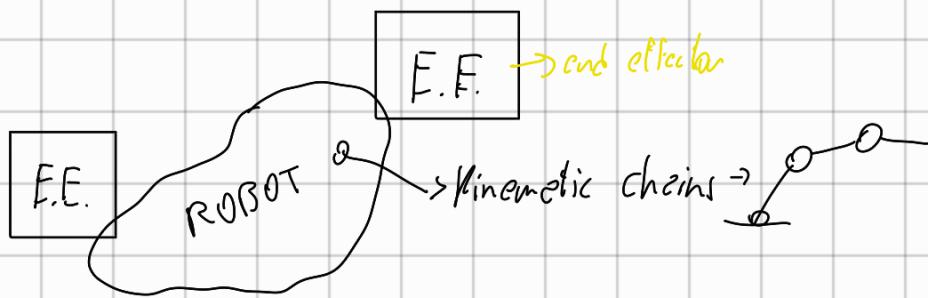


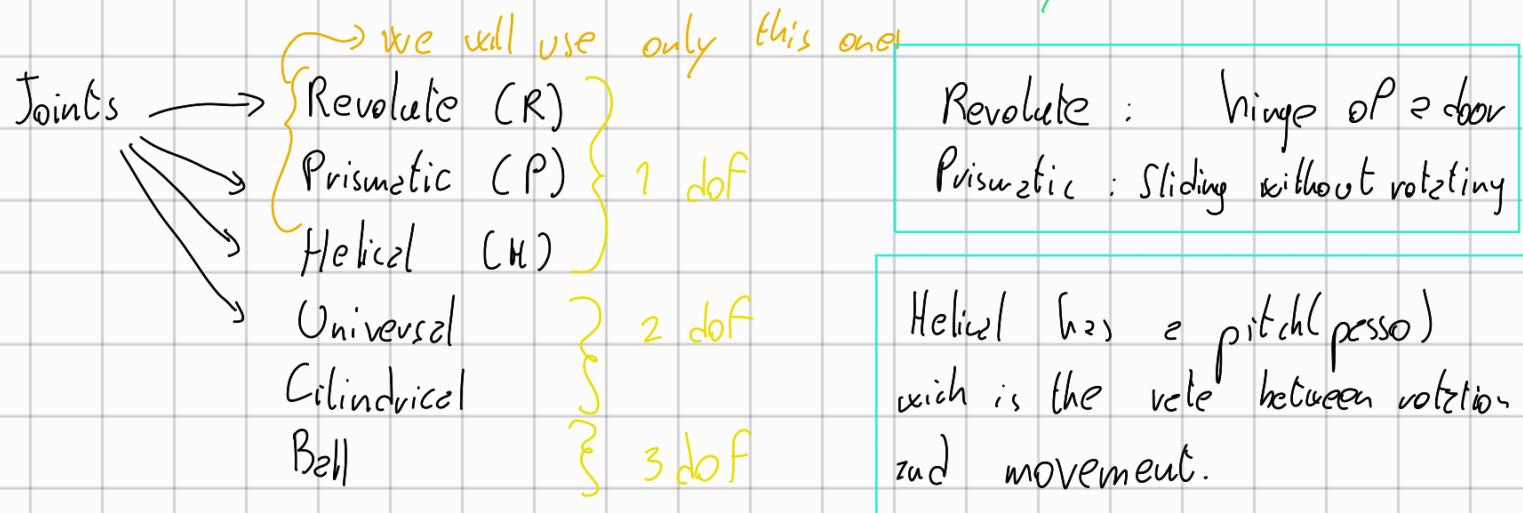
## Constraint:

End effector: part of a robot that interacts with the world. It's moving.

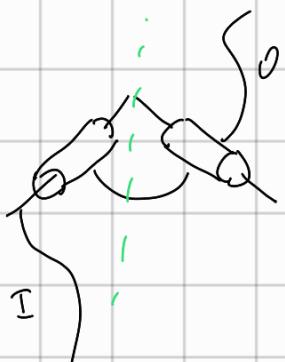


In a mechanism there are bodies (rigid) and joints.

Joint: connection that constrains the motion in a way of another



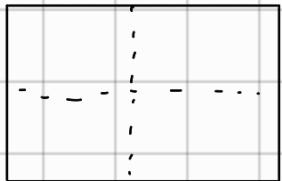
Universal  
Joint



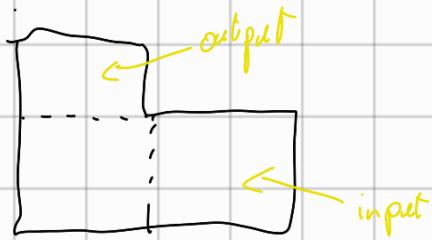
→ combining two revolute joints you get a universal joint. These two joints must not have a 90° degree between them. Only thing that does not allow is rotation.

With combination of revolute and prismatic joints we can make every type of joint.

An example of universal joint is done by folding a piece of paper like this

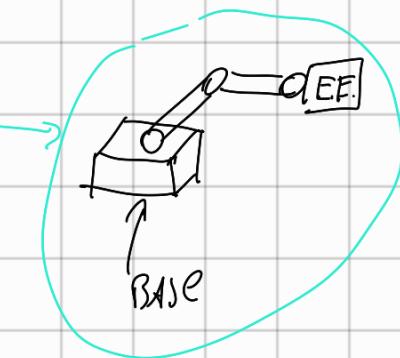
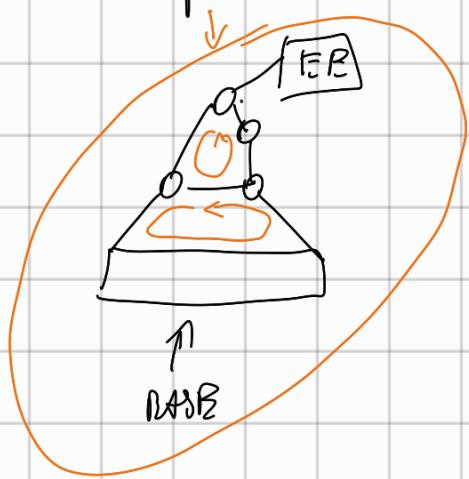


and then cutting one rectangle

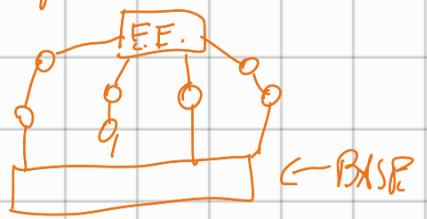


We have different types of Kinematic chains

- ↳ open chains
- ↳ closed-loop chains



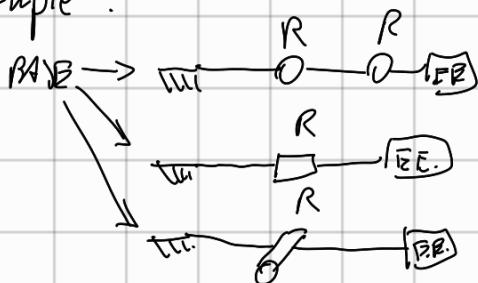
The only type of closed loop chains that will do are purely parallel



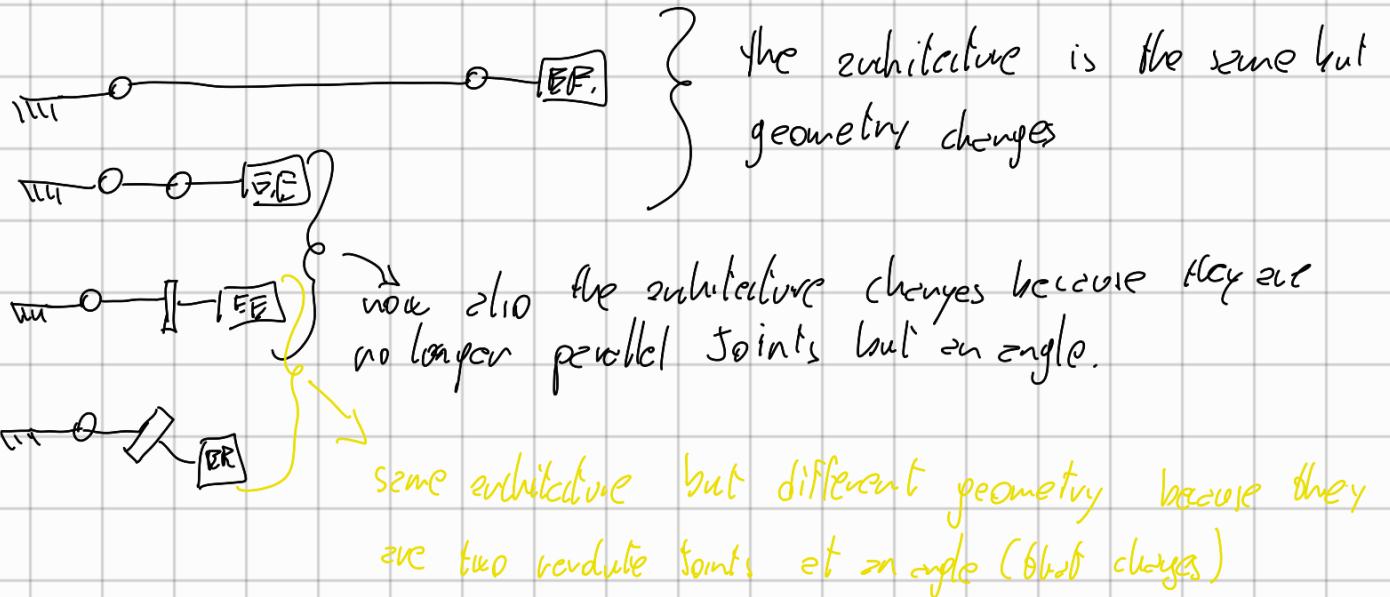
In a mechanism we have:

- architecture: the joints that you have and how they are organized.

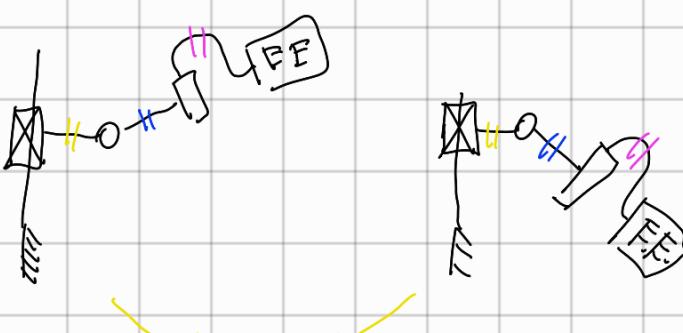
For example :



→ the architecture is two parallel revolute Joint



The prismatic joint is represented like a crossed box  
(In drawings a cross means PdM)

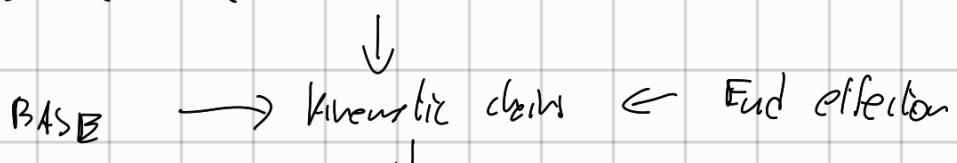


Some architecture ✓

Some geometry ✓

Different configuration ✗

In robots we have mechanisms



they generate every other linkage  
revolut

Soints  
prismatic

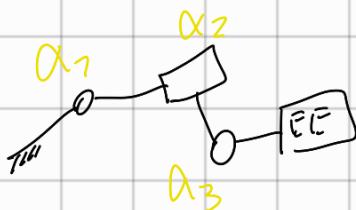
(helical joint)

Architecture: the way the chain is organized.

Geometrical configuration: the particular setting of the chain  
 Configuration: the way the chain is organized in space and can always be modified.

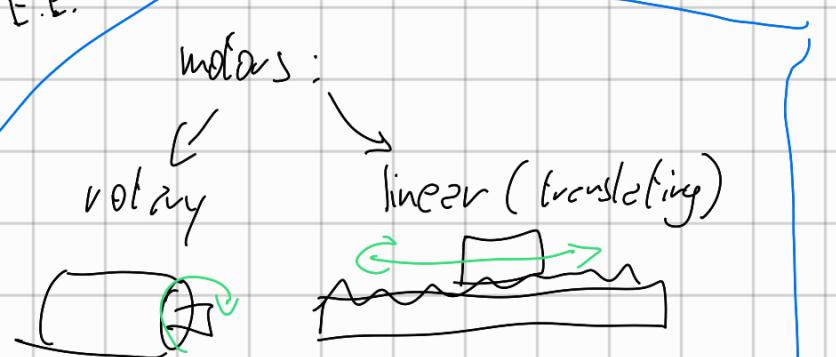
21/09/23

Simple mechanism like open chain.



Problems related to the robotic arm:

- position problem
  - > forward: config param  $\rightarrow$  pose of E.E.
  - > inverse: pose  $\rightarrow$  config parameters



In the motors we have constraint that are limiting the movement of the shaft in only one direction.

With motors we want to force reconfiguration in a mechanism.

$$\begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} = \begin{bmatrix} \frac{\pi}{6} \\ -\frac{\pi}{3} \\ -\frac{2\pi}{3} \end{bmatrix}$$

given these values we are able to calculate everything about the mechanism. This is the forward position problem.

The output of the forward is the univocal representation of the pose of the mechanism. In this case is the position of the end effector.

Euler angles

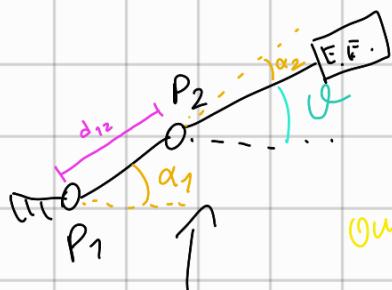


reference frame of the object.

You need the new position of  $O'$  in reference to  $O$  and then you need three angles to describe the rotation of the object

To turn the object you turn in order around each axes in order to reach the final position. So you first turn around  $i'$ , then turn around the new  $k'$  and finally the new new  $j'$

note on Euler angles



This is a planar mechanism because it is on the plane of the board

To provide the pose of the end effector you provide

$$[P_{2x}, P_{2y}, \varphi]$$

this is using Eulerian Places.

$$\varphi = \alpha_1 + \alpha_2$$

$$\begin{aligned} P_{2x} &= d_{12} c_1 \\ P_{2y} &= d_{12} s_1 \\ \varphi &= \alpha_1 + \alpha_2 \end{aligned}$$

FORWARD POSITION KINEMATIC

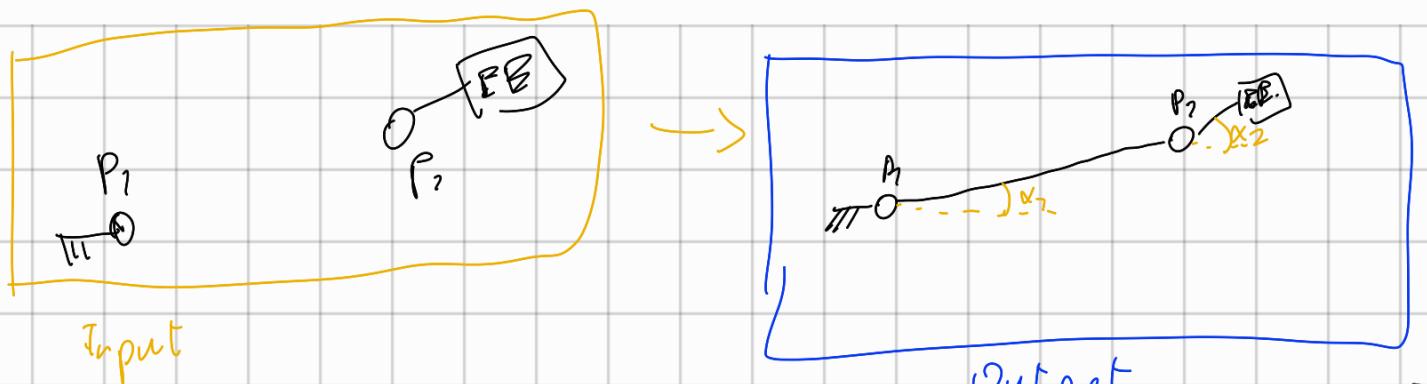
The encoder on  $P_2$  will measure  $\alpha_2$ . Some pose for  $P_1$

that's  $\theta$

You can solve it in an open chain but not always in a closed chain in open form mechanism something : to something.

Inverse position problem

We have the position of the EE and we have to figure out the position of the mechanism.

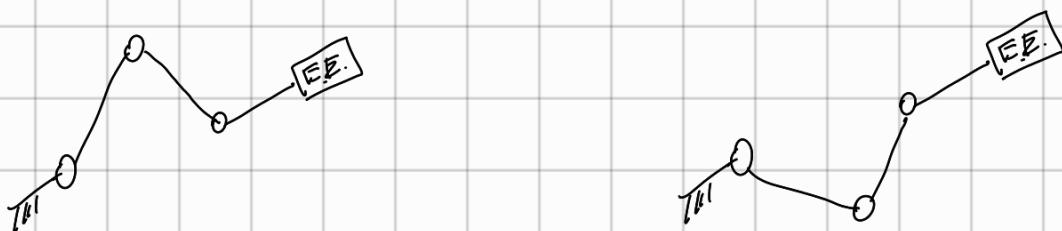


3R



This is a planar mechanism and  
3R means that  
the 3 joints are  
motorized.

Position of the base and of EE. are given and we have to calculate the position of the joint. The solution is not unique;



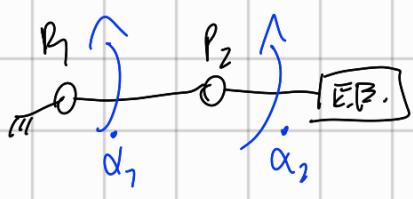
If for 2 of degree of freedom what it's possible to get 2 values and then in uncertainty for the 3<sup>rd</sup> value that can get 2 values. So the what becomes 3 degree of freedom. Search singularities to understand the behavior of degree of freedom.

## Velocity Kinematics

Everything that works for position also goes for velocity

- forward:  $\dot{\alpha}_1, \dot{\alpha}_2 \rightarrow [\dot{\vartheta}, \dot{P}_{2x}, \dot{P}_{2y}]$

- inverse:  $[\dot{\vartheta}, \dot{P}_{2x}, \dot{P}_{2y}] \rightarrow \dot{\alpha}_1, \dot{\alpha}_2$



$$\begin{bmatrix} \dot{v}_1 \\ \dot{P}_{2x} \\ \dot{P}_{2y} \end{bmatrix}$$

← this is what you want. for the forward.

$$\ddot{\varphi} = \ddot{\alpha}_1 + \ddot{\alpha}_2$$

$$\dot{P}_{2x} = d_{12} s_1 \ddot{\alpha}_1 = A \ddot{\alpha}_1$$

$$P_{2y} = d_{12} c_1 \ddot{\alpha}_2 = B \ddot{\alpha}_2$$

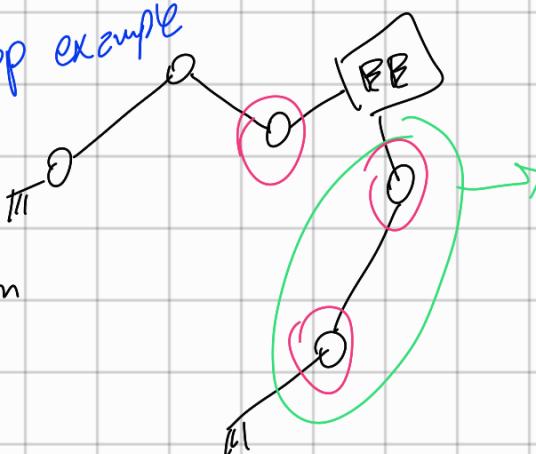
} they are linear in the derivatives of the position  
but they are non-linear in the position of the joint.

We will see that  $\overset{\circ}{\text{pos}} = f \begin{bmatrix} \dot{\alpha}_1 \\ \dot{\alpha}_2 \end{bmatrix}$

$\downarrow$   
jacobian → linear

We can derive once more and get acceleration. We derive once more and we get test.

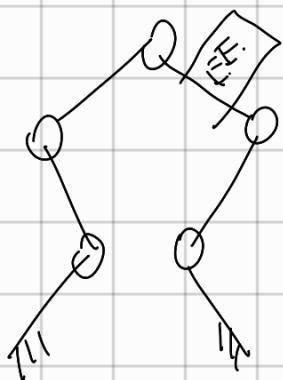
Closed loop example



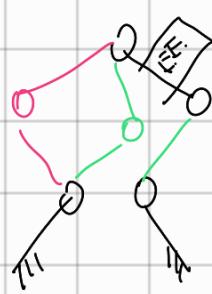
Planar mechanism

this should not be motorized otherwise  
they will fight the other motors if not  
moving in agreement. For example. But  
you could choose another subset to  
be motorized and would be the one.  
For example

Different ways for the joints to position in a way  
to put EB in a certain position.

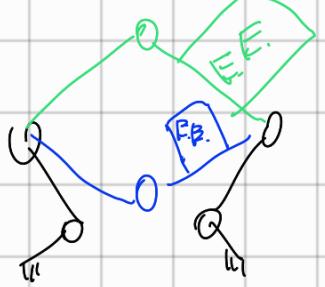


If you assign the EB you have 2 modes:



position  
Inverse kinematics handle  
we have the position of  
EB.

If we assign the nodes we get two assembly modes



This is forward position kinematics

Different ways of assembling the robot given the position of some points

TOPIC notes on vector spaces and web