MEAM 520
Lecture 2: Background and Definitions

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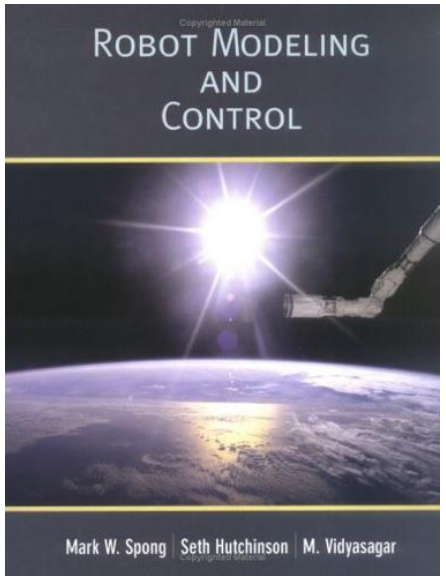
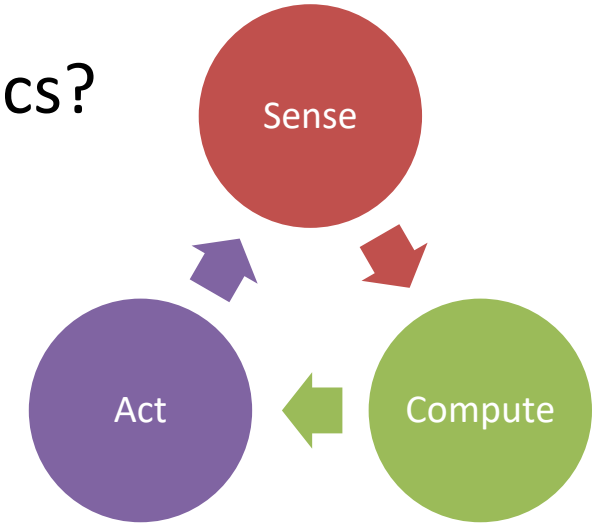
Last Time



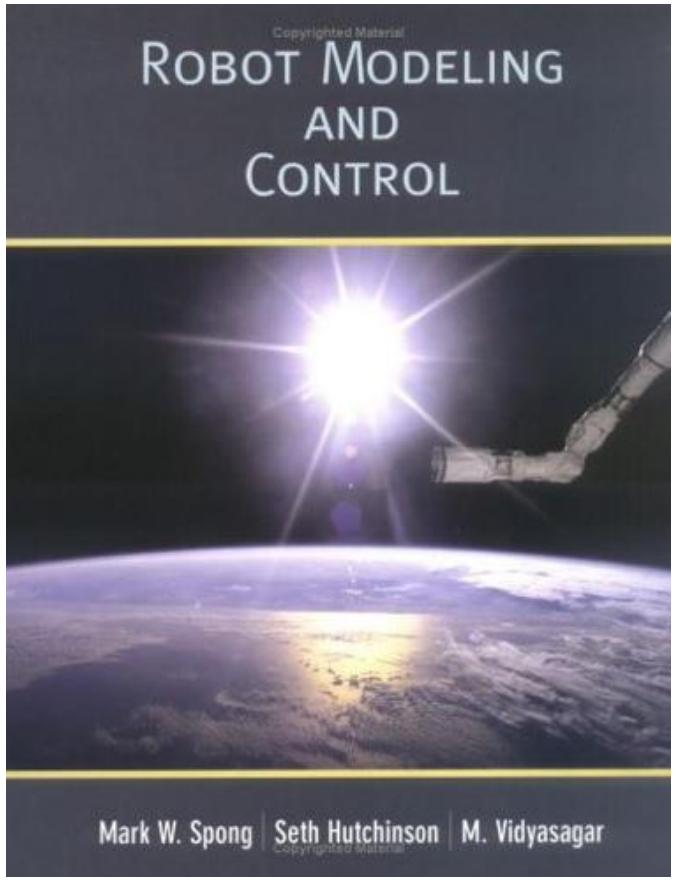
Class logistics

- Assignments and lecture slides on Canvas
- Announcements and questions on Piazza
- Office hours on Google Calendar – **fill out the poll!**
- Labs + Final Project

What is robotics?



Reading



Chapter 1: Introduction

Lab 0

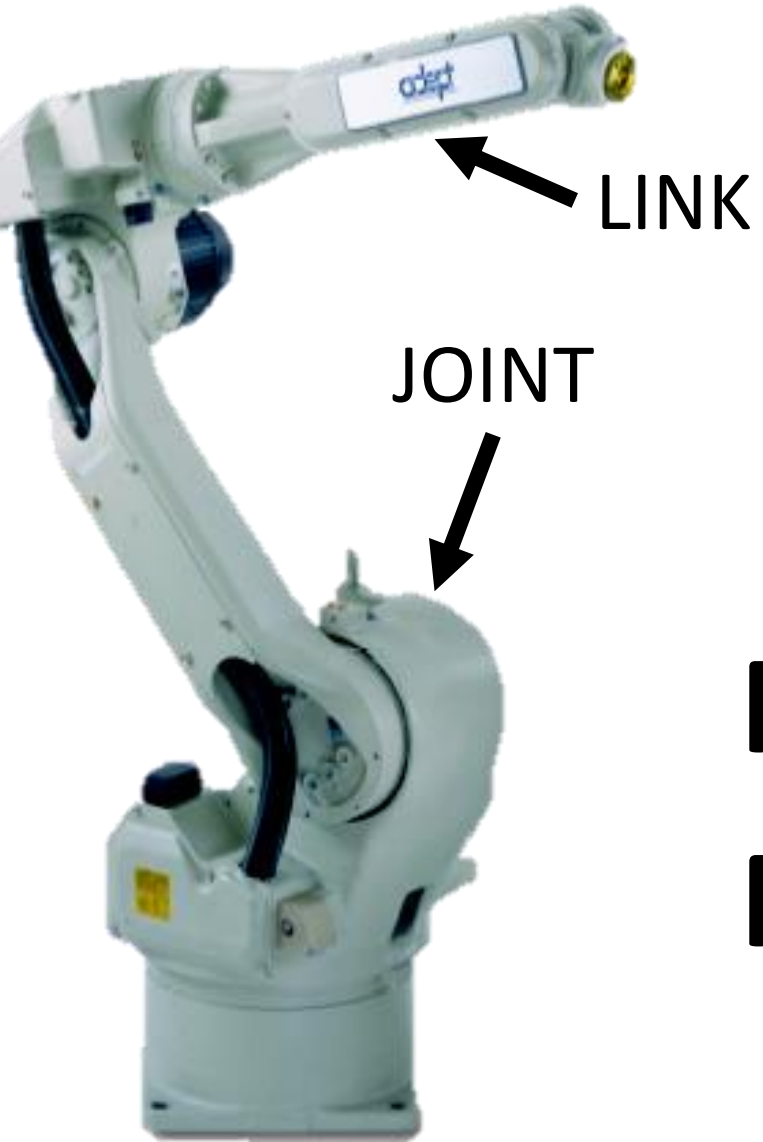
Posted yesterday

Due on Wed 9/9

Thank you to all of you have started on this and posted issues on Piazza.

There are a lot of different situations (operating systems, MATLAB/python configurations, etc) – thank you for your patience.

Robot Manipulators



Are composed of

- Rigid **links**
- Connected by **joints**
- To form a **kinematic chain**.

There are two types of basic **joints**:

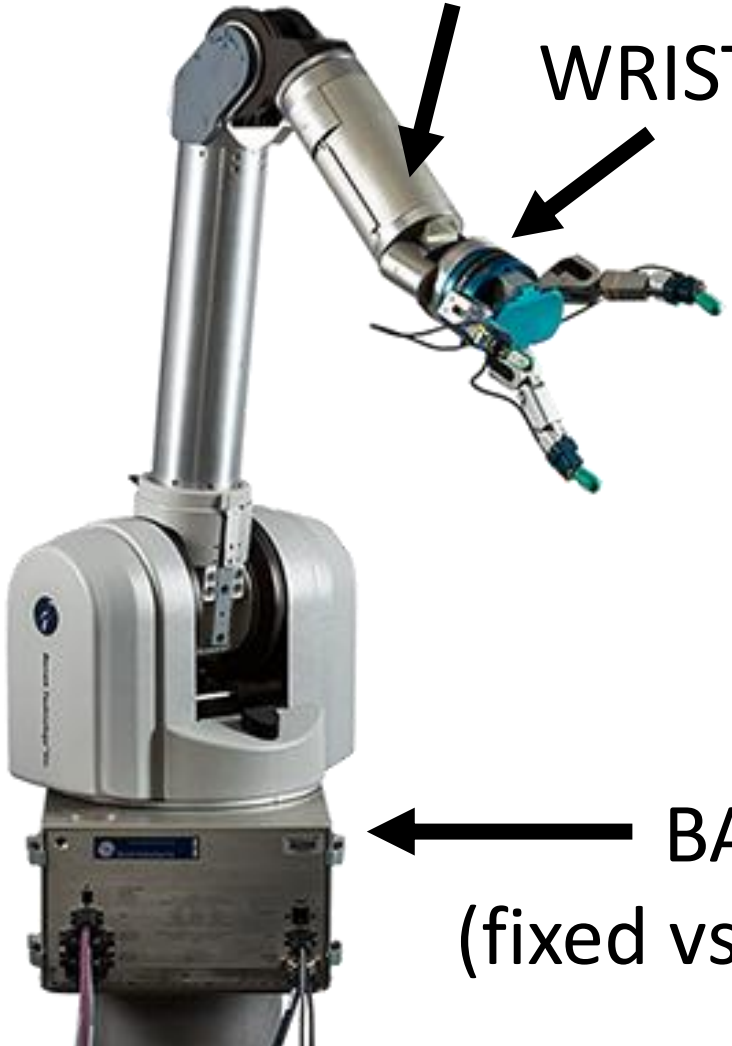
R
- Revolute (rotary), like a hinge, allows relative rotation between two links

P
- Prismatic (linear), like a slider, allows a relative linear motion (translation) between two links

How to draw **R** and **P** joints

	Revolute	Prismatic	Examples
2D			
3D			

Parts of a manipulator



Barrett WAM Arm

Symbolic representation

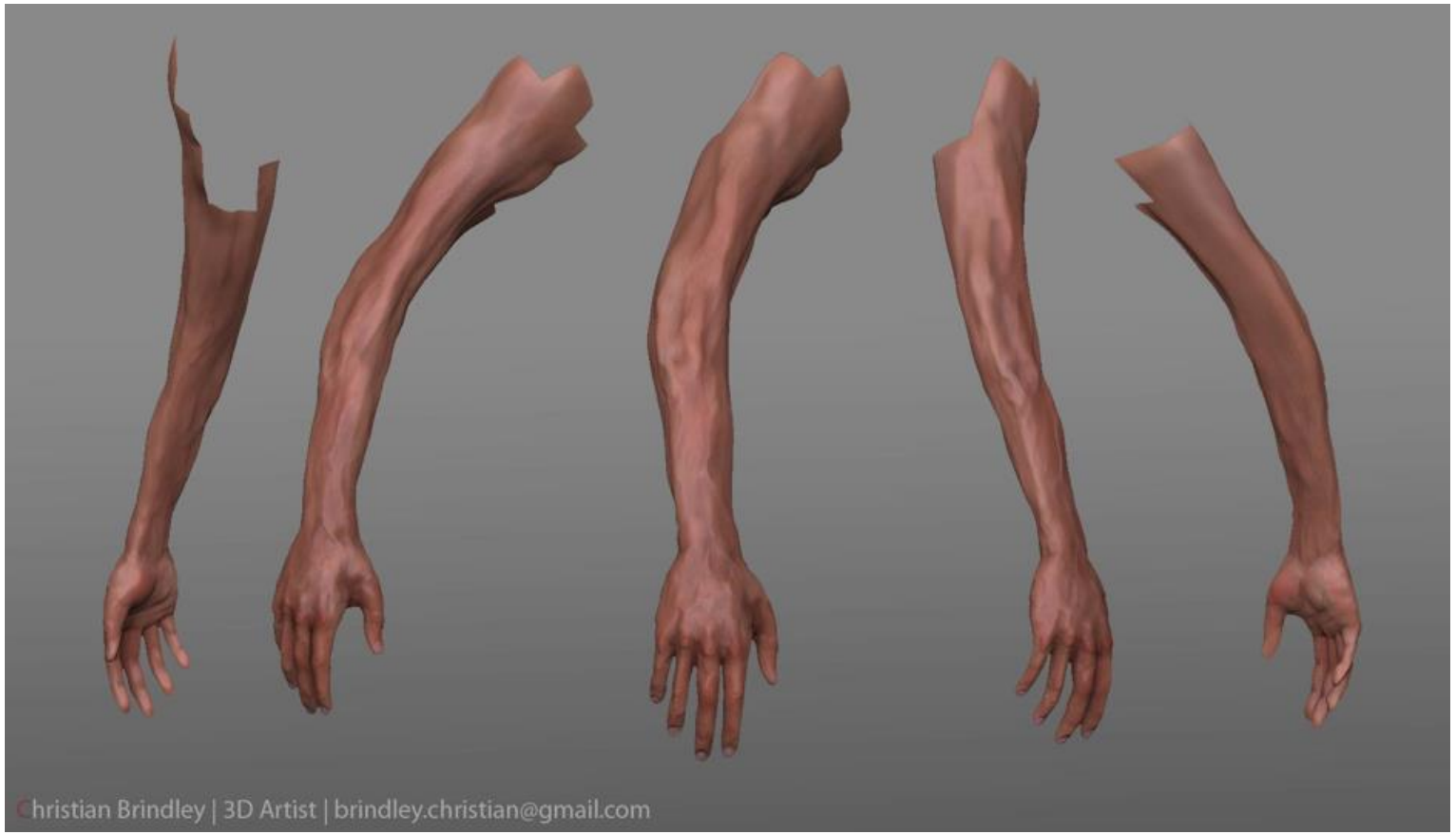
Types of Manipulators

SERIAL

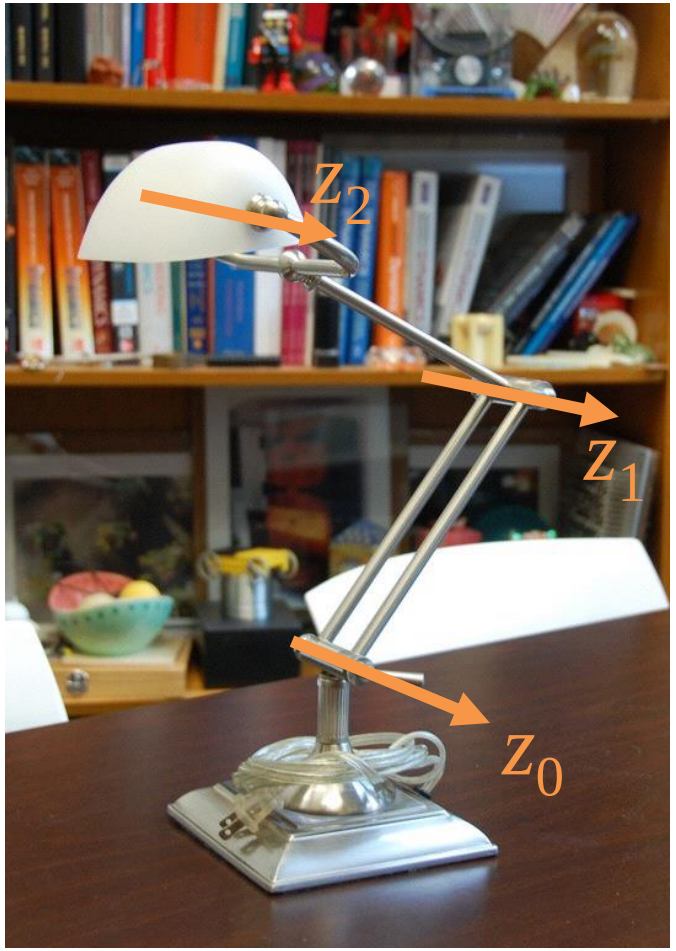
PARALLEL

Let’s describe this lamp like a robot.

What kind of joints does a human arm have?



Configuration Space (C-Space)

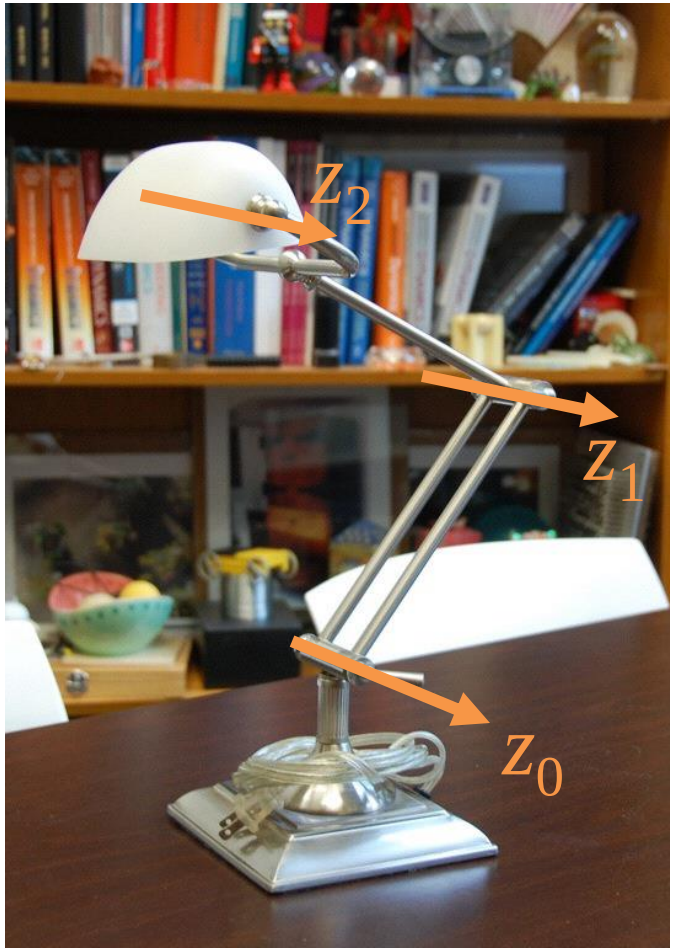


Configuration: complete specification of the location of every point on the manipulator

Configuration space: set of all configurations

How many possible configurations does this lamp have?

Joint variables



Joint variables to denote each joint's position.

Joint displacements are defined relative to the **zero configuration**.

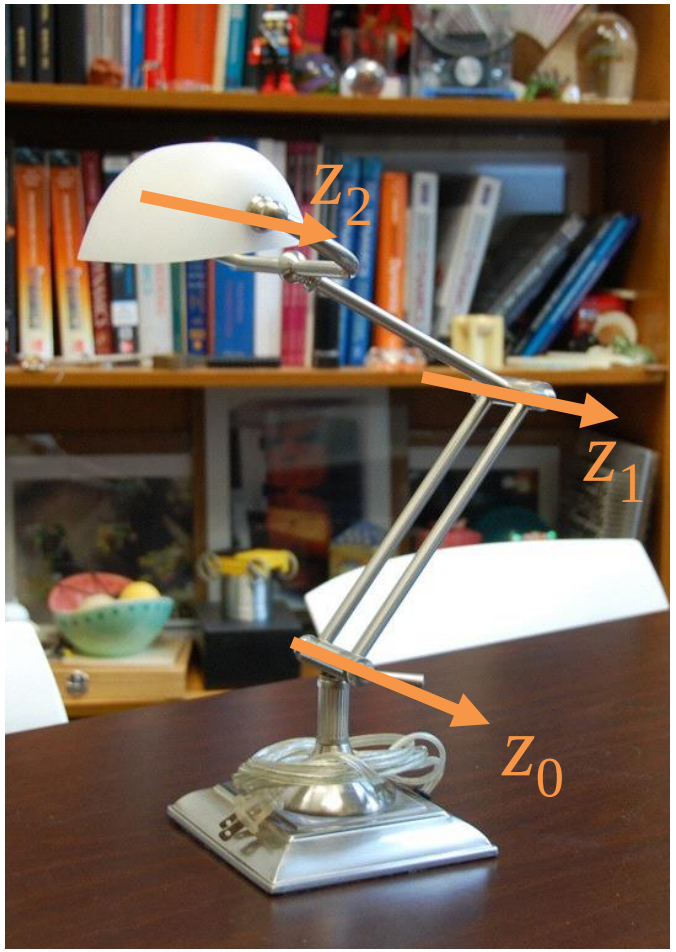
Use θ_i for revolute joints

Use d_i for prismatic joints

Axis orientation defines the positive direction (use the RHR for revolute joints)

For rigid manipulators, knowing all joint variable values defines the configuration

Degrees of Freedom

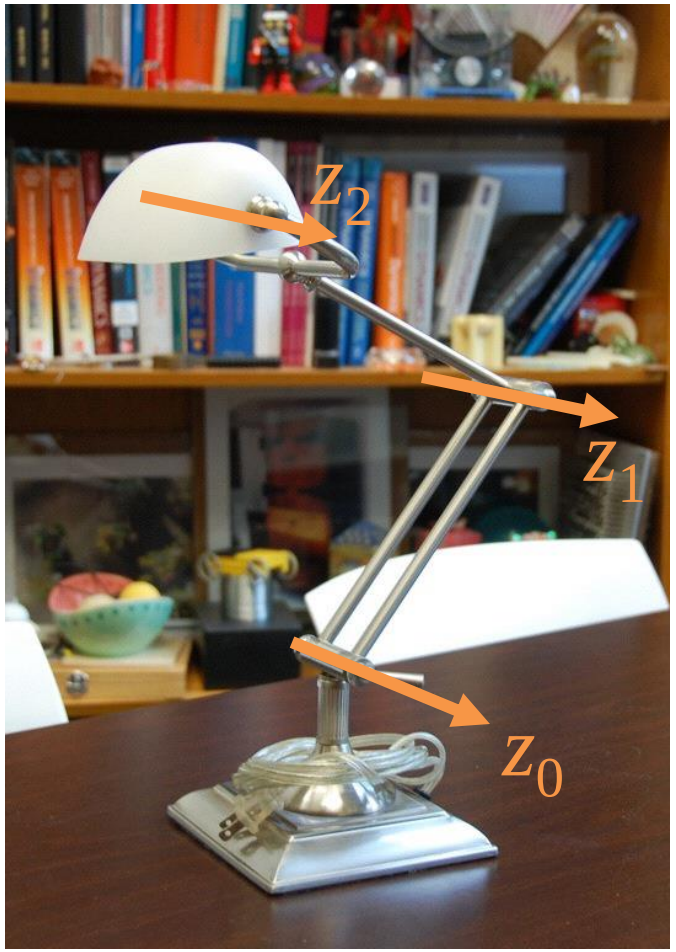


Degrees of Freedom (DOF): The minimum number of parameters needed to specify the configuration

How many DOF does a rigid body in 3D space have?

Robots need at least ___ joints (____ DOF) for the end-effector to reach every point in the workspace with arbitrary orientation

Workspace

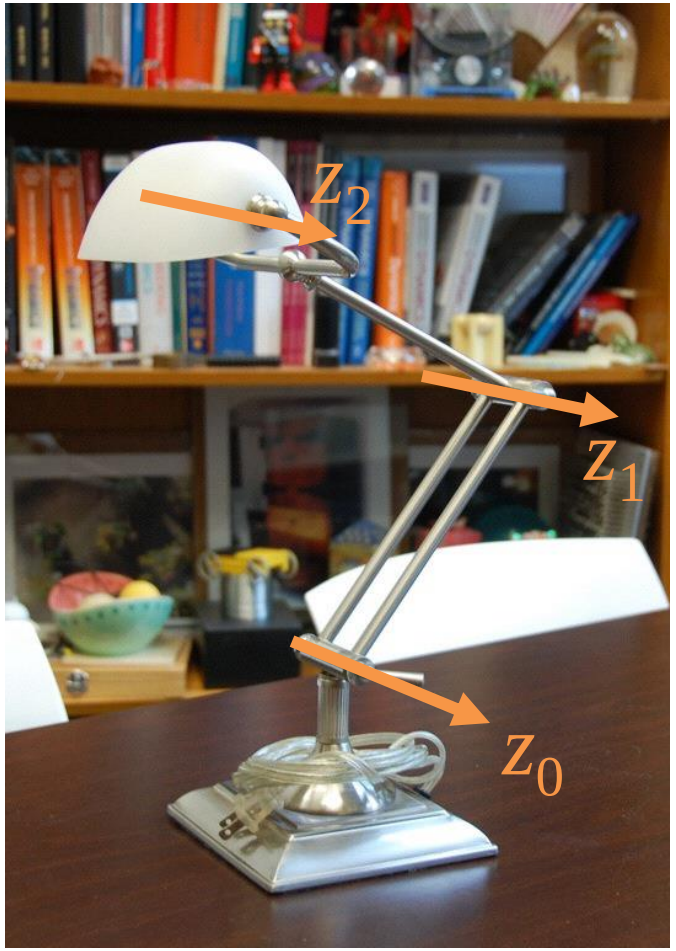


Workspace: volume swept out by the end-effector as the robot does all possible motions

- Depends on robot geometry
- Depends on joint limits
- Depends on the point on the end-effector

dexterous workspace **reachable workspace**

Workspace



NOTE: Workspace and configuration space have different dimensionality!

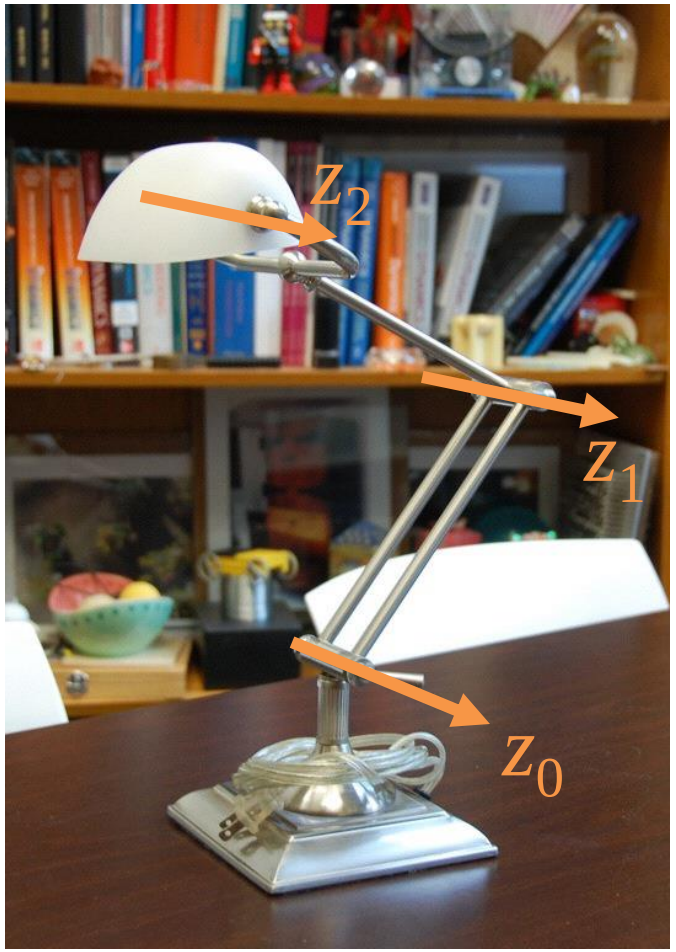
Configuration space: #{DOF} dimensions

Workspace: 3D or 2D depending on task

Task space: the parameter space for the task.

Often this is the 6D space of position/orientation

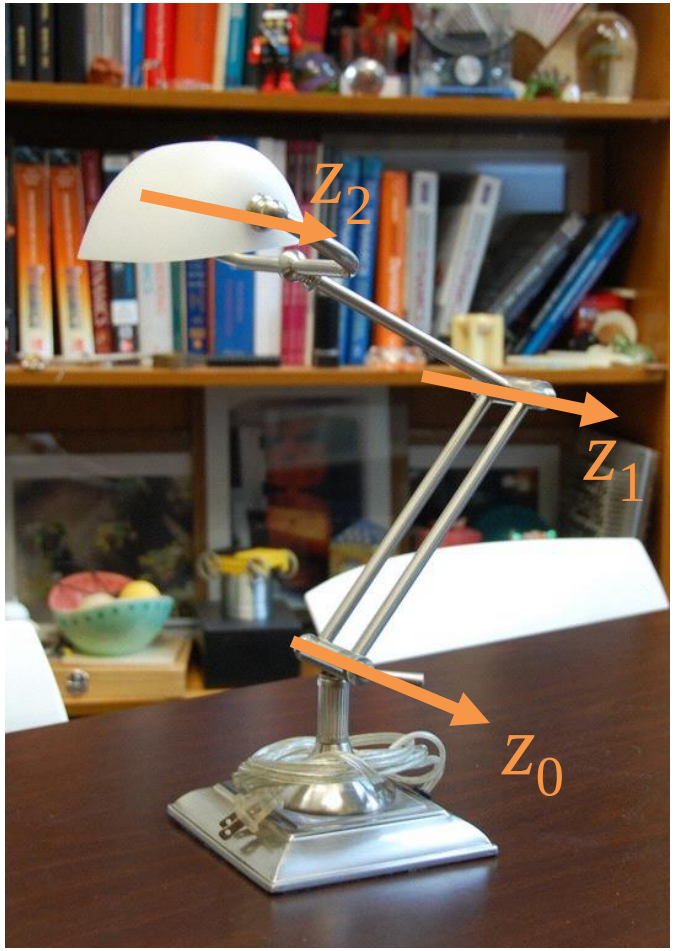
Workspace



What is the reachable workspace of the lamp?

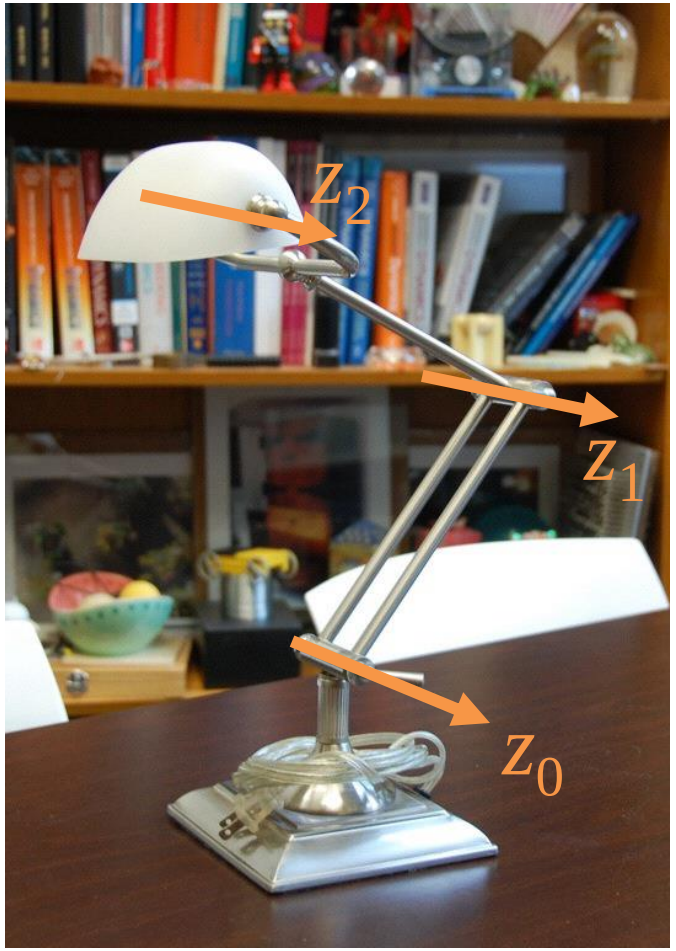
What is the dexterous workspace of the lamp?

Configuration Space



What is the configuration space of the lamp?

Spatial mechanisms



If we let the **base move and rotate** on the table, what type of robot is the lamp?

What is the new **reachable workspace** of the lamp?

We can apply the same terminology to mobile robots.

BUT it is **non-holonomic**.

Does the configuration of a manipulator fully define how it will move in the future?

The configuration gives you an **instantaneous description** of the geometry

State: set of variables sufficient to tell you the future time response when combined with dynamics and future inputs

A robot's dynamics equations determine accelerations ($\boldsymbol{F} = m\boldsymbol{a}$)

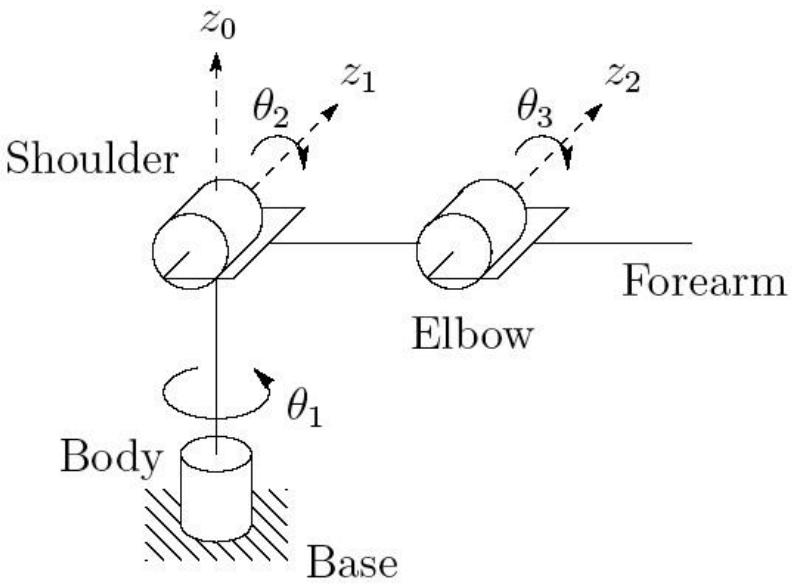
State requires **joint variables** q and **derivatives** $\dot{q}$

Practice: Unimate's 1960 manipulator arm

1. Describe this manipulator in Rs and Ps.
2. How many degrees of freedom does it have?
3. Draw the symbolic representation.
4. Sketch the robot's reachable workspace.

https://youtu.be/hxsWeVtb-JQ

5 most common serial manipulators



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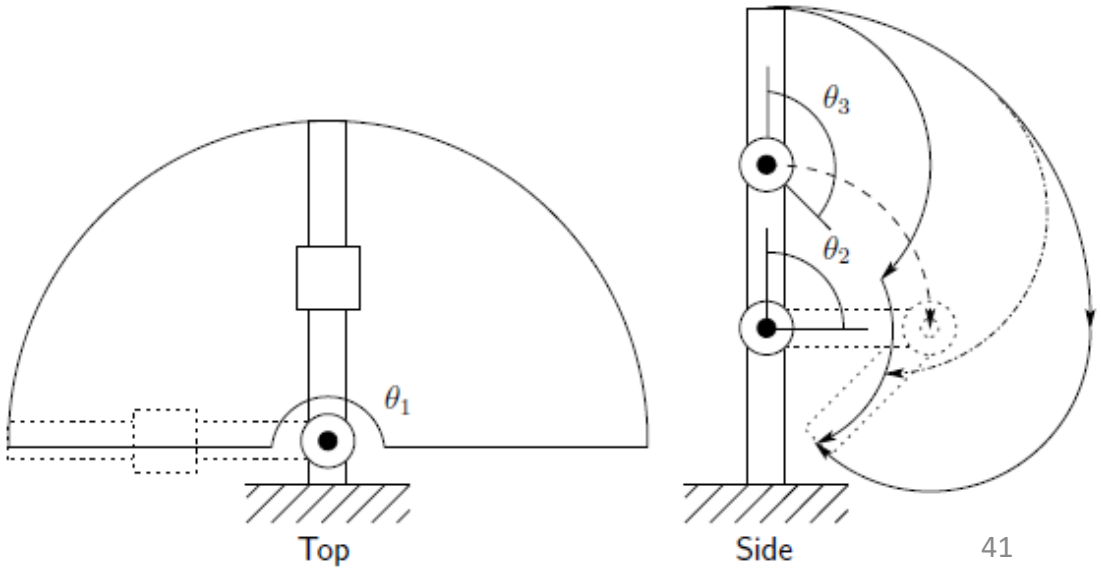
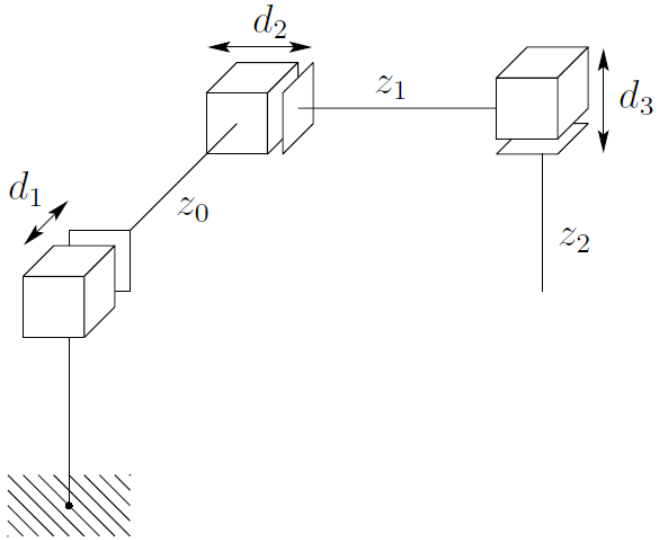
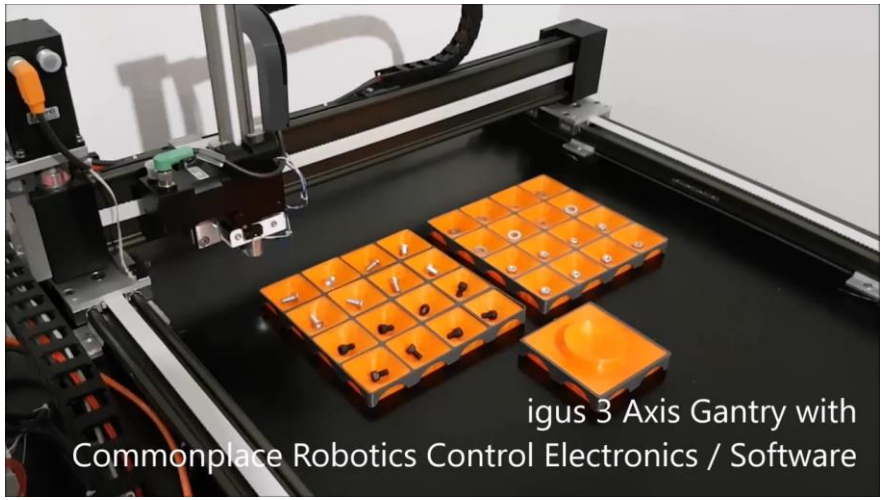


Articulated (RRR)

Useful for: small workspaces

5 most common serial manipulators





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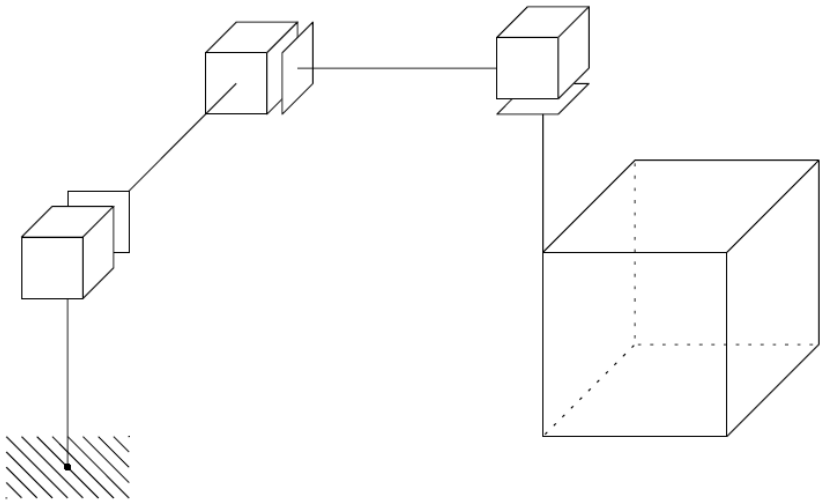
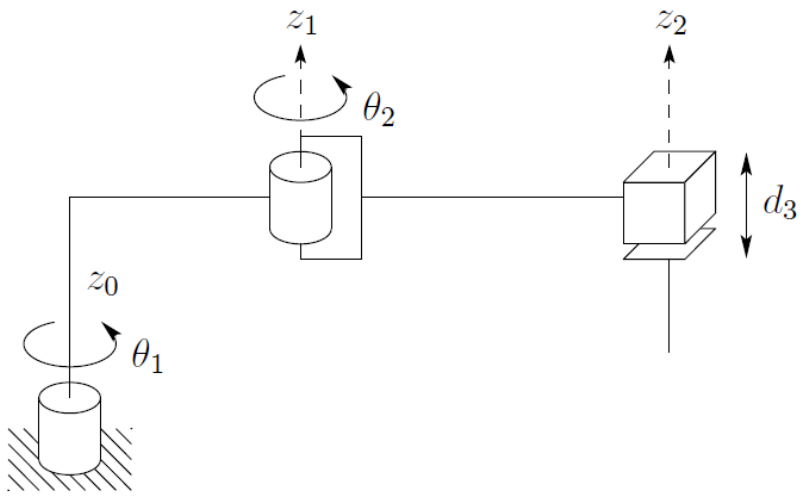
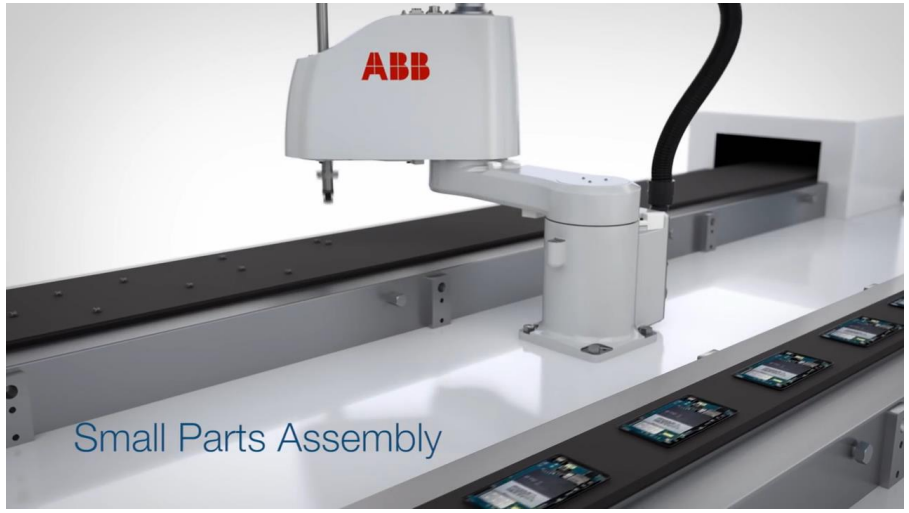


Cartesian (PPP)

Useful for: gantries

5 most common serial manipulators





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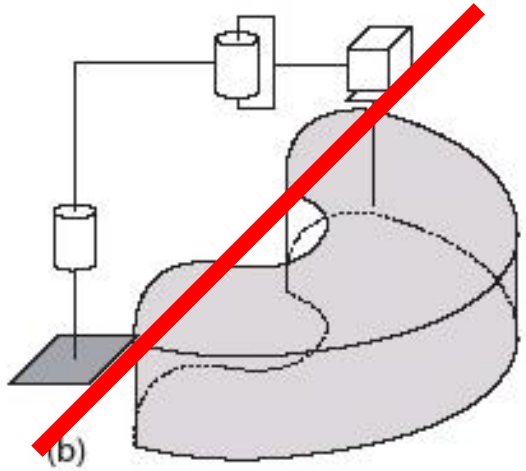
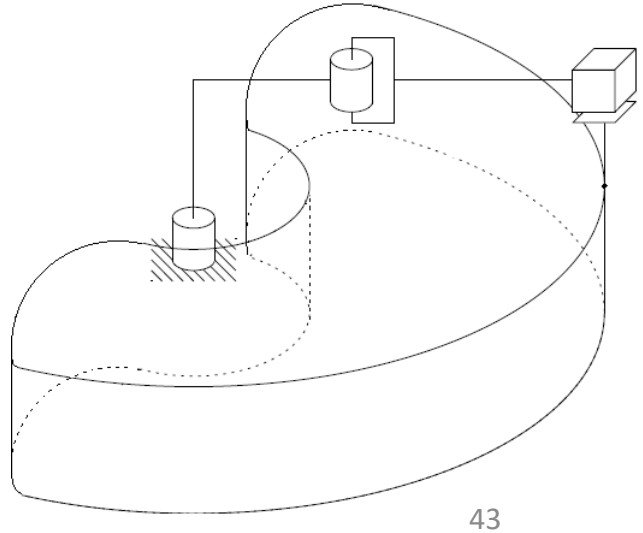
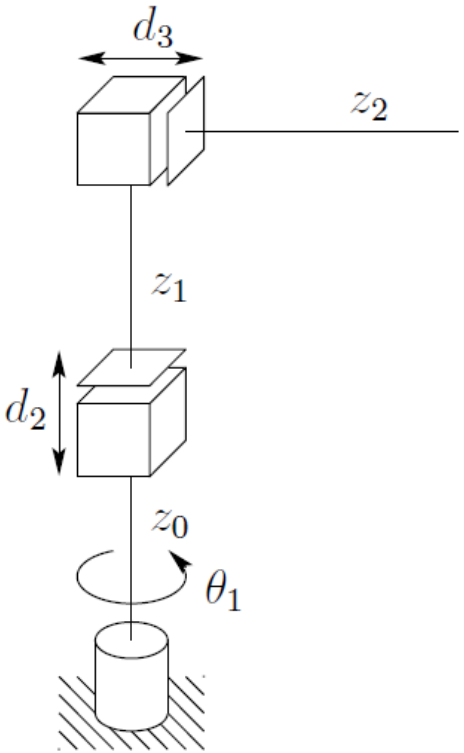


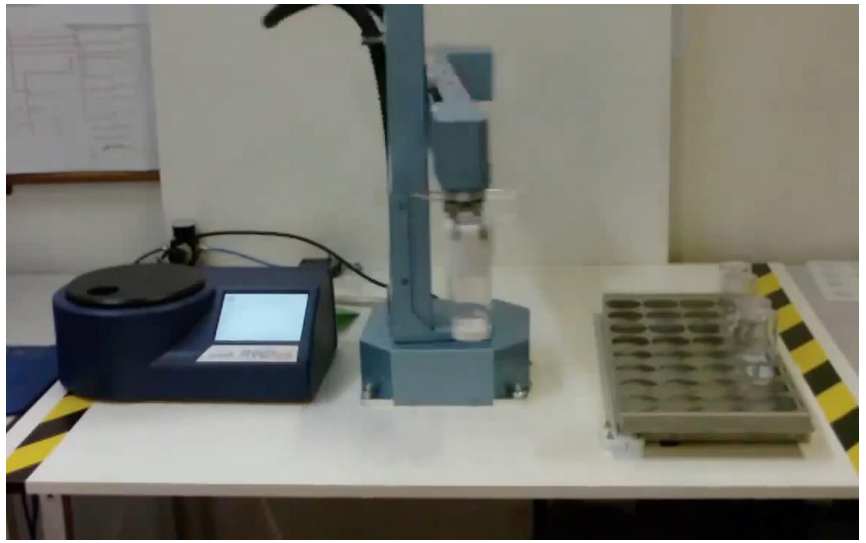


SCARA (RRP)

Useful for: speed, planar tasks

5 most common serial manipulators





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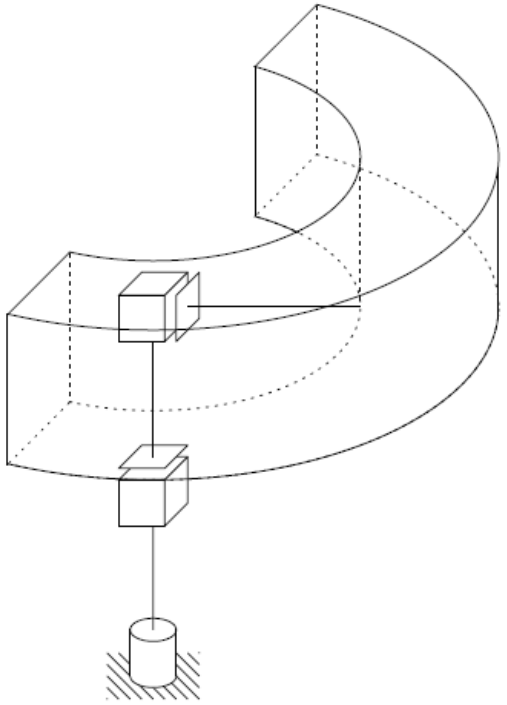


Cylindrical (RPP)

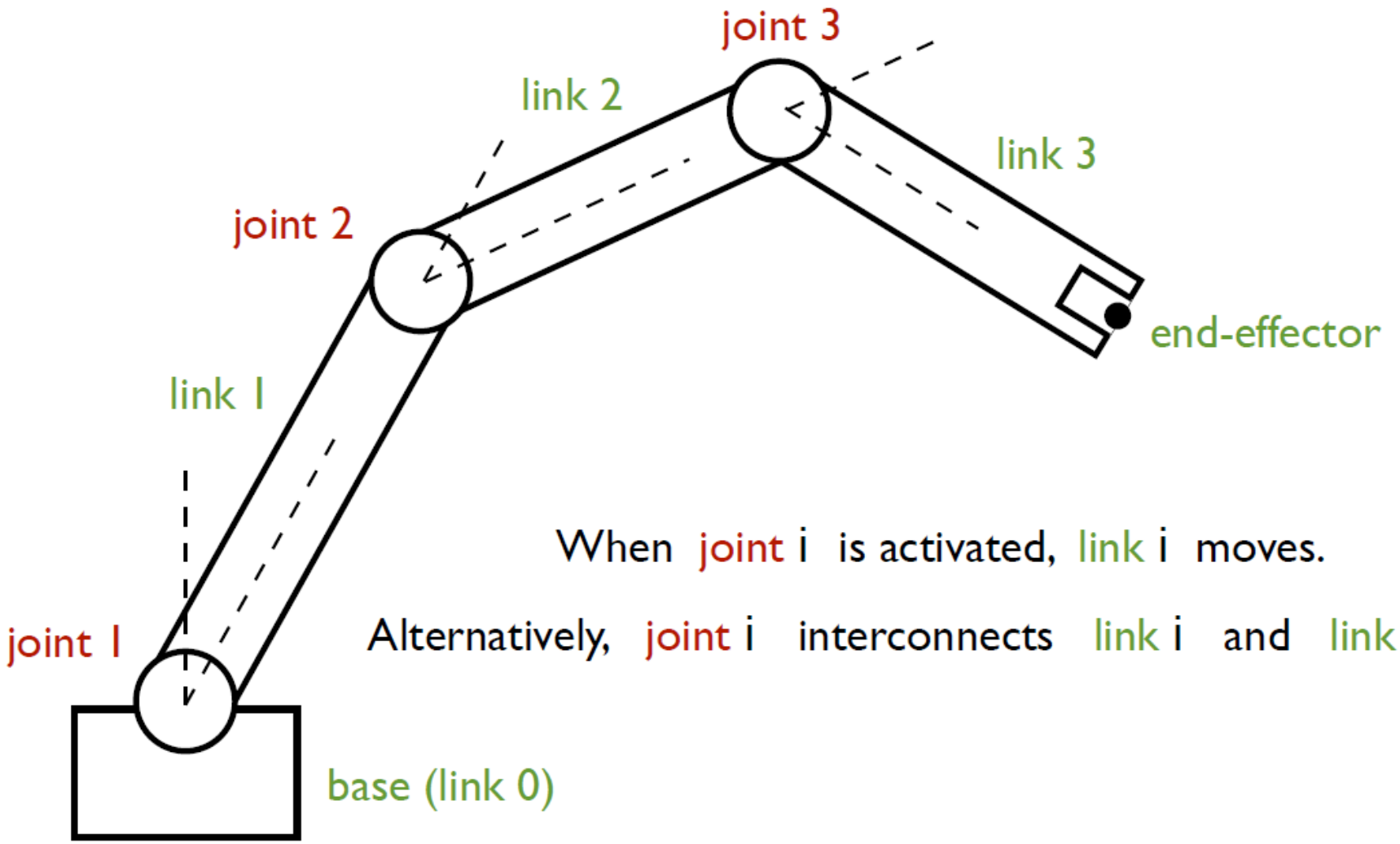
Useful for: material transfer

How do we describe these robots? Kinematics!

Kinematics is the study of motion without

references to the causes of that motion.

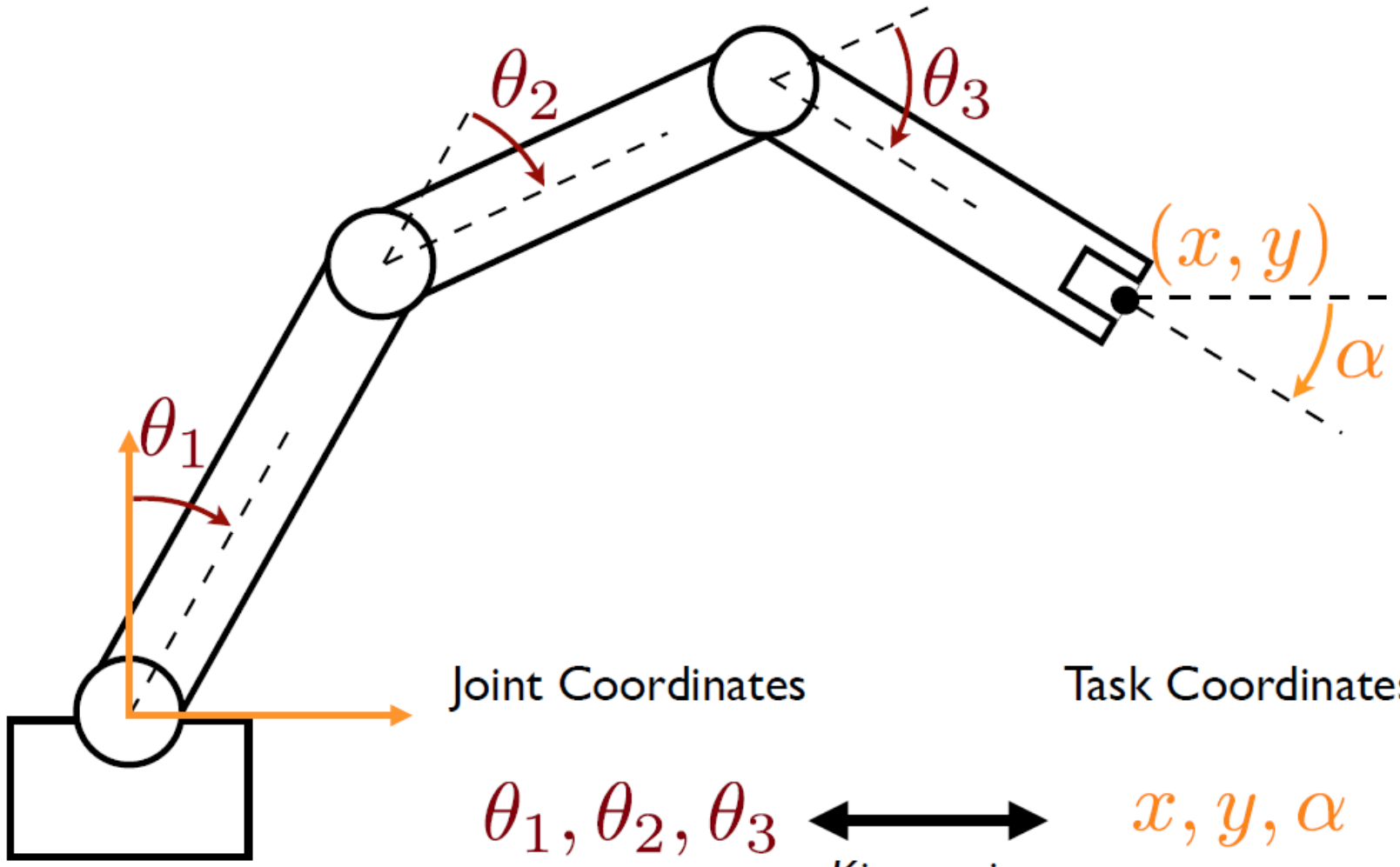
Kinematics



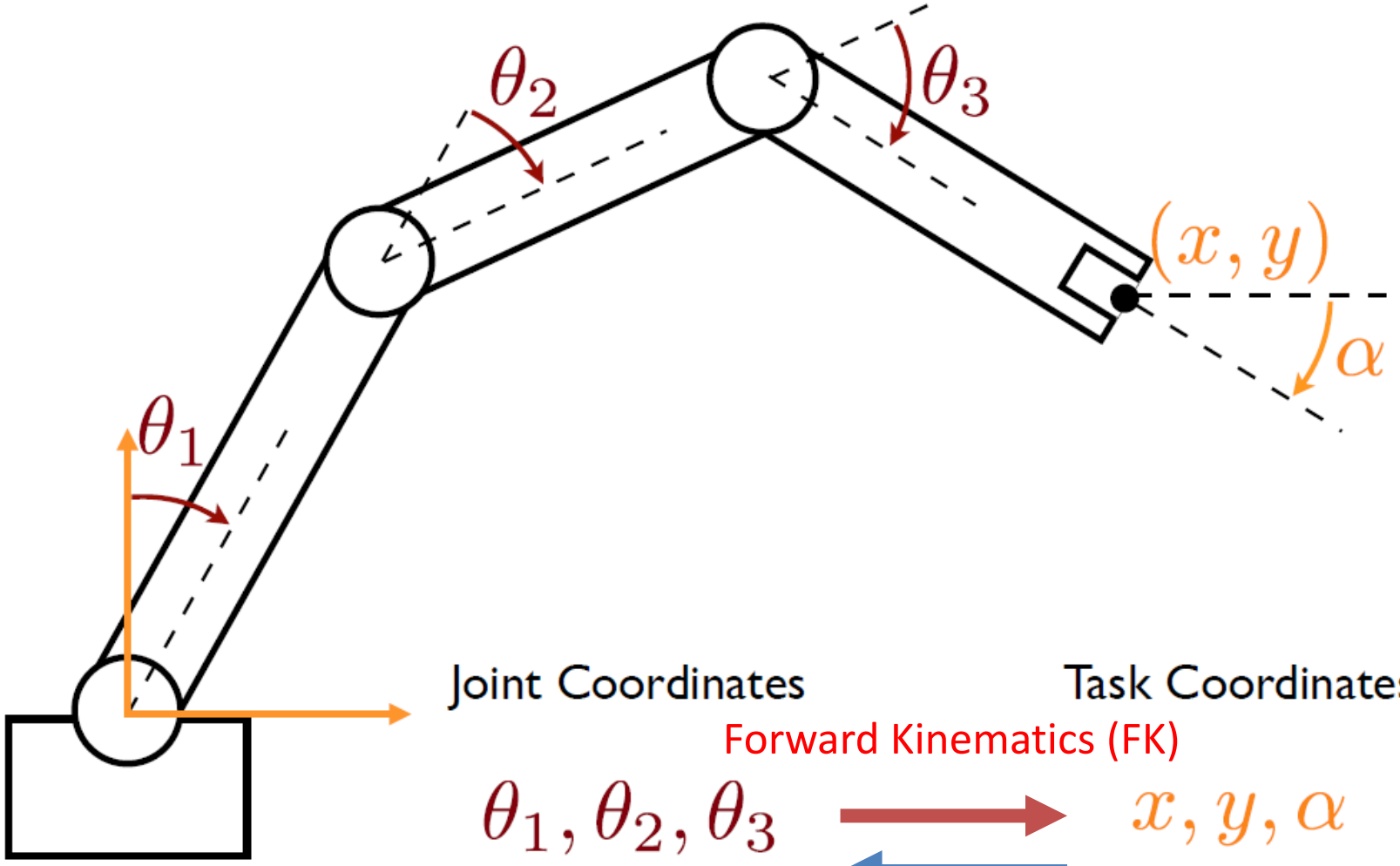
When joint i is activated, link i moves.

Alternatively, joint i interconnects link i and link i−1

Kinematics


θ_1
θ_2
θ_3
(x, y)
α
Joint Coordinates
Task Coordinates
$\theta_1, \theta_2, \theta_3$
relative to previous link
Kinematics
x, y, α
relative to base frame

Kinematics


θ_1
θ_2
θ_3
(x, y)
α
Joint Coordinates
Task Coordinates
Forward Kinematics (FK)
$\theta_1, \theta_2, \theta_3$
x, y, α
relative to previous link
Inverse Kinematics (IK)
relative to base frame

Next time: Rotation Matrices in 2D and 3D

Chapter 2: Rigid Motions

- Read Sec. 2.intro-2.5
- Brush up on B.1-B.4 if necessary
  - Key concepts: vector, matrix, transpose, dot product, norm, matrix multiplication