Introduction to Robotics

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Topics

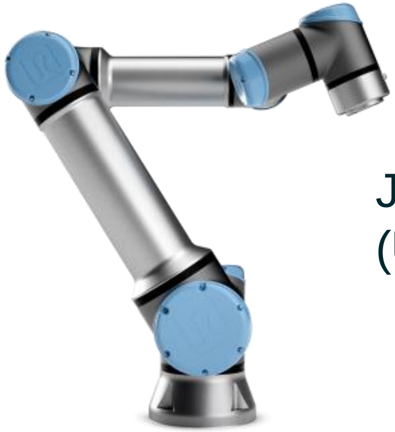
- Common types of industrial robots
- End effectors
- Break
- Modelling concepts
- Introduction to UR robot
- Exercise with UR robot

Common types of industrial robots

- Cartesian
- Jointed arm
- Scara
- Delta

Common types of industrial robots

SCARA robot
(ABB)



Jointed arm
(Universal Robot)

Cartesian robot
(Farmbot)

Delta robot
(Kawasaki)

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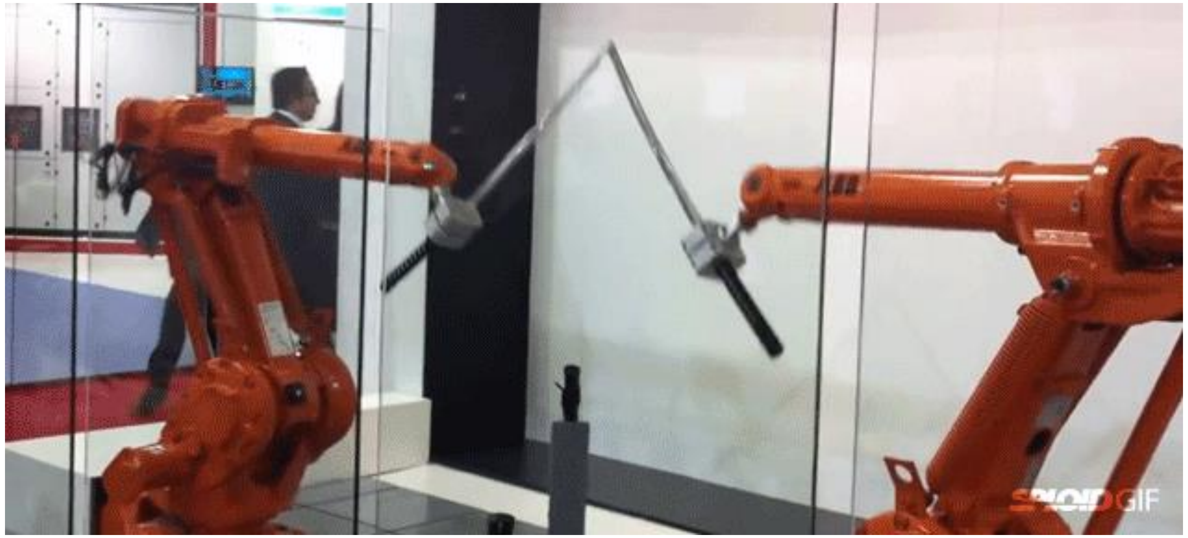
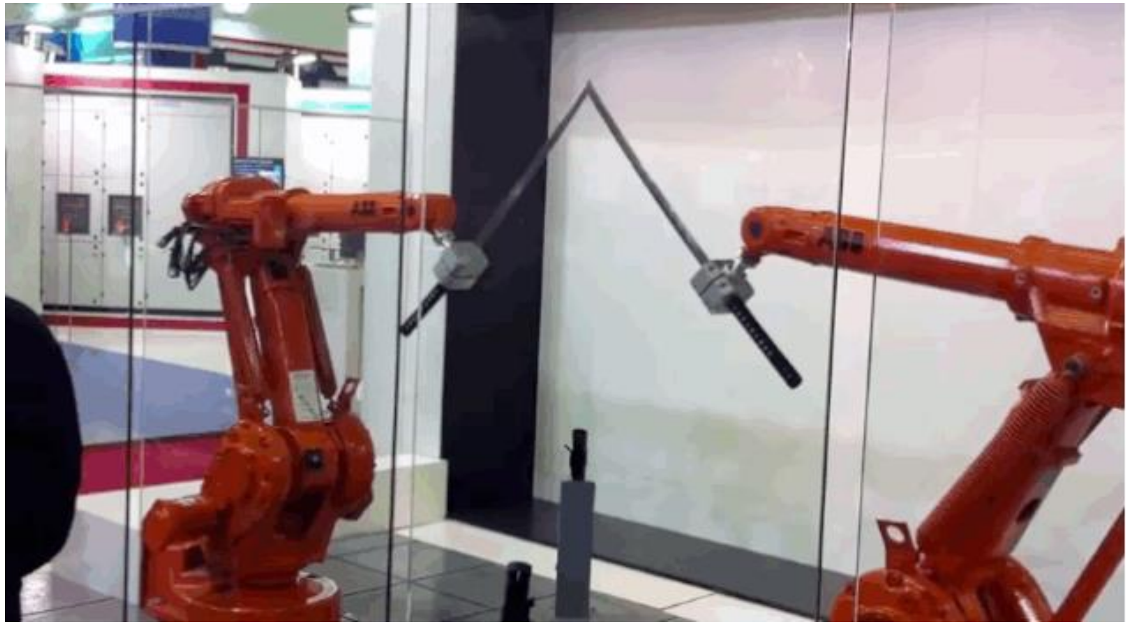
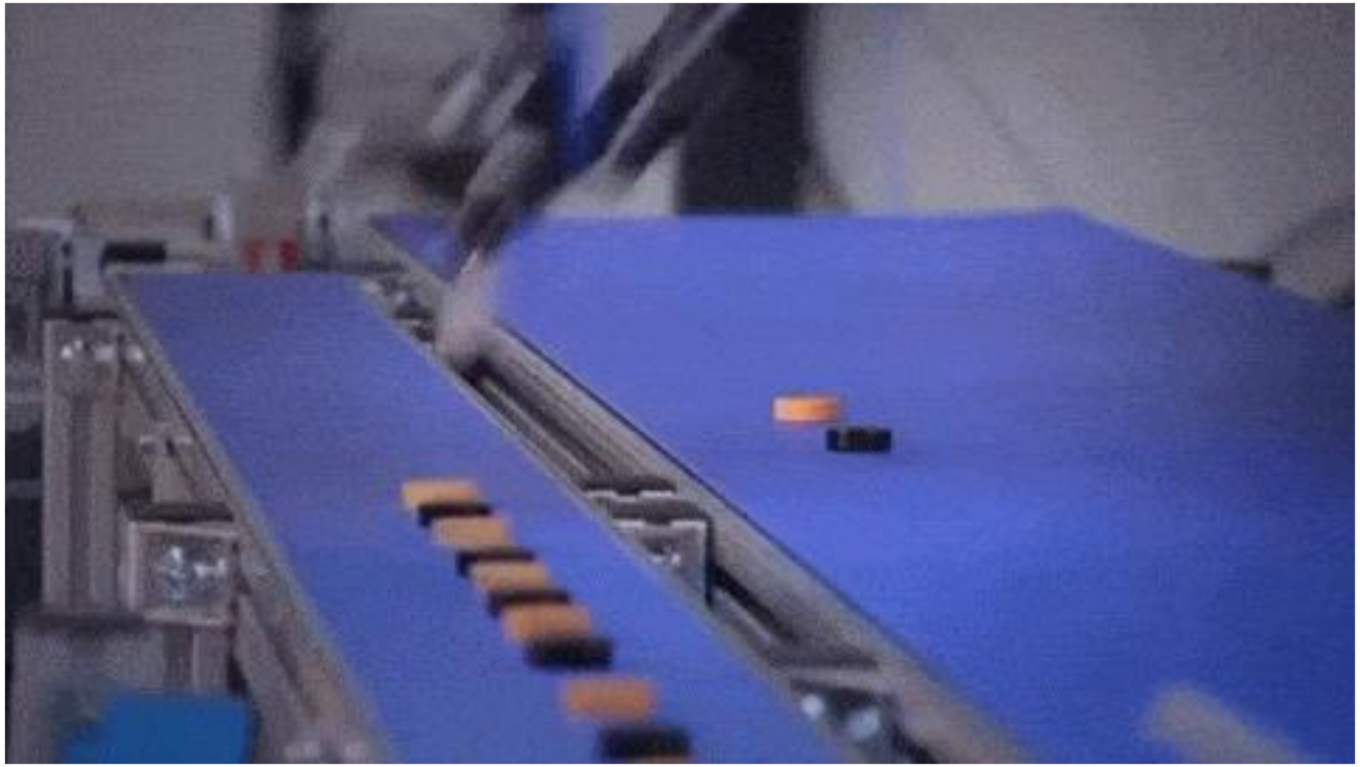
SCARA in action

Jointed arm in action





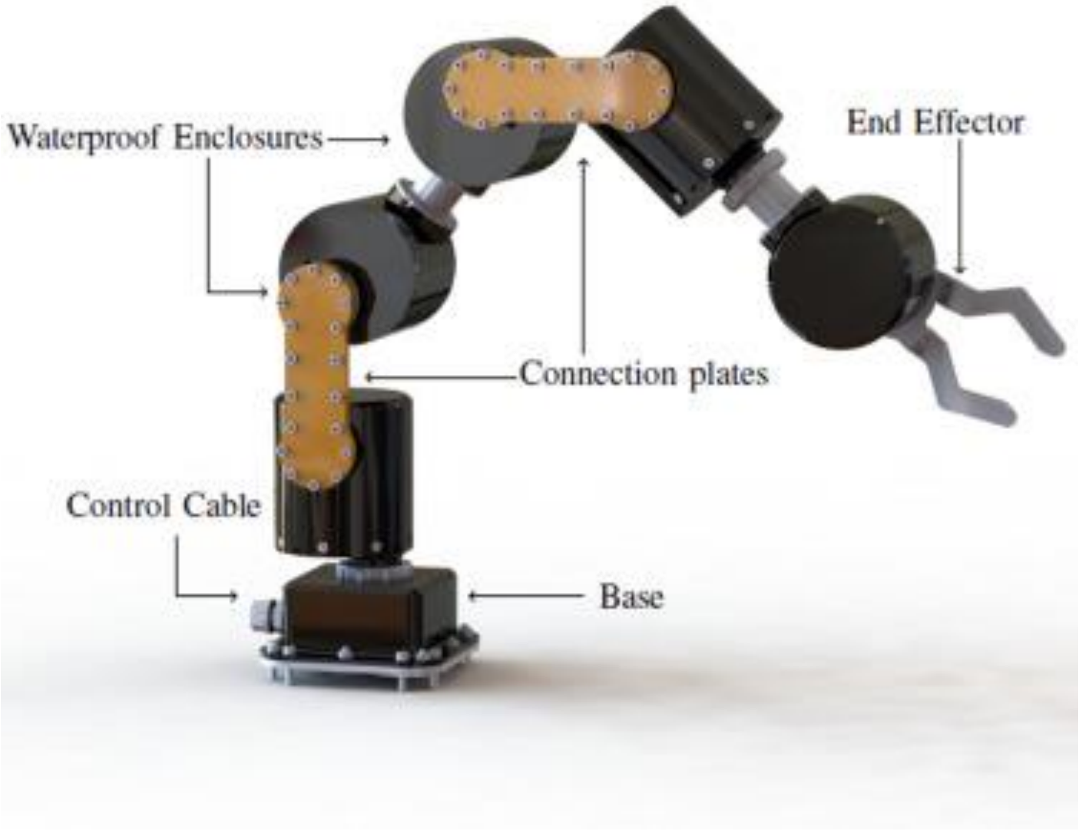
Delta in action



End effectors

- https://onrobot.com/en/products
- Grippers
  - Finger gripper
  - Magnetic gripper
  - Vacuum gripper
  - Soft gripper
- Process tools
  - Welding tool
  - Screwdriver tool
  - Sanding tool
  - Painting tool
- Sensors
  - Visual inspection

End effectors



Grippers

Finger gripper

Vacuum gripper

Soft gripper

Magnetic gripper

https://onrobot.com/en/products

Process tools

Screwdriver

Sanding

Painting

Welding

Robots in action

Sensors – Quality control

https://www.youtube.com/watch?v=PuejIauuP7o&ab_channel=UniversalRobots

Time for a break!

How do we describe something in 3D space?

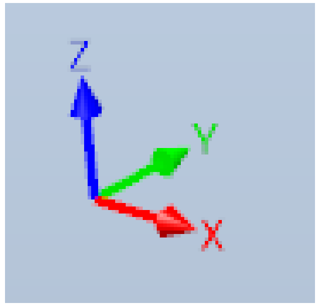
?

Modelling concepts

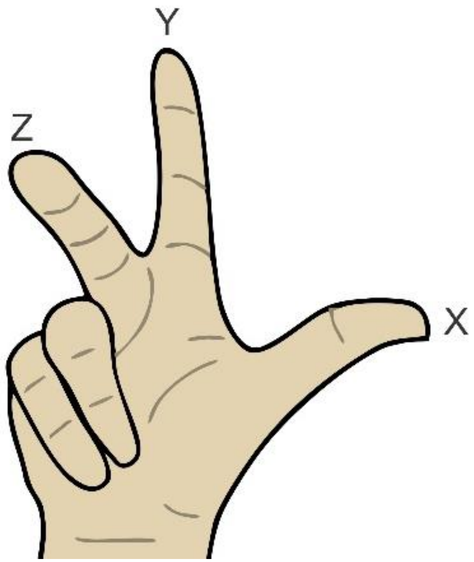
- Coordinate systems
- Frames
- Work space and joint space
- Degrees of Freedom (DoF)
- Kinematics
- Singularities

Coordinate systems

- A 3D coordinate system is described using 3 vectors (illustrated using arrows), XYZ (Red, Green, Blue)



- In most cases we are working in the Euclidean space. This means the vectors are orthogonal unit vectors.
  - Orthogonal means all vectors are perpendicular to all other vectors in the system
  - Unit means the length of the vectors are 1

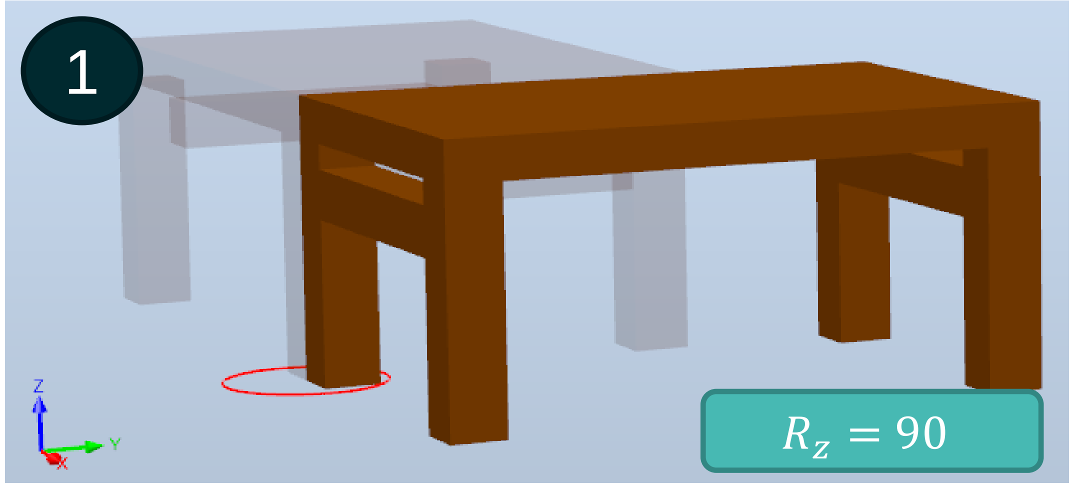


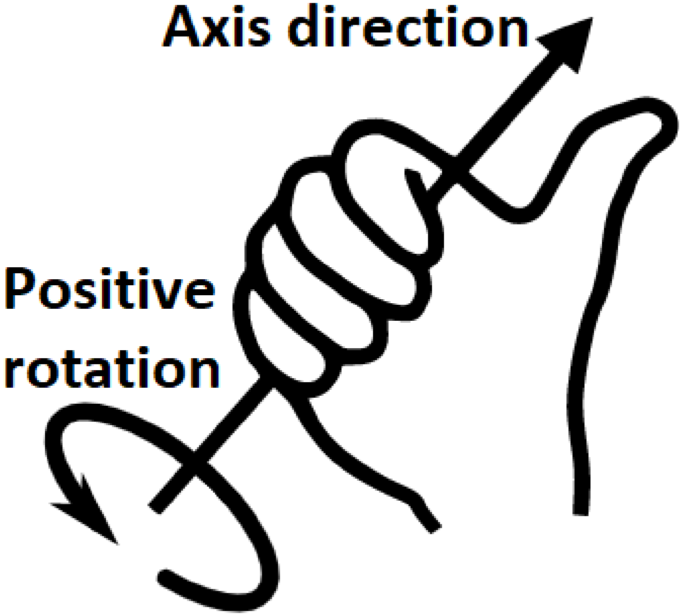
- Right hand rule for what axis is X, Y and Z. This is not a mathematical rule, but an agreement between professionals.

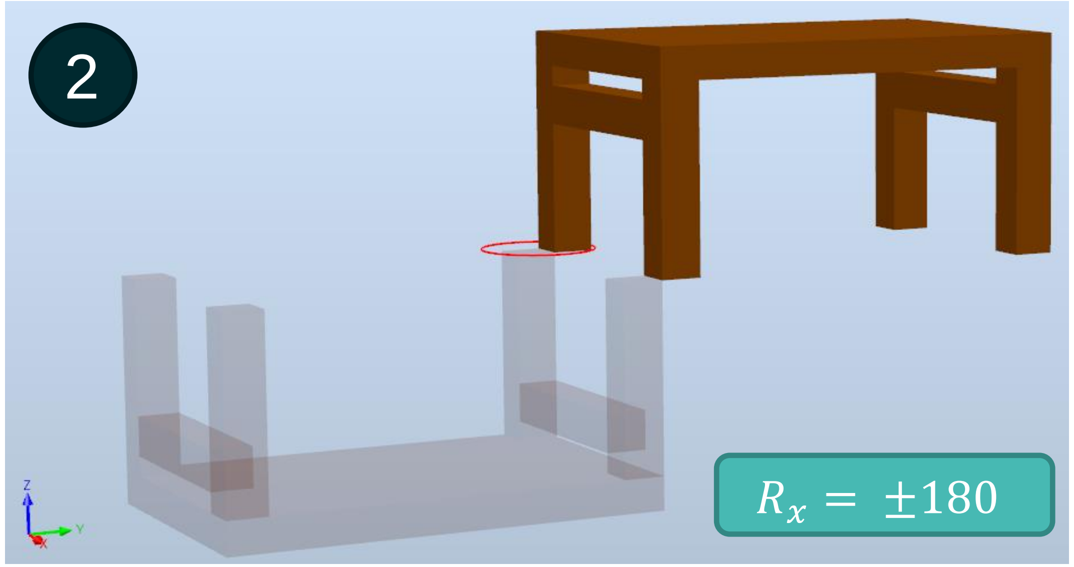
Is position enough to describe something in 3D space?

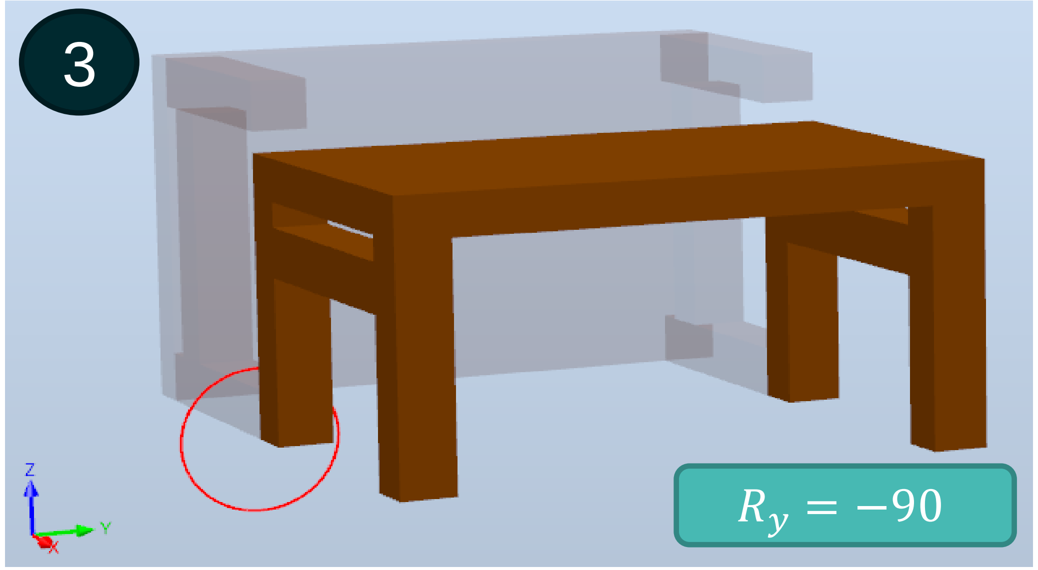
?

Rotation in 3D







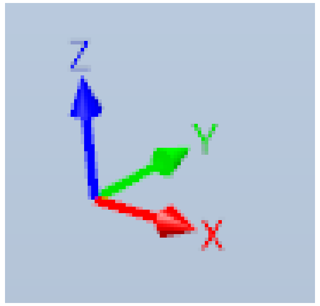


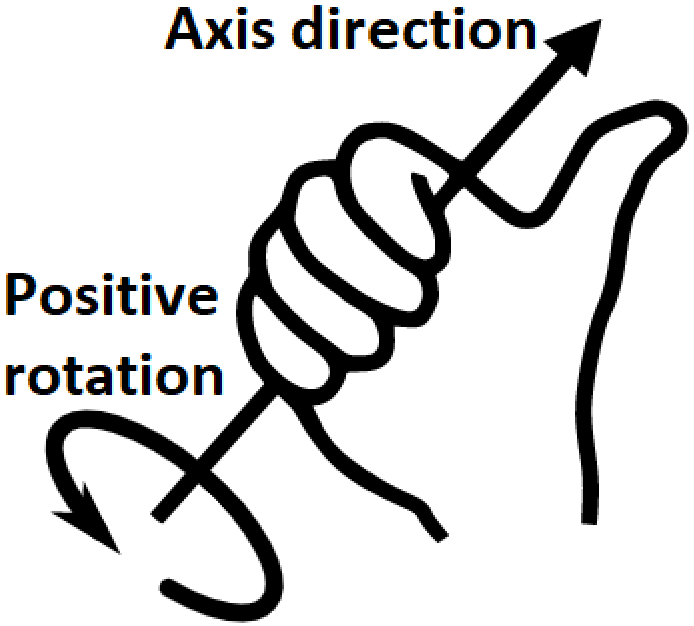
Frames

- A frame is the combination of a translation and a rotation:
  - Translation: $[X, Y, Z]$
  - Rotation: $[R_x, R_y, R_z]$

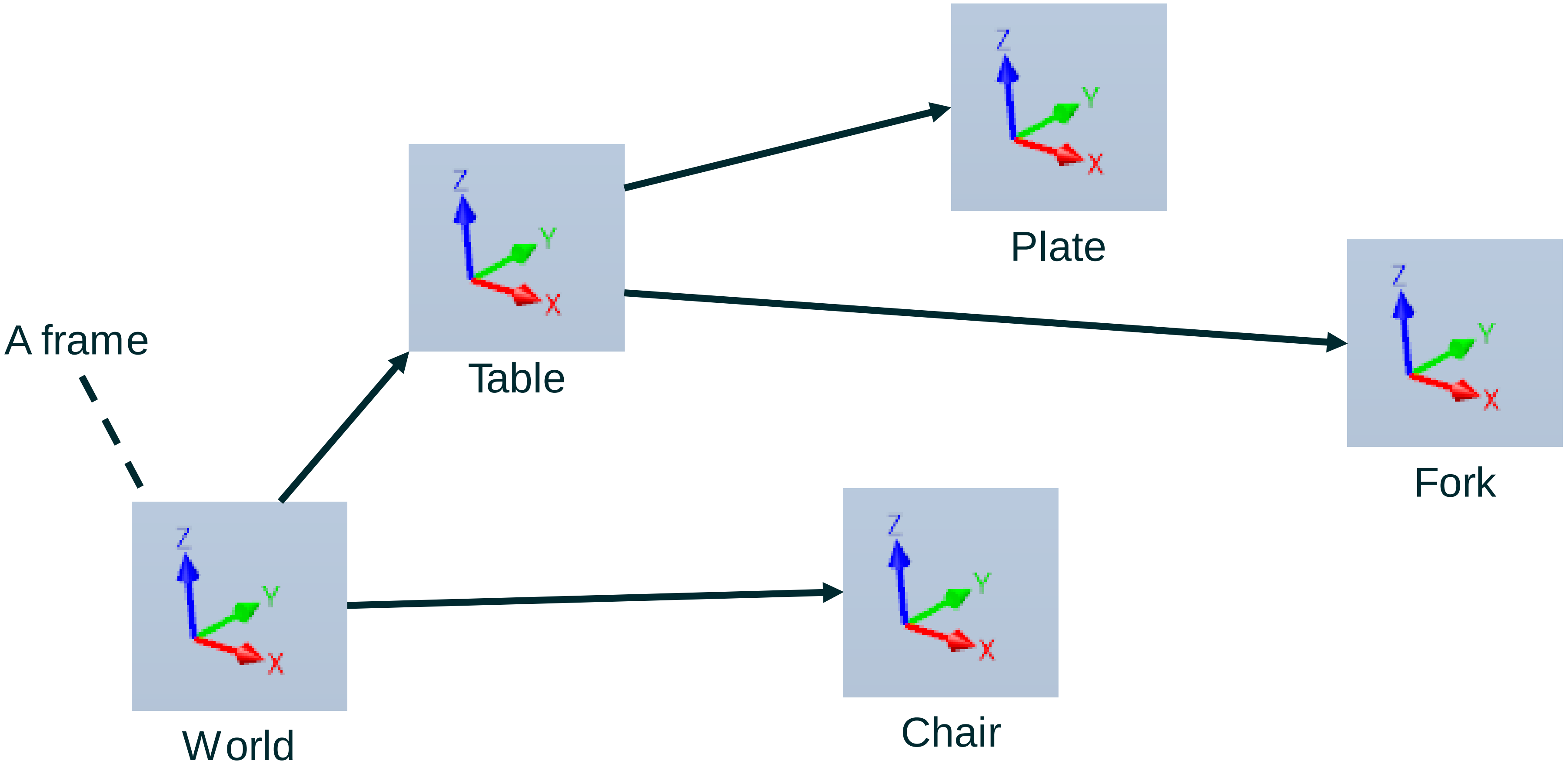
- A frame is composed of 6 values in total:

$$[X, Y, Z, R_x, R_y, R_z]$$



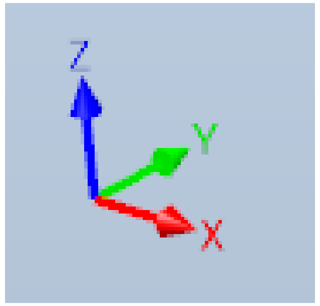


Hierarchy of frames

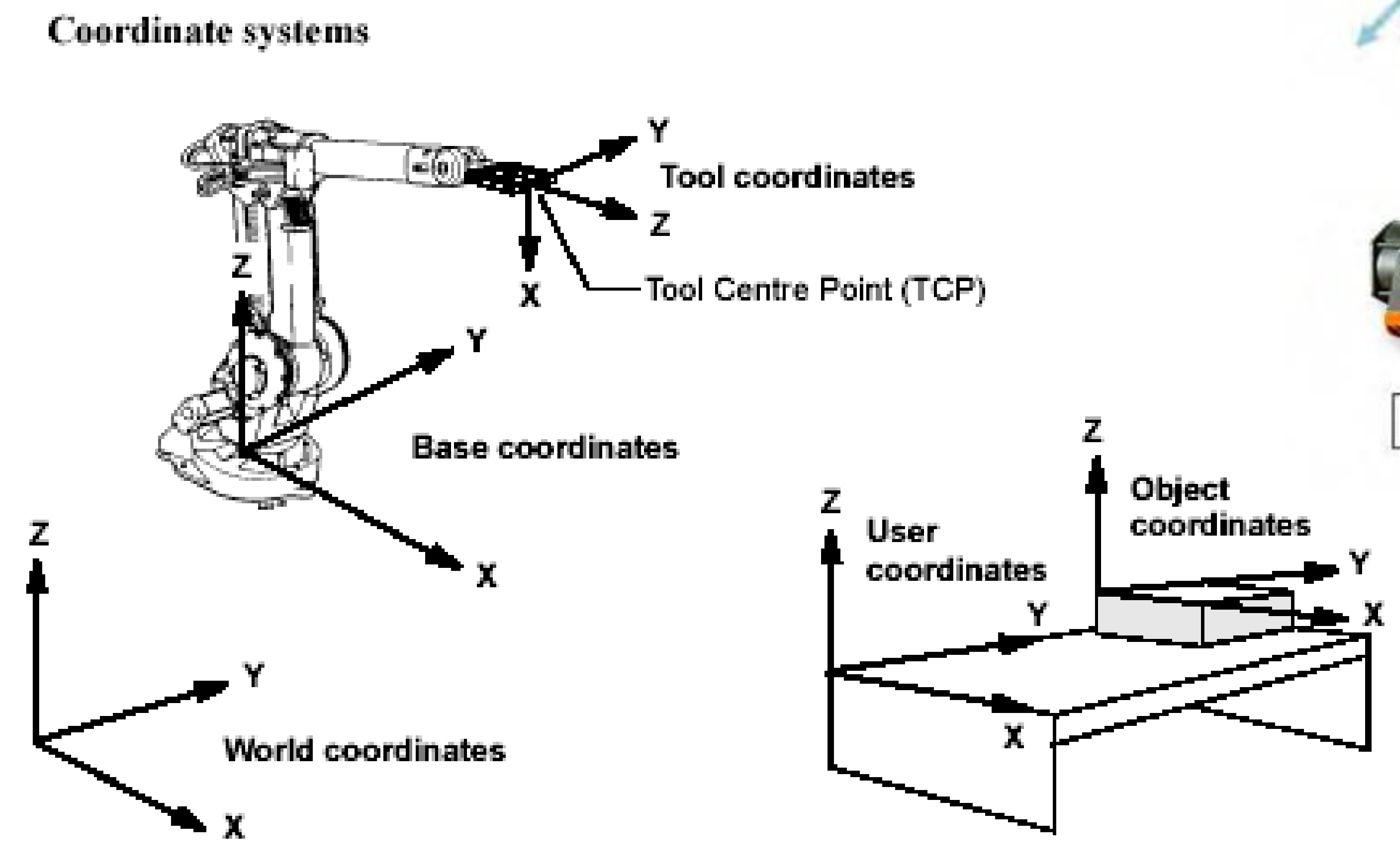


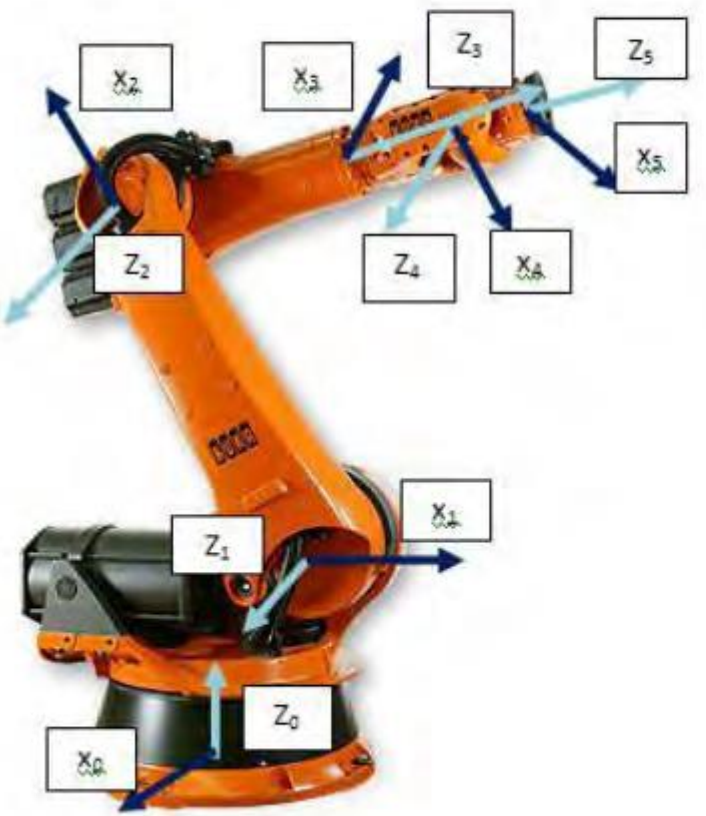
Benefits of using frames in a hierarchy

- Reference
  - It is not possible to define something without a reference
- Flexibility
  - When moving a collection of frames, you only need to move the base frame e.g. table
- Structure
  - The hierarchy is inherently a tree structure, which is a commonly used data structure

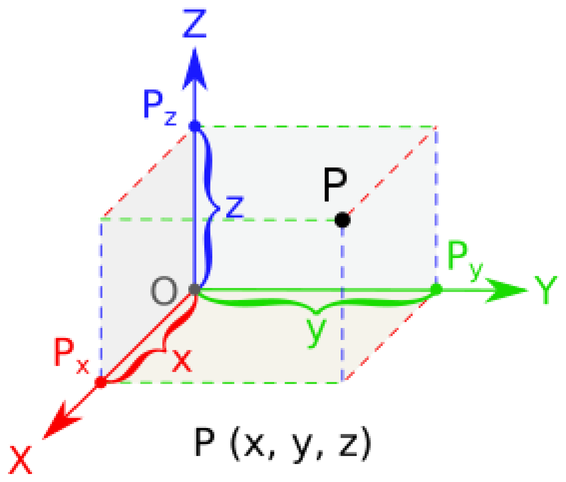


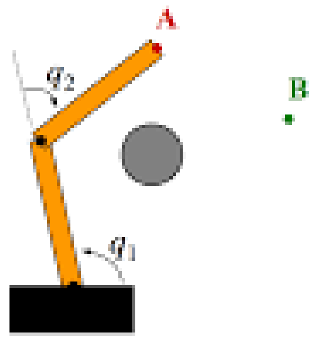
Typical use of frames in robotics



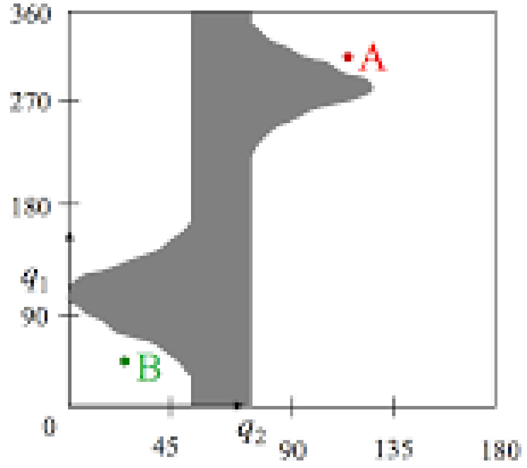


Spaces





An obstacle in the robot's workspace

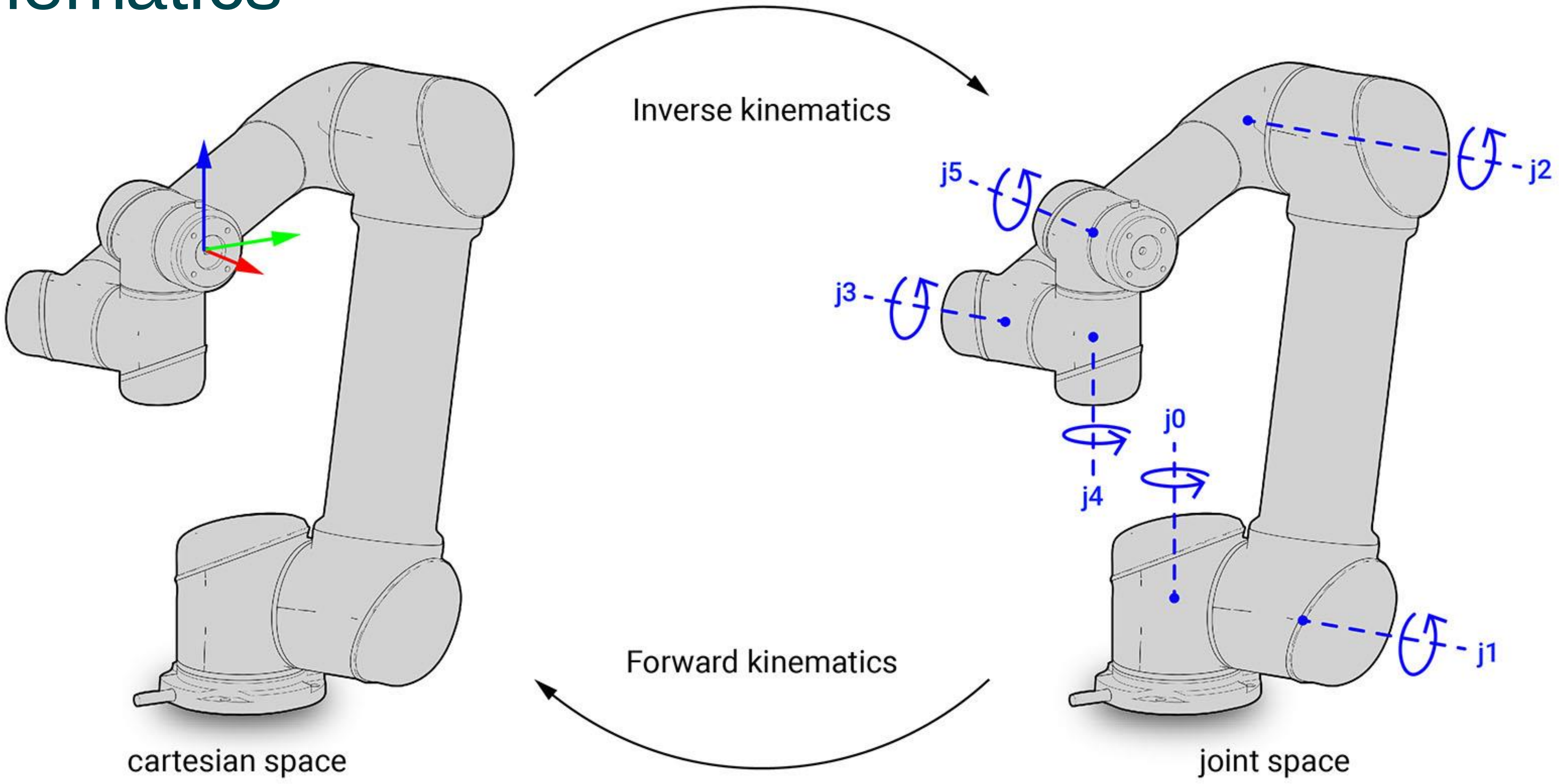


The C-space representation

Cartesian space
(Work space)

Configuration space
(Joint space)

Kinematics


Inverse kinematics
j5
j2
j3
j0
j4
j1
Forward kinematics
cartesian space
joint space

Transforms, forward kinematics

$$A_{Global} = A_1 * A_2 * A_3 * A_4$$

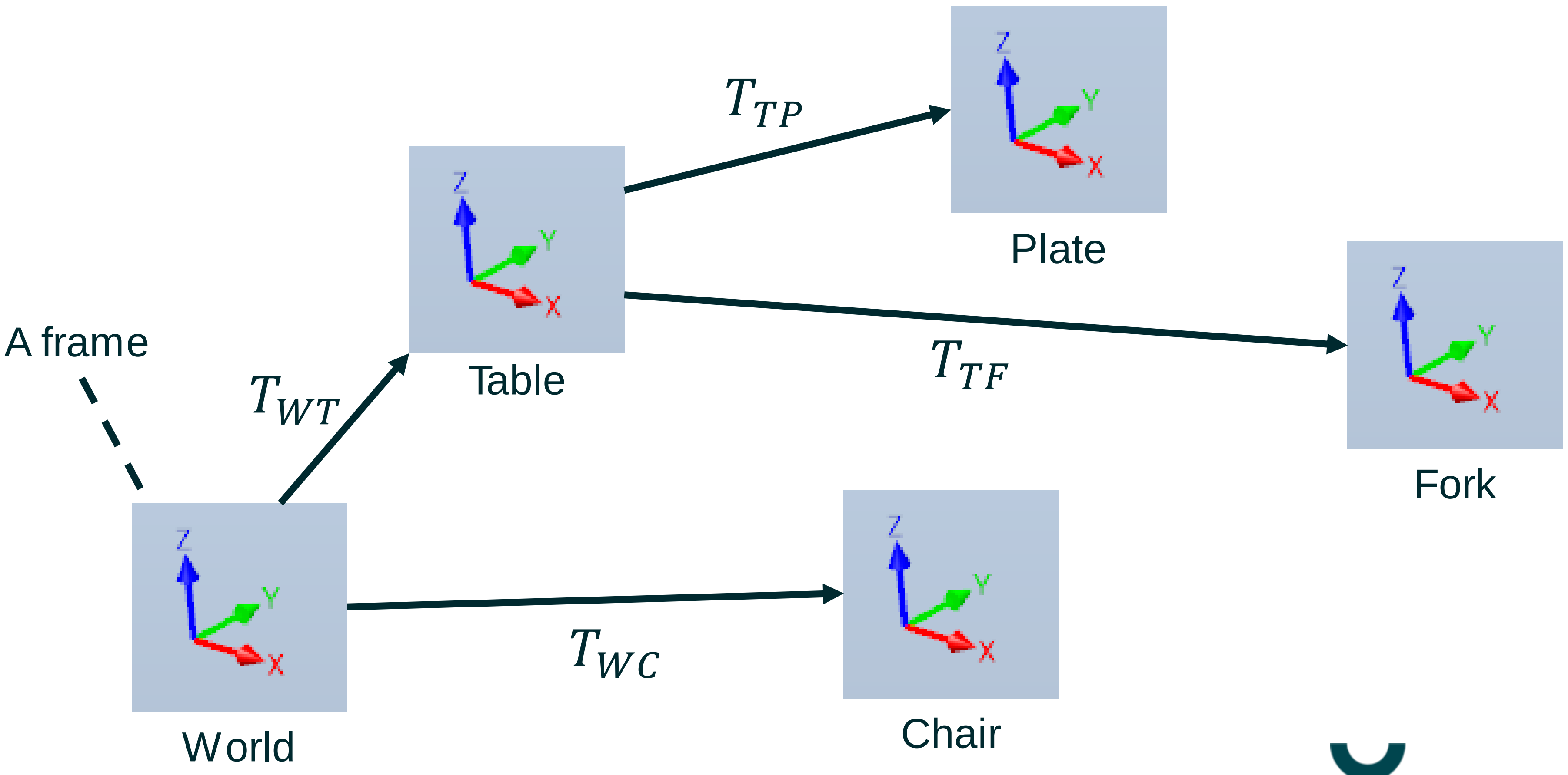
Rotation Matrix

Vector (Origin to Origin)

$$A_{Global} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & O_x \\ r_{21} & r_{22} & r_{23} & O_y \\ r_{31} & r_{32} & r_{33} & O_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Scale

Forward kinematics in action

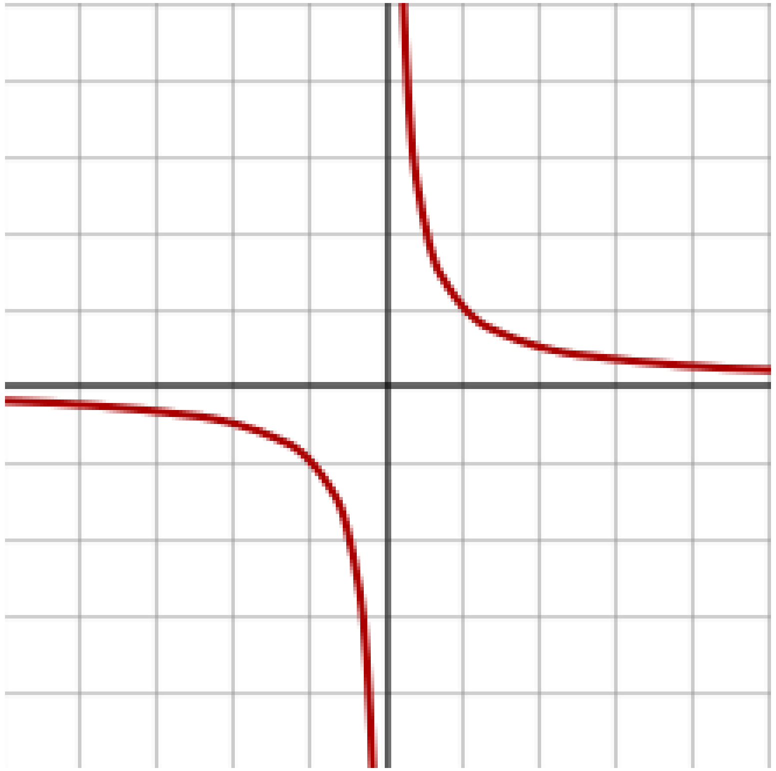


Inverse kinematics

6xn Matrix

$$J=\begin{bmatrix} \frac{fk_x(\Theta_1)-fk_x(\Theta_1+d\Theta)}{d\Theta} & \cdots & \frac{fk_x(\Theta_n)-fk_x(\Theta_n+d\Theta)}{d\Theta} \\ \vdots & \ddots & \vdots \\ \frac{fk_{yw}(\Theta_1)-fk_{yw}(\Theta_1+d\Theta)}{d\Theta} & \cdots & \frac{fk_{yw}(\Theta_n)-fk_{yw}(\Theta_n+d\Theta)}{d\Theta} \end{bmatrix}$$

Singularities



Introduction to UR robot

In lab introduction