# Kasdi Merbah University Ouargla

## Faculty of Applied Sciences

## Department of Mechanical Engineering

## Thesis

**ACADEMIC MASTER'S DEGREE**

**Field: Science and Technology**

**Major: Mechanical Engineering**

**Specialization: Mechanical Manufacturing and Production**
**Presented by: HOCINE TINAMRI**
**AND BENTABA ABDELAZIZ**
**Supervisor: Dr. mebarkiabdelyamin**

# STUDY AND MODLING OF INDESTIAL ROBOT

**Publicly defended on 11/06/2024 in front of the jury:**

| | | | |
|---|---|---|---|
| President | Rrwagdai abdelkrim | Professeur | UKM OUARGLA |
| Examiner | Hassine adale | M.C. A. | UKMOUARGLA |
| Reviewer | Mbarki abdeyamine | M.C. A. | UKMOUARGLA |

**Academic year** : **2023/2024**

**Academic year:: 2023/2024**

# الإهداء

" بسم خالقي و ميسر أموري و عصمت أمري, لك الحمد و شكر و الامتنان"
بعد مسيرة دراسية دامت سنوات حملت في طياتها الكثير من الصعوبات و التعب ها أنا اليوم أقف على عتبة تخرجي أقطف ثمار تعبي و أرفع قبعتي بكل فخر و أمتنان فالحمد لله حبا و
. شكرا
إلى من كلله الله بالهبة و الوقار .... إلى الذي أحمل أسمه بكل فخر سندي في هذه الحياة و مصدر الأمان الذي استمد منه قوتي .... الذي علمني أن دنيا كفاح و غرس فيا مكارم الأخلاق
" " أبي الغالي
لمن جعل الله جنة تحت أقدمها ... و احتضنني قلبها قبل يدها و سهلت لي شدائد بدعائها ...
" إلى الشمعة المضيئة في الليالي المظلمة سر قوتي و نجاحي "أمي حبيبة
إلى عزي و عزوتي .. الداعمين و الساندين .. أرضي الصلبة و جدار المتين إلى من شددت
" عضدي بهم "أخواتي كل باسمه و أختي
. إلى سنافر و براعم البيت و مرحه أبناء و بنات أخواتي حفظهم الله و رعاهم
ولا أنسى رفقاء الروح اللذين شاركوني خطوات هذا الطريق إلى من شجعوني على المثابرة و
. إكمال المسيرة إلى "رفقاء السنين " ممتنة لكم جميعا

ايظا اتقدم بكلمة لأخوتي الى من كللهم الله بالهيبة والوقار الى من علمانني العطاء بدون انتظار ستبقا كلماتهم نجوما اهتدي بها اليوم والغد و الى الأبد ( أيمن نصير ، كرم الدين باراك
) رحمهم الله وغفر لهم وأسكنهم فسيح جناته

الطالب : تينعمري حسين .

# شكر وتقدير

أحمد الله تعالى وأشكره بتوفيقة لي على إتمام هذا العمل، وأصلي وأسلم على أشرف الأنبياء والمرسلين وعلى آله وصحبه أجمعين

عن أبي هريرة عن النبي صلى الله عليه وسلم قال: " لا يشكر الله من لا يشكر الناس. " وإقتداء بهذا الهدي النبوي أتوجه بخالص الشكر والتقدير والعرفان إلى والدي حفضهما لي الله ورعاهما، زرعوا التفاؤل في دربي، وقدموا لي المساعدات والتسهيلات والأفكار والمعلومات، ربما دون أن يشعروا بدورهم بذلك لهم مني كل الشكر والتقدير .

لكل العائلة الكريمة التي ساندتني ولا تزال من إخوة وأخوات

إلى رفاقي في المشوار اللذين قاسمنني لحظاته رعاهم الله ووفقهم:

رضوان البوص ، نصر الدين حمادة ، حسين تينعمري ، هيشام غيلاني ، هشام بن لاغة ، لقمام بن ساسية ، صفي الدين النملي

ايظا اتقدم بكلمة لأخوتي الى من كللهم الله بالهيبة والوقار الى من علمانني العطاء بدون انتظار ستبقا كلماتهم نجوما اهتدي بها اليوم والغد و الى الأبد ( أيمن نصير ، كرم الدين باراك ) رحمهم الله وغفر لهم وأسكنهم فسيح جناته.

أتقدم بجزيل الشكر والامتنان إلى كل من أمدني بيد العون والمساعدة من قريب أو بعيد. إلى كل أساتذة وإداريين كلية العلوم االتطبيقية.

الطالب :بن طبة عبد العزيز.

# Remerciement

*THANKS FOR EVERYONE.*

# Table of Contents

## Chapter I : Different type of industrial robot

## Chapter II: Modeling of UR5 industrial robots

## Chapter III: Innovation and development of welding robot

# Liste of figures

# Liste of Table

# INTRODUCTION

## Introduction

The factory of the future envisions a highly integrated and automated industrial environment driven by the advances in artificial intelligence (AI) and robotics. The integration of AI into various industrial sectors is pivotal to achieving the goals of Industry 4.0, a paradigm shifts that focuses on modernizing production processes through the use of smart technologies. Industry 4.0 aims to revolutionize the manufacturing landscape by embedding sensors and advanced control systems into machines and equipment, facilitating real-time monitoring and control. However, this transformation faces numerous technological barriers that need to be overcome to ensure compatibility with complex AI algorithms.

Many current industrial practices rely on conventional machines that are not designed to handle the demands of modern production. These machines often struggle with manufacturing large parts or complex shapes, limiting their effectiveness in an Industry 4.0 environment. To address these limitations, the robotics sector has seen rapid development and diversification. Poly-articulated industrial robots, equipped with multiple degrees of freedom, offer a versatile solution capable of adapting to a wide range of tasks and environments. These robots can replace traditional machines, bringing flexibility and efficiency to industrial processes. By incorporating robots into the production line, industries can significantly reduce investment costs and enhance the production of large parts and intricate 3D geometries, thereby improving both technical and economic performance.[1]

One of the key advantages of industrial robots is their ability to be programmed offline. Offline programming allows for the evaluation of multiple scenarios before the actual construction of the automated cell. This method minimizes programming time and reduces the risk of errors typically associated with traditional learning methods. Robots can be programmed and simulated using advanced software without interrupting the production environment, ensuring continuous operation, and reducing down time.

Despite these advantages, the interaction between robots and their environment introduces challenges that must be addressed to ensure precision and quality. The geometric, static, and dynamic behaviour of robots is influenced by external forces during operation, leading to deformations in the robot's structure and joints. These deformations cause deviations in the end effector's trajectory, affecting the precision and quality of the final product. Compared to CNC machines, robots often face performance limitations in terms of task accuracy and product quality. These limitations are primarily due to discrepancies between the real robot and its CAD model, as well as inconsistencies in the inverse kinematic transformations used in robot control.

To overcome these challenges and enhance precision in industrial processes, optimization methods based on genetic algorithms can be employed. The goal is to correct deviations in the tool's trajectory by focusing on the precision of task execution rather than absolute positioning throughout the robot's workspace. This involves selecting the optimal position of the end effector within the workspace, ensuring accurate and efficient task performance.

This thesis is structured into three chapters, each addressing a specific aspect of the research:

- Types of Industrial Robots: The first chapter provides a comprehensive overview of the different types of industrial robots. It discusses their characteristics, applications, and evolution, highlighting the advancements and contributions of each type to industrial processes. This chapter also presents the specifications of various robots and examines the performance criteria outlined by the ISO 9283 standard.

- UR5 Robot and Simulation: The second chapter focuses on the UR5 robot, a widely used industrial robot known for its versatility and precision. It details the specifications and capabilities of the UR5 robot and explores its simulation using MATLAB. The chapter also covers the design aspects using SOLIDWORKS, demonstrating how these tools can be utilized to model, simulate, and analyse the robot's performance.

- Welding Path Simulation: The third chapter delves into the simulation of welding paths for industrial robots. It explains how to use MATLAB for calculating inverse kinematics and generating joint angle trajectories to ensure precise and efficient welding operations. The chapter emphasizes the importance of accurate trajectory tracking and discusses methods to optimize the welding process.

- Modelling a Pipe Welding Robot: The fourth chapter explores the modelling of a specialized robot for welding oil and gas pipelines and tanks. This chapter focuses on the unique requirements and challenges associated with such applications. It includes the design and simulation of the pipe welding robot in SOLIDWORKS, providing insights into the development and optimization of robotic systems for complex welding tasks.

- Conclusion and Future Work: The final chapter summarizes the findings and contributions of the research. It discusses the implications of the results and suggests areas for future research and development. The chapter highlights the potential for further enhancing the integration of robotics in industrial applications and outlines the steps needed to overcome remaining challenges.

In conclusion, the integration of AI and robotics into industrial processes is crucial for achieving the objectives of Industry 4.0. By addressing the technological barriers and optimizing robot performance, industries can enhance production efficiency, reduce costs, and improve product quality. This thesis aims to contribute to this vision by exploring the capabilities of industrial robots, particularly the UR5, and providing methodologies for optimizing their performance in various applications. Through detailed simulations and modelling, this research seeks to advance the understanding and implementation of robotic systems in modern manufacturing environments.

This introduction sets the stage for your thesis by outlining the significance of integrating AI and robotics in industry, the challenges faced, and the structure of the research.

# CHAPTER I

## 1.1. Introduction:

Our journey begins with fundamental definitions, carefully crafted to enhance memory retention. Subsequently, we delve into the intricate components that constitute a robot—its technological essence. The classification of robots follows, illuminating the diverse categories that populate this dynamic field. Finally, we conclude this chapter by exploring distinct characteristics documented in the vast expanse of robotic literature.[2]

## 1.2. Definitions:

The Robot Institute of America (1969) defines robot as a re-programmable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks‖.[3]

## 1.3. Types of robot tasks:

In the realm of robotics, various configurations emerge, each tailored to specific tasks and contexts. Let’s explore the primary types of robots:

**1-Articulâtes Robots** :

○ These versatile robots feature multiple rotary joints, resembling human arms. Their articulated structure allows them to manoeuvre in complex ways, making them ideal for assembly lines, welding, and intricate tasks.

○ Picture an articulated robot assembling intricate components on a car production line or delicately placing electronic chips onto a circuit board.[1]

**2-SCARA Robots (Sélective Compliance assemblé Robot Arm)**:

○ SCARA robots excel in precision assembly. Their design emphasizes speed and accuracy, making them indispensable in electronics manufacturing and pick-and-place operations.

○ Imagine a SCARA robot swiftly assembling tiny components on a smartphone assembly line.

**3-Delta Robots** :

○ Delta robots, with their parallel-link design, specialize in high-speed tasks. Theys Excel in packaging, storting, and handling délicate items.

○ Visualize a delta robot deftly picking candies from a conveyor belt and placing them into individual wrappers.

○ **[4]**These robots move along orthogonal axes (X, Y, and Z), akin to a 3D grid. They’re robust and precise, commonly found in CNC machining, material handling, and 3D printing.

○ Envision a gantry robot carving intricate patterns into wooden furniture or stacking bricks to construct a wall.

Now, let’s explore the autonomy spectrum:

**5- Repetitive Actions**:

○Some robots operate like clockwork, executing the same actions repeatedly. Their precision is unmatched, as they follow programmed routines meticulously.

○Consider a robot on an automotive assembly line consistently tightening bolts or welding seams with unwavering accuracy.

**6- Flexibility and Adaptability**:

○Other robots break free from rigidity. They adapt to varying orientations and tasks. These robots may need to identify objects or adjust their approach based on real-time feedback.

○For instance, a robot equipped with machine vision “eyes” scans a warehouse, identifying specific items for efficient inventory management.[1, 2]

**7-Artificiel Intelligence (AI)**:

○The modern industrial robot landscape embraces AI. Algorithms learn from data, enabling robots to make informed decisions. Whether it’s predictive maintenance or adaptive control, AI enhances efficiency.

○Imagine an AI-powered robot adjusting its welding parameters based on material variations or autonomously navigating a cluttered factory floor.

In this dynamic field, robots evolve—bridging the gap between precision engineering and intelligent autonomy.[2]

**8-Asimov’s laws of robotics**:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

## 1.4. components of the robot:

The mechanical component of an industrial robot includes precision-engineered joints and actuators, designed to provide seamless movement and positioning. These components undergo rigorous testing to ensure durability and reliability in demanding manufacturing environments. From robust linkages to specialized grippers, each part plays a crucial role in the robot's efficiency and performance. [4]

• **Mechanical platforms or hardware base:** is a mechanical device, such as a wheeled platform, arm, fixed frame or other construction, capable of interacting with its environment and any other mechanism involve with his capabilities and uses.

• **Sensors:** systems are a special feature that rest on or around the robot. This device would be able to provide judgment to the controller with relevant information about the environment and give useful feedback to the robot. [4]

• **Joints:** provide more versatility to the robot itself and are not just a point that connects two links or parts that can flex, rotate, revolve and translate. Joints play a very crucial role in the ability of the robot to move in different directions providing more degree of freedom.

• **Controller:** functions as the "brain" of the robot. Robots today have controllers that are run by programs - sets of instructions written in code. In other words, it is a computer used to command the robot memory and logic. So it, be able to work independently and automatically

• **Power Source:** is the main source of energy to fulfil all the robots needs. It could be a source of direct current as a battery, or alternate current from a power plant, solar energy, hydraulics or gas.

• **Artificial intelligence:** represents the ability of computers to "think" in ways similar to human beings. Present day "AI" does allow machines to mimic certain simple human thought component of the robot.[4, 5]

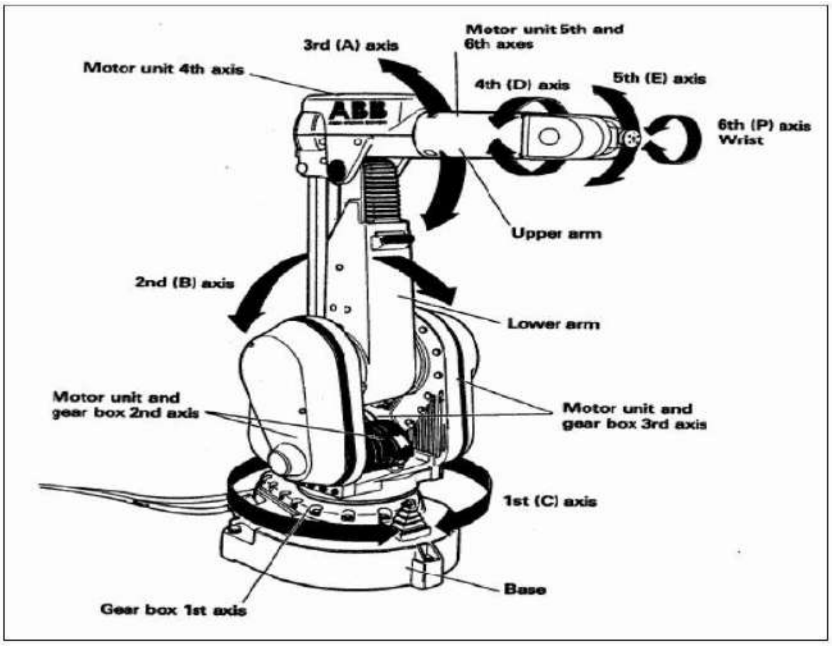


Figure1.1: components of robot.

## 1.5 The Articulâtes Mechanical Structure :

The **articulated mechanical system (AMS)** is a mechanism with a structure similar to that of the human arm. It is designed to either replace or extend the capabilities of the human arm. The AMS's primary function is to position the terminal organ (the end effector) in a specific location and orientation, adhering to predetermined speed and acceleration parameters. Its structure is a kinematic chain composed of rigid bodies linked by articulations known as joints. The system is powered by actuators—electric, pneumatic, or hydraulic—which drive the joints through suitable transmission systems.[5]

The mechanical structure of a robot can be categorized into three main components:

**The Vehicle**: This part is responsible for transporting the entire mechanical structure to the designated work area.

**The Bearer**: The bearer's task is to guide a specific point on the robot to a predetermined location in space. This involves the first three degrees of freedom, which define the robot's primary movements.[5]

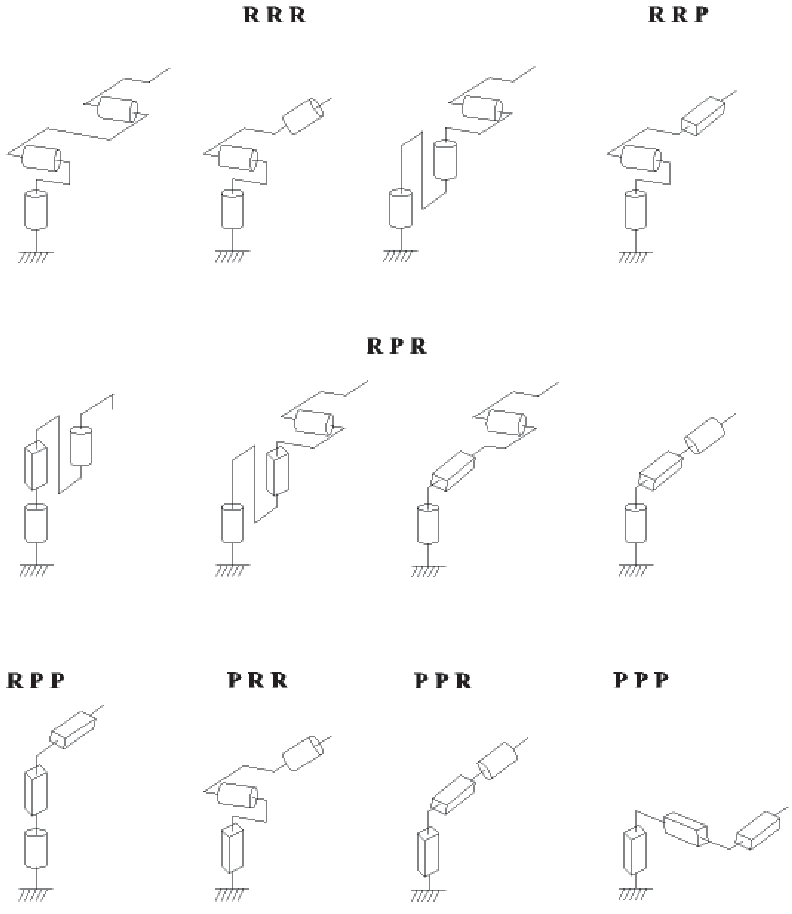


Figure1.2: robot articulated.

- **Articulated mechanical structure with simple drive chain:**

- An articulated mechanical system, or a kinematic chain, is one in which each member has a degree of connection—defined as the number of mechanical links—less than or equal to two. A serial robot consists of a simple kinematic chain. In this chain, both the base and the effector have a connection degree of one, meaning they are each connected to only a single body. The intermediate elements in the chain have a connection degree of tow.[5]

**Figure 1.3:** Structure serial.

- **Articulated mechanical structure with closed kinematic chain:**

In a kinematic chain, if a member—other than the base—has a connection degree greater than or equal to three, it is typically referred to as a complex joint. This means that the member is connected to three or more other members within the system.[5]

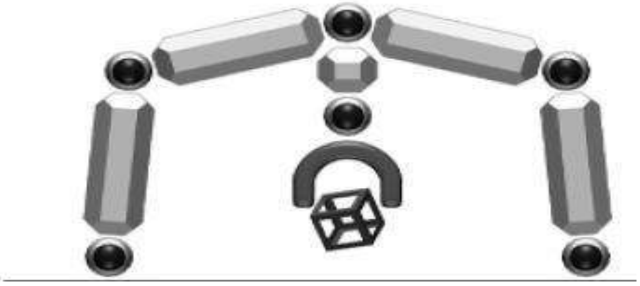


Figure1.4: Closed Structure.

## 1.6 Robot architecture:

- The base :

- The foundation of the manipulator is anchored in place at the work site, a standard setup for the vast majority of industrial robots.

The bearer represents the essential part of the articulated mechanical system, its role is to bring the terminal organ into a given situation imposed by the task (the situation of a body can be defined as the position and orientation of a mark attached to this body in relation to a reference mark). It is made up of:

- - Segment: rigid solid bodies likely to be in movement relative to the base of the bearer, and in relation to each other,

- - Joint: A joint links two successive bodies by limiting the number of degrees of freedom of one in relation to the other. Let m be the number of resulting degrees of freedom, also called mobility of the joint. The mobilité of a joint Is such That :

$$0 \leq m \leq 6$$

When m = 1, which is frequently the case in robotics, the joint is said to be simple: either rotoid or prismatic.

- Rotoid joint: This is a pivot type joint, noted R, reducing the movement between two bodies to a rotation around a common axis. The relative situation between the two bodies is given by the angle around this axis (see figure I.5).[5]

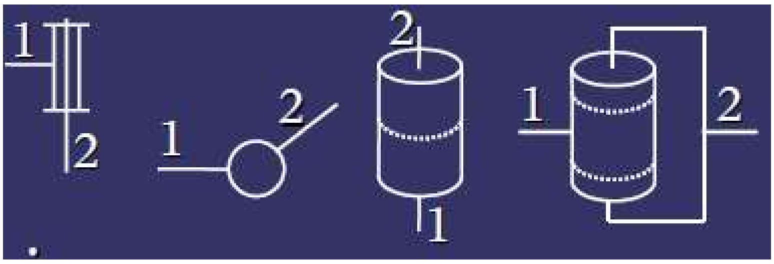


Figure 1.5: Representation of a revolute joint.

- Prismatic joint: This is a slide-type joint, denoted P, reducing the movement between two bodies to a translation along a common axis. The relative location between the two bodies is measured by the distance along this axis (see Figure I.6).[5]

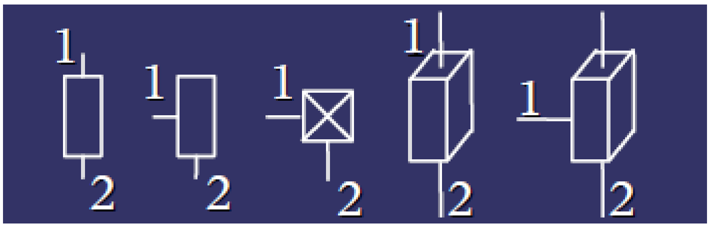


Figure I.6: Representation of a prismatic joint.

- **The actuation :**

To function, the articulated mechanical structure incorporates motors, which are typically coupled with transmission systems such as toothed belts. Together, these components form the actuators. Actuators commonly utilize **permanent magnet, DC, armature-driven electric motors**. The use of electronically commutated (brushless) motors is on the rise, and for smaller robots, stepper motors are often employed.[5]

For robots tasked with handling very heavy loads, such as mechanical excavators, the actuators are usually hydraulic. These hydraulic actuators operate either in a translational manner (using hydraulic cylinders) or in a rotational manner (using hydraulic motors).

Pneumatic actuators are widely used in cycle manipulators, also known as on-off robots. A cycle manipulator is an articulated mechanical structure with a limited number of degrees of freedom, which performs a series of movements. These movements are regulated solely by end-of-stroke sensors that are manually adjustable to achieve the desired range of motion. The positioning of servos can be challenging due to the compressibility of air.

## 1.7 The End Effecters:

. In our discussion of robot configuration, we motioned that can end effectors is usually attached to the robot’s wrist. The end effectors enable the robot to accomplish a specific task because there is wide variety of tasks performed by industrial robots. ϖ There are two types of end effectors are [6]

1. Tools

2. Grippers.

**Tool:**

• The robot is uses tool to perform processing operation on the work part.

• Example of the tool used as end effectors by robot to perform processing like spot welding, arc welding, drilling, routing, grinding, spray painting gun, assembly.

• In some application, the robot may use multiple tools during work cycle. Ex. - several sizes of routing or drilling bit must be applied to the work part.[6]

**GRIPPERS:** Gripper are the end effectors used to grasp and manipulate objects during the work cycle, machine loading and unloading application fall into this application.

θ According to variety of parts, shapes, sizes and weights most grippers must be custom designed. 13 There are many different types of gripper used in industrial for different used.

ϖ **Mechanical gripper**: It consists of two or more fingers that can be actuated by the robot controller to open and close to hold the work part.

ϖ **Vacuum gripper**: In these types of gripper suction cups are used to hold the flat objects. ϖ Magnetized devices: It is used for holding ferrous parts.

ϖ **Adhesive devices**: This is use an adhesive substance to hold a flexible material such as a fabric. ϖ Simple mechanical devices: Used as hooks and scoops.[1, 7]

ϖ **Dual gripper:**

1. It consists of two gripper devices in one end effectors for machine loading and unloading. With a single gripper the robot must reach into the production machine twice. But in dual gripper the robots pick up the next work part, while the machine is stilling processing the preceding part. 2. When the machine cycle is finished the robot reaches into the machine only once to remove the finished parts and load the next part. Thus reduce the cycle time per part. Interchangeable fingers:

- That can be used on one finger mechanism. To accommodate different parts different fingers are attached to the gripper. Sensory feedback:

- Sensory feedback in the finger that provides the gripper with capabilities such as: Tool:

1. Sensing the presence of the work part.

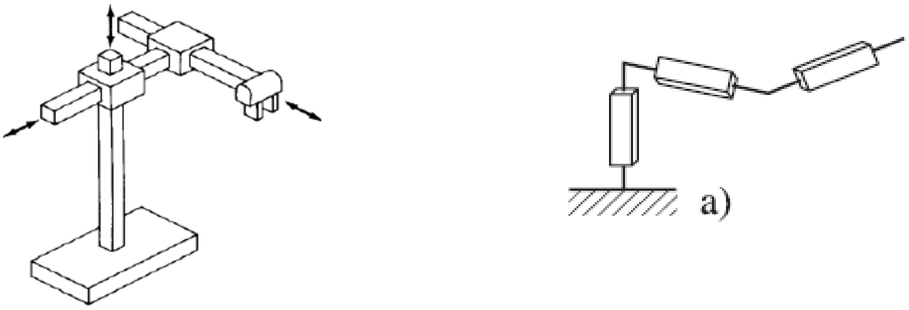
2. Applying a specified limit force to the work part during gripping.

## 1.8 Geometric classification:

Robots can be categorized based on their structural design, specifically the configuration of their supporting framework.[7, 8]

### Cartesian structure (PPP):

With three prismatic connections, it is the oldest, historically, it follows logically from the traditional design of a three-axis machine tool, such as a grinding machine or a milling machine for example. This structure is relatively little used, except in a few specific applications, practical robots, shopping robots, for example.[7]



Figuer1.7: 3DOF(PPP)

**Cylindrical coordinate arm configuration (RPP):**

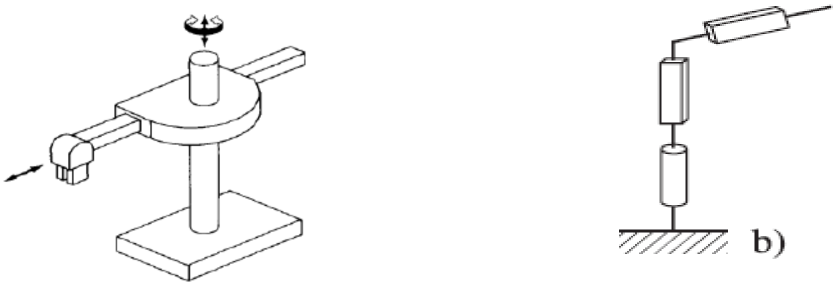


Figure1.8: 3 DOF cylindrical arm configuration

The cylindrical configuration uses two perpendicular prismatic joints and a revolute joint as shown in fig. This configuration uses a vertical column and a slide that can be moved up or down along the column. The robot arm is attached to the slide, so that it can be moved radially with respect to column. [5, 9]

By rotating the column, the robot is capable of achieving a workspace that approximates a cylinder. The cylindrical configuration offers good mechanical stiffness. Drawback: Accuracy decreases as the horizontal stroke increases. Applications: suitable to access narrow horizontal capabilities, hence used for machine loading operations. Exemple : GMF model M-1A.

## Robot SCARA:

robot (Selective compliance Assembly Robot Arm) Its full form is _Selective Compliance Assembly Robot Arm'. It is similar in construction to the jointed-arm robot, except the shoulder and elbow rotational axes are vertical. It means that the arm is very rigid in the vertical direction, but compliant in the horizontal direction.[8]

The SCARA body-and-arm configuration typically does not use a separate wrist assembly. Its usual operative environment is for insertion-type assembly operations where wrist joints are unnecessary. The other four body-and-arm configurations more-or-less follow the wrist-joint configuration by deploying various combinations of rotary joints viz. type R and

T.[8]

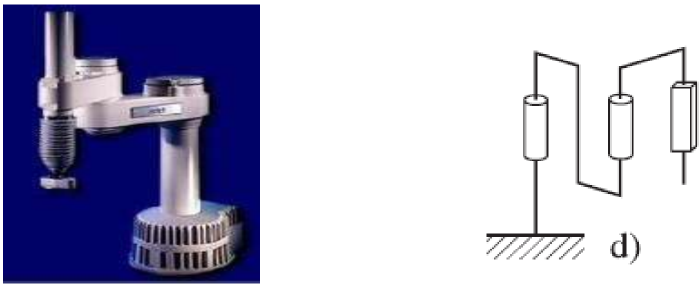


Figure1.9: Robot SCARA.

### Configuration (RRR) 3R:

2 From fig. jointed arm configurations are similar to that of human arm. It consists of two straight links, corresponding to human fore arm and upper arm with two rotary joint 11 corresponding to the elbow and shoulder joints. These two are mounted on a vertical rotary table corresponding to human waste joint. The work volume is spherical. This structure is the most dexterous one. This configuration is very widely used[5]

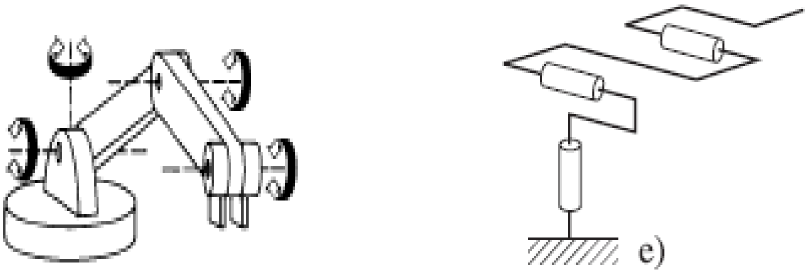


Figure1.10: Robot 3R.

## 1.9 Conclusion:

The framework of a manipulator robot consists of multiple elements linked together through connections known as joints, each allowing for a singular degree of freedom in either translation or rotation. This arrangement forms the basis of a straightforward, open-ended kinematic chain, branches out into a tree-like structure, or evolves into a more intricate chain.

# CHAPTER II

## 2.1 Introduction:

In the realm of robotics design and control, various mathematical models play crucial roles. Among these are the transformation models that bridge the operational space, defining the position of the end-effector, and the joint space, defining the configuration of the robot. These models can be classified into direct and inverse geometric models, which establish the relationship between the position of the end-effector and the joint variables of the robot, both in forward (direct) and backward (inverse) directions, and direct and inverse kinematic models, which relate the velocity of the end-effector to the velocities of the robot's joints, and vice versa, in both forward and inverse directions. In this chapter, we delve into various methodologies for deriving these models, focusing primarily on the UR5 robot, which features a simple open structure. We will explore the forward and inverse kinematic models, and dynamic models, essential for understanding the movement and control of the UR5. Additionally, we will discuss the design process using SOLIDWORKS and the simulation of the UR5 in MATLAB to validate the theoretical models and enhance practical understanding.

## UR5 industrial manipulator:

The UR5, developed by the Danish company Universal Robots, is a collaborative robot. It is part of a series that includes the smaller UR3 and the larger UR10. These robots are designed to work safely alongside human operators without the need for a protective cage. They have force sensors in their joints that allow them to stop when they encounter an object. Despite their safety features, it is essential to handle UR robots with care and follow proper precautions to avoid accidents. One notable specification from Universal Robots is the repeatability of 0.1 mm, which highlights the robot’s precision in returning to the same position consistently.[9] Additionally, we have a training session in CRTI Urfa in Setif.

Figure2. 1: UR5 Robot in CRTI URFA SETIF

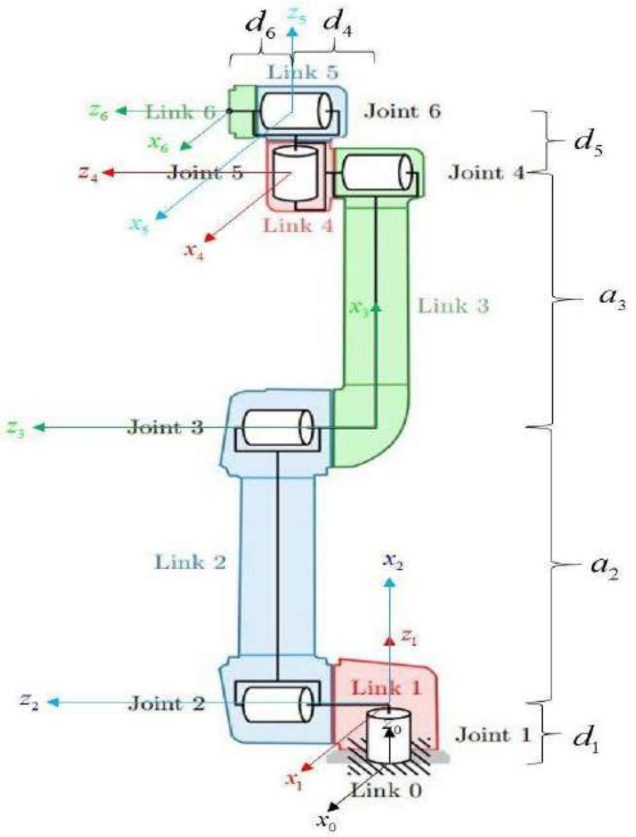
## 2.2 Technical specifications:

The robotic arm consists of six revolute joints. In this report these joints will be referred to as Base, Shoulder, Elbow, Wrist1, Wrist2 and Wrist3. The Shoulder and Elbow joint are rotating perpendicular to the Base joint. These three joints are connected with long links. The wrist joints control the Tool Centre Point (TCP) in the right orientation.[10, 11]

| | |
|---|---|
| **Weight** | 18.4 kg |
| **Payload** | 5 kg |
| **Reach** | 850 mm |
| **Joint ranges** | ± 360° |
| **Joint max speed** | 180 °/s |
| **TCP max speed** | 1 m/s |
| **Degree of freedom** | 6 rotating joints |
| **Repeatability** | ± 0.1 mm |
| **I/O Power supply** | 12 V/24 V 600 mA |
| **Communication** | TCP/IP, Ethernet socket & Modbus TCP |
| **Programming** | Polyscope graphical user interface |
| **IP classification** | IP54 |
| **Power consumption** | 150 W |
| **Power supply** | 10-240 VAC, 50-50 Hz |
| **matériels** | Aluminium, ABS plastic |
| **Température** | Working range of 0-50°C |
| **Operating life** | 35000 hours |

Table 2.1: Technical specification of UR5 robot arm.[12]

## 2.3 Denavi- Hartenberg parameters:



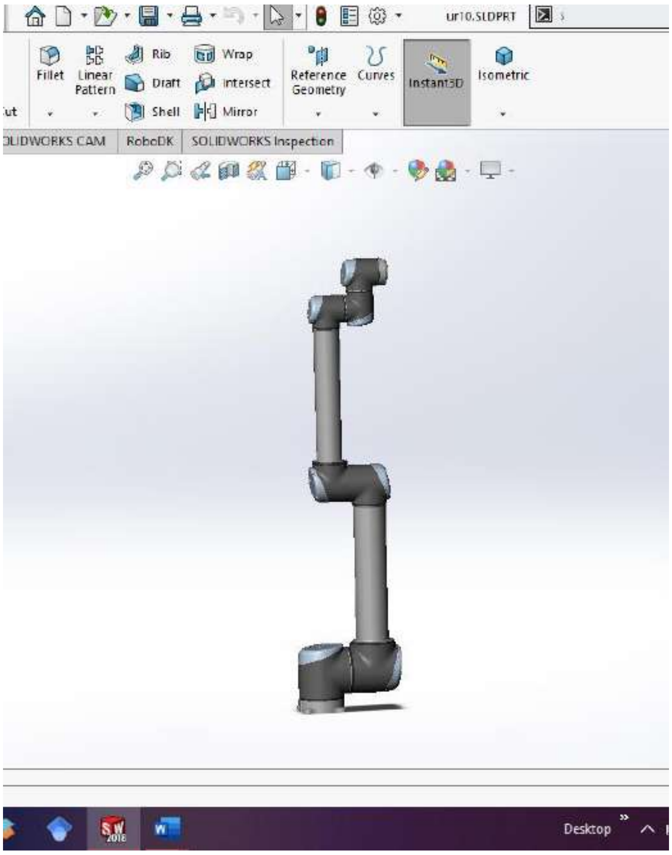


Figure2.2 Schematic and frames assignment of UR5 Figure2.3: solidworks model

| **Joint** | $q_i$ [°] | $d_i$ $[m]$ | $a_i$ $[m]$ | $\alpha_i$ [°] | *offset*$_i$ [°] |
|---|---|---|---|---|---|
| Base | q1 | 0.089159 | 0 | 90 | 0 |
| Shoulder | q2 | 0 | -0.425 | 0 | 0 |
| Elbow | q3 | 0 | -0.39225 | 0 | 0 |
| Wrist 1 | q4 | 0.10915 | 0 | 90 | 0 |
| Wrist 2 | q5 | 0.09465 | 0 | -90 | 0 |
| Wrist 3 | q6 | 0.0823 | 0 | 0 | 0 |

Table2.2: Denavit-Hartenberg parameters.[12, 13]

## 2.4 Forward kinematic:

**T_base_q1 =**

$$\begin{pmatrix} \mathrm{Cos}(q1) & -\sin(q1)*\cos(90) & \sin(q1)*\sin(90) & 0.089159*\cos(q1) \\ \mathrm{Sin}(q1) & \cos(q1)*\cos(90) & -\cos(q1)*\sin(90) & 0.089159*\sin(q1) \\ 0 & \sin(90) & \cos(90) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

**T_q1_q2 =**

$$\begin{pmatrix} \cos(q2) & -\sin(q2)*\cos(0) & \sin(q2)*\sin(0) & 0*\cos(q2) \\ \sin(q2) & \cos(q2)*\cos(0) & -\cos(q2)*\sin(0) & 0*\sin(q2) \\ 0 & \sin(0) & \cos(0) & -0.425 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

**T_q2_q3 =**

$$\begin{pmatrix} \cos(q3) & -\sin(q3)*\cos(0) & \sin(q3)*\sin(0) & 0*\cos(q3) \\ \sin(q3) & \cos(q3)*\cos(0) & -\cos(q3)*\sin(0) & 0*\sin(q3) \\ 0 & \sin(0) & \cos(0) & -0.39225 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

**T_q3_q4 =**

$$\begin{pmatrix} \cos(q4) & -\sin(q4)*\cos(90) & \sin(q4)*\sin(90) & 0.10915*\cos(q4) \\ \sin(q4) & \cos(q4)*\cos(90) & -\cos(q4)*\sin(90) & 0.10915*\sin(q4) \\ 0 & \sin(90) & \cos(90) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

**T_q4_q5 =**

$$\begin{pmatrix} \cos(q5) & -\sin(q5)*\cos(-90) & \sin(q5)*\sin(-90) & 0.09465*\cos(q5) \\ \sin(q5) & \cos(q5)*\cos(-90) & -\cos(q5)*\sin(-90) & 0.09465*\sin(q5) \\ 0 & \sin(-90) & \cos(-90) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

**T_q5_q6 =**

$$\begin{pmatrix} \cos(q6) & -\sin(q6)*\cos(0) & \sin(q6)*\sin(0) & 0.0823*\cos(q6) \\ \sin(q6) & \cos(q6)*\cos(0) & -\cos(q6)*\sin(0) & 0.0823*\sin(q6) \\ 0 & \sin(0) & \cos(0) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

**T = final :**

Tbase_q6=Tbase_q1×Tq1_q2×Tq2_q3×Tq3_q4×Tq4_q5×Tq5_q6

$$\begin{pmatrix} c1*c2*c3 - c1*s2*s3 & -c1*c2*s3 - c1*s2*c3 & s1 & -0.425*c1*s2 \\ s1*c2*c3 - s1*s2*s3 & -s1*c2*s3 - s1*s2*c3 & -c1 & 0.425*s1*s2 \\ s2*c3 + c2*s3 & -s2*s3 + c2*c3 & 0 & -0.425*c2 + 0.089159 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

## 2.5 Inverse kinematics:

For inverse kinematics, we will find the set of joint configurations Q = qi where qi = [$\theta_i$ 1, . . ., $\theta_i{}^6$ ] T ∈ [0, 2π) 6 such that satisfies 1 which describes the desired position and orientation of the the last link. Derivation of the inverse kinematic in this section is adopted from. First, finding θ1 using the position of the 5th joint. Analysing the transformation from frame 1 to frame 5 using equation 1, which results:[14]

$$-s_1(p_x - d_6 z_x) + c_1(p_y - d_6 z_y) = -d_4$$

that is known as a phase-shift equation whose solution considering Fig. 3 can be found as:

$$\tan\ \alpha_1\& = \frac{{}^0p_{5y}}{{}^0p_{5x}}$$

$$\tan\ \alpha_2 = \frac{d_4}{R} = \frac{d_4}{\sqrt{{}^0p_{5x}^2 + {}^0p_{5y}^2}}$$

Hence

$$\theta_1 = \alpha_1 + \alpha_2 + \frac{\pi}{2} = \text{atan } 2\left({}^0p_{5y}, {}^0p_{5x}\right) \pm \cos^{-1}\frac{d_4}{R} + \frac{\pi}{2} \qquad (3)$$

the UR5 is that the last three joints of it do not act as a coincidental wrist. Therefore, all its six joints contribute to the transformational and rotational movements of its end effector. This characteristic makes the kinematics analysis more complex in comparison with other manipulators with coincidental wrist.

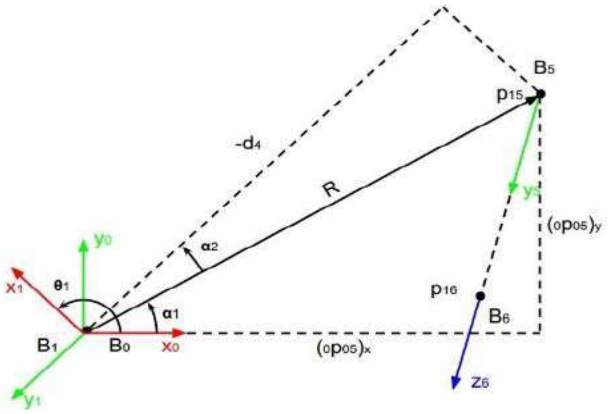


Figure2.4: Geometry of finding $\theta_1$.

There exist two solutions for $\theta_1$, where the shoulder is" left" or" right". Using the function *atan*2 is essential for insuring correct signs and behaviour when $^0p_{5x} = 0$. In Fig. 3, it is easy to see that physically, no configuration is possible which makes $\sqrt{^0p_{5x}^2 + {^0p_{5y}^2}} \leq |d_4| < 0$. Thus, both $\alpha_1$ and $\alpha_2$ always exist if an inverse solution exists.

Given a particular $\theta_1$, we can solve for $\theta_5$. Using the transformation from frame 1 to frame 6, we can form the below equality:[14]

$$[-s_1 \quad c_1 \quad 0] \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix} = -d_4 - c_5 d_5$$

which results to:

$$\theta_5 = \pm\cos^{-1} \frac{p_x s_1 - p_y c_1 - d_4}{d_6} \qquad (4)$$

Again, there are 2 solutions for θ5, which correspond to configurations where the wrist is" in/down" or" out/up".

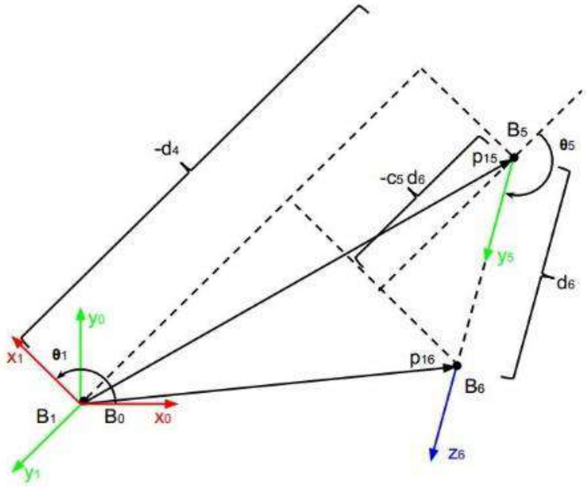


Figure2.5: Geometry of finding $\theta_5$.

To solve for the 6th joint, we look at the $^6y_1$ coordinate axis:

$$\begin{bmatrix} -x_x s_1 + x_y c_1 \\ -y_x s_1 + y_y c_1 \\ -z_x s_1 + z_y c_1 \end{bmatrix} = \begin{bmatrix} -c_6 c_5 \\ s_6 s_5 \\ -c_5 \end{bmatrix}$$

As Fig. 2.5 shows, this equality forms a spherical coordinate.

expression for the vector ${}^{6}y_1$ where $\theta_6$ is the azimuthal angle and $\theta_5$ is the polar angle. The x and y coordinates of this vector form a system which can be easily solved as:[14]

$$\theta_6 = \operatorname{atan}\ 2\left(\frac{y_y c_1 - y_x s_1}{s_5}, \frac{x_x c_1 - x_y s_1}{s_5}\right) \tag{5}$$

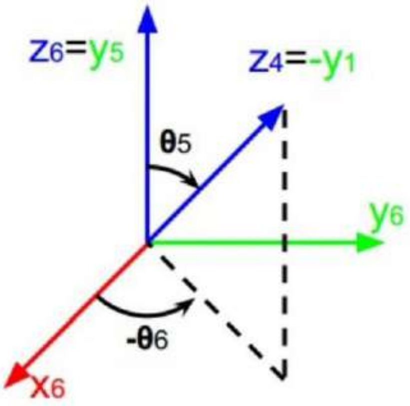


Figure2.6. Geometry for finding θ6.

When s5 = 0, we know c5 = ±1, which indicates that the joints 2, 3, 4, and 6 are all parallel and the solution is undetermined. When this occurs, a desired θ6 can be supplied to fully determine the system.

The other 3 joints can be derived easily, considering that they act as a 3-RRR planar arm. Once the previous 3 joints found, the location of the base and end-effector of this 3- RRR arm is available, then these 3 joints can be solved. There are two possible configurations,” elbow up” or” elbow down”. No solutions exist when the distance to the 4th joint exceeds the sum |a2 +a3| or is less than the difference |a2 − a3|. If a2 = a3, a singularity exists when θ3 = π, making θ2 arbitrary.[14]

## 2.6 Dynamics:

The manipulators’ dynamic equations have the general form of:

$$M(\underline{q})\ddot{q} + C(\underline{q},\dot{q})\dot{q} + \underline{g}(\underline{q}) = \underline{u} \qquad (6)$$

where M(q) is the symmetric positive definite mass inertia matrix of the system, ***C*** (q, q˙) is the matrix of Coriolis and centrifugal terms, g(q) is the vector of gravity terms and u is the input vector. The inverse dynamic has the form:

$$\underline{\ddot{q}} = M^{-1}(\underline{q})(\underline{u} - C(\underline{q},\dot{q})\dot{q} - \underline{g}(\underline{q})) \qquad (7)$$

The matrix M(q) would be simply calculated as:

$$M(\underline{q}) = \left[\sum_{i=1}^{n} \left(m_i J_{v_i}^T J_{v_i} + J_{\omega_i}^T R_i I_i R_i^T J_{\omega_i}\right)\right] \qquad (8)$$

where Jvi and Jωi are the linear and angular part of the Jacobian matrix Ji , respectively. For deriving the matrix ***C*** (q, q˙) it would be useful to know the passivity property of robotic manipulators which is the result of the skew-symmetry property of the matrix M˙ (q) − 2C(q, q˙). For reaching this property the elements of the matrix cij must be derived from the elements of the inertia matrix mij via the following formula:[13, 14]

$$c_{ij} = \sum_{k=1}^{n} \frac{1}{2}\left(\frac{\partial m_{ij}}{\partial q_k} + \frac{\partial m_{ik}}{\partial q_j} - \frac{\partial m_{kj}}{\partial q_i}\right)\dot{q}_k \qquad (9)$$

Finally, the elements of the gravity vector gi(q):

$$g_i(q) = \frac{\partial \mathcal{P}}{\partial q_i} \qquad (10)$$

Having M(q), ***C*** (q, q˙) and $g_i$(q) completes the dynamical model development.[13]

## 2.7 Solidworks Design:

**1:** Modelling the UR5 robot in SOLIDWORKS involves creating a 3D representation

**2:** of its components, assembling them, defining joints, and assigning material

**3:** properties. This model can then be used for simulations and analysis to

**4:** understand the robot's behaviour and performance.

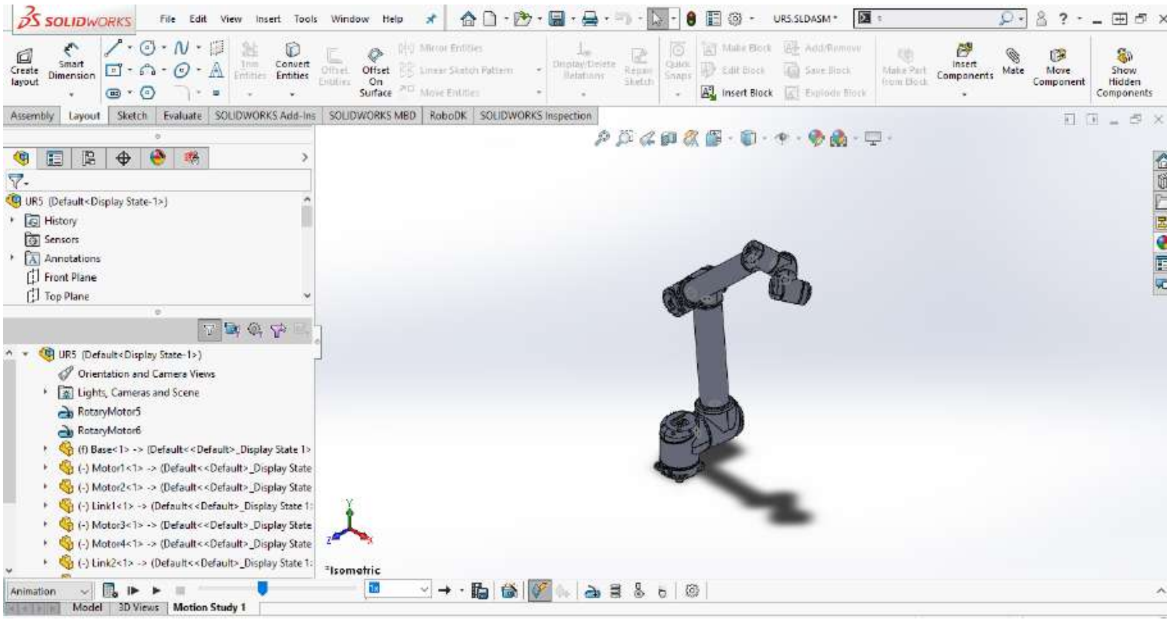


Figure2.7: UR5

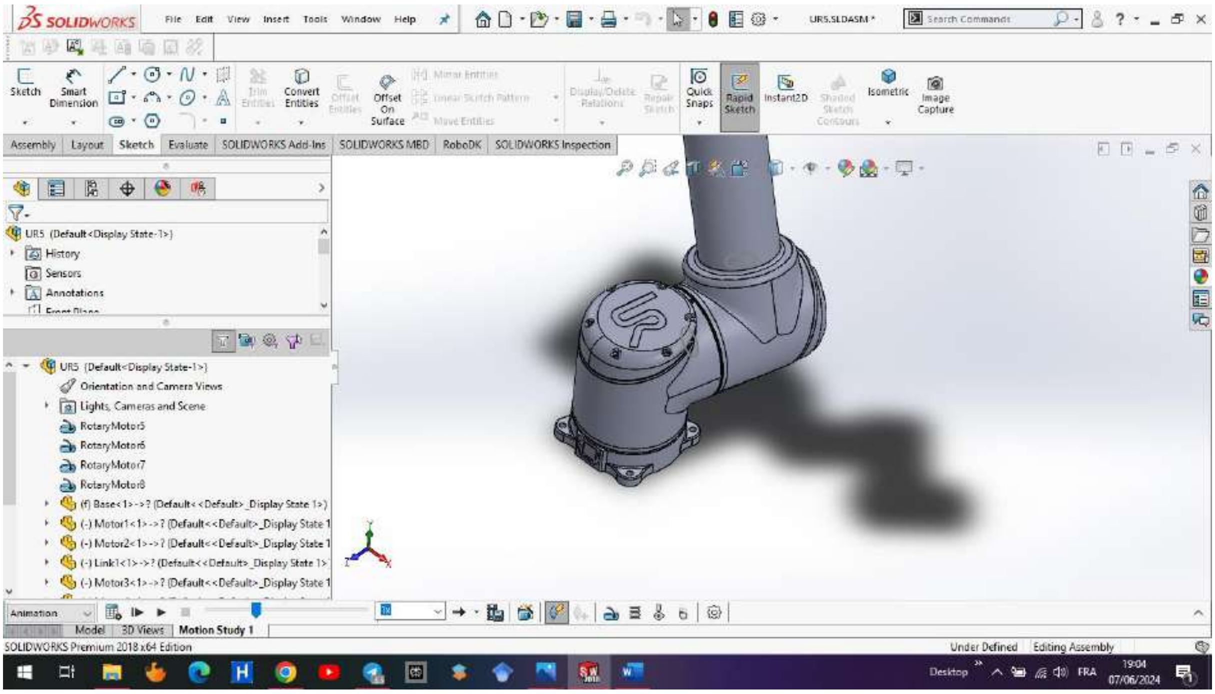


Figure2.8: ROBOT BASE.

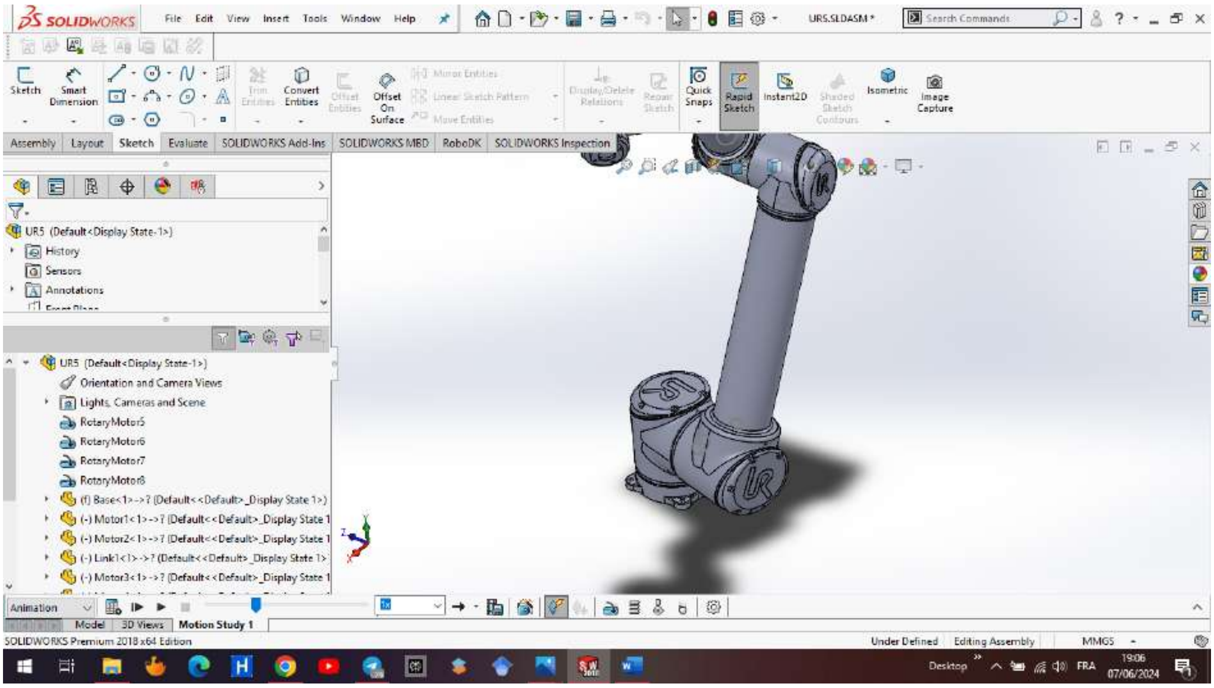


Figure2.9: UR5 ROBOT LINK AND JOINT:

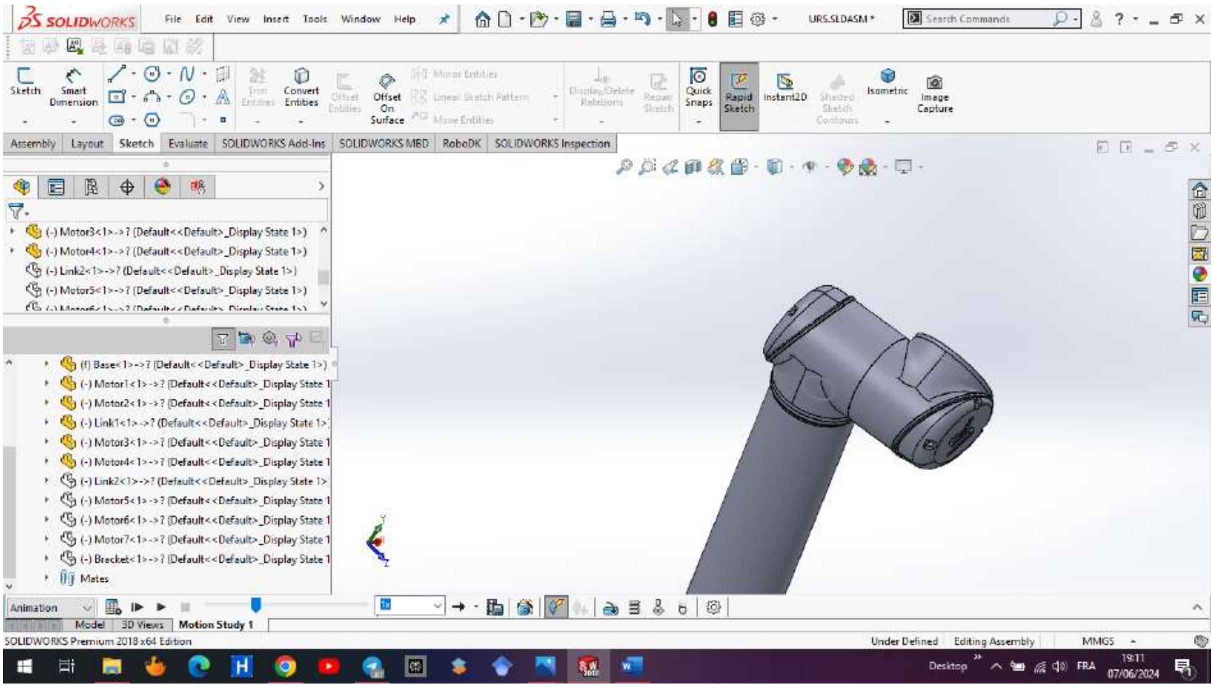


Figure2.10: THIRD AND FOURTH JOINT

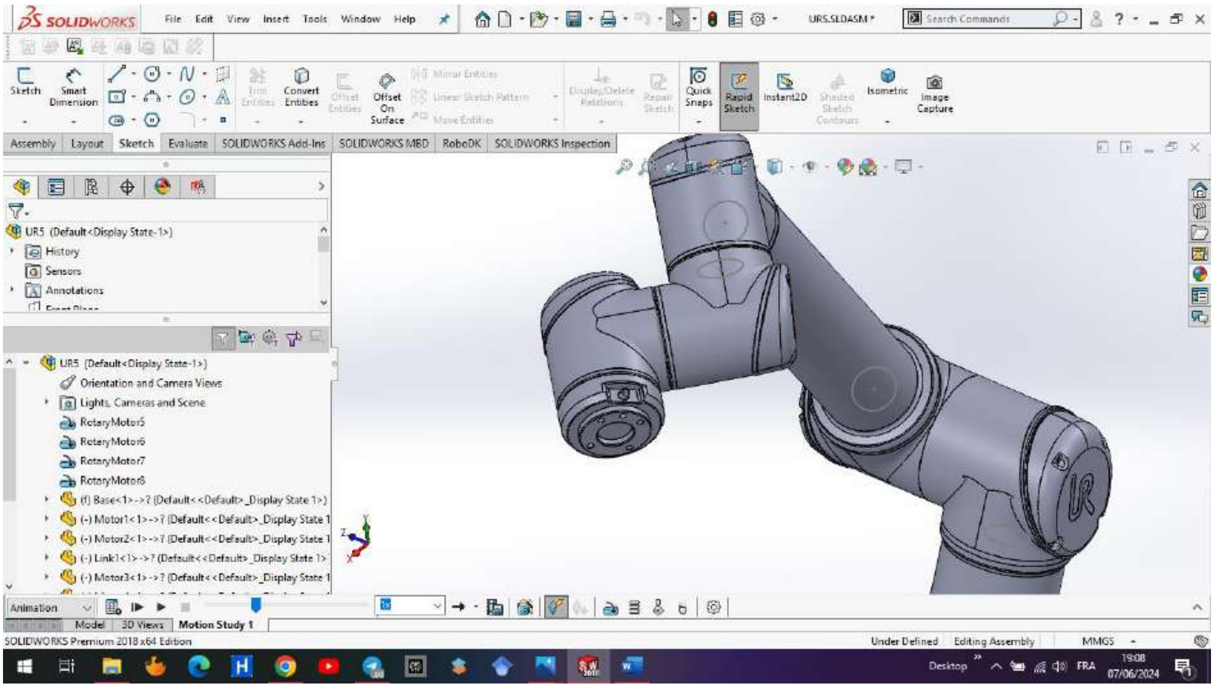


Figure2.10: END EFECTOR.

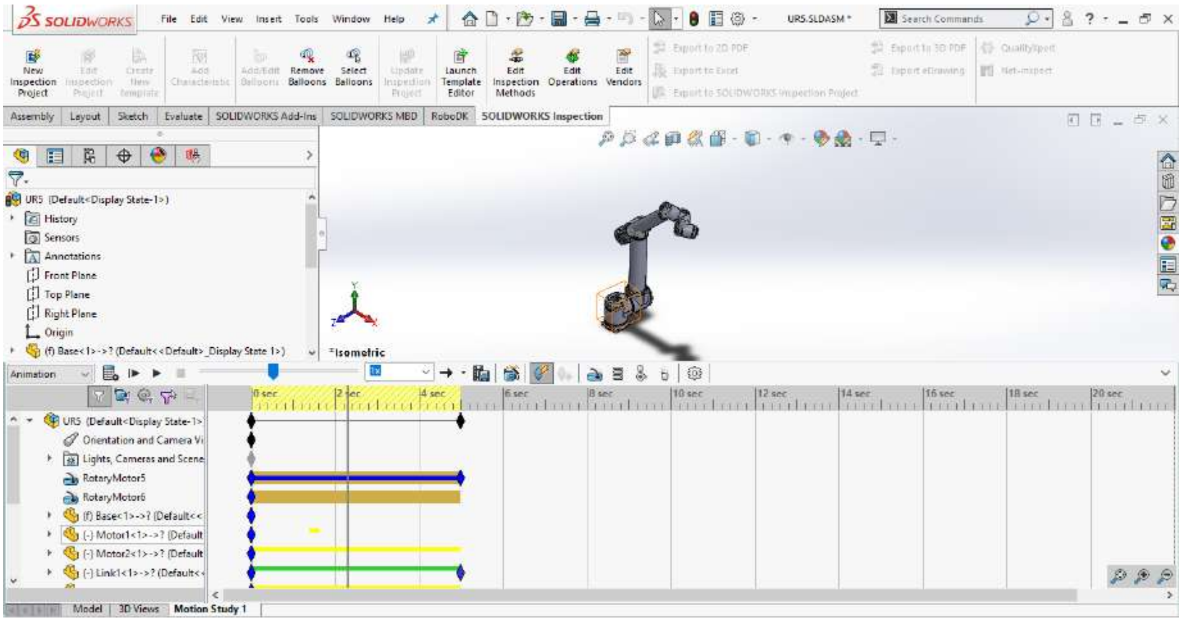


Figure2.11: Motion study of ur5.

## 2.8 Matlab Results:

Results of Inverse Kinematics and Joint Angle Trajectory

The results of the inverse kinematics (IK) for the welding path were calculated using MATLAB. These results include a matrix containing the sequence of joint angles for the UR5 robot. Each row in the matrix represents a set of joint angles that allow the robot to reach a specific point on the welding path.

These angles represent the precise movements required for each joint to ensure the robot follows the specified path smoothly and continuously. Analysing these results helps us verify the robot's ability to perform the required task efficiently and accurately, thereby improving the robot's performance and ensuring the quality of the welding process.

```
>> inverseKinematics
Joint angles trajectory:
    0.3668   -2.5714    1.7656    0.4999   -2.6692         0
    0.3415   -2.6255    1.7114    0.4377   -2.4015         0
    0.3100   -2.6903    1.6433    0.3953   -2.2474         0
    0.2952   -2.7419    1.5632    0.3779   -2.0960         0
    0.2938   -2.7766    1.4743    0.3951   -1.9271         0
    0.2916   -2.7969    1.3803    0.4579   -1.7729         0
    0.2843   -2.8032    1.2844    0.5744   -1.6473         0
    0.2748   -2.7988    1.1923    0.7422   -1.5417         0
    0.2646   -2.7907    1.1068    0.9424   -1.4494         0
    0.2539   -2.7815    1.0177    1.1464   -1.3694         0

fx >>
```

Figure2.12: results

## 2.9 Matlab Simulation of UR5:

In this project, we're simulating a UR5 robot following a specific welding path. The UR5 robot is modelled using Denavit-Hartenberg (DH) parameters, which accurately represent the robot's joints and links.

The aim is to have the robot trace an infinity-shaped path (like a figure-eight). This shape is commonly used in welding tasks to ensure thorough and precise coverage.

Here’s a breakdown of what happens:

**1.** We start by defining the DH parameters for each joint of the robot. These parameters help to create a detailed model of the robot's kinematics.

**2.** Next, we design the welding path as an infinity symbol. This involves generating a series of waypoints along this path.

**3.** For each waypoint, we use inverse kinematics to calculate the joint angles needed for the robot to reach that point. Inverse kinematics is crucial because it converts the desired path into specific joint movements.

**4.** We then simulate the robot's movement along this path. This allows us to visualize the robot's motion and ensure that it follows the intended trajectory accurately.

The simulation helps to verify that the robot can perform the welding task smoothly and precisely along the complex path. This kind of setup is useful for planning and optimizing welding operations in a controlled environment.

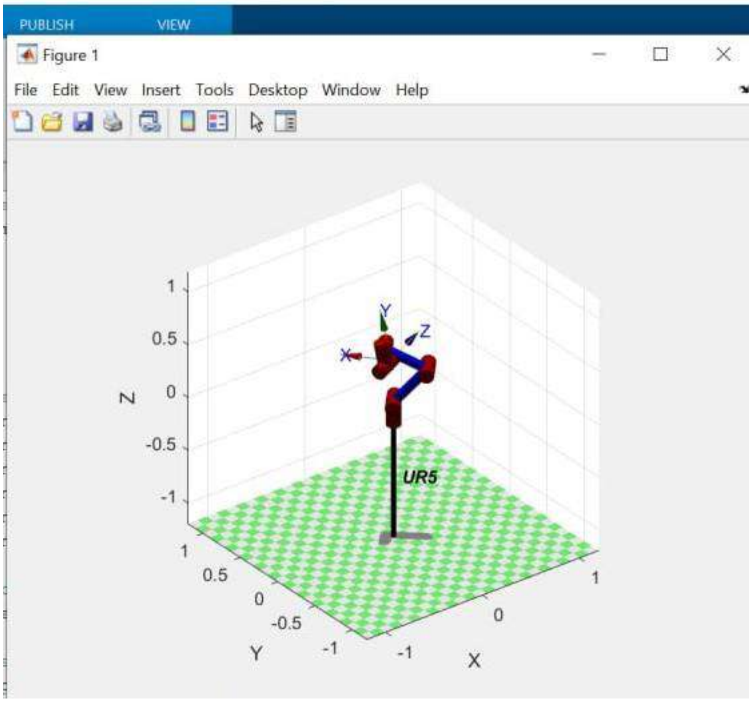


Figure2.13: matlab simulation.

## 2.10 Welding Path Trajectory (infinity symbol):

In this simulation, the UR5 robot follows a welding path shaped like the infinity symbol (∞), also known as a lemniscuses. This path is chosen for several reasons:

1. **Complexity and Coverage:** The infinity shape is more complex than a straight line, requiring the robot to move in a smooth, continuous manner. This complexity helps in testing the robot's precision and ability to cover a wide area efficiently.

**2. Smooth Transitions:** The continuous curves of the infinity symbol ensure that the robot makes smooth transitions between different sections of the path, which is critical for maintaining a consistent welding quality.

**3. Practical Applications:** In real-world welding tasks, such as those in automotive and aerospace industries, following complex paths ensures that joints and seams are thoroughly welded without missing any spots.

**4. Path Generation:** The infinity path is generated using parametric equations that describe the x, y, and z coordinates over time. These equations ensure that the waypoints are evenly spaced, allowing for a consistent speed and quality of welding.

By using an infinity-shaped path, this simulation tests the UR5 robot's ability to handle complex welding tasks, ensuring thorough coverage and smooth operation.

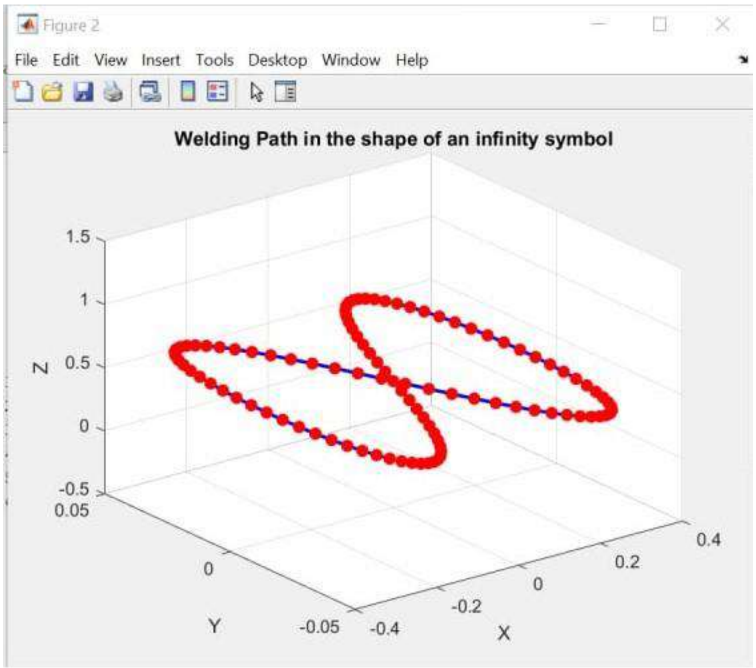


Figure2.14: UR5 Path.

## **Conclusion** :

In conclusion, our journey with the UR5 robot was a blend of technical learning and hands-on experience. We started by using SolidWorks to design a detailed 3D model of the robot, which helped us grasp its intricate mechanical structure. This step was crucial as it allowed us to visualize and tweak the design before moving forward.

Next, we used MATLAB to simulate the robot's movements and operations. This virtual testing ground was invaluable, as it let us experiment with different scenarios and identify any potential issues without the risk and cost of real-world trials.

The highlight of our journey was the training program in Sétif. Seeing the UR5 robot in action and learning directly from experts was an eye-opener. We didn't just learn how to program and operate the robot; we also understood the practical challenges and solutions involved in working with such advanced technology. The hands-on experience made everything click—literally and figuratively.

This combination of designing, simulating, and real-world training gave us a comprehensive understanding of the UR5 robot. It wasn't just about learning to use a piece of technology; it was about gaining the confidence and skills to tackle future robotics challenges. This experience has truly prepared us for the exciting developments ahead in the world of robotics.

# CHAPITRE III

## 3.1. Introduction

In advanced manufacturing, extending the use of autonomous or collaborative robots into diverse industries, such as automotive, aerospace, shipbuilding, and renewable energy, presents significant opportunities for enhancing productivity and safety. While traditional or mobile robot arms are widely used in conventional manufacturing plants, there is an emerging interest in deploying mobile robots in more challenging environments like large structures. For example, in shipbuilding, tasks such as hull welding pose unique challenges due to the size and vertical nature of the surfaces involved.[11, 15]

**Proposal:**

In this work, we propose the design of a mobile robot capable of navigating vertical steel surfaces, specifically ship hulls. The robot is intended to autonomously or semi-autonomously perform tasks that are traditionally done manually, such as welding. Hull welding currently involves a welder operating from a boom lift or scaffoldings, which is both dangerous and costly. Given the vast dimensions of ships and the requirement for multiple welding passes due to hull thickness, the automation of this process can significantly improve efficiency and safety.

- Our design focuses on a robot equipped with magnetic tracks for adherence to steel surfaces. This choice ensures that the robot remains safely attached to the hull, even in the event of a power failure. The robot carries a 2-degrees of freedom arm with an embedded welding torch, which is gui0ded by camera feedback to ensure precise welding joint analysis. While the robot's absolute localization on the hull and longitudinal positioning along the welding joint are not covered in this work, we present welding results that demonstrate the reliability of the process.[15, 16]

-

Figure 3.1: A photo of a welding robot being tested in the Algerian desert (Hassi Messaoud) 01.

**Background and Related Work:**

- A variety of climbing robots have been developed for different applications, predominantly focusing on their mechanical design and adhesion mechanisms. According to a comprehensive survey, the two most common approaches are suction and magnetic forces. Suction-based robots, like the one presented for inspecting radioactive tanks, have limited payload capacities, while quadruped robots with suction pads require complex control systems. Magnetic adhesion offers alternatives such as electromagnets, which provide controlled adhesion at the cost of energy consumption, and permanent magnets, which are energy-efficient but demand more power for navigation due to increased friction.

- Robots using alternative adhesion technologies, such as thermoplastic adhesive bonds or specialized non-magnetic wall climbing mechanisms, often face limitations in payload capacity and maintenance cycles, making them less suitable for shipbuilding applications. High-payload magnetic robots, equipped with wheels and adjustable magnets, have shown promise for tasks like welding, but many of these designs still rely on manual control. Safety and reliability are paramount for ship hull applications, making magnetic tracks an optimal choice despite the navigation constraints they introduce.

- In our design, we prioritize autonomous operation with the potential for tele-operation in complex scenarios, aiming to free human welders for more intricate tasks that require their expertise. This approach not only enhances safety and efficiency but also leverages human skills where they are most needed.

## 3.2 General Description:

The quad-wheel welding robot is designed for performing welding operations on various surfaces, especially large and complex metal surfaces such as ships, gas and oil pipelines, and large metal tanks. This robot is capable of moving on surfaces using its four wheels and following a magnetic path.

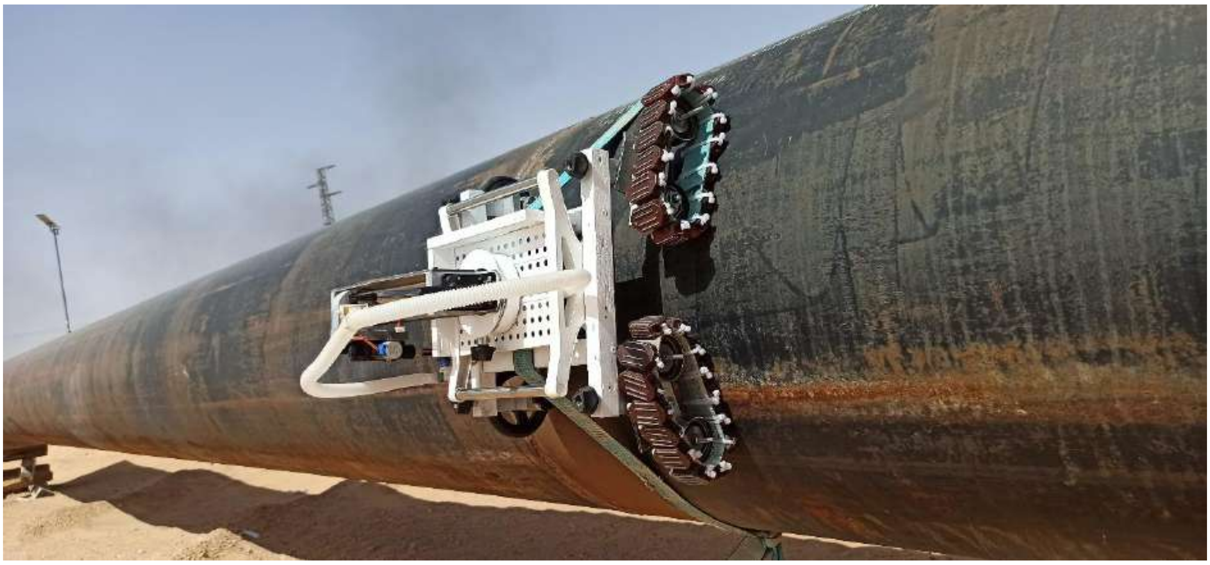


Figure 3.2: A photo of a welding robot being tested in the Algerian desert (Hassi Messaoud) 02.

## 3.4 Main Components:

**3.4.1 Magnetic Wheels:** Magnetic Wheels: The robot is equipped with magnetic wheels that provide strong adhesion to metal surfaces. This feature ensures that the robot remains securely attached to the surface it is working on, even when operating at various angles or on vertical structures. The magnetic wheels are crucial for maintaining stability and allowing the robot to perform precise movements required for high-quality welding operations.[16]

- Four-Wheel Steering System: The robot features a sophisticated four-wheel swerve steering system. This advanced steering mechanism allows each wheel to pivot independently, giving the robot exceptional maneuverability. It can move seamlessly in any direction, making it capable of navigating around obstacles such as pipes and edges with ease. This flexibility is particularly beneficial in complex and confined spaces where traditional welding methods might be challenging. The swerve steering system enhances the robot's ability to reach difficult welding spots and ensures smooth and efficient operation across diverse industrial environments.

### 3.4.2 System description:

These components of the movement system collectively enable the quad-wheel welding robot to tackle challenging welding tasks on large and complex metal structures, significantly enhancing its operational versatility and effectiveness.

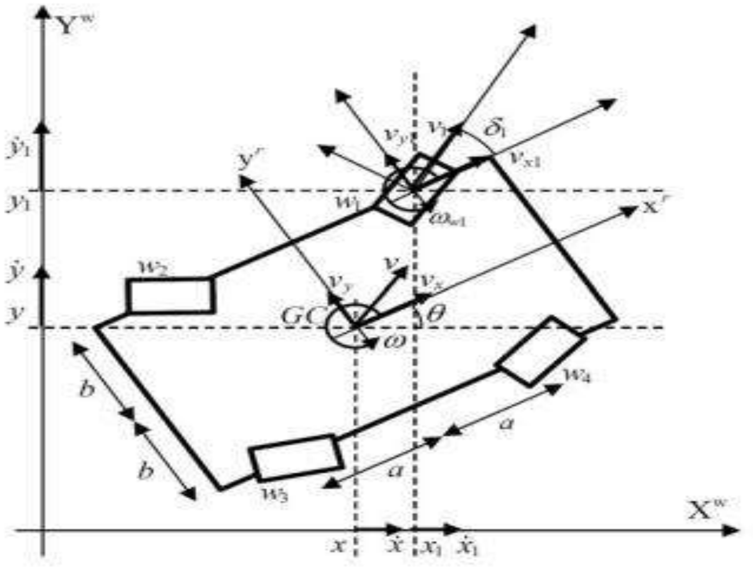


Figure 3.4: Robot motion system.

**3.4.3 Bluetooth Control System:** The robot can be remotely controlled via Bluetooth, allowing the operator to manage the robot from a safe location.

**3.4.4 Positioning Camera:** An integrated camera helps accurately determine the robot's location and guide it to the required welding areas.

**3.4.5 Welding Equipment:** Equipped with advanced welding tools that enable it to efficiently perform welding operations on long weld lines.

## 3.5 Features and Functions:

### 3.5.1Climbing and Adaptation:

The robot can climb vertical metal surfaces and adapt to various welding positions.

**3.5.2 Precision Work**: Thanks to the camera and advanced control system, the robot can accurately locate welding spots and perform high-quality welds.

**3.5.3 Safety and Remote Control:** The Bluetooth system allows the operator to control the robot from a distance, enhancing safety and reducing risks associated with welding operations in hazardous environments.

**3.5.4 High Efficiency:** Designed to perform long and continuous welding operations quickly and efficiently, increasing productivity and reducing the time needed to complete large projects.

Figure 3.5: One of the risks and difficulties that exist in places where welding gas and oil pipelines.

## 2.6 Applications:

-The robot is primarily used for gas and oil pipeline welding, where precise angle control and stable positioning are crucial for achieving high-quality welds.[16]

- It is suitable for industrial environments that require welding complex or long pipelines, reducing the need for human labor and increasing accuracy and efficiency.[17]

- Welding ship structures.

- Welding large metal tanks and reservoirs.

This robot is an ideal solution for challenging and complex welding operations due to its advanced design and ability to adapt to various working conditions.[16]

Figure 3.6: Robot welding method for gas and oil pipelines.

Figure 3.7: Robot moving between welding joints.

## 2.7 General design of the prototype:

In this section we detail the mechanical design and the components of the robot. The starting point for the sizing of the platform was the weight and payload that directly impact the number of magnets, hence the general size of the robot. The current form factor is 65 cm length and 45 cm width, with 4 kg total weight including the weight of the external cables (power supply and welding torch cable). The robot structure is composed of firewood, plastic and metal. We first list the robot components before detailing the sizing of the magnetic track. We first list the robot components before detailing the sizing of the magnetic track.

## 2.8 Solidwarks design of the robot:

- SOLIDWORKS allows for precise 3D modeling of the robot, ensuring that all components, including the magnetic wheels, the steering mechanism, and the welding torch system, are accurately represented.

- The detailed model helps in visualizing the robot's overall structure and identifying potential design issues before manufacturing.

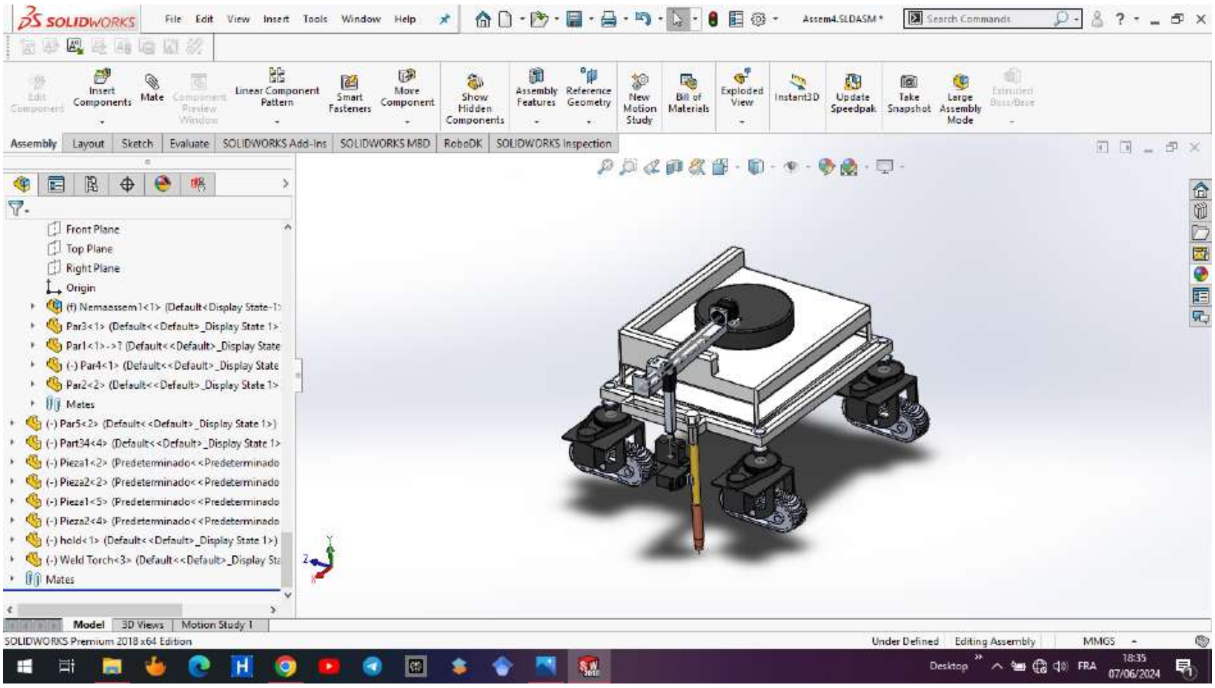


Figure 3.8: SolidWarks design of the robot.

## 2.9 SolidWorks model of the Prototype:

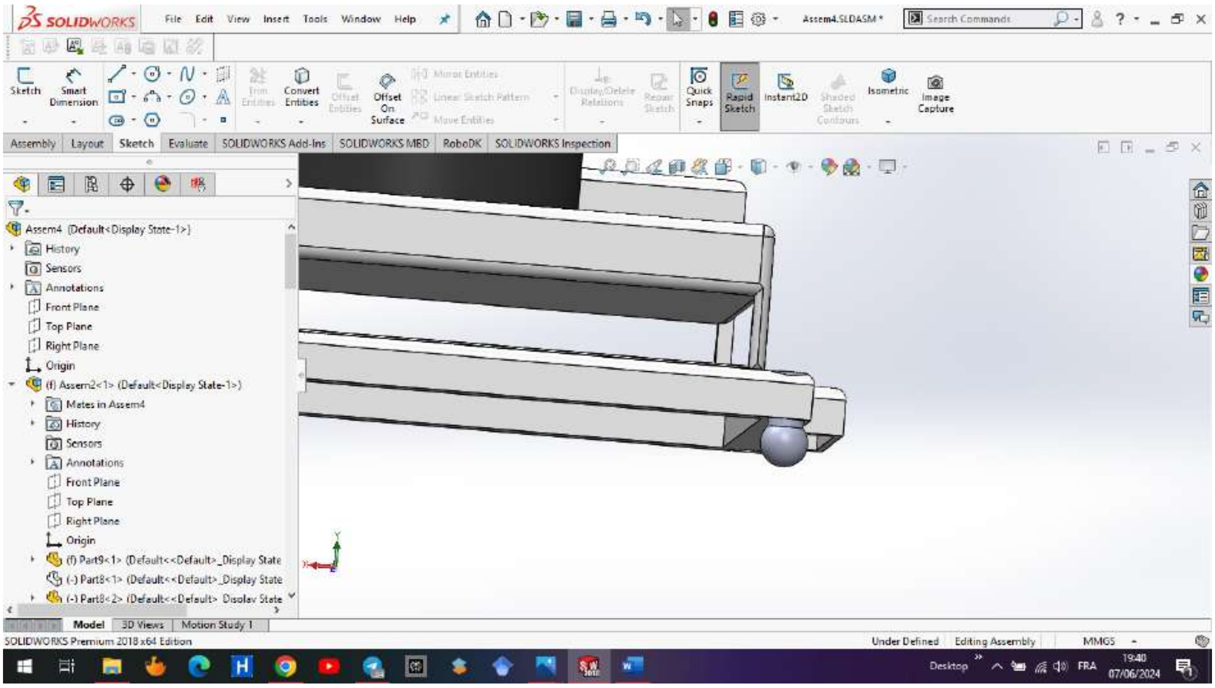


Figure3.9: Ball joint for adjusting the movement.

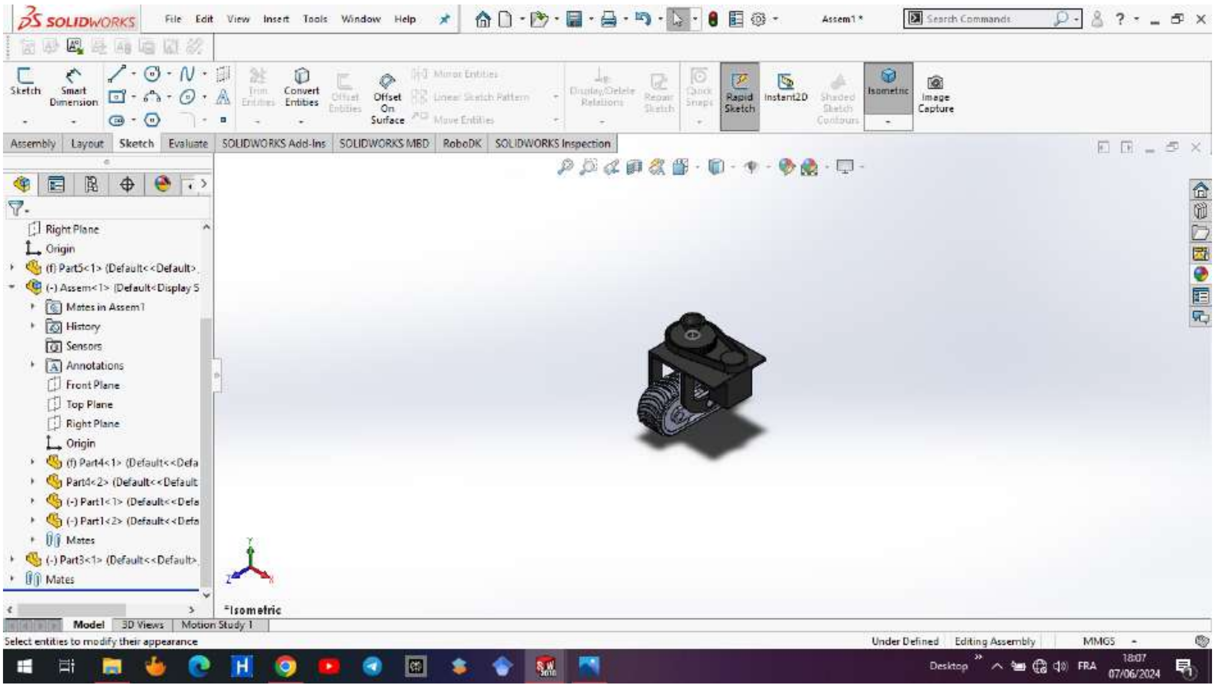


Figure 3.10: Magnetic 360-degree wheel steering.

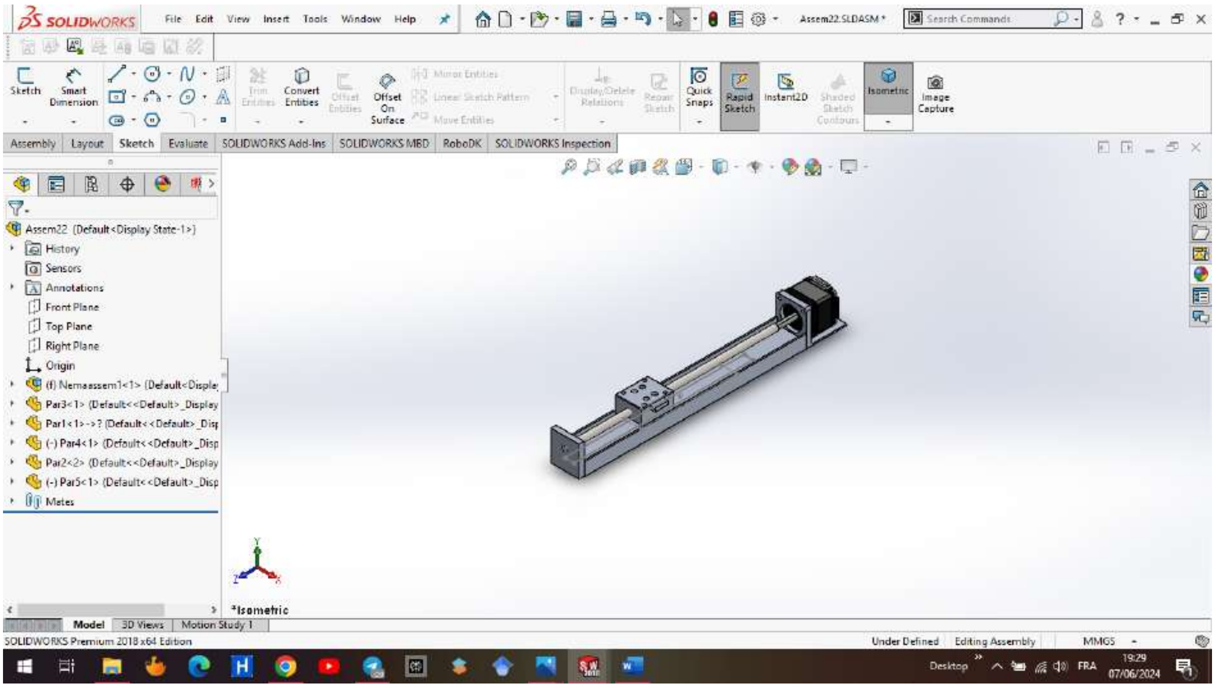


Figure3.11: Linear movement mechanism.

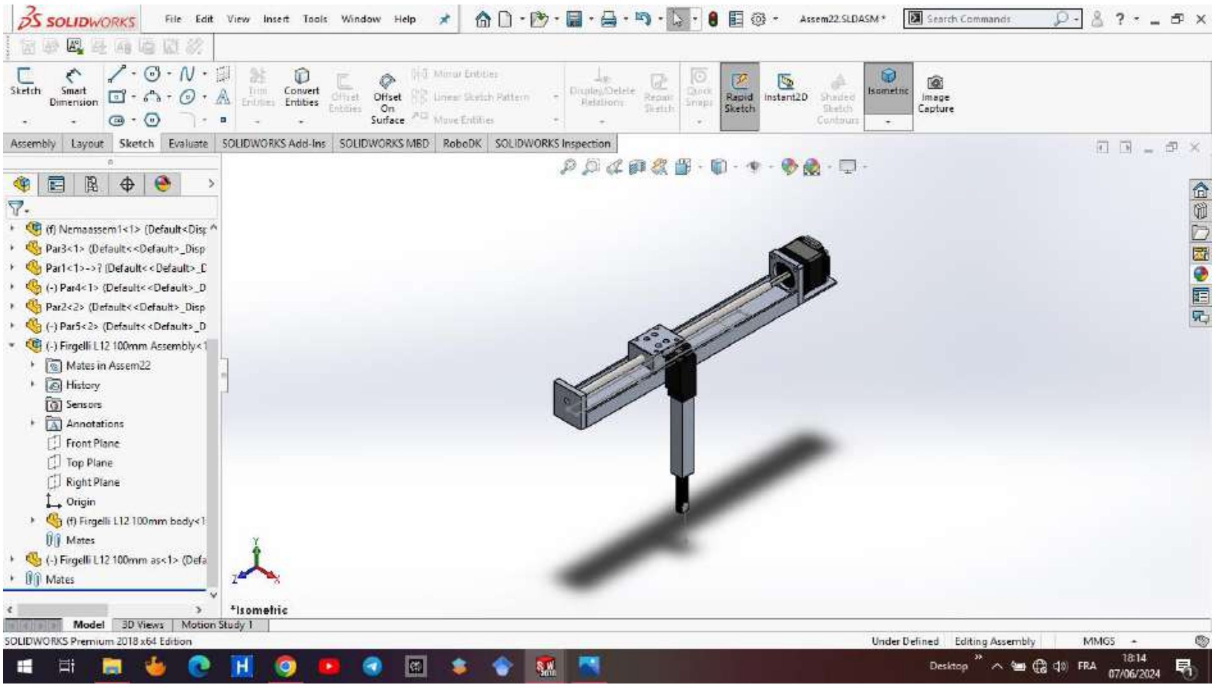


Figure 3.12: 2 axes linear movement.

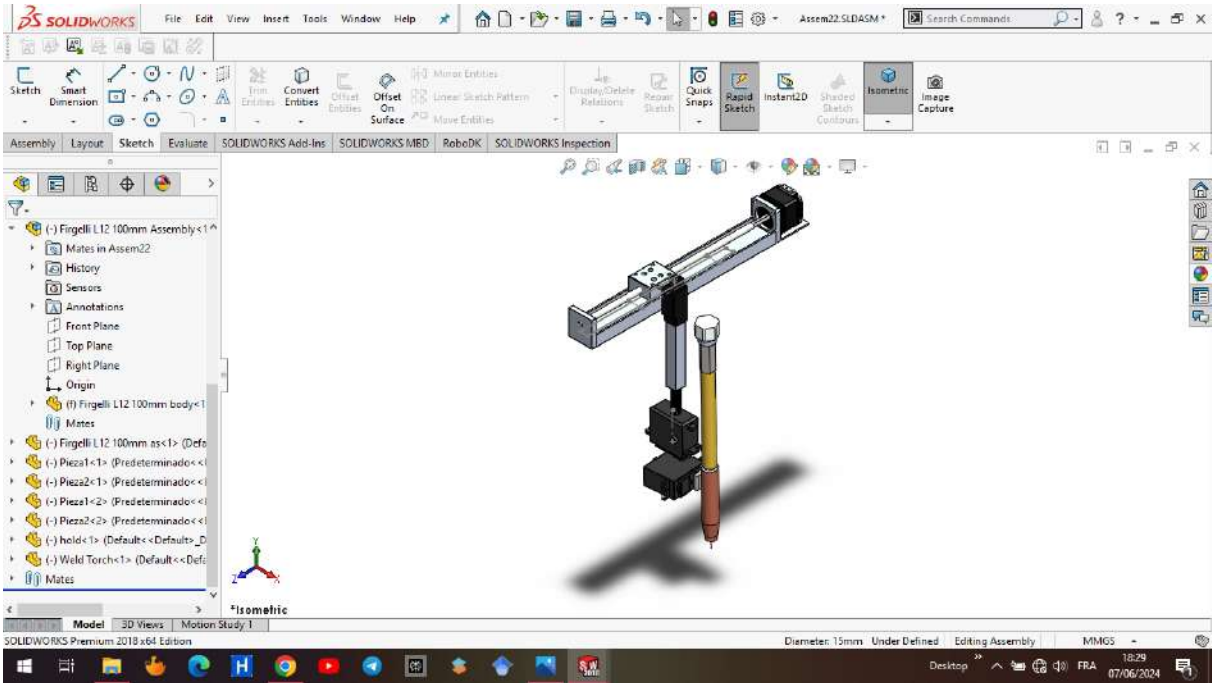


Figure 3.13: the total mechanism

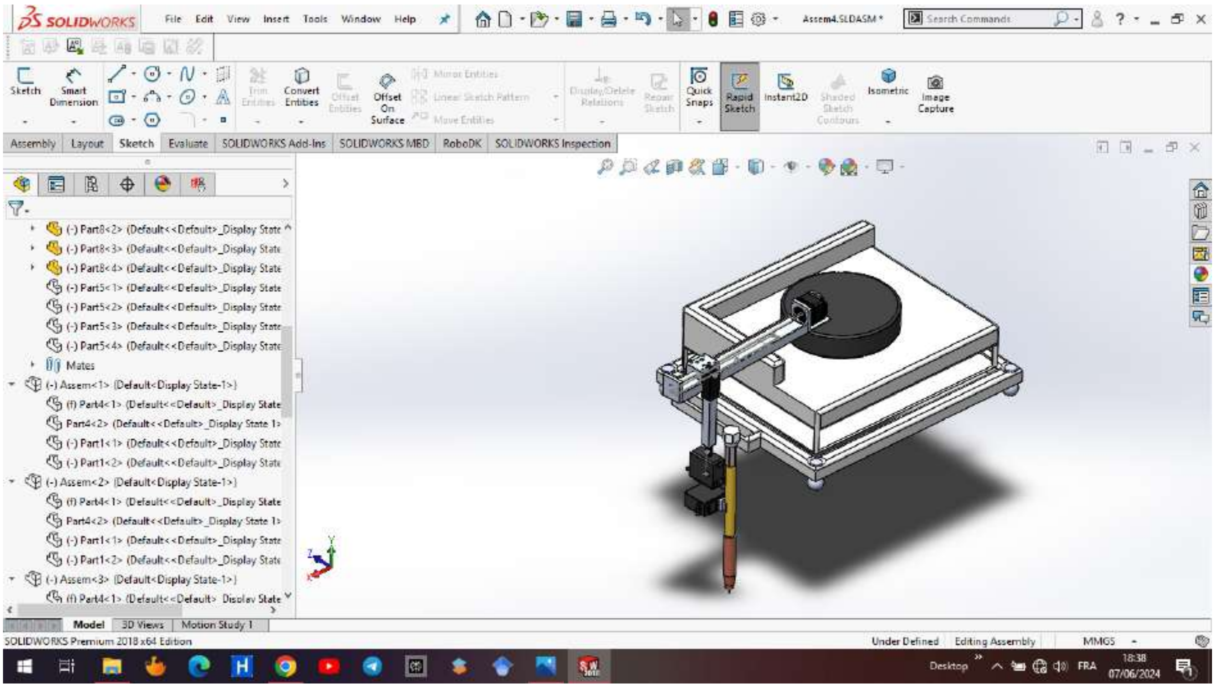


Figure 3.14: Placement of the mechanism

**Example:**

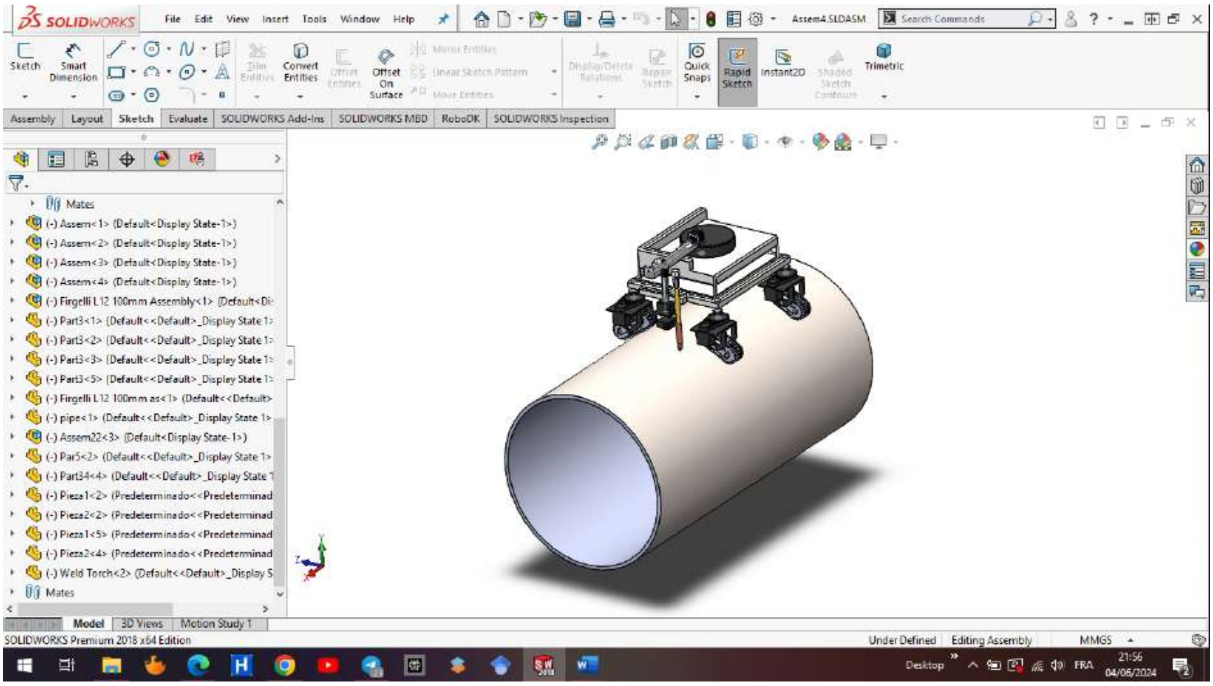


Figure 3.15: petroleum pipeline welding operation.

## 3.10 Components

The prototype is shown in Fig. 1. The robot consists of four wheels operating on a magnetic track, along with a Bluetooth-controlled unit. In the middle of the robot, there is an arm equipped with a welding torch.

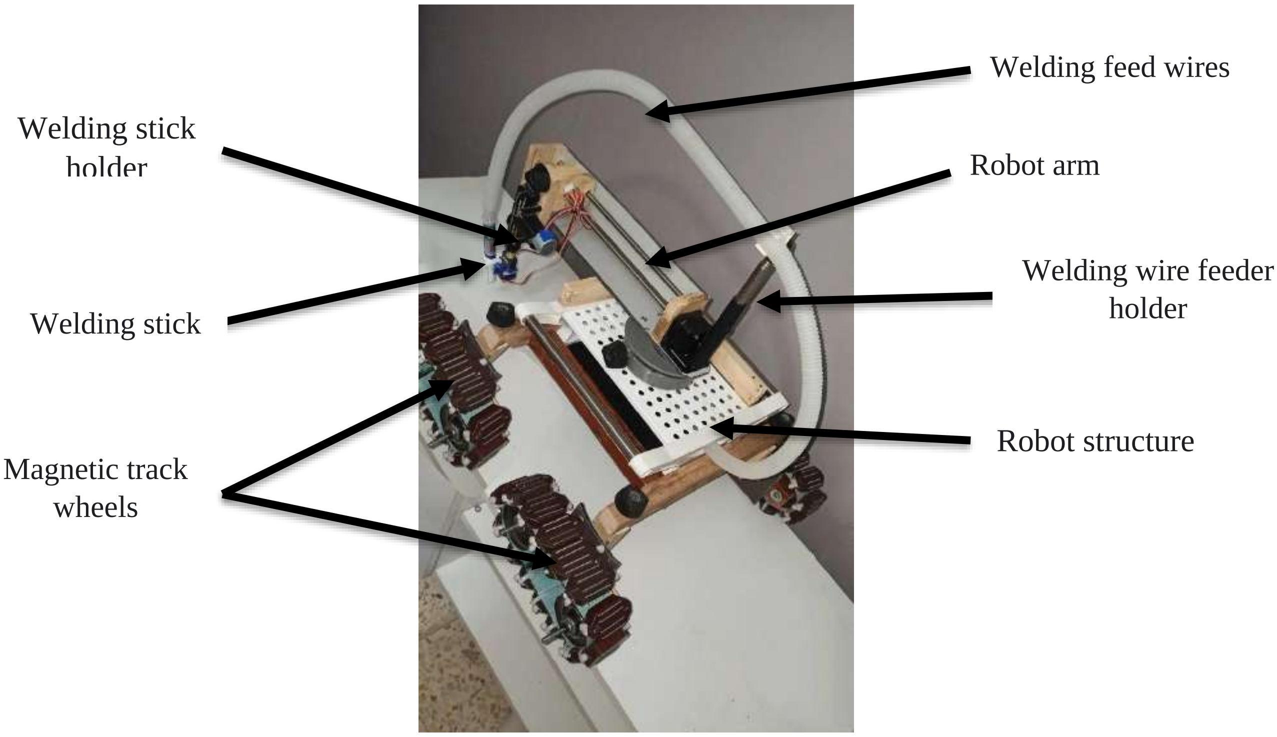


Figure 3.16: Overview of the mobile robot in horizontal position.

## 3.11 control unit:

This robot has been programmed using an Arduino Uno controller for ease of use and programming, and it comes with a relatively low cost compared to other initial models.

### 3.12 Continuous tracks and motors:

The continuous tracks and their magnetic pads have been sized to carry the robot and its payload. The robot features 4 track wheels, each containing 28 magnetic pieces, facilitating seamless motion without interruptions, thus ensuring smooth welding operations. Each track is initially connected to a DC motor to ensure the robot's mobility

## 3.13 degrees of freedom arm:

The robot carries an arm containing a linear motion unit, which helps increase welding positions and facilitates locating the welding position. The stepper motor at the end of the arm ensures the up and down movement of the welding torch, and servo motor (1) switches the welding rod position from circular pipe welding to straight surface welding. Servo motor (2) helps carry the welding rod and swing it to form the appropriate welding angle for welding position

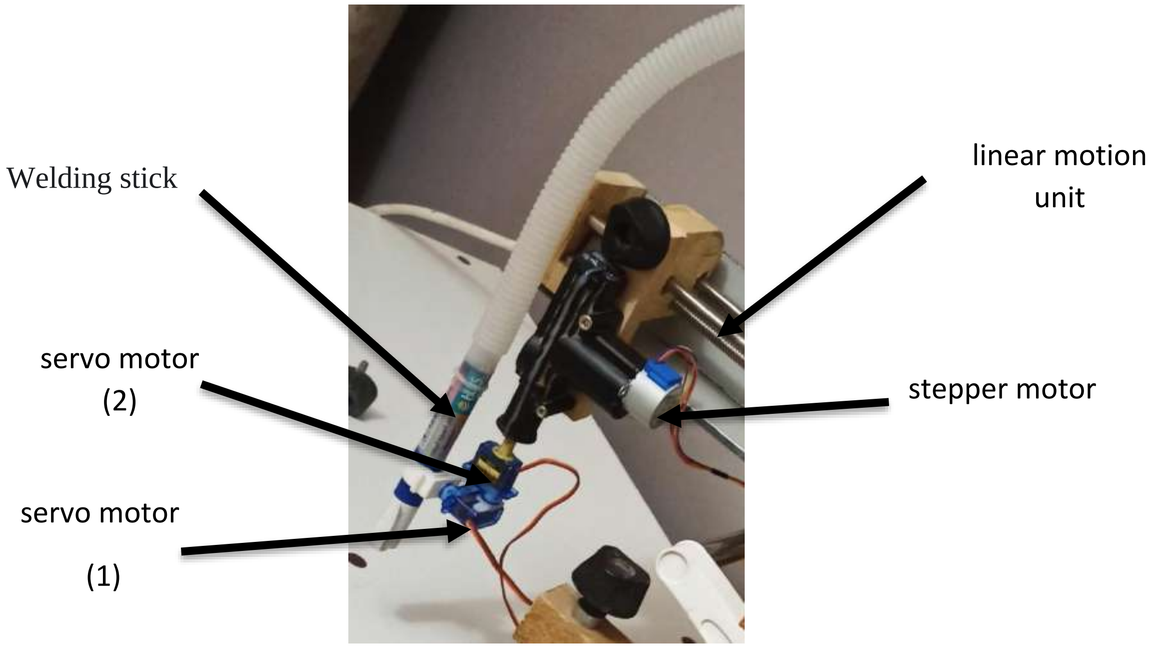


Figure 3.17: Illustrative image of a welding torch holder.

## 3.14 Welding process:

In the current state of the robot, the welding torch is directly connected to the welding ground station through a cable that provides shielding gas and wire. On longer distances, it will be necessary to mount a wire sub feeder on the robot.

## 3.15 Magnetic track sizing:

The main challenge of the mechanical design is the sizing of the magnetic tread. Indeed, safety protocols in the considered industry force a magnetic device to have a grip equal to at least five times its weight. This is due to the possibility of slippery surface in case of humidity or even rain. The robot also has to be able not to fall even in one caterpillar is broken. The considered robot and payload weighting about 100 kg, this means that each caterpillar has to have an attractive force of at least 500 kg

Figure 3.18: magnetic track sizing.

## 3.16 Conclusion:

In conclusion, the quad-wheel welding robot, equipped with a magnetic path, Bluetooth control system, and positioning camera, represents a significant leap in welding technology and aligns with the principles of Industry 4.0. With its advanced design and ability to climb and adapt to various metal surfaces, it can reach difficult and dangerous welding areas inaccessible to humans. The Bluetooth remote control system enhances safety by allowing operators to control the robot from a safe distance. The integrated camera and advanced guidance system ensure high precision in identifying welding spots, improving quality and reducing time and costs. This robot embodies the smart industry concept by integrating automation, data exchange, and advanced manufacturing technologies. It is an indispensable tool for increasing productivity and reducing risks in heavy industries like shipbuilding, pipeline installation, and large metal tank manufacturing. With ongoing advancements in artificial intelligence, remote control technologies, and Industry 4.0 frameworks, we can expect even higher levels of precision, efficiency, and reliability in the future.

# Conclusion

# General Conclusion:

Throughout this project, we explored the fascinating world of robotics, focusing specifically on the types of robots, the UR5 robot, and the practical application of building a welding robot. In the first chapter, we looked at the different kinds of robots out there. We saw how robots can vary greatly, from those used in industries to mobile robots and service robots. Each type has its unique characteristics and uses, and it was interesting to see how they fit into various aspects of our lives and industries. The second chapter took us deeper into the specifics of the UR5 robot.

We learned about its technical features and why it's so well-suited for many industrial tasks. We even got to simulate its welding path using MATLAB, which helped us see how the robot performs and how we can make it work more efficiently.

Creating a 3D model with SolidWorks was another highlight, as it allowed us to visualize and refine our design, ensuring it would integrate well into an industrial setting. In the final chapter, we brought everything together by building our own industrial welding robot and creating a miniature model of it. Using SolidWorks for the design helped us ensure that our model was both effective and practical.

This hands-on experience was invaluable, as it gave us a chance to apply everything we had learned in a real-world context. Overall, this project highlighted the incredible advancements in robotics and showed how tools like simulation and 3D modeling can significantly improve the design and functionality of robots.

It's exciting to think about how these technologies can continue to evolve and impact our future. We hope this work not only contributes to a better understanding of robotics but also inspires further research and innovation in this crucial field.

## Abstract :

This dissertation, structured in three parts, details the work undertaken. The first part offers a thorough explanation of the technological components that define a robotic system and introduces the essential terminology of the robotics field. The second part focuses on the UR5 robot, providing a framework for modeling and designing it using SolidWorks. The third part explores the development of a welding robot, detailing the creation of a prototype and its validation through the SolidWorks model.

Keywords:

Robot System, UR5, SolidWorks Design, Welding Robot, Prototype

## ملخص :

تتألف هذه الأطروحة من ثلاثة أجزاء، وتتناول تفاصيل العمل الذي تم إنجازه. يقدم الجزء الأول شرحًا شاملاً للمكونات التكنولوجية التي تحدد النظام الآلي ويقدم المصطلحات الأساسية في مجال الروبوتات. أما الجزء الثاني فيركز على الروبوتUR5 ، حيث يقدم إطار عمل لنمذجة وتصميمه باستخدام برنامج SolidWorks. يستكشف الجزء الثالث تطوير روبوت اللحام، ويوضح تفاصيل إنشاء نموذج أولي والتحقق من صحته من خلال نموذج SolidWorks.

الكلمات المفتاحية:

نظام الروبوت، UR5، تصميمSolidWorks ، روبوت اللحام، النموذج الأولي

## Résumé :

Ce mémoire, structuré en trois parties, détaille les travaux entrepris. La première partie offre une explication approfondie des composants technologiques qui définissent un système robotique et introduit la terminologie essentielle du domaine de la robotique. La deuxième partie se concentre sur le robot UR5, fournissant un cadre pour le modéliser et le concevoir à l'aide de SolidWorks. La troisième partie explore le développement d'un robot de soudage, détaillant la création d'un prototype et sa validation via le modèle SolidWorks.

Mots clés :

Système robotique, UR5, conception SolidWorks, robot de soudage, prototype

# Références Bibliographiques

## Bibliographies

1. Rehaiem, A., *Conception, Réalisation et Command D'un Robot Mobile.*
2. Singh, B., N. Sellappan, and P. Kumaradhas, *Evolution of industrial robots and their applications.* International Journal of emerging technology and advanced engineering, 2013. **3**(5): p. 763-768.
3. Hunt, H.A. and T.L. Hunt, *The Robots are Coming.* 1983.
4. Rajput, R., *Robotics and Industrial Automation*. 2008: S. Chand.
5. Merouane, C., *Modélisation cinématique d'un robot manipulateur à chaine continue ouverte*. 2013.
6. Malla, O. and M. Shanmugavel, *Simplified model to study the kinematics of manipulators with parallelogram linkages.* Industrial Robot: the international journal of robotics research and application, 2024.
7. BOUZIANE, F.Z., *Rétro-conception du bras horizontal de robot manipulateur de la cellule flexible (Tlemcen)*. 2013.
8. Das, M.T. and L.C. Dülger, *Mathematical modelling, simulation and experimental verification of a scara robot.* Simulation Modelling Practice and Theory, 2005. **13**(3): p. 257-271.
9. Chen, J., et al., *RoboScript: Code Generation for Free-Form Manipulation Tasks across Real and Simulation.* arXiv preprint arXiv:2402.14623, 2024.
10. Vivas, A. and J.M. Sabater. *Ur5 robot manipulation using matlab/simulink and ros*. in *2021 IEEE International Conference on Mechatronics and Automation (ICMA)*. 2021. IEEE.
11. Silva, M.F., J.T. Machado, and J.K. Tar. *A survey of technologies for climbing robots adhesion to surfaces*. in *2008 IEEE international conference on computational cybernetics*. 2008. IEEE.
12. Rodriguez Vidriales, C., *Universal Robots® UR5. Desarrollo de Programación.* 2020.
13. Craig, J.J., *Introduction to robotics*. 2006: Pearson Educacion.
14. Hawkins, K.P., *Analytic inverse kinematics for the universal robots UR-5/UR-10 arms.* 2013.
15. Savall, J., A. Avello, and L. Briones. *Two compact robots for remote inspection of hazardous areas in nuclear power plants*. in *Proceedings 1999 IEEE International Conference on Robotics and Automation (Cat. No. 99CH36288C)*. 1999. IEEE.
16. Gu, D. and H. Hu, *Receding horizon tracking control of wheeled mobile robots.* IEEE Transactions on control systems technology, 2006. **14**(4): p. 743-749.
17. Hascoet, J.Y., et al. *Shiphull Welding: Trajectory Generation Strategies Using a Retrofit Welding Robot*. in *Materials Science Forum*. 2012. Trans Tech Publ.