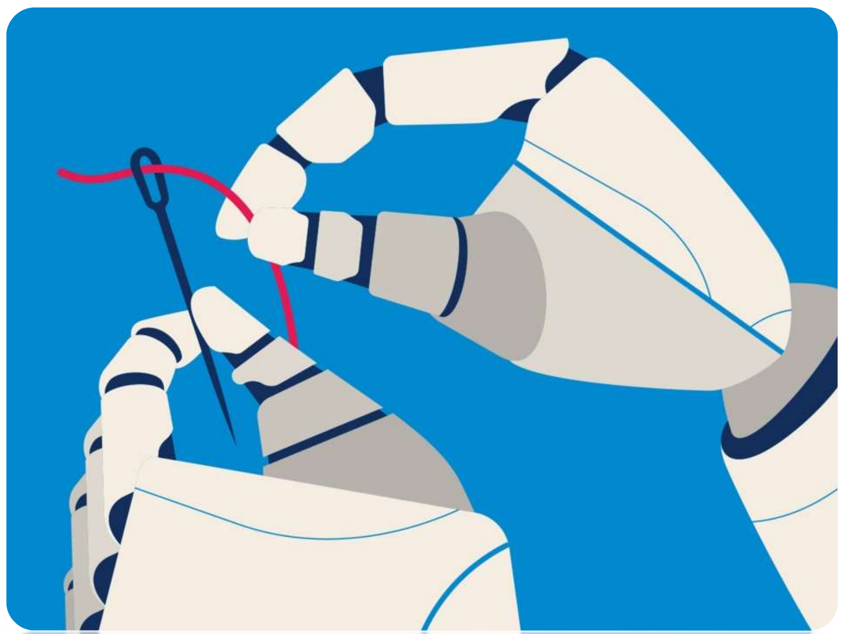
INDUSTRIAL ROBOTS
AND MANIPULATORS

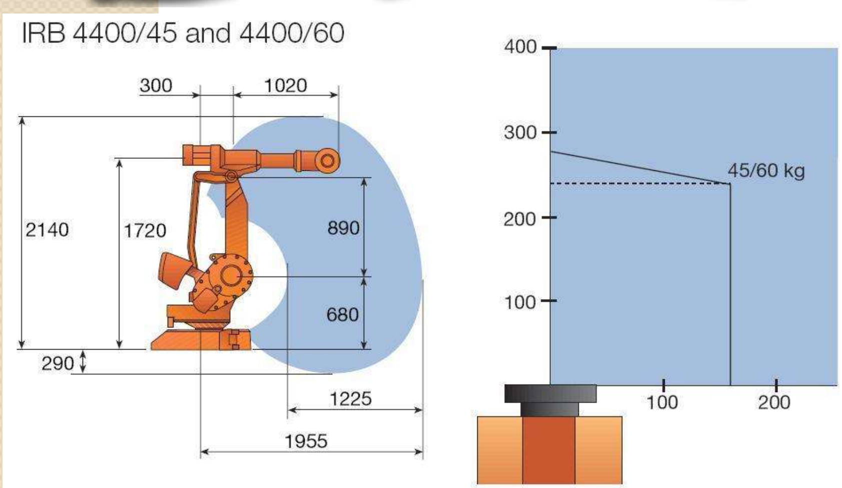
ROBOTICS MANIPULATORS



[1]

INDUSTRIAL ROBOTS AND MANIPULATORS

Industrial robot



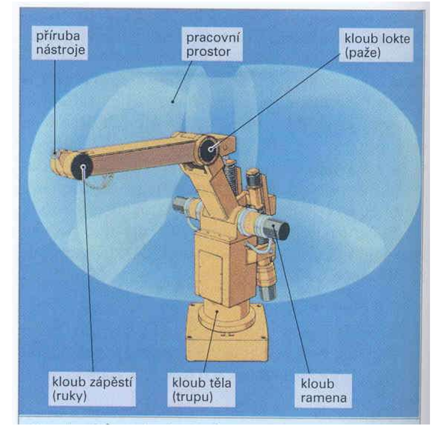
Robot´s Work Envelope

The term ROBOT was introduced by the Czech writer *Karel Čapek* in 1920 in the play R.U.R.
(Rosums Universal Robots)

ROBOT DEFINITION

An **industrial robot** is a robot system used for manufacturing. Industrial robots are automated, programmable and capable of movement on three or more axes.

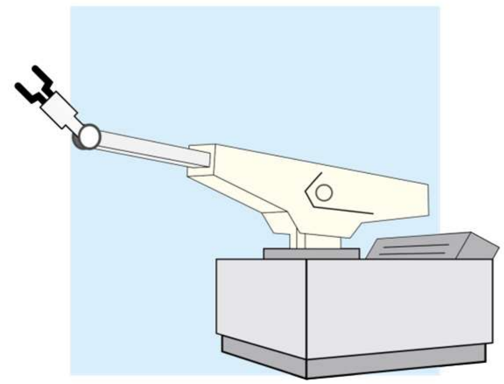
INDUSTRIAL ROBOTS AND MANIPULATORS



First Industrial robot

company UNIMATE v 1961

- only for material handling



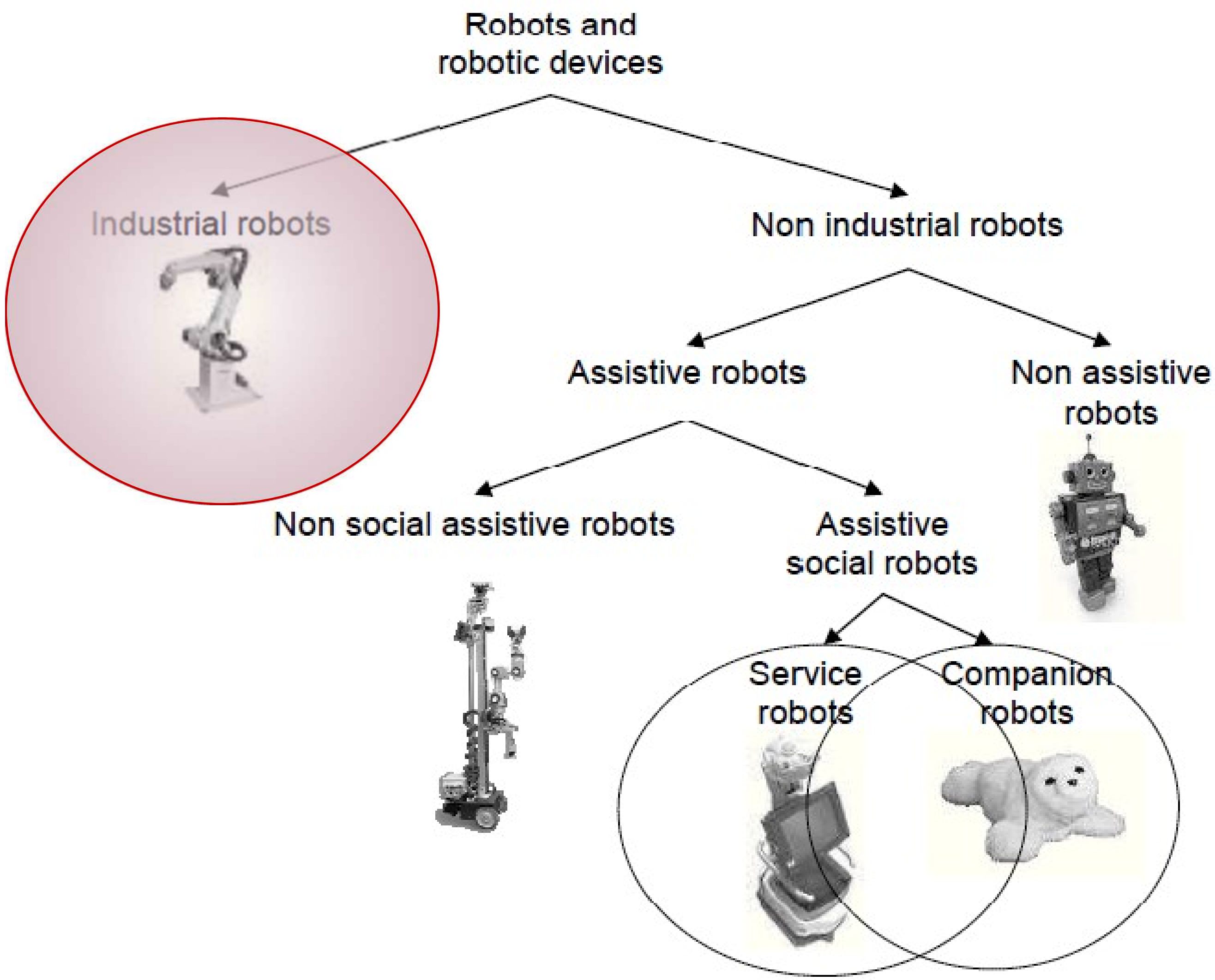
Menzel P., Faith D. (2000). Robo sapiens: evolution of a new species. The MIT Press. ISBN 0-262-13382-2.

Transport moving bodies form place to place over greater distances, without directional orientation of the object.

Manipulation relocation of the body to a shorter distance with respect to the orientation of the object

Storage placement of bodies in a certain area for a temporary period before further handling or transport

Industrial robot classification



Orha, I. & Oniga, Stefan. (2012). *Assistance and telepresence robots: a solution for elderly people*. Carpathian Journal of Electronic and Computer Engineering ISSN 1844 - 9689. 5. 87-90.

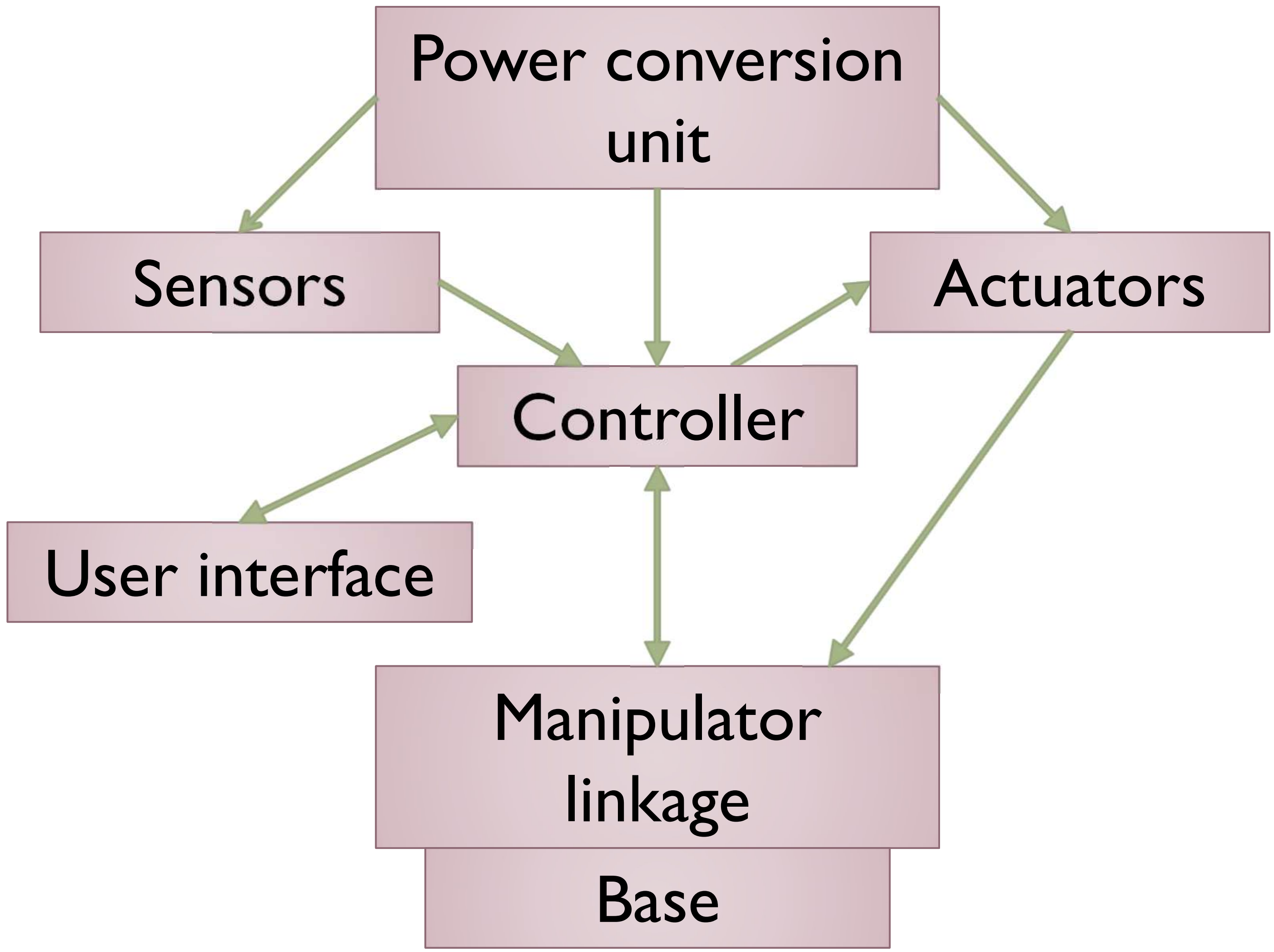
Industrial robot classification

- Classification base on degree of automation

Information source	Energy used for actuation	Level – Description of the machine	What robot
External environment	Electric Hydraulic	10 – Self-improving machine	Neural network controlled robot
Variable program	Pneumatic	8 – Machine that corelates its program with external conditions	
Programmable	Pneumatic	7 – Numerical control machine 6 – Single operation machine	Programmable robot on-line or off-line
Fixed program	Pneumatic	5 – Multiple operation machine 4 – Single operation automated machine	
Human	Human	3 – Automated machine and hand tool 2 – Hand tool 1 – Hand	

Mihai Dan. *Standards and Classifications of Indrustrial Robots* [online]. ©2012. Available from: https://www.smashingrobotics.com/standards-and-classifications-of-industrial-robots/

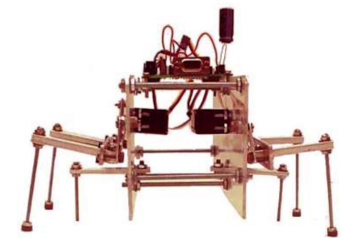
Key Components of Industrial Robot



Wang H. *Introduction to Robotics* [online]. Available from: https://robotics.sjtu.edu.cn/upload/course/5/files/Introduction.pdf

Key Components of Industrial Robot

- **Robot base** ⇒ Fixed v/s Mobile



- **Actuators** ⇒ Common robotic actuators utilize combinations of different electro-mechanical devices (DC motor, AC servo motor, Stepper motor, Pneumatic Cylinder, Hydraulic motor, …)
- **Controller** ⇒ Provide necessary intelligence to control the manipulator / robot
  ⇒ Process the sensory information and compute the control commands for the actuators to carry out specified tasks

Wang H. *Introduction to Robotics* [online]. Available from: https://robotics.sjtu.edu.cn/upload/course/5/files/Introduction.pdf

Field of application

- Material handling
- Material transfer
- Machine loading and/or unloading
- Spot welding
- Continuous arc welding
- Spray coating
- Assembly
- Inspection

Industrial robot types

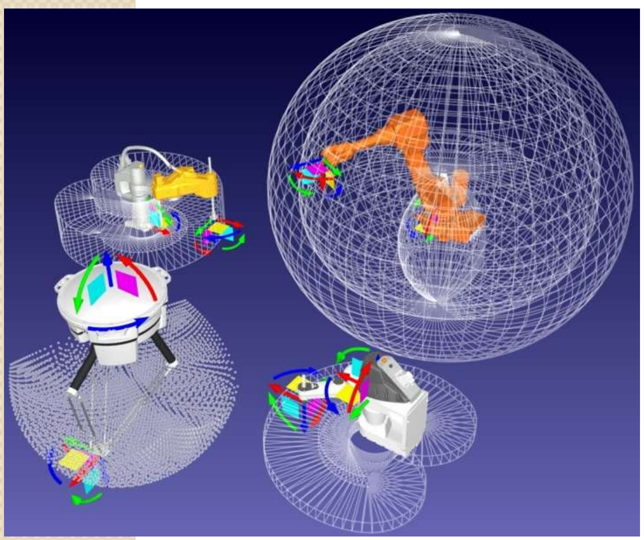
- Classification by mechanical structure

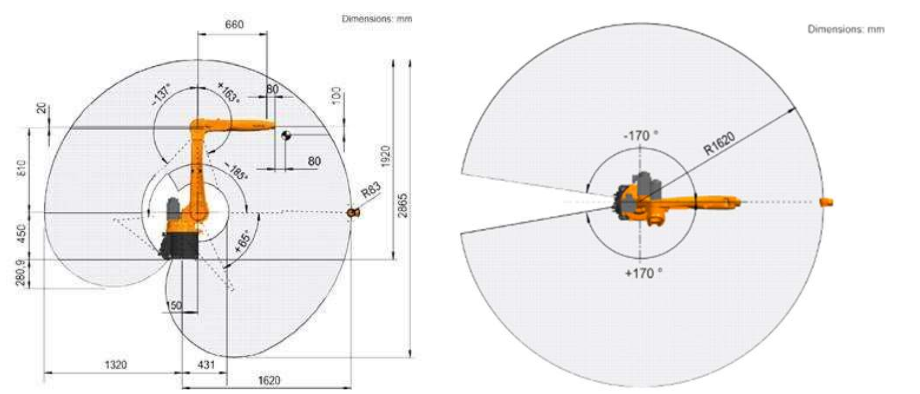
  - Cartesian (or Rectangular, Rectilinear, Gantry)
  - Cylindrical
  - Spherical (or Polar)
  - Articulated (or Jointed-arm)
  - Delta (or Parallel)
  - SCARA

Inlearc. *Basic about industial robots* [online]. Available from: https://www.tthk.ee/inlearcs/1-basic-about-industrial-robots/

Robot Workspace
Robot Envelope

- Workspace is the volume of space reachable by the end-effector mount
- Everywhere a robot reaches must be within this space
- Tool orientation and size also important!





Reddit. Create robot workspace screenshot? [online]. Available from: https://www.reddit.com/r/SolidWorks/comments/ci05sy/create_robot_workspace_screenshot/

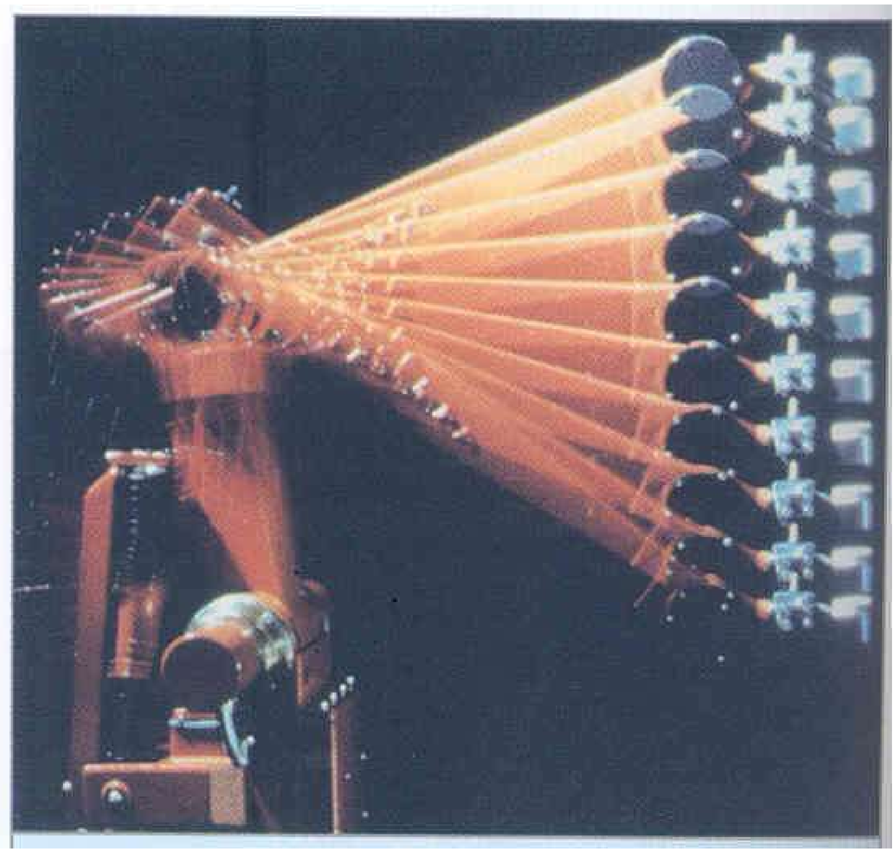
RoboDK . *Robot Workspace* [online]. Available from: https://robodk.com/blog/off-line-programming/workspace/

Motion control of Industrial Robots and Manipulators

- Motion control – very complicated

⇓

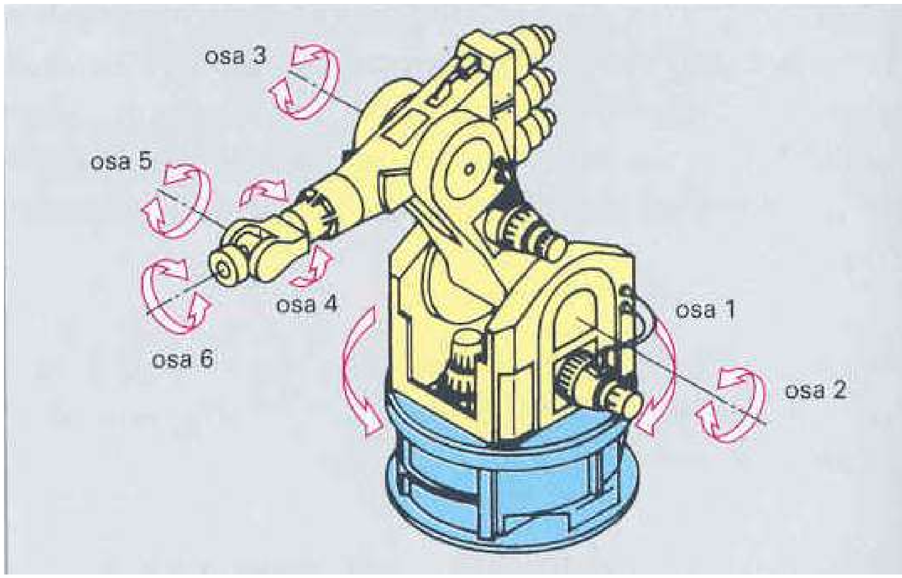
The path of the end element depends on the movements in all joints



SCHMIDT, D. a kol. *Řízení a regulace pro strojírenství a mechatroniku.* 1. vydání. Praha : Europa-Sobotáles, 2005 420 s. ISBN 80-86706-10-9

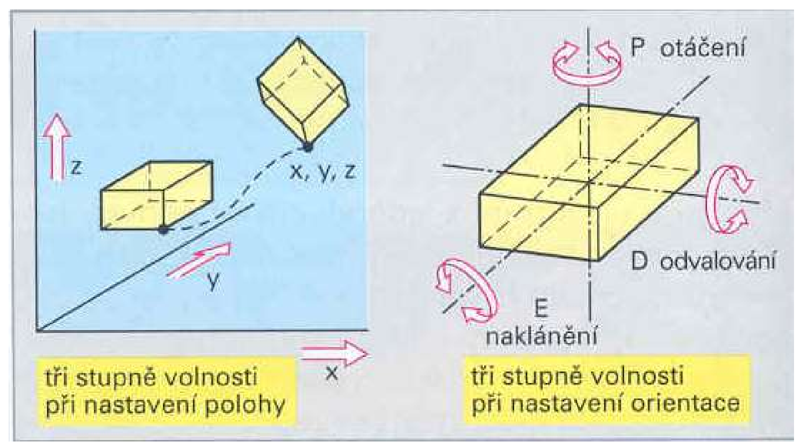
Figure: Interplay of arm part movements during rectilinear too movement

Robot types
Mechanical structure



The robot moves in six axes to set any position and any orientation

Therefore, **six axes** corresponding to **six degrees of freedom** of movement of the body in space are required to adjust the gripped object or the inserted tool to any position in any part of the robot's workspace.



SCHMIDT, D. a kol. *Řízení a regulace pro strojírenství a mechatroniku.* 1. vydání. Praha : Europa-Sobotáles, 2005 420 s. ISBN 80-86706-10-9

CARTHESIAN

Robot types
Mechanical structure

Kinematics TTT

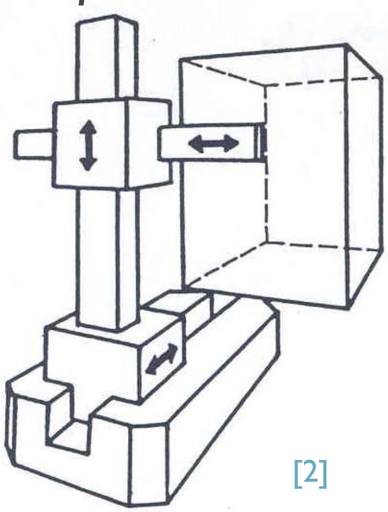
translational motion
translational motion
translational motion

Three sliding motions on three perpendicular axes (x, y and z)

Orthogonal workspace

Excellent for material handling

The simplest kind of robot configuration



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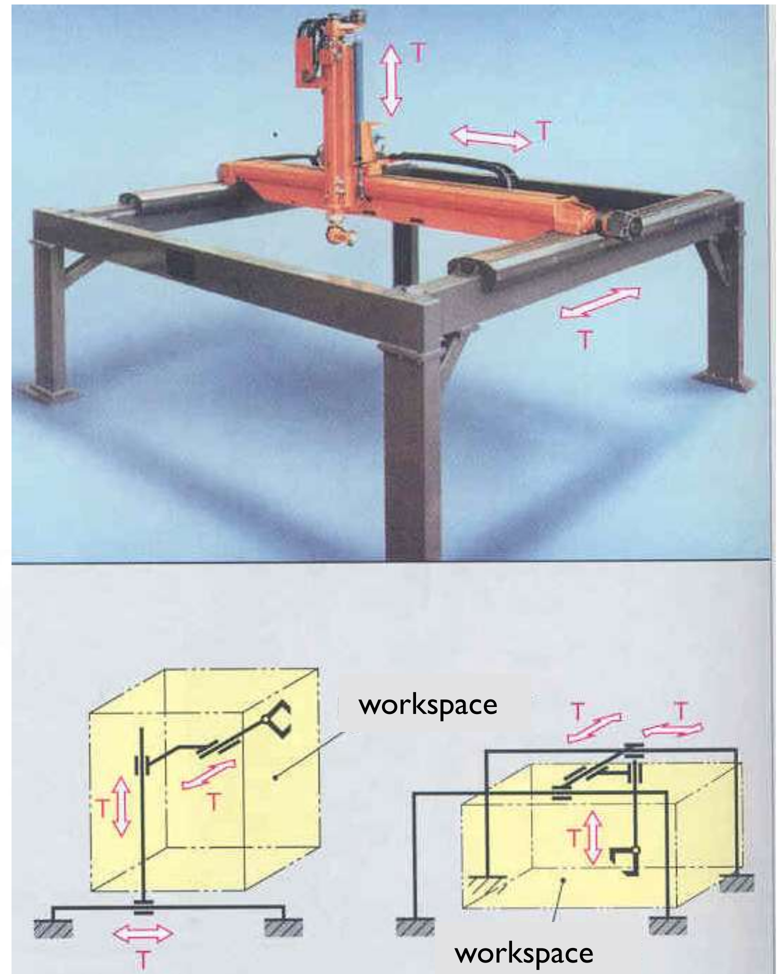


[2]

CYLINDRICAL

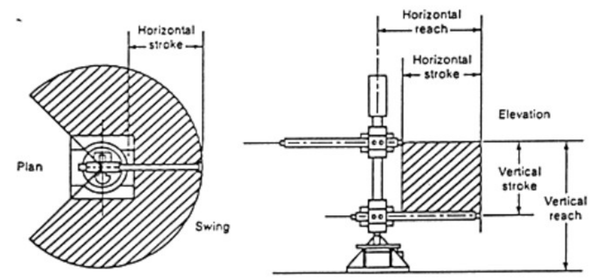
Robot types
Mechanical structure

Kinematics RTT

rotational motion
translational motion
translational motion

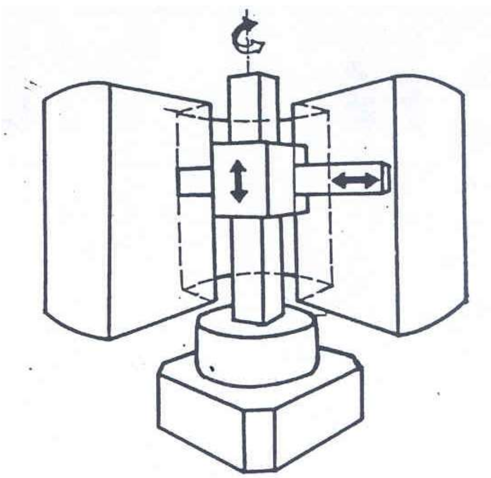
One rotary joint at base
Vertically and sliding motion

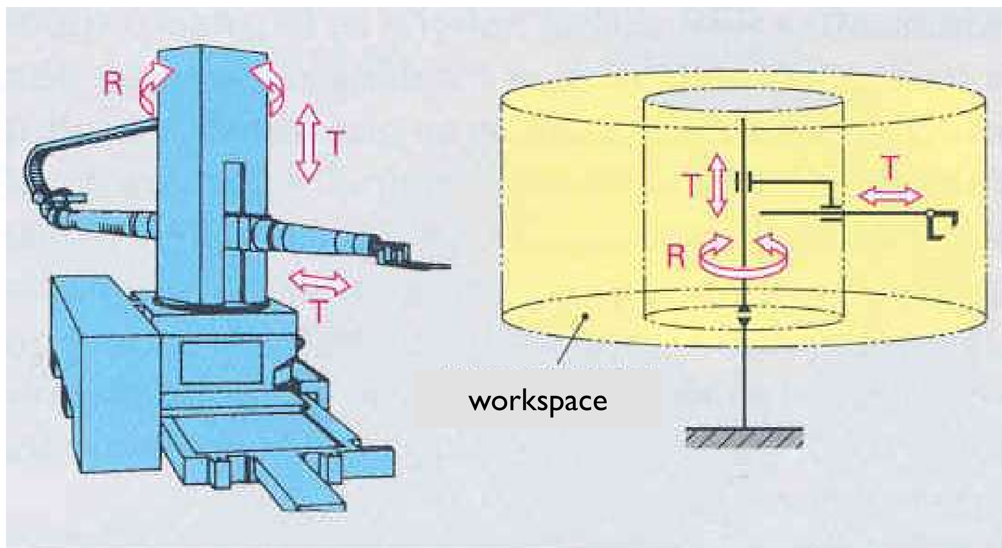
Workspace – cylinder



For handling purposes

Orientation of the object in one axis





[2]

Robot types
Mechanical structure

SPHERICAL

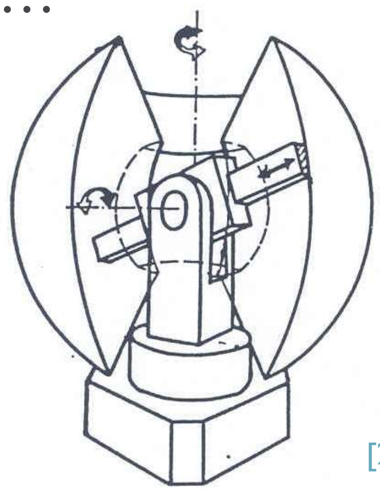
Kinematics RRT

rotational motion
rotational motion
translational motion

Linear motion system, coupled with base and shoulder rotation

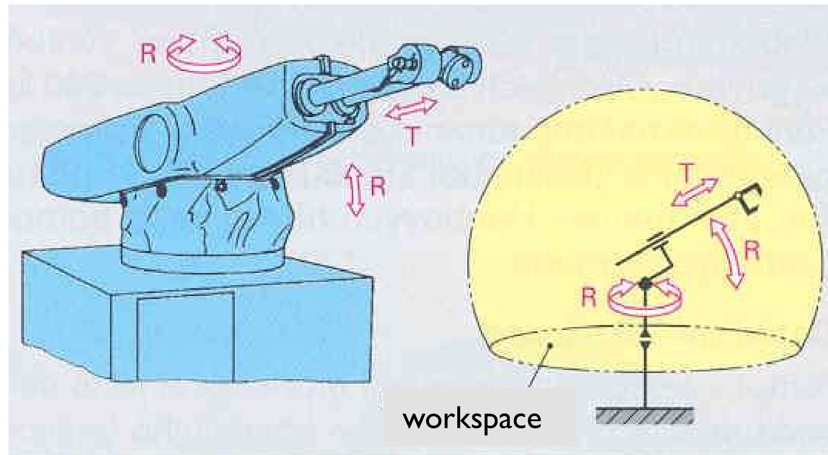
For handling purposes, assembly…

The orientation of the object changes in 2 axes

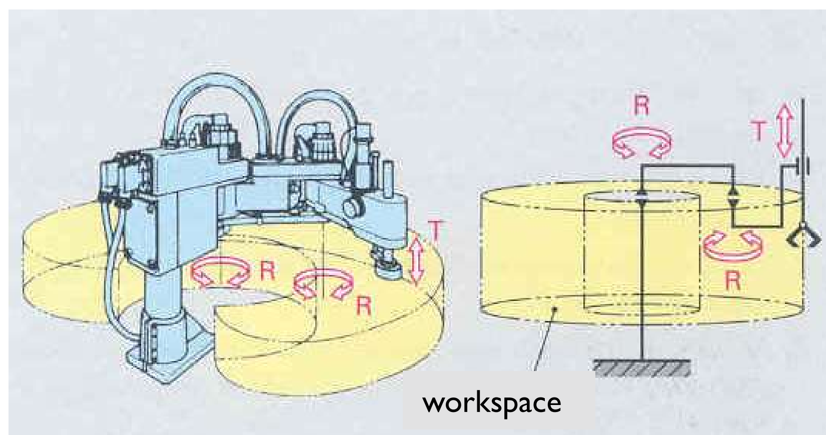


[2]

Workspace – bounded by a spherical surface and a plane



Workspace – cylinder (ring)



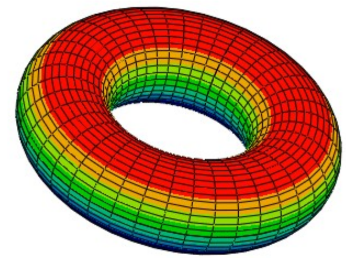
ARTICULATED

Robot types
Mechanical structure

Kinematics RRR

rotational motion
rotational motion
rotational motion

Workspace – torus

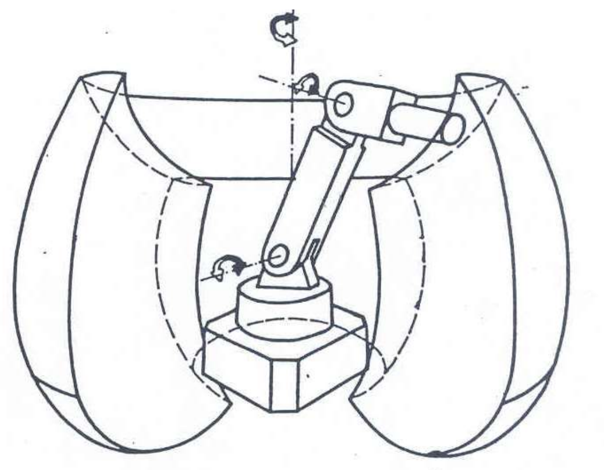


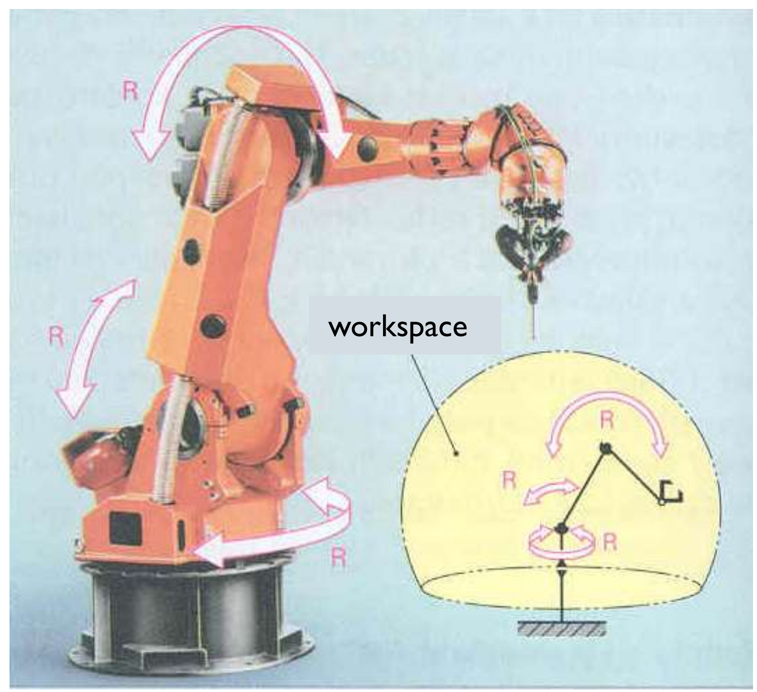
Mechanical configuration – resembles a human arm
(The number of rotary joints connecting the links in the arm can range 2÷10 joints)

For complex technological operations (spatial sewing, shearing, cutting,…)

He can avoid obstacles

The orientation of the object changes in 3 axes





[2]

DELTA

Robot types
Mechanical structure

Kinematics

three or more jointed parallelograms (parallel joint linkages) with common base.

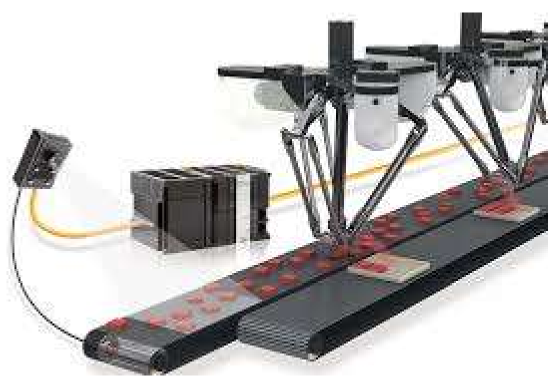
Workspace – dome

https://www.youtube.com/watch?v=dx5dYdQ7NDo

For „pick and place“ tasks

Usually hang down (arms reach down and grab items

High speed operation



Design World. Motion systems perspective: Robots in automation [online]. Available from: https://www.designworldonline.com/motion-systems-application-examples-robots-in-action/

Robot types
Mechanical structure

SCARA

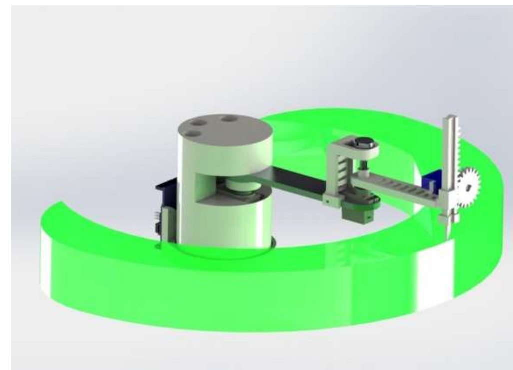
Selective Compliant Assembly Robot Arm or
Selective Compliant Articulated Robot Arm

Kinematics

"smart" cylindrical robot, not an articulated robot

two (or three) parallel joints that provide compliance in one selected plane.

Workspace – ring



Angeles S.. SCARA Robot [online]. Available from: https://grabcad.com/library/scara-robot-9

- move faster and have easier integration than cylindrical and cartesian robots

Mitsubishi Electric. Factory Automation – Eruope [online]. EXPO21XX. Available from: https://www.expo21xx.com/automation21xx/15419_st3_robotics/default_Kopie(1).htm

Degrees of freedom

The number of degrees of freedom is equal to the total number of independent movements

Degrees of freedom, in a mechanics context, are specific, defined modes in which a mechanical device or system can move.

A machine may operate in two or three dimensions but have more than three degrees of freedom.

A robot arm built to work like a human arm. Shoulder motion can take place as pitch (up and down) or yaw (left and right). Elbow motion can occur only as pitch. Wrist motion can occur as pitch or yaw. Rotation (roll) may also be possible for wrist and shoulder.

$$D.O.F. = 6 \cdot (n-1) - \sum_{1}^{6} jdj$$

n total number of links in a mechanism
dj number of pairs in „j“ degree of freedom
(n-1) number of the movable links
6.(n-1) degree of freedom of (n-1) movable links

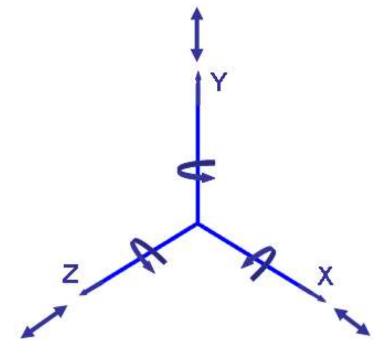
$$D.O.F. = 6 \cdot (n-1) - 5j_1 - 4j_2 - 3j_3 - 2j_4 - 1j_5$$

Degrees of freedom

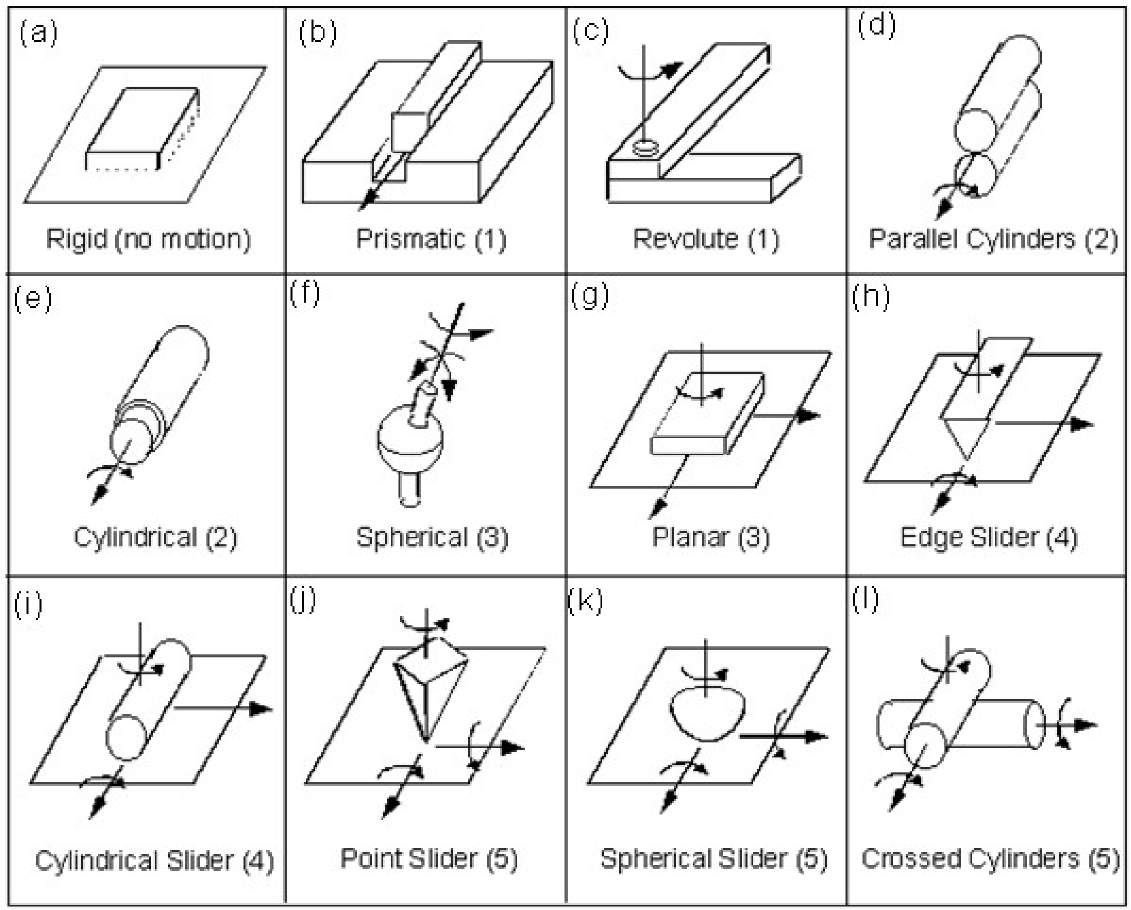
An object in space has six degrees of freedom.

Translatory motion along X, Y, and Z axis (3 D.O.F.)

Rotary motion about X, Y, and Z axis (3 D.O.F)



Pairs having varying degree of freedom



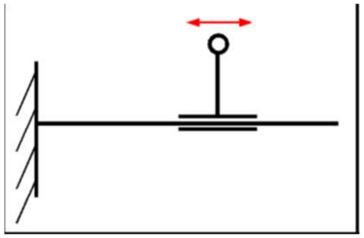
Therory of Machines. Lesson3. Degree of Freedom [online]. Available from: http://ecoursesonline.iasri.res.in/mod/page/view.php?id=125546

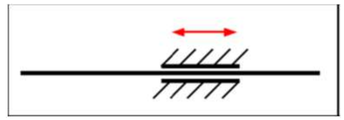
Pairs having varying degree of freedom

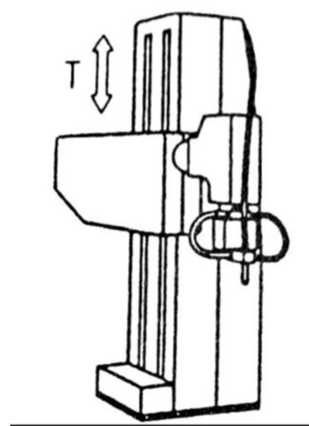
S. No.	Geometrical Shapes involved	Restraints on		Degree of freedom	Total restraints
		Translatory motion	Rotary motion		
(a)	Rigid	0	0	0	6
(b)	Prismatic	2	3	1	5
(c)	Revolute	3	2	1	5
(d)	Parallel cylinders	2	2	2	4
(e)	Cylindrical	2	2	2	4
(f)	Spherical	3	0	3	3
(g)	Planer	1	2	3	3
(h)	Edge slider	1	1	4	2
(i)	Cylindrical slider	1	1	4	2
(j)	Point slider	1	0	5	1
(k)	Spherical slider	1	0	5	1
(l)	Crossed cylinder	1	0	5	1

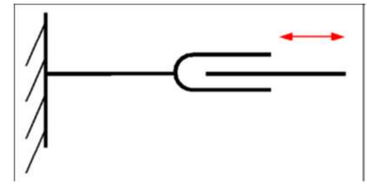
Therory of Machines. Lesson3. Degree of Freedom [online]. Available from: http://ecoursesonline.iasri.res.in/mod/page/view.php?id=125546

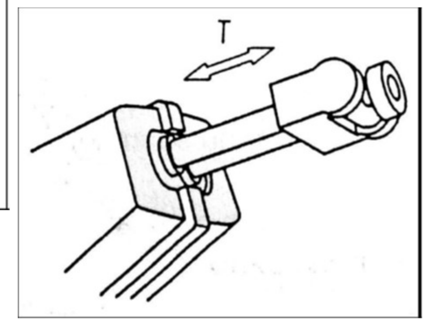
KINEMATIC PAIRS

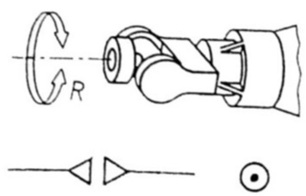


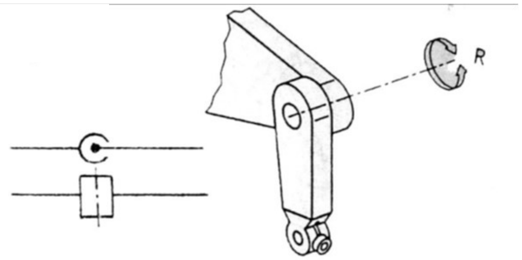






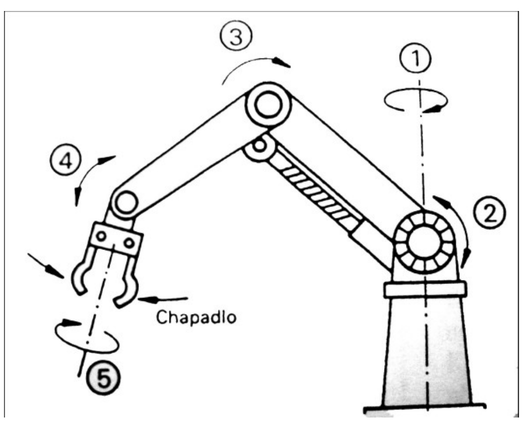


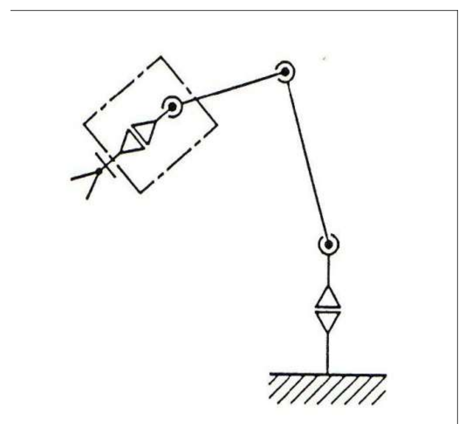




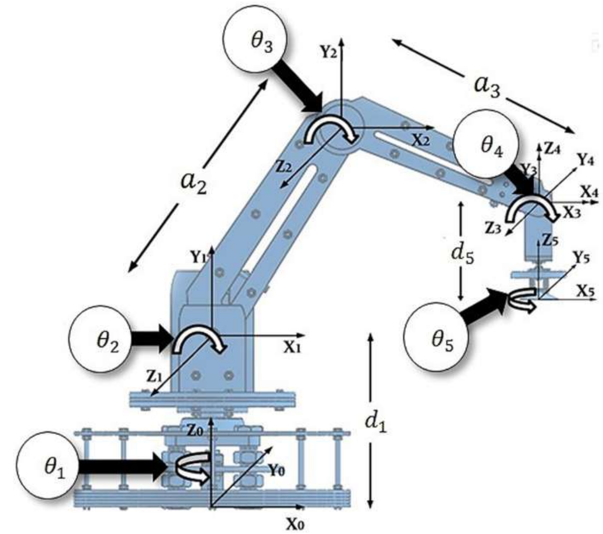
KINEMATIC STRUCTURE

- The interconnected pairs form kinematic chains.
- These chains then form the kinematic structure of the robot

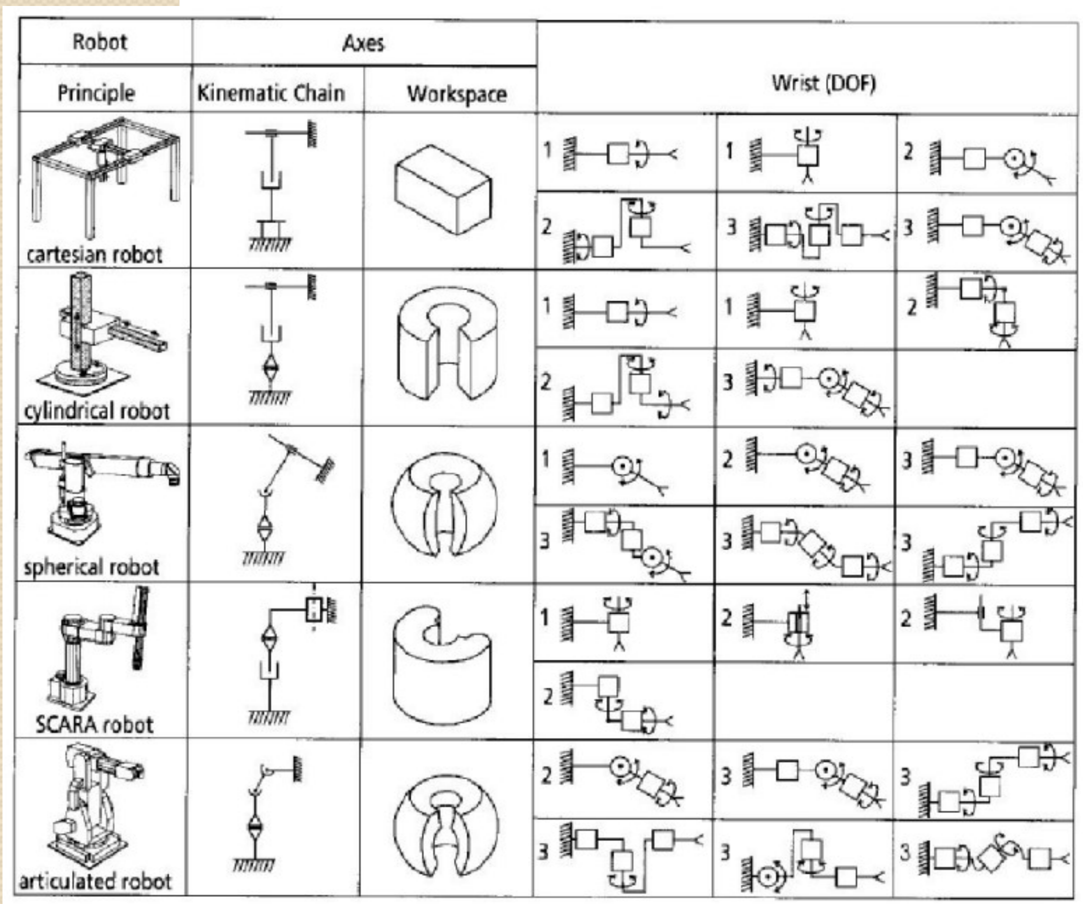




Kinematic robot structure

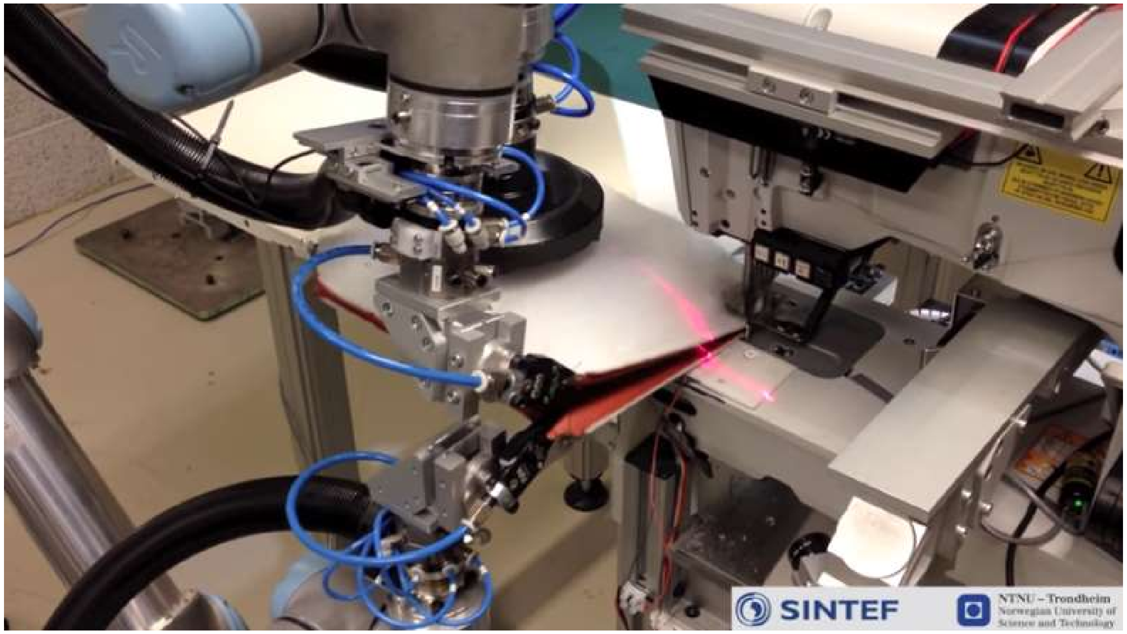


Zarrin, A., Azizi, S. & Aliasghary, M. A novel inverse kinematics scheme for the design and fabrication of a five degree of freedom arm robot. Int. J. Dynam. Control 8, 604–614 (2020). https://doi.org/10.1007/s40435-019-00558-1



Yasar, S. A. Design and kinematic analysis of a RRPR robot arm. (2016) International Journal of Innovative Research in Engineering & Management (IJIREM) ISSN: 2350-0557, Volume-3, Issue-6, DOI: 10.21276/ijirem.2016.3.6.7

Sewing Robot *https://www.youtube.com/watch?v=xrudo-ckSNU*



Multi-robot sewing of recliner covers

https://www.youtube.com/watch?v=pMB5PZgPsnk

Can Robots Transform the Garment Industry?
https://www.youtube.com/watch?v=BA96-WX-oXc

Bangladesh production unit
https://www.youtube.com/watch?v=URIQjQ7QGZE&t=240s

Automatic sewing department

https://www.youtube.com/watch?v=XsZ8JUJjbBI

KUKA robot sews car seat covers

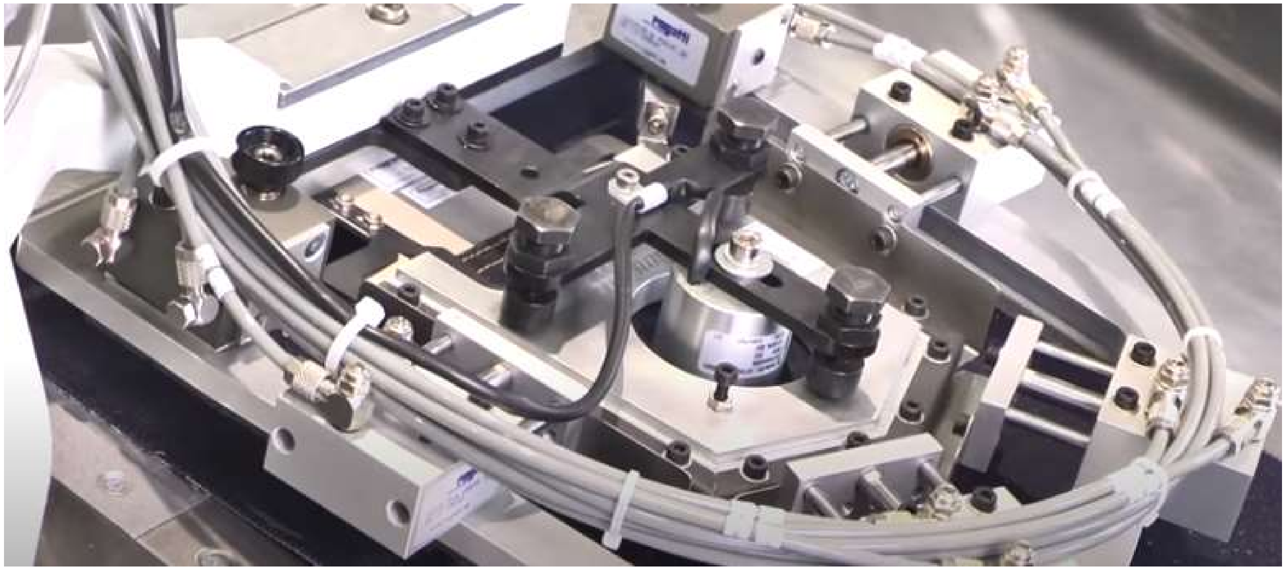
https://www.youtube.com/watch?v=2Qwqxpcr2zA

Automatic fabric cutting machine

https://www.youtube.com/watch?v=Yht03YyNQWY

Maica Full Automatic Production Line for Shirt - Portugal

https://www.youtube.com/watch?v=sv536cciOiQ



PFAFF 3588 Programmable automatic pocket setter

https://www.youtube.com/watch?v=oaOtX1btpUM

Automatic Coverstitch Bottom Hemmer - Model 1278-8

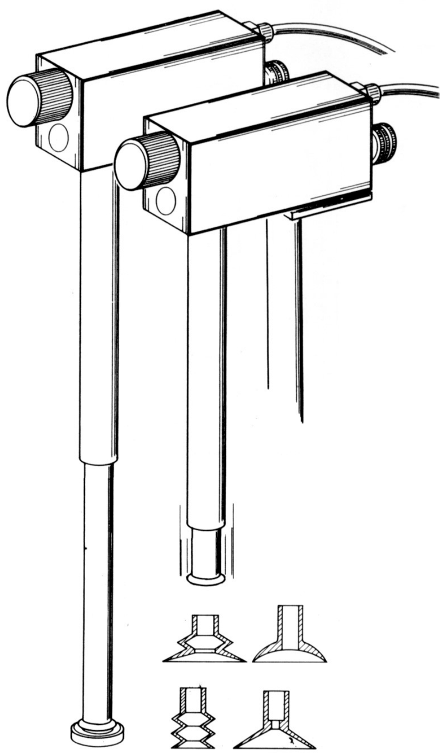
https://www.youtube.com/watch?v=9rC141oForE

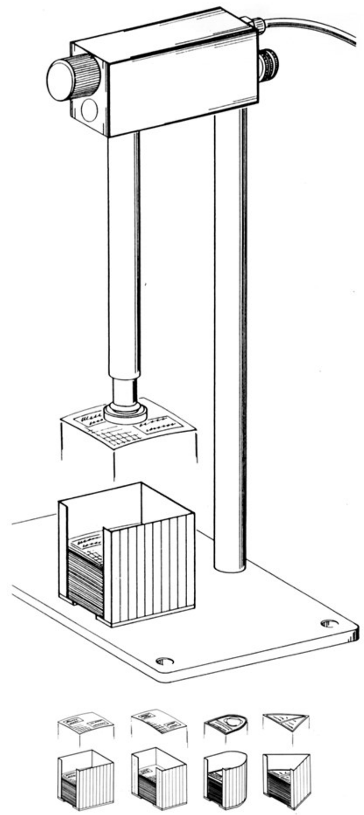
Packing T-shirt:
[*https://www.youtube.com/watch?v=-1T0ScVt-aE*](https://www.youtube.com/watch?v=-1T0ScVt-aE)
[*https://www.youtube.com/watch?v=gGlLr4Ftdfc*](https://www.youtube.com/watch?v=gGlLr4Ftdfc)

Packing shirt:https://www.youtube.com/watch?v=kuhXy2z3HNI
[*https://www.youtube.com/watch?v=4YkQrgLRtO0*](https://www.youtube.com/watch?v=4YkQrgLRtO0)

Examples of robot end effectors

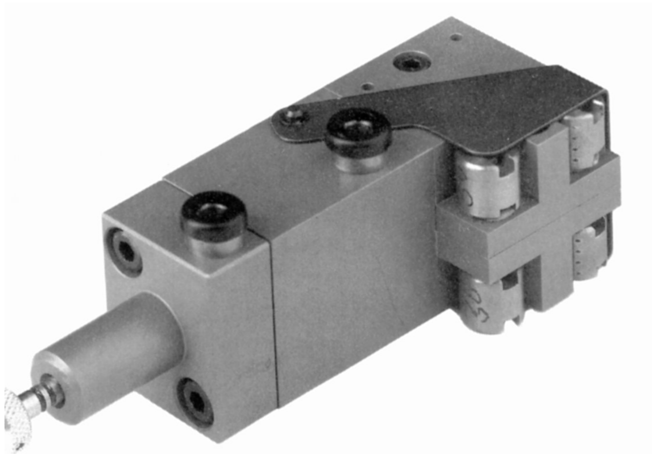
Passive vacuum heads





Details on robot gripping heads in lecture
07 - Robot effectors

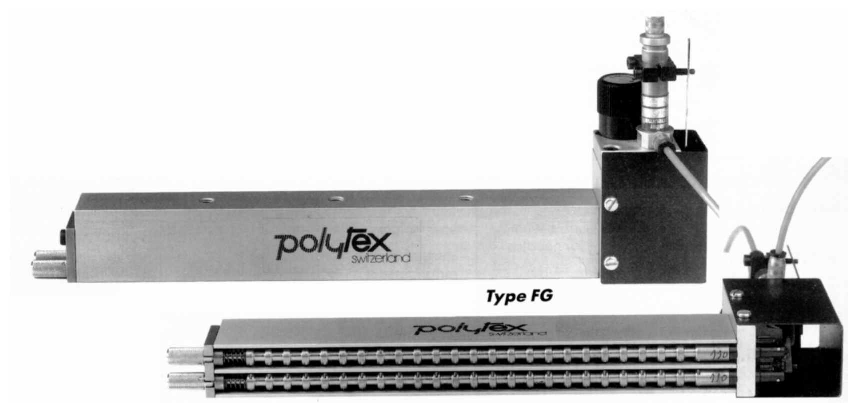
Needle gripping head



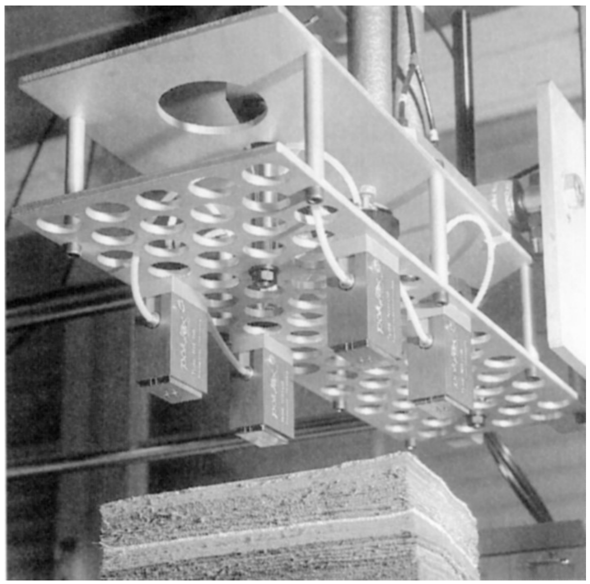
Type BG

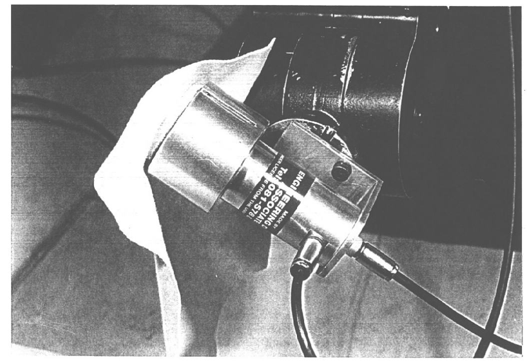
Type NG

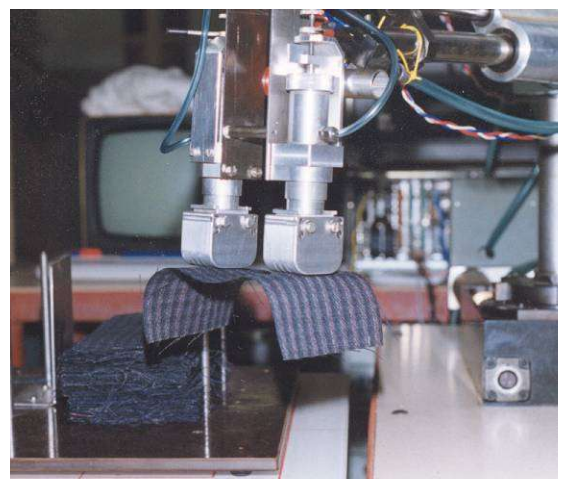
Type SG



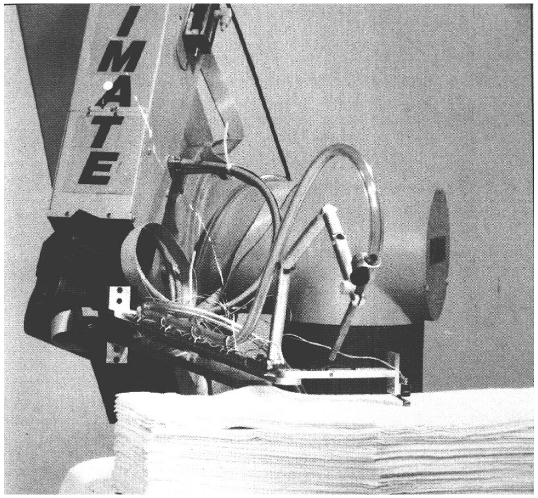
Needle gripping head

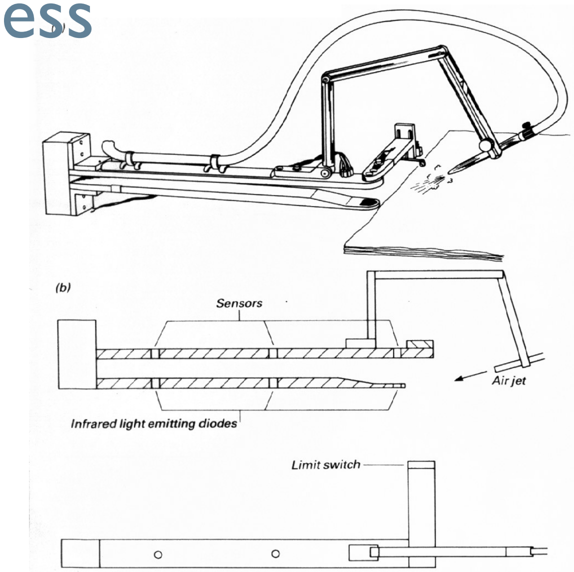


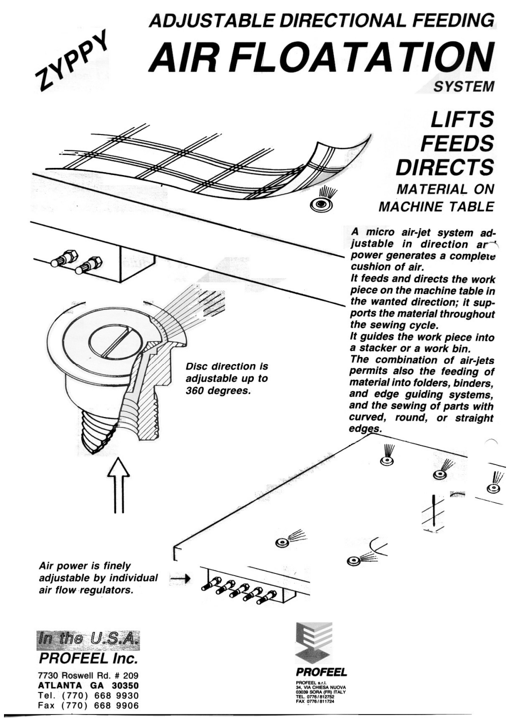


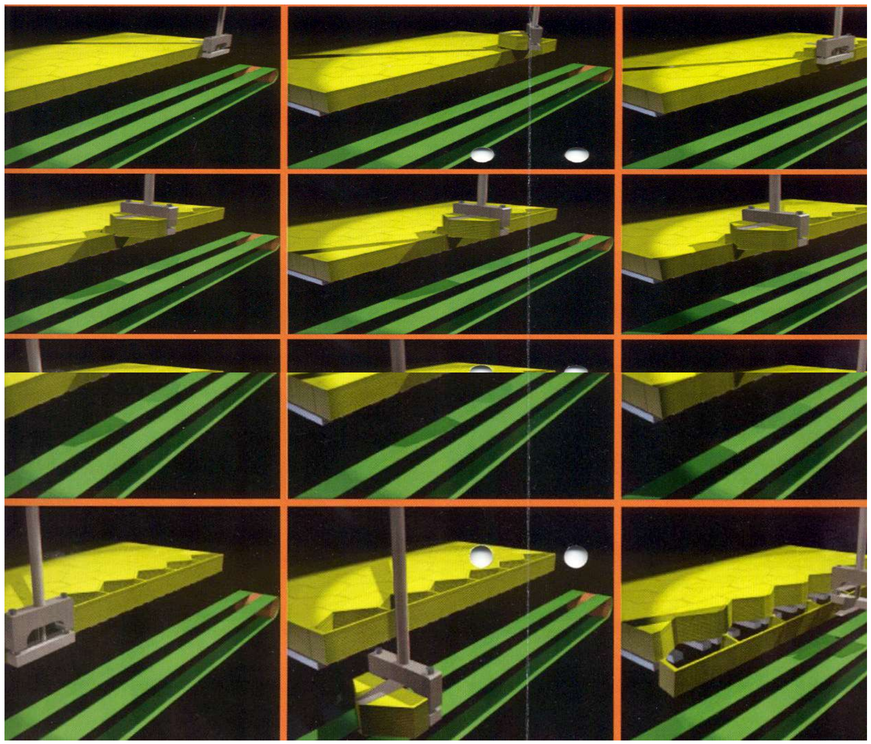


Automation of cutting process









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