Robotics Fundamentals

Dr. Mustafa Shiple

Module Agenda

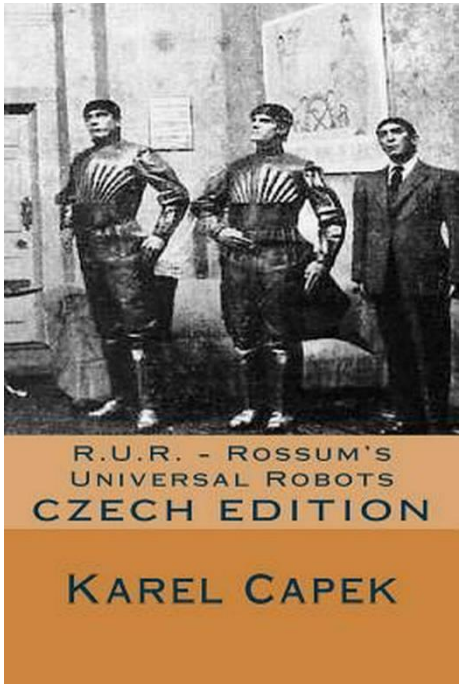
- **Robot Definition**
- **Robot Actuators and Effectors**
- **Robot Sensors**
- **Robot Computation and Communication**
- **Robot Design**

Robot Definition

Robot History

- 1921: Czech playwright Karl Capek premiered his play *R.U.R.* in Prague . (machines conquer).
- Definition: Robot the word comes from the Czech word *robota* which translates to labor or slave.

Karel Capek



Eye on Robotics

- Robotics is a multi-disciplinary field. Best robotics researchers and engineers will touch upon all disciplines:

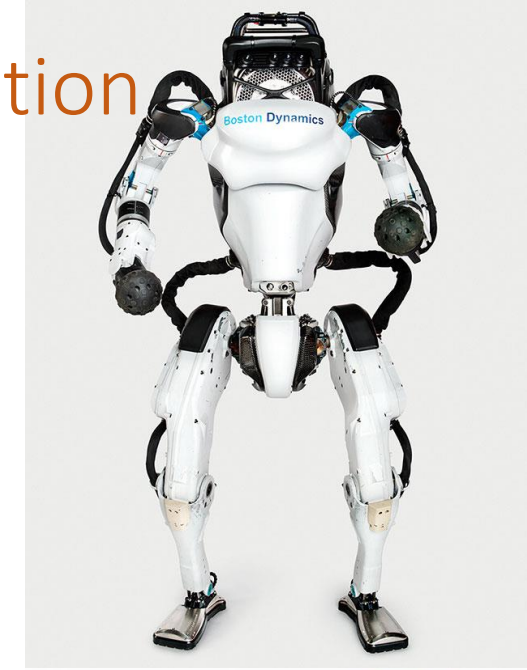
- **Mechanical Engineering** – concerned primarily with manipulator/mobile robot design, kinematics, dynamics, compliance and actuation.
- **Electrical Engineering** – concerned primarily with robot actuation, electronic interfacing to computers and sensors, and control algorithms.
- **Computer Science** – concerned primarily with robot programming, planning, and intelligent behavior.

Definition

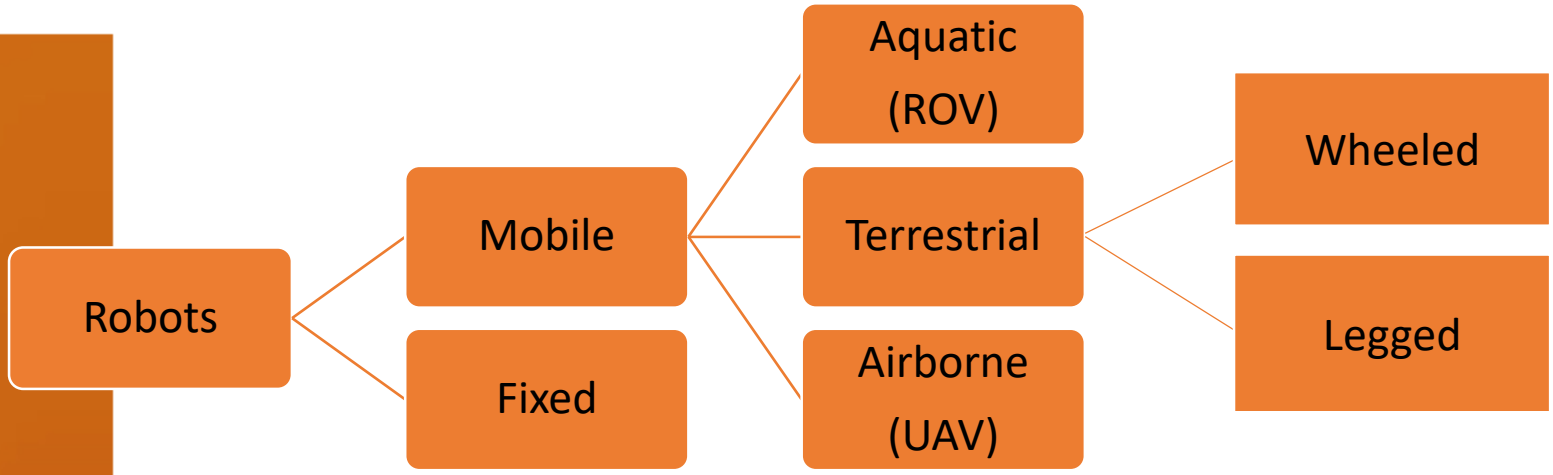
- A *robot* is an autonomous system which exists(1) in the physical world, can sense(2) its environment, and can act(3) on it to achieve some goals(4).

Locomotion and Manipulation

- Rolling,
- Walking,
- Running,
- Jumping,
- Sliding
- Crawling,
- Climbing,
- Swimming, and
- Flying.

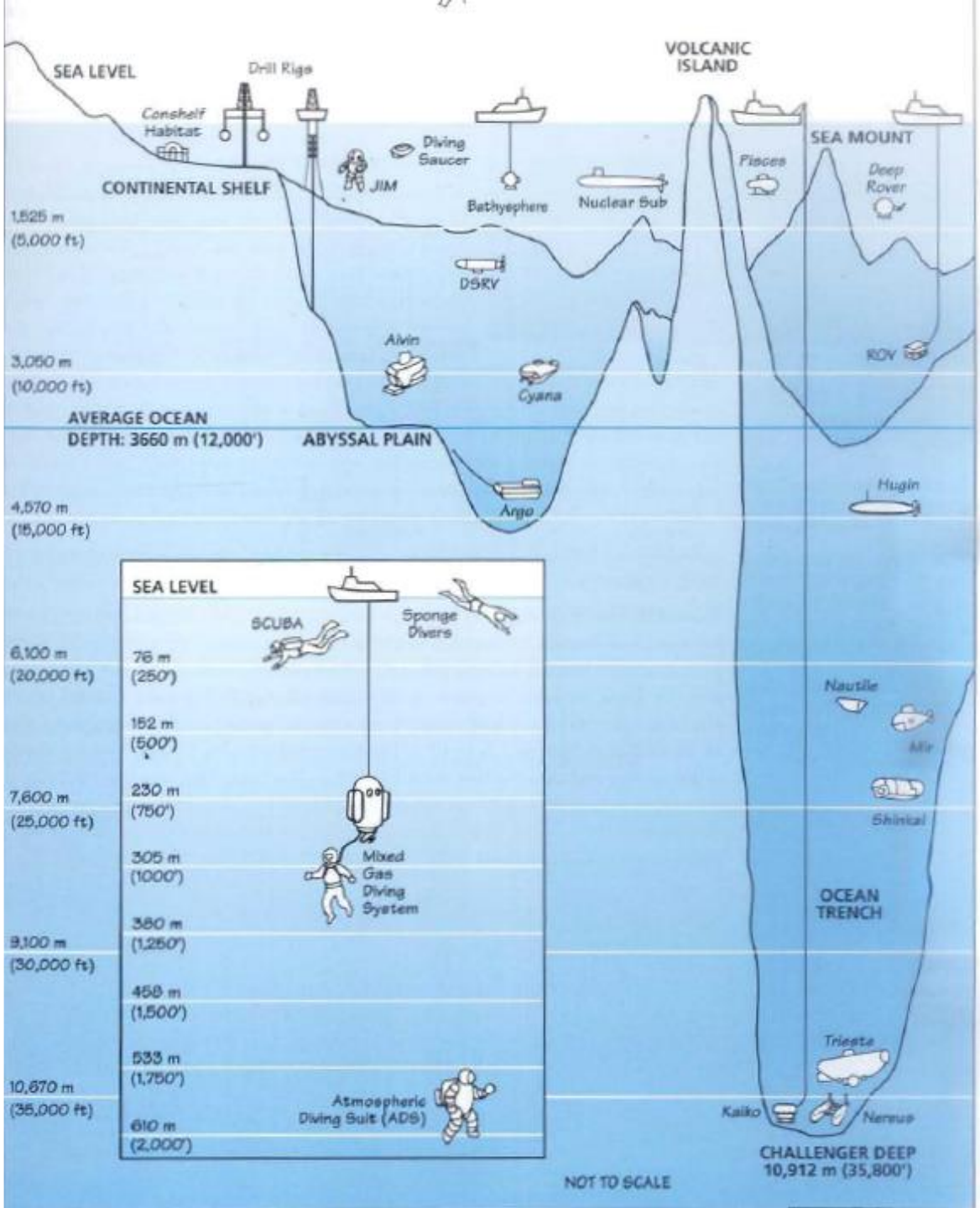


Classification of Robots



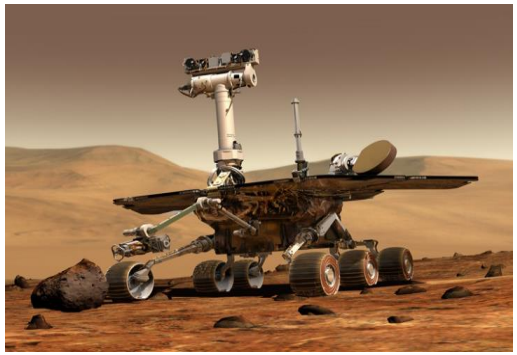
ROV

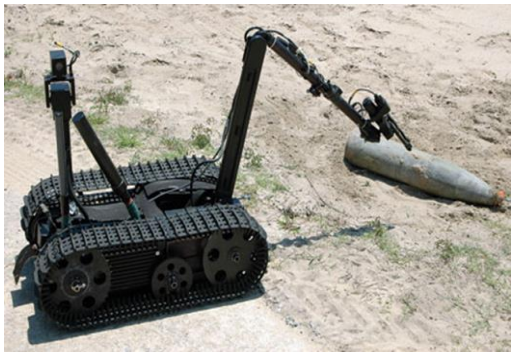
Species video

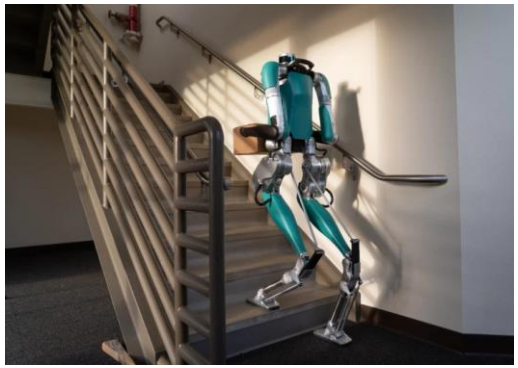


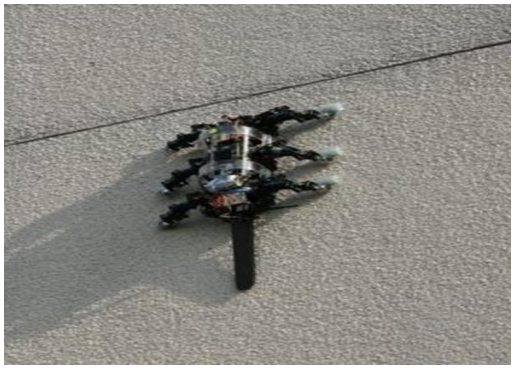
Introduction

- TERRESTERIAL ROBOTS
  - WHEELED ROBOTS
  - LEGGED ROBOTS

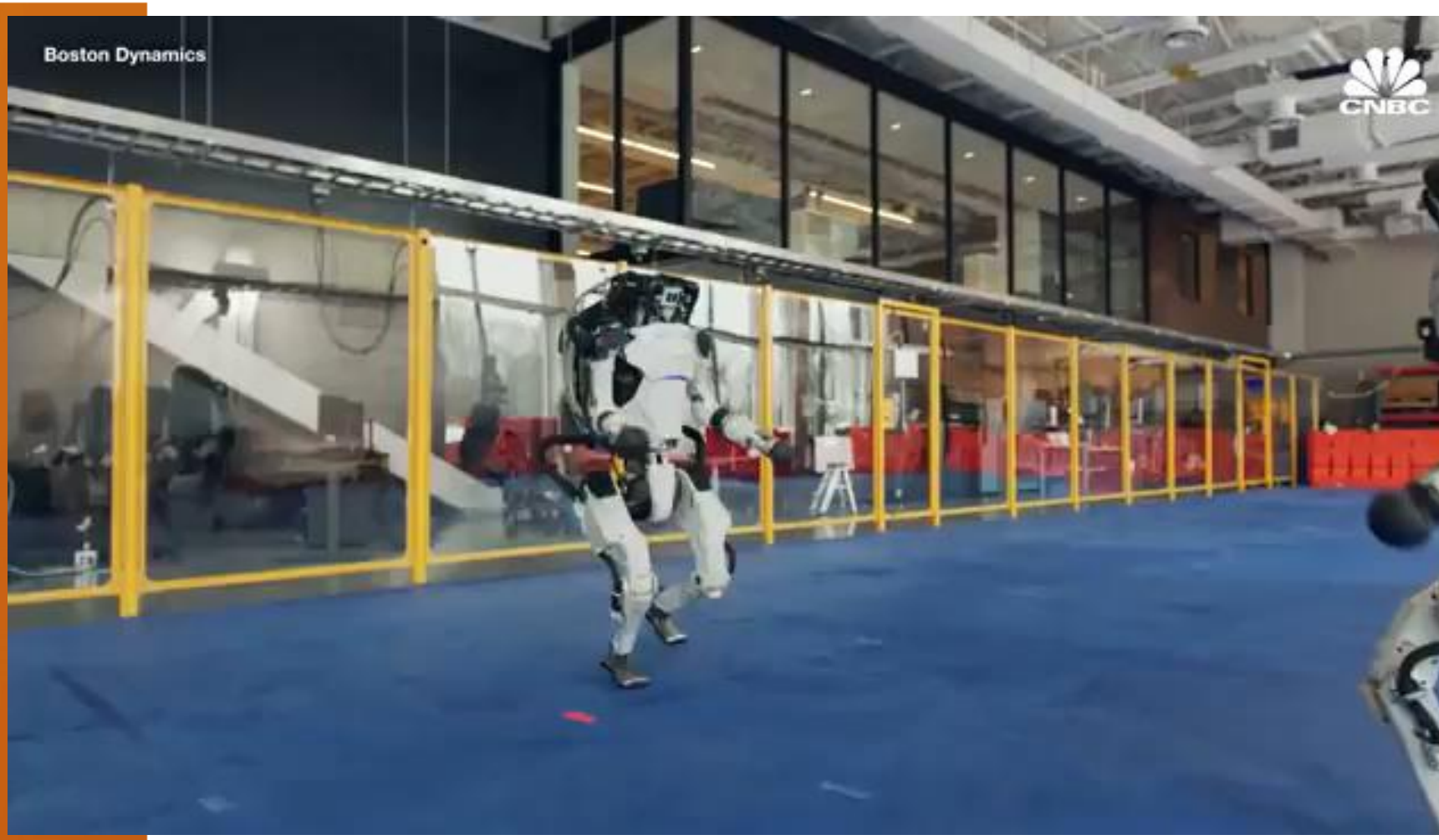








Terrestrial



Module Agenda

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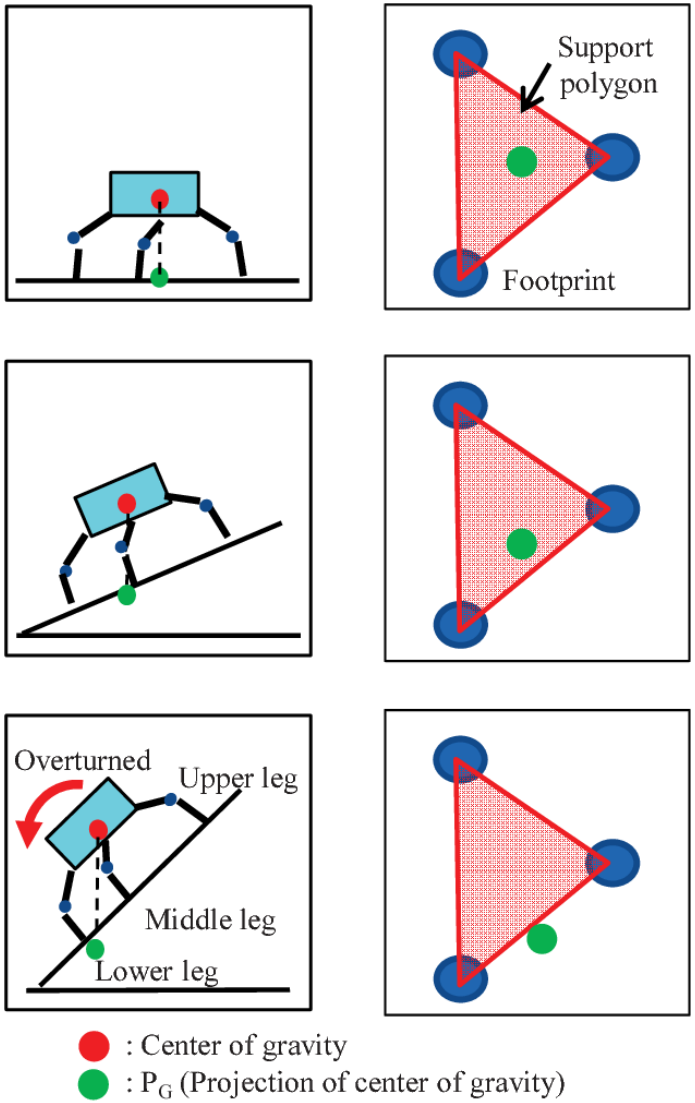
- **Robot Actuators and Effectors**
- Robot Sensors
- Robot Computation and Communication
- Robot Design

Stability and polygon of support



- Center of gravity (COG) is within the polygon determined by the contact points of the robot on the ground, also called **polygon of support**.

Static: a statically stable robot can stand still without falling over.

Dynamic: a dynamically stable robot is stable only while moving

Stability and polygon of support

Static: a statically stable robot can stand still without falling over.

Dynamic: a dynamically stable robot is stable only while moving

LEGGED

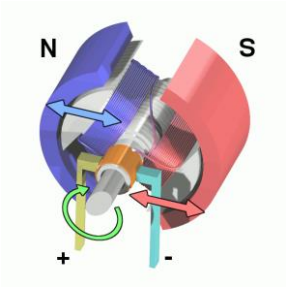
Wheel

Actuators

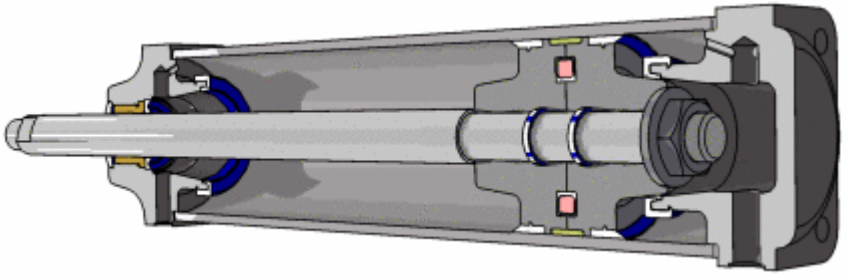
Definition:

The actual mechanism that enables the effector to execute an action

Passive



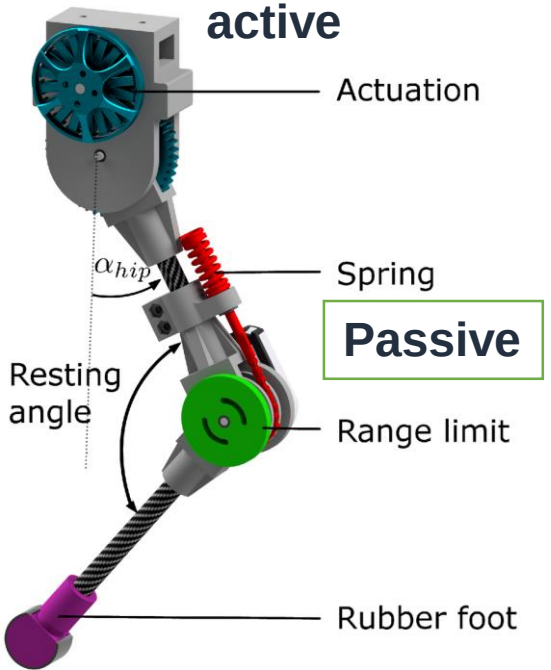
active



Functions:

- Locomotion
- Manipulation

- typically include:
  - electric motors (DC ,Servo ,brushless , stepper)
  - hydraulic cylinders
  - pneumatic cylinders



most simple actuators control one degree of freedom

Actuators

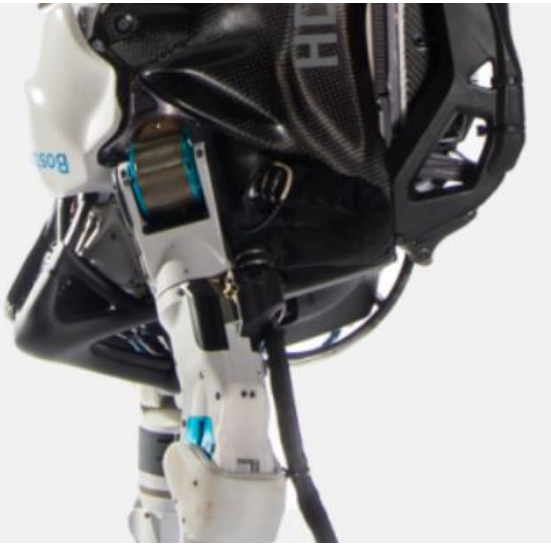
- Typically include:
  - Electric motors (DC ,servo ,brushless , stepper).
  - Hydraulic cylinders .
  - Pneumatic cylinders.
  - Photo-reactive materials.
  - Chemically reactive materials.
  - Thermally reactive materials.
  - Piezoelectric materials

Hydraulic cylinders

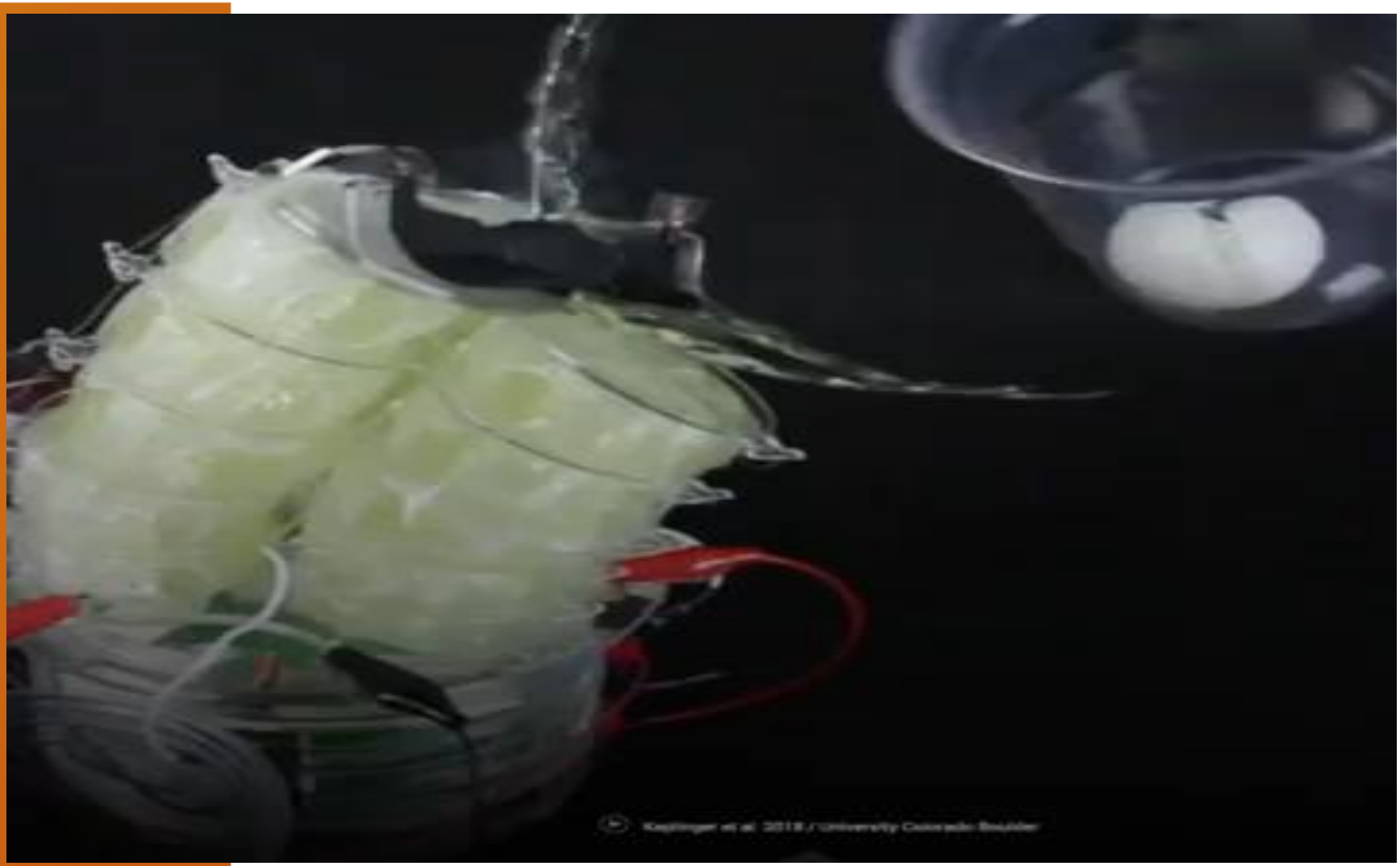
EFFICIENT

Atlas has one of the world's most compact mobile hydraulic systems. Custom motors, valves, and a compact hydraulic power unit enable Atlas to deliver high power to any of its 28 hydraulic joints for impressive feats of mobility.

ACTUATION	JOINTS
Hydraulic	28



Actuators (thermal – electrical)

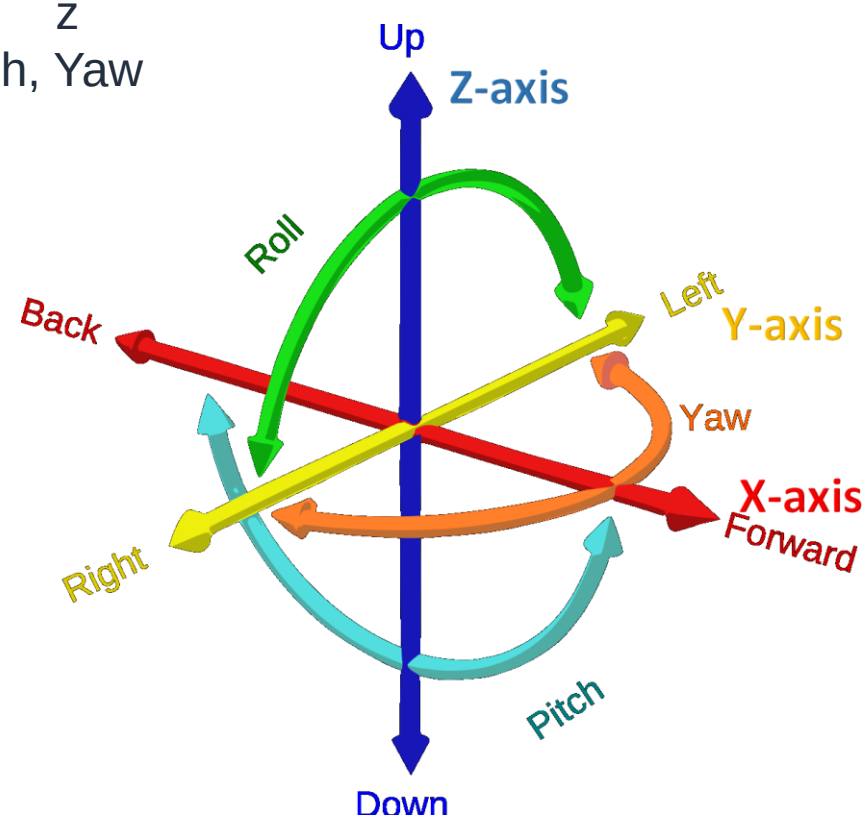


Actuators (example2)

Degree of freedom

- Describes the number of independent movements that an object can perform in a three-dimensional space

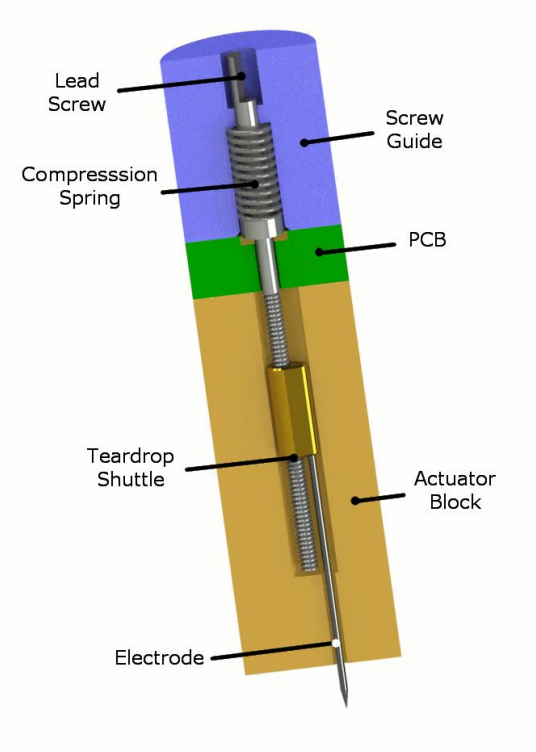
Translation: x, y, z
Rotation: Roll, Pitch, Yaw

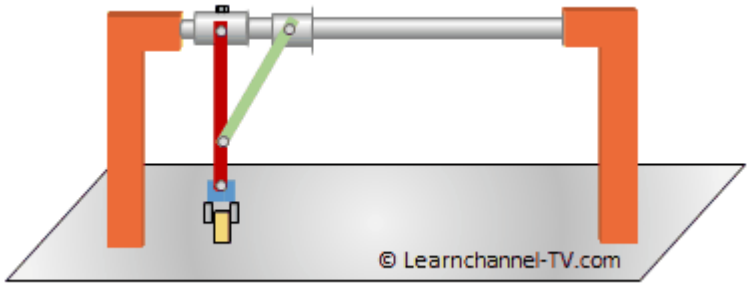


Manipulator Joints (1 DOF)

Translational motion

- Linear joint (type L)
- Orthogonal joint (type O)

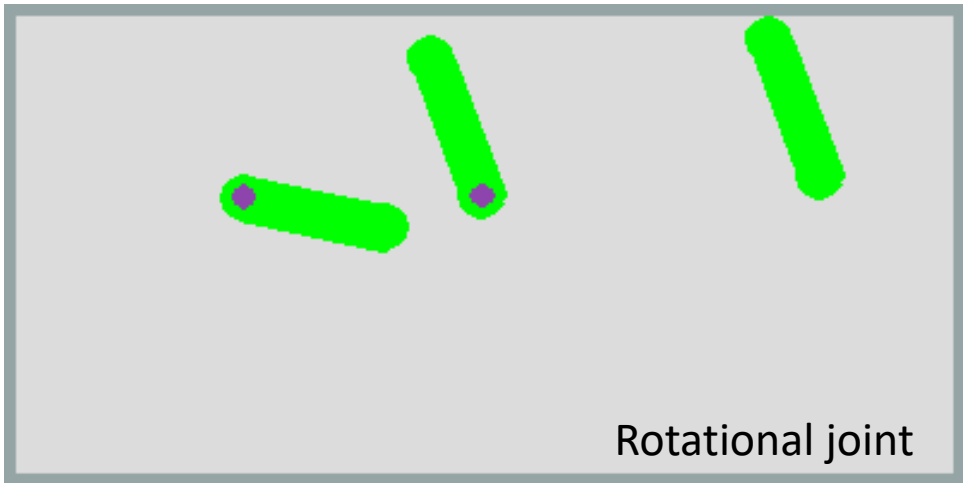




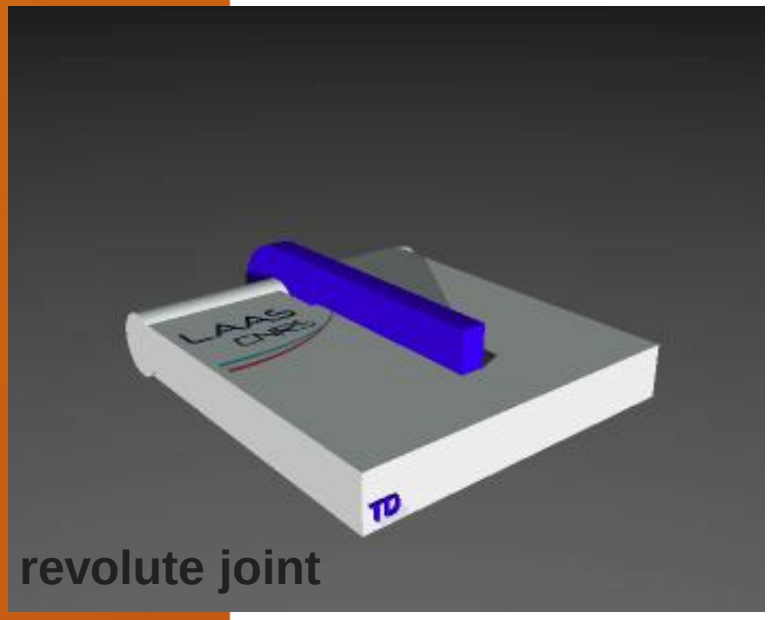
Manipulator Joints (1 DOF)

Rotary motion
- Rotational joint (type R)
- Twisting joint (type T)
- Revolving joint (type V)

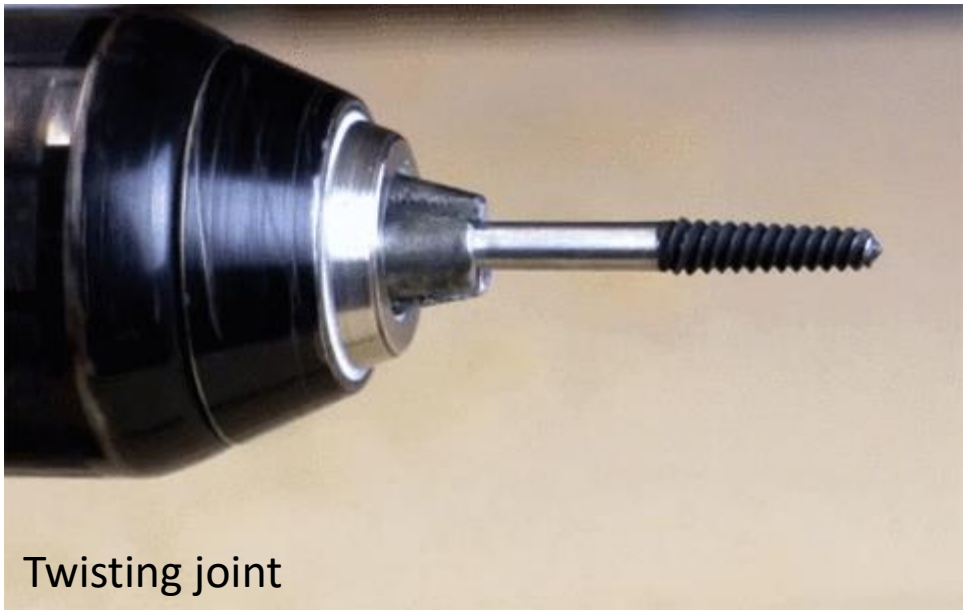
Three different types of revolute joints, each type can rotate around one of the 3-axis, x-axis, y-axis or z-axis



Rotational joint



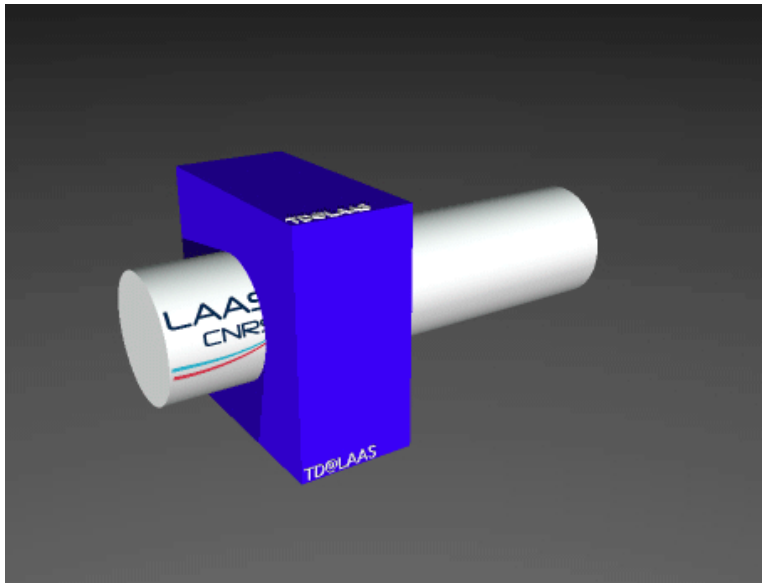
revolute joint



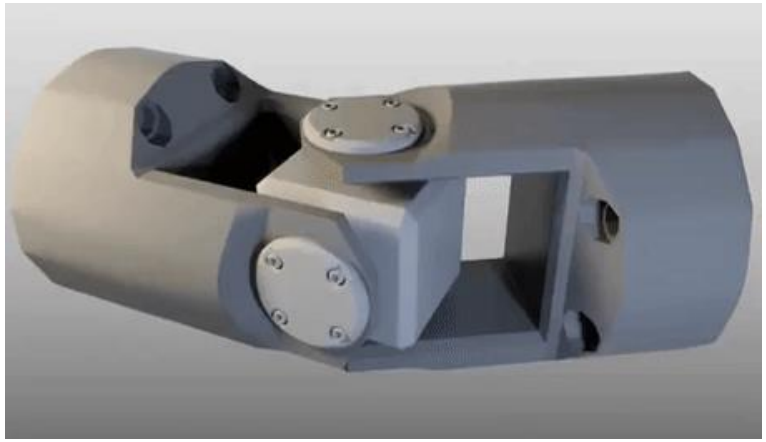
Twisting joint

Manipulator Joints (2 DOF)

Cylindrical joint (C)



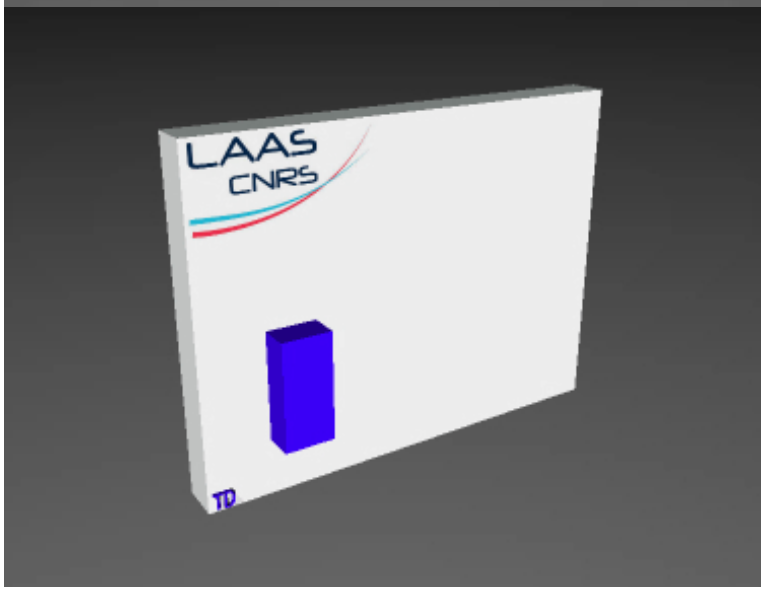
Universal joint (U)



Manipulator Joints (3 DOF)

Spherical joint (S)

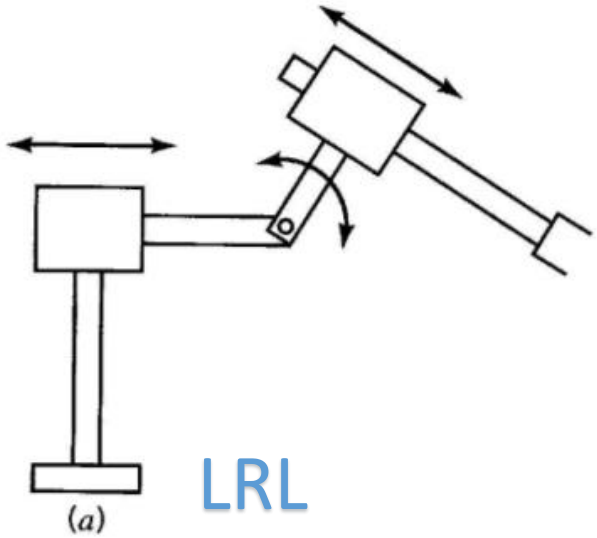
Planer joint (P)



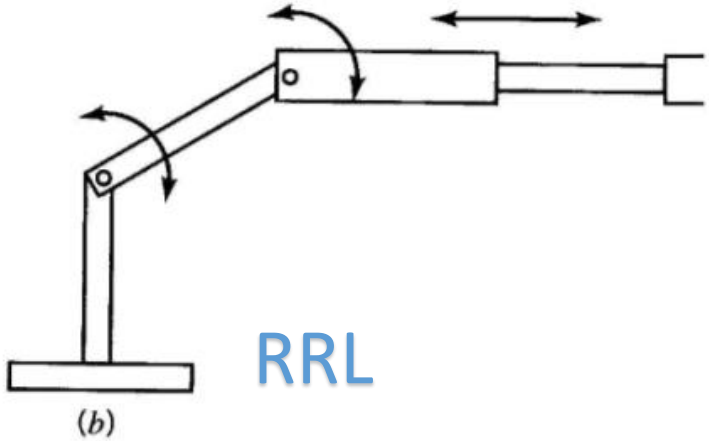
two translations and one rotation

Robot configuration ?

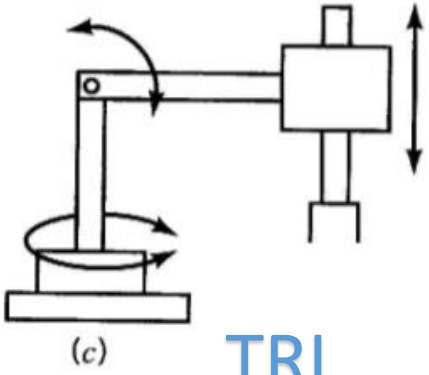
- Linear (L)
- Orthogonal (O)
- Rotational (R)
- Twisting (T)
- Revolving (V)
- Cylindrical (C)
- Universal (U)
- Spherical (S)
- Planer (P)



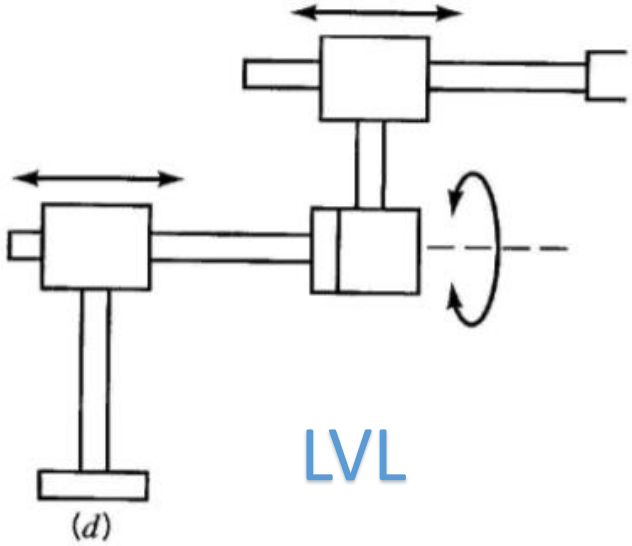
LRL



RRL



TRL

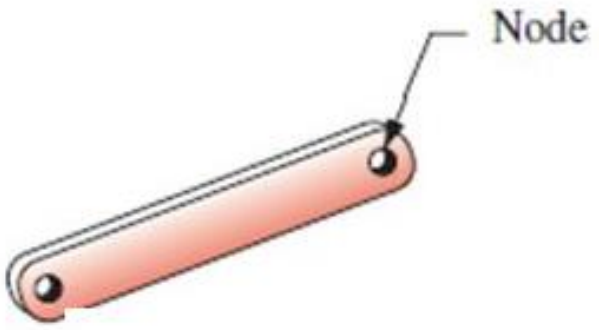


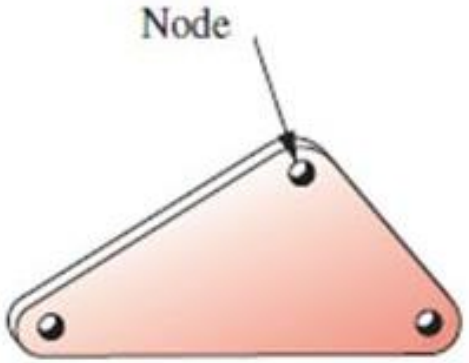
LVL

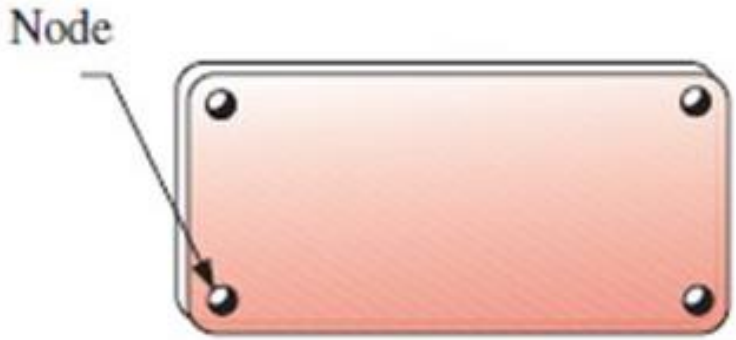
Links

Rigid body that possesses at least two nodes for attachment to other links.

- Binary link
- Ternary link
- Quaternary link

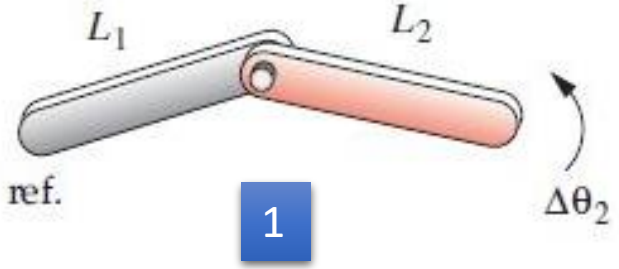




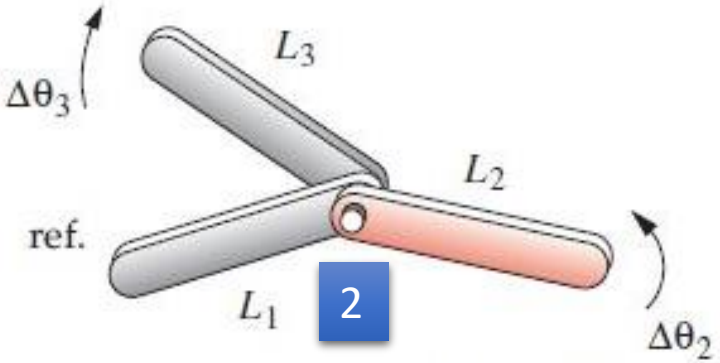


Joint order

Joint order = number of joined links -1

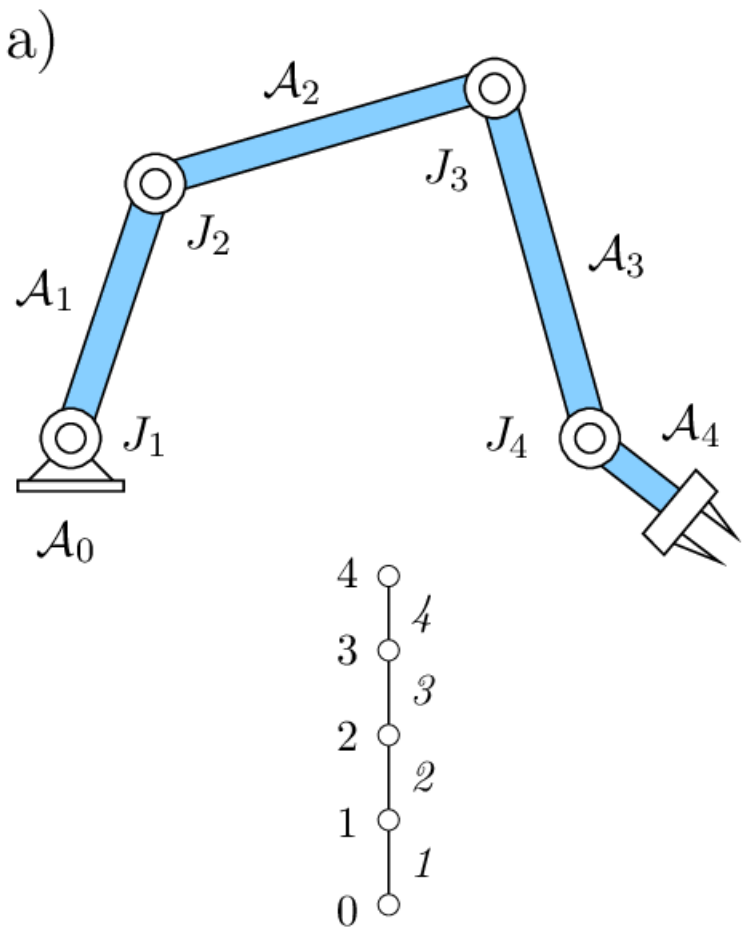


First order pin joint - one *DOF*
(two links joined)

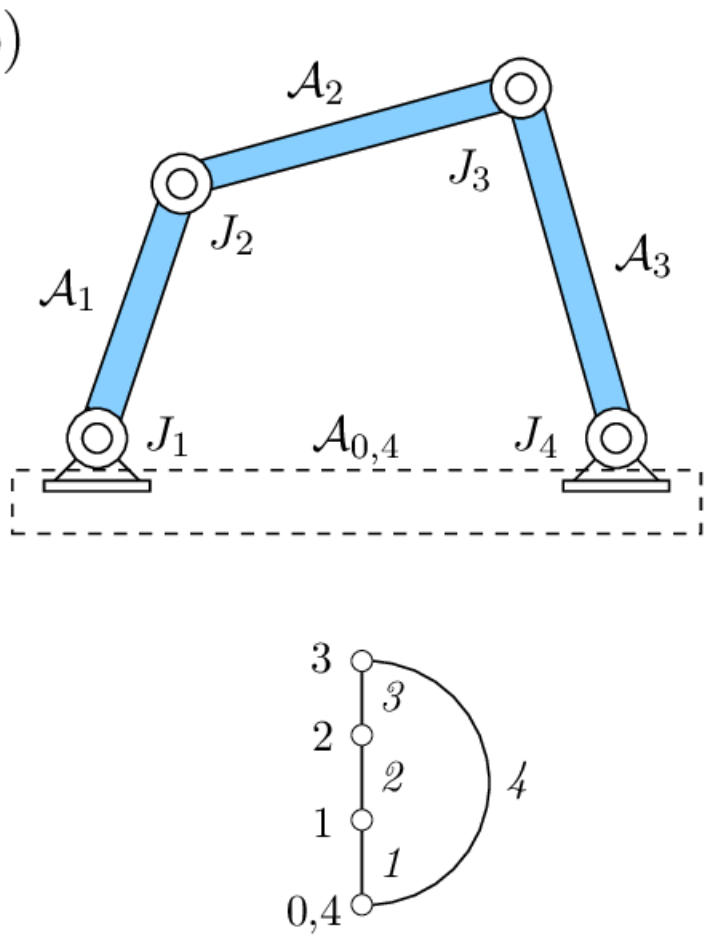


Second order pin joint - two *DOF*
(three links joined)

Mechanism chain



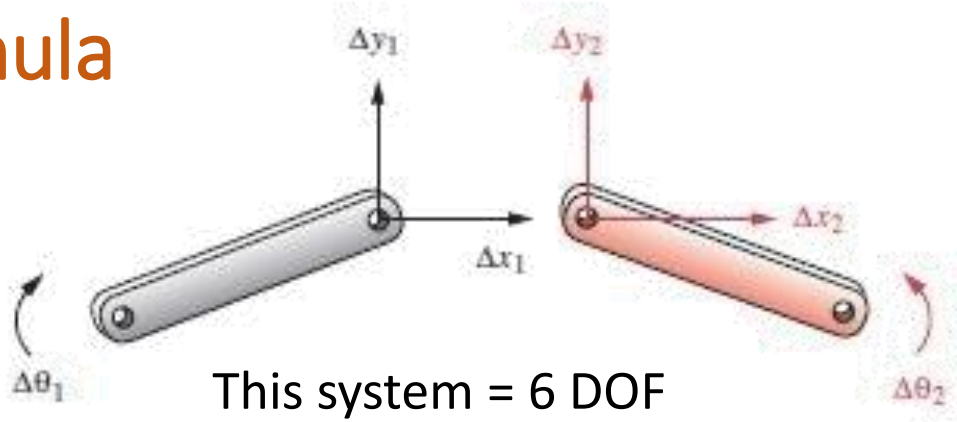
Open chain
DOF= 4



Closed chain
DOF =1

Grübler's Formula

Any link has 3 DOF

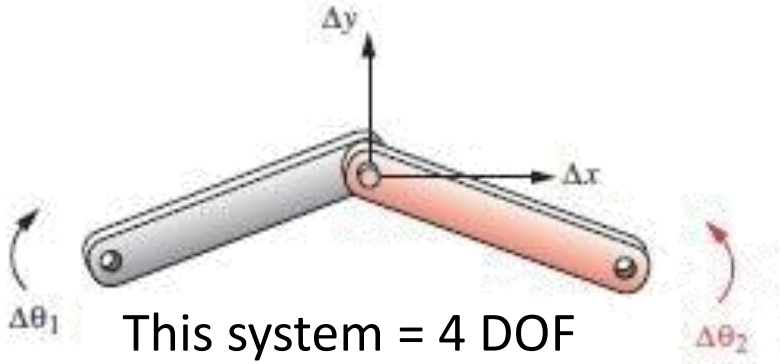


This system = 6 DOF

By using full joint:

y1,y2 and x1,x2 are combined

Full joint reduce 2

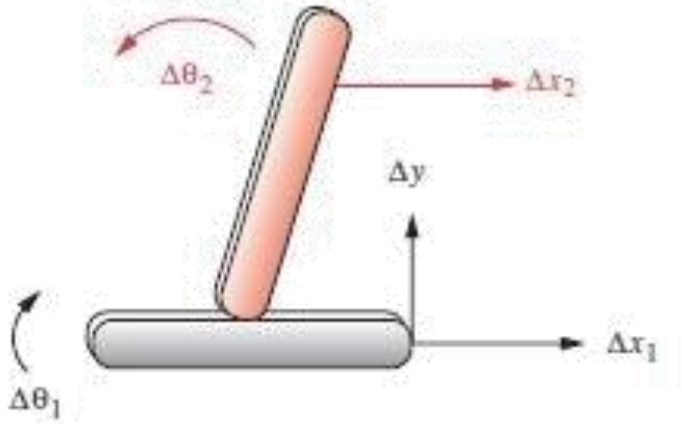


This system = 4 DOF

By using half joint:

y1,y2 are combined

Half joint reduce 1



Grübler's Formula

General rules:-

1. Any links (L) has 3 DOF.
2. Any ground (G) link reduces DOF by 3
3. Any full joints (J_f) reduces DOF by 2
4. Any half joints (J_h) reduces DOF by 1

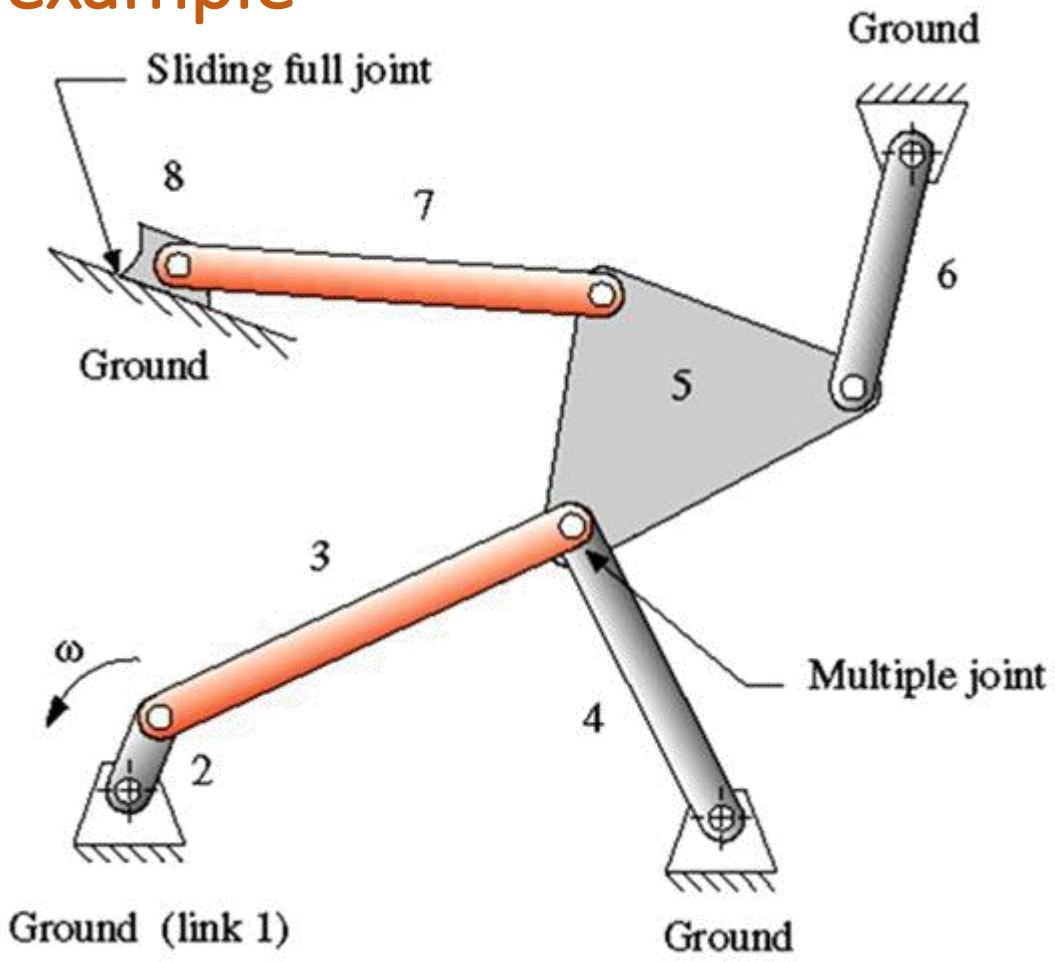
$$DOF = 3L - 3G - 2J_f - J_h$$

Almost G=1

$$DOF = m(L-1) - 2J_f - J_h$$

Where:
M = robot Mobility $\begin{cases} 6 & \text{spatial bodies} \\ 3 & planer\ bodies \end{cases}$

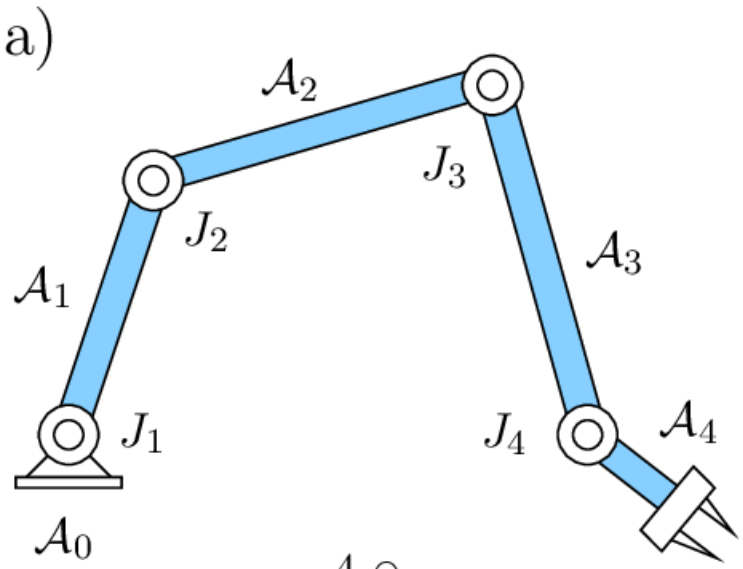
Grübler's example

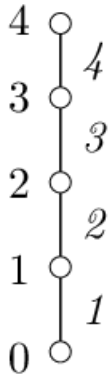


$$DOF = m(L-1) - 2J_f - J_h$$

= 3(8-1)-2*10-0 =1

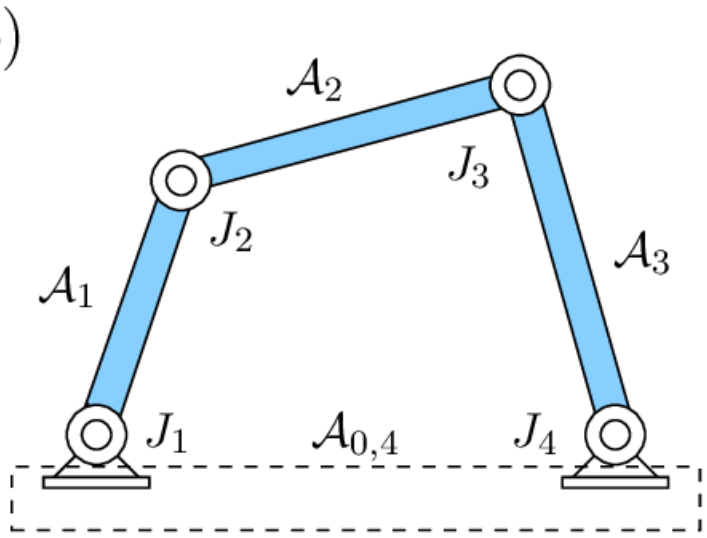
Grübler's example

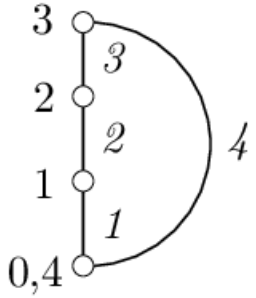




$$DOF = m(L-1) - 2J_f - J_h$$

= 3(5-1)-2*4-0 =4



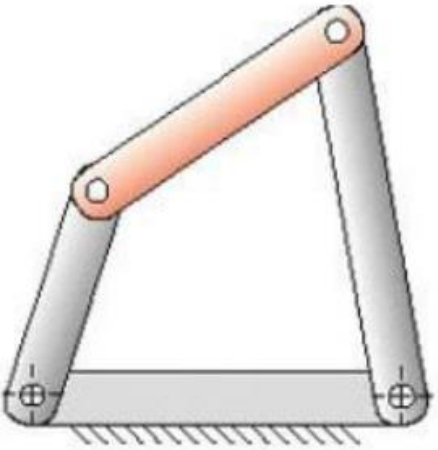


$$DOF = m(L-1) - 2J_f - J_h$$

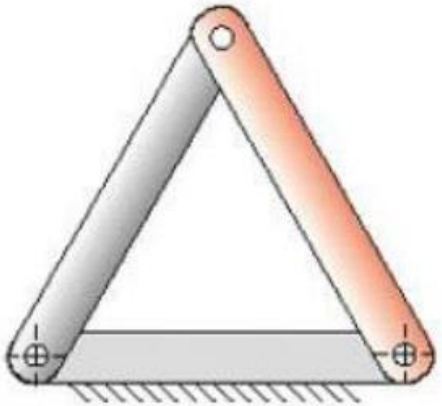
= 3(4-1)-2*4-0 =1

Grübler's example

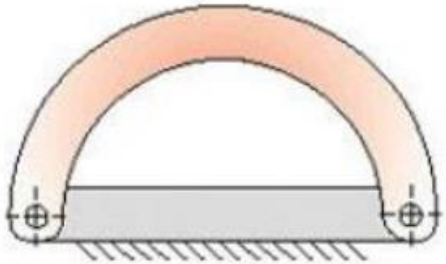
- Positive DOF → assembly is a mechanism → links will have relative motion
- Zero DOF → assembly is a structure → no motion is possible
- Negative DOF → assembly is a preloaded structure → no motion is possible and some stress may be present at the assembly time



(a) Mechanism—*DOF* = +1

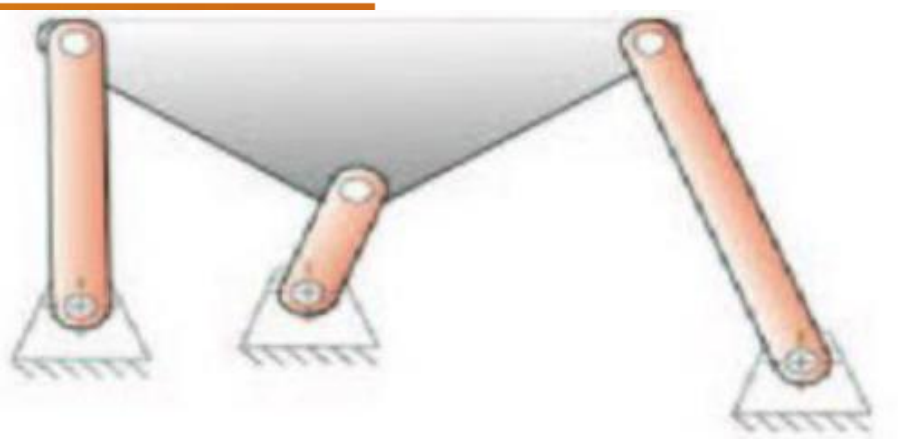


(b) Structure—*DOF* = 0



(c) Preloaded structure—*DOF* = -1

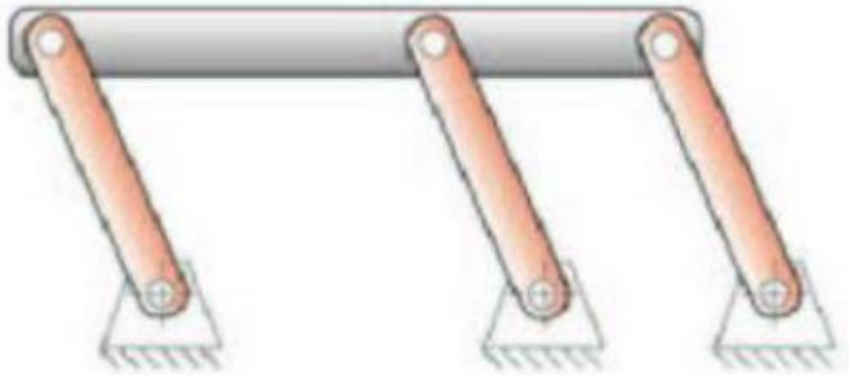
Grübler's example



$$DOF = m(L-1) - 2J_f - J_h$$

= 3(5-1)-2*6-0 =0

structure



$$DOF = m(L-1) - 2J_f - J_h$$

= 3(5-1)-2*6-0 =0

mechanism

Grübler's example

1. Does not take into account size and shapes of the mechanism (wrong result)
2. DOF can be calculated by inspection

DOF example (soft robot)

Ref.

- https://www.redblobgames.com/pathfinding/a-star/introduction.html

Ref.

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