Durham University

Robotics – Planning and Motion

Manipulators

COMP52815

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Lecture 3: Learning Objectives

We will introduce the relevant terminology to describe how a manipulator is configured and operates

- Objectives:
  - Introduction to Manipulators
  - Manipulators and joints

Robotic Manipulators

A wide range of robotic manipulators exist. Typically, all manipulators represent a different price, performance & capability trade-off.

Manipulator Application (before)

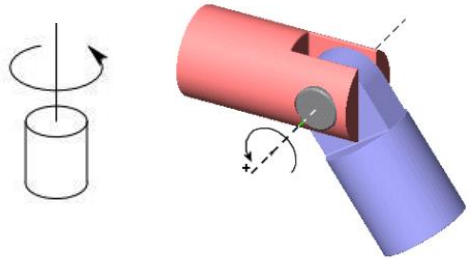
Benefits in repetitive operation:

- Increase volume / capacity
- Improve quality and consistency
- Untouched by human hand
- Reduce wastage
- “Up skilling” of work force

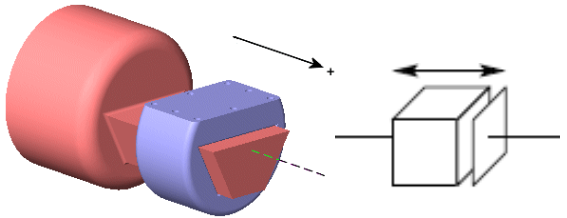
A Return On Investment (ROI) study would be performed to quantify these factors and justify the investment in a bespoke robotics solution.

Joints

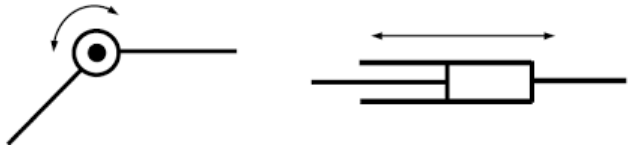
- Different types of joints:



Revolute Joint **(R)**

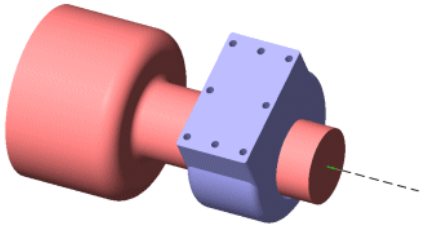


Prismatic Joint **(P)**

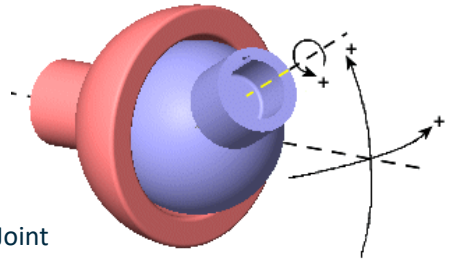


Joints

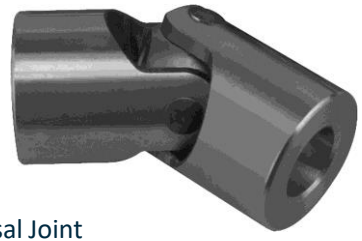
- Different types of joints:



Cylindrical Joint



Spherical Joint

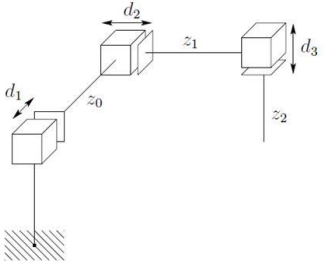


Universal Joint

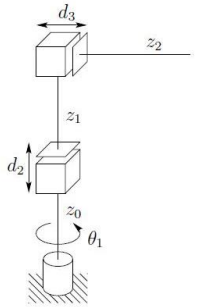
Manipulators

Different types of manipulator:

- Cartesian PPP



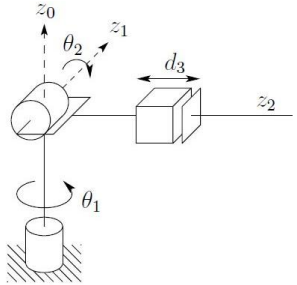
- Cylindrical RPP

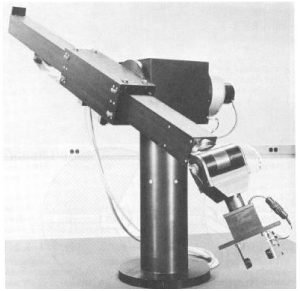


Manipulators

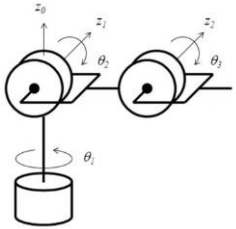
Different types of manipulator:

- Spherical RRP





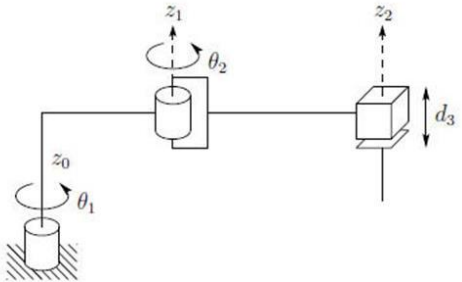
- Articulated RRR



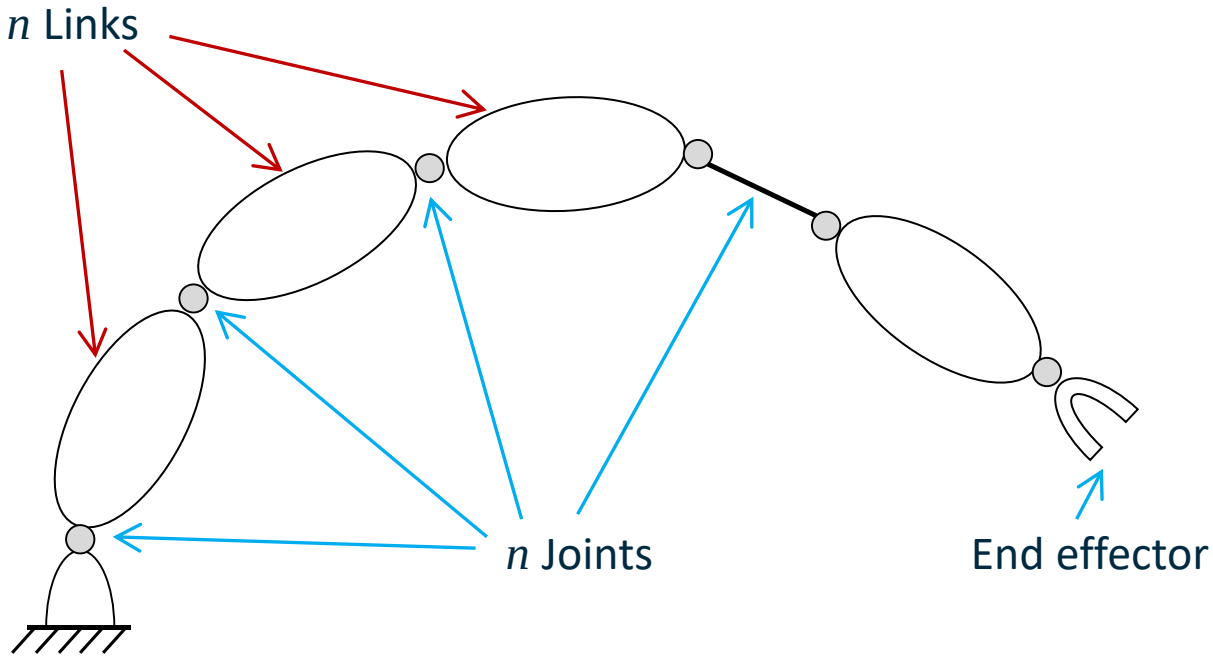
Manipulators

Different types of manipulator:

- SCARA, RRP

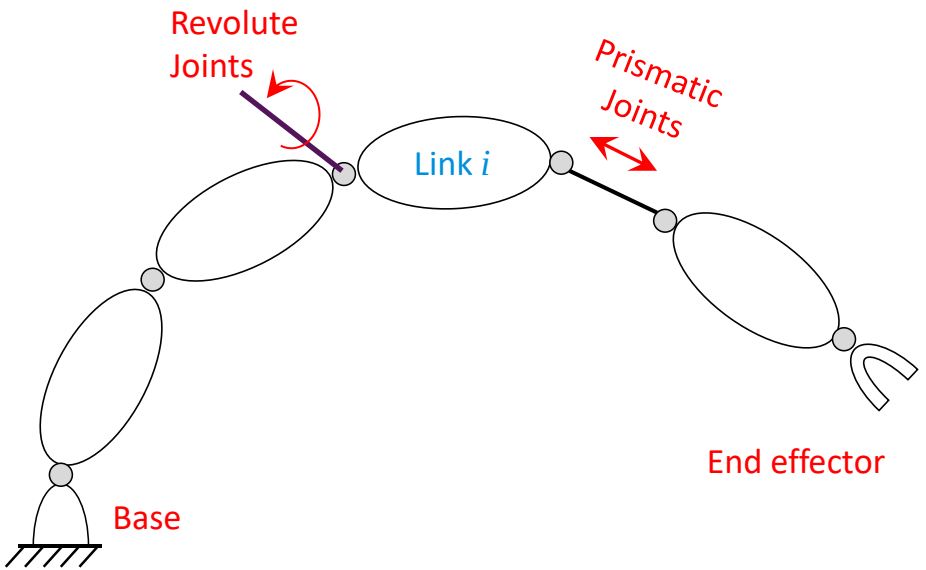


Manipulators Configuration



Manipulator

- Links:
  - n moving link(s)
  - 1 fixed link
- Joints
  - Revolute (1 DOF)
  - Prismatic (1 DOF)

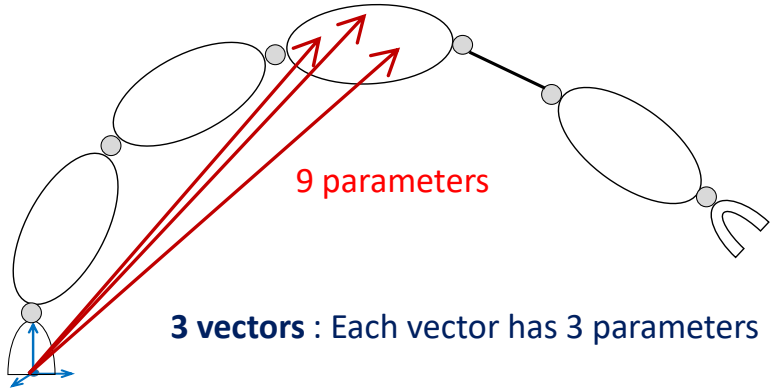


Position Parameters

Position parameters describe the full configuration of the system

If we have *n* link?

9*n* parameters



Generalised coordinates:

A set of independent configuration parameters

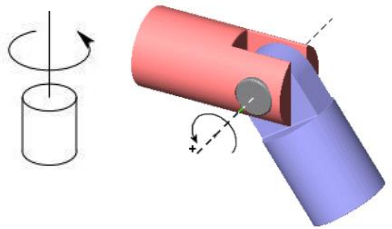
Degree of Freedom:

Number of generalised coordinates

Position Parameters

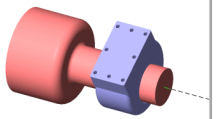
- We need 6 DOF to have access to all space
  - 3 DOF : Position
  - 3 DOF : Orientation

Revolute and prismatic joints have 1 DOF

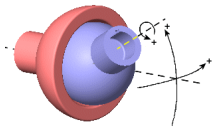


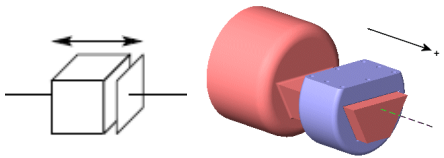
Revolute Joint

How about Cylindrical joint?



How about Spherical joint?





Prismatic Joint

Generalised coordinates:

- A set of independent configuration parameters
- Each rigid body needs 6 parameters to be described
  - 3 positions
  - 3 orientations

- For *n* rigid body, we need 6*n* parameters
- Constrains must be applied:
  - Each joint has 1DOF, so 5 constrains

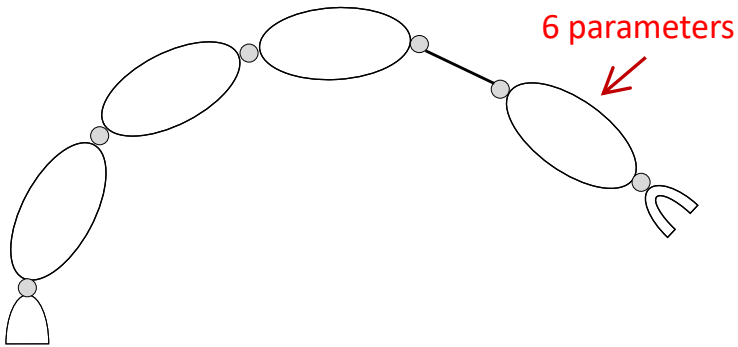
  will be introduced.

n moving links → 6*n* parameters
n joints → 5*n* constrains

How many DOF?

$6n - 5n = n$ DOF

This is for manipulator with fixed base



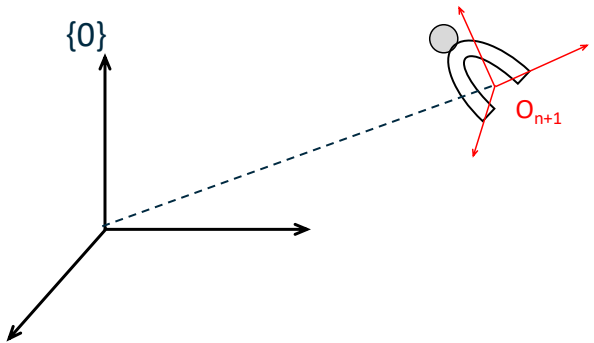
End effector configuration

End effector is the last rigid-body and it has all the freedom from previous links.

A set of parameters describing position and orientation of the end effector:
$(x_{1,}, x_2, x_3, ..., x_m)$ with respect to {0}
O_{n+1} : is operational coordinates (task coordinates)

A set of $x_{1,}, x_2, x_3, ..., x_{m_o}$ of m_o independent configuration parameters

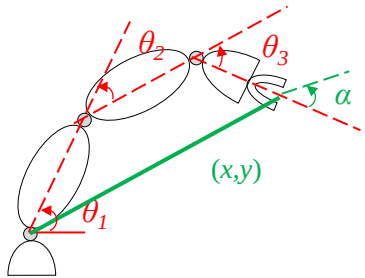
m_o is number of DOF of the end effector,
max 6 DOF



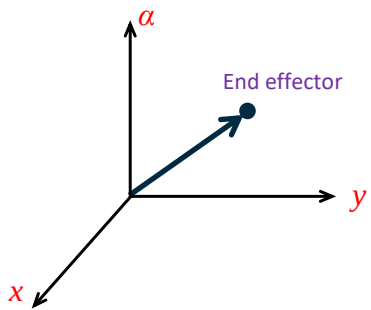
End effector, Joint coordinate:

Joint space (configuration space) is the space that a manipulator is represented as a point.

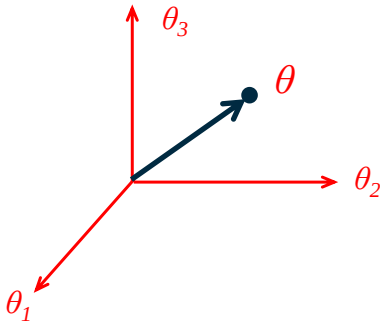
(x,y) is a vector for position of end effector
α defines orientation (angle) of end effector



Defines:
operational coordinates → Operational space



End effector in operational space

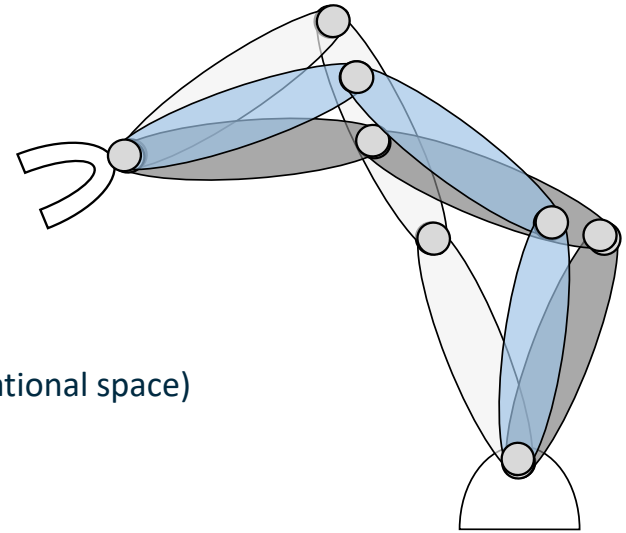


Robot is configuration space

Redundancy

A manipulator is redundant if

$$n > m$$



n number of DOF of the manipulator

m number of DOF of the end effector (operational space)

Degree of redundancy: $n - m$

General Manipulator Videos

- Where it all began (in the 70s)

http://www.youtube.com/watch?v=2xNgQhLAPyI

- ***Precise motion control***

http://www.youtube.com/watch?v=SOESSCXGhFo

- 10 application areas for robotics

http://www.youtube.com/watch?v=fH4VwTgfyrQ

- Programming robots

http://www.youtube.com/watch?v=acJ3WDnoDCM

- Couple of FlexPicker videos

http://www.youtube.com/watch?v=8G59zTXVHHU

http://www.youtube.com/watch?v=KC70eDs1D2Y

- Robotics for Extreme Environments

https://www.bloomberg.com/news/features/2017-02-16/one-job-the-robots-can-have-cleaning-nuclear-waste

https://www.youtube.com/watch?v=OLvAQFz5wh8&t=171s

Lecture 3 Summary

- Introduction to robotic Manipulator
- Joints
- Position parameters
- End-effectors