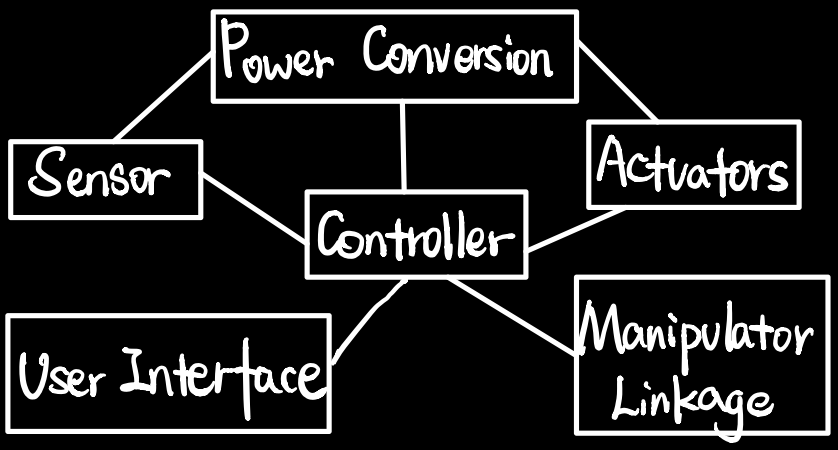
§1. Important Basics

DoF : number of independent movements the robot is capable of
= # of joints for manipulator

- Prismatic Joints : Linear motion along a straight line
- Revolute Joints : Rotational

Mechanical Types Configuration
- Cartesian : PPP >> Gantry Type * 3 prismatic Joints
- Cylindrical : RPP * Rotation + 2 Prismat.
- Spherical : RRP >> SCARA
- Anthropomorphic : RRR * Most common

* Workspace : Reachable space of robots (with orientation)



A Problem of R : Accumulated Error

§2. Manipulator Kinematics

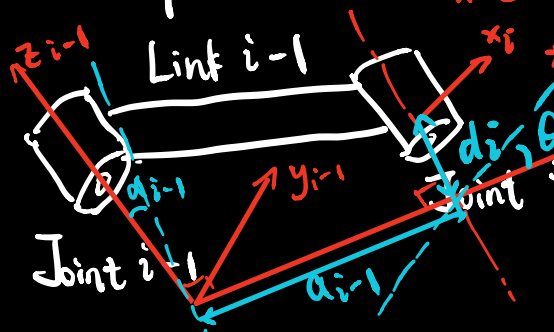
A set of joint variables θ. $\vec{x} = f(\vec{\theta})$ * Forward Kinematics

$\vec{\theta} = f^{-1}(\vec{x})$ * Inverse Kinematics

Rotation & Homogeneous Transformation Matrix

$$ {}^{A}T_{B} = \begin{bmatrix} {}^{A}R_{B} & \vec{p} \\ 0 & 1 \end{bmatrix} $$

- D-H Representation



* z-axis is given by motion direction

* x-axis given by perpendicular line of the 2 axis pointing to i

y is given by x & z

* Last frame's x parallel to the last one

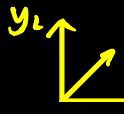
a_{i-1} : distance from z_{i-1} to z_i along x_{i-1}

α_{i-1} : angle from z_{i-1} to z_i about x_{i-1}

d_i : distance from x_{i-1} to x_i along z_i

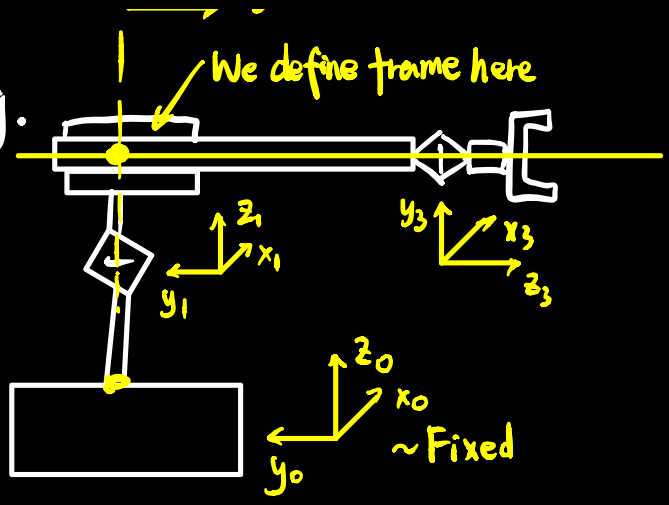
θ_i : angle from x_{i-1} to x_i about z_i

→ D-H Parameters



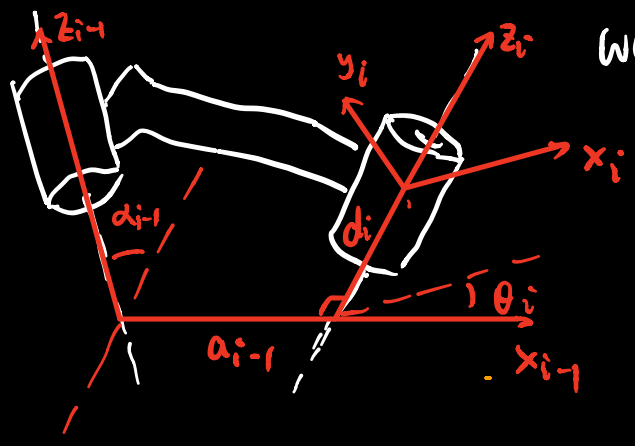
* x can be any where . for convenience here

e.g.



i	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	0	θ_1
2	90°	0	d_2	0
3	0	0	0	θ_3

Transformation between Frames



we can make

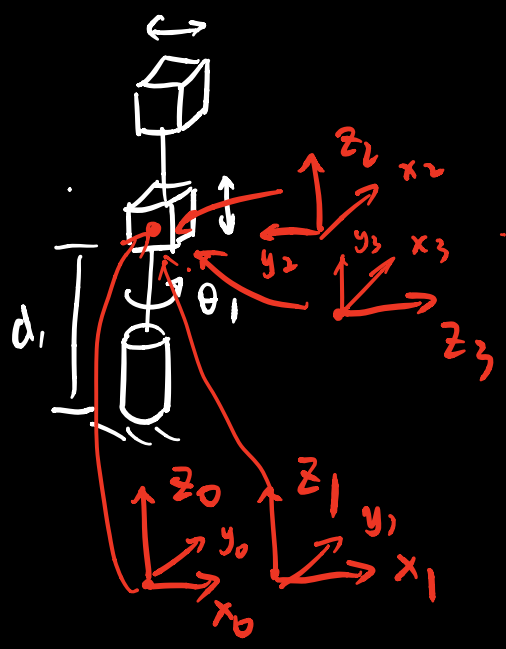
$C_{i-1} = C_i$

By D-H parameters

$$
{}^{i-1}T_i = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C\alpha_{i-1} & -S\alpha_{i-1} & 0 \\ 0 & S\alpha_{i-1} & C\alpha_{i-1} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I & \begin{matrix} a_{i-1} \\ 0 \\ 0 \end{matrix} \\ \begin{matrix} 0 & 0 & 0 \end{matrix} & 1 \end{bmatrix} \begin{bmatrix} C\theta_i & -S\theta_i & 0 & 0 \\ S\theta_i & C\theta_i & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I & \begin{matrix} 0 \\ 0 \\ d_i \end{matrix} \\ 0 & 1 \end{bmatrix}
$$

$$
= \begin{bmatrix} C\theta_i & -S\theta_i & 0 & a_{i-1} \\ S\theta_i C\alpha_{i-1} & C\theta_i C\alpha_{i-1} & -S\alpha_{i-1} & -S\alpha_{i-1} d_i \\ S\theta_i S\alpha_{i-1} & C\theta_i S\alpha_{i-1} & C\alpha_{i-1} & C\alpha_{i-1} d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

* Only 1 Variables here



i	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	0	θ_1
2	0	0	d_2	90°
3	90°	0	d_3	0