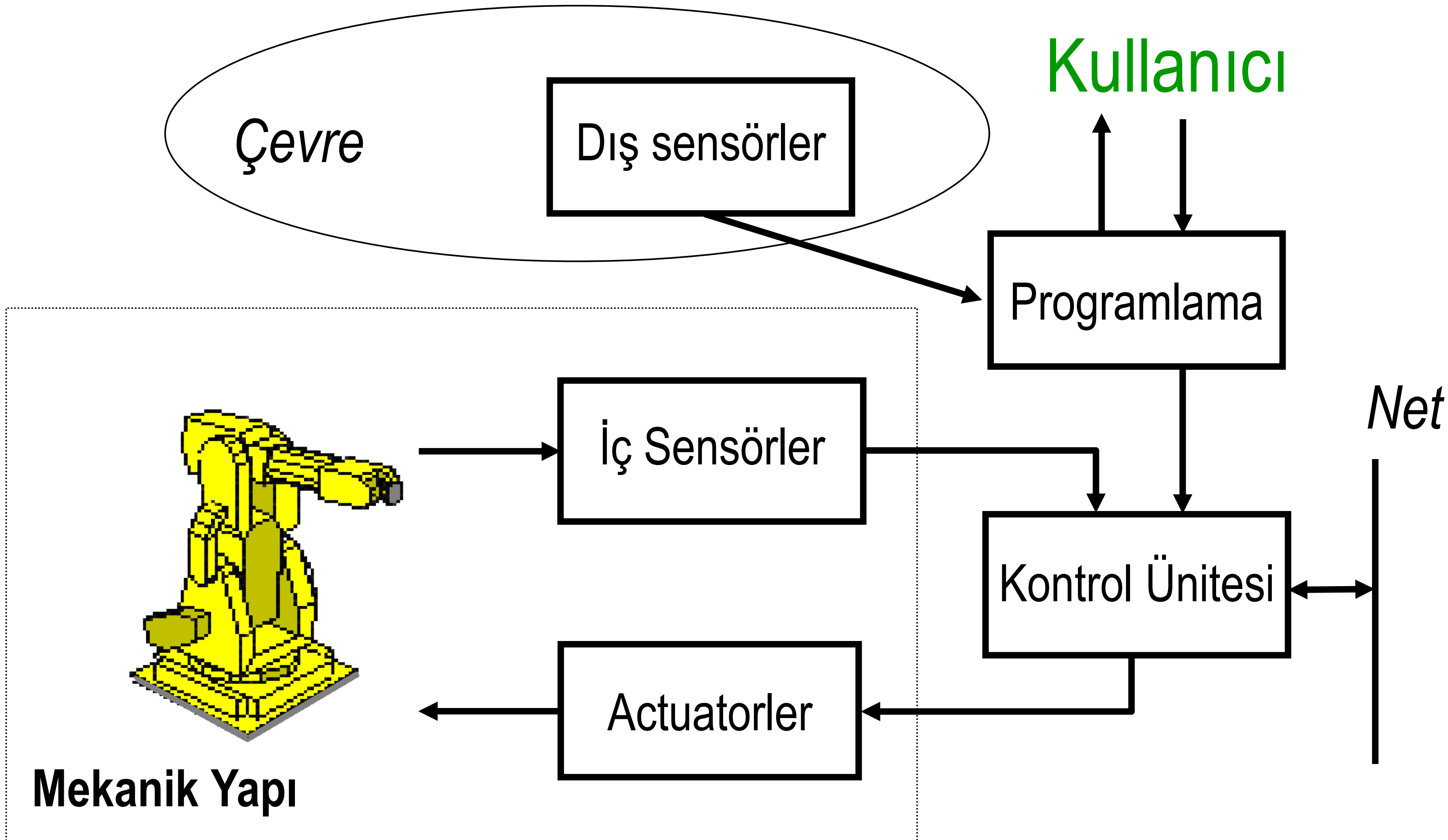
ROBOT TEKNOLOJISI

Ege Üniversitesi Ege MYO
Mekatronik Programı

BÖLÜM 2

Robotların Yapısı

Robotun Parçaları



Robotun Yapısı

Temel Özellikleri:

- Kinematik zincir (chain)
- Serbestlik derecesi (Degree of freedom)
- Manevra (Maneuvering) derecesi
- Yapısı (Architecture)
- Hassasiyet (Precision)
- Çalışma alanı (Working space)
- Erişilebilir (Accessibility)
- Taşıma Kapasitesi (Payload)

Serbestlik Derecesi

Serbestlik derecesi robotta yer alan ve diğerlerlerinden farklı hareket veren aktuator sayısına bağlıdır.

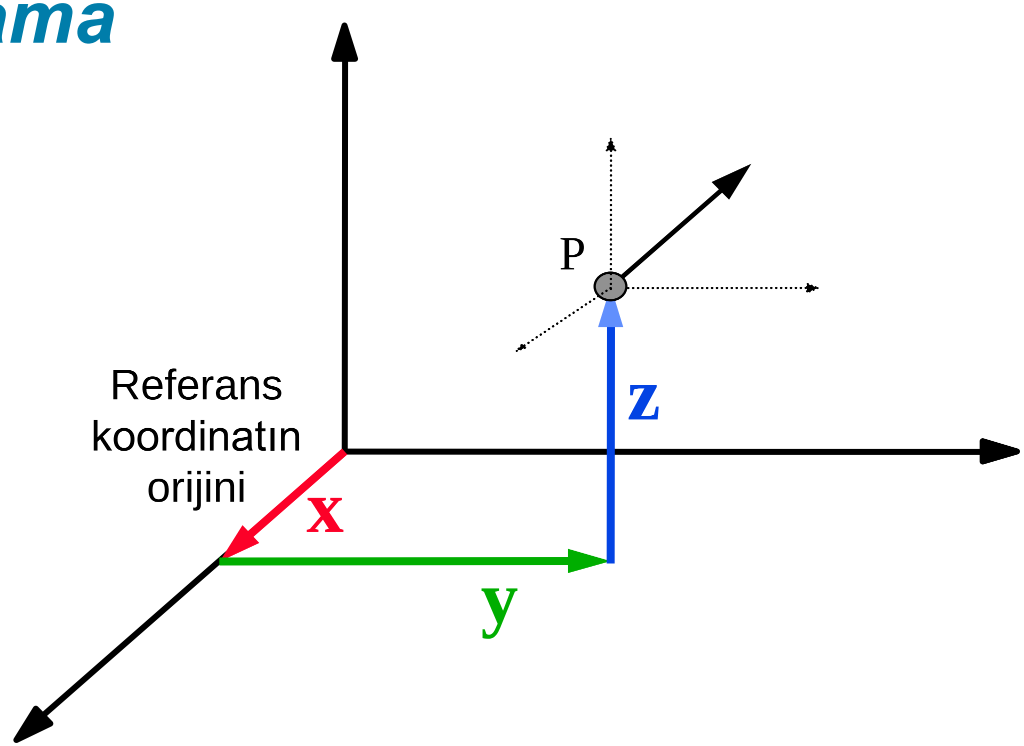
D o F

Her eklem manipulatöre bir serbestlik derecesi ekler, son işi yapan elemana (end effector, parmak, delici uç, kaynak elektrodu) bu eklemein verdiği hareketi diğer eklemlerden biri veya birleşiminin vermiyor olması gerekir.

Serbestlik Derecesi

Yerleşme, Pozisyonlama

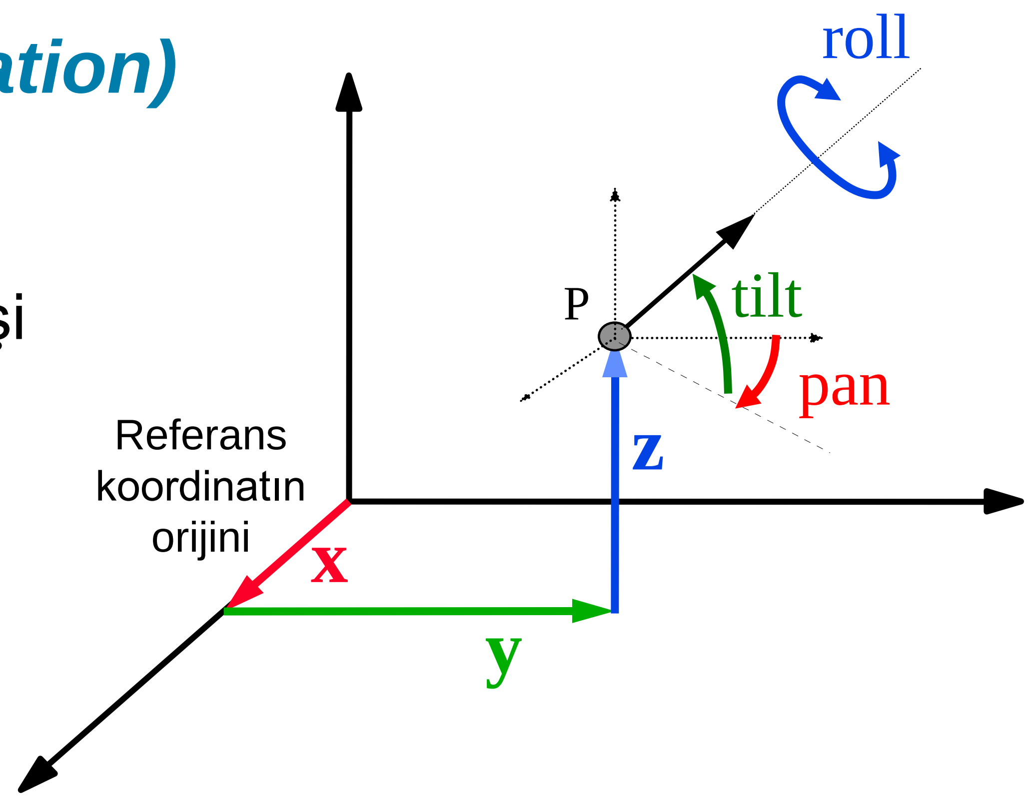
end effectorun üç boyutlu uzayda dönel veya kayar hareketler ile yerleştirilmesine yerleşme veya pozisyonlama adı verilir.



Serbestlik Derecesi

Oryantasyon (Orientation)

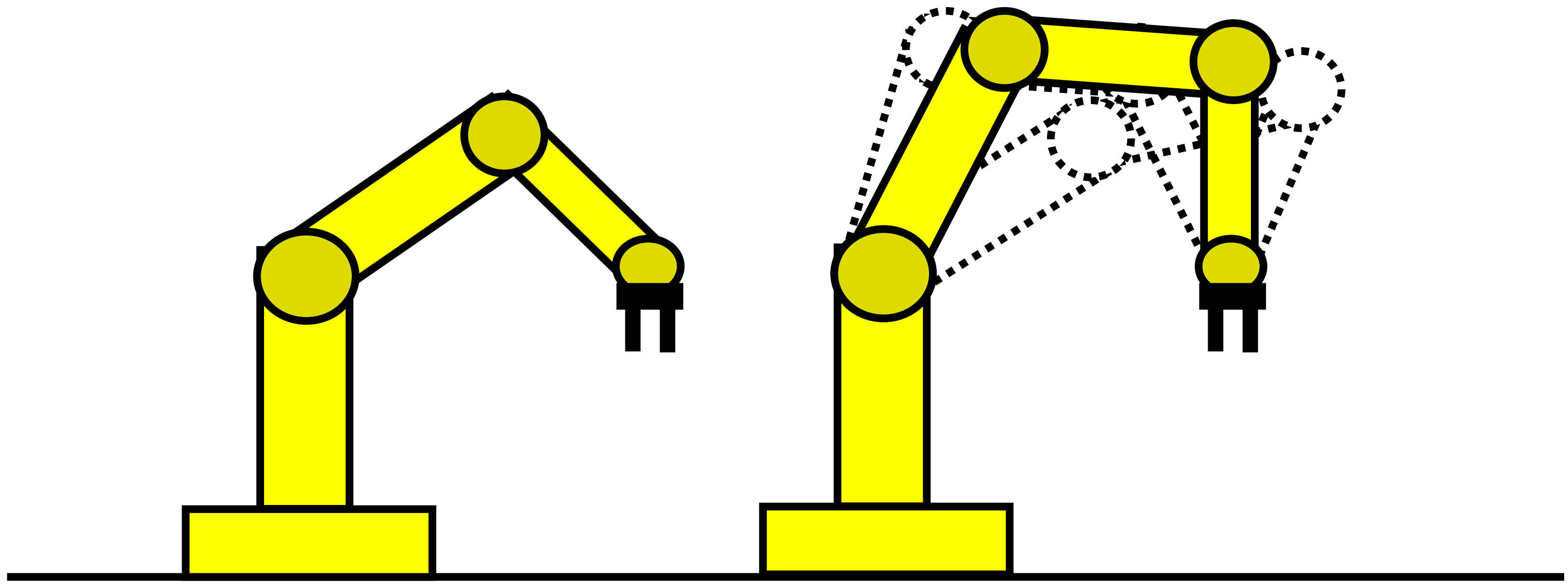
End effectorun üç boyutlu uzay içerisinde istediğimiz işi yapacak pozisyon ve şekle getirilmesi işlemine oryantasyon denir. Bu iş için robotun en az 3 serbestlik derecesine sabip olması gerekiyor.



Manevra Derecesi

Manevra derecesi yeni bir serbestlik derecesi yaratmadan yeni bir hareket ettiren aktuator sayısıdır.

Manevra derecesi



Zorlanmış erişim

Çoklu erişim lüszumsuz DoF kullanılmış

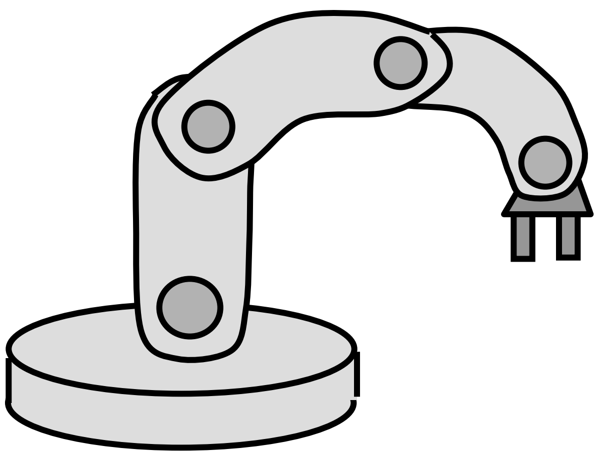
Robot Mimarisi

Robot Mimarisi; robotun kinematik zincirini tamanlayan farklı eklemlerin birleşimidir.

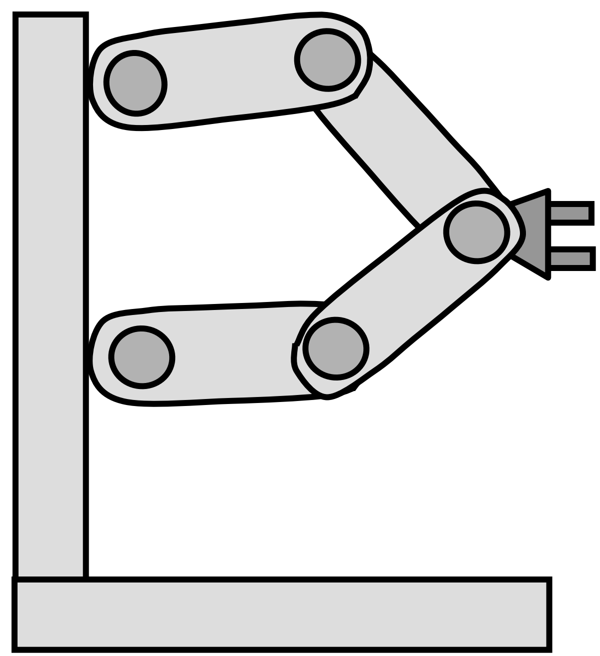
Mekanik Yapı

Kinematik zincir: bir hareketi yapmak için katı elemanların belli bir sırada eklemlerle birleştirilmesine denir

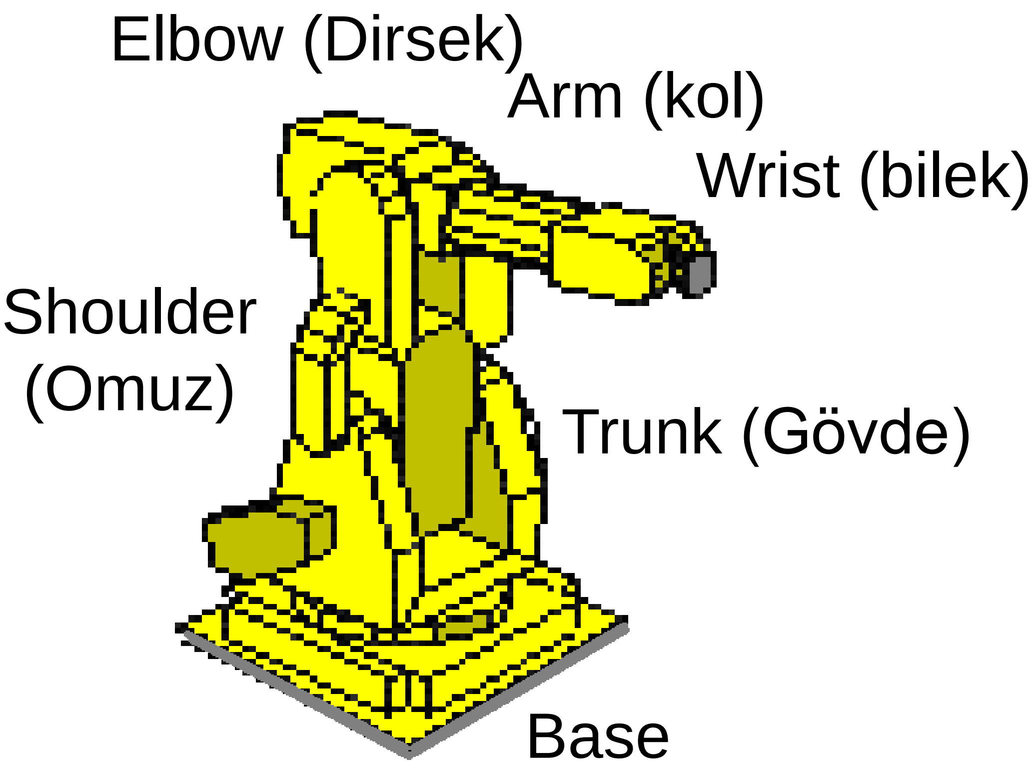
Açık:



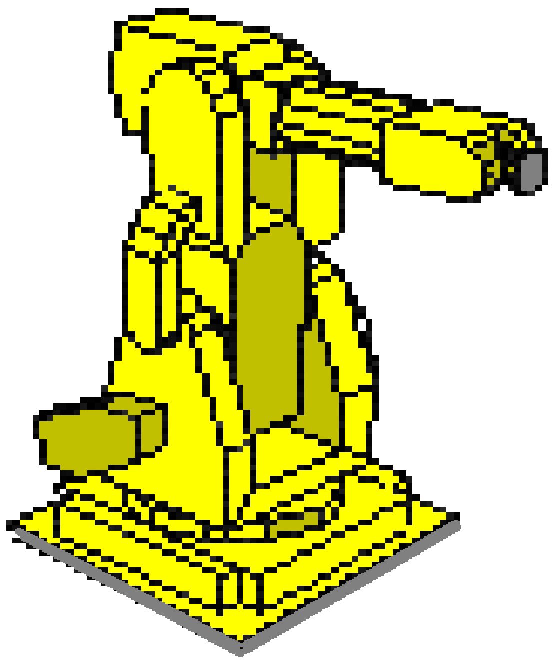
Kapalı (Parallel):



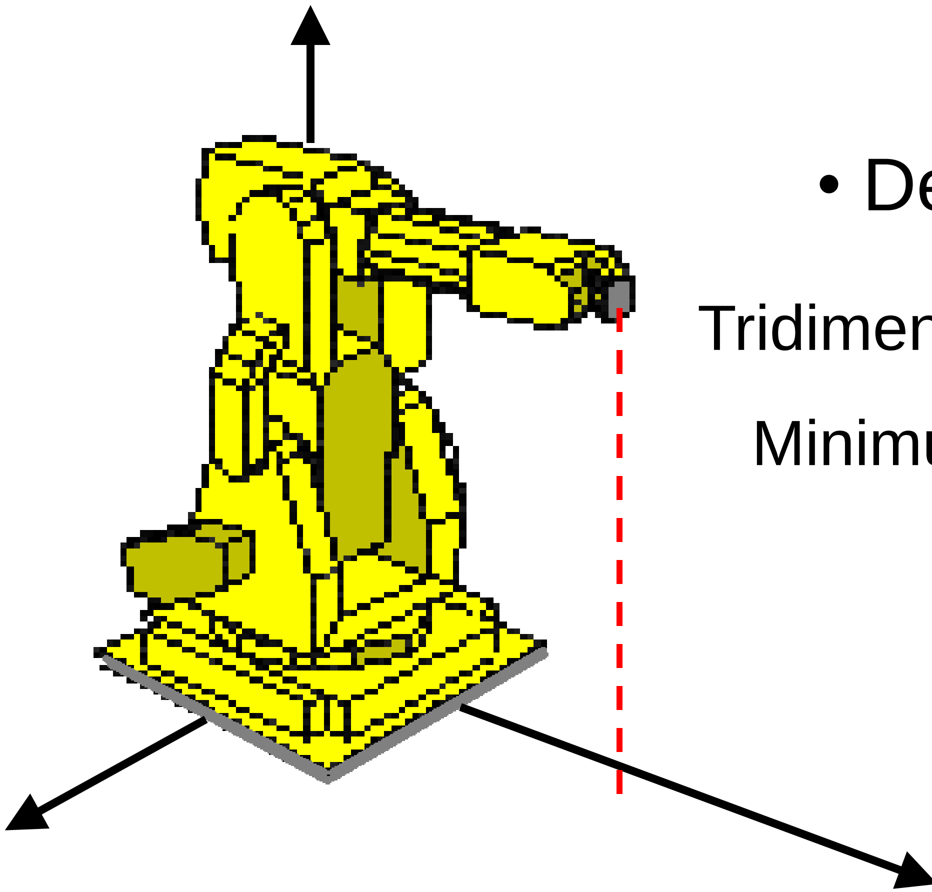
Parçaların Adlandırılması



Mekanik yapıdan robotun tanımlanması:



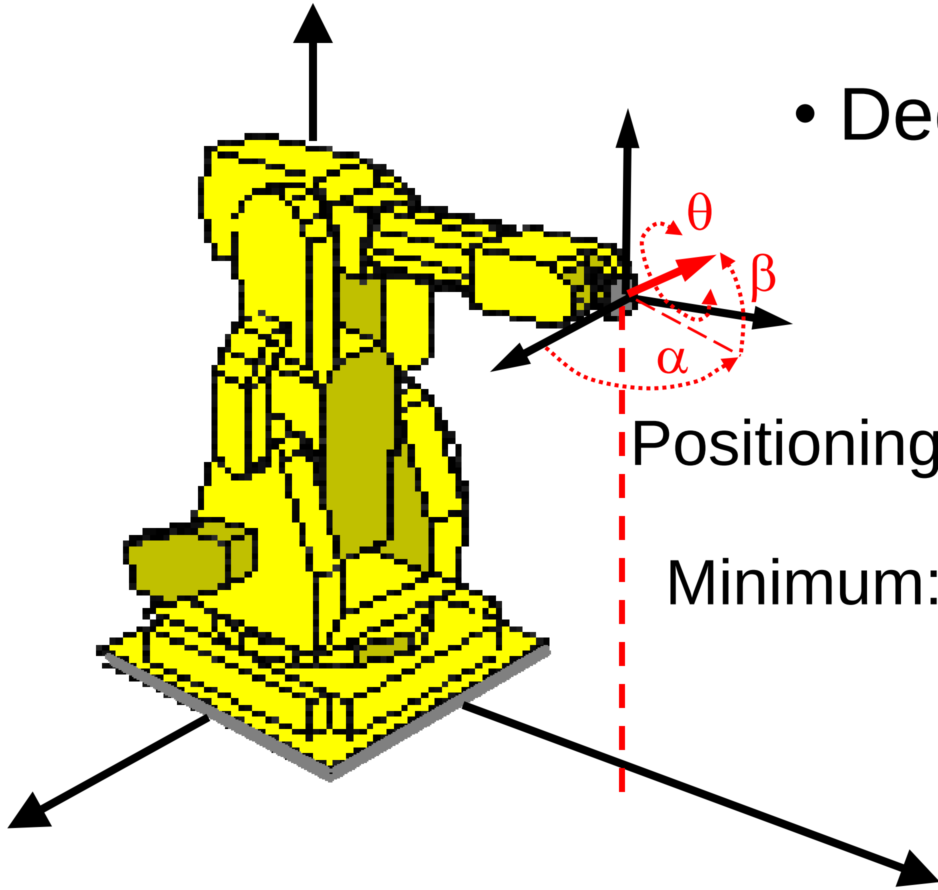
- Serbestlik derecesi
- Çalışma uzayı
- Erişebilirlik
- Yükleme
- Hassasiyet



- Degrees of freedom

Tridimensional positioning: (x,y,z)

Minimum: 3 Degrees of freedom



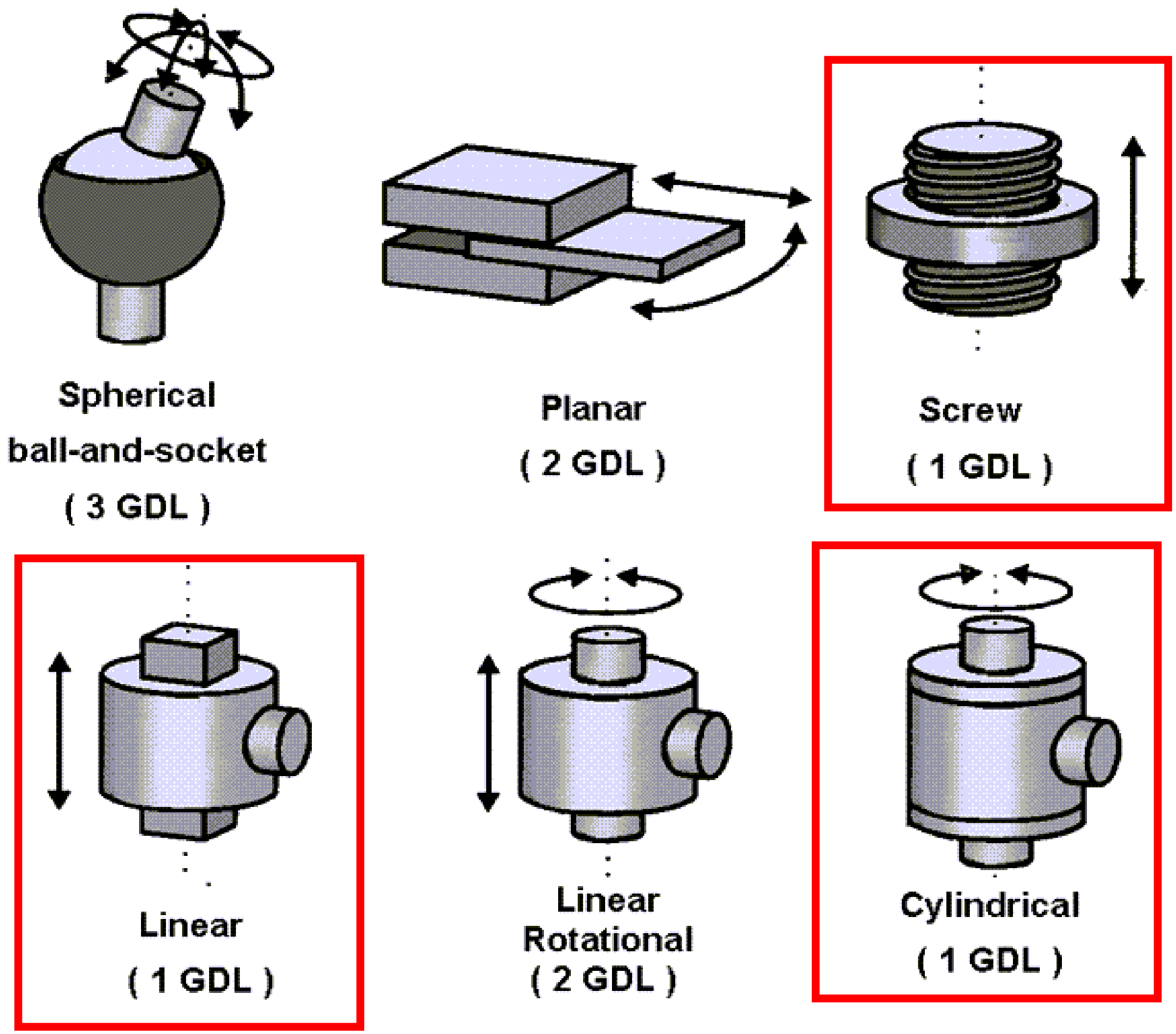
- Degrees of freedom

Positioning + orientation: $(x,y,z,\alpha,\beta,\theta)$

Minimum: 3 + 3 Degrees of freedom

Architecture: Configuration and kind of articulations of the kinematical chain that determine the working volume and accessibility

Eklem Çeşitleri (joints)



In red, those usually used in robotics as they can be motorized without problems

Temel Özelliklerinin Tanımlanması

- ***Serbestlik derecesi*** (Degrees of freedom)

  Tam hareket edebilme sayısı.

- **Hareket Yeteneği** (Movement capability)

  Çalışma alanı, Erişebilme ve manevra yeteneği

- **Hareket Hasasiyeti** (Movement precision)

  Resolution, Repetitiveness, Precision and Compliance

- **Dinamik Özellikleri** (characteristics)

  Taşıma kapasitesi (Payload), Hız (Speed) ve güvenirliklik (Stability)

Hareket hassasiyeti

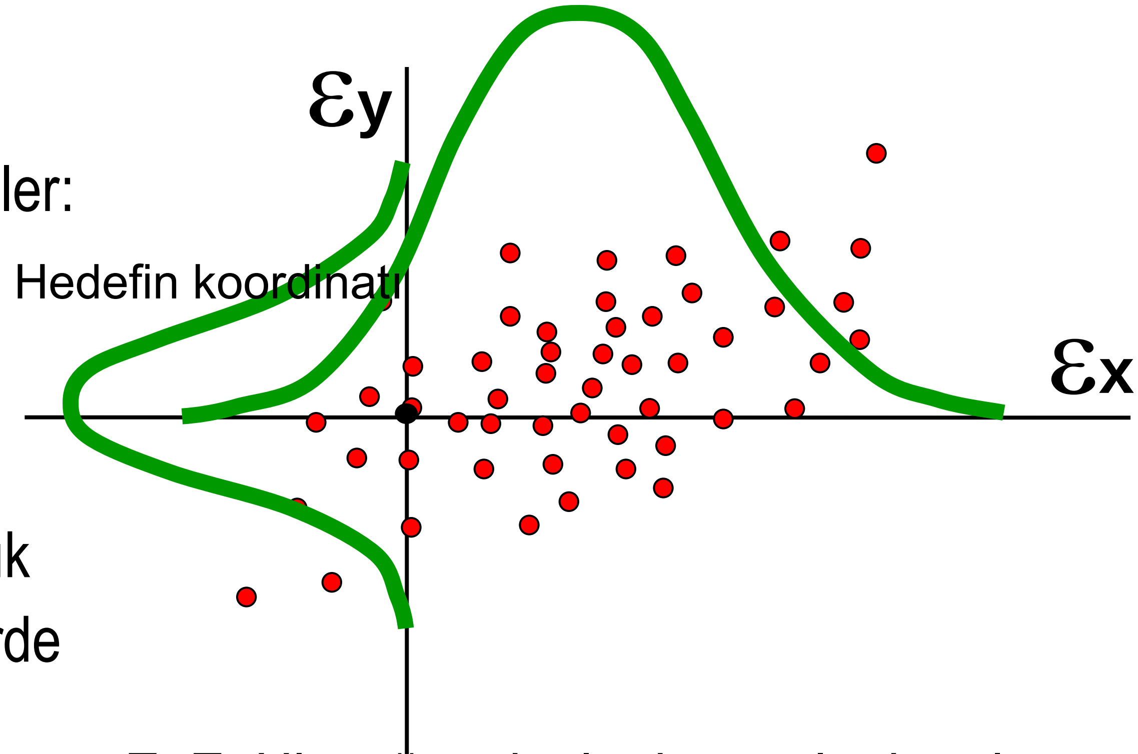
Precision (Accuracy) hassasiyet veya doğruluk

- end effectorun istenilen pozisyon ve oriyantosyona getirlmesindeki sapma.

ε sapma miktarı.

Hassasiyet bağlı olduğu değişkenler:

- Mekanik hareketten kaynaklı (backlash, ters tepme)
- Sensors offset
- Sensors resolution, çözünürlük
- end-effector (E.E.) veya zincirde oluşan sapmalar



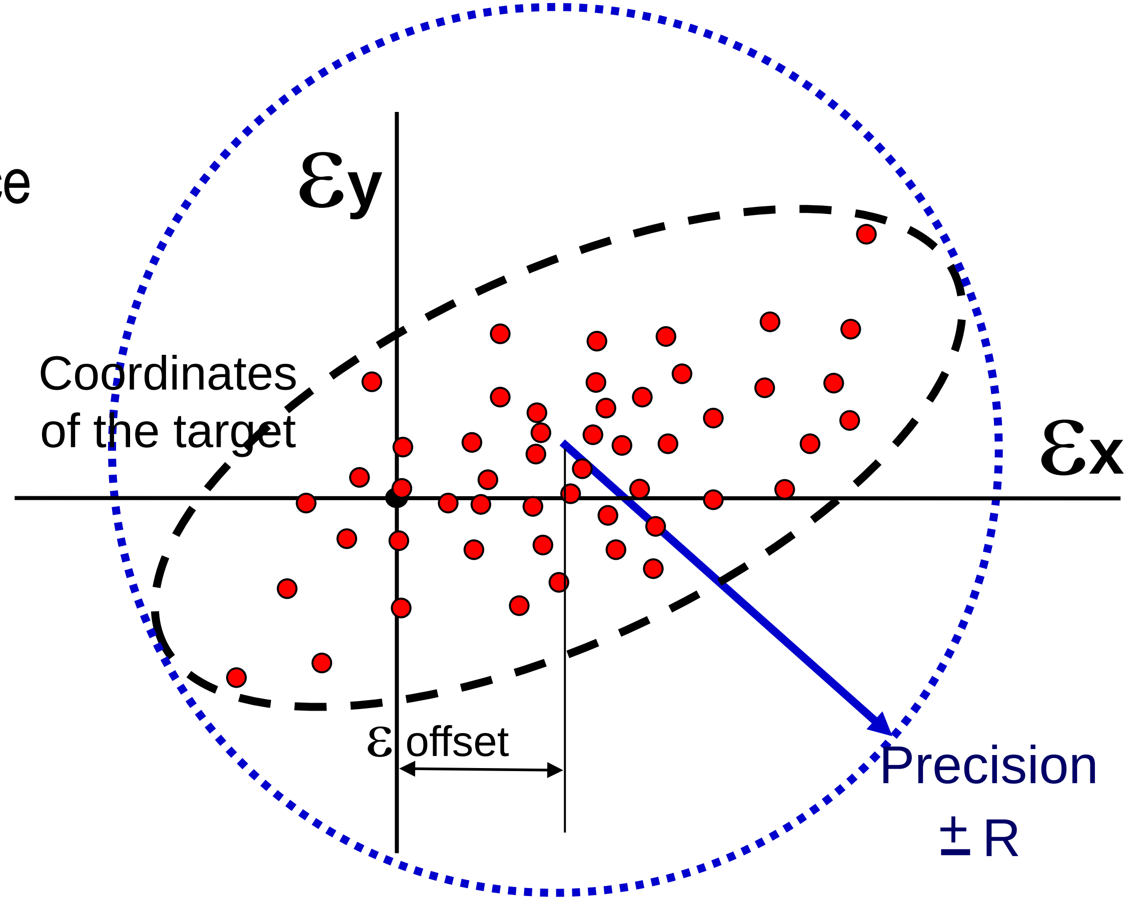
E. E. Ulaştığı noktalar kırmızılar hatalı

Movement precision

Precision (Accuracy)

- Capacity to place the end effector into a given position and orientation (pose) within the robot working volume, from **a random** initial position.

ε increases with the distance to the robot axis.



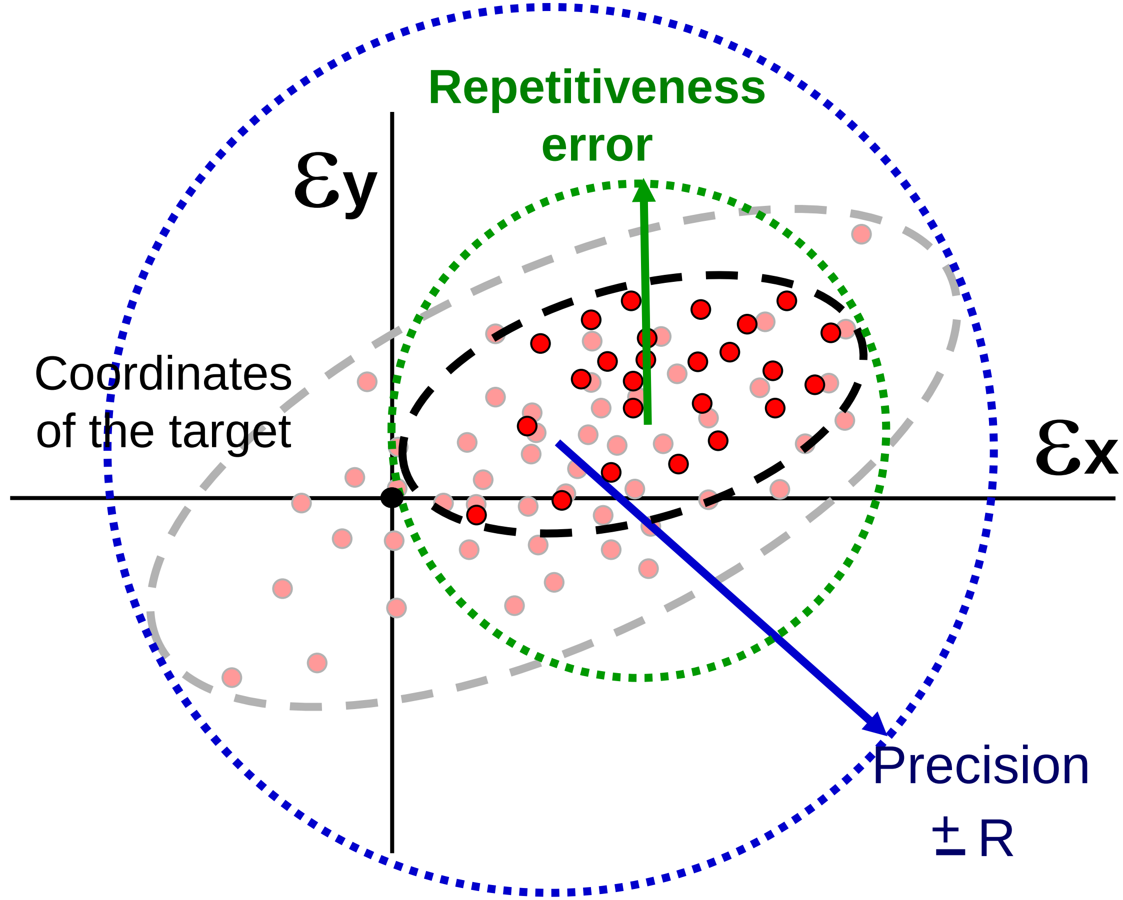
Movement precision

Repetitiveness

- Capacity to place the end effector into a given position and orientation (pose) within the robot working volume, from **a given** initial position.

Repetitiveness depends on:

- Mechanical play (backlash)
- Target position
- Speed and direction when reaching the target



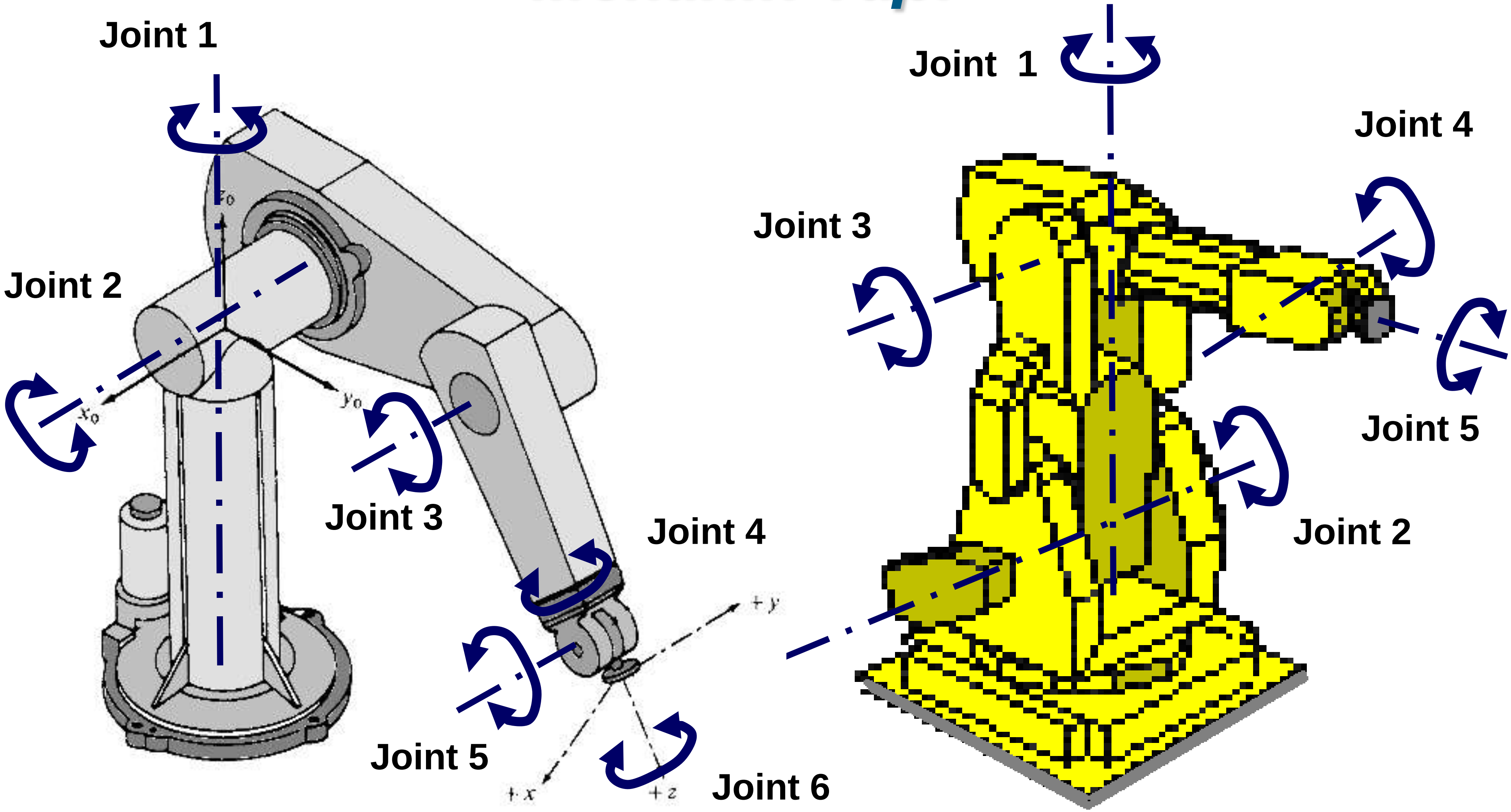
Movement precision (Statics)

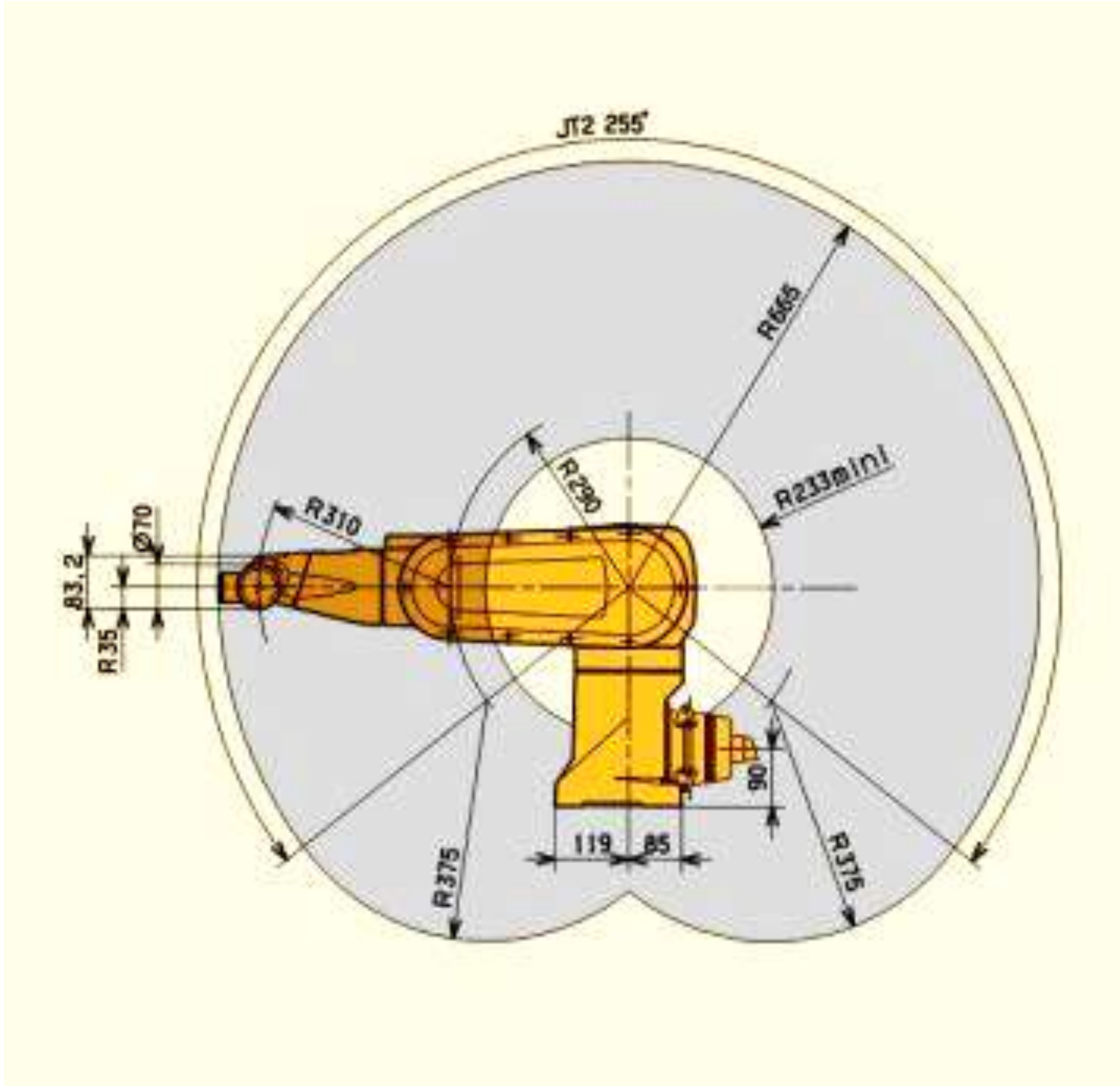
Resolution:

- Minimal displacement the EE can achieve and / or the control unit can measure.
- Determined by mechanical joints and the number of bits of the sensors tied to the robot joints.

Error resolution of the sensor = Measurement Rank / 2^n

Mekanik Yapı





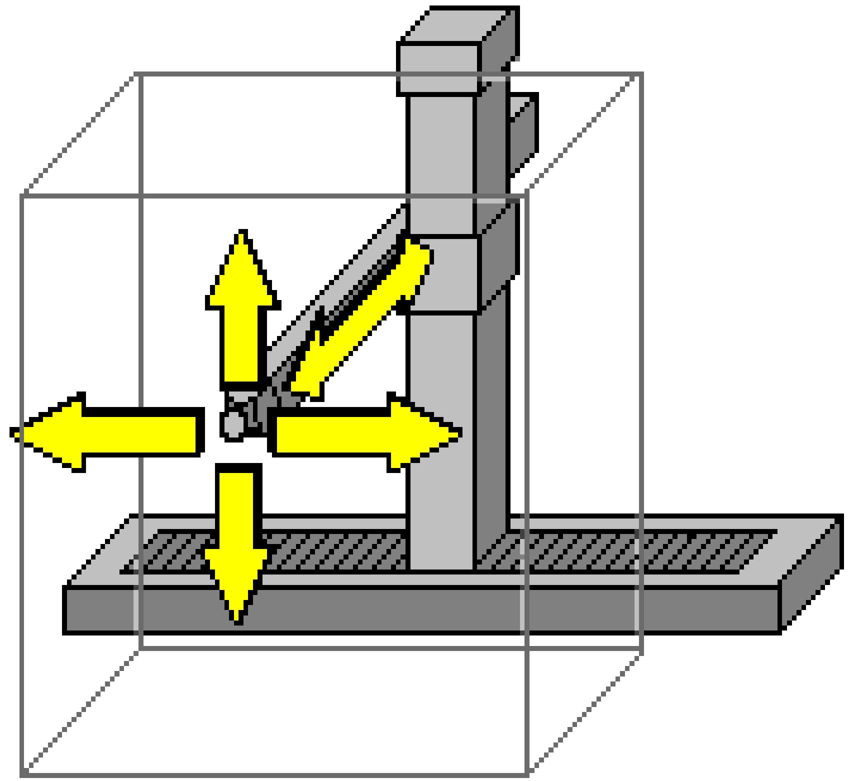
Çalışma hacminin kesiti

Architectures

Architecture: Configuration and kind of articulations of the kinematical chain that determine the working volume and accessibility

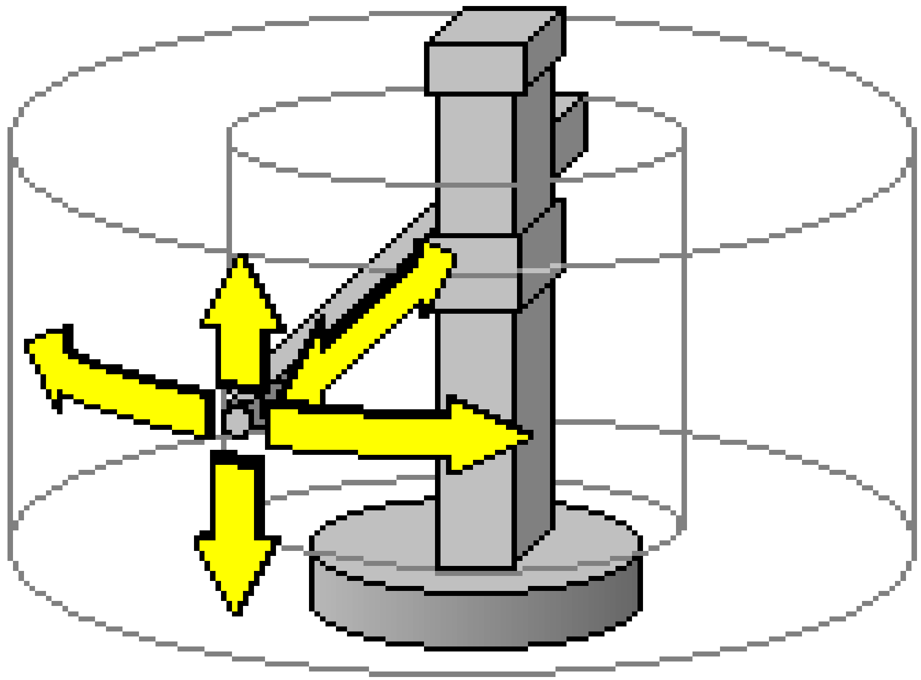
Classical Architectures:

- Cartesian
- Cylindrical
- Polar
- Angular



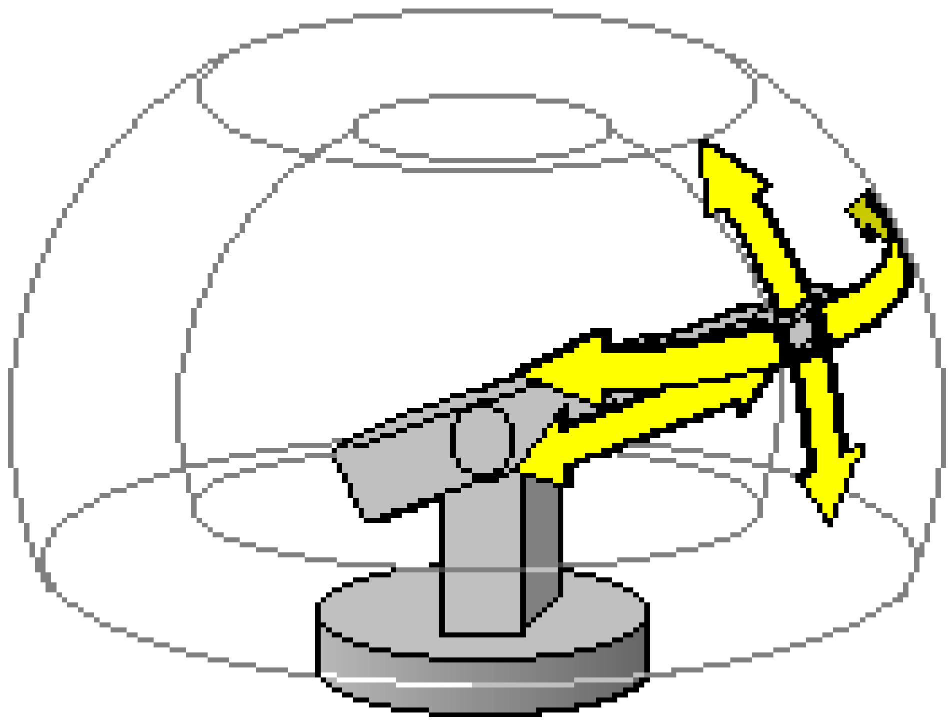
Cartesian Work Space (D+D+D)

Example of a Cartesian Work Space Robot (D+D+D)



Cylindrical Work Space (R+D+D)

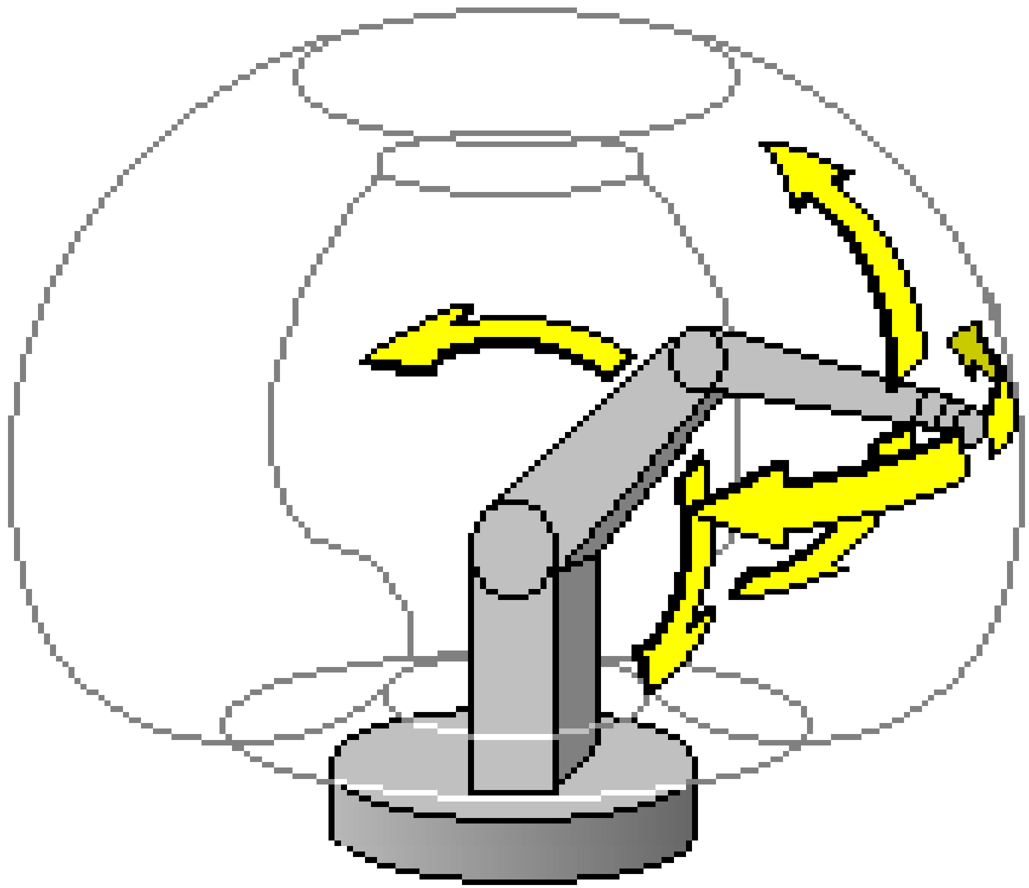
Example of a Cylindrical Work Space Robot (R+D+D)



Polar Work Space (R+R+D)

Example of a Polar Work Space Robot (R+R+D)

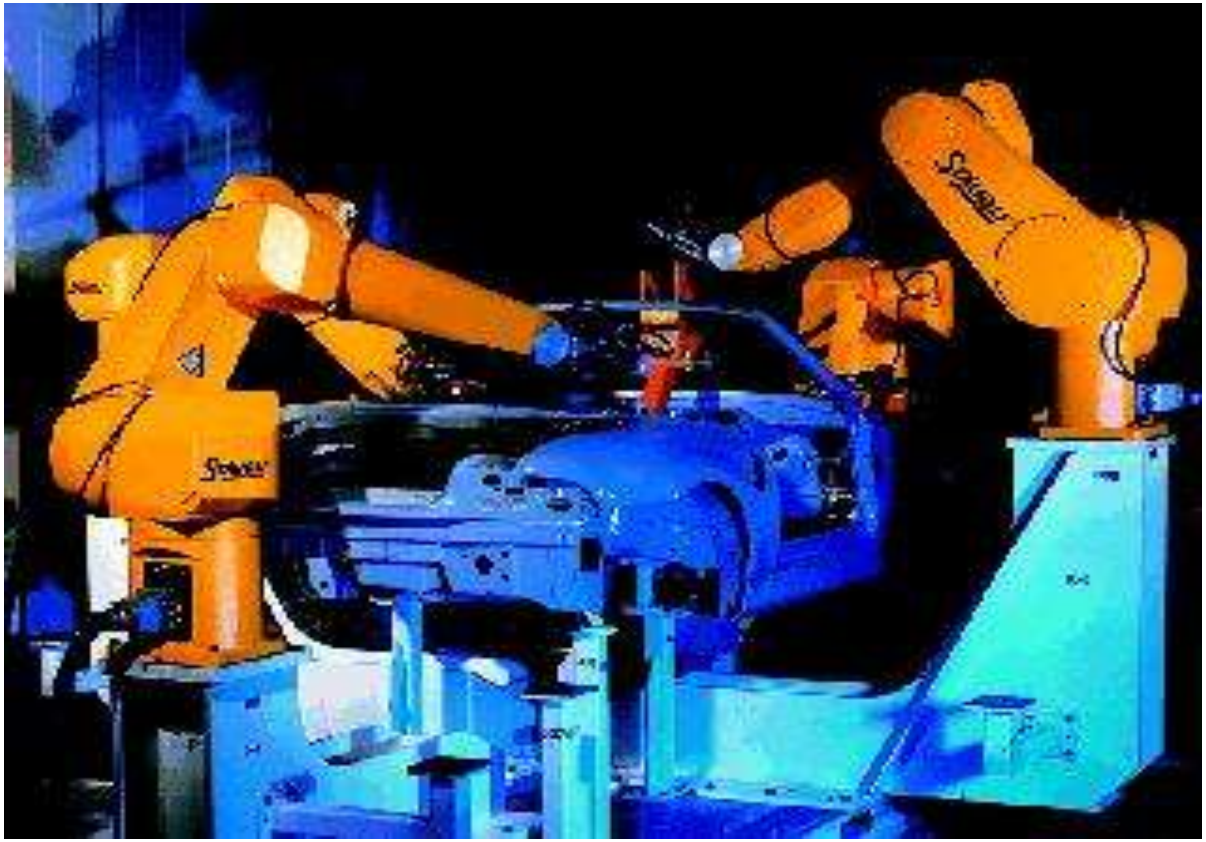
Classical Architectures



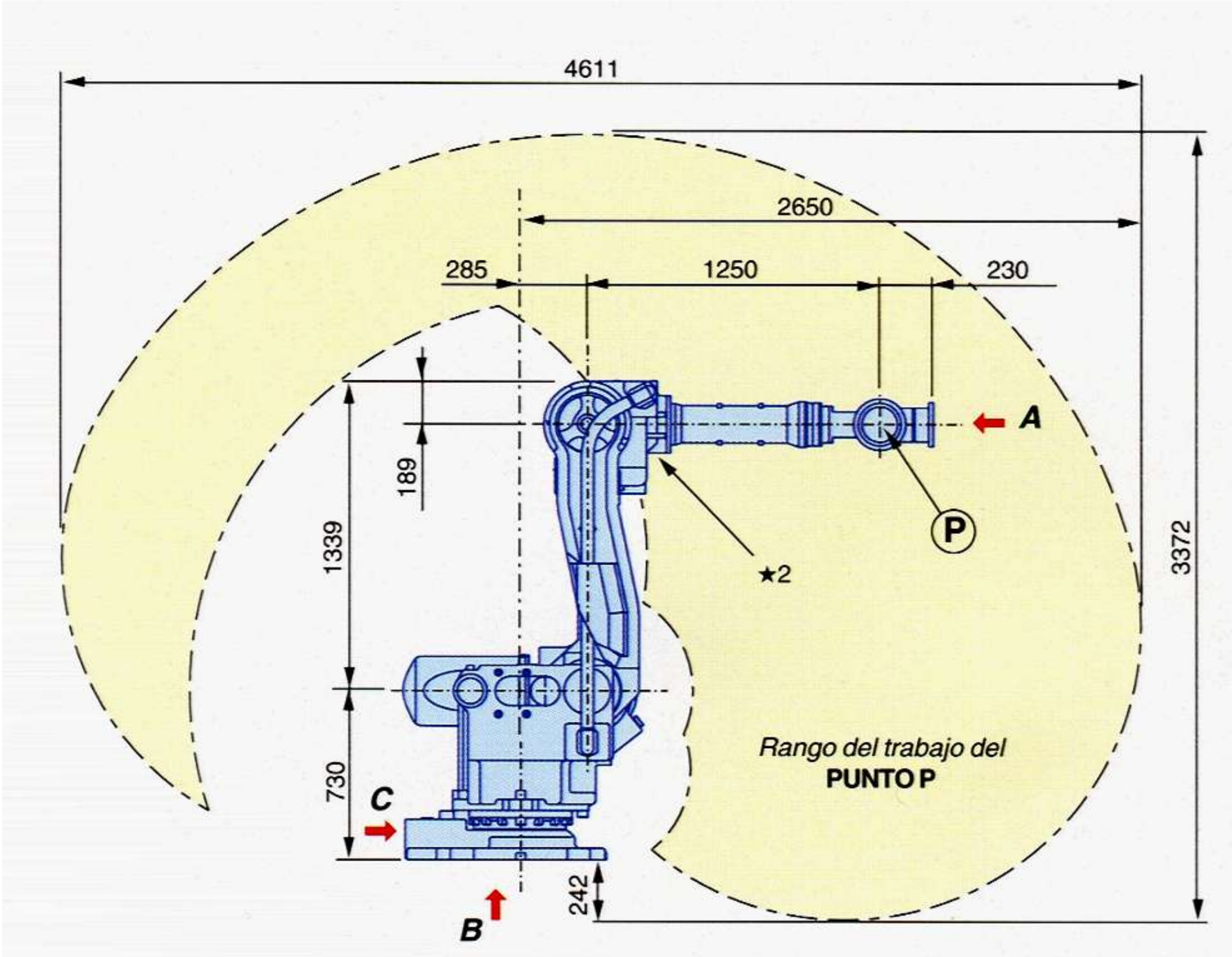
Angular Work Space (R+R+D)

Classical Architectures

Angular Work Space (R+R+R)

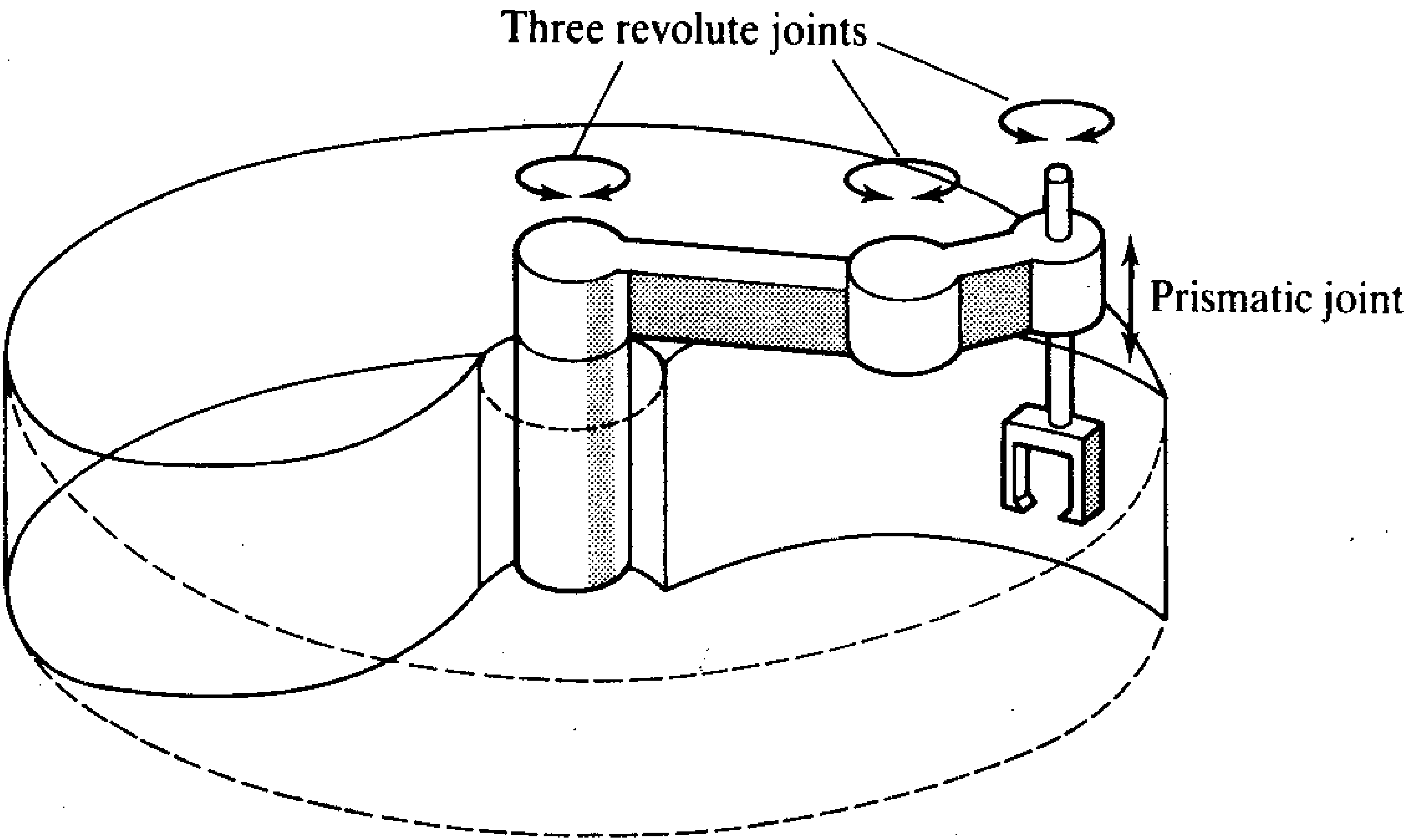


Example of Angular Work Space Robots (R+R+R)



Working space of a robot with angular joints

Inverted robot: Increase the useful working volume

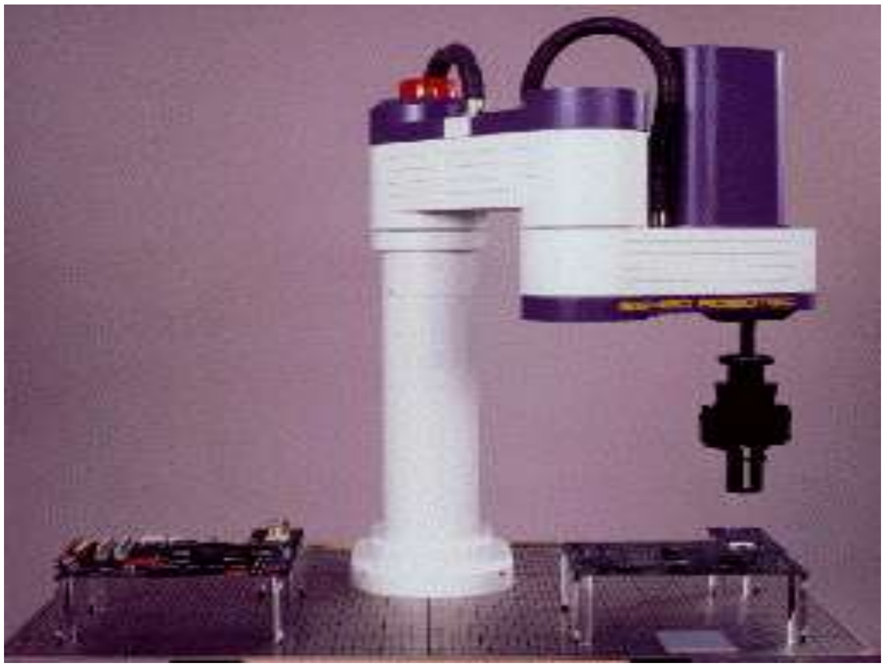


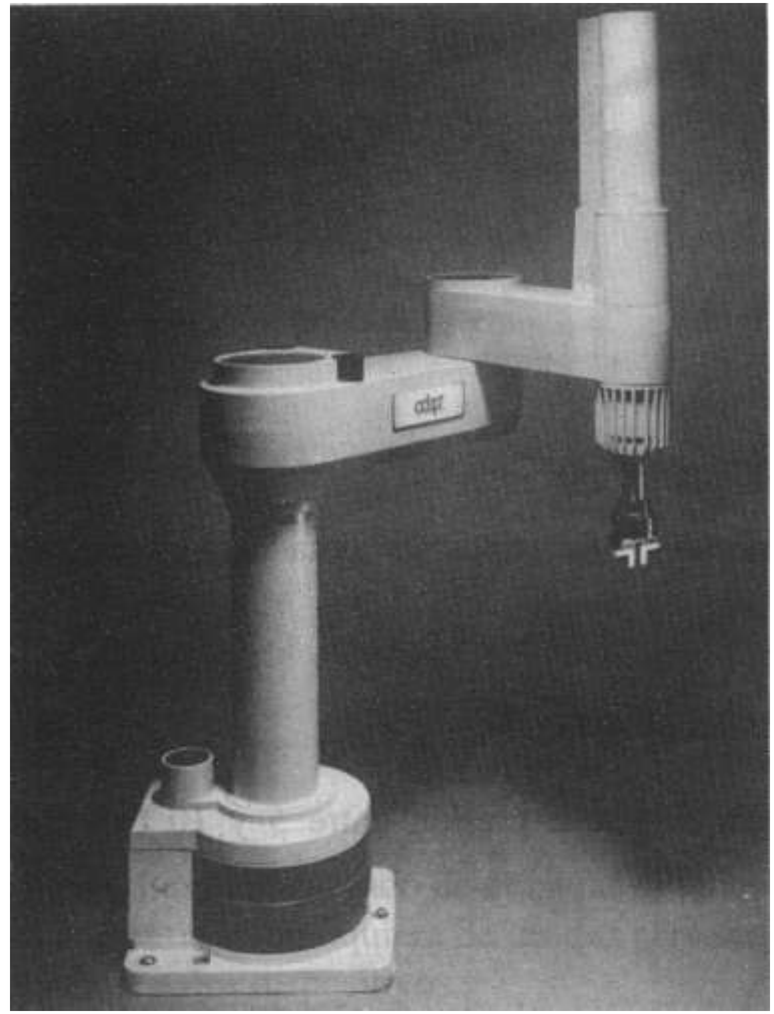
Architecture "SCARA"

Architecture R-R-D with cylindrical coordinates

(SCARA: Selective Compliance Assembly Robotic Arm)

SCARA Robot : examples





Resume Cartesian Robot Characteristics

Robot	Joints	Observations
Cartesian	1a. Linear: X 2a. Linear: Y 3a. Linear: Z	**Advantages:** • linear movement in three dimensions • simple kinematical model • rigid structure • easy to display • possibility of using pneumatic actuators, which are cheap, in *pick&place* operations • constant resolution **Drawbacks:** • requires a large working volume • the working volume is smaller than the robot volume (crane structure) • requires free area between the robot and the object to manipulate • guides protection

Resume Cylindrical Robot Characteristics

Robot	Joints	Observations
Cylindrical	1a. Rotation: θ 2a. Linear: Z 3a. Linear: ρ	**Advantages:** • simple kinematical model • easy to display • good accessibility to cavities and open machines • large forces when using hydraulic actuators **Drawbacks:** • restricted working volume • requires guides protection (linear) • the back side can surpass the working volume

Resume Polar Robot Characteristics

Robot	Joints	Observations
Polar	1a. Rotation: θ 2a. Rotation: φ 3a. Linear: ρ	**Advantages:** • large reach from a central support • It can bend to reach objects on the floor • motors 1 and 2 close to the base **Drawbacks:** • complex kinematics model • difficult to visualize

Resume Angular Robot Characteristics

Robot	Joints	Observations
Angular	1a. rotation θ_1 2a. rotation θ_2 3a. rotation θ_3	**Advantages:** • maximum flexibility • large working volume with respect to the robot size • joints easy to protect (angular) • can reach the upper and lower side of an object **Drawbacks:** • complex kinematical model • difficult to display • linear movements are difficult • no rigid structure when stretched

Resume SCARA Robot Characteristics

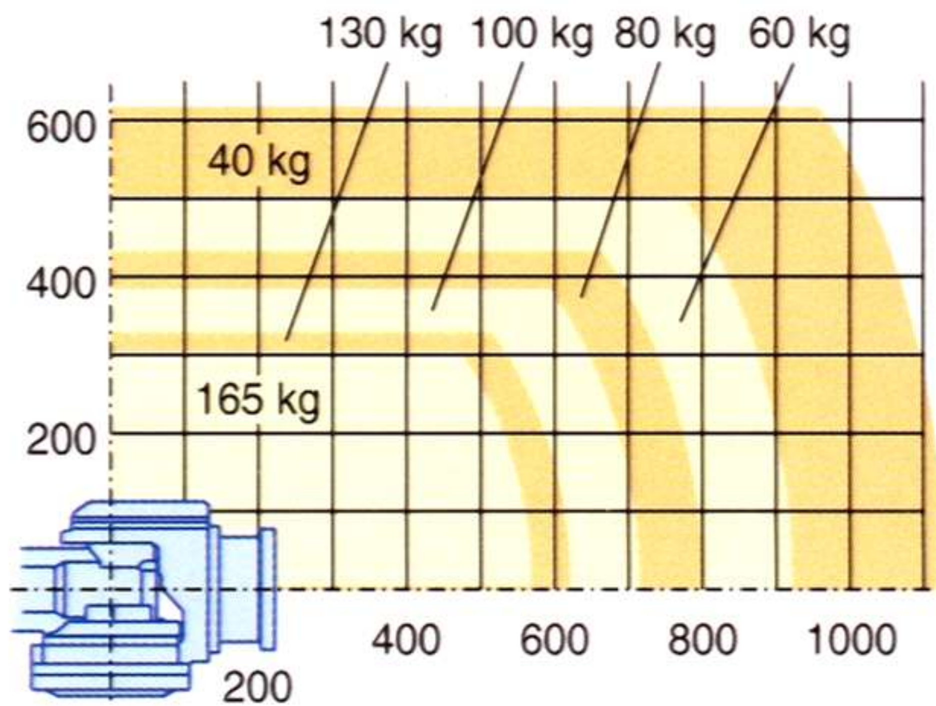
Robot	Joints	Observations
SCARA	1a. rotation θ_1 2a. rotation θ_2 3a. rotation θ_3	**Advantages:** • high speed and precision **Drawbacks:** • only vertical access

Dynamic Characteristics

Payload:

- The load (in Kg) the robot is able to transport in a continuous and precise way (stable) to the most distance point
- The values usually used are the maximum load and nominal at acceleration = 0
- The load of the End-Effector is not included.

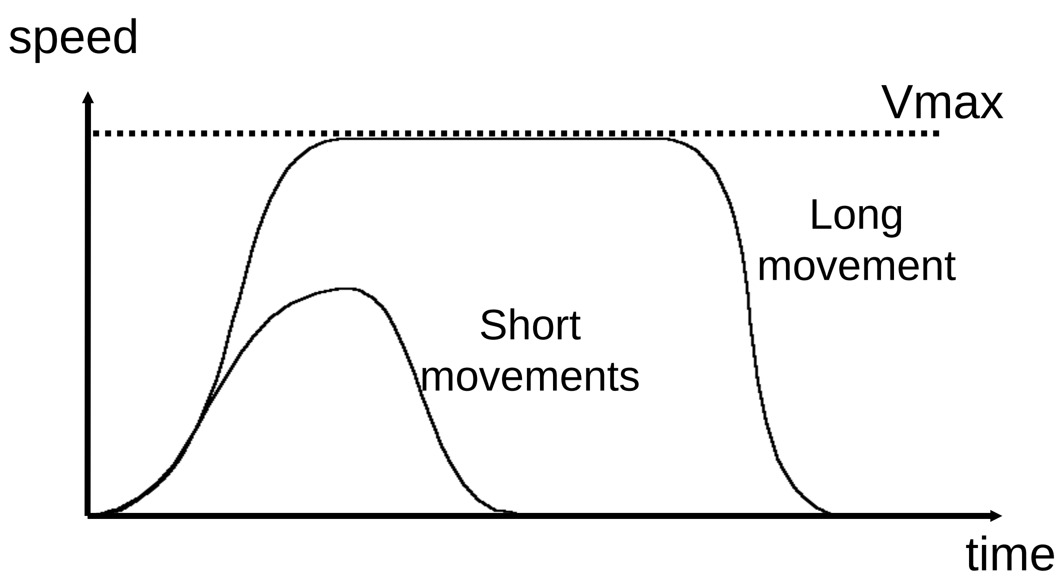
Example of Map of admitted loads, in function of the distance to the main axis



Dynamic Characteristics

Velocity

- Maximum speed (mm/sec.) to which the robot can move the End-Effector.
- It has to be considered that more than a joint is involved.
- If a joint is slow, all the movements in which it takes part will be slowed down.
- For shorts movements it can be more interesting the measure of acceleration.



Architectures

- Classical Architectures: Cartesian

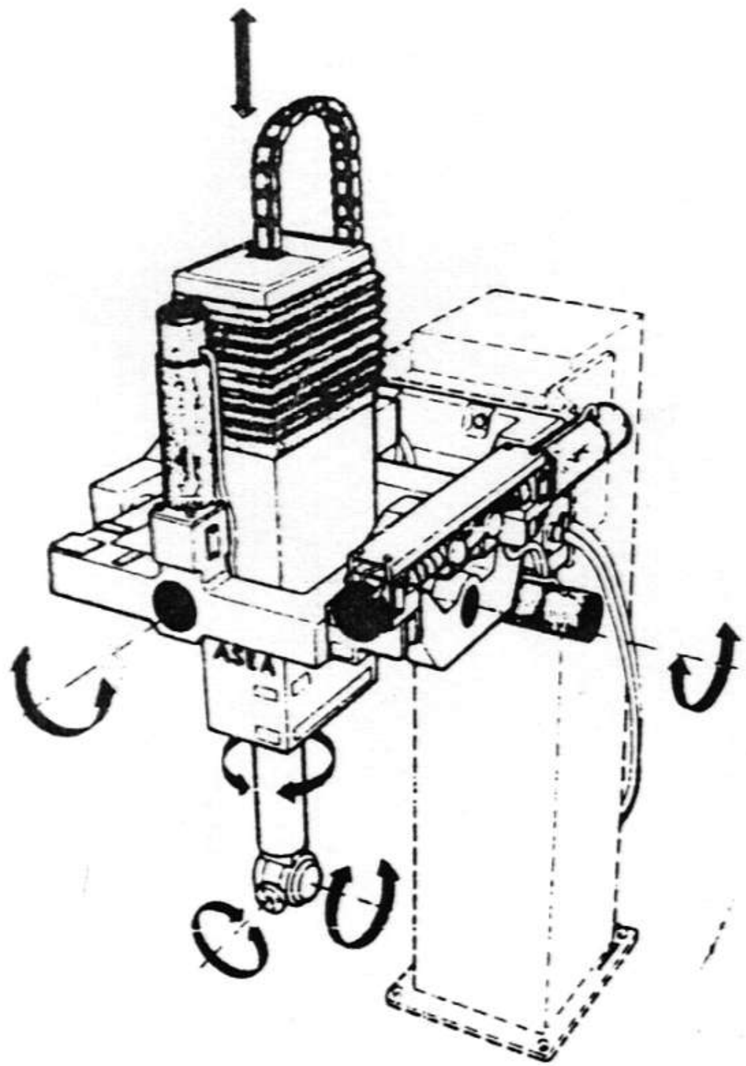
  Cylindrical

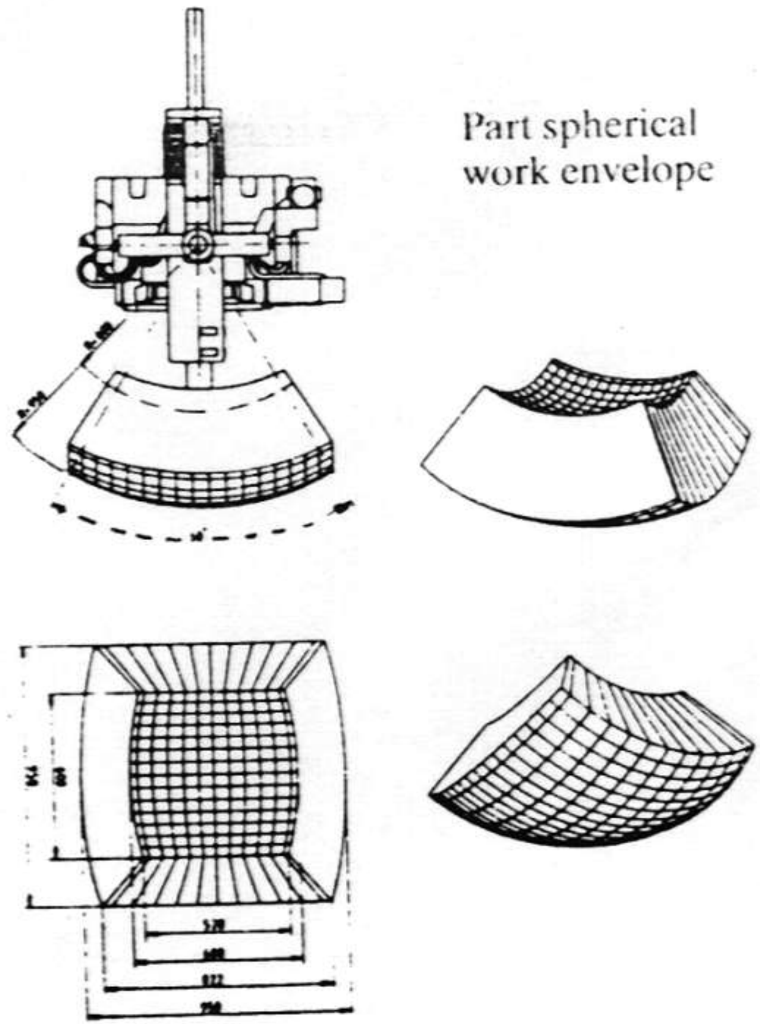
  Polar

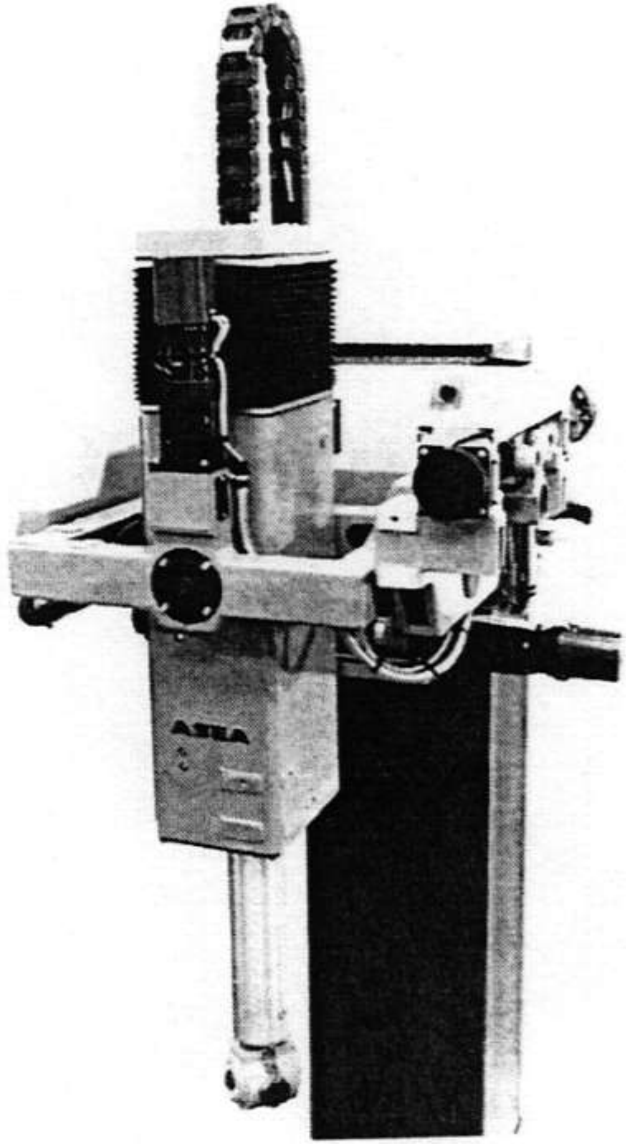
  Angular

- Special configurations

Special Configurations. Pendulum Robot GGD

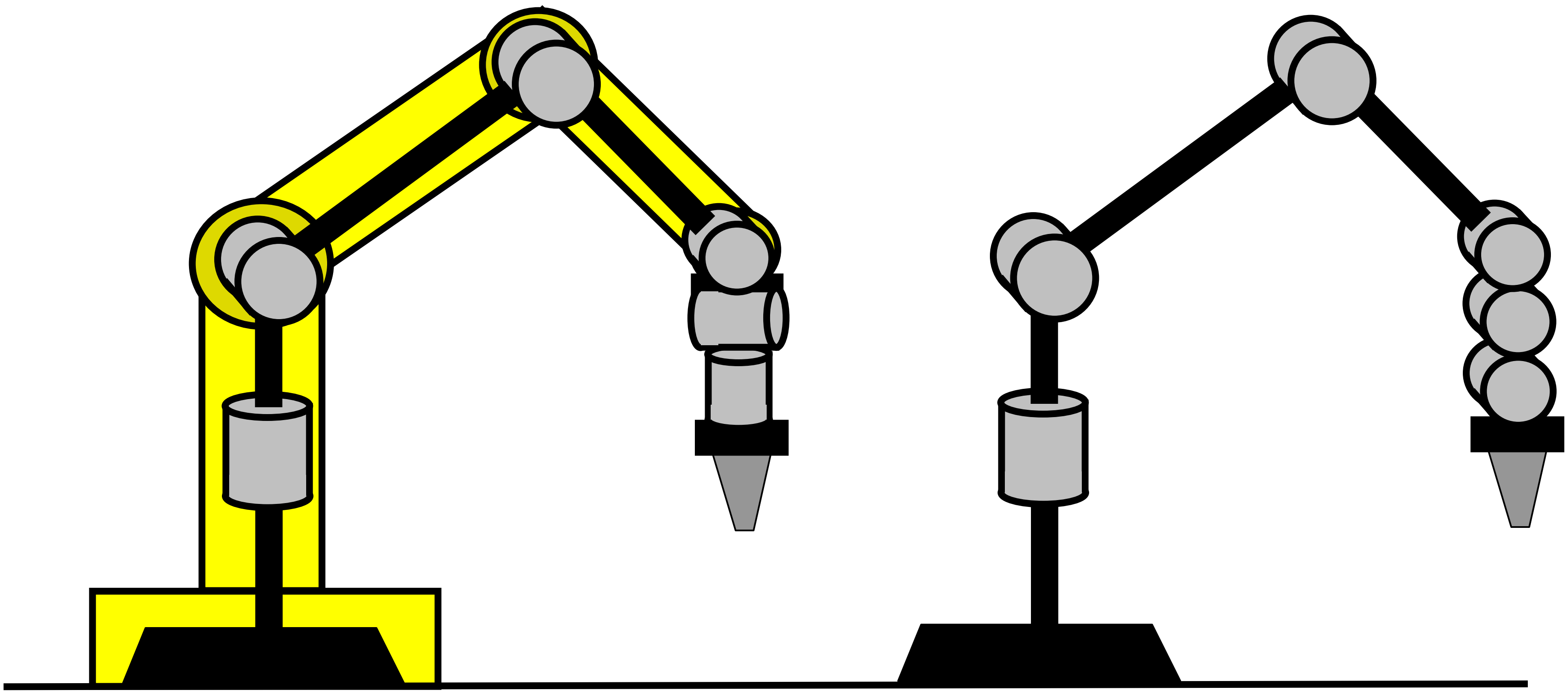






Example of a Pendulum Robot RRD

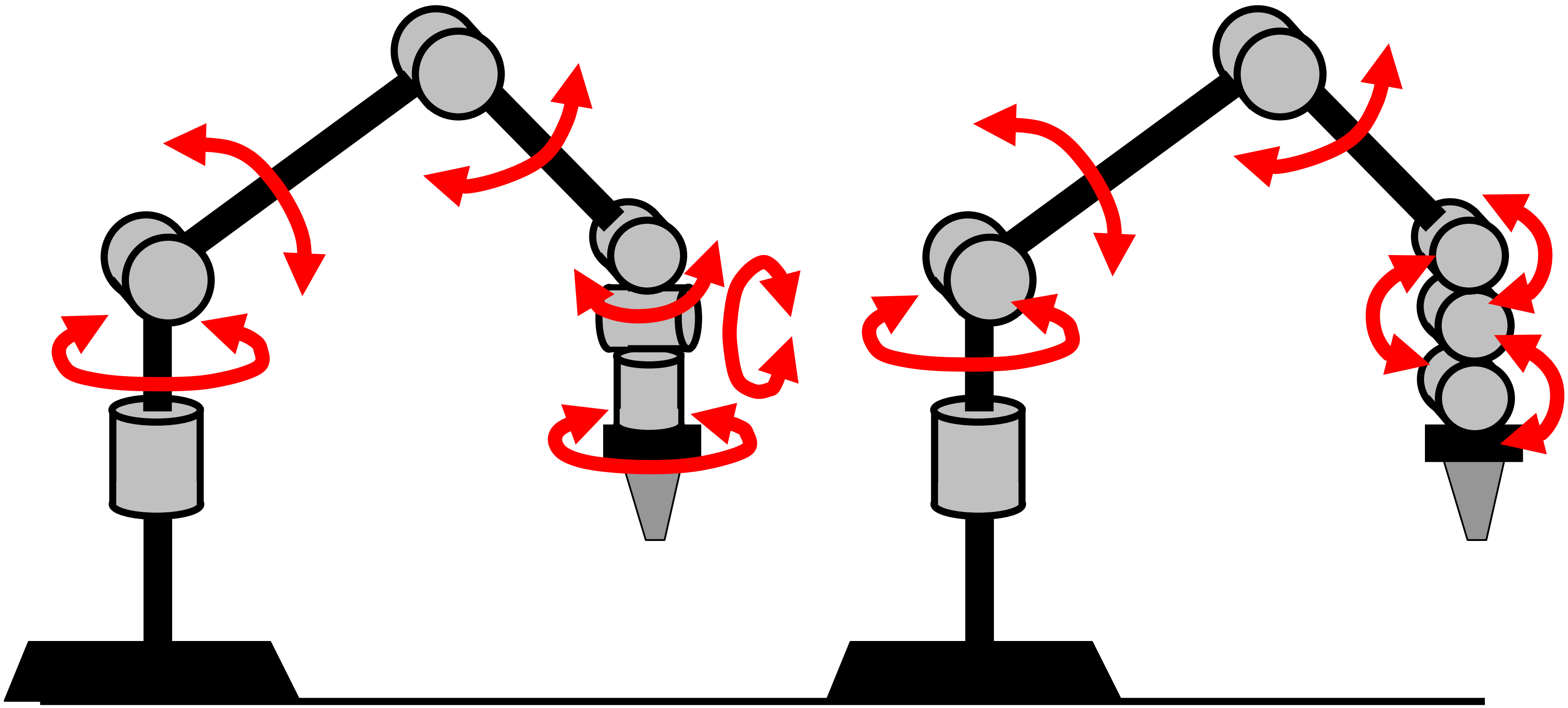
Special Configurations. Elephant Trunk



Classical Degrees of freedom

Concatenated Degrees of freedom (elephant trunk)

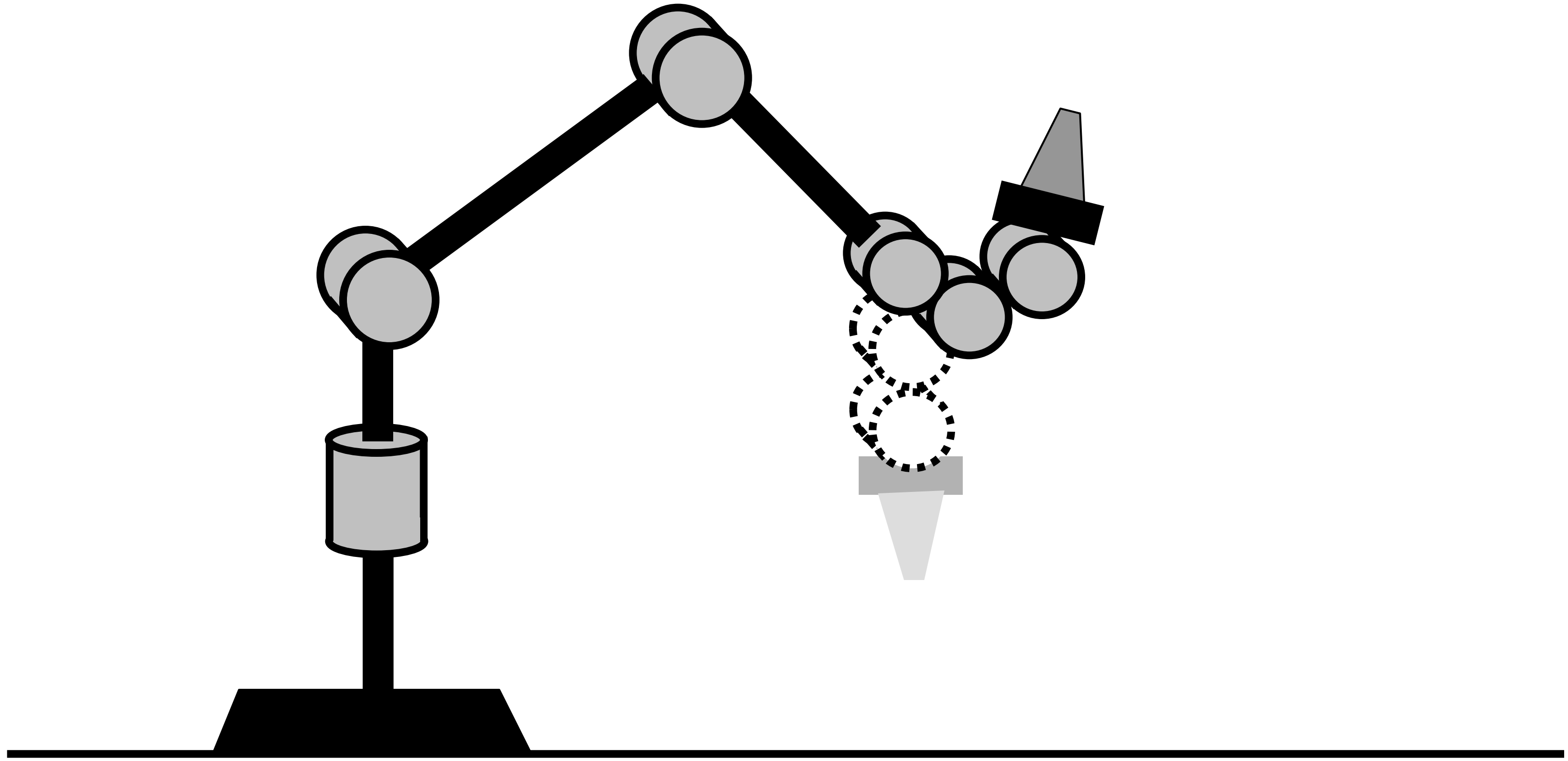
Special Configurations. Elephant Trunk



Classical Degrees of freedom

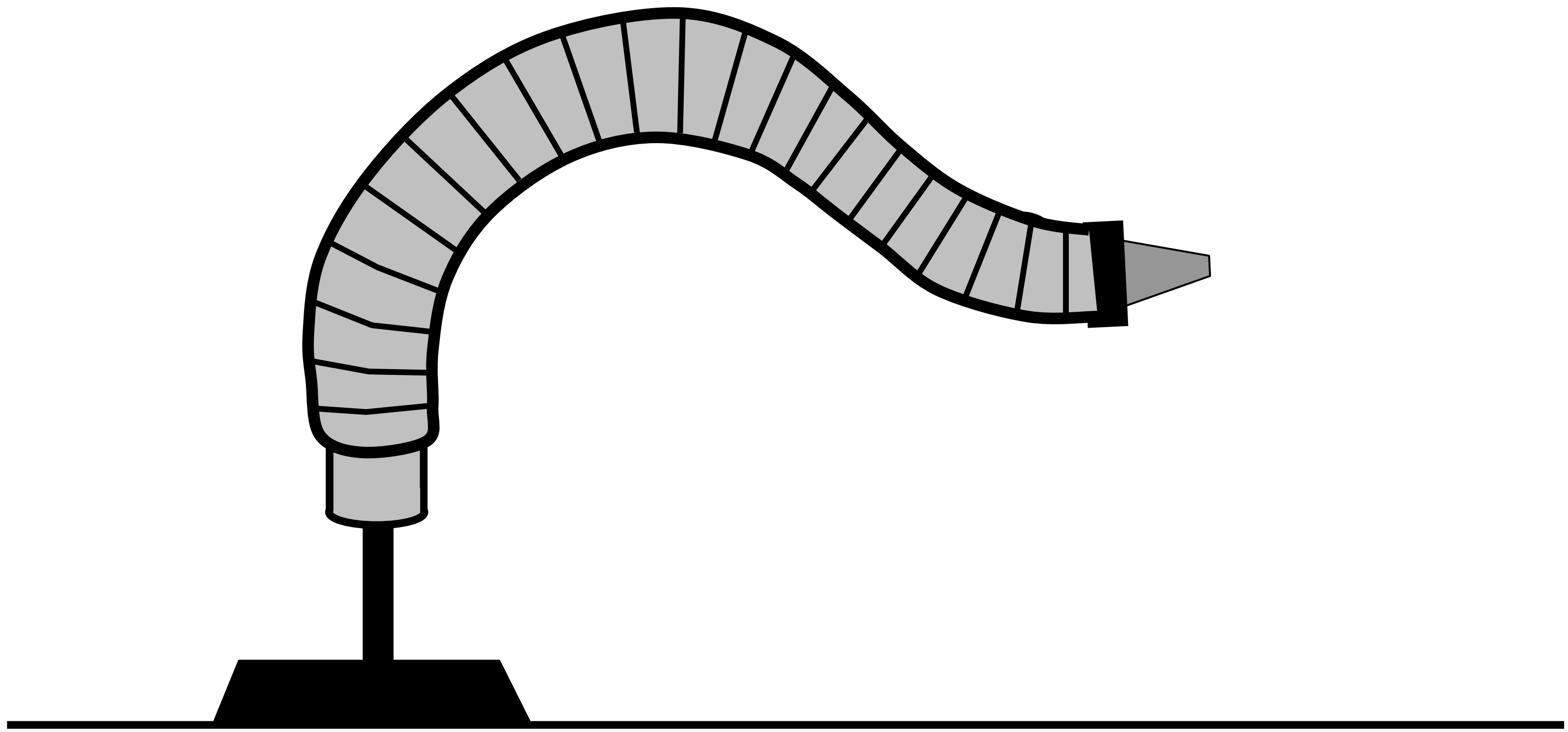
Concatenated Degrees of freedom (elephant trunk)

Special Configurations. Elephant Trunk



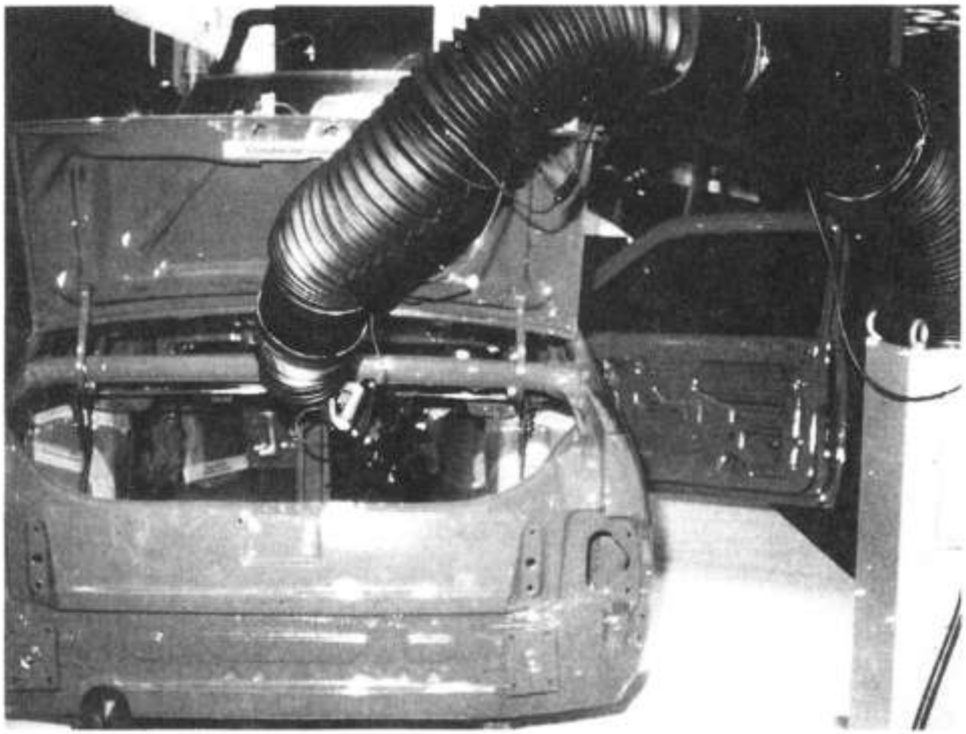
Increase of accessibility

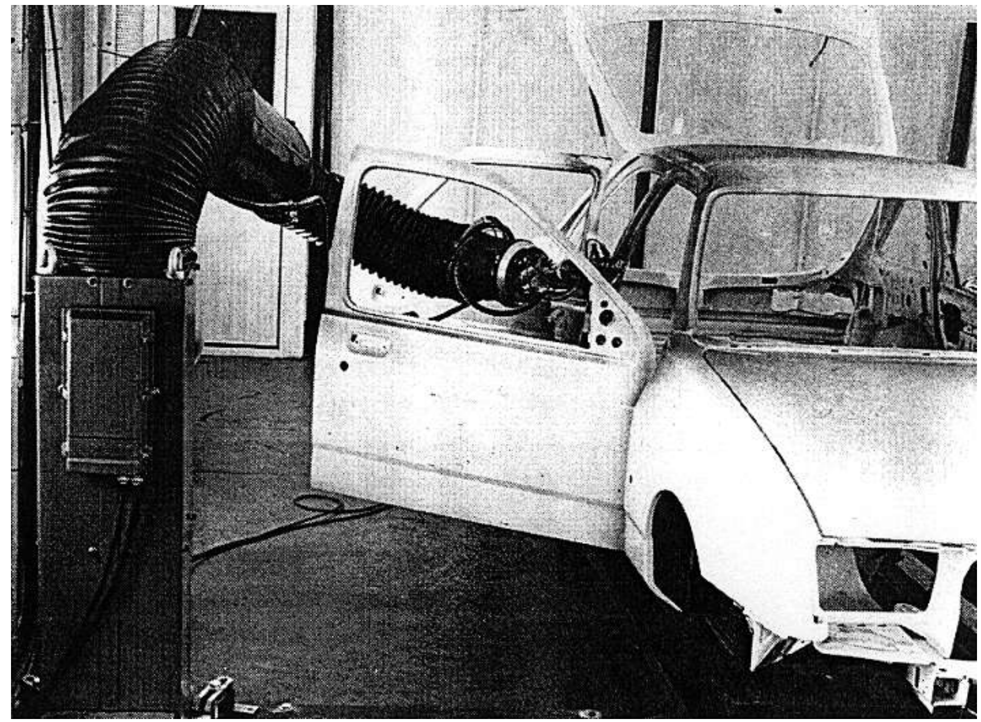
Special Configurations. Elephant Trunk



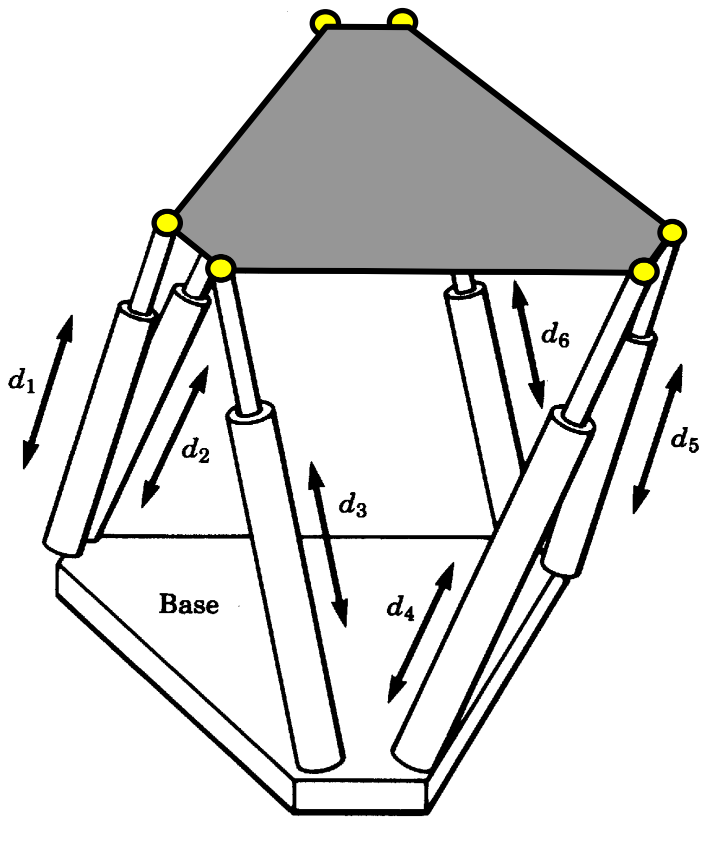
Distributed Degrees of Freedom.

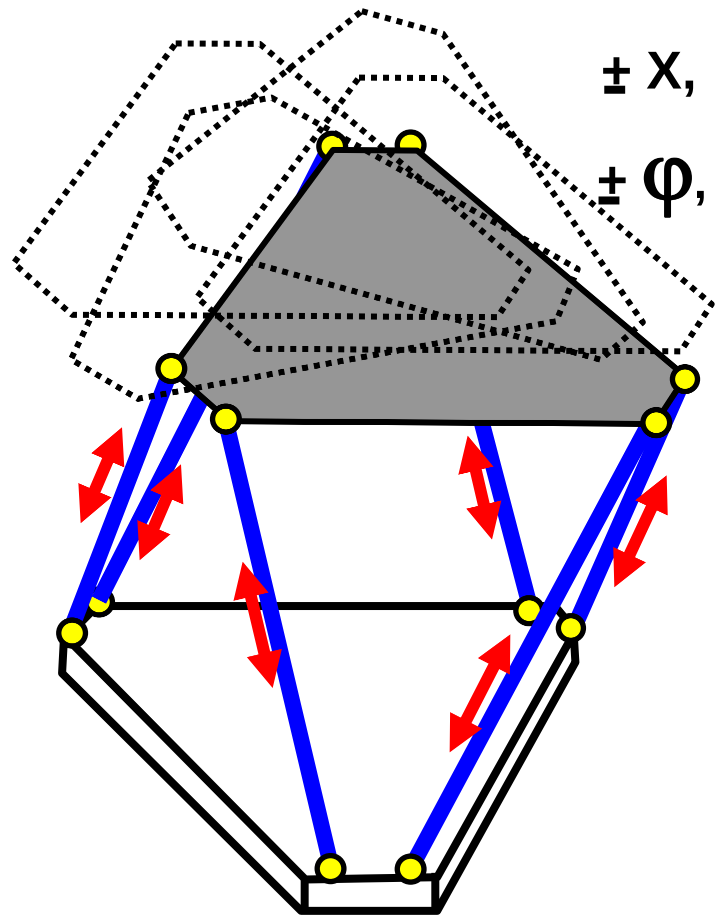
Elephant Trunk Examples Applications





Special Configurations. Stewart Platform



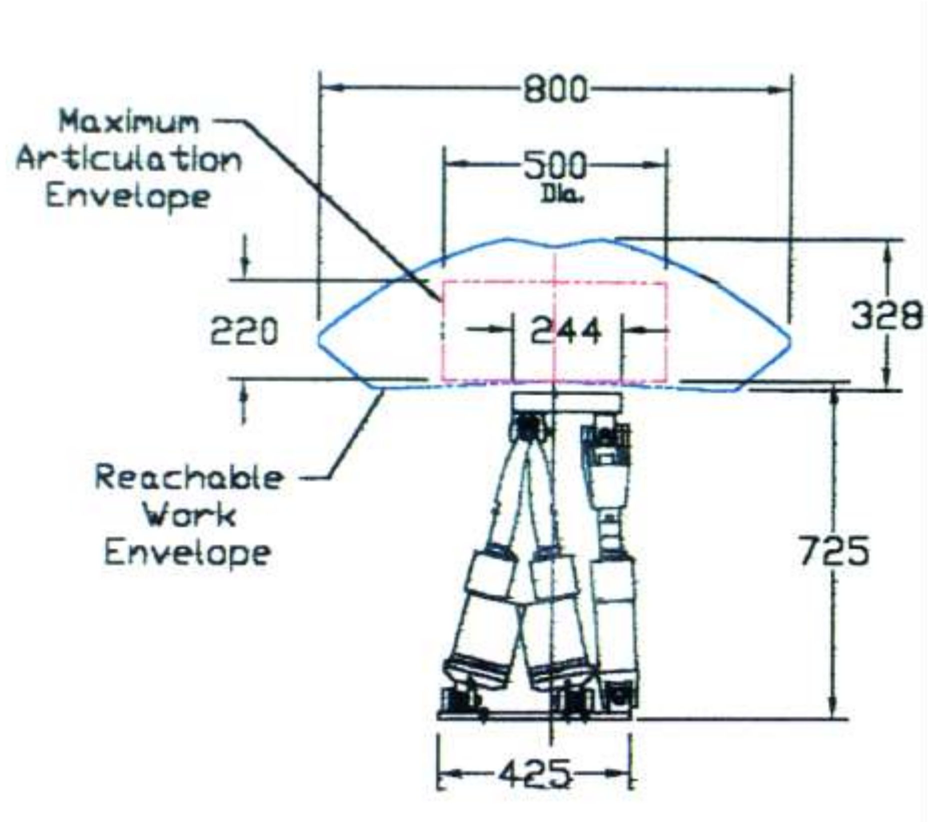


± X, ± Y, ± Z

± φ, ± ϕ, ± θ

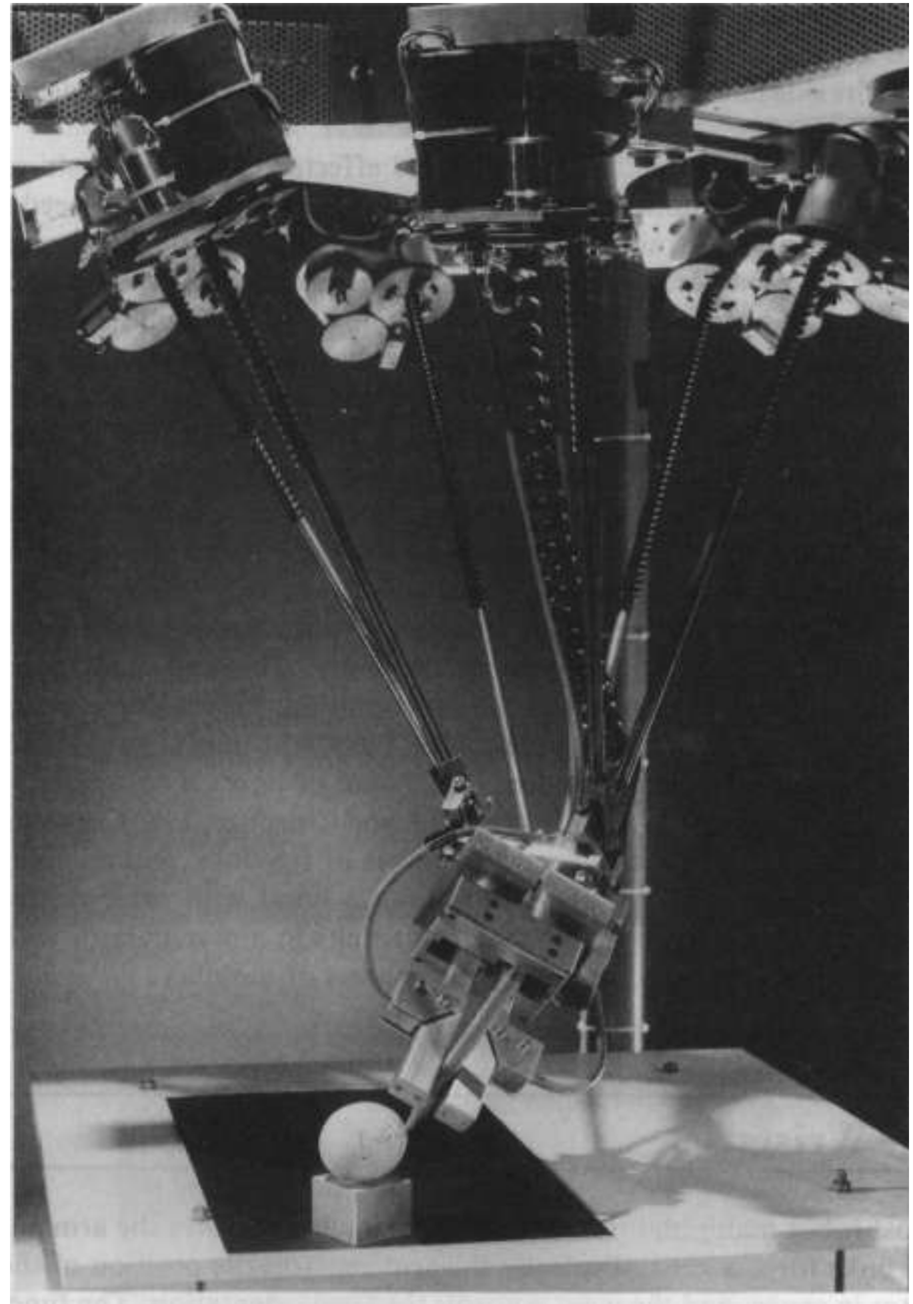
6 Displacements → 6 DoF.

Platform "Stewart" Example

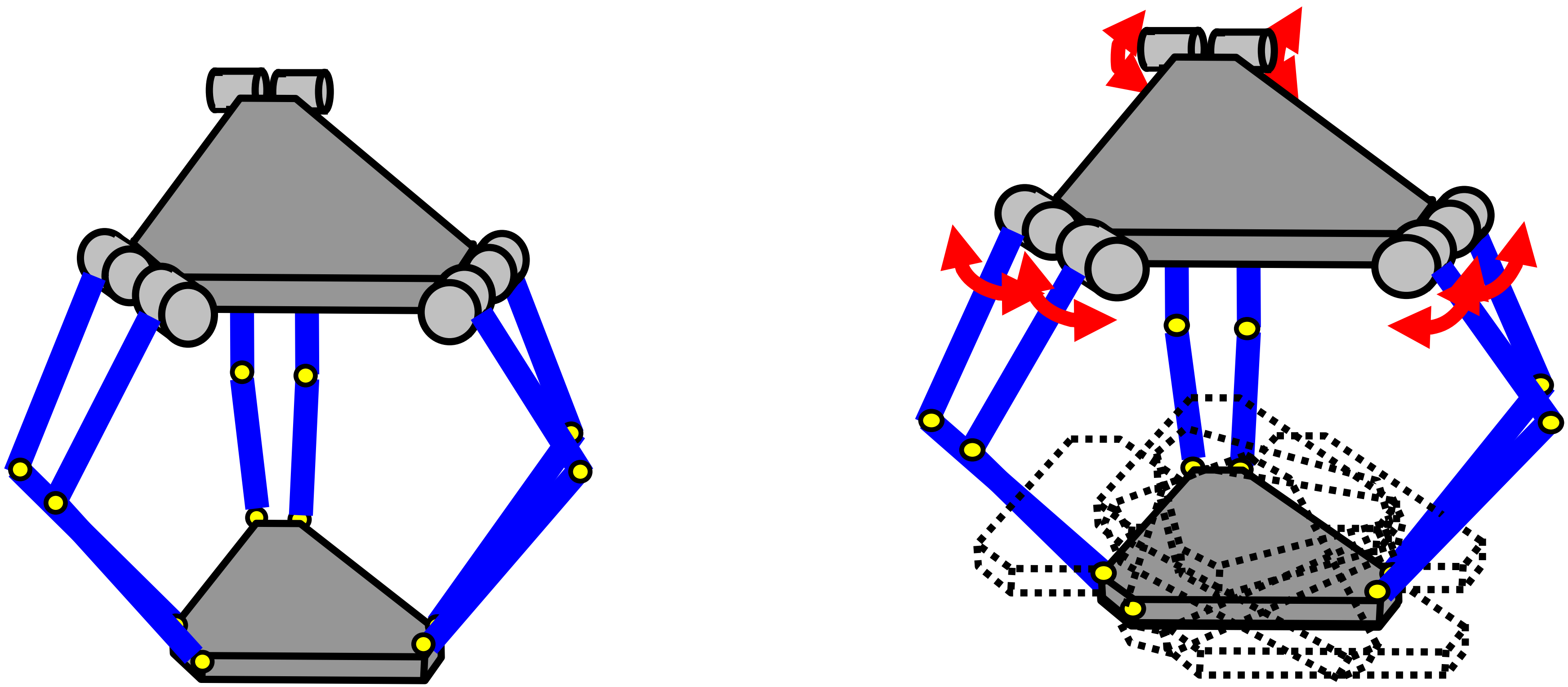


Workspace

Example of "Stewart" Robot



Δ Robots



6 Rotations → 6 DoF.

Movement capabilities

1. Working volume (Workspace):

- Set of positions reachable by the robot end-effector.
- Shape is more important than the volume (m^3)

2. Accessibility:

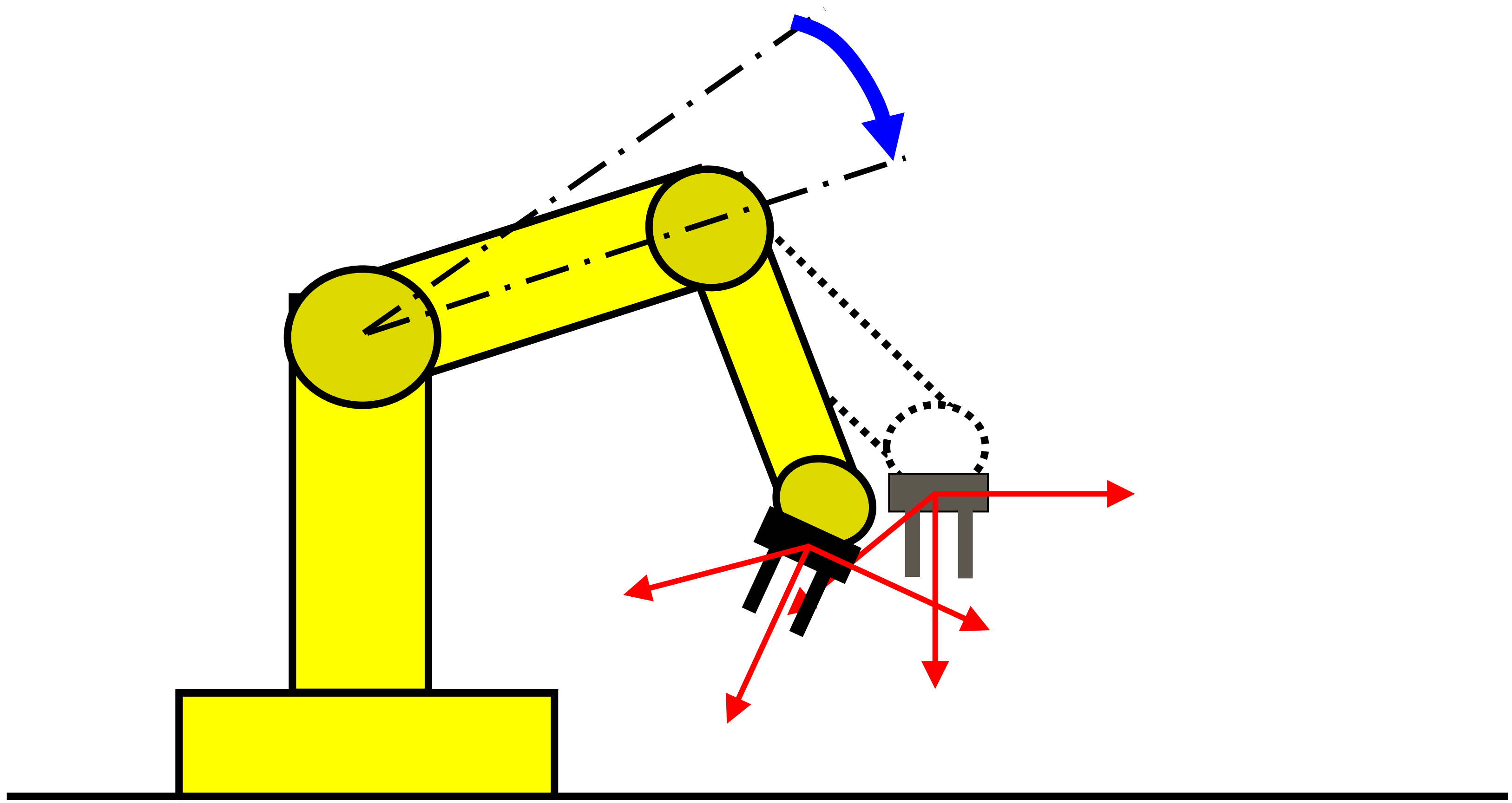
- Capacity to change the orientation at a given position.
- Strongly depend on the joint limits.

3. Maneuverability

- Capacity to reach a given position and orientation (pose) from different paths (different configurations).
- Usually implies the presence of redundant joints (degrees of manipulability or degrees of redundancy).

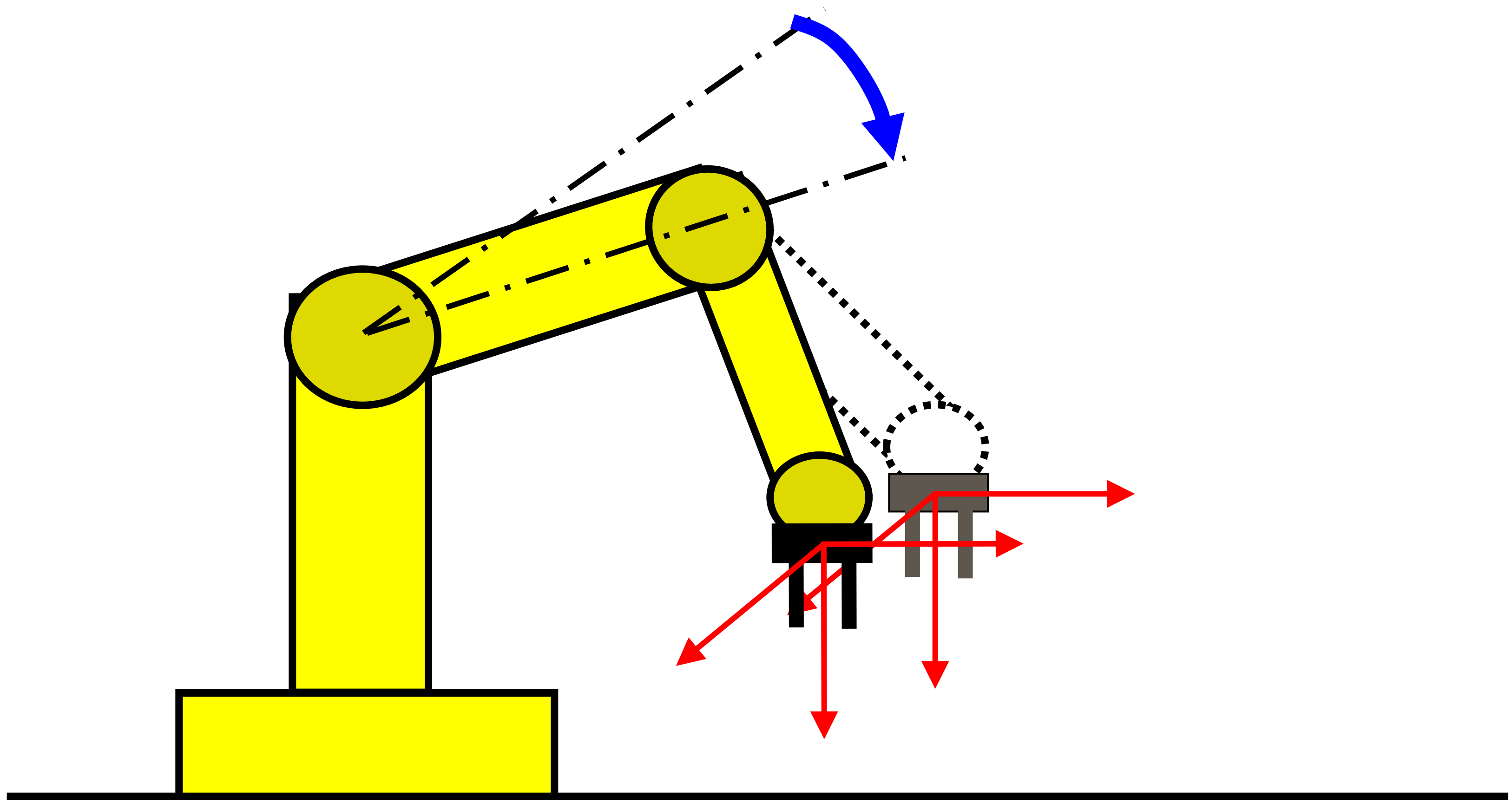
- ***Coupled movements***
- ***Decoupled movements***

Coupled movements



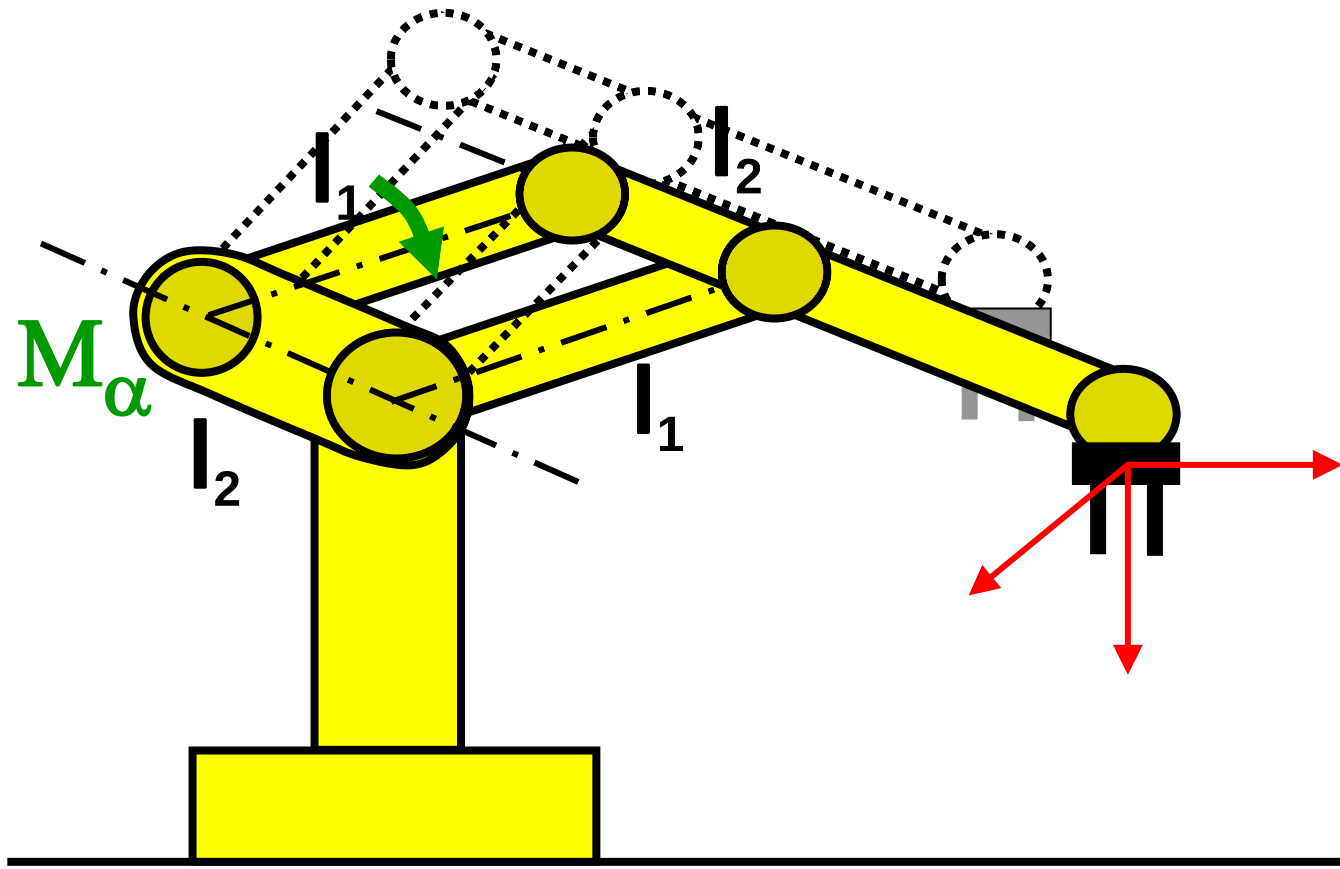
The rotation of a link is propagated to the rest of the chain

Decoupled movements

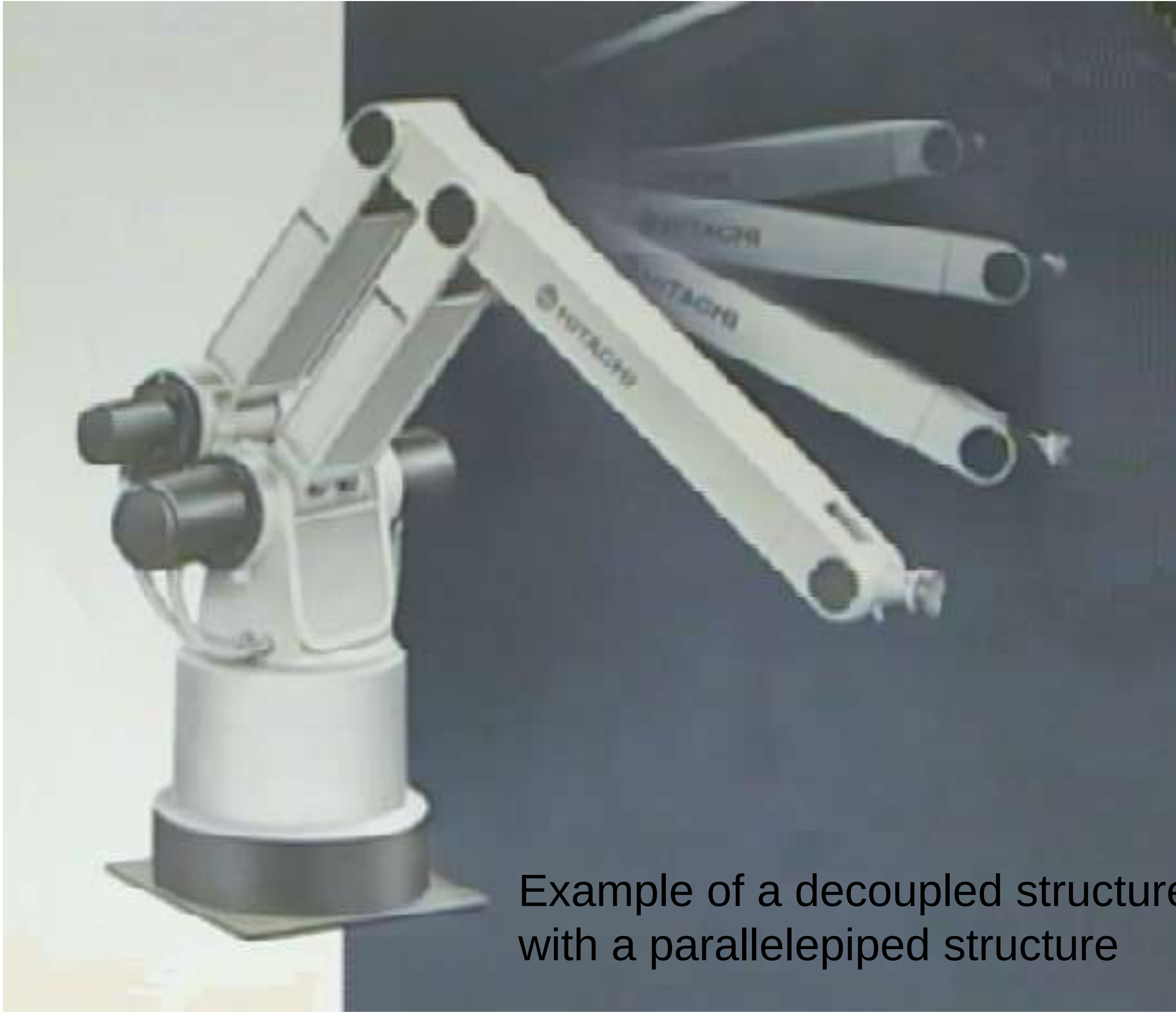


The rotation of a link is not propagated to the rest of the chain

Mechanical decoupling architectures

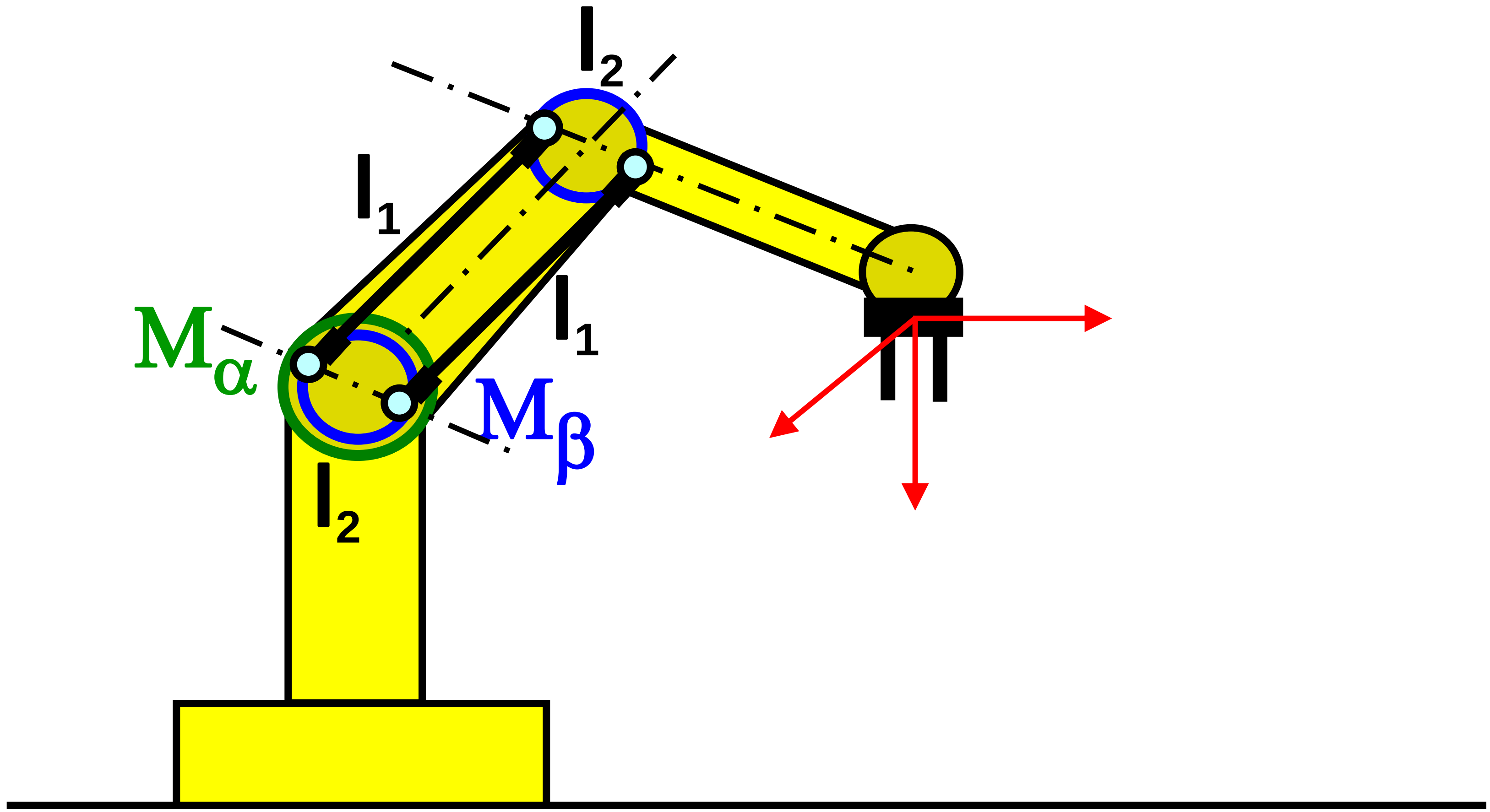


Decoupling achieved with a parallelepiped structure



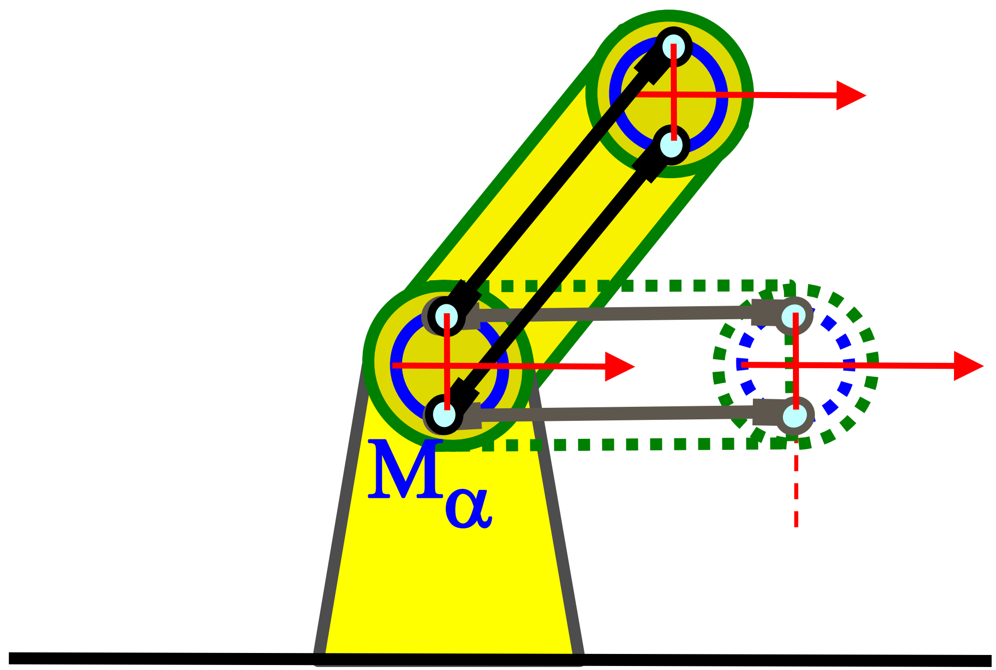
Example of a decoupled structure
with a parallelepiped structure

Mechanical decoupling solutions



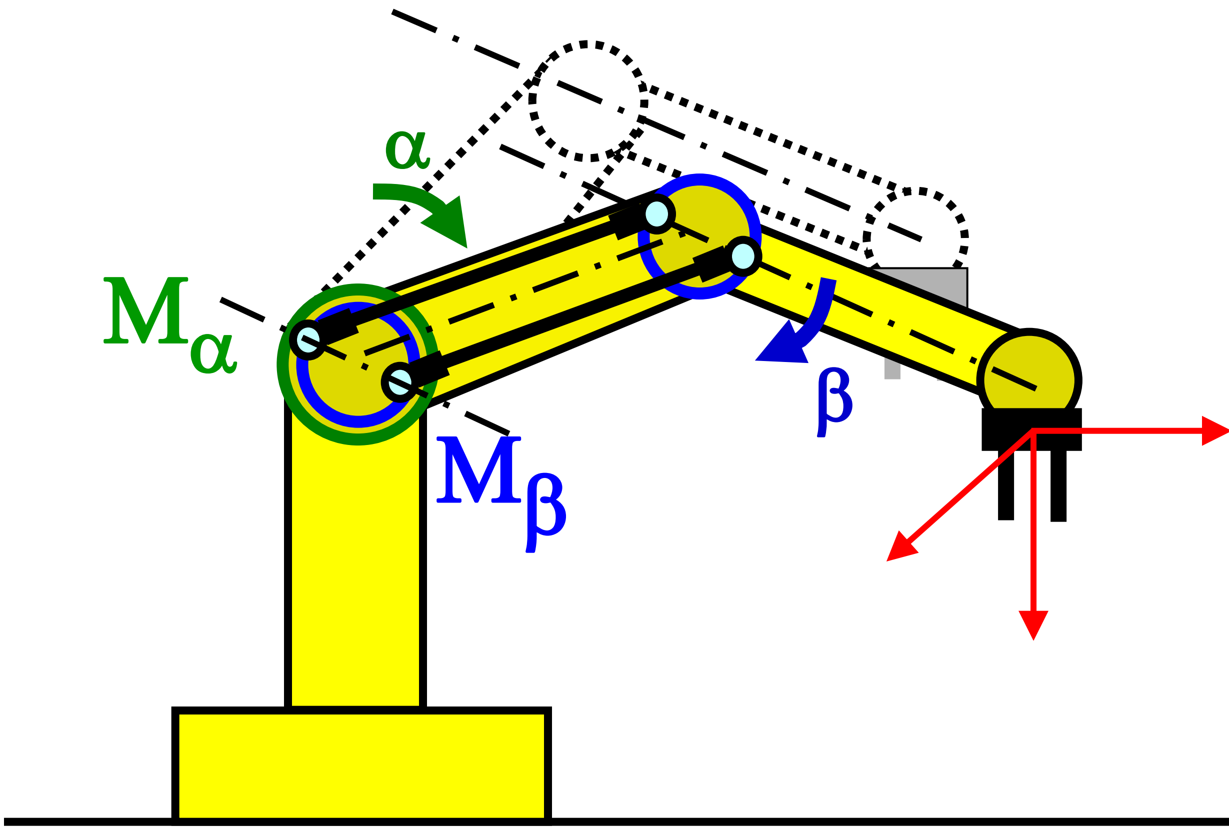
Structure decoupled with connecting rods

Decoupling with connecting rods



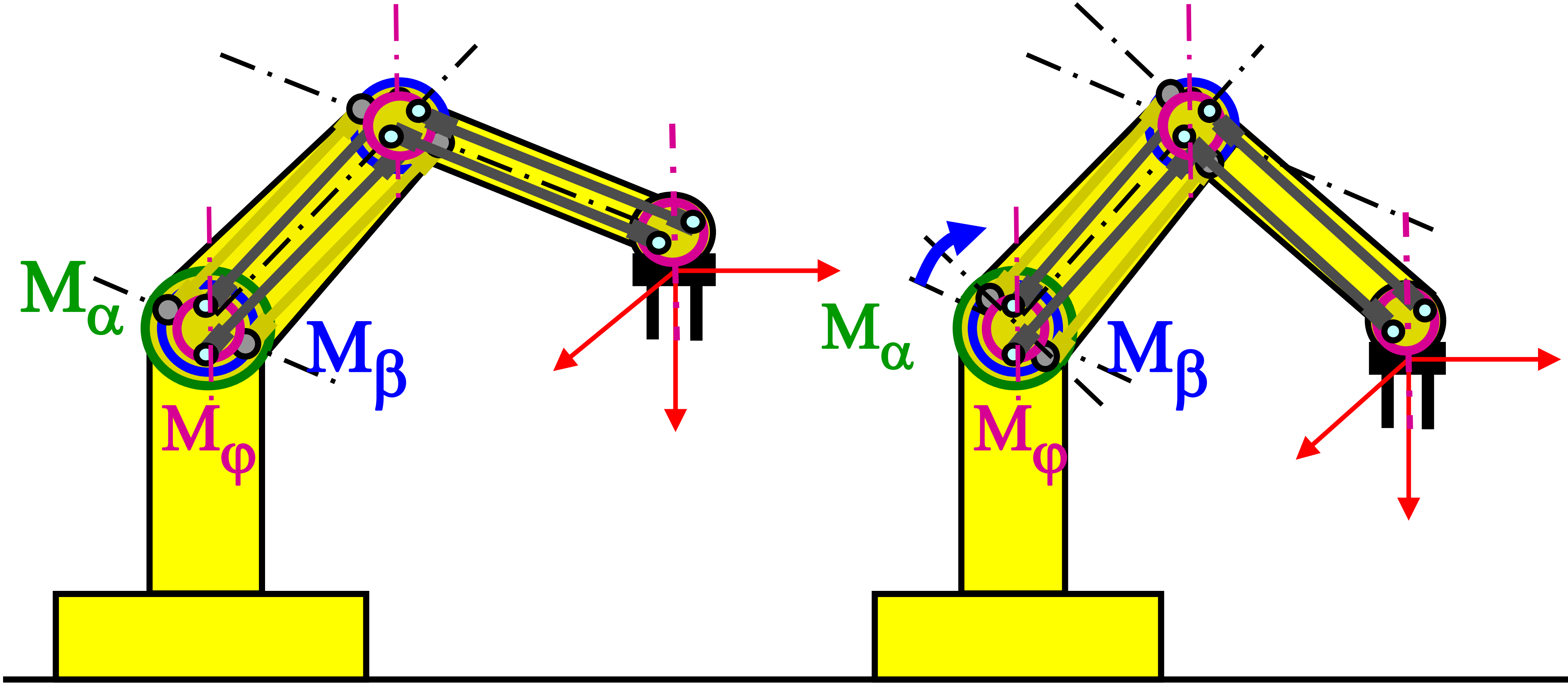
By transmitting the movement with connecting rods, the rotation of a joint does not propagates to the following.

Decoupling with connecting rods



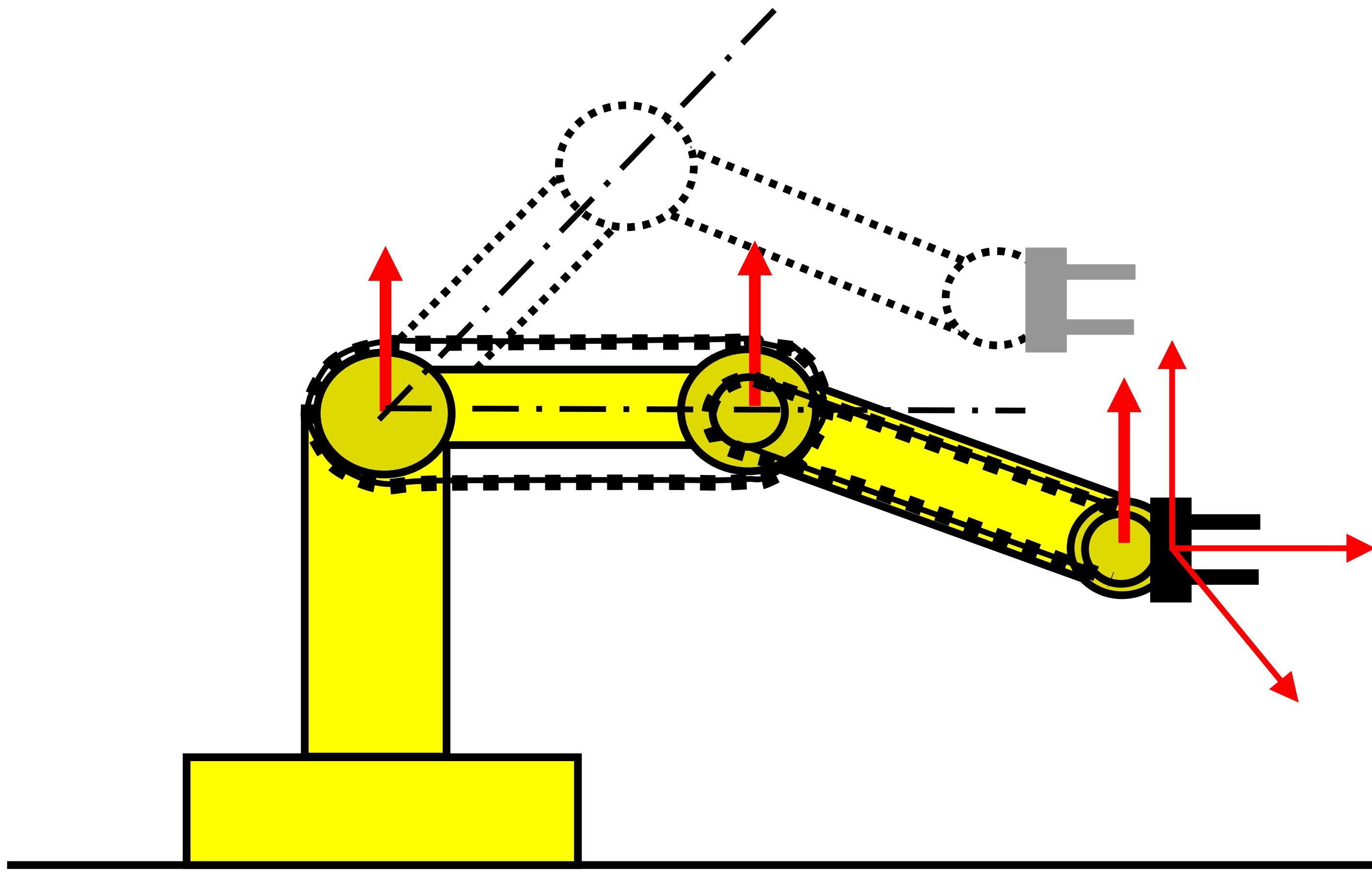
By transmitting the movement with connecting rods, the rotation of a joint does not propagates to the following.

Decoupling with connecting rods



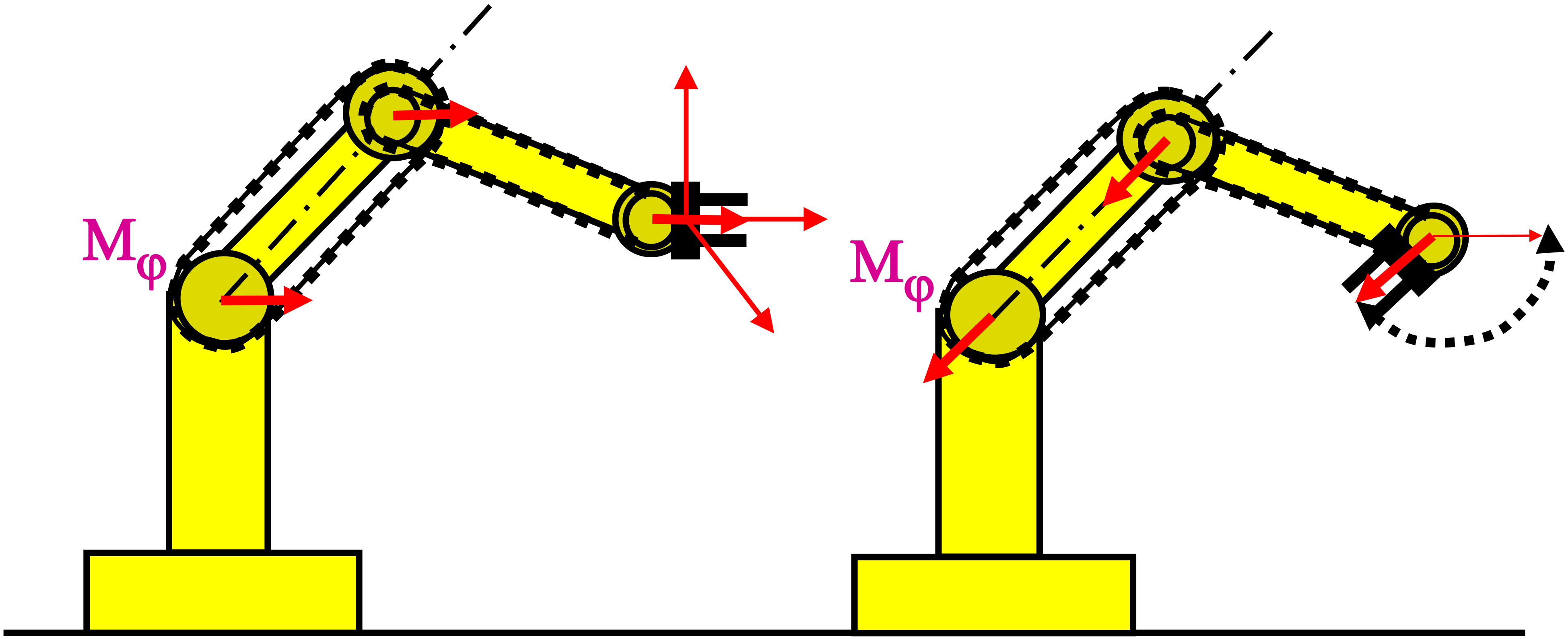
Transmission with connecting rods through two consecutive joints maintains the orientation of the E.E.

Mechanical decoupling solutions



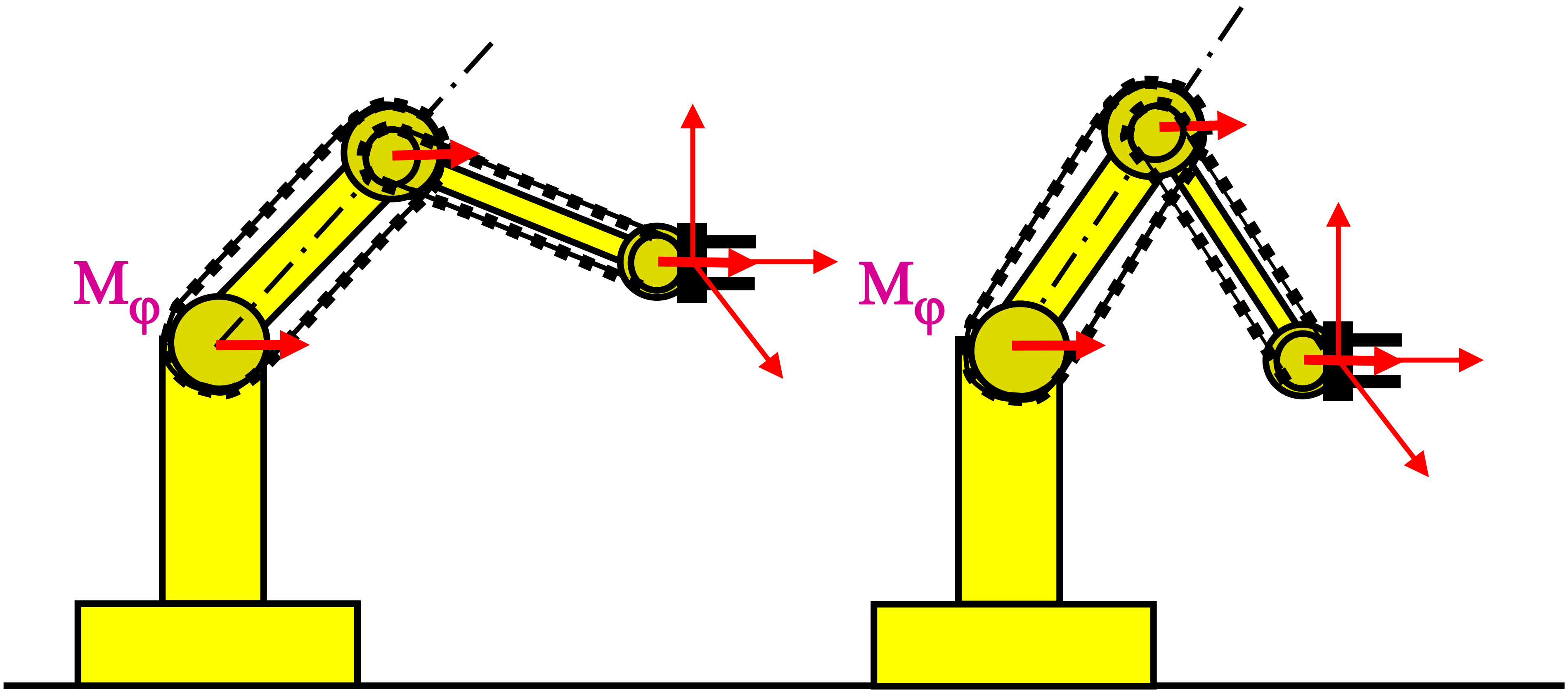
Structure decoupled with chains

Decoupling with chains



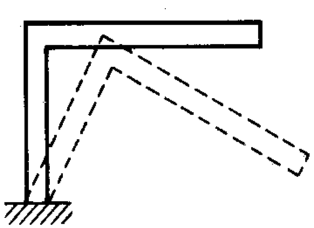
Transmission movements with chains

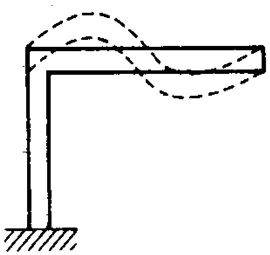
Decoupling with chains



Transmission systems with chains produce decoupled movements

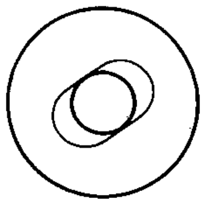
Points potentially weak in mechanical design

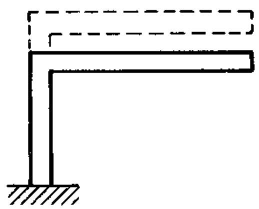


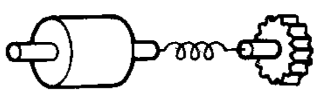


Weak points	Mechanical correction
Permanent deformation of the whole structure and the components	• Increase rigidness • Weight reduction • Counterweight
Dynamic deformation	• Increase rigidness • Reduction of the mass to move • Weight distribution
Backlash	• Reduce gear clearances • Use more rigid transmission elements

Points potentially weak in the mechanical design







Weak points	**Mechanical correction**
Axes clearance	• Use pre stressed axes
Friction	• Improve clearance in axes • Increase lubrication
Thermal effects	• Isolate heat source
Bad transducers connection	• Improve mechanical connection • Search for a better location • Protect the environment