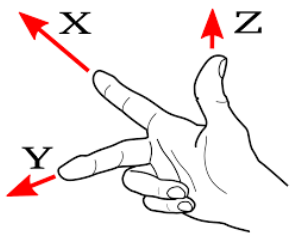
$$R_{x,\theta} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$



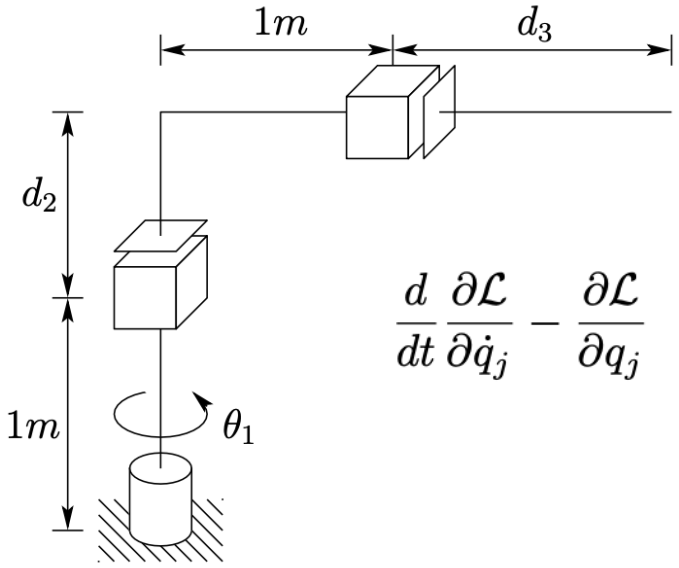


Link	a_i	α_i	d_i	θ_i
1	a_1	0	0	θ_1^*
2	a_2	0	0	θ_2^*

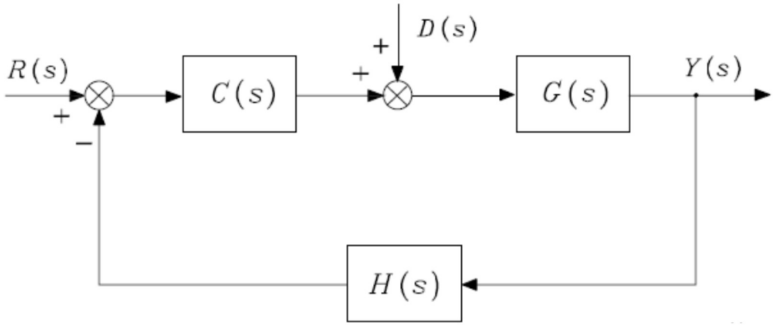


Seminar nr. 1 IN3140

Oscar & Claudia & the two others & Abdullah



$$\frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{q}_j} - \frac{\partial \mathcal{L}}{\partial q_j} = \tau_j$$





Lecture plan

Week #	Start-End	Lecture Topic	Mandatory Assignments
3	Jan 15 - Jan 18	Introduction	
4	Jan 22 - Jan 26	Homogeneous Transforms	**Start: Assignment 1**
5	Jan 29 - Feb 2	Forward Kinematics	
6	Feb 5 - Feb 9	Inverse Kinematics I	
7	Feb 12 - Feb 16	Inverse Kinematics II	
8	Feb 19 - Feb 23	Velocity Kinematics I	**Deadline: Assignment 1 (Feb 23, 23:59)** **Start: Assignment 2**
9	Feb 26 - Mar 1	Velocity Kinematics II	
10	Mar 4 - Mar 8	Dynamics I	
11	Mar 11 - Mar 15	Dynamics II	**Deadline: Assignment 2 (Mar 15, 23:59)** **Start: Assignment 3**
12	Mar 18 - Mar 22	Recap or xiolongbao.	
13	Mar 25 - Mar 29	NO LECTURE - Easter holidays	
14	Apr 1 - Apr 5	ROS (Robot Operating System) I	
15	Apr 8 - Apr 12	ROS (Robot Operating System) II	**Deadline: Assignment 3 (Apr 5, 23:59)** **Start: Assignment 4**
16	Apr 15 - Apr 19	Control Theory I	
17	Apr 22 - Apr 26	Control Theory II	
18	Apr 29 - May 3	AI and robotics	**Deadline: Assignment 4 (May 3, 23:59)** **Lab exercise - assignment 5 (May 3)**
19	May 6 - May 10	NO LECTURE - Ascension day	**Lab exercise - assignment 5 (May 6)**
20	May 13 - May 17	Recap lecture/exam preparations	
21	May 20 - May 24	Recap lecture/exam preparations	
22	May 27 - May 31	**Exam: 31. mai 15:00-19:00**	

Administrative stuff: communication channels

- E-mail
  - Oscar: oscarhbj@ifi.uio.no
  - Afsah: afsahar@ifi.uio.no
  - Claudia: claudaba@ifi.uio.no
  - Ola: olathor@ifi.uio.no
  - Abdullah: amalmuda@ifi.uio.no
  - Ege: eged@ifi.uio.no
  - OJ: oelle@ous-hf.no

- Course page: https://www.uio.no/studier/emner/matnat/ifi/IN3140/v24/index.html
  - We will decorate the course page with links to the learning material, messages, assignments, lecture notes and group sessions notes (etc..) – stay tuned :)

- We will also open a Mattermost channel and/or a Discourse channel as soon as possible! :D

Administrative stuff: assignments

- There will be 4 assignments and you MUST pass all of them to take the final exam.
- The assignments don’t count towards the final grade, only the exam counts.
- Platform for submission: https://devilry.ifi.uio.no/
- There will be another voluntary assignment 5 towards the end.
- You can get an extension for 3 CALENDAR days, if you ask for it BEFORE the deadline (via e-mail)
- You may get a second attempt – additional 3 WORK days
- Longer extensions or third attempts will involve the IFI administration

Administrative stuff: assignment tips

- Assignments are super relevant for the exam!!!!
- Try your best on all tasks (you will thank yourself later :D)!!
- The tasks build on each other!!
- Read the assignment text and the requirements!!!!



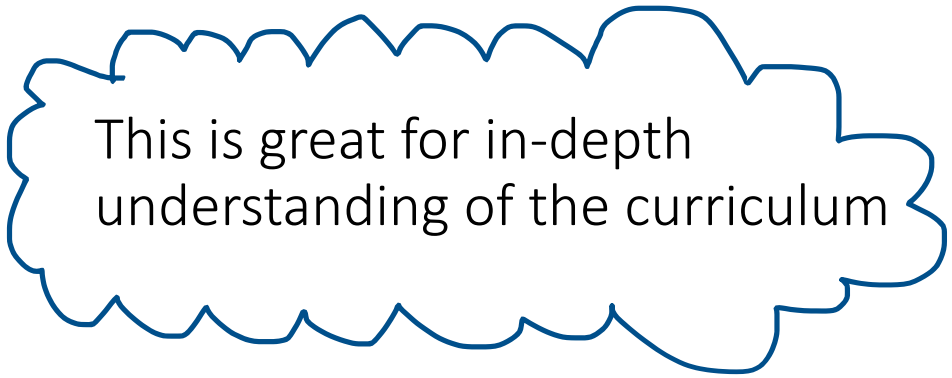
Administrative stuff: learning materials

- **Course book**: Mark W. Spong, Seth Hutchinson, M. Vidyasagar: Robot Modeling and Control, 2005. Wiley. ISBN: 978-0- 471-64990-8.
  - https://bibsys-almaprimo.hosted.exlibrisgroup.com/primo-explore/search?vid=UIO&tab=default_tab&query=any,contains,051848953
  - Or the 2020 version is fine as well!

- GitHub: https://github.uio.no/IN3140/Groupsessions

Lectures and group sessions

- Lectures:
  - Theoretical review of the curriculum
  - Relevant example calculations



- Group sessions:
  - Repetition from the lectures
  - Practical examples relevant for exam and assignments
  - Time to work on tasks and assignments
  - And time to ask lots of questions :)



Focus of the course

Robotic manipulators (“robot arms”):

→ how they work

→ how they move

→ how to calculate their movements

→ how to program them

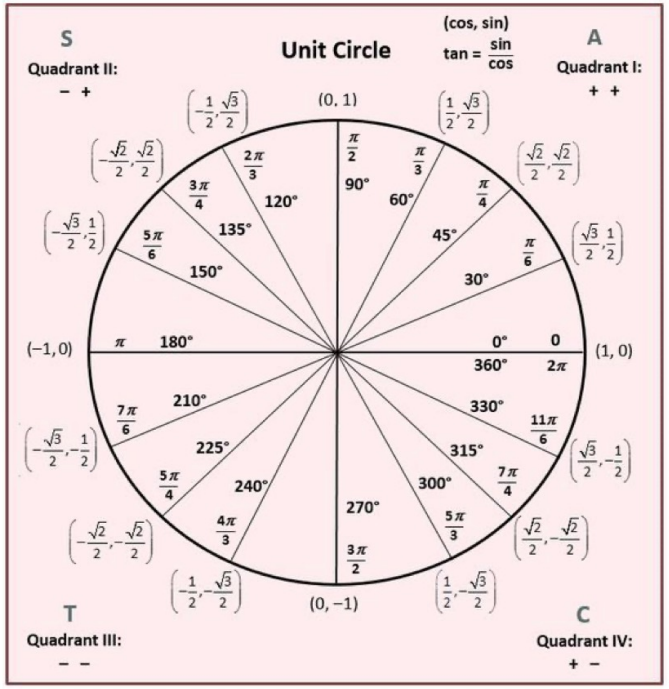


Course topics

- Homogeneous Transformations: math for linear movement and rotations, written as 4x4 matrices
- Forward kinematics: given joint angles and extensions, find where the arm tip is
- Inverse kinematics: given position of the tip, find joint angles and extensions
- Velocity kinematics: given velocity of joints, find velocity of tip
- Dynamics: how to find force/torque equations (yes, physics…)
- Robot Operating System (ROS): how to program real robots
- Control theory: how to control robot movement to make it smooth

Expected prior knowledge: trigonometry

- Sine, cosine and tangent
- Sin and cos of 0, 30, 60, 90 and 180 degrees
  - Or use the unit circle
- Trigonometric identities:
  - http://www.sosmath.com/trig/Trig5/trig5/trig5.html
- Abbreviated notations:
  - $\sin(\theta_1) = s_1$
  - $\cos(\theta_1) = c_1$
  - $\sin(\theta_1) * \cos(\theta_2) = s_1 c_2$



Expected prior knowledge: other things

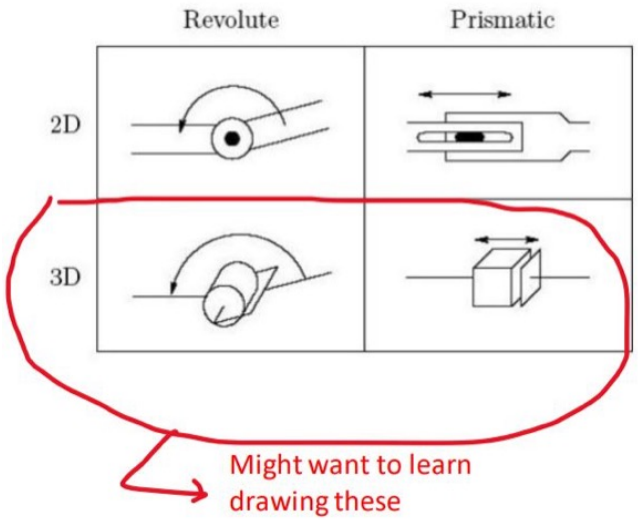
- Math:
  - Matrix multiplication (used in kinematics)
  - Differentiation + differentiation rules (used in dynamics)
- Physics:
  - Newton's laws, force formulas etc. (used in dynamics)
- Programming:
  - Basic Python skills
  - Packages: numpy and sympy

Recap from lecture: manipulator structure

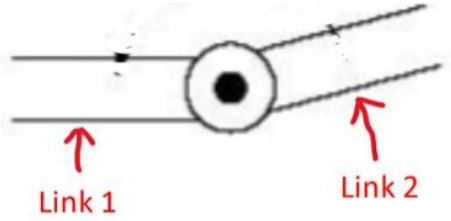
A manipulator is typically made up of joints and/or links and an end-effector.

Joints: revolute (like your elbow)

or prismatic (telescopic)



Links: the “bones” of the manipulator

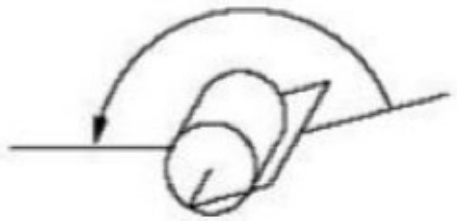


End-effector: a tool at the end of the manipulator (a gripper, welding torch, paint sprayer etc)

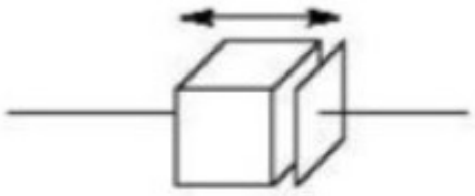


<--- gripper

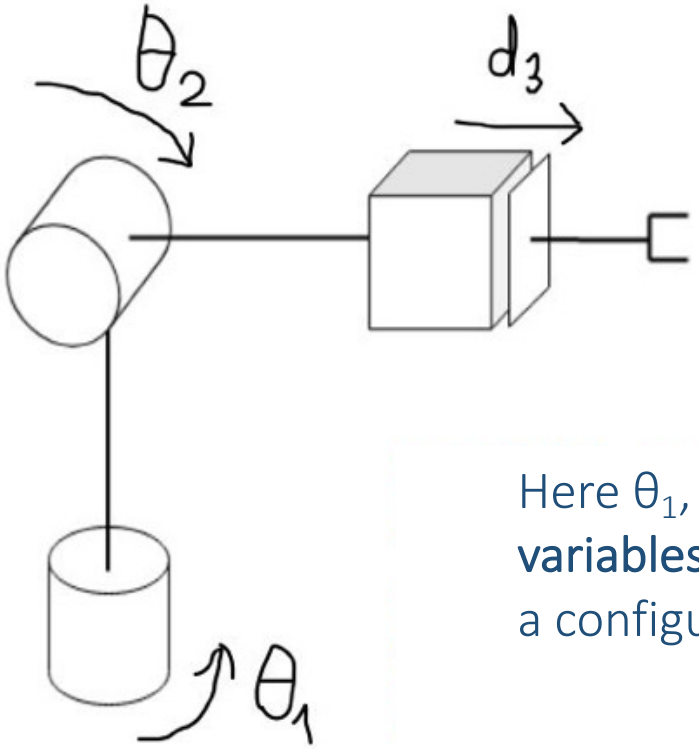
Recap from lecture: joint variables



Rotation angle of a revolute joint: θ (measured in radians or degrees)



Extention length of a prismatic joint: d (measured in meters or millimeters)



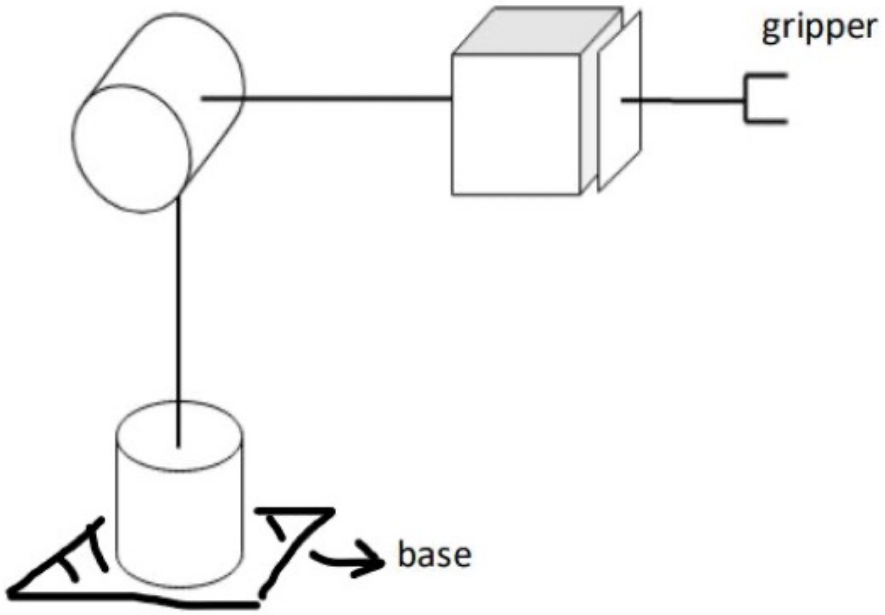
Subscript corresponds to joint number

Here θ_1, θ_2, and d_3 are **joint variables**. Together they from a configuration vector q:

$$q = \begin{bmatrix} \theta_1 \\ \theta_2 \\ d_3 \end{bmatrix}$$

Recap from lecture: manipulator drawing

- Manipulator with 3 joints - 3 Degrees of Freedom (DOF)



→ You will have to draw diagrams like these

Manipulator classification:

By joints: starting from the base and adding to the name an R for revolute joints and a P for prismatic joints

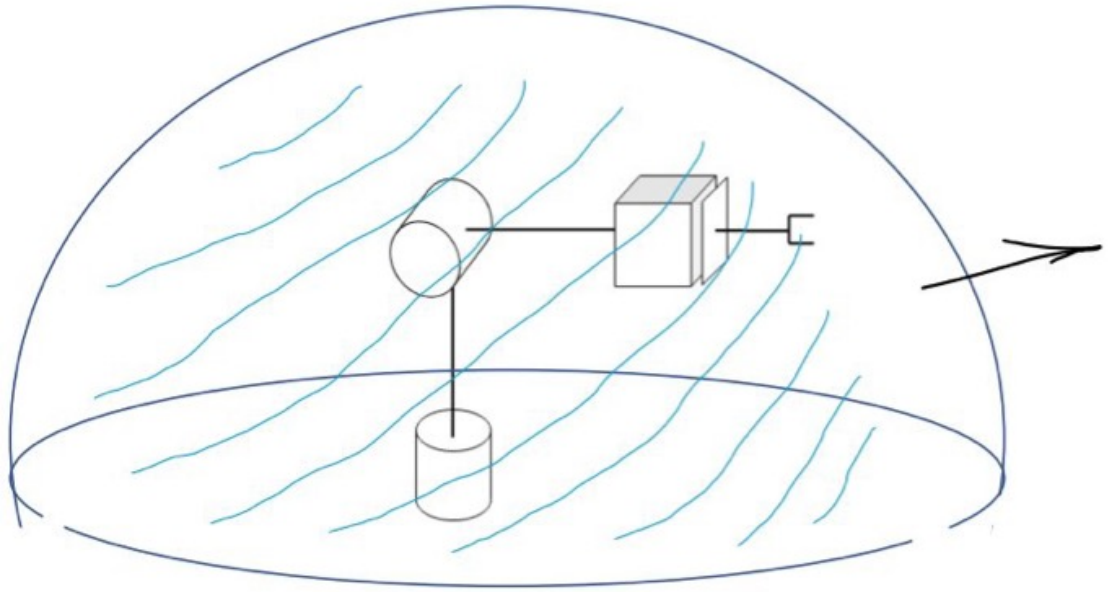
→ Revolute joint + revolute joint + prismatic joint = RRP

By workspace: classifying the manipulator from its workspace

→ spherical

Recap from lecture: workspace

- Workspace: all the points the manipulator can reach



Workspace is half a sphere → the manipulator is a **spherical manipulator**

→ When asked to draw the workspace, draw the workspace AND the manipulator

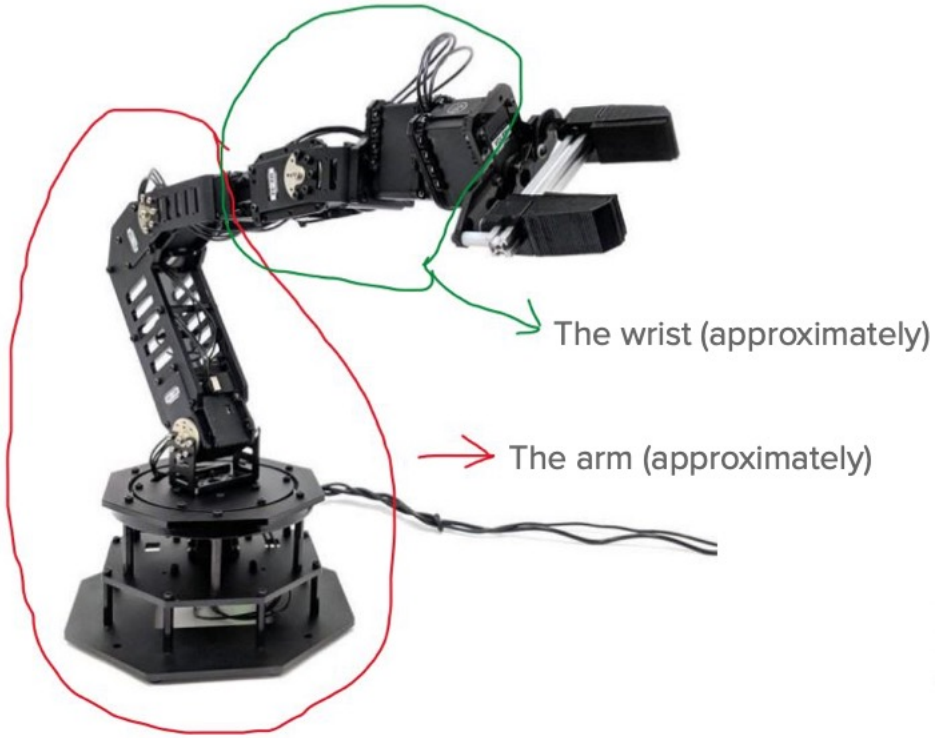
→ When drawing the workspace, consider the joints and how they move – use your imagination and spacial intelligence to draw

Recap from lecture: DOF and wrists

- DOF = Degrees Of Freedom

- The wrist by itself is usually 3DOF
- A "complete" manipulator is usually 3DOF of the arm + 3DOF of the wrist = 6DOF.

- You will normally work with 2-4 DOF manipulators in this course
- You will not be expected to do calculations for 6DOF – near impossible to handle without a computer
- Rule of thumb: if more than 3 joints, run to your computer :D



A human arm has a writs - sometimes a manipulator also has one :)