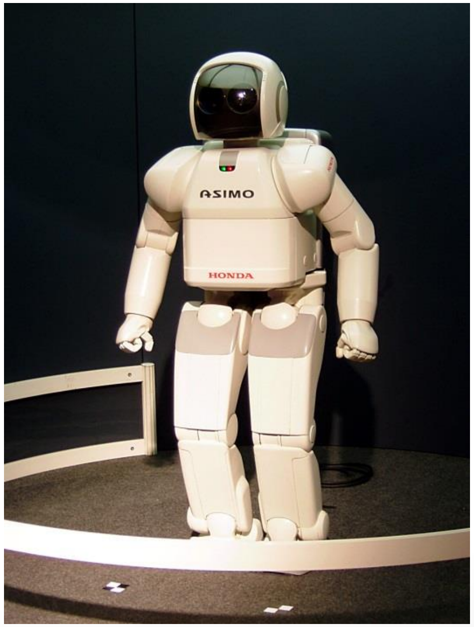
Week 1– Introduction

Advanced Robotic Systems – MANU2453

Dr Ehsan Asadi, School of Engineering
RMIT University, Victoria, Australia
Email: ehsan.asadi@rmit.edu.au

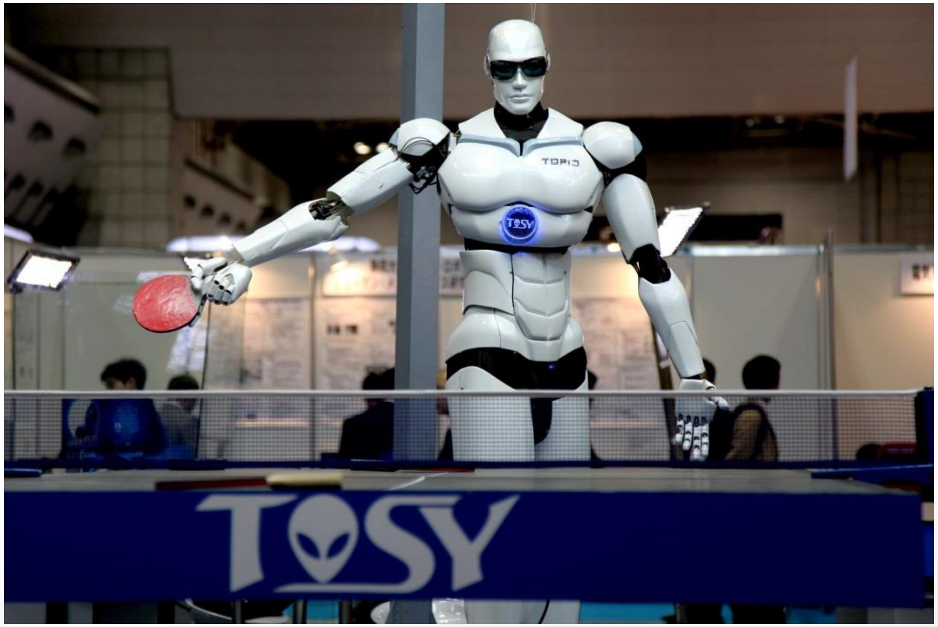
What is a Robot? - Appearance

- Humanoid Robots:



Honda ASIMO
https://commons.wikimedia.org/wiki/File:HONDA_ASIMO.jpg

https://www.youtube.com/watch?v=HM5aGm2slXY

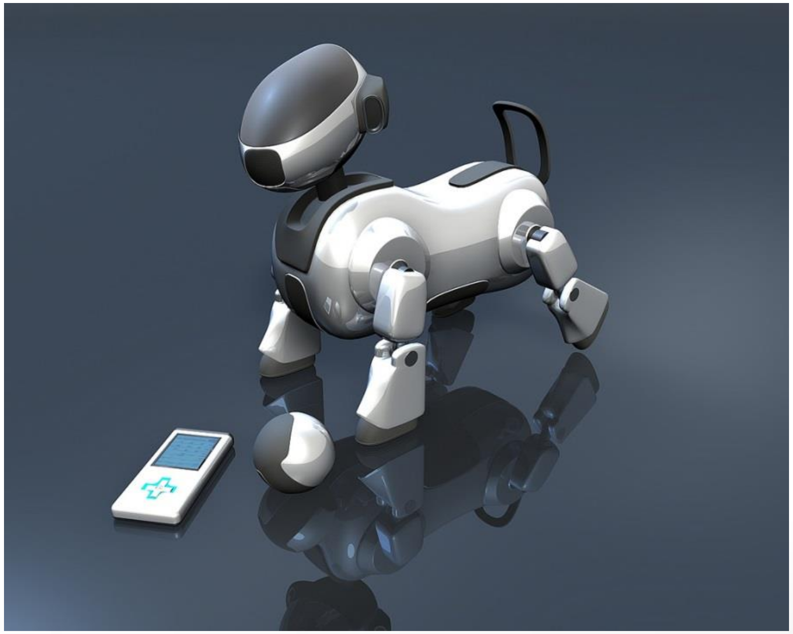


TOSY Ping Pong Playing Robot
https://commons.wikimedia.org/wiki/File:TOPIO_3.jpg

https://www.youtube.com/watch?v=HM5aGm2slXY

What is a Robot? - Appearance

- Animal-like Robots:



Robot Dog
https://www.flickr.com/photos/54011404@N05/4999858187

https://www.youtube.com/watch?v=fV7fTkGUIWI

Jessiko Swimming Robot
https://commons.wikimedia.org/wiki/File:Jessiko_Robot_Fish_Yeosu2012.jpg

The Guardian

https://www.youtube.com/watch?v=wXxrmussq4E

What is a Robot? - Appearance

- Industrial Robotic Manipulators:

Industrial Robots
https://commons.wikimedia.org/wiki/File:Float_Glass_Unloading.jpg

https://www.youtube.com/watch?v=7U1-X5ogsKA

Industrial Robots on Mobile Platform
http://www.kuka-robotics.com/NR/rdonlyres/15C0E6DD-A56A-413C-B16B-812175F7131A/0/Slider_youBot.jpg

My Research : Robotics Manipulation of Objects in Dynamic Environment

What is a Robot? - Applications

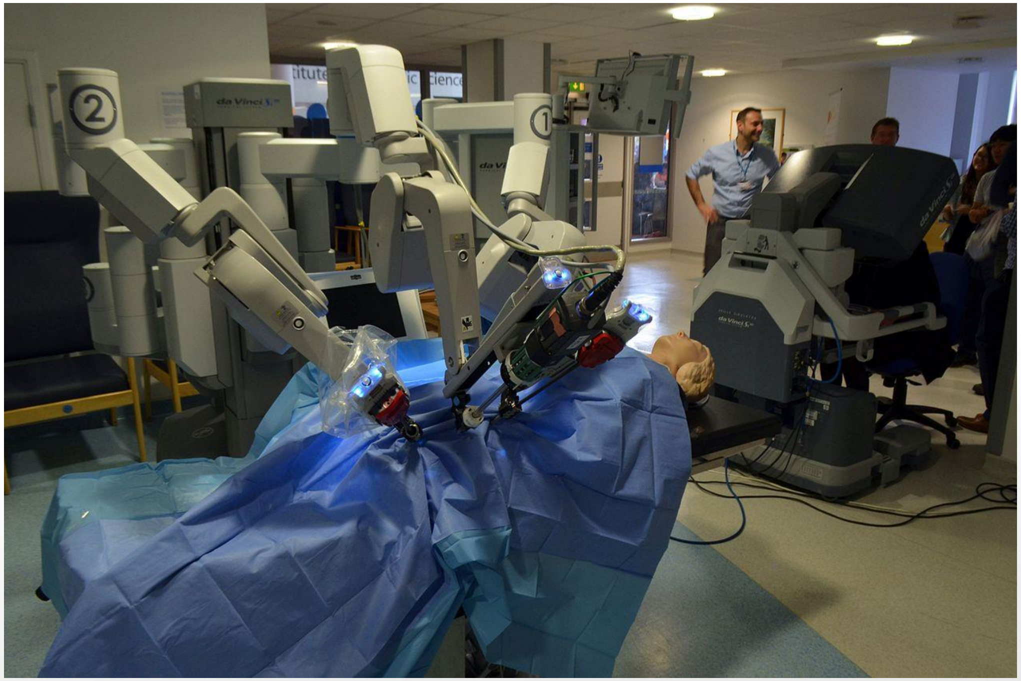
- Service robots:
  - Perform services useful to the well-being of humans, excluding manufacturing operations.

Robotic Vacuum Cleaner
https://commons.wikimedia.org/wiki/File:Roomba3g.jpg

Robotic Waiters
http://i.dailymail.co.uk/i/pix/2014/11/26/23846A8F00000578-0-image-33_1417002924952.jpg

What is a Robot? - Applications

- Surgical robots:
  - Allows doctors to perform complex procedures with more precision
  - Usually used in minimally invasive surgery.



Da Vinci Robot

https://commons.wikimedia.org/wiki/File:Cmglee_Cambridge_Science_Festival_2015_da_Vinci.jpg

https://www.youtube.com/watch?v=VJ_3GJNz4fg

What is a Robot? - Applications

- Mobile robots / Automated guided vehicles:
  - For moving of materials around manufacturing facility or warehouse.

Automated Forklift

https://en.wikipedia.org/wiki/Automated_guided_vehicle#/media/File:Forklift_AGV_with_Straddle,_courtesy_of_Egemin_Automation_Inc..jpg

What is a Robot? - Applications

- Industrial Robotic Manipulator:
  - An “automatically controlled, programmable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.” (ISO 8373)

Industrial Robot
https://commons.wikimedia.org/wiki/File:Automation_of_foundry_with_robot.jpg

What is a Robot? - Applications

- There are a lot more applications of robots including:
  - Education
  - Military https://www.youtube.com/watch?v=uy6zdEbxjuU https://www.youtube.com/watch?v=cNZPRsrwumQ
  - Mining
  - Home automation for elderly and healthcare
- There are also active research in the area of:
  - Biomimetic robots https://www.youtube.com/watch?v=mWiNlWk1Muw
  - Aerial Robotics
  - Underwater and marine robotics
  - Reconfigurable robots
  - Soft robots
- In this course, we will focus on Industrial Robotic Manipulators.
  - The fundamentals can also be applied to many other types of robots, which can be further explored in research projects.

Exoskeleton
https://www.technologyreview.com/s/546276/this-40000-robotic-exoskeleton-lets-the-paralyzed-walk/

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Industrial Robotic Manipulators

- Industrial robotic manipulators are widely used in:
  - Pick-and-Place / Palletizing and packaging.
    - E.g. Rapidly taking drink cartons from conveyor belt and placing them into box.
  - Machine tending.
    - E.g. Loading and unloading machining centers.
  - Welding.
  - Spray painting

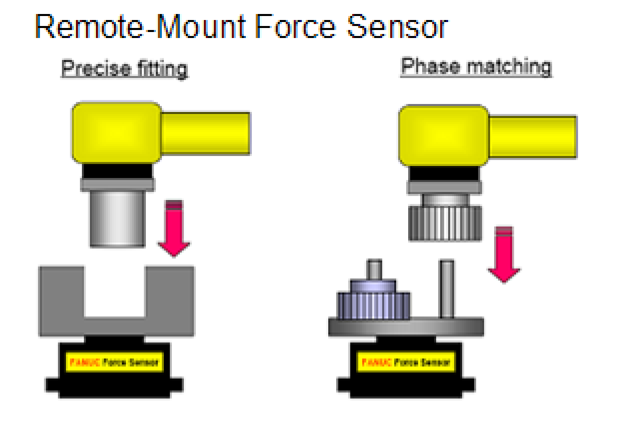
Dirty, Dangerous and Dull (3D) Tasks

Welding Robots

https://en.wikipedia.org/wiki/File:Robotworx-arc-welding-robots.jpg

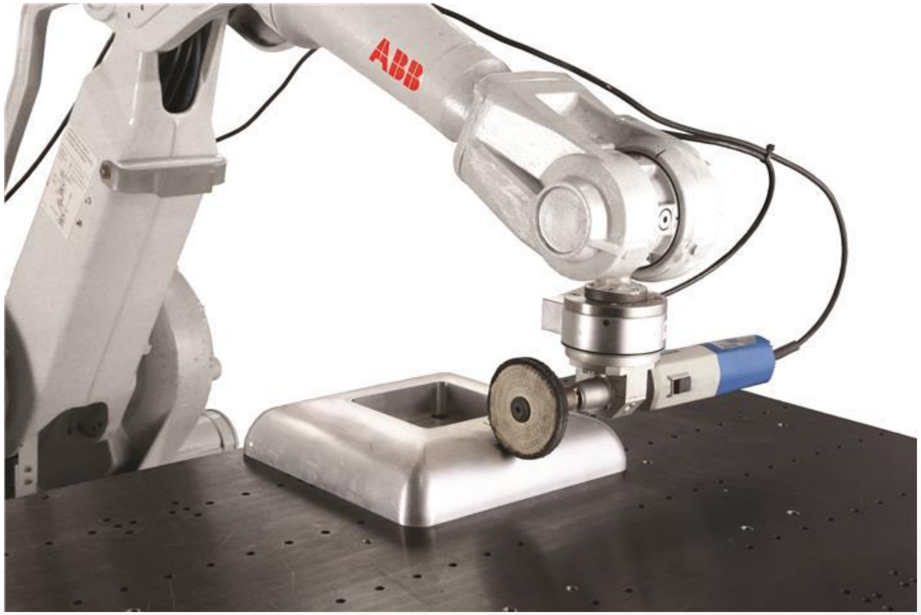
Industrial Robotic Manipulators

- They are also increasingly being used for contact type operations which need force control:
  - Assembly (Peg in hole)
  - Polishing
  - Deburring



Assembly

http://blog.robotiq.com/some-robot-manufacturers-offer-force-control-packages

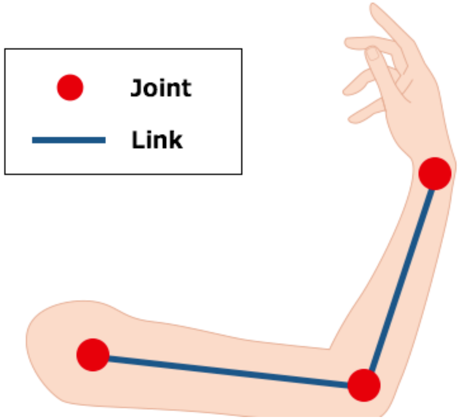


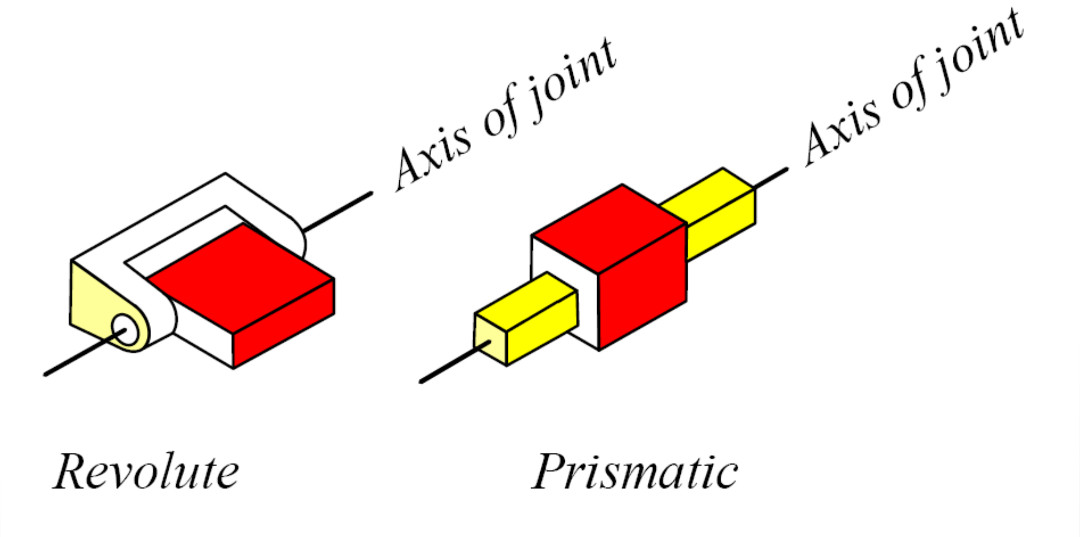
Robot Polishing

http://new.abb.com/products/robotics/application-equipment-and-accessories/integrated-force-control

Terminologies

- Industrial robots are mostly made by arms / links connected by joints.
  - The joints could be revolute (R) or prismatic (P).

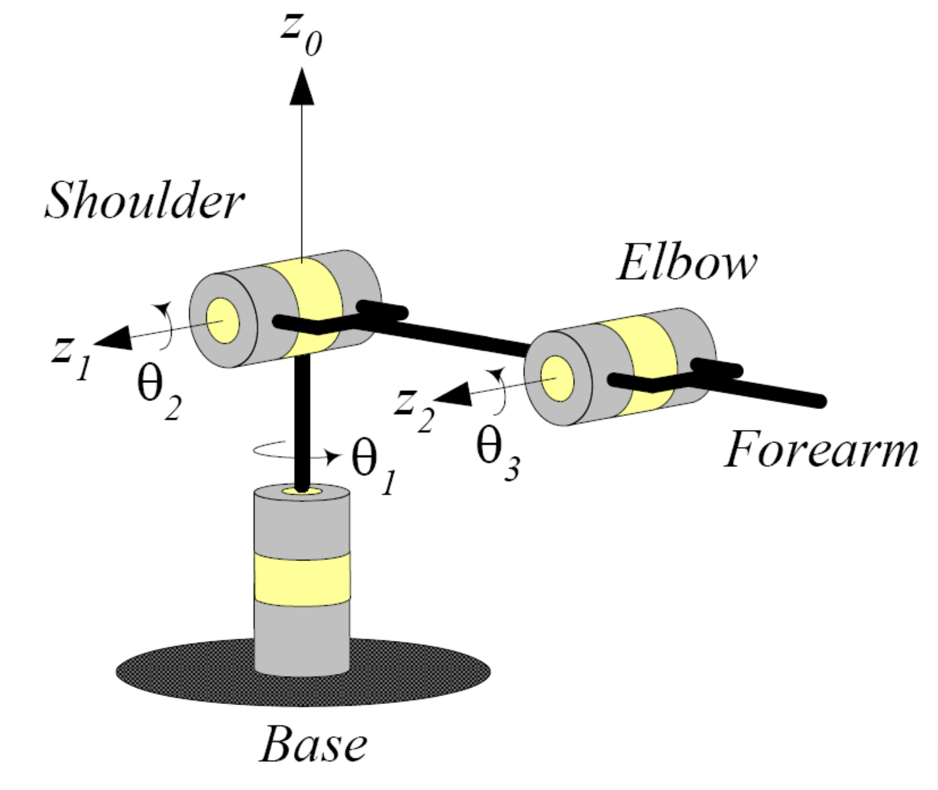




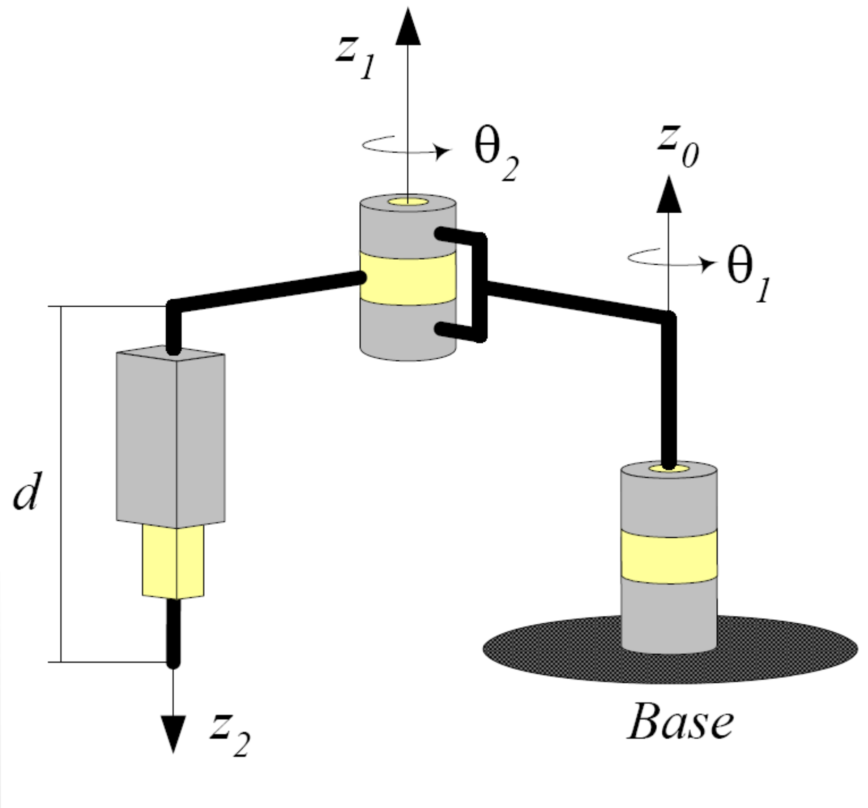
  - Each joint allows only one degree-of-freedom (DOF).
  - Note: spherical joints with 3 DOF can be viewed as 3 revolute joints connected through links with zero length.

Terminologies

- Examples of 3-DOF Manipulators (3 joints):



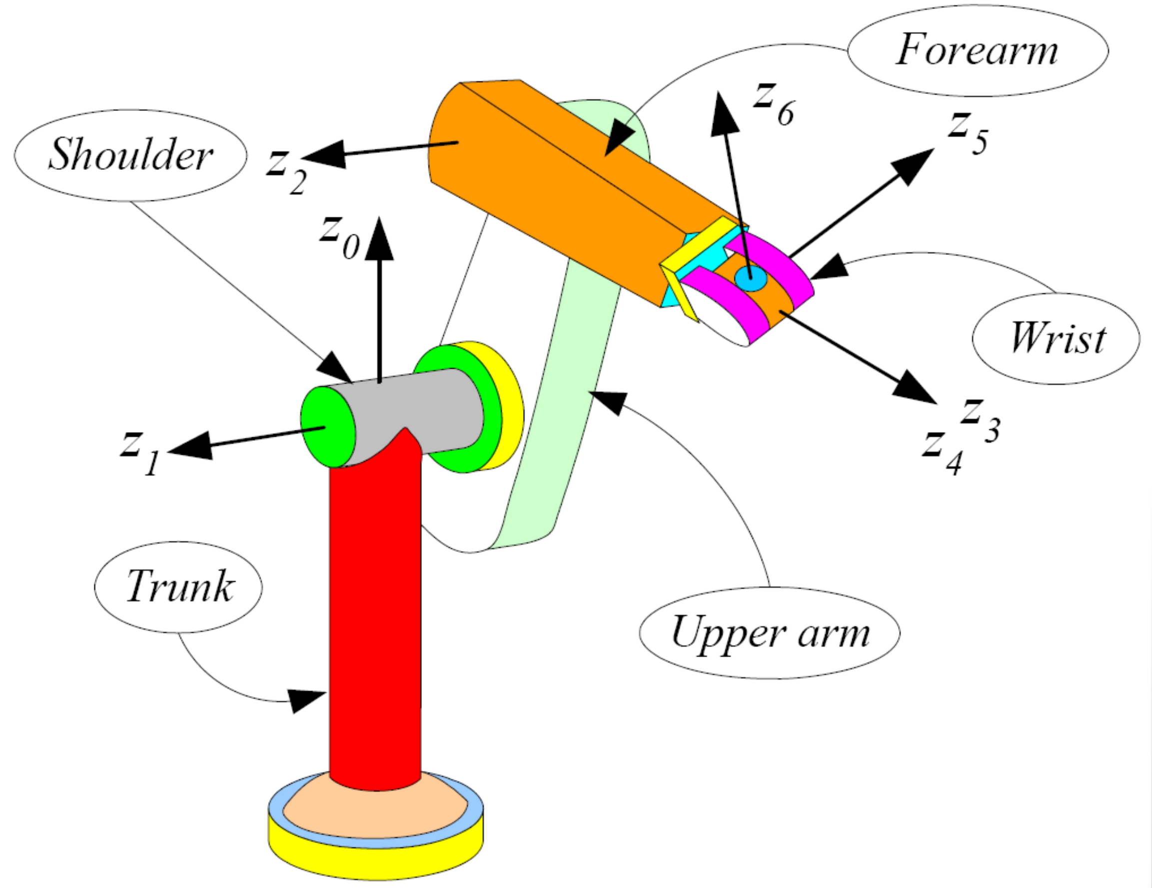
3R-Manipulator



RRP-Manipulator

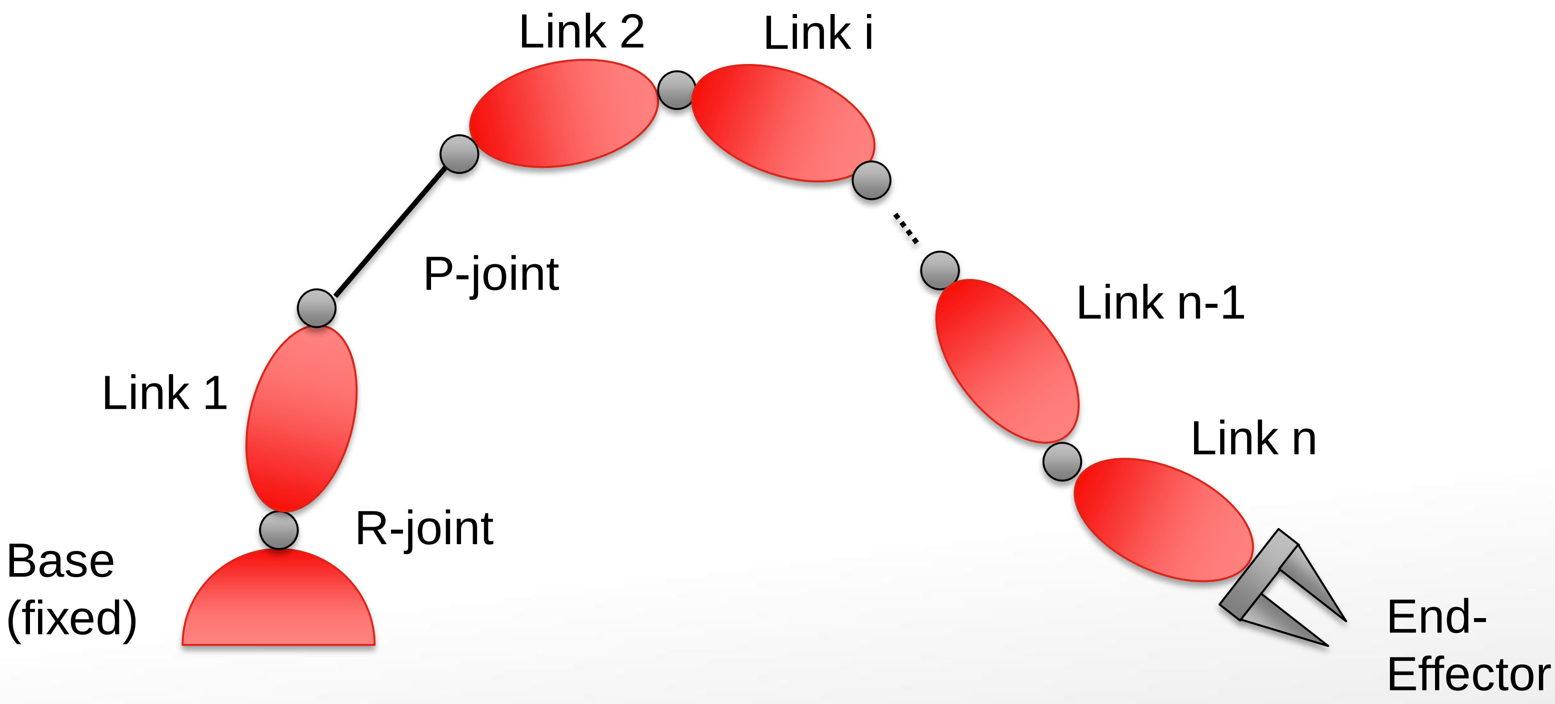
Terminologies

- Examples of 6-DOF Manipulators (6 joints):



Terminologies

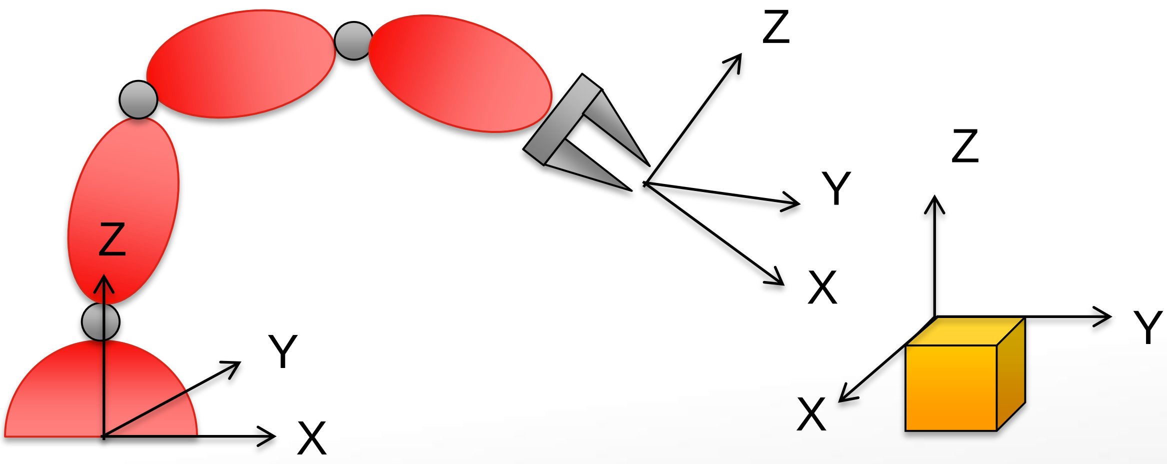
- Manipulator with End-Effector



- Examples of end-effectors:
  - Gripper
  - Welding torch

About this Course

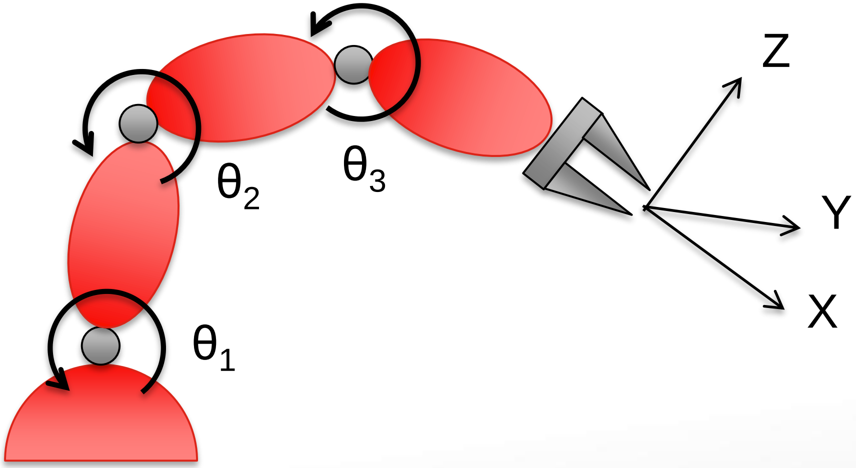
- A preview of topics which will be covered in this course:
- Description of position and orientation:



- In robotics, location of objects in 3-D space is of utmost importance.
- Objects include parts, tools, end-effector, and the manipulator itself.
- We will learn how to describe the position and orientation of the objects.

About this Course

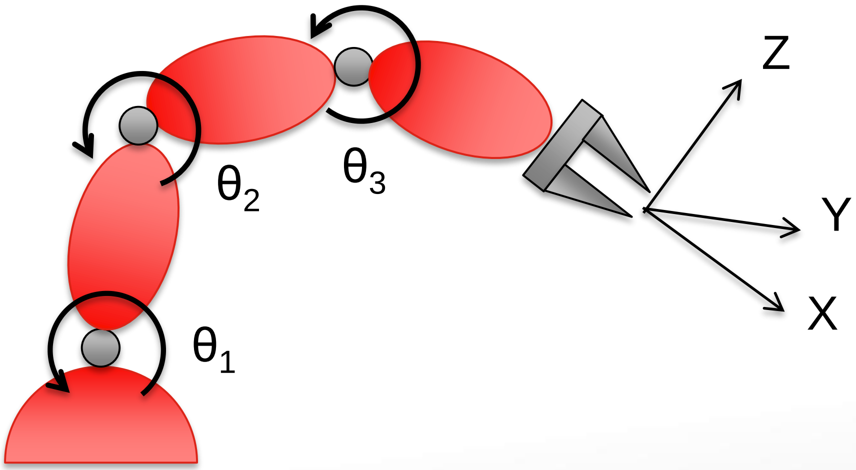
- (Forward) Kinematics:
  - The study of motion without regard to forces which causes it.



  - Given the joint space parameters (angles for revolute joints, or offsets for prismatic joints), as well as the lengths of the links, what is the position and orientation of the end-effector in Cartesian space?

About this Course

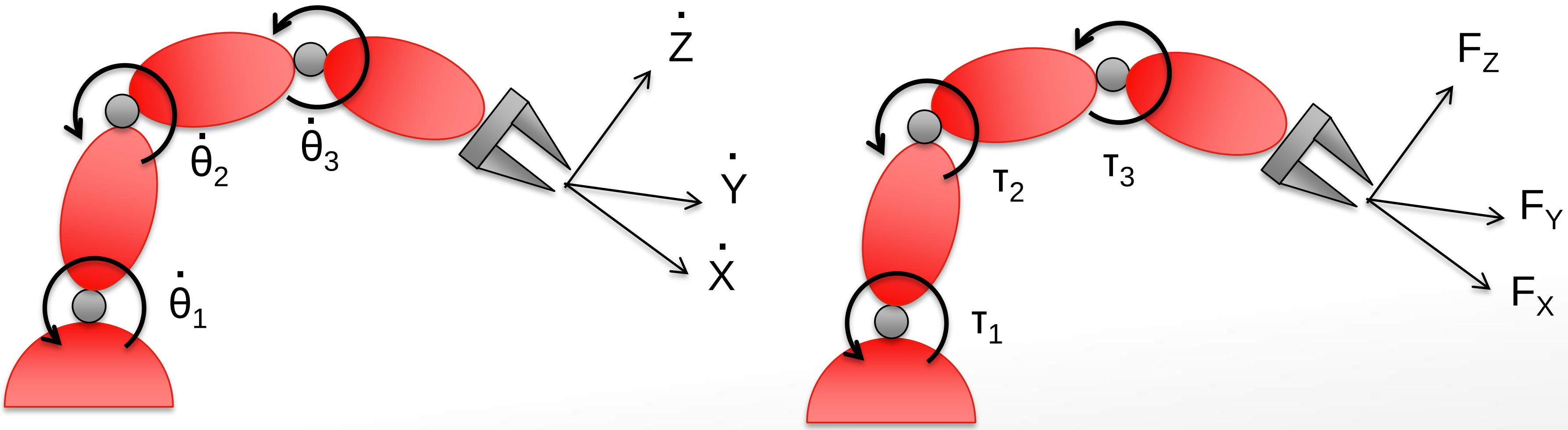
- Inverse Kinematics:
  - The opposite of forward kinematics:



  - Given the position and orientation of the end-effector in Cartesian space, what are the parameters in joint space (joint angles or offsets)?
  - Much harder than forward kinematics.
  - Analysed on a case-by-case basis.

About this Course

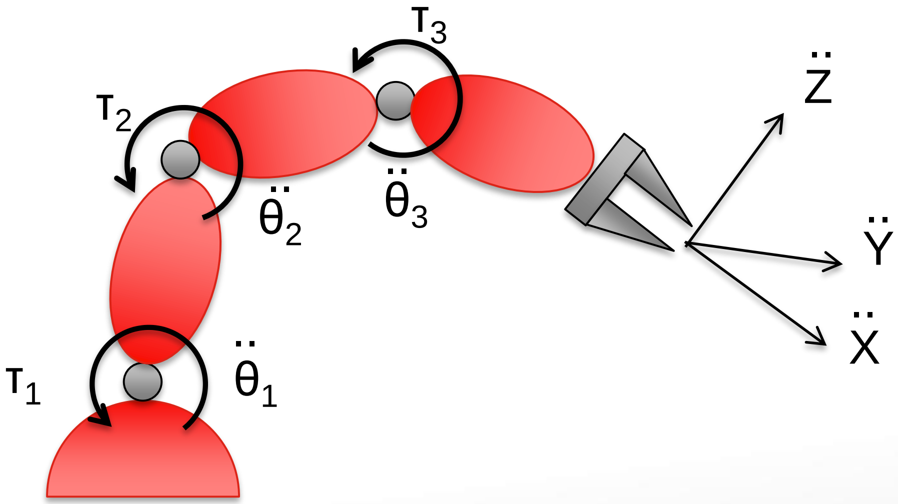
- Jacobians: Velocities and Static Forces
  - Relationship between velocity in joint space and that in Cartesian space.



  - Specified by a matrix called "Jacobian".
  - Interestingly, the same matrix also describes the relationship between the joint torques and the static force applied by end-effector onto a work surface.

About this Course

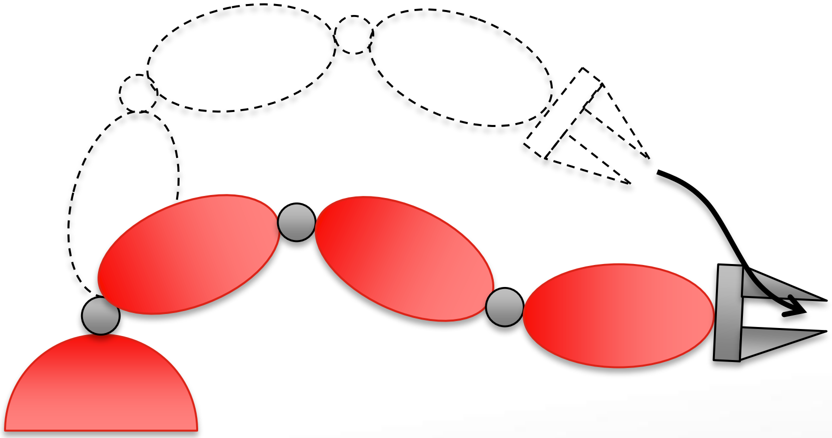
- Manipulator Dynamics:
  - The study of forces which cause motion.



  - How much torque is needed to accelerate the manipulator from rest to constant velocity, and then back to stop?
  - Dynamics also provide us a model (equations of motions) for simulation and control design purpose.

About this Course

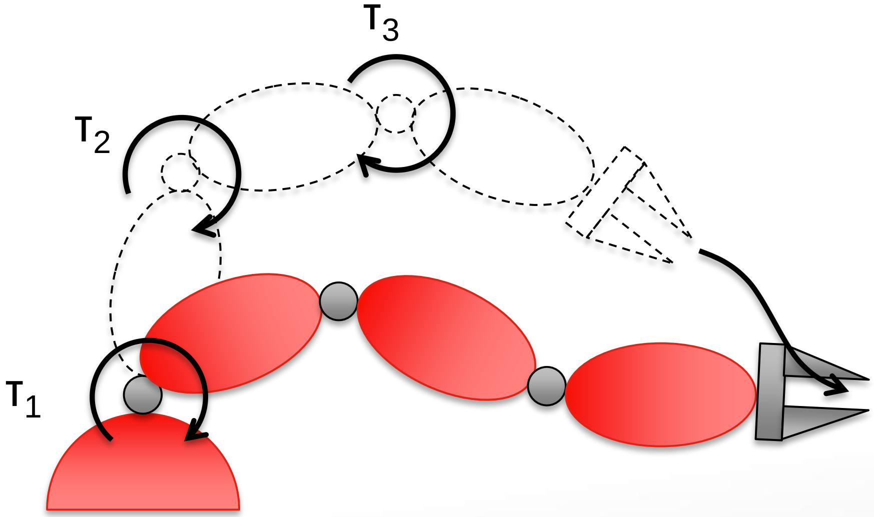
- Trajectory Planning
  - Design of a path for the manipulator to follow.



  - We may want to include some intermediate locations or via points.

About this Course

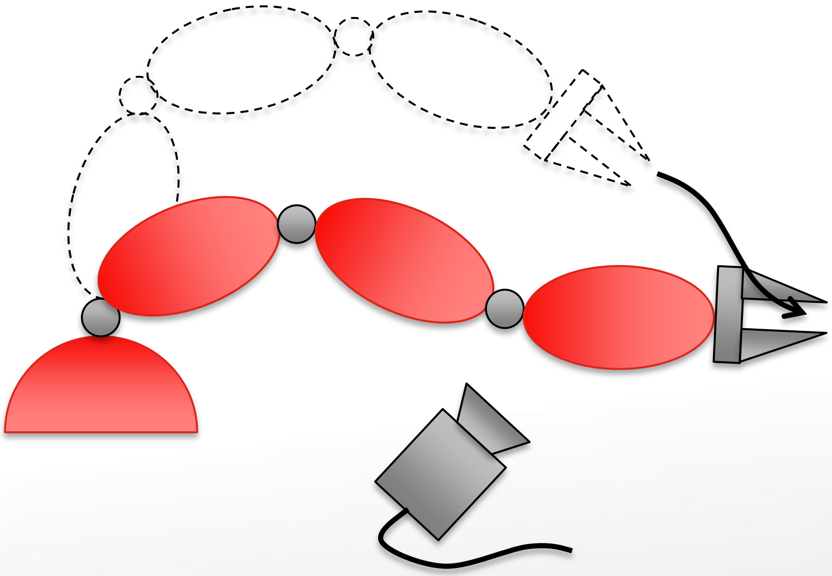
- Linear and Nonlinear Position Control
  - Control the torque of the motors at the joints.



  - In order to execute the planned trajectory.
  - Linear control: Simple and widely-used.
  - Nonlinear control: Improved performance.

About this Course

- Robotic Vision
  - Using vision to guide robot in trajectory planning or grasping of object.



  - Eye-to-Hand configuration (as shown)
  - Eye-in-Hand configuration (camera mounted on robot)

About this Course

- Programming of robot to carry out tasks can be done in several ways.
  - The most common method is by using Teaching Pendant

https://www.prlog.org/10975425-abb-robotics-training-lab-to-open-at-the-indiana-center-for-applied-technologyvincennes-university.html

About this Course

- Offline Programming in ABB Robot Studio
  - Offline programming is getting popular:
    - No need to stop robot in production for programming purpose.
    - Program can be generated in virtual environment based on CAD drawings, and then downloaded to the real robot.

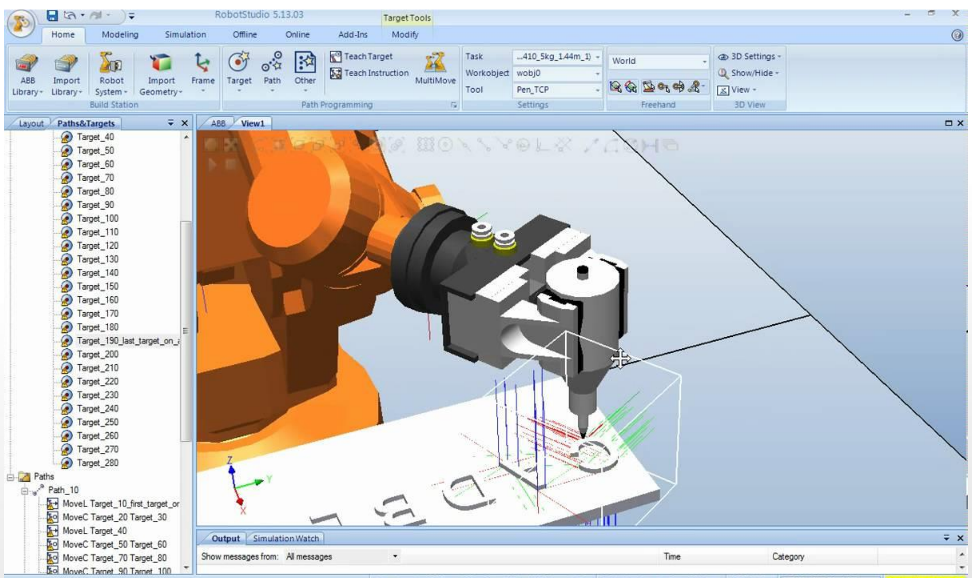


ABB RobotStudio
https://i.ytimg.com/vi/NxI3h6u8wk0/maxresdefault.jpg

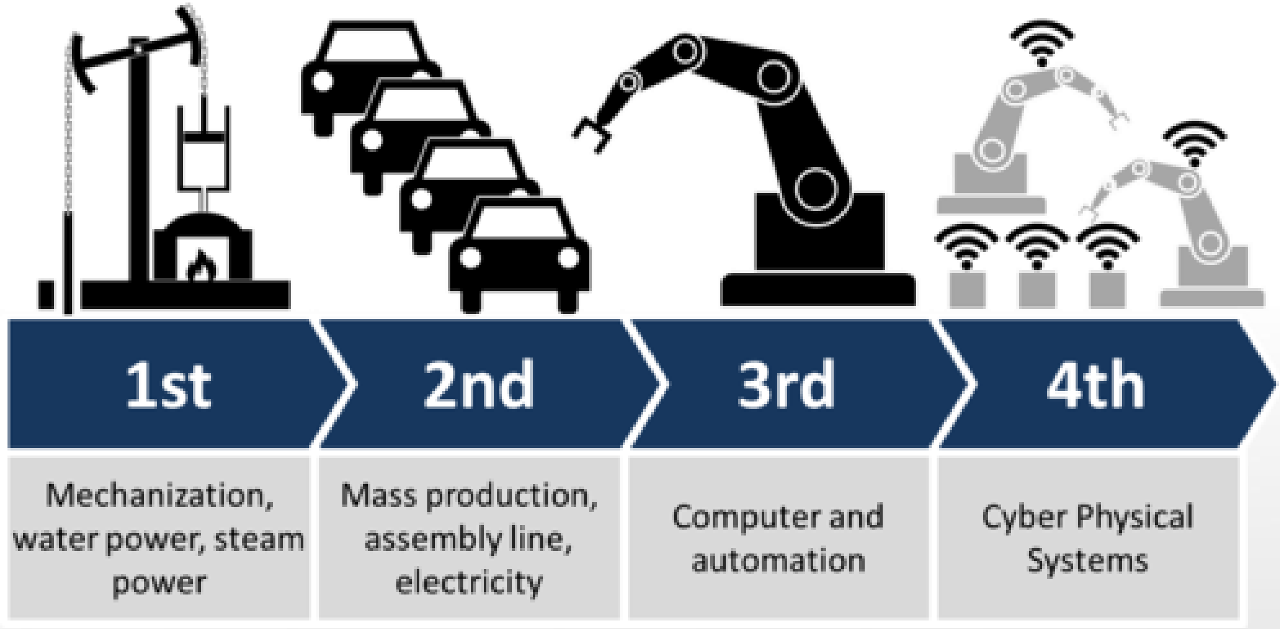
About this Course

- Robotic Work-cell Design:
  - Common components of an automated robotic cell, including part loading, transfer, storage, recognition etc.

http://d2n4wb9orp1vta.cloudfront.net/resources/images/cdn/cms/1013CT_Emerging_PreformCenter.jpg

About this Course

- Introduction to Industry 4.0
  - What is I4.0 and how it transform manufacturing



https://en.wikipedia.org/wiki/Industry_4.0

Lectures

Wk	Date	Lecture (NOTE: video recording)	Maths Difficulty	Hands-on Activity	Related Assessment
1	24/7	• Introduction to the Course • Spatial Descriptions & Transformations			
2	31/7	• Spatial Descriptions & Transformations • Robot Cell Design			Robot Cell Design Assignment
3	7/8	• Forward Kinematics • Inverse Kinematics			Test 1
4	14/8	• ABB Robot Programming via Teaching Pendant • ABB RobotStudio Offline Programming		ABB RobotStudio Offline Programming	Offline Programming Assignment
5	21/8	• Jacobians: Velocities and Static Forces			Test 1
6	28/8	• Manipulator Dynamics			Test 1
7	11/9	• Manipulator Dynamics		MATLAB Simulink Simulation	Test 1
8	18/9	• Robotic Vision		MATLAB Simulation	Robotic Vision Assignment,
9	25/9	• Robotic Vision		MATLAB Simulation	Test 2
10	2/10	• Trajectory Generation			Test 2
11	9/10	• Linear & Nonlinear Control		MATLAB Simulink Simulation	Test 2
12	16/10	• Introduction to I4.0 • Revision			Test 2

Online Sessions

- Every Friday 6.30pm to 8.30pm Via Collaborate Ultra
- Lecturer: Ehsan ASADI
  - Office: City Campus, Building 57, Level 1, Room 10
  - Email: ehsan.asadi@rmit.edu.au
  - Phone: 99254515
- Consultation hours:
  - By appointment by email.
  - Location: Online – Microsoft Teams.

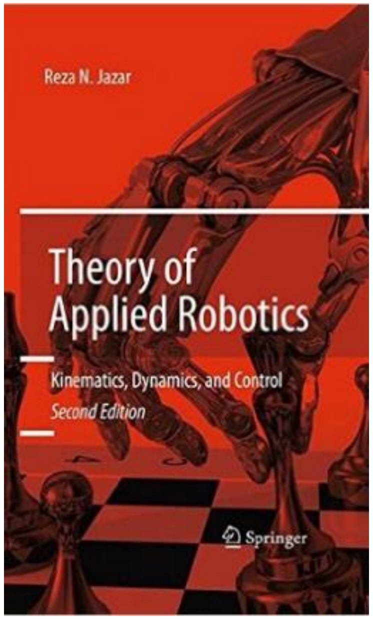
Notes, Videos and Tutorials

- Most lectures and solutions will be **pre-recorded**.
- **Lecture slides**, **videos** and all other materials related to the course will be placed on the course website (under Canvas) every week.
- Please watch the videos and go through notes at your own time.
- We will have **online sessions** via **Collaborate Ultra**, every Fridays.

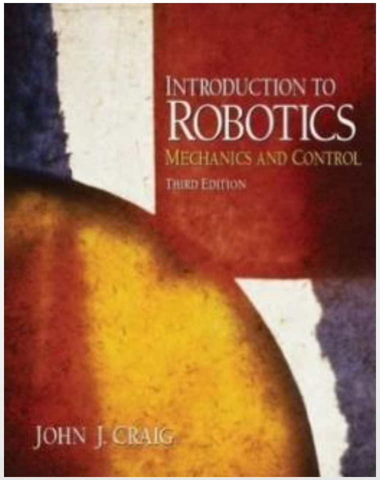
- During online sessions, there will be discussions and interactive activities as well. You are strongly recommended to actively attend the sessions for asking questions and most fruitful learning.
- Consistent and active reading of lectures with the help of videos will significantly help you obtain a good mark in the final exam. The final exam is mainly focused on what was explained in the lectures.

Textbooks and References

- *Theory of Applied Robotics: Kinematics, Dynamics, and Control* by **R. N. Jazar**, Second Edition, Publisher: Springer



- *Introduction to Robotics: Mechanics and Control* by **J. J. Craig**, Third Edition, Publisher: Pearson Prentice Hall



Assessment

Item	MANU2453
Robot Cell Design (Group)	20% • Start in Week 2 • Submit by Thursday of Week 4
Offline Programming (Group)	20% • Start in Week 4 • Submit by Thursday of Week 7
Vision Assignment (Group)	20% • Start in Week 8/9 • Submit by Thursday of Week 11
Two Tests (Individual)	20% • Open Book Canvas Test • by Thursday of Week 13
	20% • Open Book Canvas Test • by Thursday of Week 15

- Please form a group of 3 now.

Important Notes

- Lecture slides, videos and all other materials related to the course will be placed on the course website (under Canvas).
- Understanding the concept and the big picture is more important than memorizing formulae.
- Study constantly. Learning does not happen overnight.

This course is very mathematical. However, if you pay attention during class and practise constantly, you will be able to understand it.

You are expected to spend at least 6 hours a week working on this course.