EE-381 Robotics-1
UG ELECTIVE

Lecture 1

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Student Introduction

- Introduce Yourself
  - Name
  - Belongingness
  - Motivation behind opting for this course

Class Norms

- Attendance timings
- Cell phone ringing
- Respect peer, faculty and staff through actions and speech
- Should not disturb your fellows
- Assignment submissions
- We will follow the SEECS policy on plagiarism

Course Material

Enrollment Code: **983675410**

- Textbook
  - **Robot Dynamics and Control**

    by M. W. Spong, Seth Hutchinson, and M. Vidyasagar

  - **Robot Modeling and Control**

    by M. W. Spong and S. Hutchinson

Course Assesment

Assessments/CLOs	CLO 1	CLO 2	CLO 3	CLO 4
Quizzes : $5-20\%$ of the theory part	✓	✓		
Assignments: $5-10\%$ of the theory part	✓	✓		
Mid Exam: $25-40\ \%$ of the theory part	✓	✓		
End Semester Exam: $35-50\%$ of theory part	✓	✓		
Project: $5 - 10\%$		✓	✓	✓
Labs: 25% of the course			✓	✓

Course Material

- Reference book:
  - **Robotics, Vision and Control** by Peter Corke.
  - **Introduction to Robotics, Mechanics and Control** by John J. Craig.
  - **Introduction to Autonomous Mobile Robots (Intelligent Robotics and Autonomous Agents series)** by Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza.
  - **Learning ROS for Robotics Programming** by Aaron Martinez, Enrique Fernández.
- Slides

Course Objective

Line follower

Humanoid Robot

Industrial Arm Robot

- Robot Structure
- Robot Modeling
- Robot Actuators and Driving Systems
- Sensors
- Kinematic (Forward and Inverse)
- Robot Control
- Robot Programming
- Applications

Course Outcome

- Student will be able to:
  - Select a particular type of robot based on the **requirement**; solve problems in **forward and inverse kinematics**
  - Select a **suitable drive system**; select a suitable **vision system**
  - Select a suitable robot cell **layout** for various needs
  - Choose the right **problem-solving technique**

Lecture Agenda

- Introduction to Robotics
- Robot accessories
- Classification of Robots
- Robot coordinates
- Robot Programming

Introduction to Robotics

What is a Robot???

Robot

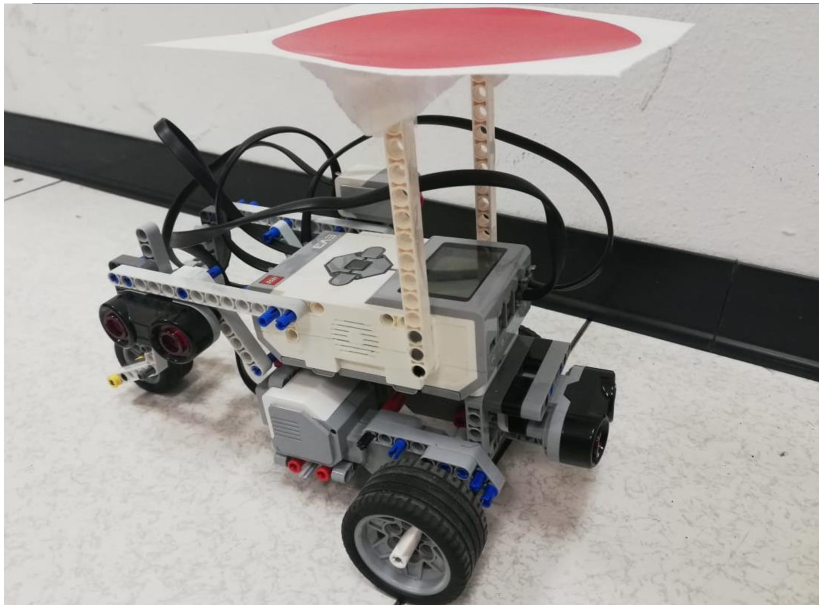
- **As defined by Robotics Industries Association (RIA)**

A **re-programmable**, **multifunctional manipulator** designed to move materials, parts, tools or specialized devices through variable programmed motion for a variety of tasks

- **As defined by ISO 8373 (Robots and Robotic devices)**

An **<u>automatically controlled</u>**, **re-programmable**, **multipurpose manipulator** programmable in three or more axes, which may be either fixed in place or <u>mobile</u> for use in industrial automation applications.

Applications of Robots



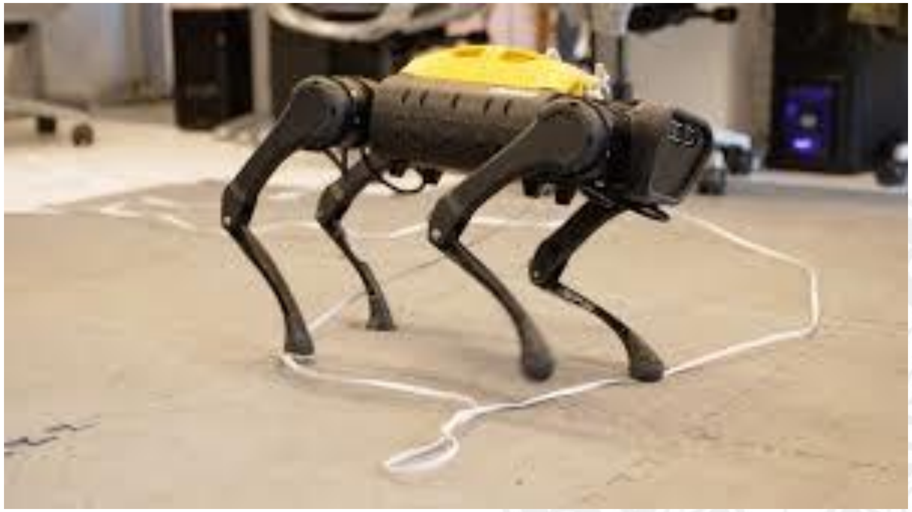
Wheeled Robot

Autonomous Vehicles

Applications of Robots

Manipulator

Legged Robot



Applications of Robots

Autonomous underwater vehicle

Autonomous Aerial vehicle


AEROBOTIX
Video by Aerobotix
AEROBOTIX

This Robotic Design can Climb Up and Down the Stairs!!

https://www.mdpi.com/2076-3417/11/11/5280


>> She's got this
>> All right. Okay

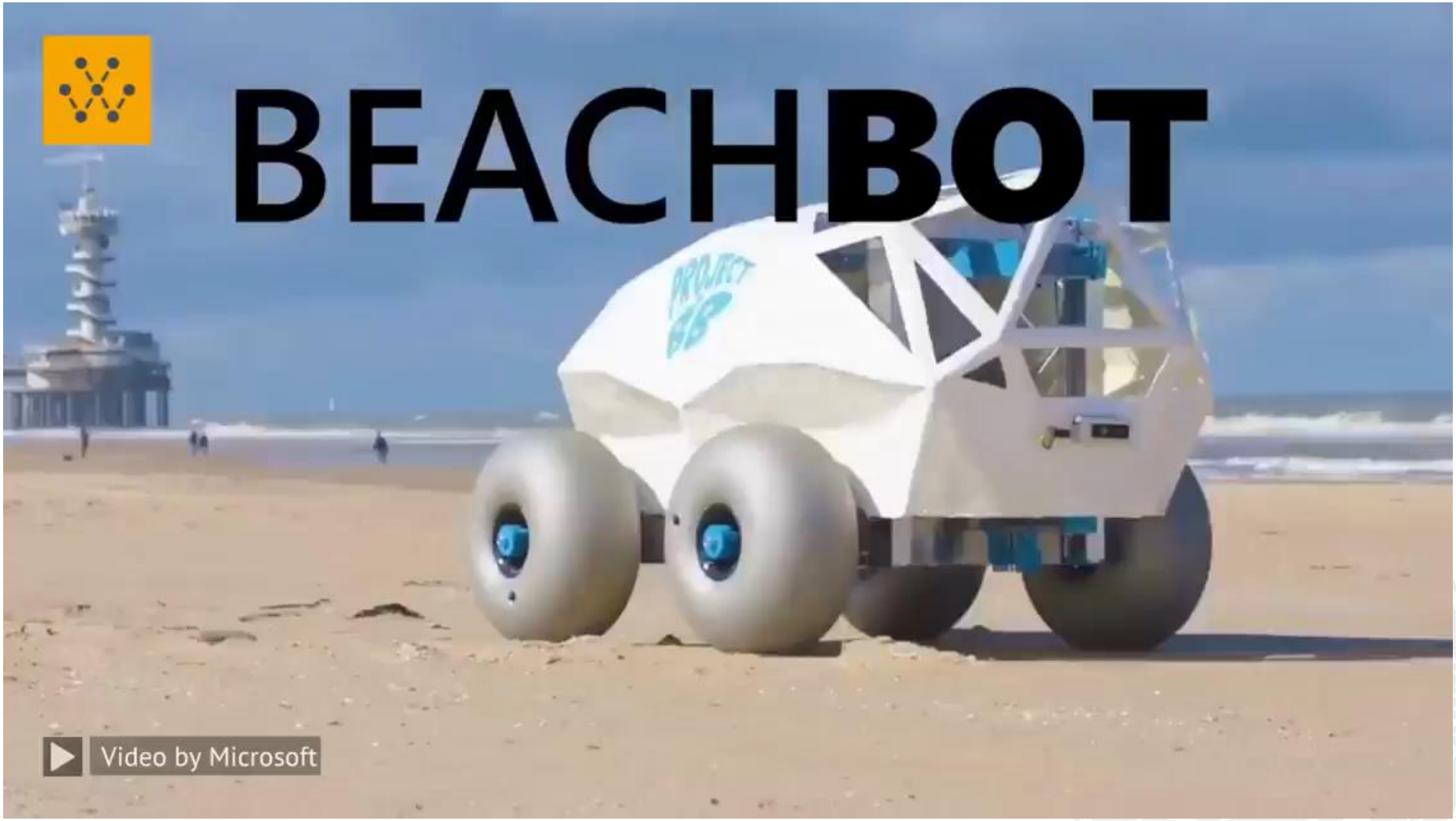
Swarm Drones

Cleaning Robot

Drone Umbrella

Construction Robots

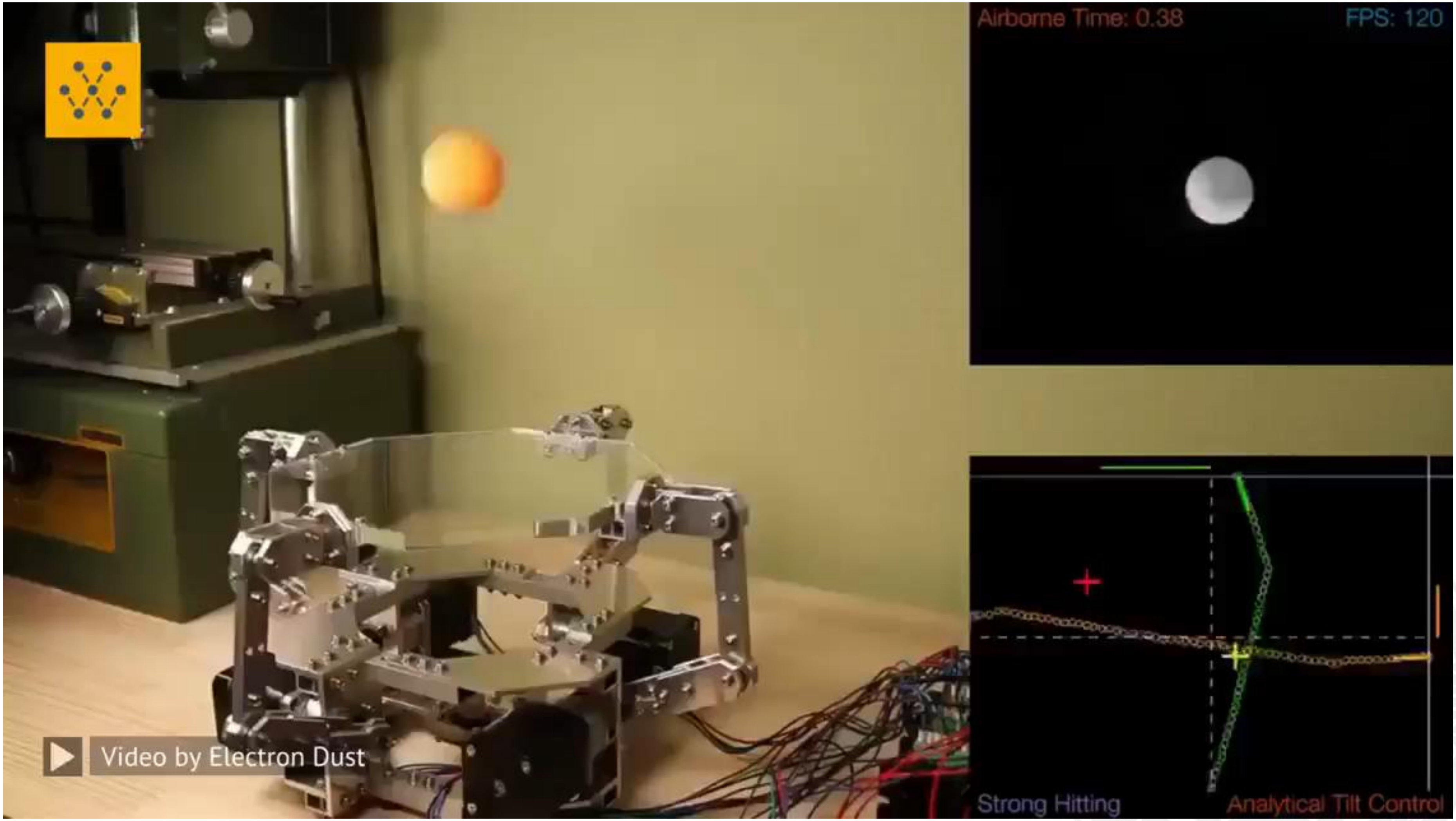
BeachBot



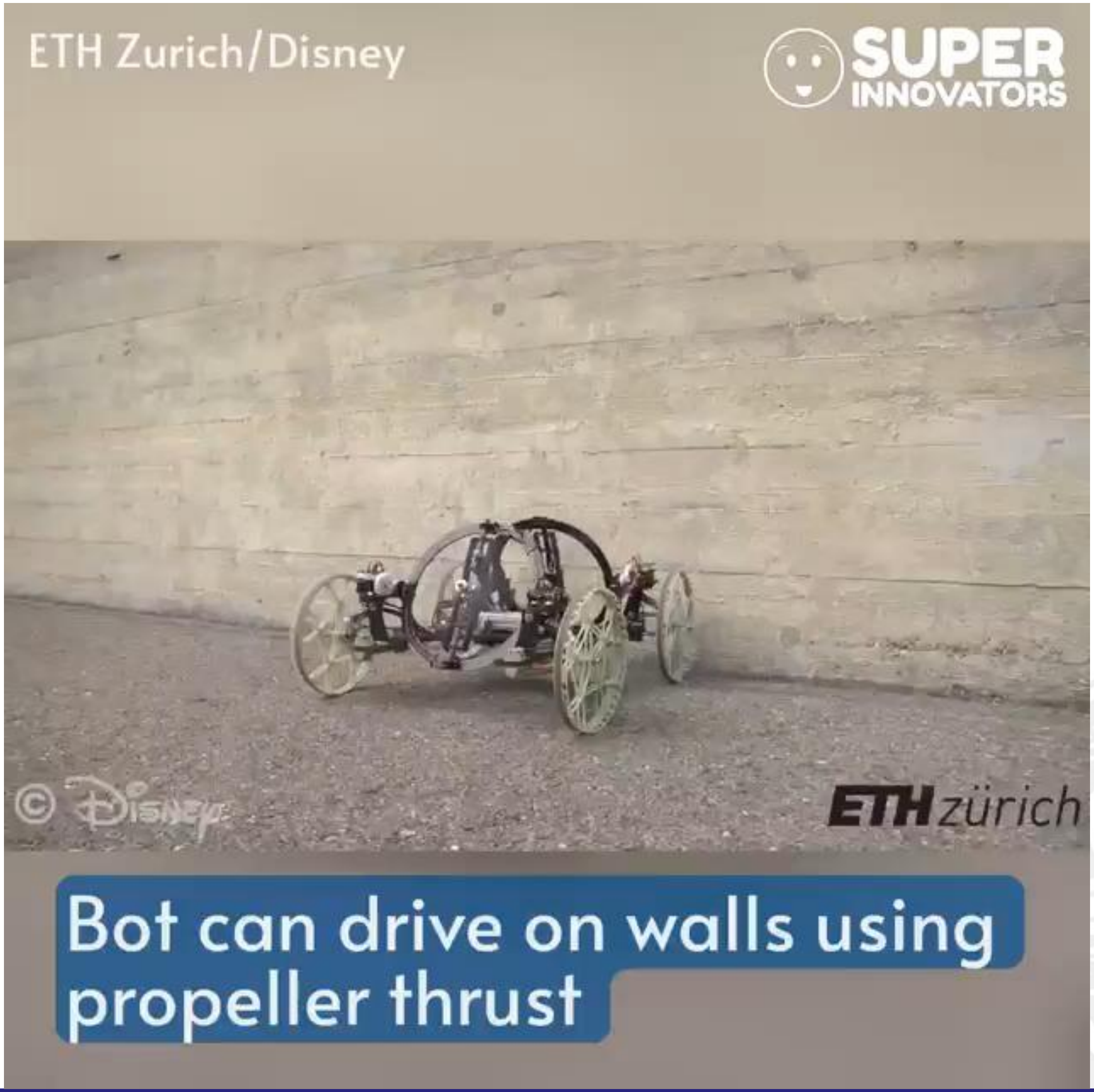
Drone

Low-cost robot that can cook

The Octo-Bouncer: Advanced Bouncing Patterns

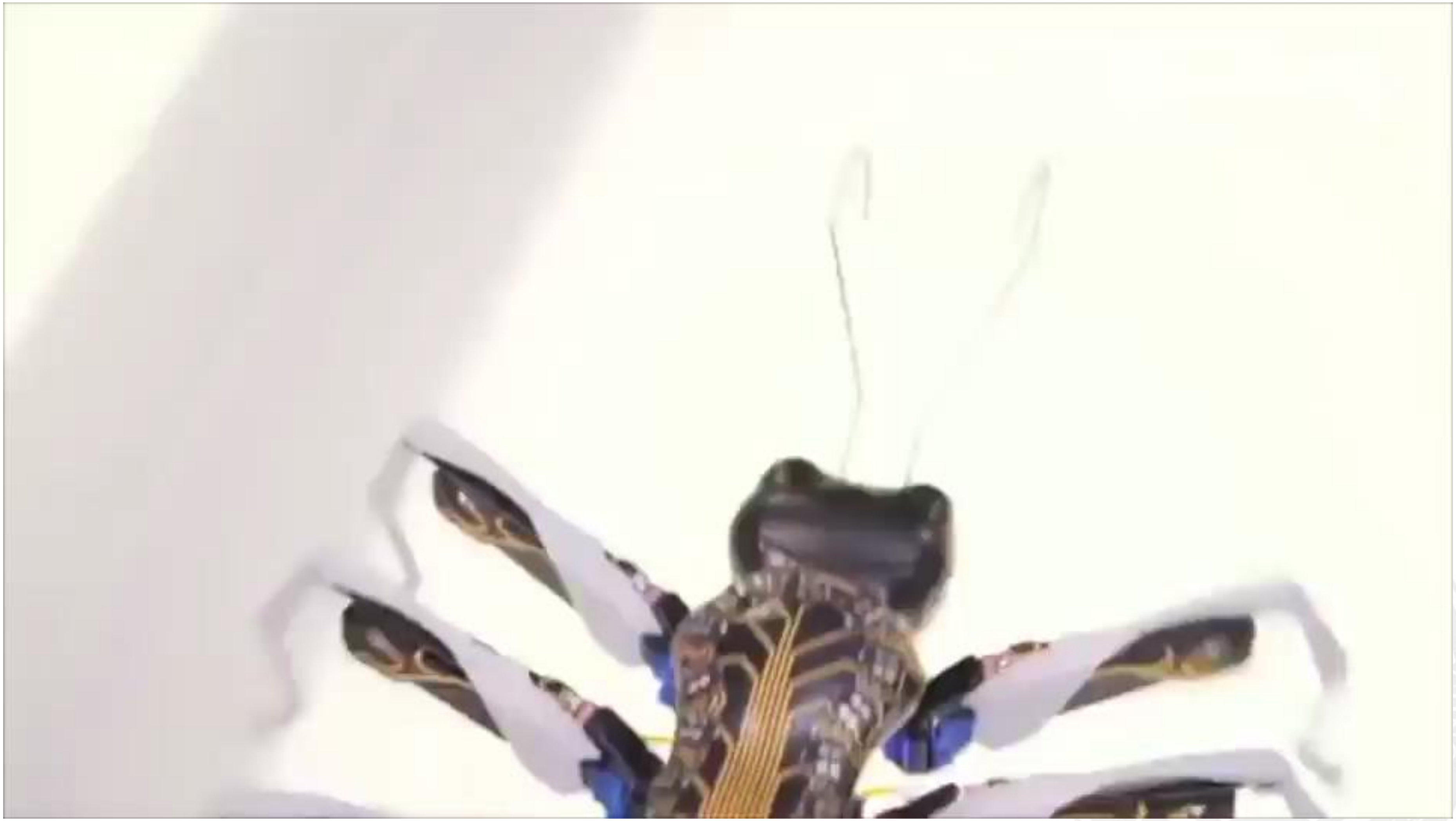


Bot can drive on walls using propeller thrust

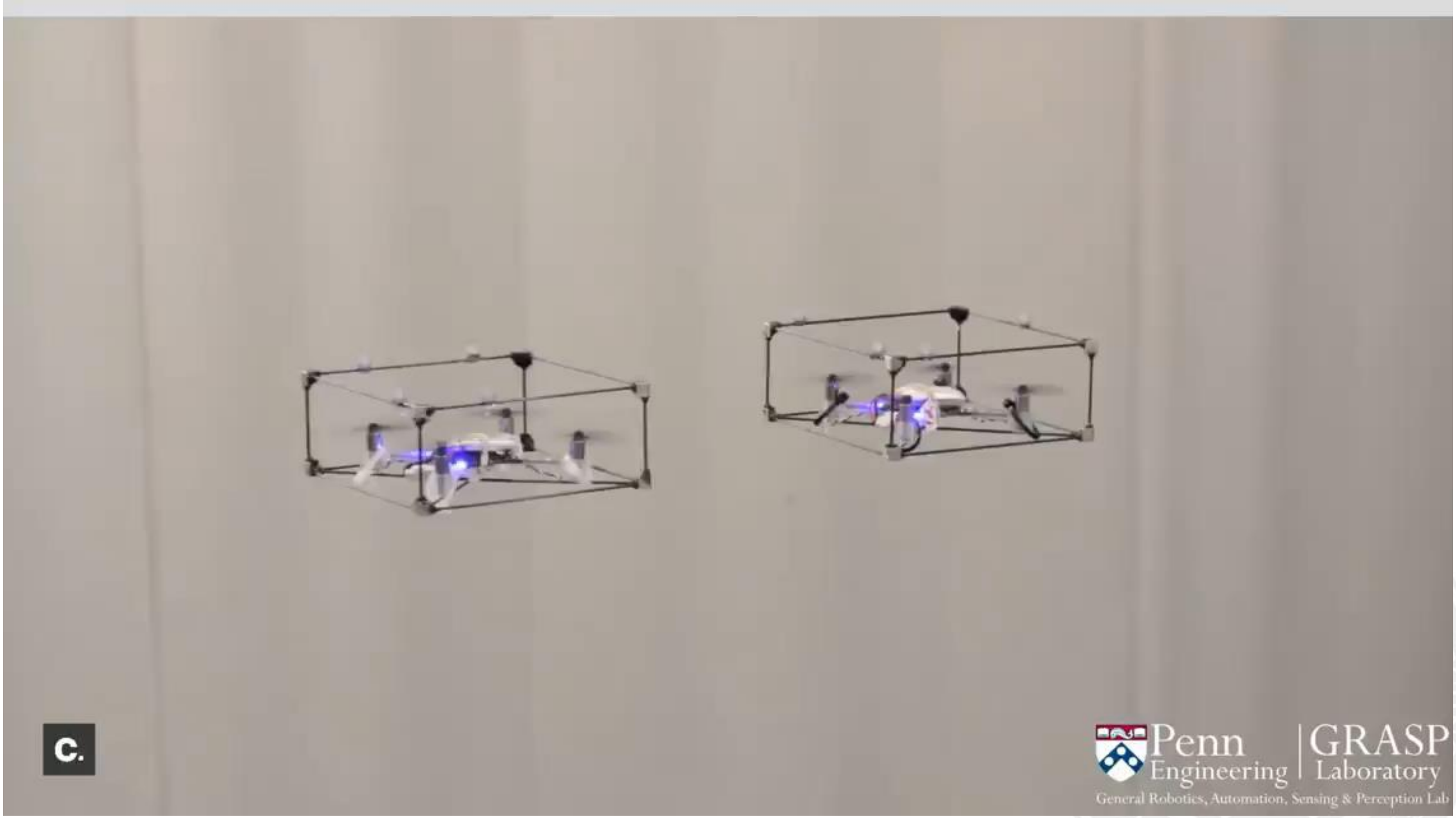



Video by S.L. Kanthan

Robo-ant-tics!

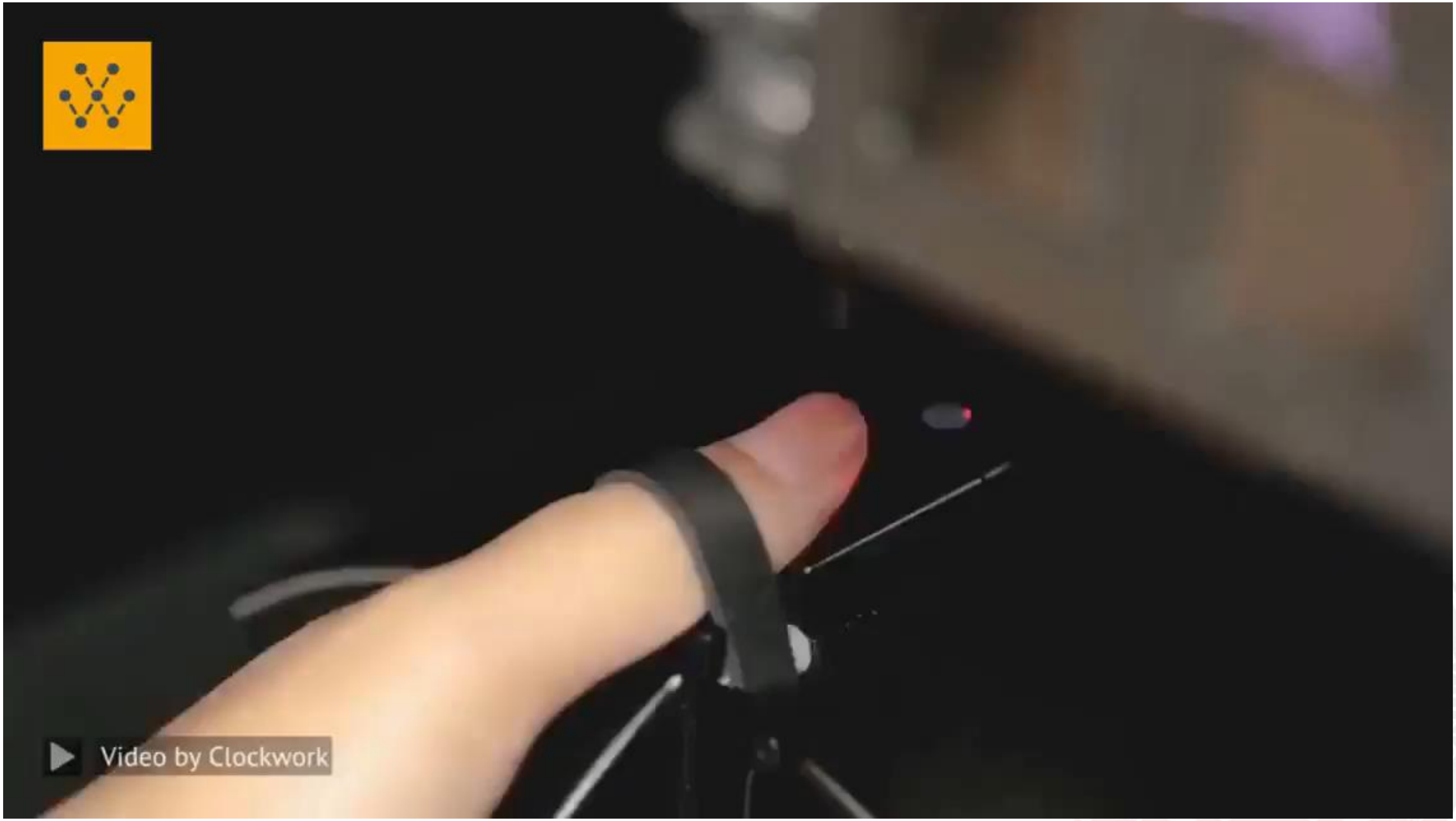


Self-assembling of Aerial Robots




Stanford
University

Clockwork MiNiCURE Robot



Intelligent parking chair

When Nissan made self parking AI office chairs just for their own offices

Loitering drones

Toy drone

Autonomous tool-carrier Orio

Industrial Automation

Robots will take over the World?

History of Robotics (THE ORIGIN)

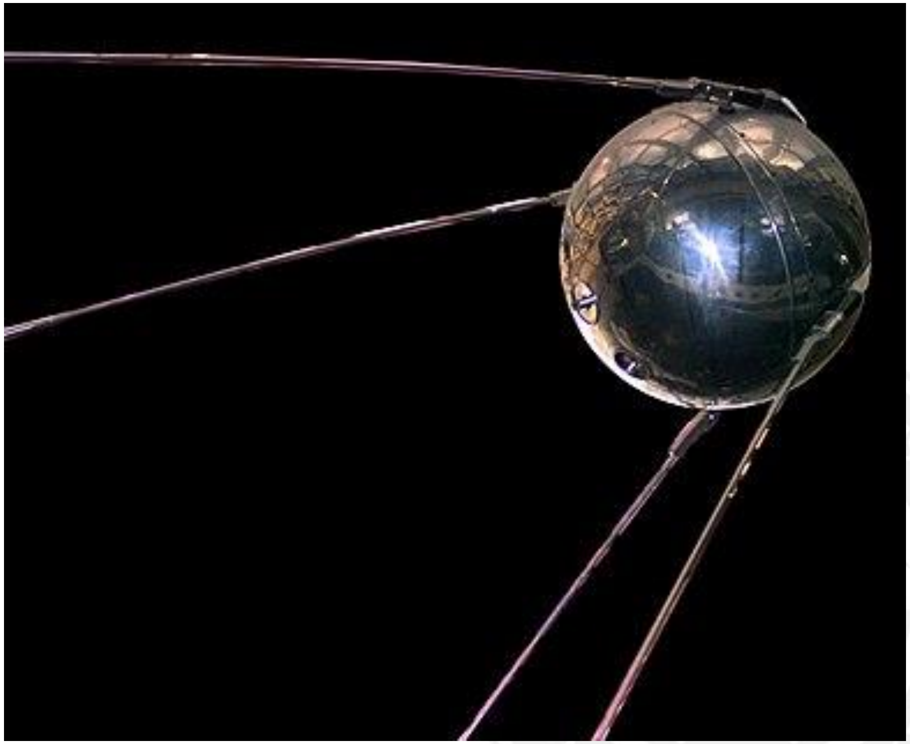
- **1920** Czech author Karel Capek wrote a story called Rossum’s Universal and introduced the word ”Rabota” (Czech word, meaning worker/servitude)

- **1948** George Devol design the first programmable robot; automate the welding and metal working.

History of Robotics (THE ORIGIN)

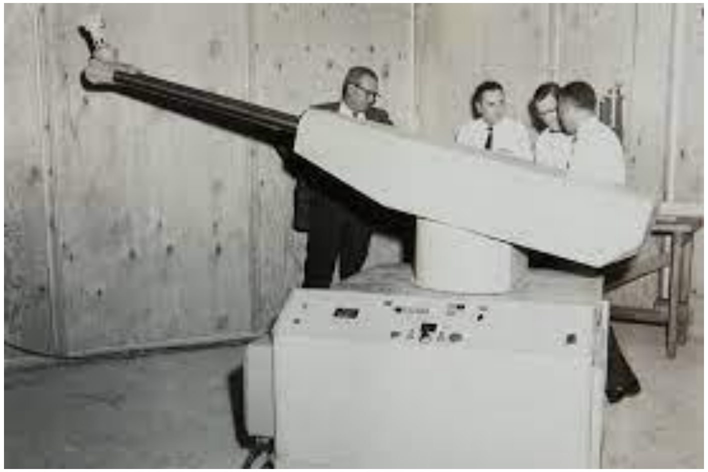
- **1956** Josseph Engel berger, a Columbian University physics student, buys the rights to Devol's robot and funds the Unimation Company

- **1957** launch of first artificial satellite Sputnik 1



History of Robotics (THE ORIGIN)

- **1960** industial robots created and Robotic Industries Association officially defines the robot



- **1961** the Unimate robot is installed in a Trenton, New Jersey plant of General Motors (to tend a die casting machine) https://www.youtube.com/watch?v=hxsWeVtb-JQ

History of Robotics (THE ORIGIN)

- **1962** George Devol and Josseph Engel berger start a first Robotic industry named as Unimation and develop industrial Robots
- **1963** the first robot vision system is developed
- **1971** the Stanford Arm is developed at Stanford University

History of Robotics (THE ORIGIN)

- **1973** the first robot programming language (WAVE) is developed at Stanford

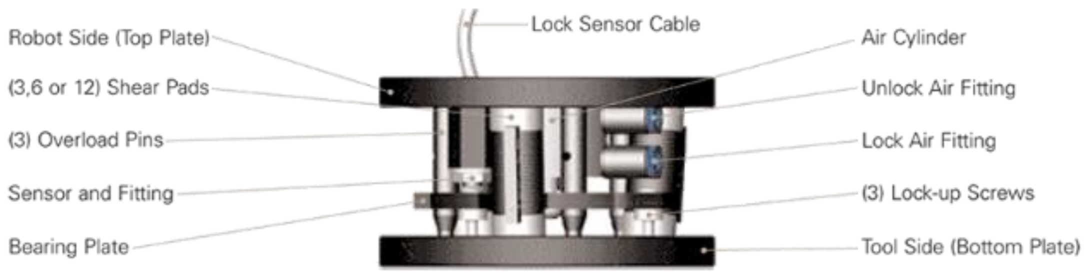
- **1974** Cineinnati Milacron introduces

the T3 robot with computer control

- **1975** Unimation Inc. registers its first financial profit

History of Robotics (THE ORIGIN)

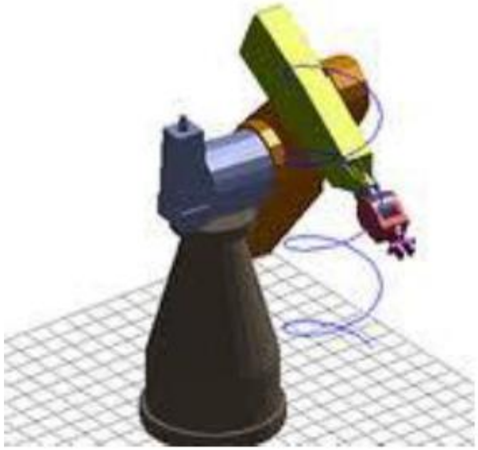
- **1976** the Remote Center Compliance (RCC) device for part insertion in assembly is developed at Draper Labs in Boston

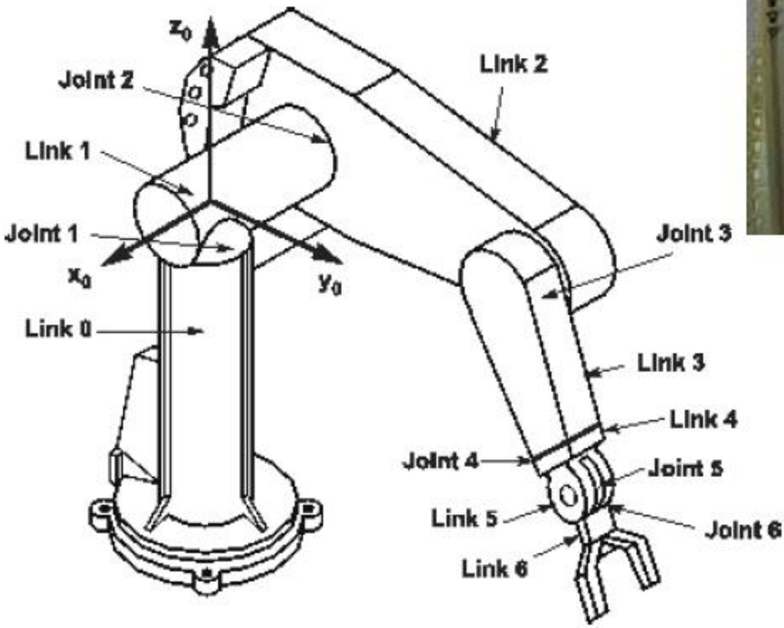


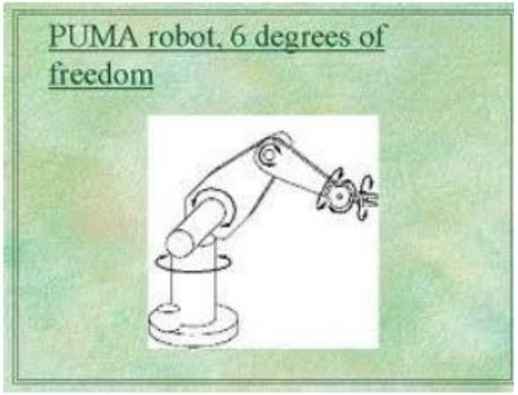
- <u>Two famous Robots</u>
  - **1978** PUMA
  - **1979** SCARA

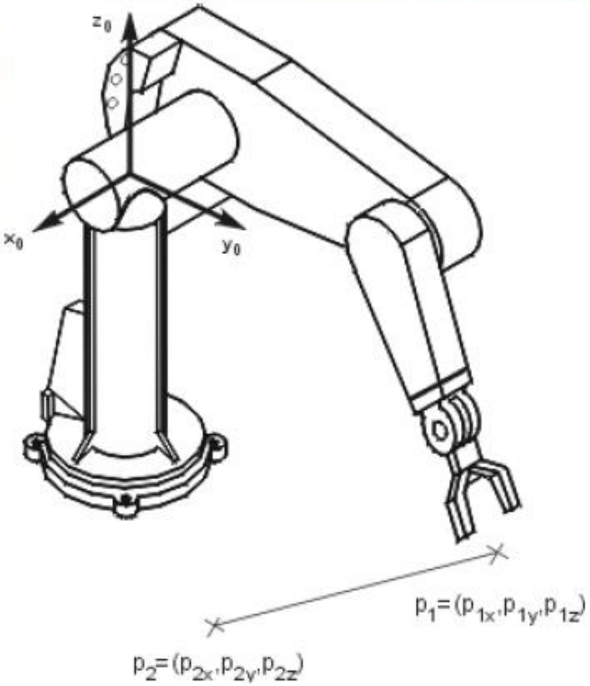
PUMA:

1978 –PUMA: the Programmable Universal Machine for Assembly, introduced by Unimation









SCARA: **1979** –SCARA (Selective Compliant Articulated Robot for Assembly) robot design is introduced in Japan

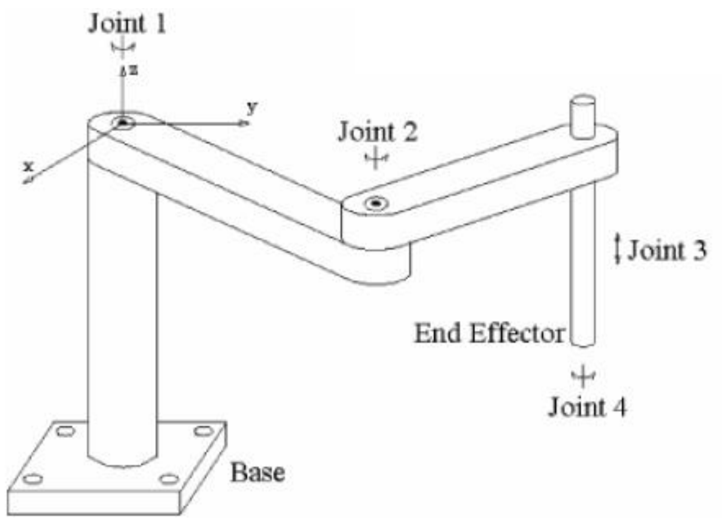


Figure 5. SCARA - Selective Compliance Assembly Robot Arm.

History of Robotics (THE ORIGIN)

- **1981** – the first direct-drive robot is developed at Carnegie-Mellon University

- **2000**'s - Military applications – Robotic assistants for dangerous environments and reconnaissance (military observation of a region to locate an enemy), NASA, AUVs etc.

History of Robotics (THE ORIGIN)

- **2000**'s – Intuitive Surgical introduces the Da Vinci surgical robot

- **2000**'s - IRobot introduces the first autonomous vacuum –"Roomba".

Robots

- Amazon warehouse

https://www.youtube.com/watch?v=TUx-ljgB-5Q

- Industrial robots

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

- Arc welding robot

https://www.youtube.com/watch?v=5HphVrleXlQ

- Worm robot

https://www.youtube.com/watch?v=ilbT2QcPGvo

- Hexapod robot

https://www.youtube.com/watch?v=-uKIDyFMTyQ

https://www.youtube.com/watch?v=Mfjn79oiMoQ

- CyberDog

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

https://www.youtube.com/watch?v=4oSavAHfodg

Three laws by Asimov – 1942

1. A robot may not injure a human being, or, through inaction, allow a human to be harmed
2. A robot must obey orders given by human except when that conflicts with the First Law.
3. A robot must protect its own existence unless that conflicts with the First or Second laws

Robotics

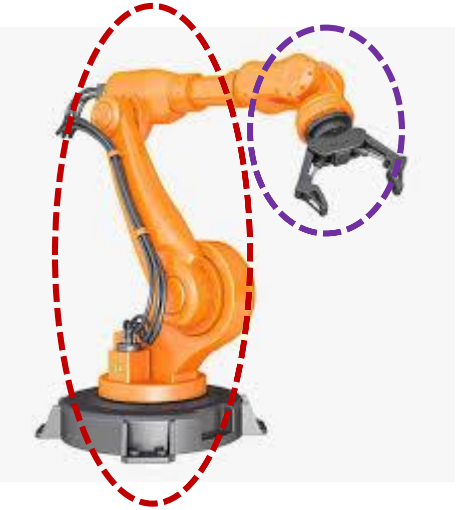
It is a multidisciplinary field, comprises of knowledge from the field of

- **Mechanical Engineering-** concerned with manipulator/mobile robot design, kinematics, dynamics, compliance and actuation.

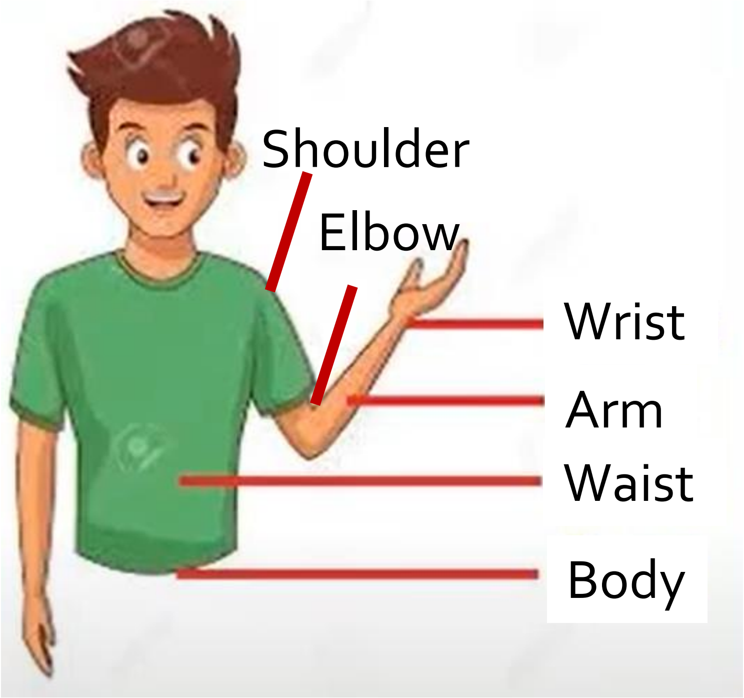
- **Electrical Engineering-** concerned with robot actuation, electronic interfacing to computers and sensors and control algorithms
- **Computer Science-** concerned with robot programming, planning and intelligent behavior.

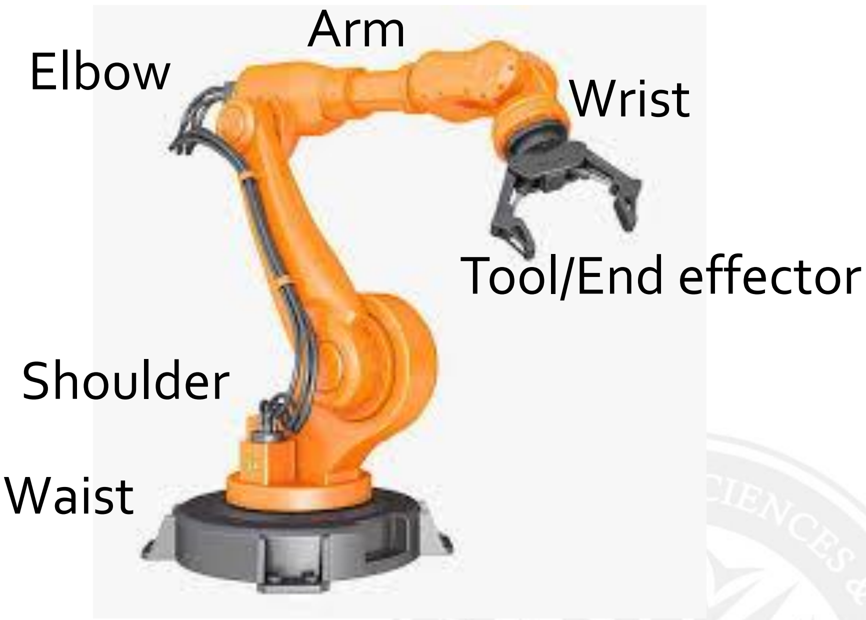
Robot Accessories

- **Manipulator:** Main body of the robot & consists of links, joints and structural elements.
- **End Effector:** part that generally handles objects, makes connection to other machines, or performs the required tasks.



Robot Accessories



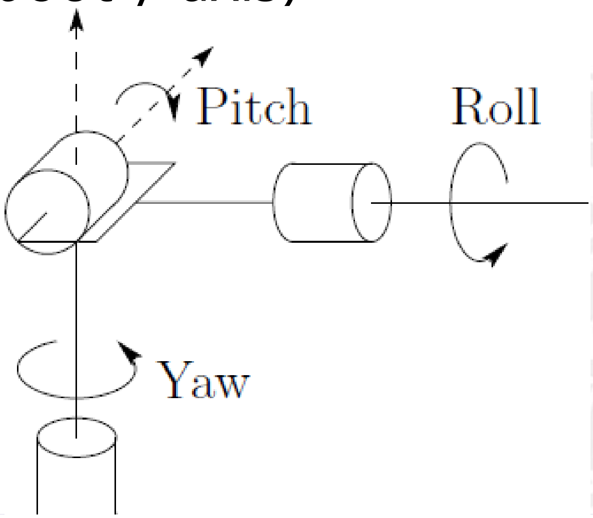


Robot Accessories: Wrist

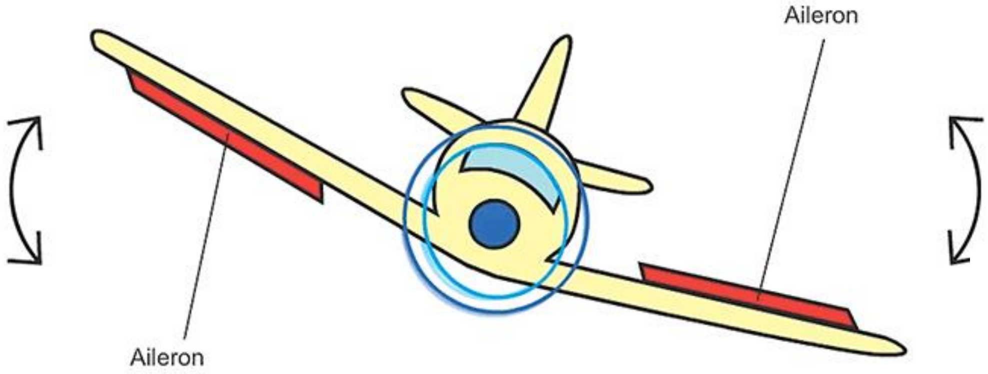
- **Wrist**: refers to joints in kinematic chain between arm and hand

- 3 DOF degree of freedom
  - **Roll**: involves rotating the wrist about the arm axis (about x-axis)
  - **Yaw**: left-right rotation of wrist (about z-axis)
  - **Pitch**: up-down rotation of wrist (about y-axis)

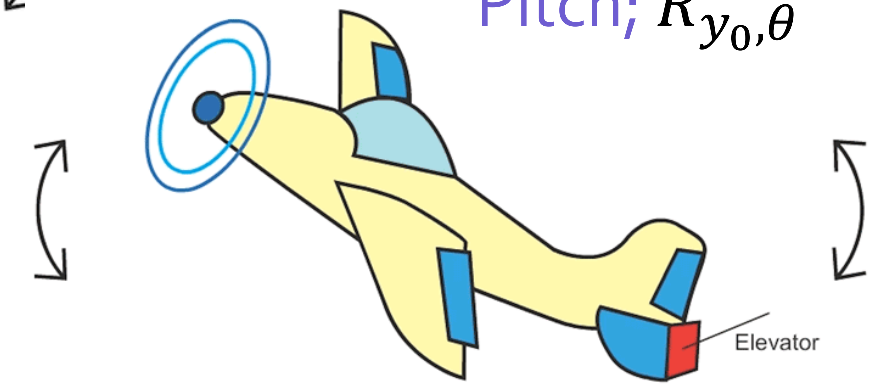
- End effector is mounted on wrist



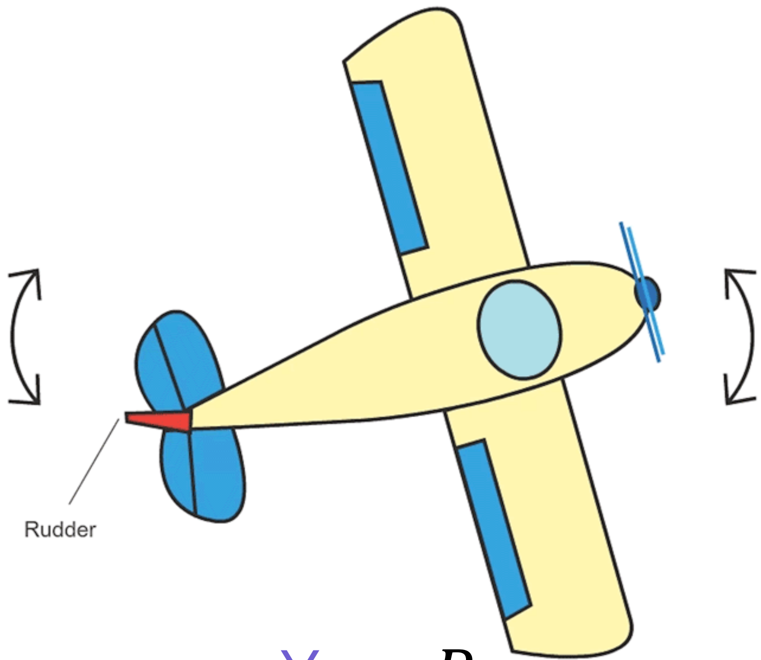
Structure of spherical wrist

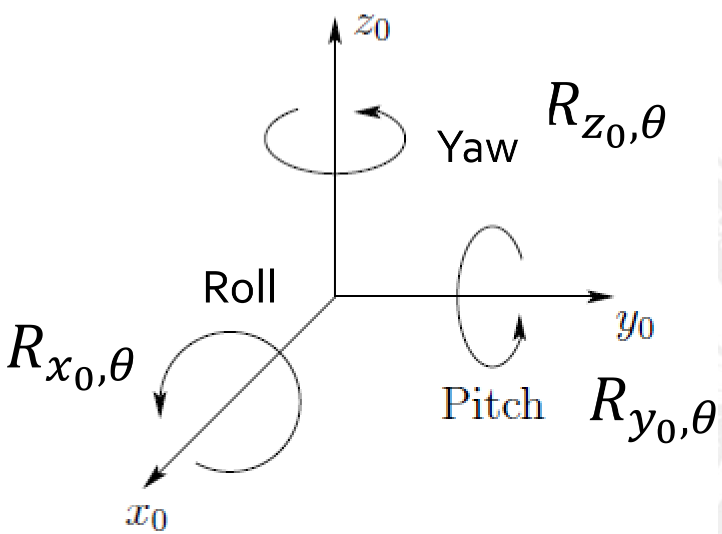


Pitch; $R_{y_0,\theta}$



Roll; $R_{x_0,\theta}$





Yaw; $R_{z_0,\theta}$

https://howthingsfly.si.edu/flight-dynamics/roll-pitch-and-yaw#:~:text=Imagine%20three%20lines%20running%20through,vertical%20axis%20is%20called%20yaw.

Robot Accessories

- **Actuators:** (muscles of the manipulator) Servomotors, stepper motors, pneumatic, hydraulic cylinder etc.

- **Sensors**: collect information about the internal state of the robot or to communicate with the outside environment: vision system, touch and tactile sensors etc.

- **Controller**: controls the motions of the actuator and coordinates these motion with the sensory feedback information.

- **End Effector**: Hand (not part of anatomy)

Representation of Robot

- Robot Manipulators are composed of links connected by joints into a kinematic chain.

z_i →axis of rotation
d_i and θ_i → joint variables
i → are the number of links

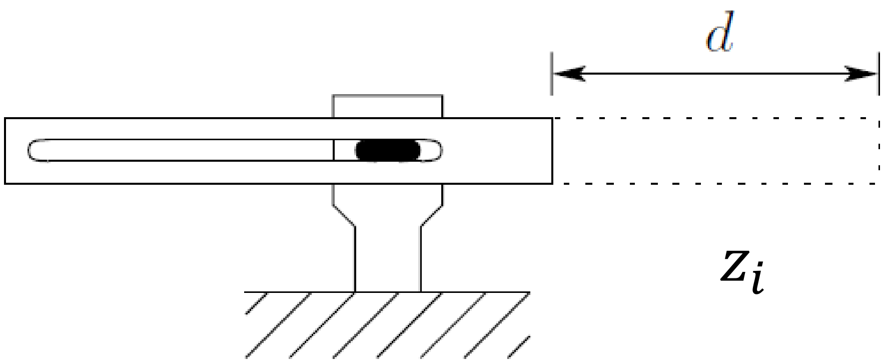
Joints are of two types

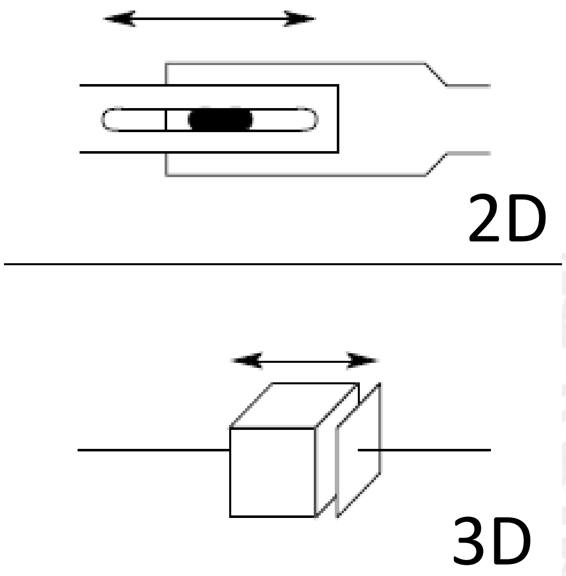
- Rotary (Revolute)
- Linear (Prismatic)

Robotic Joints

Prismatic Joint: allows a linear relative motion between two links.

- Represented with P

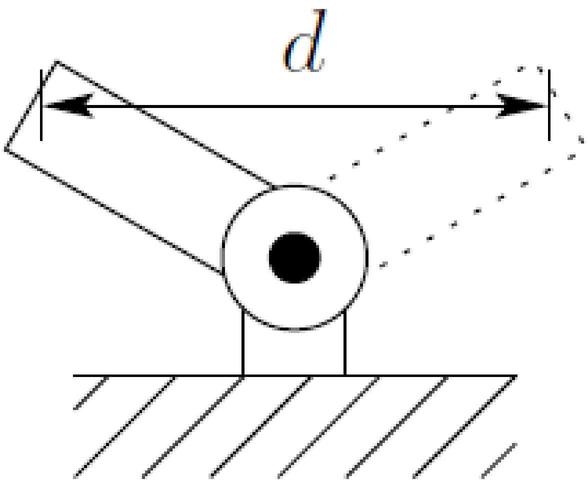


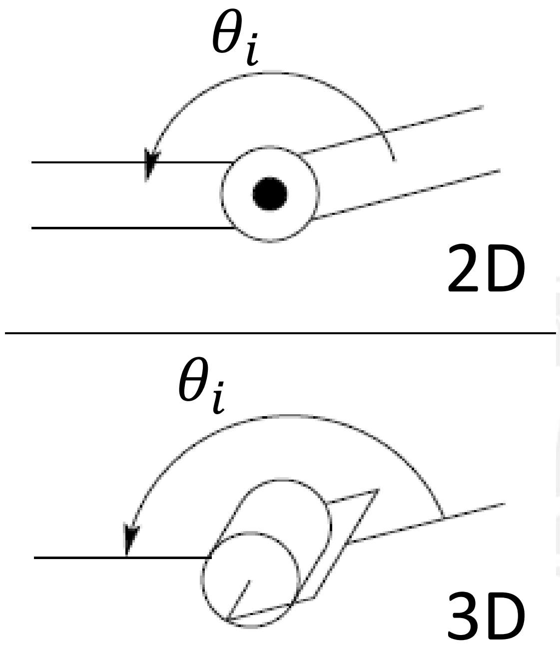


Robotic Joints

Revolute Joint: is like a hinge and allows relative rotation between two links

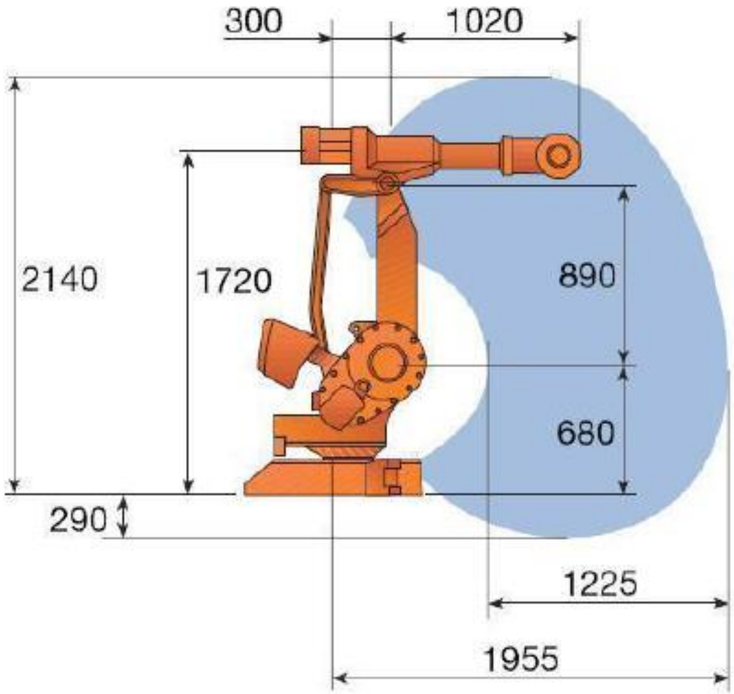
- Represented with R





Work Envelop

A robot's **work envelop** is its range of movement. It is the shape created when a manipulator reaches forward, backward, up and down. These distances are determined by the length of a robot's arm and the design of its axes.



Robot Classification

Robot manipulators classified based on

- Power source
  - Electrically
  - Hydraulically →Liquid Pressure
  - Pneumatic→Gas/Pressure powered
- Application area
  - Assembly robots
  - Non-assembly robots

Robot Classification

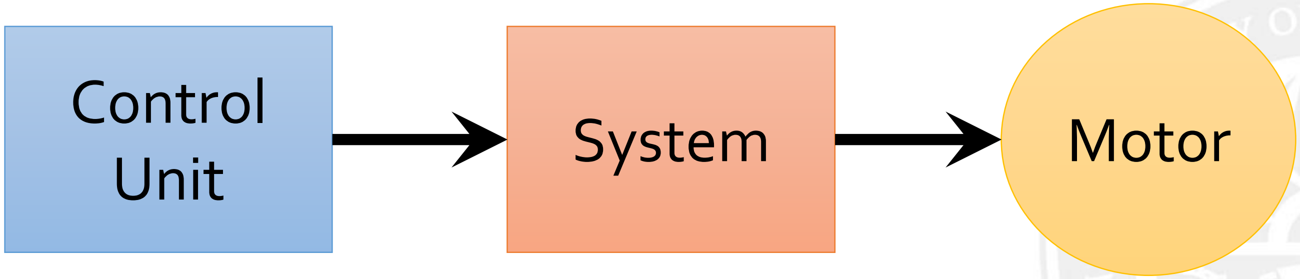
- Control systems
  - Open loop control system
  - Closed loop control system

- Method of control
  - Servo robots
    - Point-to-point robot system
    - Continuous-path robot system
  - Non-servo robots

- Geometry (coordinate system) (based on first three joint of arm)
  - Articulate (RRR)
  - Spherical (RRP)
  - SCARA (RRP)
  - Cylindrical (RPP)
  - Cartesian (PPP)

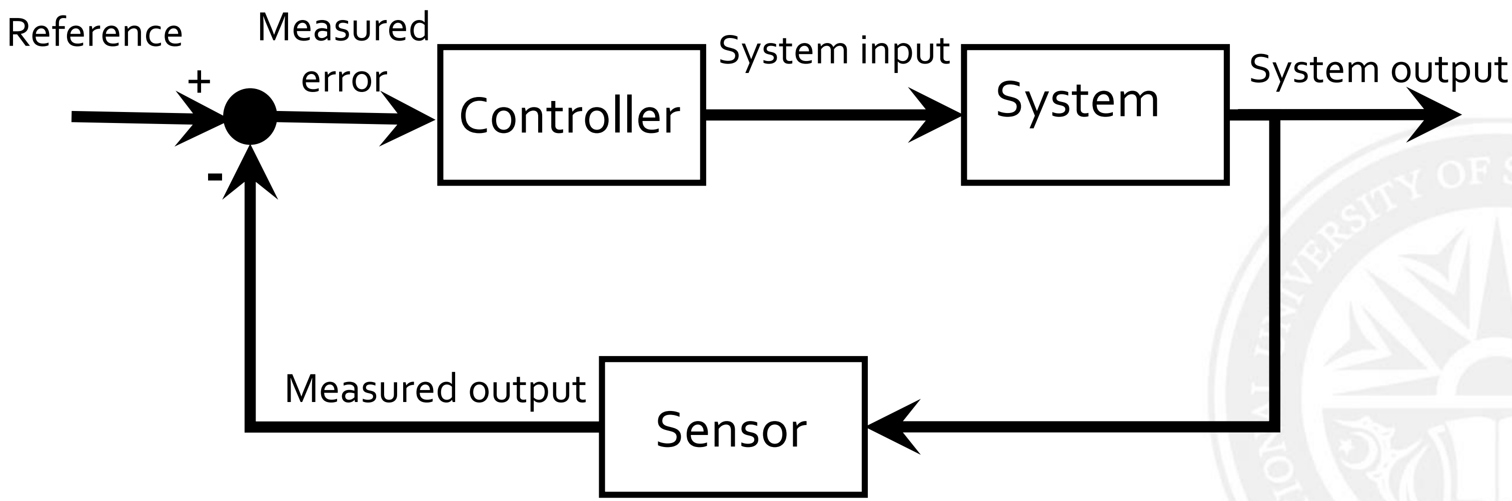
Control Systems

- Open loop control system
  - Control is given to the individual axis
  - No feedback is obtained
  - Used for loading/unloading applications



Control Systems

- Closed loop control system
  - Control is given to the individual axis
  - Feedback is obtained through sensors
  - Corrective signals are sent by control unit



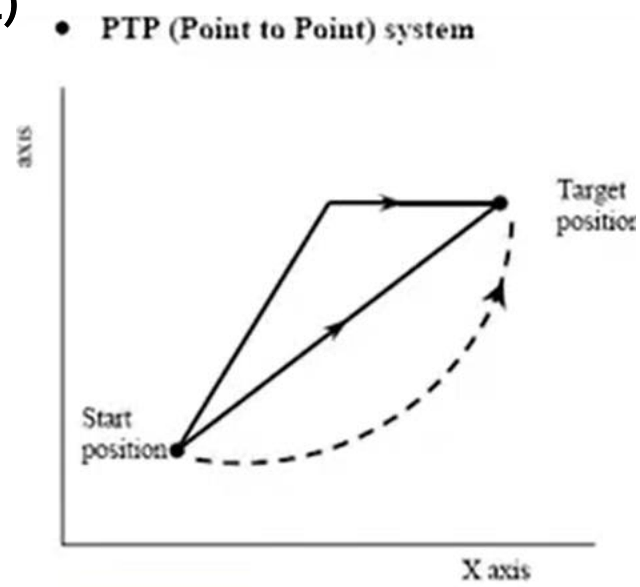
Method of Control

- Servo control robot:
  - Hydraulic and electric robots. Users closed loop control system
  - Information of position and velocity is monitored and feedback to control system

- Non-servo control robot:
  - Pneumatic robots, limited sequence robots, pick and place robots
  - Uses open loop control system
  - Controlled by setting mechanical stops or limit switched to establish end points to travel of end joints

Servo Robots

- **Point-to-point robot system** **(straight cut)**
  - Only the end points are programmed, the path used to connect the end point are computed by the controller
  - User can control velocity and may permit linear or piece-wise linear motion
  - **Feedback** control is used during motion to ascertain that individual joint have achieved desired location

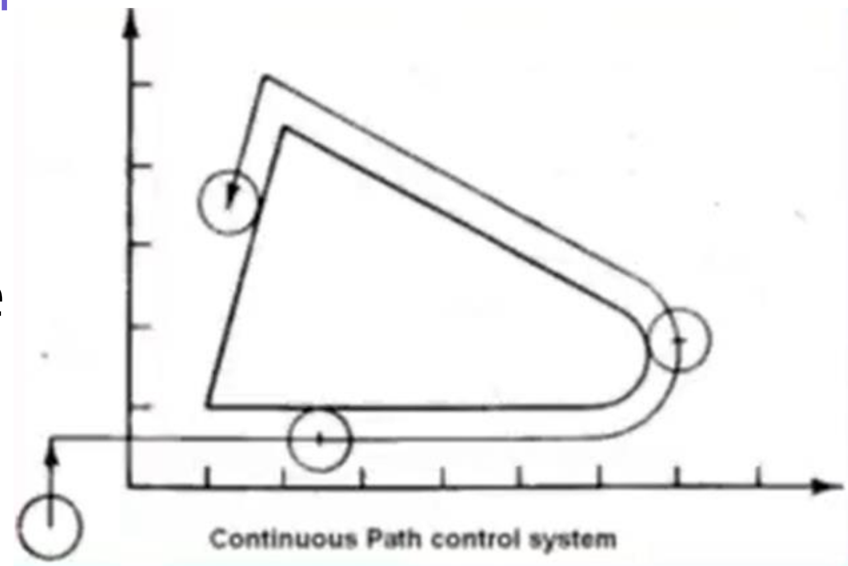


- Applications: palletizing, machine loading

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

Servo Robots

- **Continuous path robot system**: the entire path of the end effector can be controlled
- For-example:
  - Robot end effector can be taught to follow a straight line between two points
  - Follow a contour in case of welding seam



- Velocity/acceleration of the end effector can be controlled
- Applications: spray painting, polishing, grinding, arc welding