Exercise set 1 – Geometry

Reminder: Representations of kinematic links

Pivot

Pivot (fr)

Pivot joint / Rotary joint (en)

Cardan

Cardan (fr)

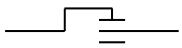
Universal joint / cardan joint (en)

Spherical joint

Rotule (fr)

Spherical joint (en)

Prismatic joint

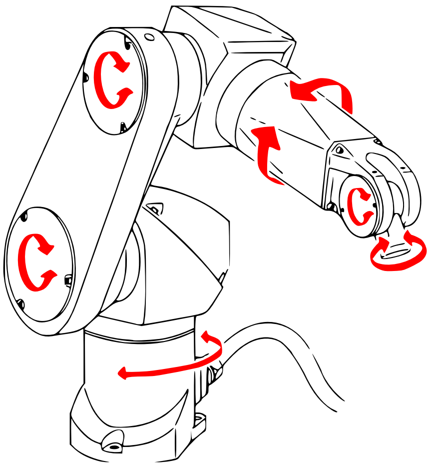


Important notice:

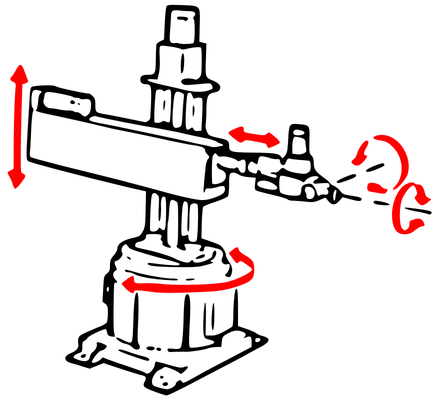
In the following exercises and in the solutions, the used representation will be the one on the left for each joint.

Exercise 1

For the following two structures:



(a) Stäubli TX60



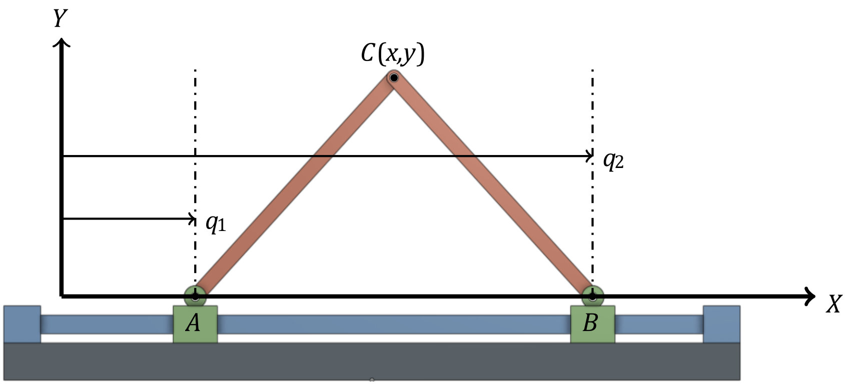
b)

What is the:

1. Number of motors?
2. Mobility (MO)?
3. Number of degrees of freedom (DOF)?

Exercise 2

Consider the following Lambda robot:

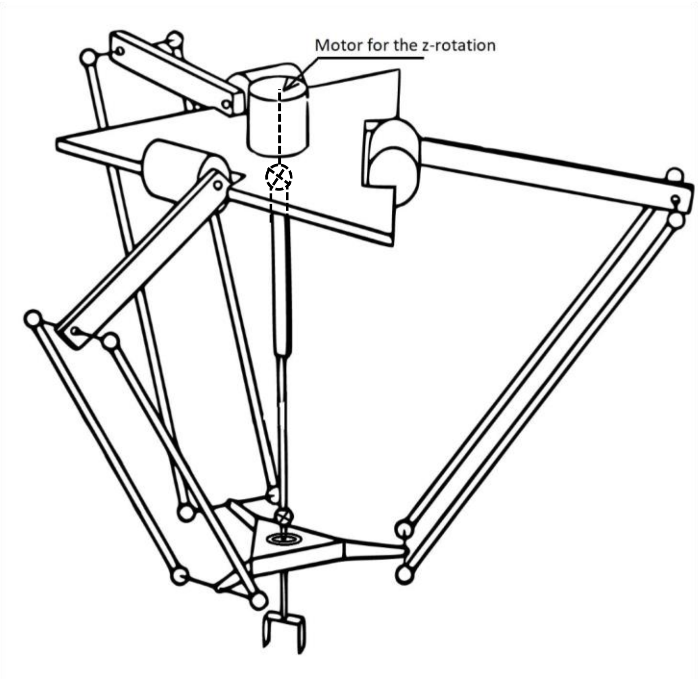


Each rotational joint is a pivot. The end effector is fixed to arm AC, they can thus be counted as a single rigid body.

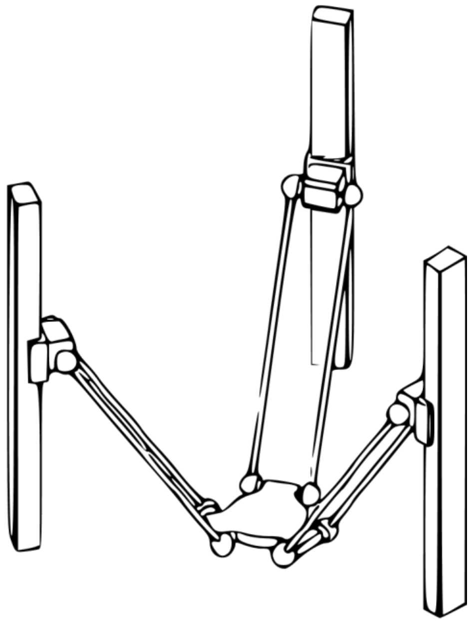
1. Give the kinematic representation of the structure.
2. Calculate the mobility of this structure:
   - **(a)** by Grübler's formula.
   - **(b)** by the formula of loops.
3. Give the number of degrees of freedom.

4. By comparing the DOF (degrees of freedom) and the MO (mobility), discuss if the structure is over-constrained (fr: hyperguidée) or not.

Exercise 3



a) Delta 4 (4 DOF delta robot, XYZ and of the self-rotation along the tool)



b) Linear delta (the three vertical axes are part same base)

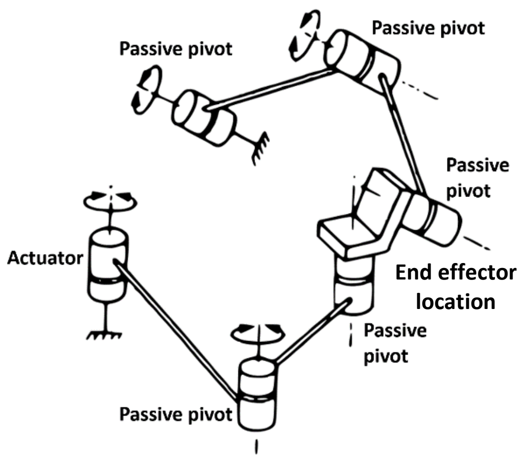
For each structure:

1. Give the kinematic representation.

   For the Delta 4, think about the functional diagram of the telescopic arm that helps in the construction of the entire kinematic representation.
2. Calculate the mobility:
   (a) by Grübler's formula.
   (b) by the formula of loops.

Exercise 4

Here is the kinematic representation of the robot NR-611 from NEC. One could recognize it as a Sarrus mechanism. The planes of the two arms are not parallel.



1. How many degrees of freedom do you think this robot has?
2. Calculate the mobility of the mechanism.
3. Make comments about your results.

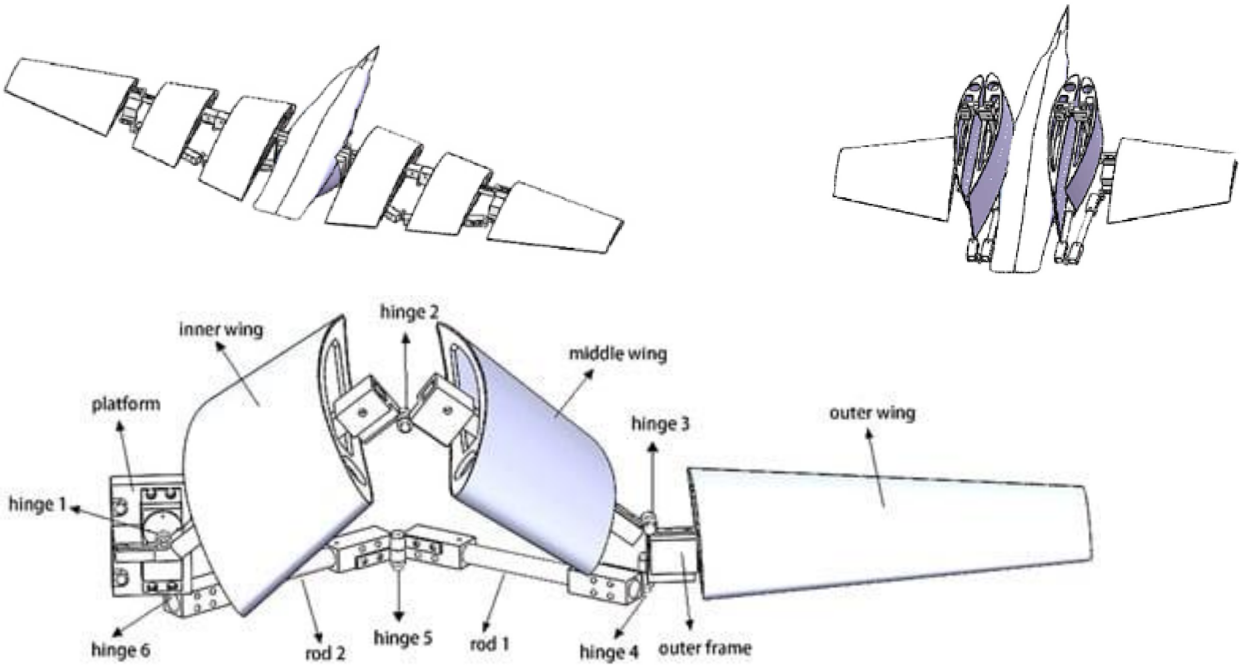
More examples with a Sarrus mechanism are given below to provide more intuition about the mechanism:

Example 1:

Fig. 1 Our mechanism, shown here attached to the skids on the bottom of an RC helicopter, uses a bilateral configuration of Sarrus-based linkages to passively grip cylindrical perches

[Source: Burroughs, M. L., Beauwen Freckleton, K., Abbott, J. J., and Minor, M. A. (August 18, 2015). "A Sarrus-Based Passive Mechanism for Rotorcraft Perching." ASME. J. Mechanisms Robotics. February 2016; 8(1): 011010.]

Example 2:



[Source: Yun Z, Feng Y, Tang X, Chen L. Analysis of Motion Characteristics of Bionic Morphing Wing Based on Sarrus Linkages. *Applied Sciences*. 2022; 12(12):6023.]

Also, you can check simulations of the mechanism through the links:
https://www.youtube.com/watch?v=gfXWDGGip-0
https://www.youtube.com/shorts/pQBJcgJe6t0