Robot Kinematics, Dynamics & Control

Professors:

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Schedule

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Robot Kinematics, Dynamics & Control: Scheduling
2017 - 2018

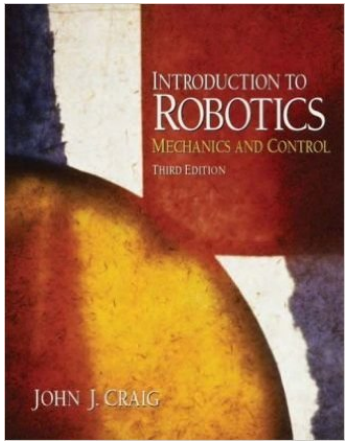
	Week	W1		W2		W3		W4		W5		W6		W7		W8		W9		W10		W11		W12		W13		W14	
Topic	Date	19-sept	21-sept	26-sept	28-sept	3-oct	5-oct	10-oct	12-oct	17-oct	19-oct	24-oct	26-oct	31-oct	2-nov	7-nov	9-nov	14-nov	16-nov	21-nov	23-nov	28-nov	30-nov	5-dic	7-dic	12-dic	14-dic	19-dic	21-dic
Introduction	Tuesday								Bank Holliday					Partial Exam											Bank Holliday				
Kinematics	Thursday																												
Dynamics	Tuesday																												
	Thursday																												
Trajectory	Tuesday																												
	Thursday																												
Control	Tuesday																												Delive
	Thursday																												rable

Kinematics & Dynamics Short project	Wenesday									G1		G2								G1		G2							
	Date									18/10/17		25/10/17								22/11/17		29/12/17							

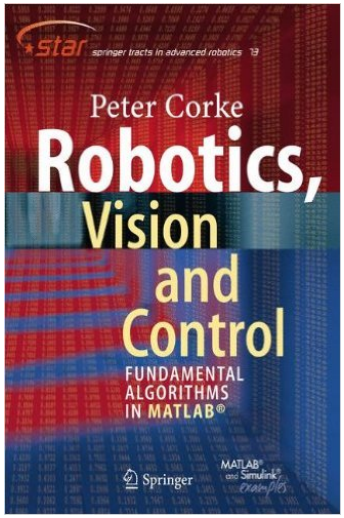
Control of Selfbalancing Robot	Wenesday																									G1		G2	
	Date																									13/12/17		20/12/17	

Programming Lab	Wenesday															G1		G2											
	Date															To be scheduled													
	Week	W1		W2		W3		W4		W5		W6		W7		W8		W9		W10		W11		W12		W13		W14	

Bibliography

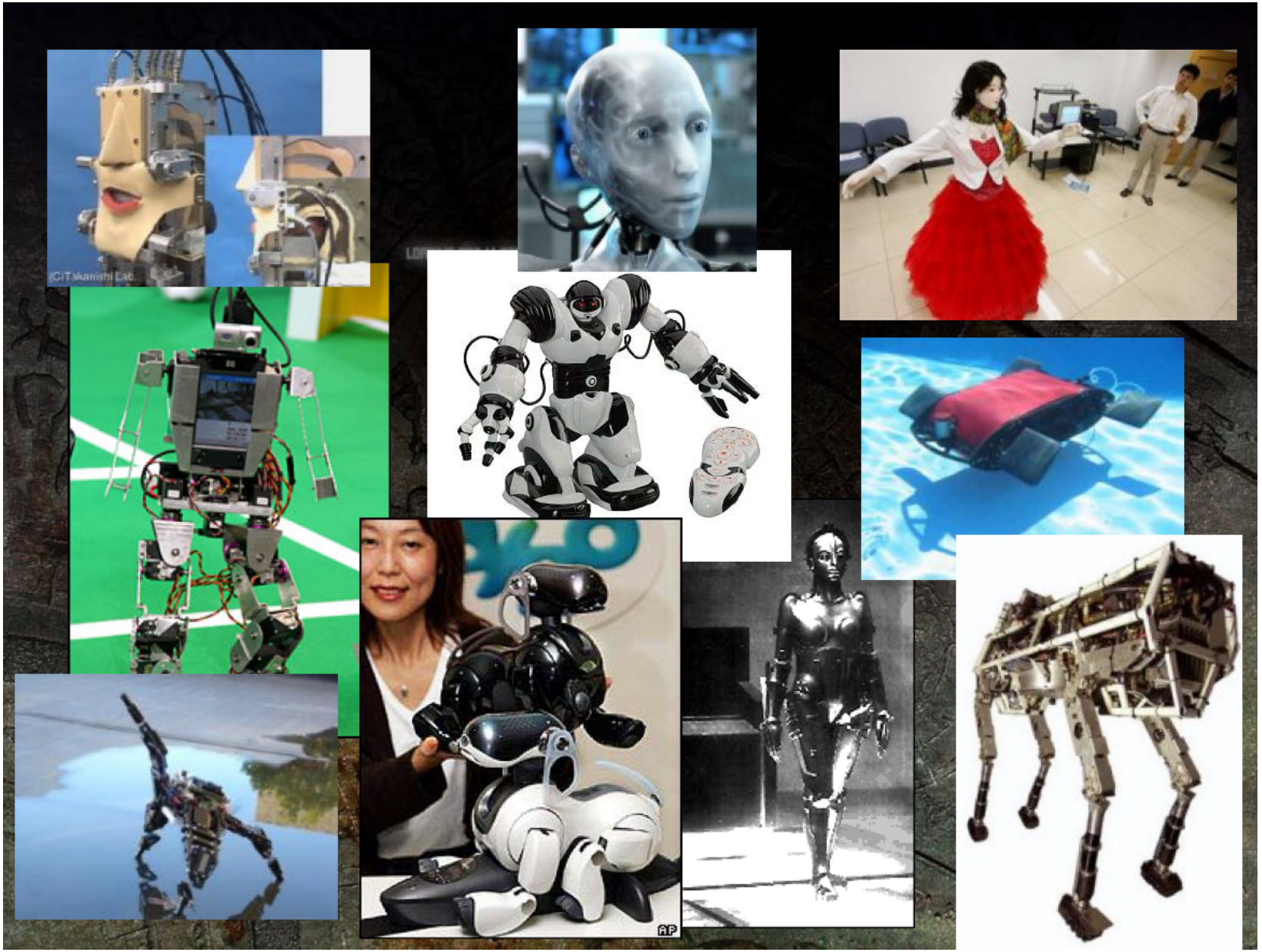


J.J. Craig, **Introduction to Robotics: Mechanics and Control** (3rd Edition), Pearson, 2004.



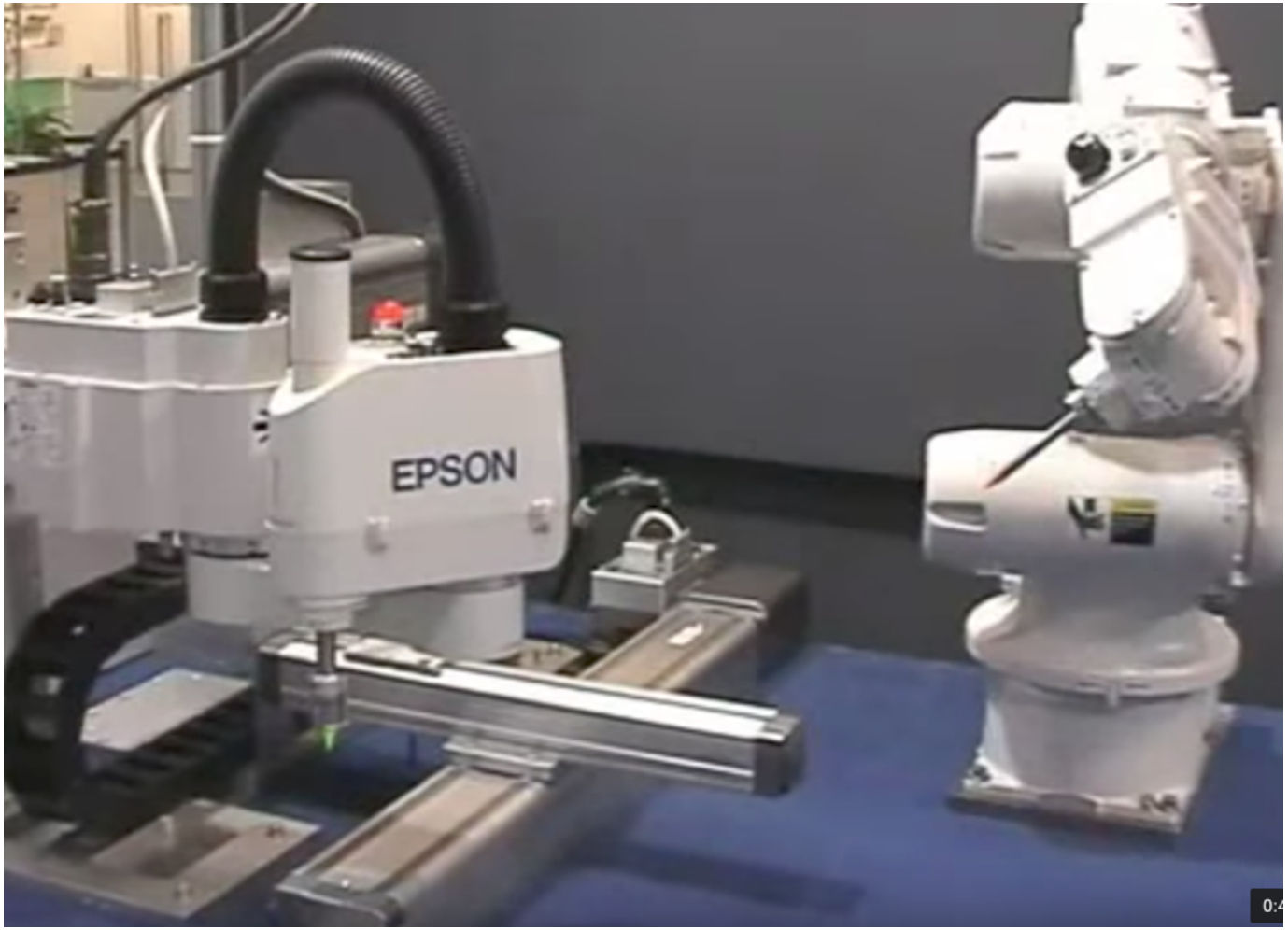
P. Cork, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer, 2011.

Robots as Humanoids or as Animals



We will study the kind of robots used in the industry

Robot Morphologies



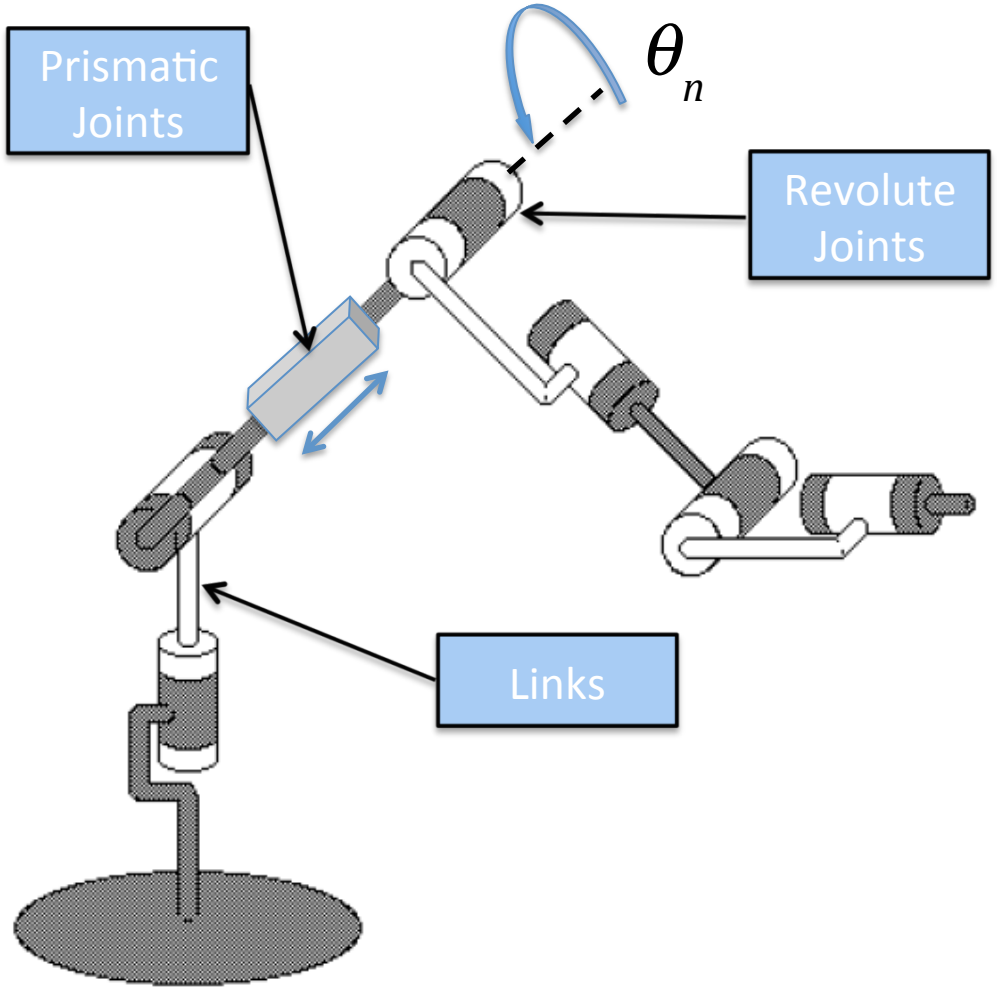
https://www.youtube.com/watch?v=AfJrNXgTQT8&index=7&list=PLCDA19AB0BE17E0A9

Robot Kinematics, Dynamics & Control

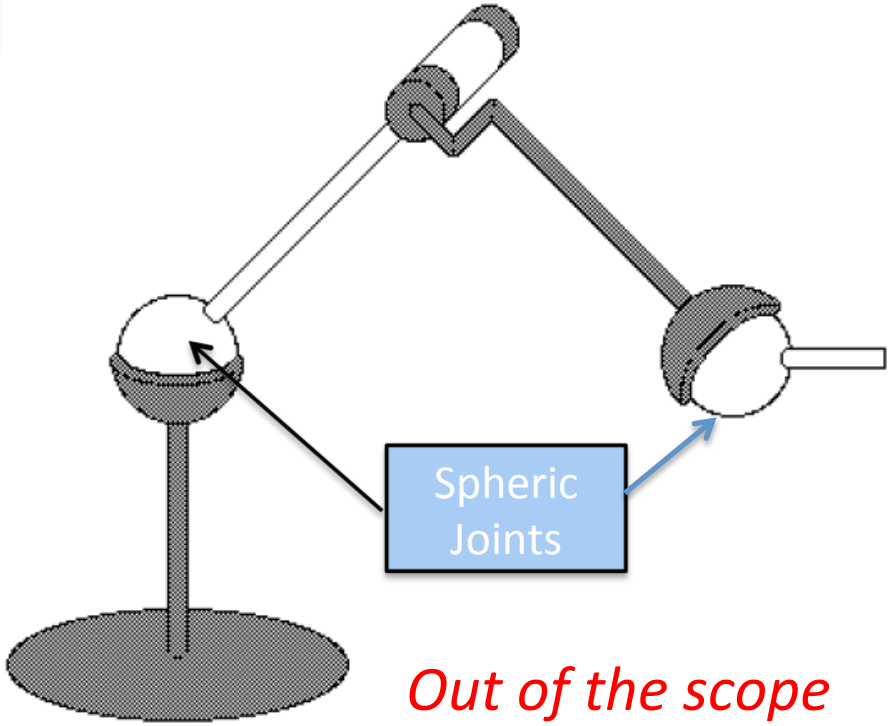
Kinematics
Dynamics
} *Mathematic models*

Trajectory
Motion control
} *Planning & Control laws*

Manipulators



2RP4R Robot Manipulator



Out of the scope of the course

2S Robot Manipulator

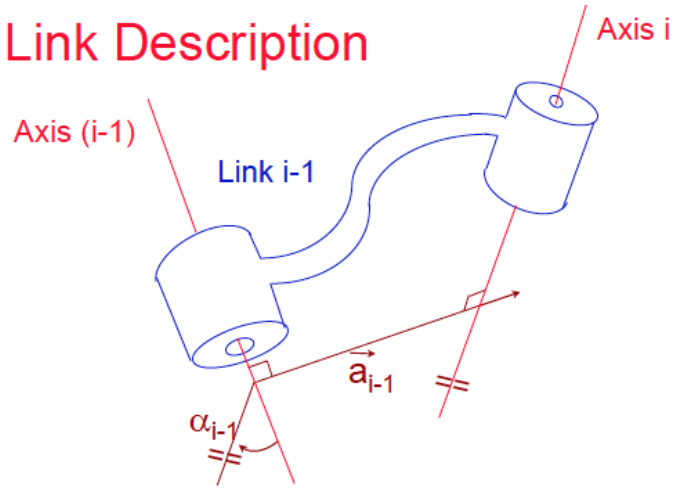
Spatial Description

- Position and orientation descriptions
- Transformations between frames

Manipulator Kinematics

- Link description
- Denavit-Hartenberg parameters
- Forward Kinematics

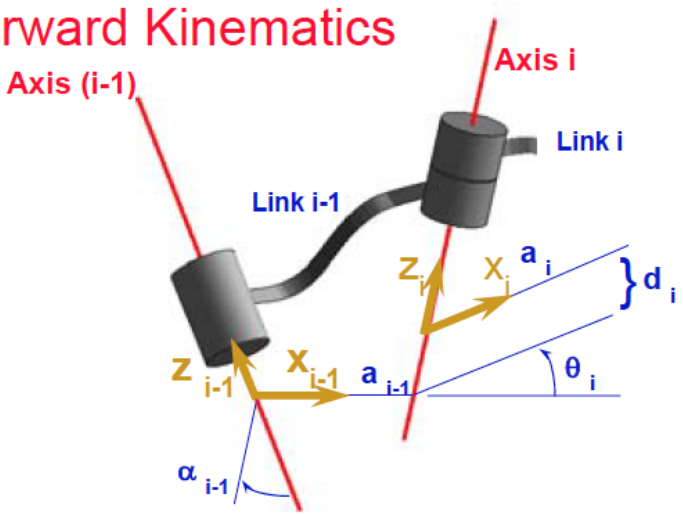
Link Description



a_{i-1}: Link Length - mutual perpendicular
unique except for parallel axis

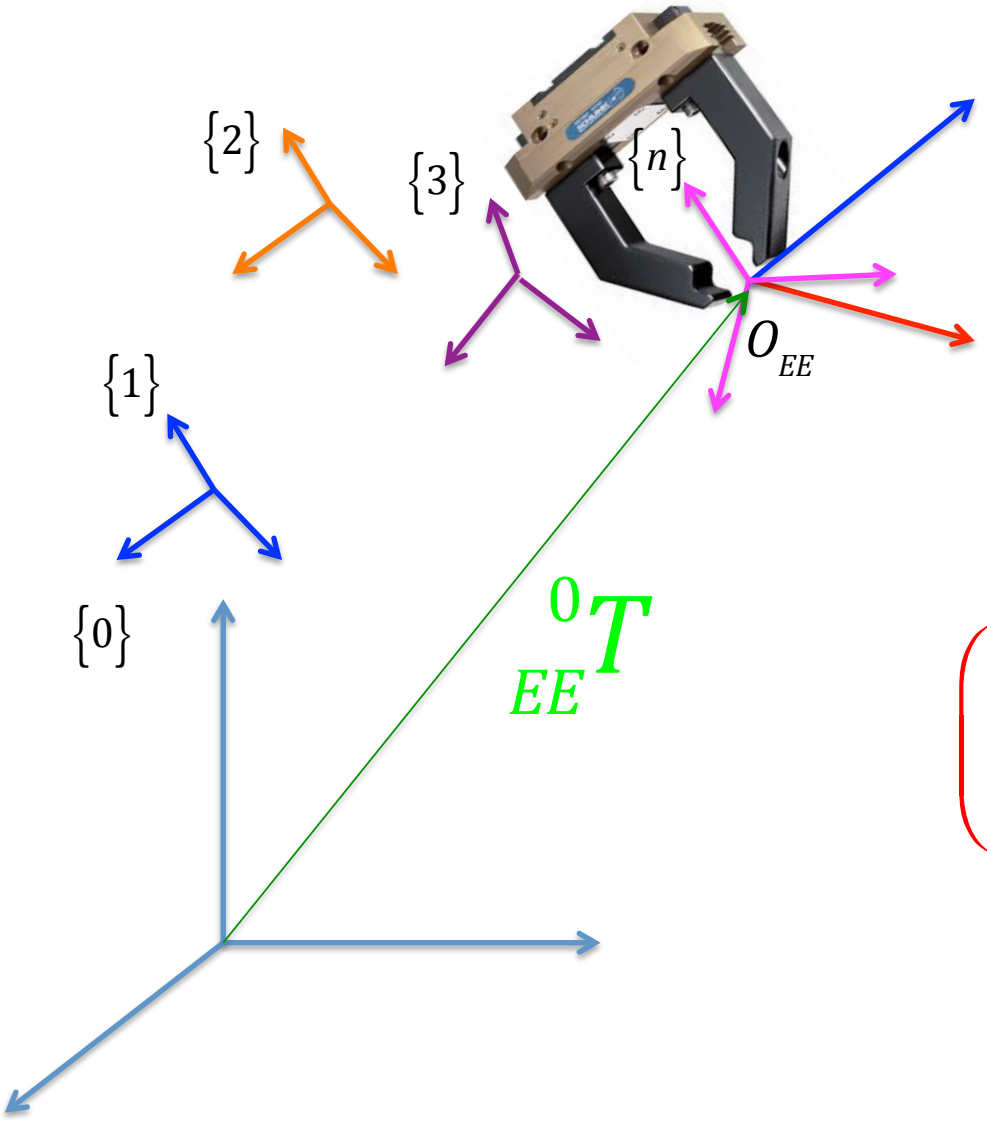
α_{i-1}: Link Twist - measured in the right-hand sense about $\vec{a}_{i-1}$

Forward Kinematics



Forward Kinematics: ${}^{0}_{N}T = {}^{0}_{1}T \; {}^{1}_{2}T \; \ldots \; {}^{N-1}_{N}T$

Jacobian: Velocity / Force duality



$v \rightarrow$ *Lineal velovity*

$w \rightarrow$ *Angular velovity*

O_{EE} :*Operational point*

$$\begin{pmatrix} v \\ w \end{pmatrix}_{6x1} = J_0(q)_{6xn}\,\dot{q}_{nx1}$$

$$\dot{x} = J\,\dot{\theta}$$

$$\tau = J^T F$$

Dynamics

- Rigid Body Dynamics
- Newton-Euler Formulation
- Articulated Multi-Body Dynamics
- Recursive Algorithm
- Lagrange Formulation
- Explicit Form

Joint Space dynamics

$$M(q)\ddot{q} + V(q,\dot{q}) + G(q) = \Gamma$$

q: Generalized Joint Coordinates

$M(q)$: Mass Matrix - Kinetic Energy Matrix

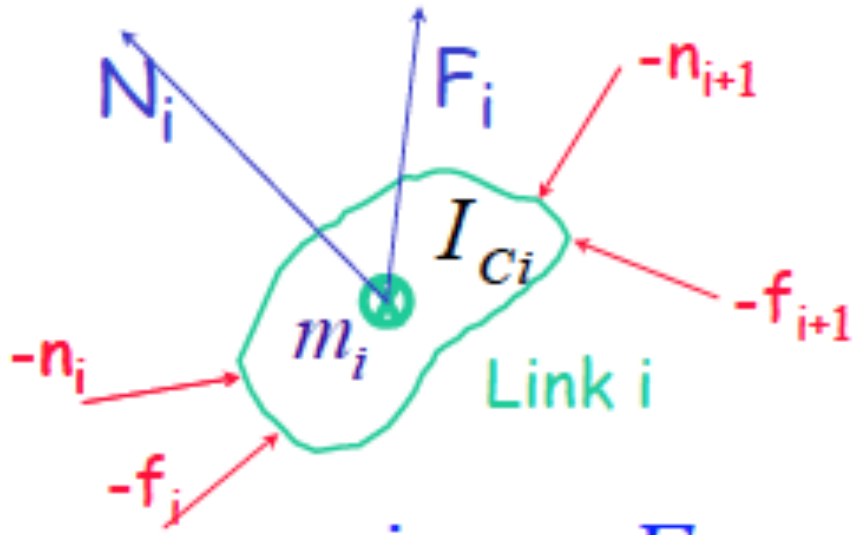
$V(q,\dot{q})$: Centrifugal and Coriolis forces

$G(q)$: Gravity forces

Γ: Generalized forces

Formulations

Newton-Euler



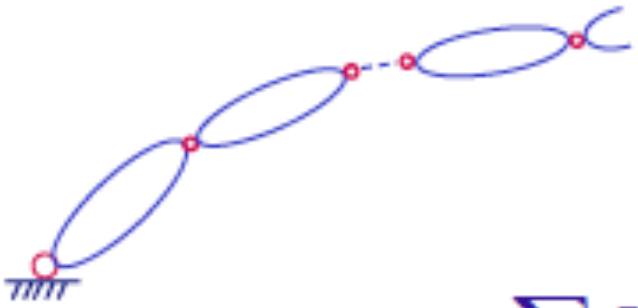
Newton: $m\dot{\mathbf{v}}_C = F$

Euler: $N_i = I_{C_i}\dot{\omega}_i + \omega_i \times I_{C_i}\omega_i$

Eliminate Internal Forces

$$\tau_i = \begin{cases} n_i^T . Z_i & \text{revolute} \\ f_i^T . Z_i & \text{prismatic} \end{cases}$$

Lagrange



Kinetic Energy: $\sum_i K_i$

Potential Energy

Generalized Coordinates

$$K = \frac{1}{2}\dot{q}^T M \dot{q}$$

$$M\ddot{q} + V + G = \tau$$

Trajectory Generation

- Path Description
- Joint Space Trajectories
- Cartesian Space Trajectories

Trajectory Generation basic problem:

Move the $\{EE\}$

from initial position $\{A\}$

to final *position* $\{C\}$

going through $\{B\}$

Inverse Kinematics

- Solvability, Existence
- Close Form / Numerical Solutions

Inverse Kinematics task:

Finding joint positions given end-effector pose

Manipulator Control

- PID Control
- Joint Space Dynamics Control
- Cartesian Space Dynamics Control