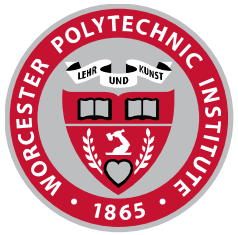


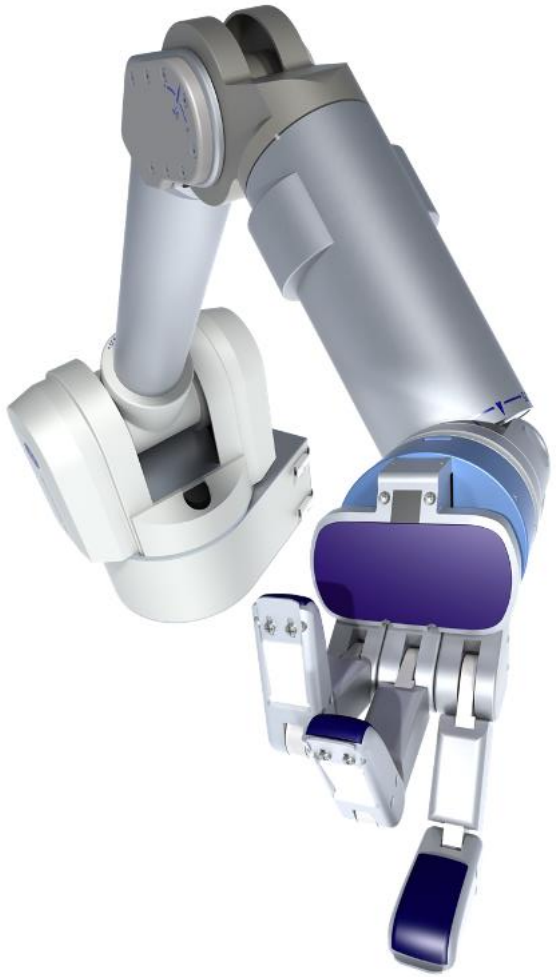
WPI

Lecture 1

Course Introduction – Types of Robots and Application Areas – Terminologies

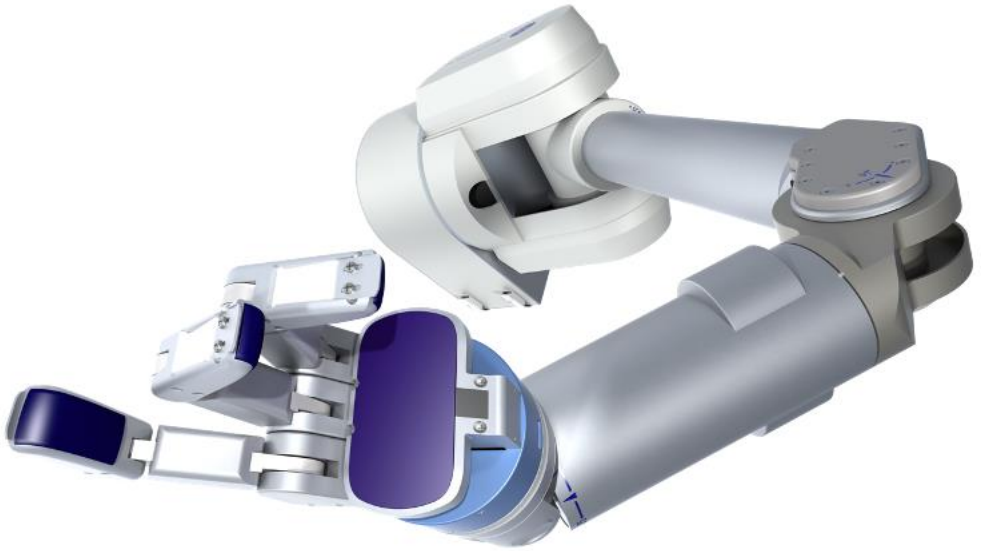
Alexandros Lioulemes, PhD

Course Introduction

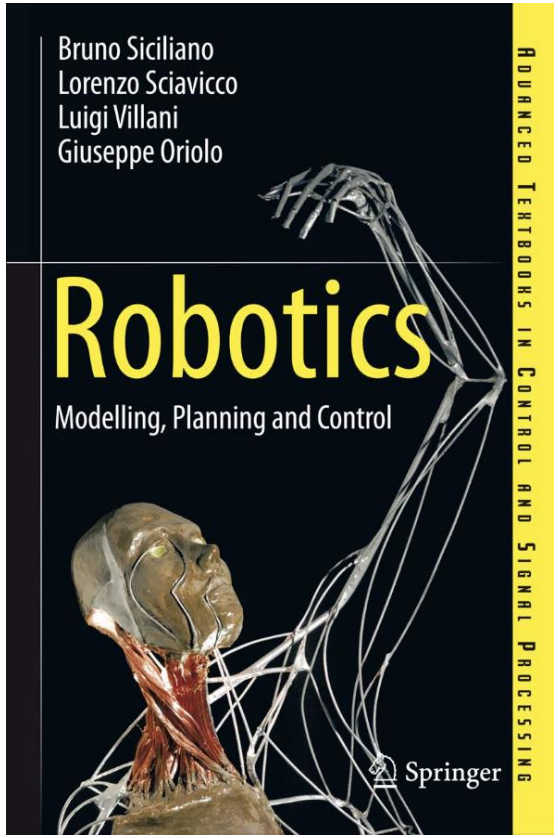


Course Introduction - Topics

- Forward Kinematics
- Inverse Kinematics
- Velocity Kinematics
- Differential Kinematics
- Trajectory Generation
- Linear Control for Manipulators
- Robot Forces
- Dynamics
- Ethics



Course Introduction - Textbooks



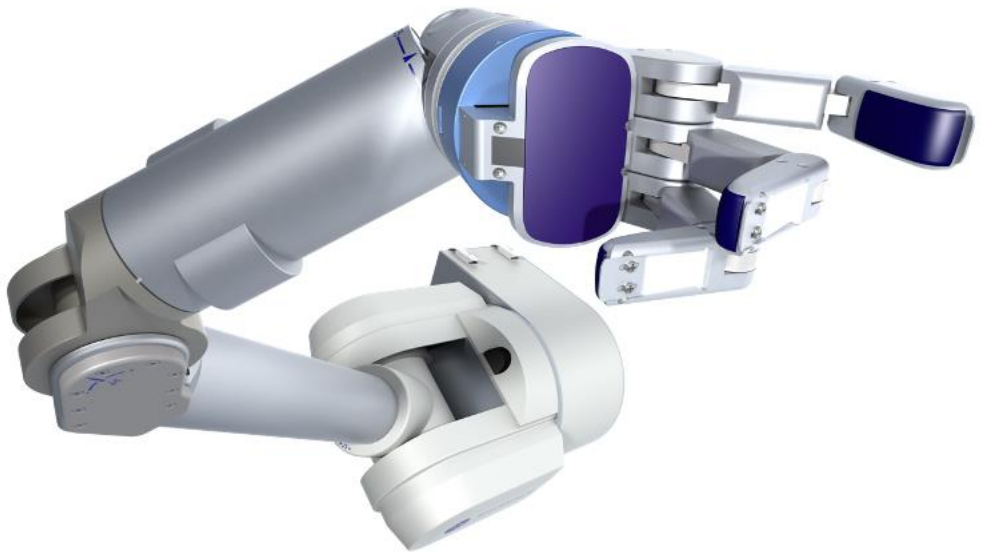
Course Introduction - Outcomes

- Identify various terms for serial robot manipulators
- Derive kinematics and dynamic models
- Design algorithms to control the motion of the robot
- Program a complete real-world robotic system with ROS
- Choose and utilize sensors and actuators for a given robot configuration and task
- Implement kinematic models and control algorithms in robotic simulators

Course Introduction - Grading Policy

Quizzes and assignments	50%
Lab assignments	50%

Late Policy: Each day (>24 hours) of late submission results in a deduction of one point



Letter Grade	Percentage
A	90 - 100
B	80 - 89
C	70 - 79
D	60 - 69
F	< 60

What is a robot?

Definition by Britannica:

> "any **automatically operated machine that replaces human effort**, though it may not resemble human beings in appearance or perform functions in a humanlike manner."

https://www.britannica.com/technology/robot-technology

Laws of Robotics

1. *A robot may not injure a human being or, through inaction, allow a human being to come to harm.*
2. *A robot must obey the orders given by human beings, except when such orders would conflict with the first law.*
3. *A robot must protect its own existence, as long as such protection does not conflict with the first or second law.*

Isaac Asimov

https://en.wikipedia.org/wiki/Three_Laws_of_Robotics

Today: Robotics is extensive and growing

Types of Robots

1. Aerospace
2. Consumer
3. Disaster Response
4. Drones
5. Education
6. Entertainment
7. Exoskeletons
8. Humanoids
9. Industrial
10. Medical
11. Military & Security
12. Research
13. Self-driving Cars
14. Telepresence
15. Underwater

https://en.wikipedia.org/wiki/Robot

Types of Robots - Aerospace

- SmartBird
  - Robotic seagull
- Raven
  - Surveillance drone
- Space robots
  - NASA's Robotnaut

SmartBird

Raven

NASA Robonaut

https://en.wikipedia.org/wiki/Robot_Aviation

Types of Robots - Consumer

- Used for fun or help with your chores:
  - Aibo
  - Roomba vacuum
  - AI-powered robot assistants for kids

Aibo iRobot Moxie

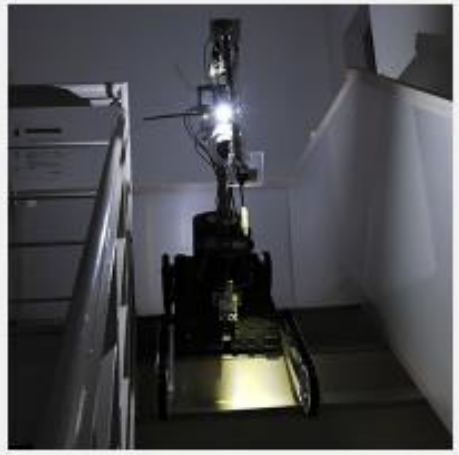
https://en.wikipedia.org/wiki/Domestic_robot

Types of Robots - Disaster Response

- Perform dangerous jobs
  - survivor searching
  - PackBots
    - Damage inspectors
    - Nuclear power station

Packbots

Flyability



Quince

https://en.wikipedia.org/wiki/Rescue_robot

Types of Robots - Drones

- Unmanned Aerial Vehicles (UAVs)
  - DJI Phantom
  - Skydio
  - Global Hawk

DJI Phantom

Skydio

Global Hawk

https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle

Types of Robots - Education

- Aimed for the next generation of roboticists
  - Home
  - classroom robots
    - Programmable Legos
    - 3D printers
    - Teacher robots
      - EMYS

Lego Makerbot FLASH Robotics

Types of Robots - Entertainment

- Designed to evoke emotional responses.
  - RoboThespian
  - Disney's' theme park robots
    - Navi Shaman
  - Musicians
    - Partner

RoboThespian

Navi Shaman

Toyota Partner

Types of Robots - Exoskeletons

- Physical-therapy robot
  - Industrial
  - Military
- Added mobility, endurance to the wearer

Ekso bionics

Guardian XO

HAL (Hybrid Assistive Limb)

https://en.wikipedia.org/wiki/HAL_(robot)

Types of Robots - Humanoids

- Human-like structure and behavior
  - Honda Asimov
- Human-like appearance
  - Geminoid series

Asimov

Geminoid F

Geminoid DK

https://en.wikipedia.org/wiki/Humanoid_robot

Types of Robots - Industrial

- Robotic manipulators
  - Unimate
  - Amazon's warehouse robots
  - Collaborative robots
    - Rethink robots
      - Baxter
      - Sawyer

Unimate

Warehouse robot

Baxter

https://en.wikipedia.org/wiki/Industrial_robot

Types of Robots - Medical

- Health-care robots
  - Surgical
    - Da Vinci
  - Bionic Prostheses
  - Exoskeletons
- Answering medical-related questions
  - Watson supercomputer

Da Vinci

Bionic Prostheses

IBM - Watson

https://en.wikipedia.org/wiki/Medical_robot

Types of Robots - Military & Security

- Ground systems
  - Endeavor Robotics' Packbot
- Troop assisting robot
  - BigDog
- Security systems
  - Cobalt

BigDog

Mostly

PackBot 510

https://en.wikipedia.org/wiki/Military_robot

Types of Robots - Research

- University-based robots
  - Laboratories
  - Corporate research labs

FLASH /Wroclaw University of Technology

Agility Robotics /Oregon State University

Dash /University of California Berkeley

Types of Robots - Self-Driving Cars

- Autonomous vehicles that drive people
  - DARPAS' autonomous-vehicle competition
  - Google's Toyota Prius
  - Waymo

Carnegie Mellon University

Google's Autonomous Prius

Waymo

https://en.wikipedia.org/wiki/Self-driving_car

Types of Robots - Telepresence

- Robotic avatars connected to the internet
- Tele-Medicine
- Tele-Education

https://en.wikipedia.org/wiki/Telepresence

Types of Robots - Underwater

- Deep-sea exploration
  - Aquanaut
  - Ocean One
  - ACM-R5H snakebots

Aquanaut

Ocean One

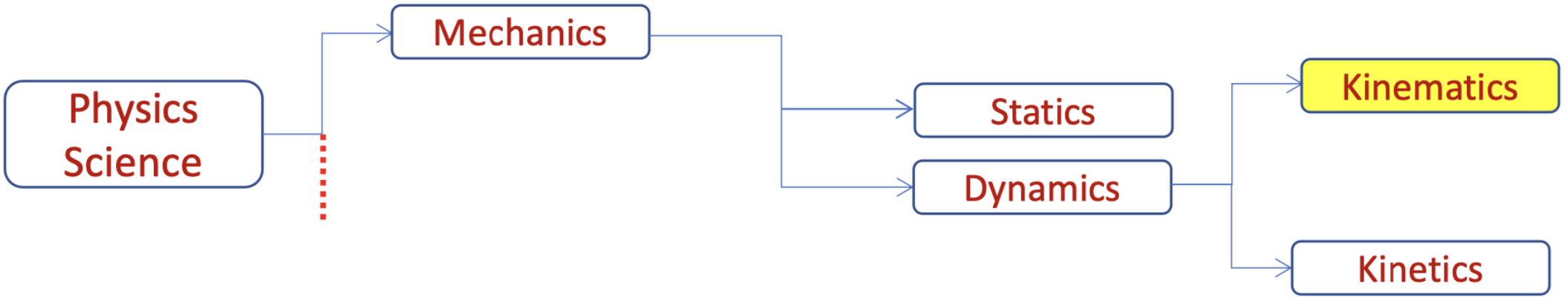
ACM-R5H

https://en.wikipedia.org/wiki/Autonomous_underwater_vehicle

Terminologies

Kinematics vs. Kinetics

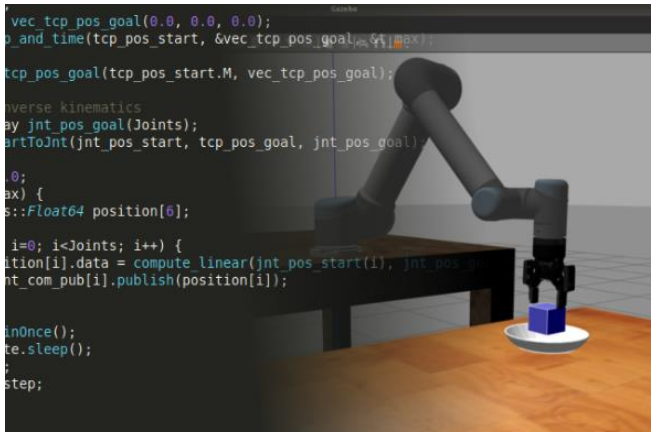
- **Kinematics**: Study of the motion of the body including position, velocity, and acceleration without considering the force causing the motion.
- **Kinetics**: Study of forces in the system. Usually known as **Dynamics**!



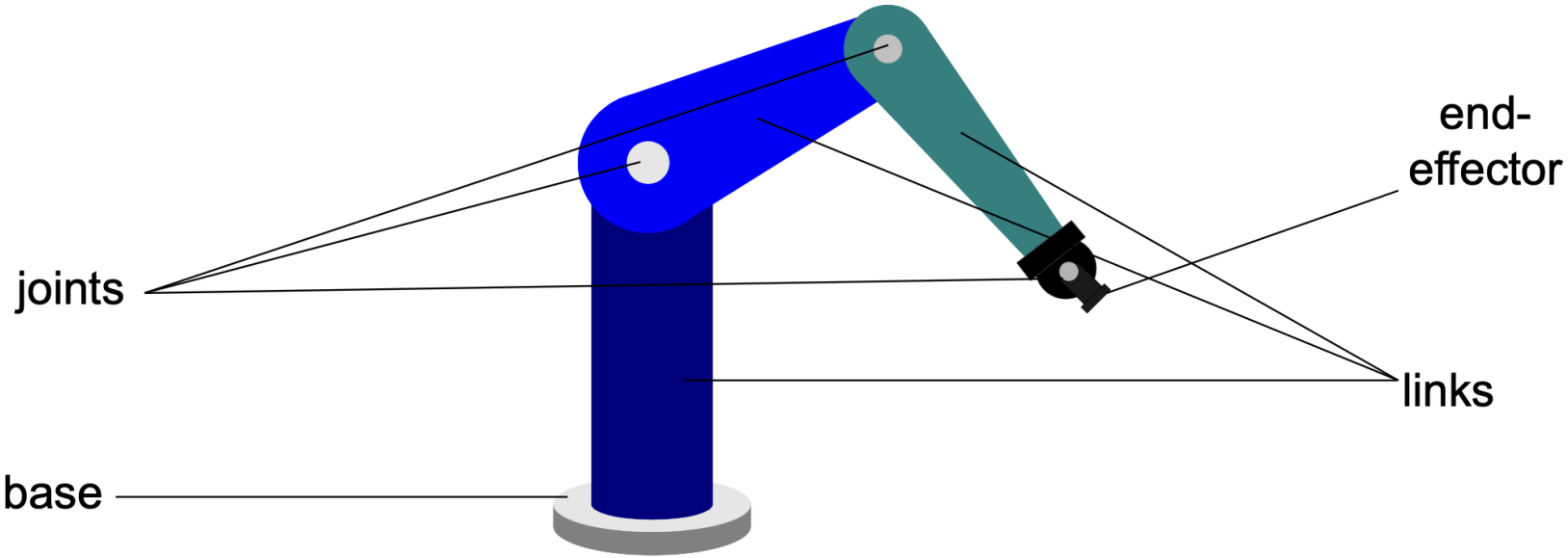
https://en.wikipedia.org/wiki/Robot_kinematics

Robotic Manipulators

- Manipulator
  - Series of links connected via joints
  - Actuators (e.g., motors) cause relative motion
  - Base
  - End-effector



[Robotic Operating System (ROS)]



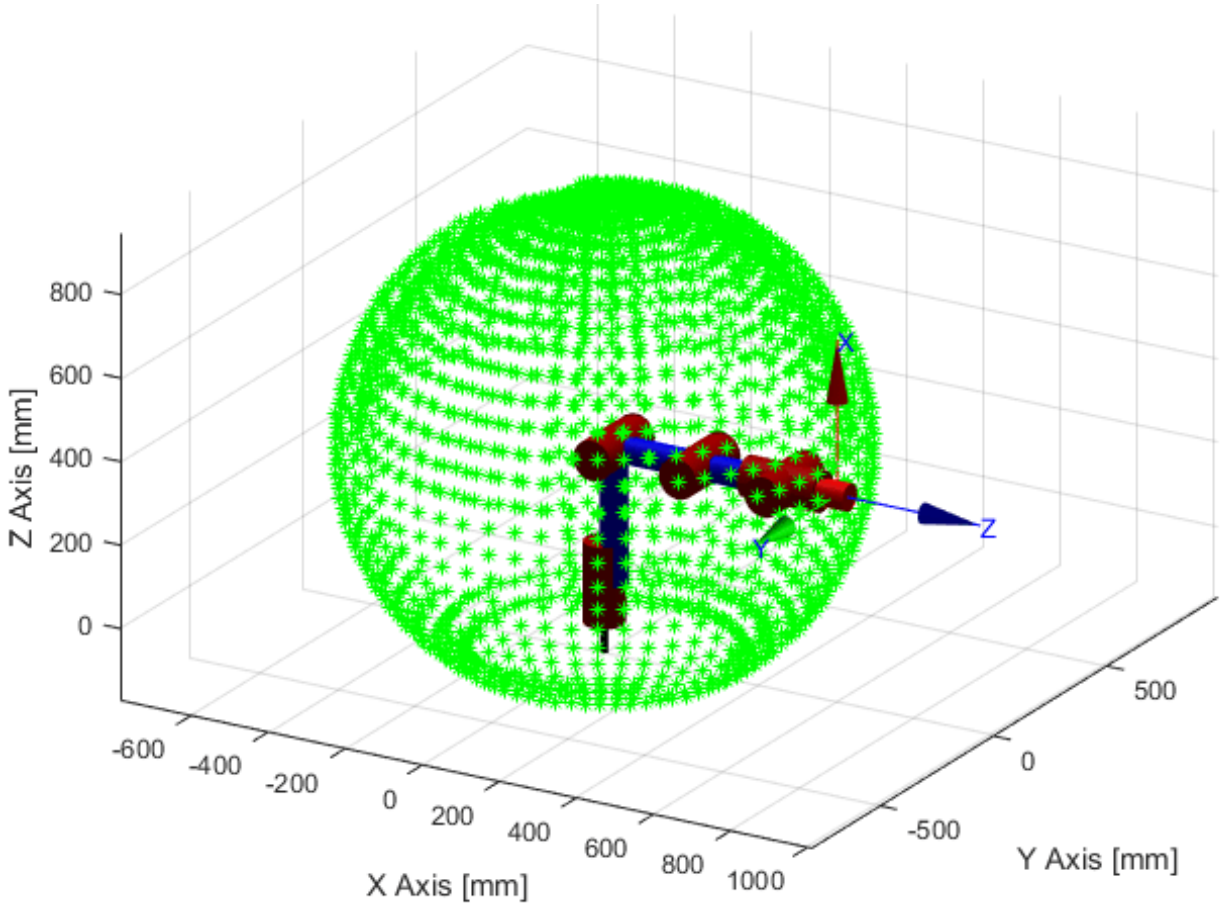
Robotic Manipulators

- **Fixed Robots:** (fixed in place) manipulation (mostly industrial robots)
  - Serial arm robots (manipulators)
- **Basic terms:**
  - Manipulation: making changes to the environment no matter what!
  - Manipulator: A robot that does manipulate (does manipulation tasks)!
  - Workspace: the space or the total volume reachable by the end-effector of the manipulator.
  - End-effector: the tip of the manipulator used to manipulate the environment
  - Degrees-of-freedom: an independent joint that can provide freedom of movement of the manipulator
  - Joint-type: the way a joint link moves the neighbor joints.

https://en.wikipedia.org/wiki/Serial_manipulator

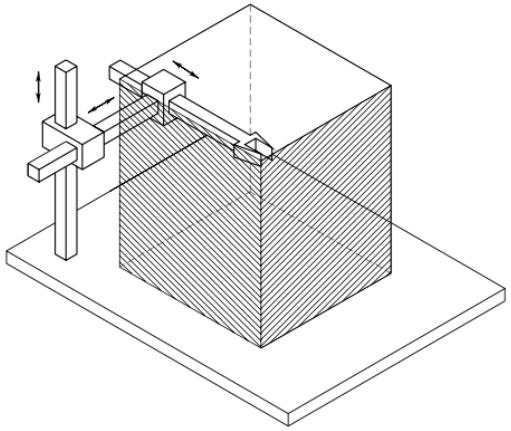
Robotic Manipulators - Workspace

- Representation of the portion of the environment the manipulator's end-effector can access.
- Shape and volume depend on
  - the manipulator structure
  - the mechanical joint limits

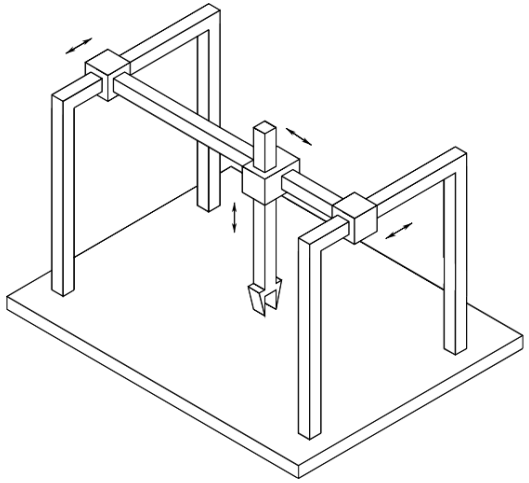


https://en.wikipedia.org/wiki/Workspace

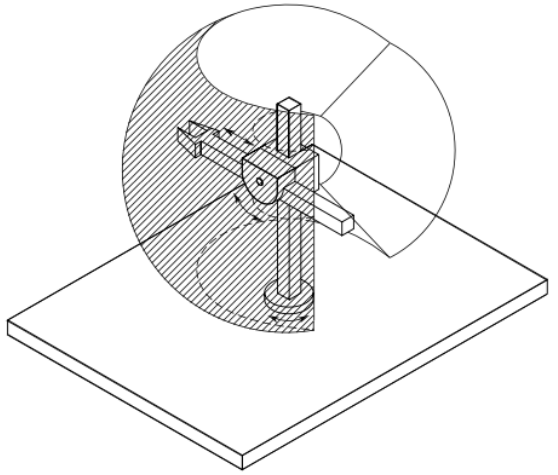
Robotic Manipulators - Workspace - Examples



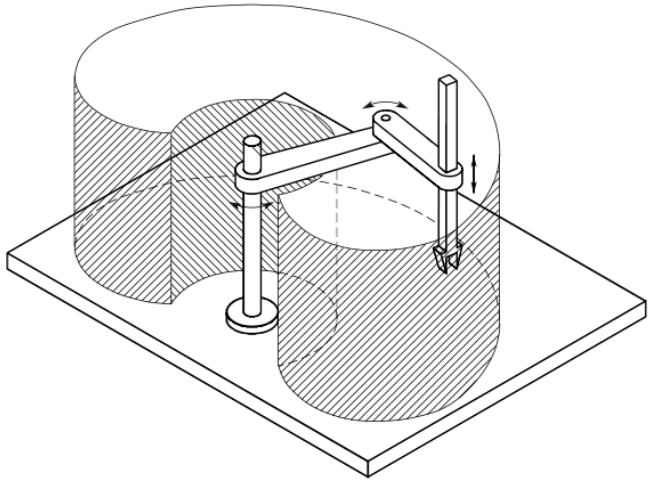
Cartesian manipulator and its workspace



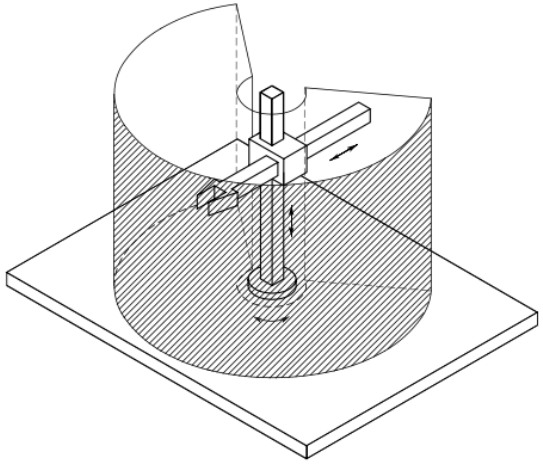
Gantry manipulator



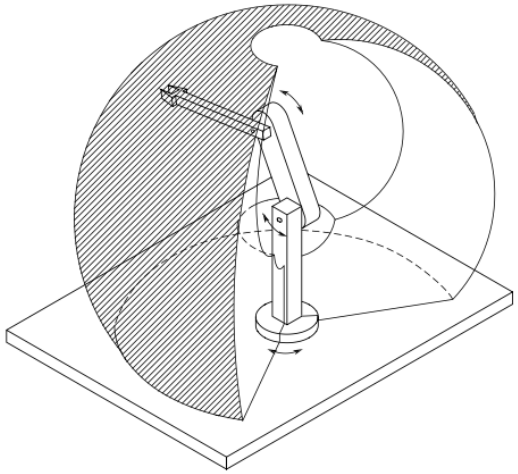
Spherical manipulator and its workspace



SCARA manipulator and its workspace



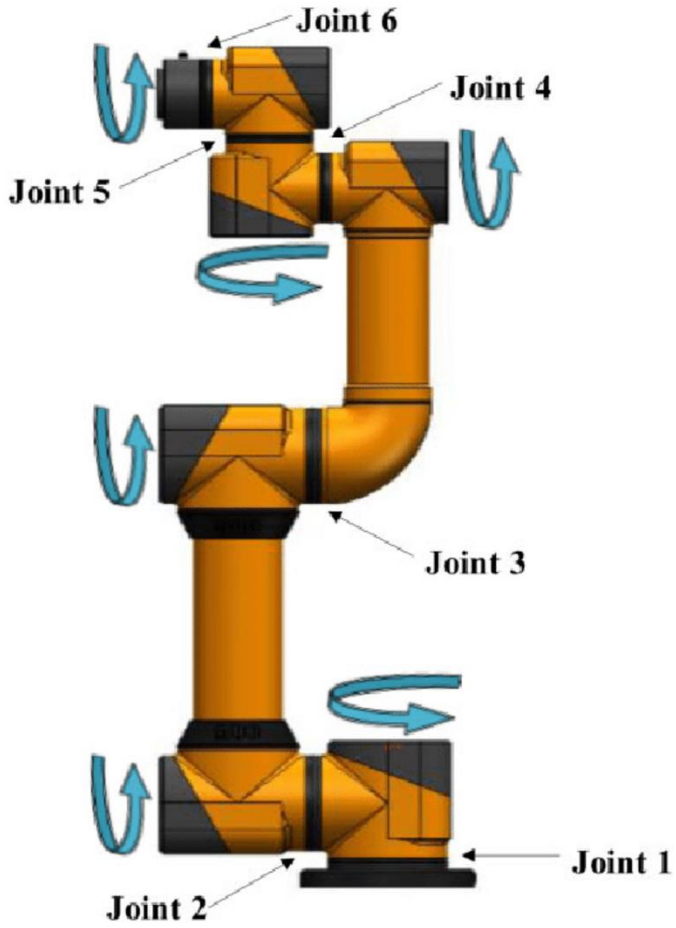
Cylindrical manipulator and its workspace



Anthropomorphic manipulator and its workspace

Robotic Manipulators - Degrees of Freedom (DoF)

- Independent joint that provide freedom of movement
  - Rotational
  - Translational
- 6 DoFs required for manipulation of objects in 3D space
- > 6 DoFs: Redundant manipulator

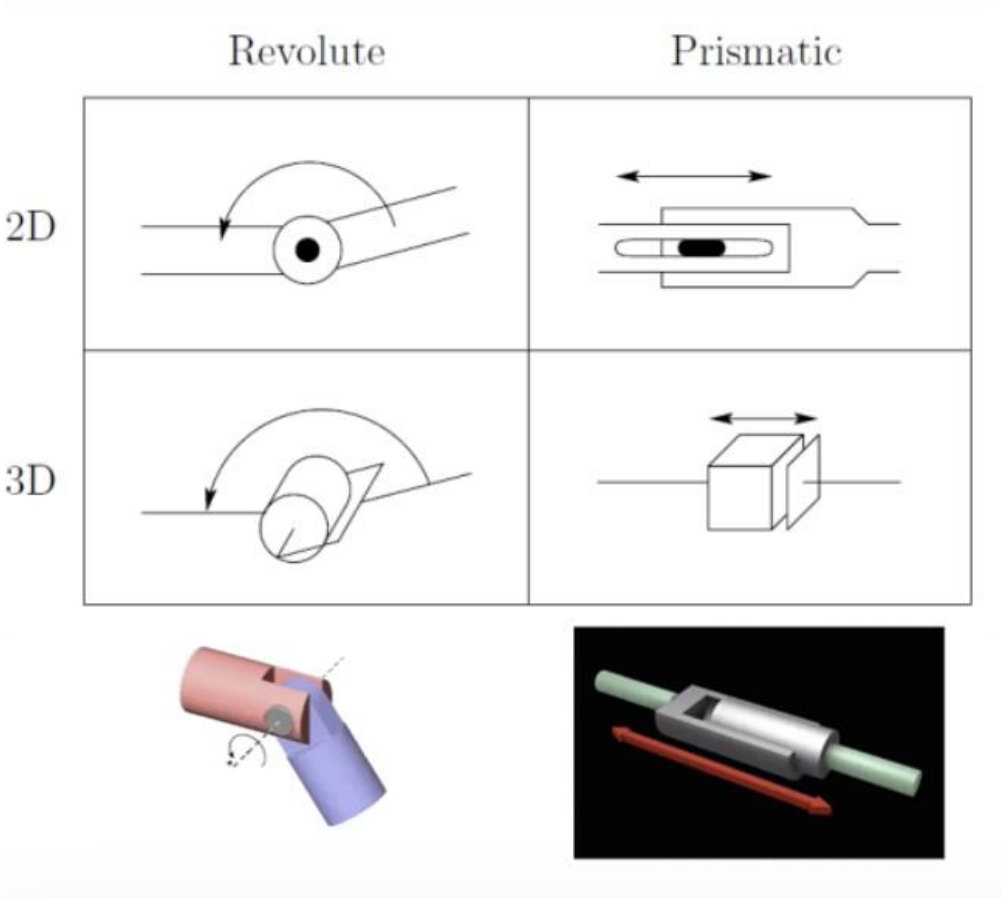


6-DOF serial robot OUR-1.

https://en.wikipedia.org/wiki/Degrees_of_freedom_(mechanics)

Robotic Manipulators – Joint types

- **Revolute joint** (R): is like a hinge and allows relative rotation between two links.
  - The joint variable is θ.
- **Prismatic joint** (P): allows a linear relative motion between two links.
  - The joint variable is d.



https://en.wikipedia.org/wiki/Revolute_joint

https://en.wikipedia.org/wiki/Prismatic_joint

Robotic Manipulators - Joint types - Examples

RRR
Articulated

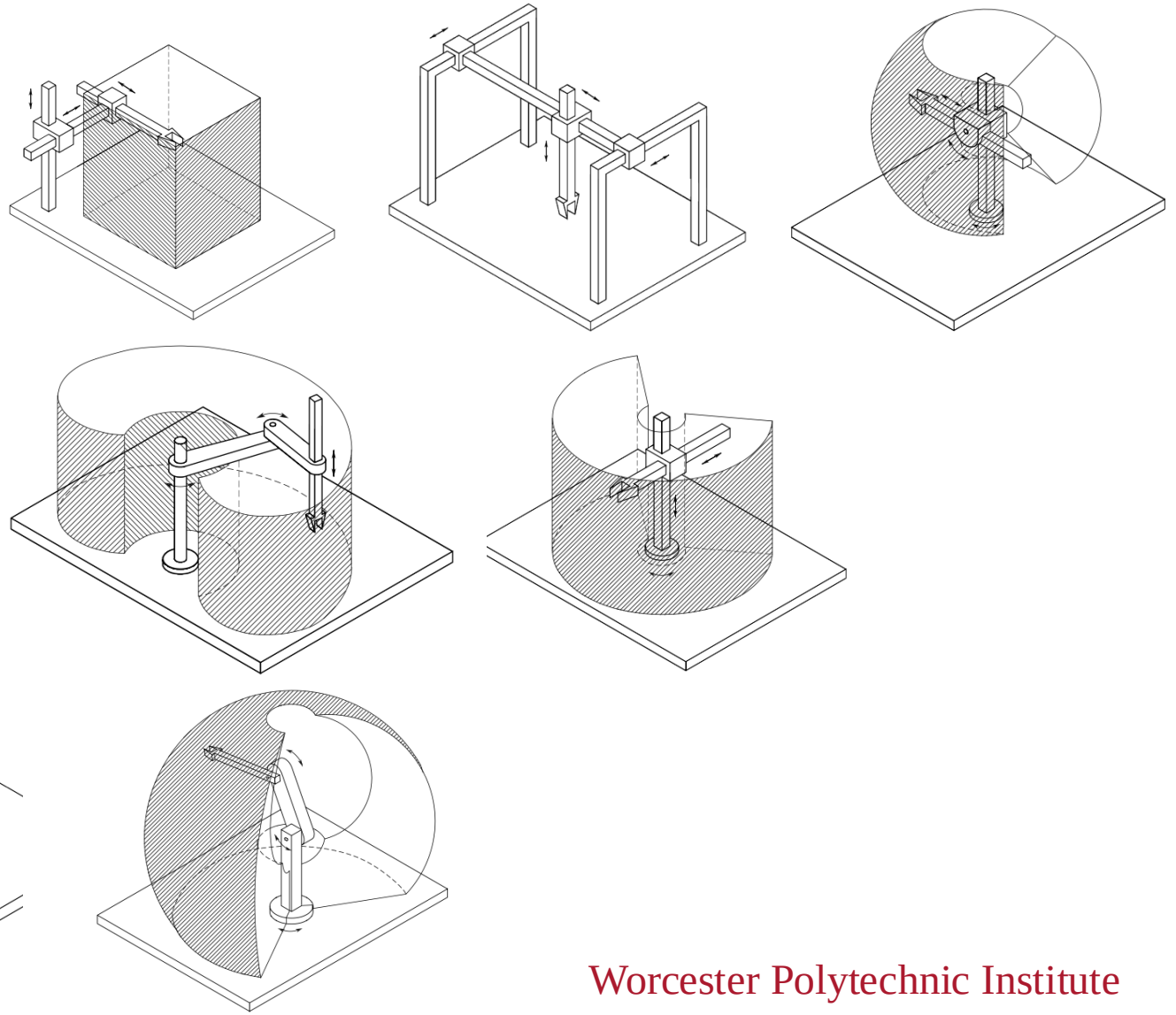
PPP
Cartesian

RPP
Cylindrical

RRP
Spherical

Robotic Manipulators - Types

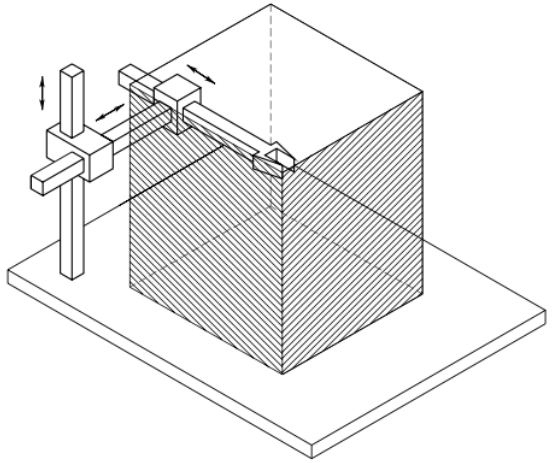
1. Cartesian / Gantry robot
2. Collaborative robot / Cobot
3. Cylindrical
4. Spherical / Polar
5. SCARA
6. Articulated
7. Parallel
8. Anthropomorphic

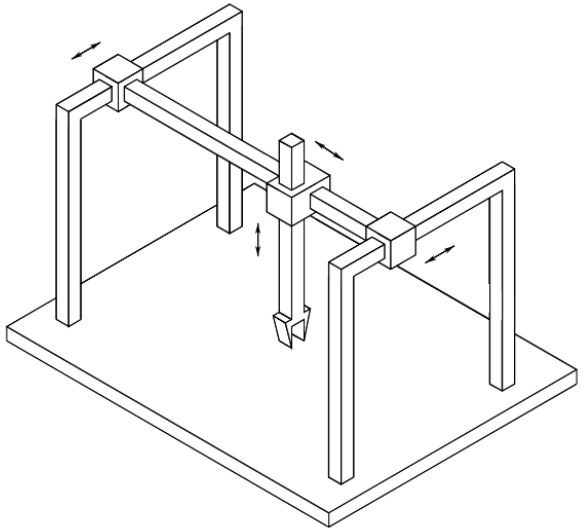


https://en.wikipedia.org/wiki/Robotic_arm

Robotic Manipulators - Types - Cartesian/Gantry

- Designed with three perpendicular axes (x, y, z)
- Accurate positioning along straight lines
- Constructed with rigid beams and linear actuators
- High repetitive tasks with speed
- Applications:
  - Manufacturing
  - Packaging
  - Assembly lines

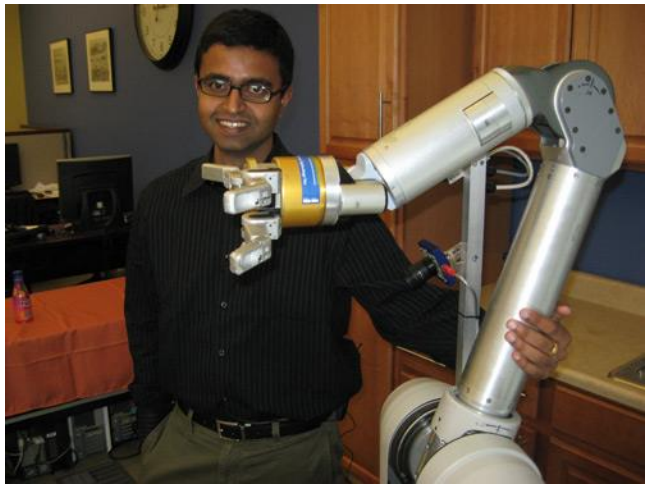


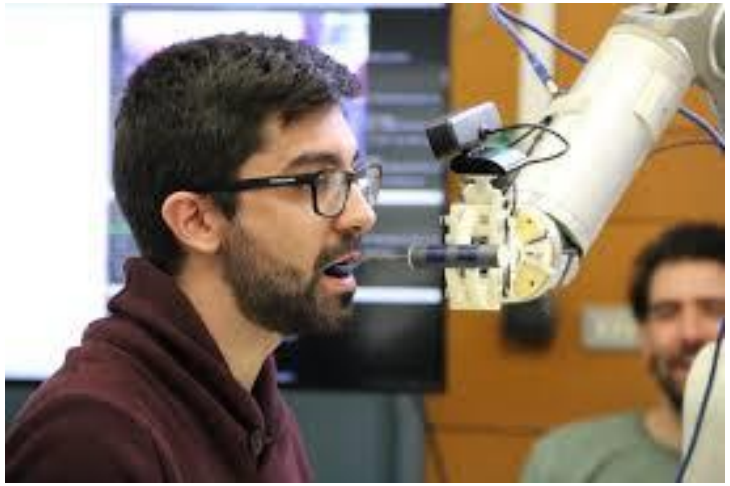


https://en.wikipedia.org/wiki/Cartesian_coordinate_robot

Robotic Manipulators - Types - Collaborative

- Designed to work alongside humans
- Equipped with advanced sensors and safety features
- Flexible, adaptable to perform various tasks
- Safe Human-Robot Interaction (HRI)

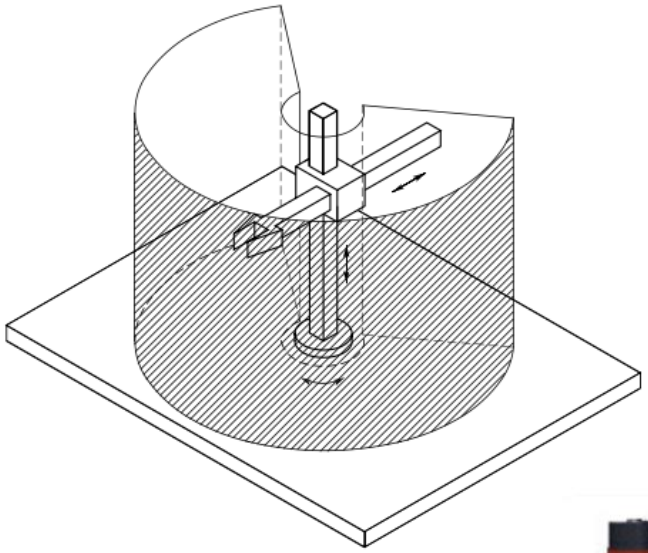




https://en.wikipedia.org/wiki/Cobot

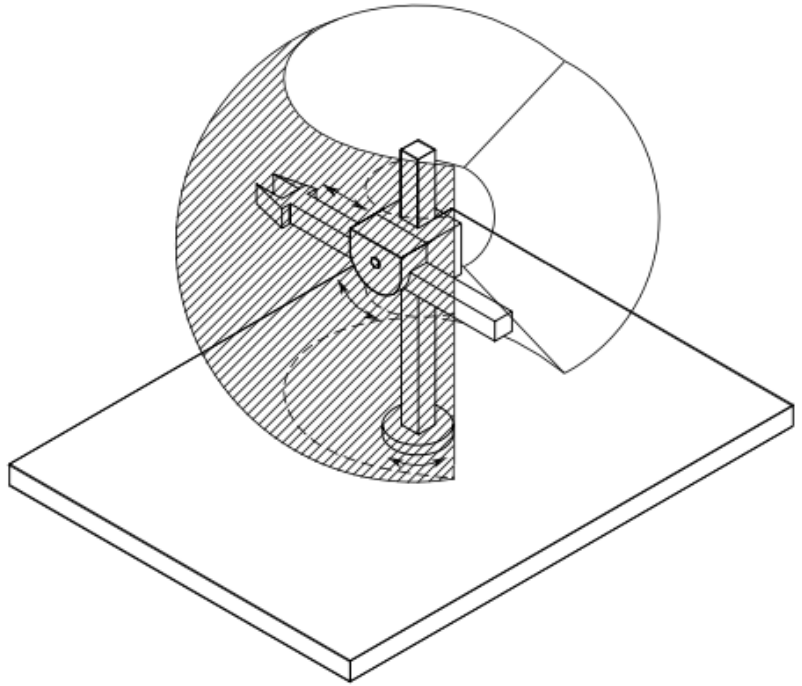
Robotic Manipulators - Types - Cylindrical

- Designed with a cylindrical coordinate system
- Precise lateral movements and vertical reach
- Navigate around object
- Access areas with restricted space
- Applications:
  - Assembly lines
  - Materials handling
  - Machining operations



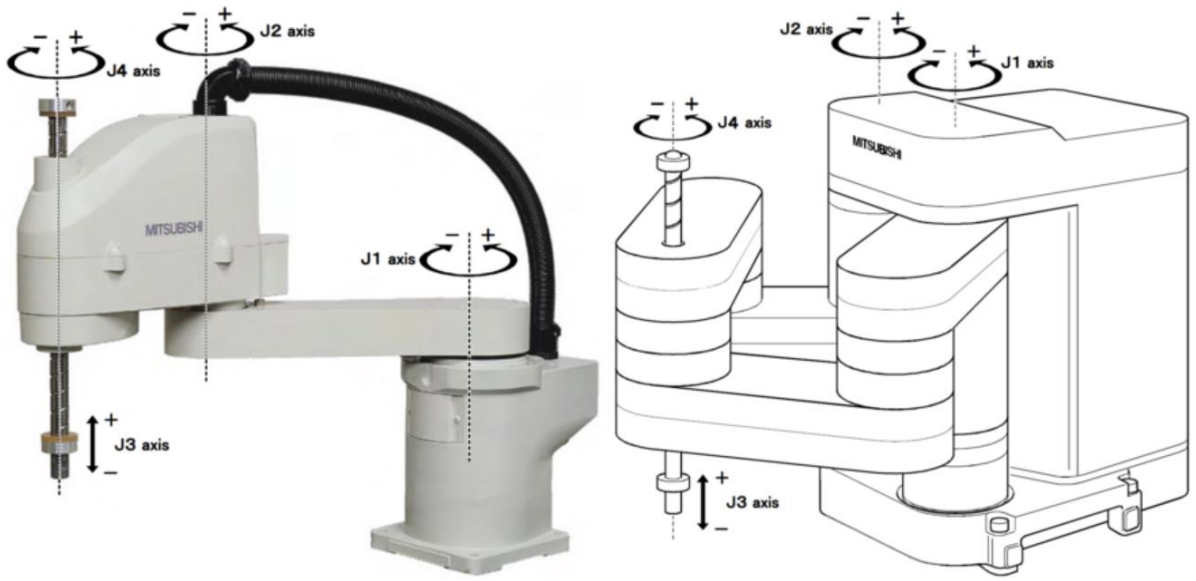
Robotic Manipulators - Types - Spherical / Polar

- Designed with spherical joints
- Employ spherical coordinate system
- Flexibility in reaching diverse positions and orientations
- Applications:
  - Assembly lines
  - Inspection
  - Medical procedures



Robotic Manipulators - Types - SCARA

- Selective Compliance Assembly Robotic Arm (SCARA)
- Feature three parallel rotary joints
  - movements X-Y plane
  - arm remains rigid in Z-axis direction
- Assembly lines, pick and place
- Handling tasks with high speed and accuracy



https://en.wikipedia.org/wiki/SCARA

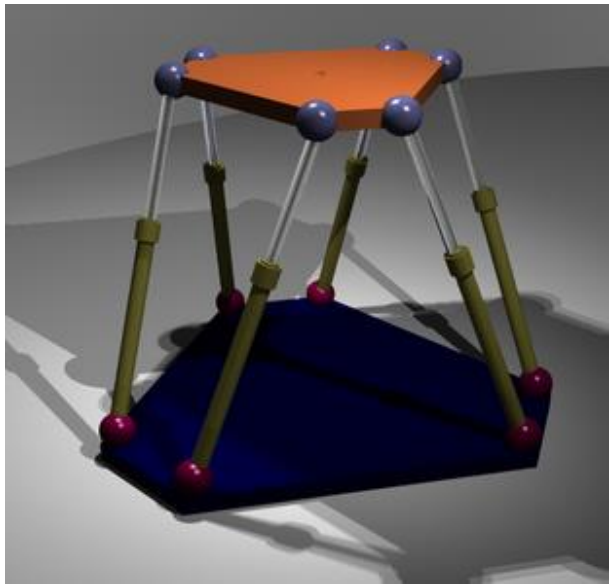
Robotic Manipulators - Types - Articulated

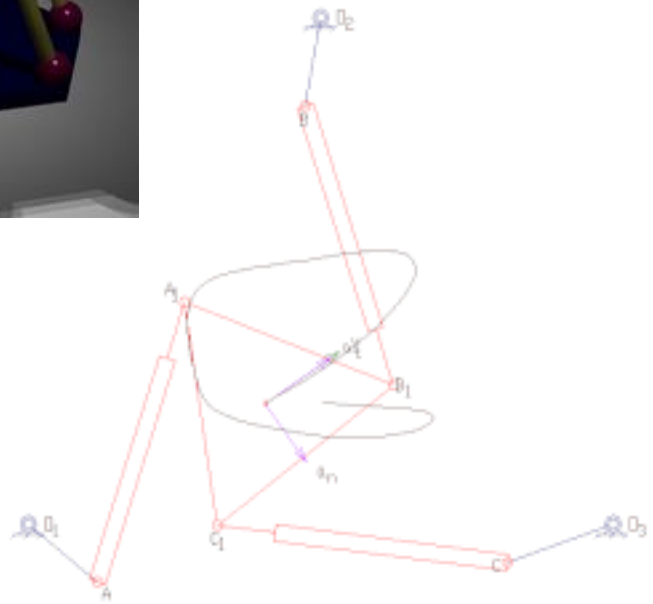
- Mimic the human arm
- Wide range of motion
- Equipped with sensors, motors and advanced control systems
- Applications:
  - Manufacturing,
  - Assembly lines
  - Surgery

https://en.wikipedia.org/wiki/Articulated_robot

Robotic Manipulators - Types - Parallel

- Interconnected, parallel-arranged links and joints
- Multiple limbs that converge on a common end -effector
  - Enhanced stability and precision
  - Efficient force distribution
  - Reduced inertia
  - Increased payload capacity
- Applications:
  - Manufacturing
  - Aerospace
  - Medical fields

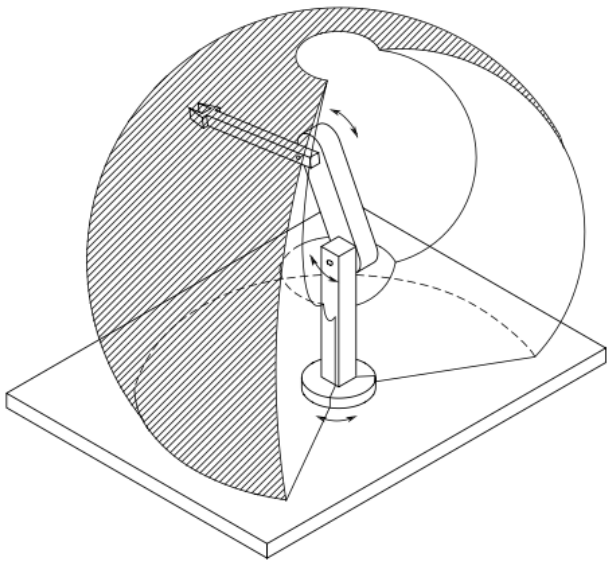


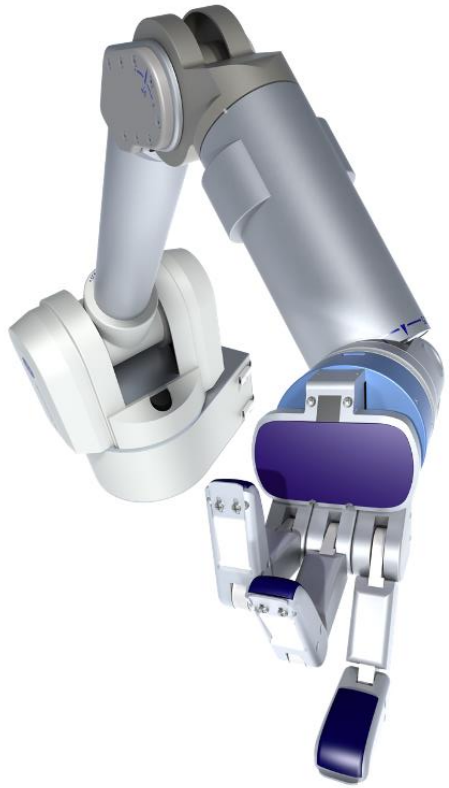


https://en.wikipedia.org/wiki/Parallel_manipulator

Robotic Manipulators - Types - Anthropomorphic

- Mimic the structure and functionality of the human arm
- Human-like movements and dexterous manipulation
- Perform tasks that may be hazardous to humans
- Applications:
  - Manufacturing
  - Healthcare
  - Space exploration





… end of Lecture 1