URDF model as a digital twin of the hardware. This digital twin allows for smooth integration and synchronization between the virtual simulation and the actual system, ensuring accurate control and coordination.

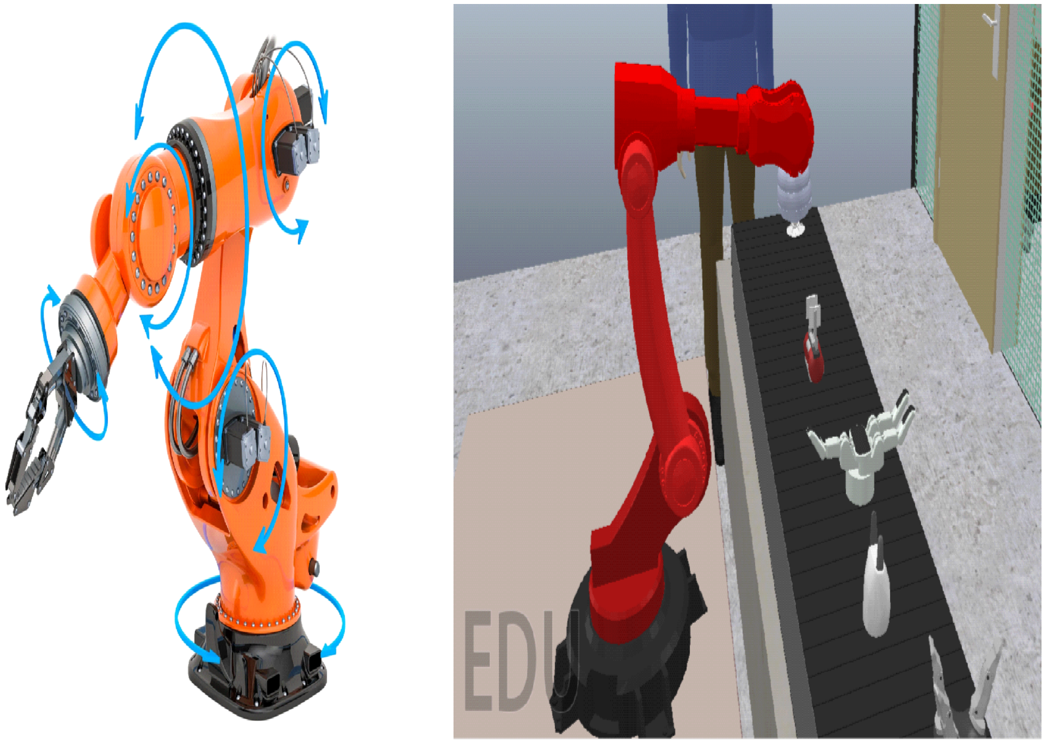


Fig. 1: Coupled Industrial Robotic Arm

In this paper we will cover many aspects of the robot built. In section I, we cover the hardware components used and the circuit diagram and design. Section II, the assignment of the robot's frame is going to be presented. Section III, is going to present the DH-convention analysis of the robot including the DH-Convention table and the DH- Convention Final Matrix. Then Finally we highlight and include the simulation results along with our conclusion and future recommendations.

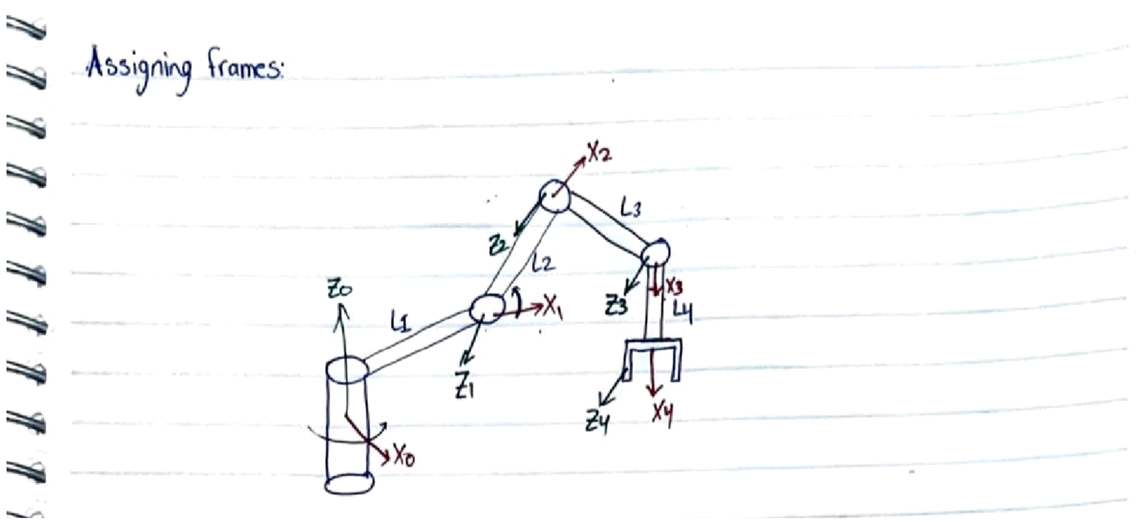
- TOPIC 01 (EX. Hardware Components and Circuit Design)

In our project, the hardware design of the handling robot incorporates key elements to enable precise and efficient material handling within an industrial setting. The robot features a 6-degree-of-freedom (DOF) arm, allowing for versatile movement and manipulation of cut pieces on the production line. Utilizing a suction-based end effector, the robot can securely grip and transport both finished products and scrap materials.

The robotic arm is powered by stepper motors, with each joint controlled through dedicated motor drivers to ensure precise articulation. To achieve smooth motion control, an Arduino microcontroller regulates the stepper motors, employing a Proportional-Integral-Derivative (PID) control strategy similar to that used in autonomous robotic arms. The PID controller enables accurate joint movement by minimizing error in the robot's positioning, providing the necessary precision for the handling tasks.

Table 1: Hardware Components Table

- TOPIC 02 (EX. ROBOT'S FRAME ASSIGNMENT)



- TOPIC 03 (EX. DH CONVENTION)

DH Convention:

Frames	θ_i	d_i	a_i	α_i
$0 \to 1$	q_1	$L_1 \sin\theta$	$L_1 \cos\theta$	$\frac{\pi}{2}$
$1 \to 2$	q_2	0	L_2	0
$2 \to 3$	q_3	0	L_3	0
$3 \to 4$	0	0	L_4	0

$$^{0}T_{1} = \begin{matrix} C_{q1} & 0 & S_{q1} & L_1 C_\theta C_{q1} \\ S_{q1} & 0 & -C_{q1} & L_1 C_\theta S_{q1} \\ 0 & 1 & 0 & L_1 S_\theta \\ 0 & 0 & 0 & 1 \end{matrix} \qquad ^{1}T_{2} = \begin{matrix} C_{q2} & -S_{q2} & 0 & L_2 C_{q2} \\ S_{q2} & C_{q2} & 0 & L_2 S_{q2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$$

$$^{2}T_{3} = \begin{matrix} C_{q3} & -S_{q3} & 0 & L_3 C_{q3} \\ S_{q3} & C_{q3} & 0 & L_3 S_{q3} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix} \qquad ^{3}T_{4} = \begin{matrix} 1 & 0 & 0 & L_4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$$

Table 2: DH- Parameters Table

q1	4sin(theta)	L1cos(theta)	pie/2
q1	0	L2	0
q3	0	L3	0
0	0	L4	0

- SIMULATION RESULTS

This section should include the simulation environment used to simulate the robot’s motion (Ex. MATLAB/Simulink), the robot’s parameters used (length, width, thickness of each link) and finally the simulation results with the figures and visualization response as well as the comments on each response.

- CONCLUSIONS AND FUTURE RECOMMENDATIONS

The milestone successfully demonstrated the feasibility of the handling robot within the coupled industrial robotic system, achieving efficient material transportation and workflow optimization through the integration of the digital twin. The simulation results confirmed the system's ability to maintain accurate control and coordination, validating the design choices for hardware components and the end effector. Future recommendations include refining the control algorithms to further enhance synchronization, expanding the robot's functionality to accommodate more complex tasks, and integrating additional sensors for improved feedback and precision. Further milestones will focus on these enhancements and the implementation of a fully functional robotic system in a real-world setting.

- APPENDIX

For any further or detailed analysis (if any).