

# **C-ARM ROBOT FOR SCANNING APPLICATION**

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NNM22RI031 Murali Krish Karkera

NNM22RI035 Nihal E Praveen

NNM22RI036 P Kaushik

NNM22RI051 Shaikh Aizaz Badar

NNM22RI062 Suhan Mohan Puthran

**Department of Robotics and Artificial Intelligence**

# INTRODUCTION

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- **C-arm geometry** – C-shaped frame carrying an imaging device, sensor, or tool.
- **Actuated motion** – precision motors provide controlled rotation or translation.
- **Wide workspace** – reaches many angles without moving the subject.
- **Applications** – used in medical imaging (X-ray, fluoroscopy) and industrial inspection.
- **Accuracy & repeatability** – robotic control gives smooth, precise positioning.
- **Workflow efficiency** – compact, open design speeds access and imaging tasks.



# PURPOSE AND USE OF C-ARM ROBOT

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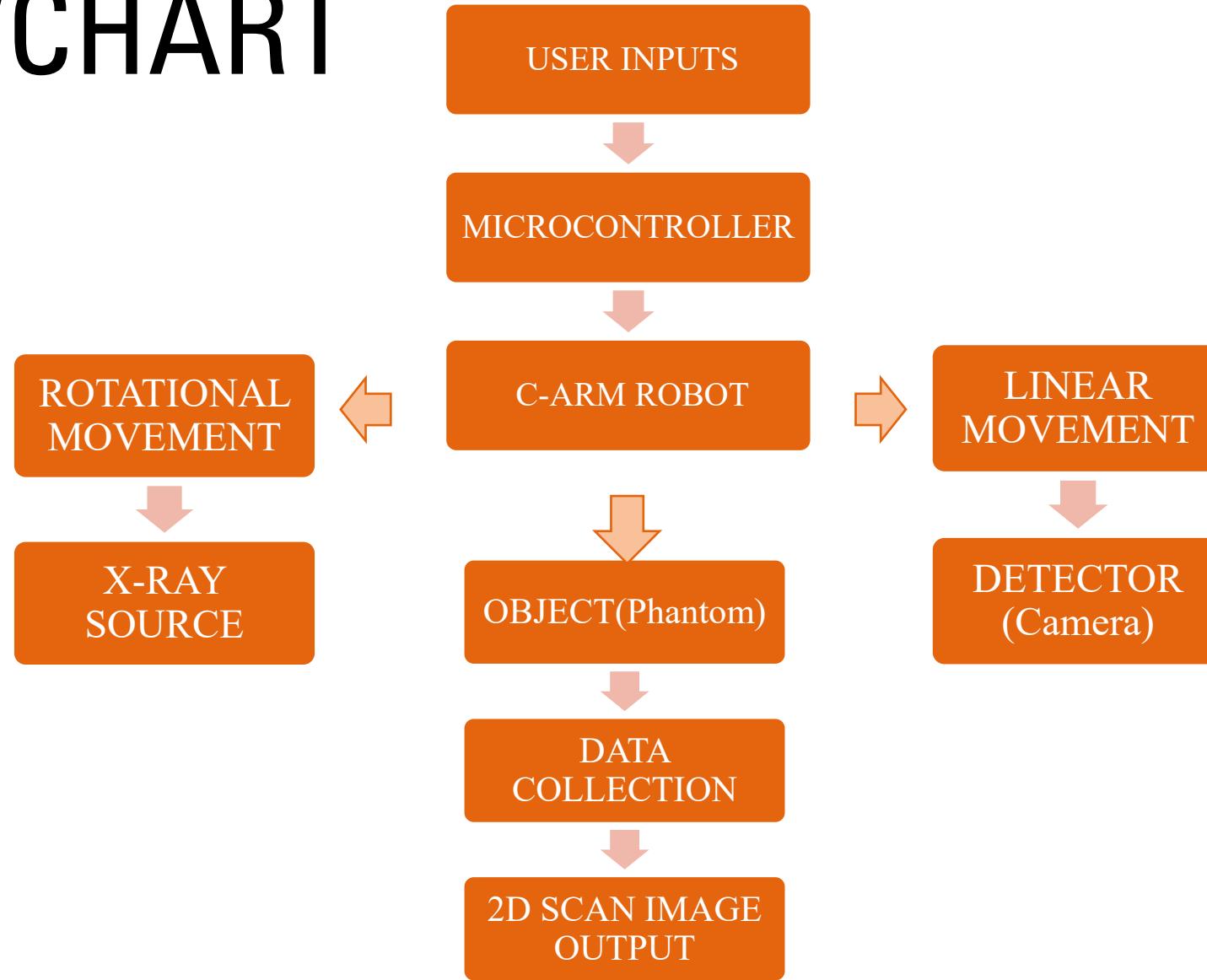
- To take live X-ray images during surgeries
- To help doctors see inside the body without big cuts or moving the patient.
- To be used in bone, heart, and emergency surgeries.
- To give clear images that guide doctors in placing tools and implants.
- To reduce radiation exposure using advanced technology.
- To make medical procedures faster and more accurate with real-time images.

# WORKING OF C-ARM ROBOT

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- The user inputs the **scan parameters** (like how many angles to scan and step size).
- The **microcontroller** calculates the movement needed using **kinematic equations**.
- The robot moves the **C-Arm structure** in two ways:
  - Rotational Movement (around the object)** → To scan from different angles.
  - Linear Movement (along the arm)** → To cover different sections of the object.
- At each step:
  - The **simulated X-ray source (LED)** shines light through the object.
  - The **simulated detector (photodiode or camera)** records the light intensity.
- The data collected at different positions is stored.
- Finally, a **simple 2D image is created** by combining all the recorded data, showing a projection of the object.

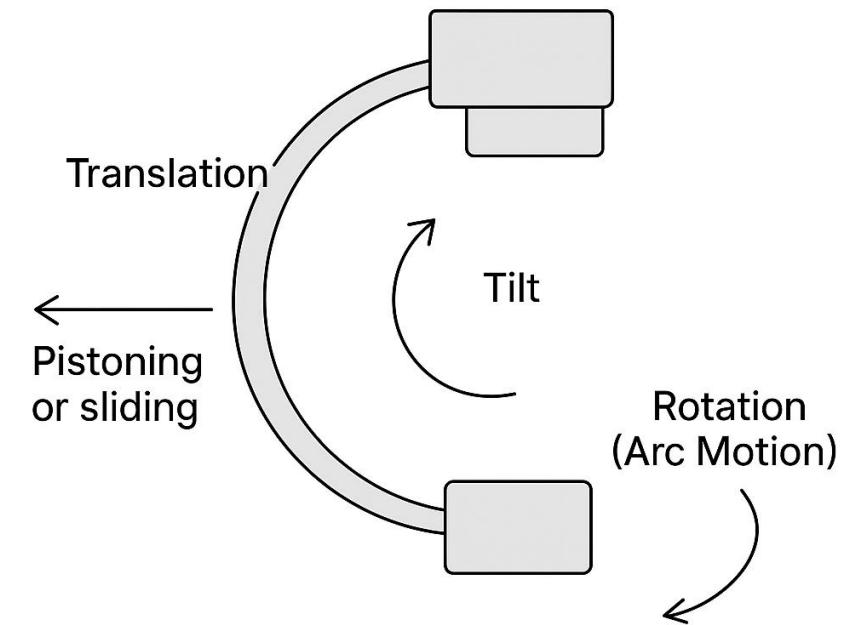
# FLOWCHART



# METHODOLOGY

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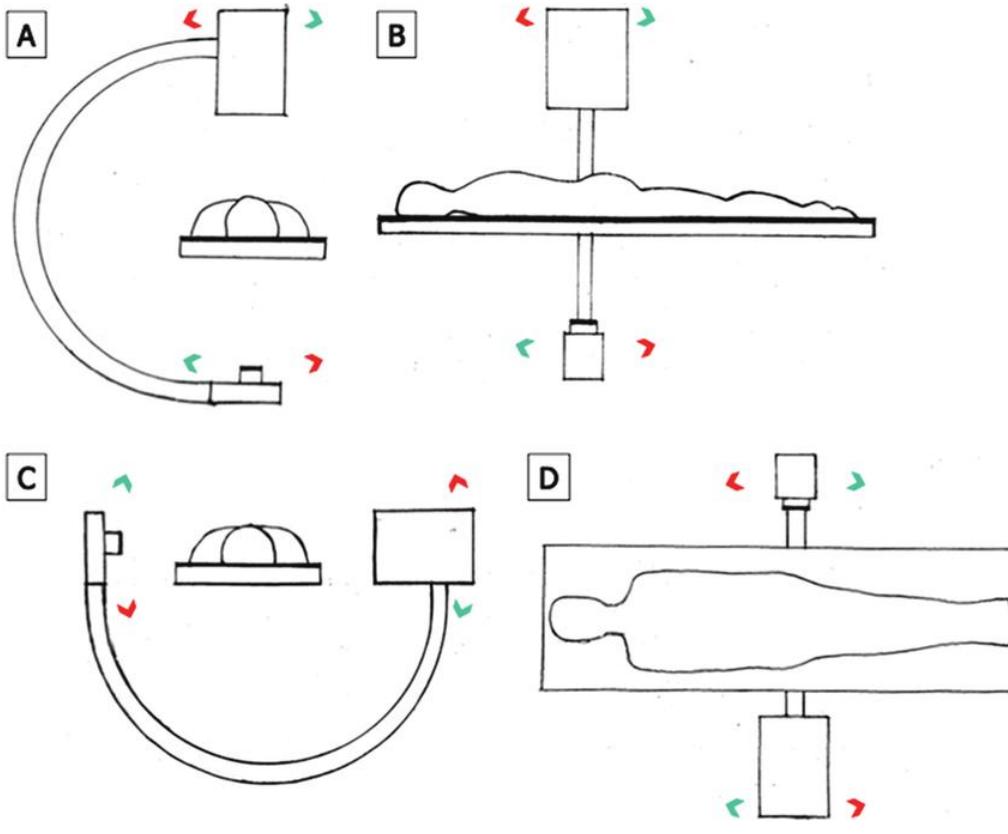
Movement	Visual Label in Diagram	Description
Translation (Pistoning)	Arrow showing in-and-out movement	Linear shift of the C-arm toward or away from the patient.
Tilt	Arrow indicating tilt along transverse axis	Angling the arm cephalad or caudal to align with anatomy.
Rotation (Arc)	Curved arrow around the patient	Circular sweep for multi-angle imaging or 3D scans.



**Elementary axes of C-arm rotation**

# METHODOLOGY

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## 1. Requirement Analysis

- Identify scanning application and imaging simulation needs.
- Define motions: rotation around object + linear translation.

## 2. System Planning

- Control Platform using micro controllers
- Selecting actuators (stepper motors) for two motions.

## 3. Control Algorithm Development

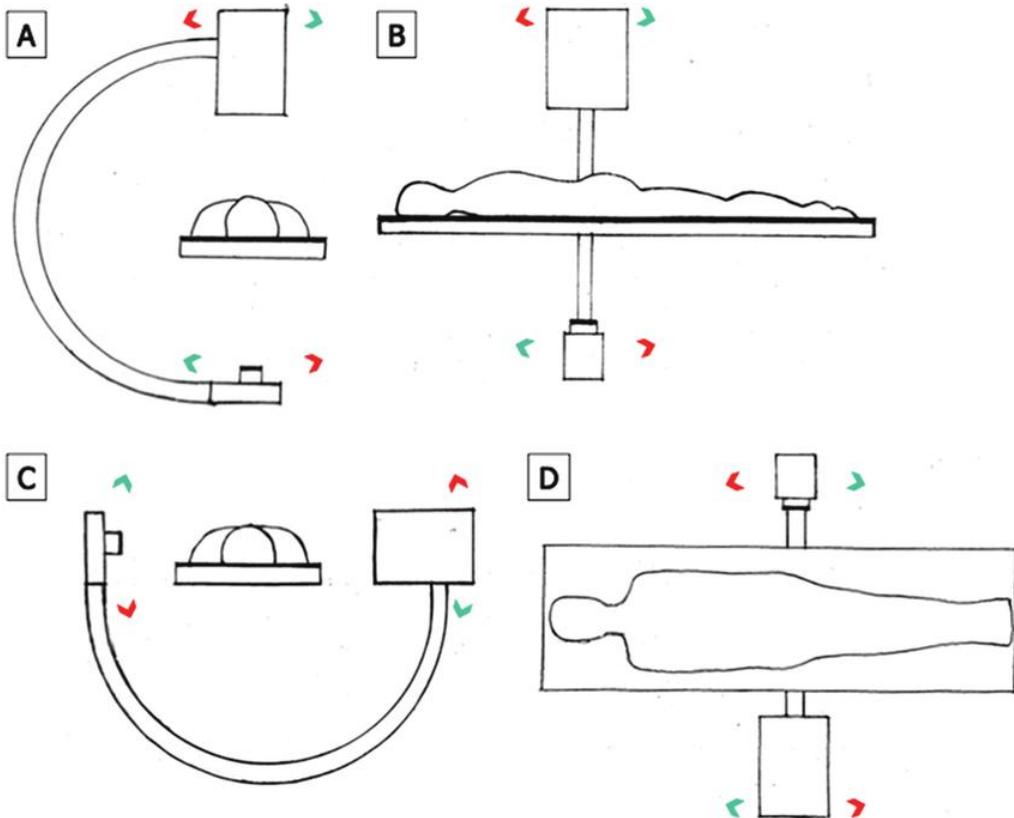
- Writing code for motion planning using kinematic equations.
- Mapping user inputs (angle, step size) into robot movements.

## 4. Prototype Development

- Build basic C-Arm structure using available mechanical components

# METHODOLOGY

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## 5. Safety & Testing

- Simulate motion limits to avoid collisions.
- Test system under different scanning scenarios (speed, step size, object positions).

## 6. Calibration & Optimization

- Calibrate motion accuracy of the arm (angle and linear steps).
- Optimize exposure or sensor sensitivity for better signal detection.

## 7. Data Acquisition & Processing

- Collecting light intensity values at each position.
- Store readings on PC.

## 8. Image Formation & Validation

- Combine collected data to reconstruct a simple 2D projection.
- Validate system performance against expected scan pattern.

# NEMA 42 STEPPER MOTOR

- The NEMA 42 stepper motor is a large, high-torque motor commonly used in CNC machines, industrial automation, and heavy-load robotics.
- It has a 4.2 × 4.2-inch frame, a 1.8° step angle, and typically operates at 3–6 V with 4–8 A per phase.
- Known for delivering very high holding torque (10–30Nm) and accurate positioning, it performs best with high-current micro stepping drivers. Although bulky and power-hungry, it is ideal for applications requiring strong, precise, and reliable motion control.



# LINEAR GUIDE ACTUATOR

- A linear guide actuator is a precision motion device used to move loads smoothly and accurately along a straight path.
- It typically consists of a linear rail, a guided carriage, and a drive mechanism such as a ball screw, belt, or linear motor.
- Linear actuators offer high rigidity, low friction, and excellent repeatability, making them ideal for CNC machines, automation systems, robotics, and material handling.
- They ensure stable motion even under heavy loads and are widely used wherever controlled, reliable linear movement is required



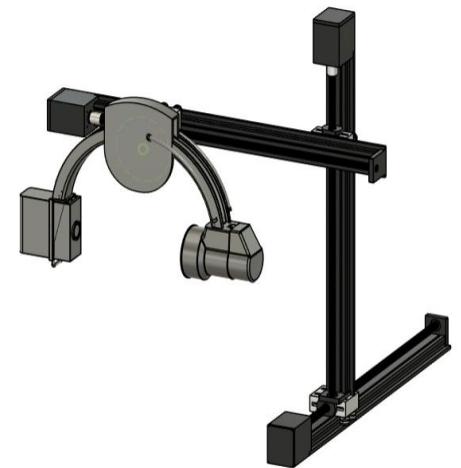
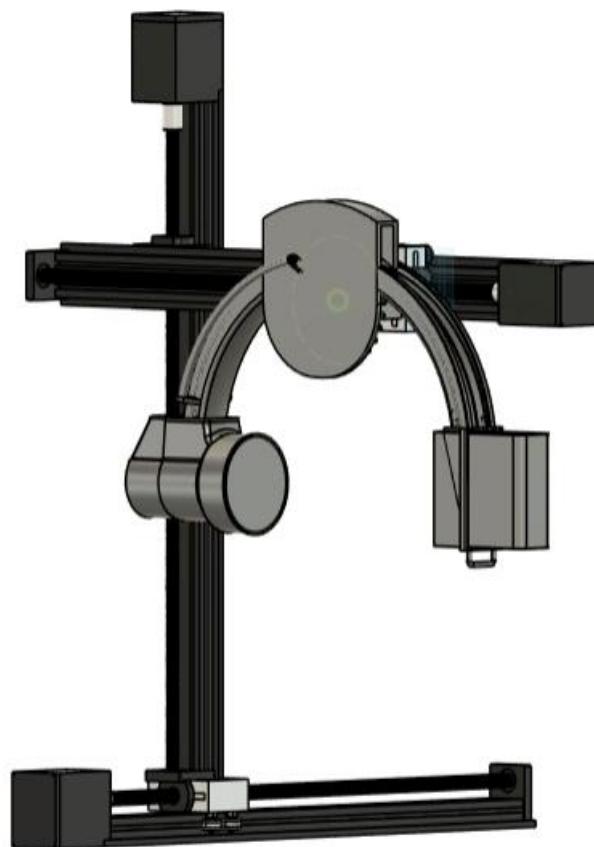
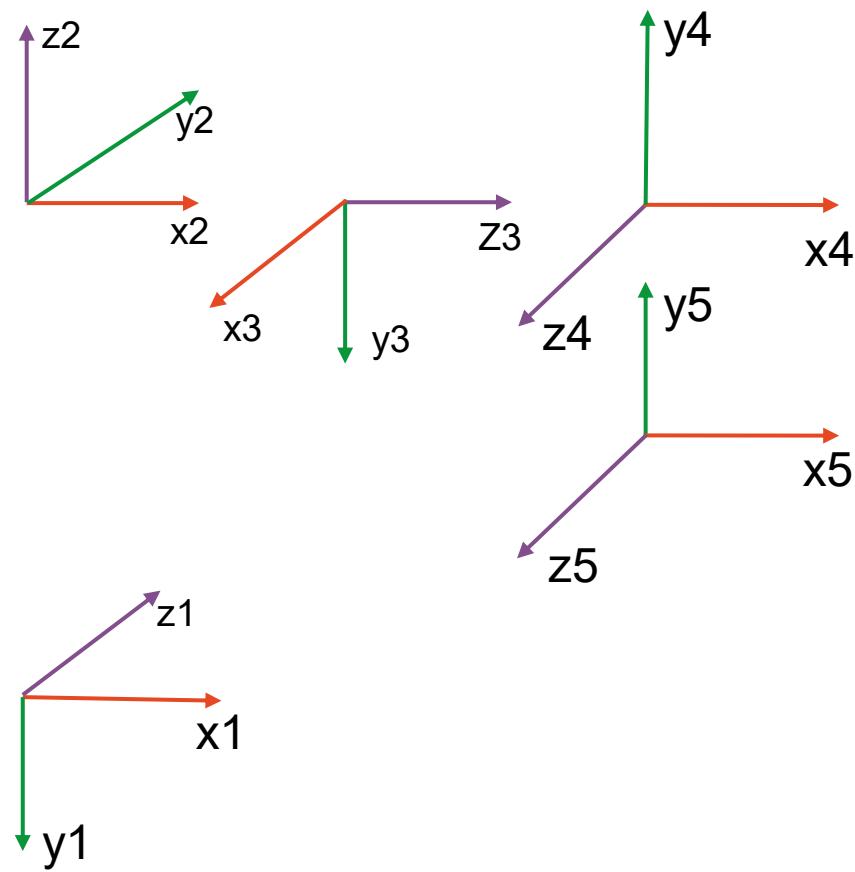
# RACK AND PINION

- A rack and pinion is a simple mechanical system used to convert rotational motion into linear motion.
- It consists of a circular gear (pinion) that meshes with a straight toothed bar (rack). When the pinion rotates, it moves the rack smoothly in a straight line.
- This mechanism is known for its high efficiency, precise control, and ability to handle large forces.
- It is commonly used in steering systems, CNC machines, linear actuators, and industrial automation where accurate and reliable linear motion is needed.



# FORWARD AND INVERSE KINEMATICS EQUATIONS

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# FORWARD AND INVERSE KINEMATICS EQUATIONS

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D-H Parameters:

Links	Theta	D	A	Alpha
1	0	d2	0	90
2	0	d3	0	-90
3	Theta3+90	z	0	90
4	Theta4	0	a4	0

# FORWARD AND INVERSE KINEMATICS EQUATIONS

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For each Link  $i$ :

Let

$$C_{\theta i} = \cos \theta_i, S_{\theta i} = \sin \theta_i$$

$${}_{i-1}T_i = \begin{bmatrix} C_{\theta i} & -S_{\theta i}C_{\alpha i} & S_{\theta i}S_{\alpha i} & a_i C_{\theta} \\ S_{\theta i} & C_{\theta i}C_{\alpha i} & -C_{\theta i}S_{\alpha i} & a_i S_{\theta} \\ 0 & S_{\alpha i} & C_{\alpha i} & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

# FORWARD AND INVERSE KINEMATICS EQUATIONS

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**Link 1:**  $\theta_1=0$ ,  $d_1=d_2$ ,  $a_1=0$ ,  $\alpha_1=90^\circ$

**Link 2:**  $\theta_2=0$ ,  $d_2=d_3$ ,  $a_2=0$ ,  $\alpha_2=-90^\circ$

$${}^0\mathbf{T}_1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^1\mathbf{T}_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

# FORWARD AND INVERSE KINEMATICS EQUATIONS

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Link 3:  $\theta_3 = \theta_3 + 90^\circ, d_3 = 0, a_3 = 0, \alpha_3 = 90^\circ$

Link 4:  $\theta_4 = \theta_4, d_4 = 0, a_4 = a_4, \alpha_4 = 0^\circ$

$$2T3 = \begin{bmatrix} C(\theta_3+90) & 0 & S(\theta_3+90) & 0 \\ S(\theta_3+90) & 0 & -C(\theta_3+90) & 0 \\ 0 & 1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$3T4 = \begin{bmatrix} C\theta_4 & -S\theta_4 & 0 & a_4 C\theta_4 \\ S\theta_4 & C\theta_4 & 0 & a_4 S\theta_4 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$OT4 = OT1 * 1T2 * 2T3 * 3T4$$

# FORWARD AND INVERSE KINEMATICS EQUATIONS

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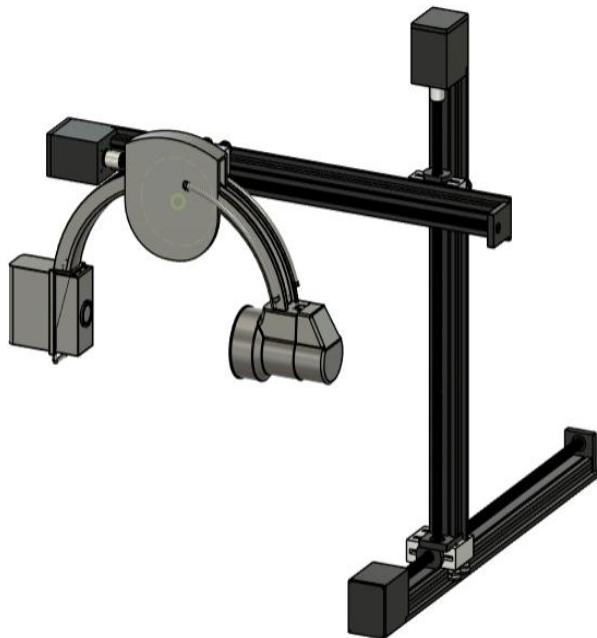
$${}^0T_4 = \begin{bmatrix} -S(\theta_3)C(\theta_4) & S(\theta_3)S(\theta_4) & C\theta_3 & -a_4S(\theta_3)C(\theta_4) \\ C(\theta_3)C(\theta_4) & -S(\theta_3)C(\theta_4) & S\theta_3 & a_4C(\theta_3)C(\theta_4)-d_3 \\ S\theta_4 & C\theta_4 & 0 & a_4S(\theta_4) + d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

# FORWARD AND INVERSE KINEMATICS EQUATIONS

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## Inverse Kinematics Equation

To find the arm rotation angle  $\theta$ , we look at the end-effector position relative to the rotary joint. The arm moves in a circular arc, so the horizontal and vertical offsets give:



$$\theta = \tan^{-1} \left( \frac{Z_{ee} - Z}{X_{ee} - X} \right)$$

This directly gives the angle from the X–Z plane needed for the arm to reach the target point.

# REFERENCES

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- [https://PMC5963391/?utm\\_source=perplexity](https://PMC5963391/?utm_source=perplexity)
- <https://www.tandfonline.com/doi/abs/10.3109/10929080009148898>
- <https://automaticaddison.com/the-ultimate-guide-to-inverse-kinematics-for-6dof-robot-arms/>
- [https://scholar.google.com/scholar?hl=en&as\\_sdt=0%2C5&q=Automatic+C-arm+Positioning+Using+Multi-Functional+User+Interface&btnG=#d=gs\\_qabs&t=1758595373369&u=%23p%3D5e3cUCBHC7oJ](https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Automatic+C-arm+Positioning+Using+Multi-Functional+User+Interface&btnG=#d=gs_qabs&t=1758595373369&u=%23p%3D5e3cUCBHC7oJ)