41013 Industrial Robotics

Overview

- Staff
- About you
- Class Structure
- Can you be at UTS?
- Assessments
- Quizzes
- Textbook
- General Rules
- Lab Exercises

Staff



- Subject Coordinator
  - Gavin Paul
- Lecturers
  - Teresa Vidal-Calleja
  - Marc Carmichael
- Tutors
  - Jonathan Woolfrey
  - Sheila Sutjipto
  - Tony Le
  - Nuwan Munasinghe
  - Thanh Vu
  - Federico Albano
  - Khoa Nguyen





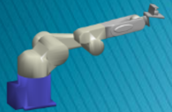


About You?

- Who has done Mx1 or FoMxE with me?
- Played with an industrial robot (manipulator)?
- Visited / worked in CAS?

What coding languages have you used?

https://www.menti.com/qr6hgn4hyf



Class Structure

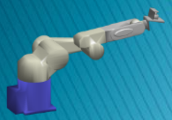
- 3-hour of weekly support at UTS from Wed @ 11:00 in CB11.B1.203-204
  & simultaneously on Zoom (link) supported by Teams (link)
- Learning material (e.g. links, lectures, exercises & videos) on UTSOnline (Canvas)
- Do the pre-work before class time
  - read the Canvas pages, textbook pages and slides
  - watch the videos
  - carefully go through the "Lab Starter" (i.e. write + run + play with code)
  - attempt "Lab Exercises" then participate during class time to interact with others
  - watch the "Lab Solution" after class
- Discussion board (Teams/Canvas): responses within 2 weekdays
- For private (non-technical) matters, DM / email Gavin

Assessable task in class time
100% online assessment tasks
No assessment but you should join us

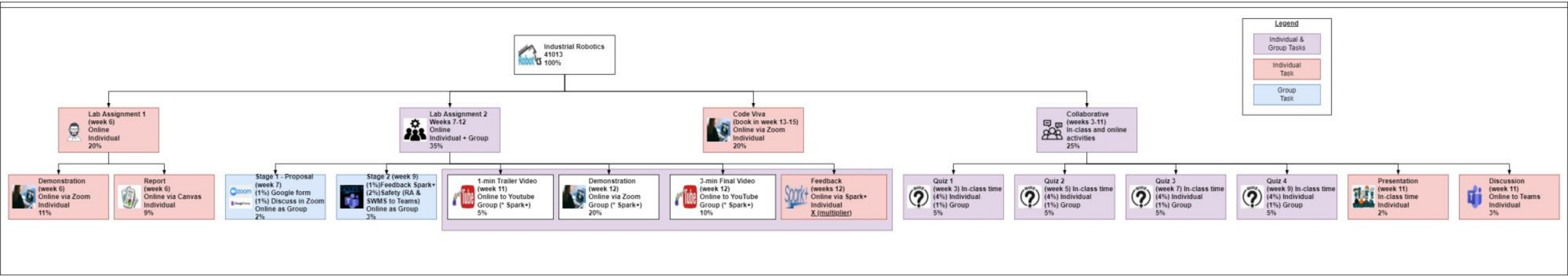
- Weekly overview:

1	2	3	4	5	6	7	8	9	10	11	12	13	14

  - Quiz in class (practice in Week 2, and assessable in Weeks 3,5,7,9),
  - Demonstration and vivas online via Zoom for Lab Assignments (Weeks 6 and 12, then sometime 13-14),
  - Assessed presentations and discussion about robots affecting our world (Week 11)



Assessments



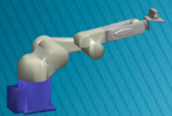
- Assessment 1 (25%): 4x Online, in-class quizzes, limited open book worth 5% each, plus an in-class & online discussion 5%
- Assessment 2 (20%): Individual Lab Assignment 1 20%
- Assessment 3(35%): Lab Assignment 2 both individual and group parts
- Assessment 4 (20%): Code viva
- For Lab Assignments 1 & 2 and Viva
  - You will book via Airtable a Zoom with a tutor (recorded for standardisation by me only)
  - Reports are submitted via UTSOnline TurnItIn
  - Videos are shared in Teams
  - For Autumn 2022 the use of real robots in is encouraged but not mandatory. It is assessed only if you choose for it to be assessed
- Details of Assignments are on UTSOnline

Quizzes (weeks 3,5,7,9) + Practice in Week 2

- Warning: Next slide is busy!

Quizzes (weeks 3,5,7,9) + Practice in Week 2

- From start of class time, so log into single PC and setup Matlab & Toolbox
- **Limited** open book:
  - CAN use Canvas resources provided, textbook, Matlab Toolboxes + its documentation, and your prepared code
  - CANNOT use Word/Excel documents or databases (online or local) with stored Q&A, nor any method of communicating about the Quiz with anyone else except tutors
- Individual "in-class" Quiz – First ≈30 minutes – Worth 4%
  - **Where are you?**
    - **In classroom:** You'll get a password then tutors will monitor you and your screen. May ask for student card.
    - **100% online students:** You'll be DMed a Zoom link & Quiz password. Share your face & entire PC desktop throughout the quiz. Show all working out.
  - Only a 1 PC may be used. Separate devices must not be used (no phone, calculator, other computer).
  - Must attain 80% in every quiz (can "re-attempt" if required)
  - Mark for subject is **only the first** "in-class" attempt
  - Onramp course certificate uploaded before Quiz 1
- Group "team" Quiz (groups of 2-3 people) – Next ≈ 20 minutes – worth 1%
  - Group is pre-allocated and DIFFERENT EVERY TIME
  - Once everyone in your group is ready to start you may start
  - Keep siting at your own computer, communicate online (only within team), divide & concur the questions
  - If 1 person is away don't write their name in. If 2 people are away talk to Gavin

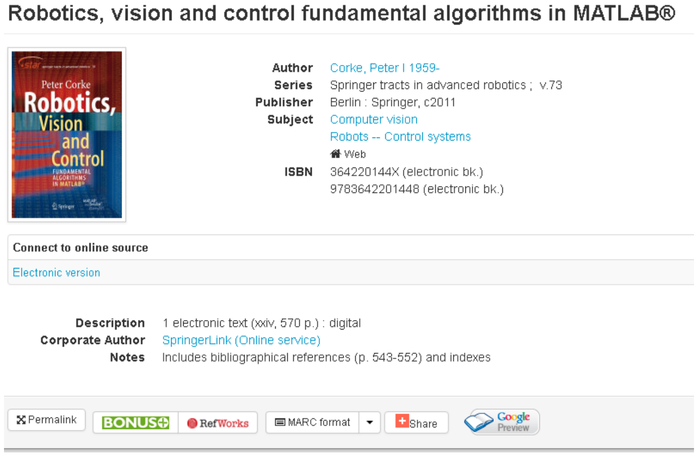


Textbook, Software & Toolbox

- Textbook: Available for free online from the UTS Library.

- Software: Matlab and we recommend (2020a). It is free to download for UTS students.

- Toolbox: a modified version of Peter Corke's Robotics Toolbox for Matlab that accompanies the textbook. Download link on Canvas.


Robotics, vision and control fundamental algorithms in MATLAB®

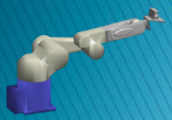
Author	Corke, Peter I 1959-
Series	Springer tracts in advanced robotics ; v.73
Publisher	Berlin : Springer, c2011
Subject	Computer vision
	Robots -- Control systems
	Web
ISBN	364220144X (electronic bk.)
	9783642201448 (electronic bk.)

Connect to online source

Electronic version

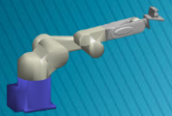
Description	1 electronic text (xxiv, 570 p.) : digital
Corporate Author	SpringerLink (Online service)
Notes	Includes bibliographical references (p. 543-552) and indexes

Permalink BONUS+ RefWorks MARC format Share Google Preview



General Rules

- Academic Conduct
  - Plagiarism detection tools will be used
  - Be respectful on discussion boards
- Late submissions (assignments)
  - Penalty: -10% per day, Up to 5 days (then 0% is awarded)
- Quizzes
  - No attendance or late = 0, must redo in own time till an 80% mark reached
- Extenuating circumstances: formally required to apply for Special Consideration
- Peer Review
  - Used for peer review and feedback (i.e. Spark+)
- Feedback provided
  - During and after demonstrations
  - For each assignment on UTS Online



Scenario 1: Collaboration or Copying?

- Gavin’s mum has been sick so he didn’t do assignment 1. Sheila did the subject last year, so he borrows her code to have a look. He ends up using most of her code, but he changes the variable names and comments so the TurnItIn score is low.

- Is this collaboration or copying?
- What could Gavin/Sheila have done better?

Voting link

Scenario 2: Collaboration or Copying?

- Nuwan's been busy with work so he missed a few key classes, and he cannot finish assignment 1. He asks Teresa what lecture and code examples he should look at to finish part 3. Teresa sends him the code presented in class and a link to the lecture.

- Is this collaboration or copying?
- What could Nuwan/Teresa have done better?

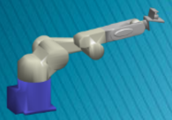
Voting link

Discussion (2 minutes)

- *“Robotics Assignment 2 is a group coding & robot demo followed by a video submission and a separate assessment for the code viva.”*
- Discuss with people nearby: what does this mean to you?

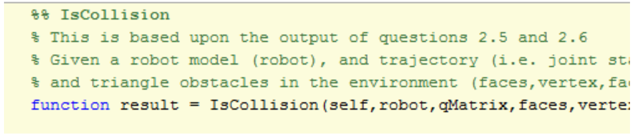
Code/Model Plagiarism (1 of 2)

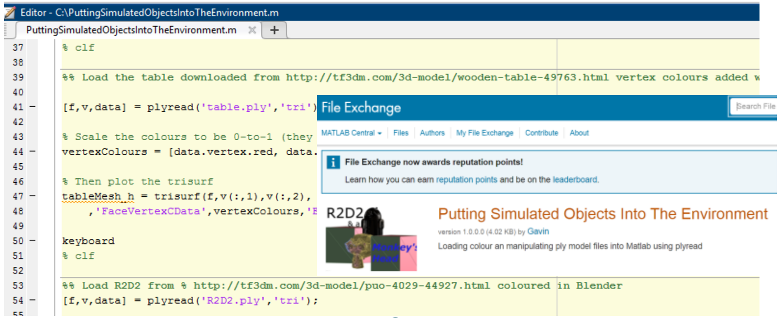
- What is NOT ok?
  - Copying a previous student's models and changing the filename (to avoid detection)
  - Copying a previous student's code and
    - doing find/replace so the variable/ function names are different
    - Just adding more comments to the original code
    - Minor reordering of code blocks to try to avoid detection
- Detection
  - Turnitin on code submissions is easy to get around
  - However, I have Matlab scripts, Excel macros and other tools to compare files and to find big patches of code similarity
  - Also, I have run the subject from inception, and the tutors Jonathan and Sheila have been involved from the start too
  - The combination of identical files and code which overlaps (without any fundamental IP addition) plus a difficulty explaining pieces of code, makes plagiarism detection and misconduct proceedings straightforward (but emotionally draining for everyone)
- We care about the subject integrity and your learning outcomes!!



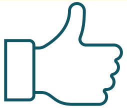
Code/Model Plagiarism (2 of 2)

- What is ok?
  - Write your own code from scratch
  - Tell us clearly in the demo that you got someone else's model/code and don't want to be marked on it, but you included it for some reason (e.g. safety)
  - Use our subject's, toolbox's (or an internet source's) code/models with clear reference to it



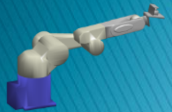


Let's do the right thing!



LMS, Resources and Communication

- Show:
  - Subject outline
  - Matlab (2020a) & PC's Robotics Toolbox
  - Labs (Starter -> Exercise -> Solution video and code)
  - Assignments/Quizzes
  - Teams (@Tutors, no DMs to tutors)
  - Canvas discussion board for Modules
  - Expected work and prerequisites
- Remember to do:
  - Onramp course and certificate before Quiz 1 (week 3)
  - Mechatronics lab induction (if on campus)



Canvas Modules

- Show learning material layout in Canvas for 5-10 minutes

Lab 1 Exercise (Sheila)

- Talk through in Canvas for 5 minutes

Note/slides from the textbook

- Textbook readings for week 1:
  - Chapter 1 (pages 1–6): "Introduction"
  - Chapter 2 (pages 15–23): "Representing Position and Orientation"

- It is better to read the textbook, however some notes (in slide format) are included

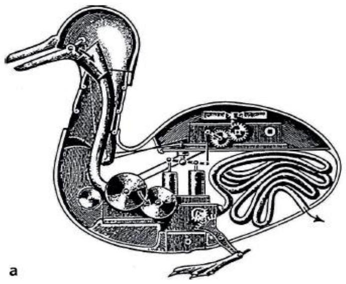
Introduction

- "Robot" means different things to everyone
- Science fiction has influenced what people expect a robot to be or do
- Sadly, robotics fails to live up to popular myth
- Robotics will be an important technology going forwards
- Smart machines (e.g. vacuum cleaner robots) will increasingly be in our homes/workplaces.

Roomba
http://www.irobot.com.au/Home-Robots/Vacuum-Cleaning

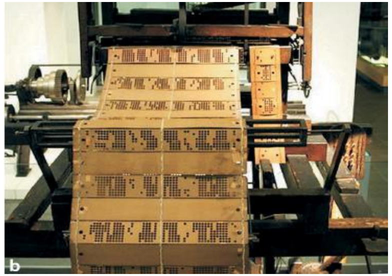
Early Programmable Machines

- Vaucanson's duck (1739) was an early programmable machine
  - Could flap its wings, eat grain and defecate
  - Driven by a clockwork mechanism
  - Executed a single program



a

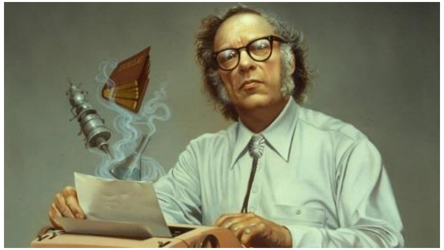
- The Jacquard loom (1801) was a reprogrammable machine
  - Program was held on punched cards



“Robot”

- Term “robot” coined in 1921 Czech science fiction play “Rossum’s Universal Robots” by Karel Capek
- Isaac Asimov’s robot stories (1950-1985)
  - Explored issues of human robot interaction and morality
  - Robots equipped with “positronic brains” encoded with the “Three laws of robotics”
  - Influenced subsequent books and movies which have shaped the public perception of robots

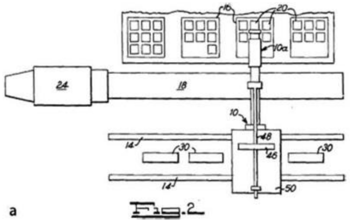
*



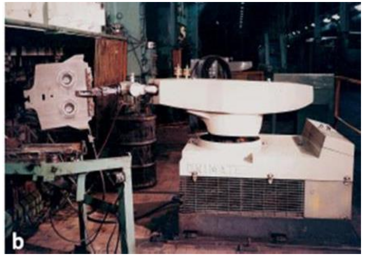
- In the mid 20th century, “cybernetics” was “an exciting science at the frontiers of understanding life and creating intelligent machines”

* Dvorsky G. (2016) Why Asimov's Three Laws Of Robotics Can't Protect Us Gizmodo

Robots Enter Industry



- First robot patent in 1954 by G.C. Devol
  - Comprised a mechanical arm with a gripper mounted on tracks
  - The sequence of motions was encoded as magnetic patterns stored on a rotating drum



- First robotics company "Unimation"
  - Founded by Devol and Engelberger in 1956
  - Installed their first industrial robot in 1961
- Millions of arm-type robots have been put to work
- Many products are assembled or handled by robots
- Robots have led to increased productivity and improved product quality
- Rather than take jobs they help keep manufacturing industries viable in high-labour cost countries

Manufacturing robots as a subclass of Robotics

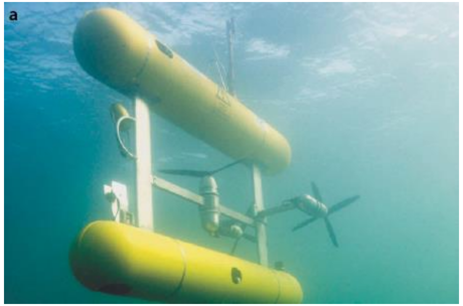
- 1st gen. robots are now a subclass of robotics known as "*manufacturing robots*"
  - Typically an arm-type manipulator on a fixed base that perform repetitive tasks within a local work cell
  - Parts are presented in an orderly fashion to capitalise on the robot's high speed and precision
  - High-speed robots are hazardous and safety is achieved by excluding people from robotic work places.
- Other subclasses include:
  - *service robots* – supply services such as cleaning, personal assistance or medical rehabilitation;
  - *field robots* – work outdoors or outside a controlled cell
  - *humanoid robots* – have the physical form of humans

Challenges for Field and Service Robots

- These robots must:
  - Operate and move in a complex, cluttered and changing environment
    - A hospital delivery robot must operate despite crowds of people and obstacles
    - Mars rovers must navigate rocks and small craters despite not having an accurate local map in advance of its travel.
    - Robotic cars, such as “Google Car” must follow roads, obey traffic signals and the rules of the road.
  - Operate safely in the presence of people
    - The hospital delivery robot operates amongst people,
    - the robotic car contains people and
    - a robotic surgical device operates inside people.

Non land-based mobile robots

- SeaBed type Autonomous Underwater Vehicle (AUV) operated by the Australian Centre for Field Robotics



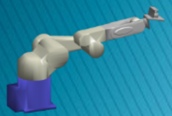
- Global Hawk
  unmanned aerial vehicle (UAV) (NASA)

What is a Robot?

“a goal oriented machine that can sense, plan and act.”

- A robot
  - *senses* its environment
  - uses that information,
  - together with a *goal*,
  - to *plan* some *action*.

- The action might be to move the tool of an arm-robot to grasp an object or it might be to drive a mobile robot to some place

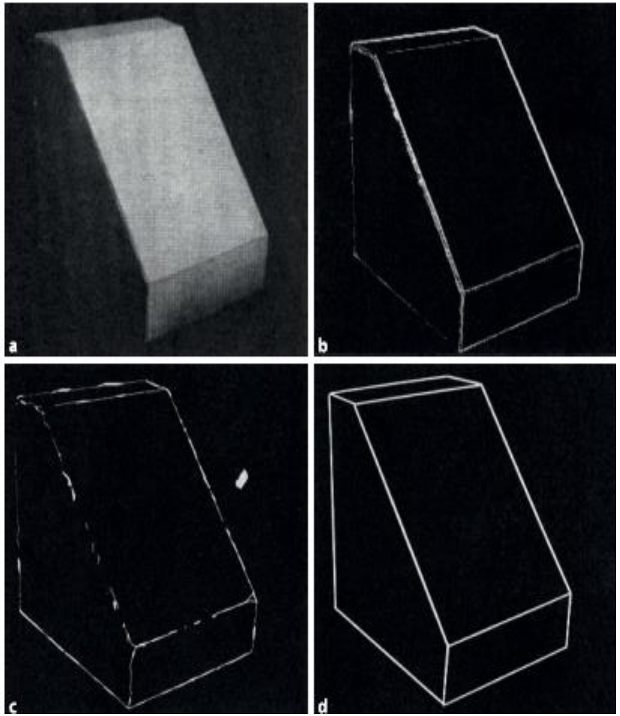


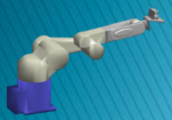
What are Sensors?

- Sensing is critical to robots.
  - **Proprioceptive sensors** measure the state of the robot itself:
    - the angle of the joints on a robot arm
    - the number of wheel revolutions on a mobile robot or the current drawn by an electric motor.
  - **Exteroceptive sensors** measure the state of the world with respect to the robot.
    - The sensor might be a simple contact switch on a vacuum cleaner robot to detect collision.
    - It might be a GPS receiver that measures distances to an orbiting satellite constellation, or a compass that measures the direction of the Earth's magnetic field relative to the robot's heading.
    - It might also be an active sensor avoidance and manipulation so vision has long been of interest to robotics researchers.

The 3-Dimensional Wireframe Model

- Figure 1.5 shows early work reconstructing 3D wireframe model from an image and gives some idea of the difficulties involved.
- An important limitation of a single camera is that the 3D structure must be inferred from the 2D image.
- An alternative approach is stereo vision, using two or more cameras, to compute the 3D structure of the world.
- The Mars rover shown in Fig. 1.6a has a stereo camera on its mast.





Telerobots and Teleautomation

- Tele-robots are robot-like machines that are remotely controlled by a human operator.
- Perhaps the earliest was a radio controlled boat demonstrated by Nikola Tesla in 1898 and which he called a teleautomaton.
- According to the definition above these are not robots but they were an important precursor to robots and are still important today (Goldberg and Siegwart 2001; Goldberg 2001)
  - Example 1: The underwater robots that surveyed the wreck of the Titanic were technically remotely operated vehicles (ROVs).
  - Example 2: The Mars rovers Spirit and Opportunity autonomously navigate the surface of Mars but human operators provide the high-level goals.

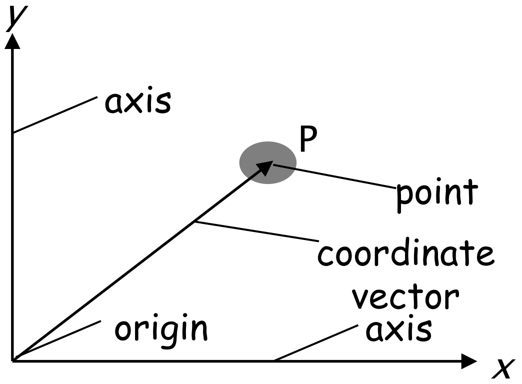
Mobile Robots

- The operators tell the robot where to go and the robot itself determines the details of the route.
- Local decision making on Mars is essential given that the communications delay is several minutes.
- Some robots are hybrids and the control task is shared or traded with a human operator.
- In traded control, the control function is passed back and forth between the human operator and the computer.

Representing Position and Orientation

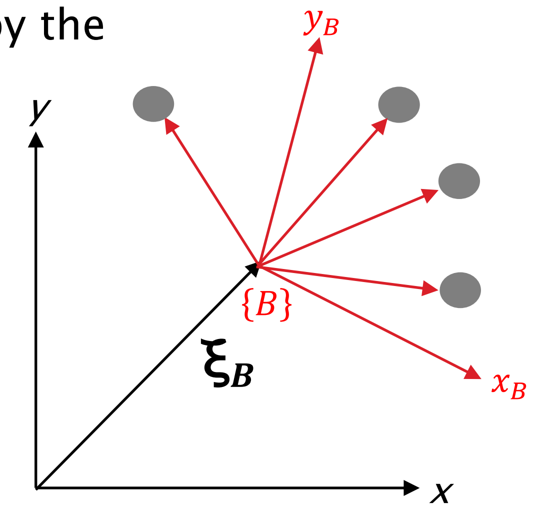
- A fundamental requirement in robotics and computer vision is to represent the position and orientation of objects in an environment:
  - E.g. robots, cameras, workpieces, obstacles and paths.

- A point in space is a familiar concept from mathematics and can be described by a coordinate vector, also known as a bound vector.
  - The vector represents the displacement of the point with respect to some reference coordinate frame.
  - A coordinate frame, or Cartesian coordinate system, is a set of orthogonal axes which intersect at a point known as the origin.



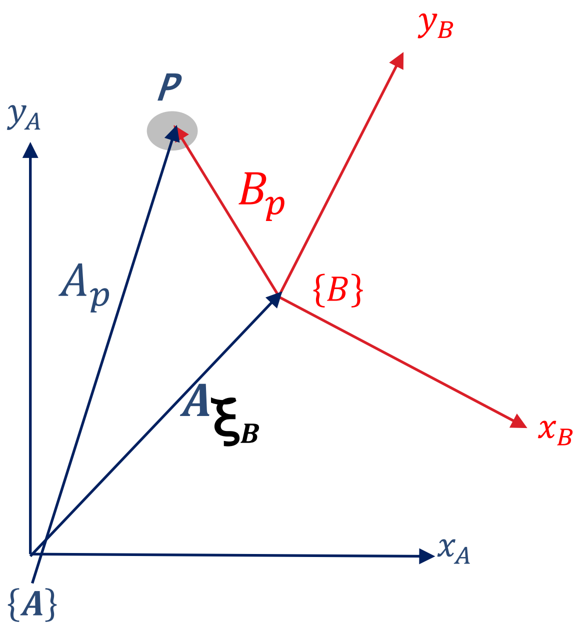
Constant Relative Position

- Its constituent points maintain a constant relative position with respect to the object's coordinate frame.
  - We describe the position and orientation of the object by the position and orientation of its coordinate frame.
  - A coordinate frame is labelled, {B} in this case, and its axis labels x_B and y_B adopt the frame's label as their subscript.
  - The relative pose of a frame with respect to a reference coordinate frame is denoted by the symbol ξ – pronounced ksi.



Displacement and Motion

- Figure 2.2 shows two frames {A} and {B} and the relative pose ${}^{A}\xi_{B}$ which describes {B} with respect to {A}.
- We could also think of ${}^{A}\xi_{B}$ as describing some motion
  - imagine picking up {A} and applying a displacement and a rotation so that it is transformed to {B}.
- If the initial superscript is missing we assume that the change in pose is relative to the world coordinate frame denoted O.



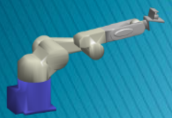
Displacement and Motion (continued…)

- The point P in Fig. 2.2 can be described with respect to either coordinate frame. Formally we express this as

  $$A_p = A_{\xi_B} \cdot B_p \qquad (2.1)$$

  where the right-hand side expresses the motion from {A} to {B} and then to P.

- The operator · transforms the vector, resulting in a new vector that describes the same point but with respect to a different coordinate frame.



Composed or Compounded

- An important characteristic of relative poses is that they can be composed or *compounded*.
  - If one frame can be described in terms of another by a relative pose then they can be applied sequentially

$$A_{\xi_C} = A_{\xi_B} \oplus B_{\xi_C}$$

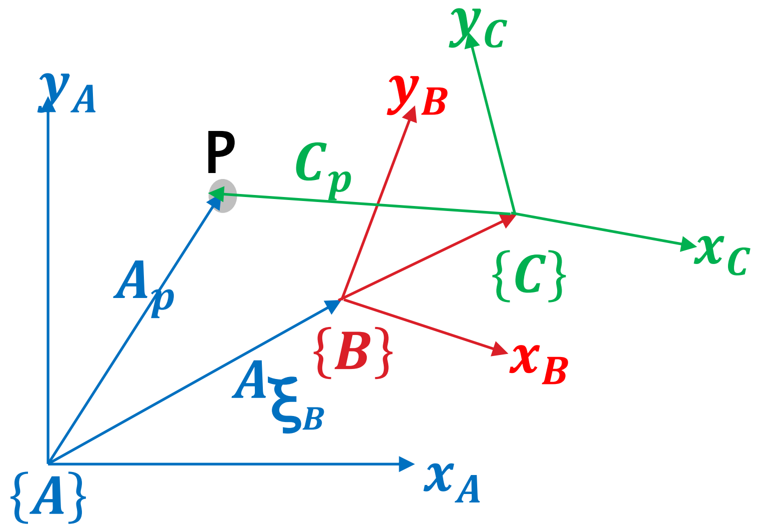
which says, in words, that the pose of {C} relative to {A} can be obtained by compounding the relative poses from {A} to {B} and {B} to {C}.

  - We use the operator ⊕ to indicate composition of relative poses. For this case the point P can be described

$$A_p = (A_{\xi_B} \oplus B_{\xi_C}) \cdot C_p$$

Relative Pose Composition

- Fig. 2.3. The point P can be described by coordinate vectors relative to either frame {A}, {B} or {C}. The frames are described by relative poses



Relative Pose Composition (continued…)

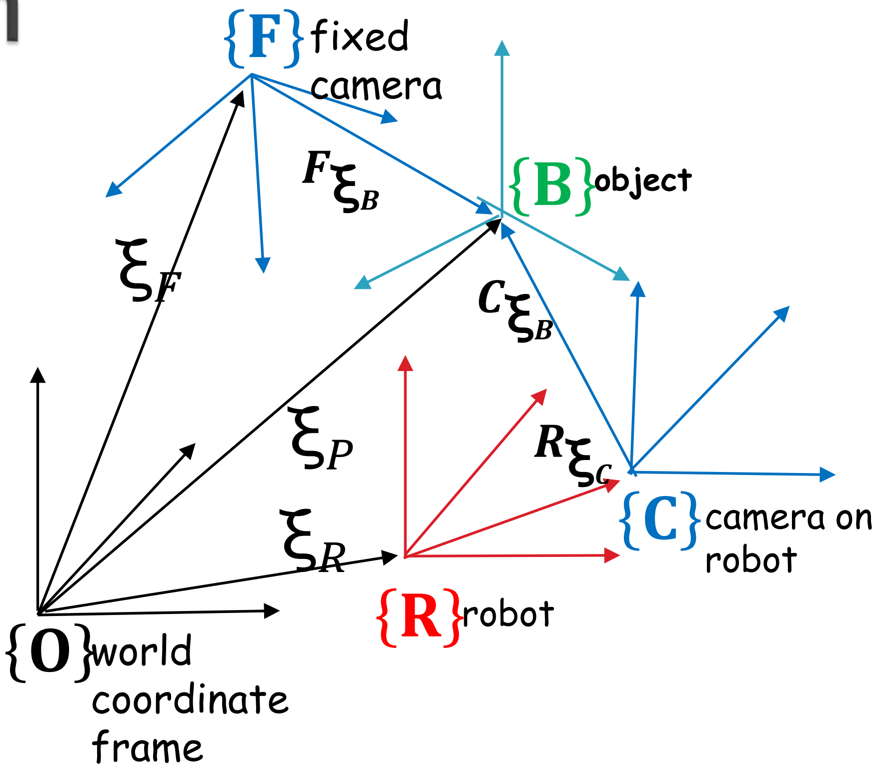
- We can check that we have our reference frames correct by ensuring that the subscript and superscript on each side of the $\oplus$ operator are matched.
- We can then cancel out the intermediate subscripts and superscripts

$$ {}^{X}\xi_{Z} = {}^{X}\xi_{\cancel{Y}} \oplus {}^{\cancel{Y}}\xi_{Z} $$

leaving just the end most subscript and superscript which are shown highlighted.

Multiple 3-Dimensional Example in a Graphical Form

- Figure 2.4 shows a more complex 3-dimensional example in a graphical form where:
  - We have attached 3D coordinate frames to the various entities and indicated some relative poses.
  - The fixed camera observes the object from its fixed viewpoint and estimates the object's pose relative to itself.
  - The other camera is not fixed, it is attached to the robot at some constant relative pose and estimates the object's pose relative to itself.



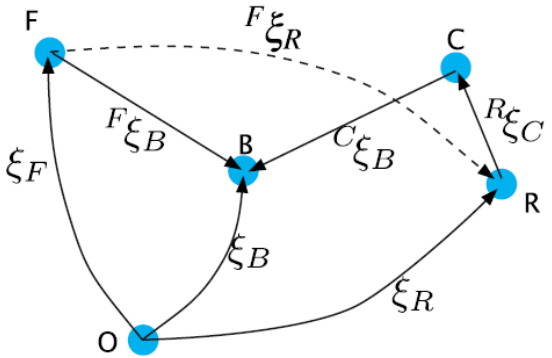
Alternative Representation of the Spatial Relationships

- An arrow from X to Y is denoted ${}^{X}\xi_{Y}$ and describes the pose of Y relative to X.
  - Recalling that we can compose relative poses using the $\oplus$ operator we can write some spatial relationships

$$\xi_F \oplus {}^{F}\xi_B = \xi_R \oplus {}^{R}\xi_C \oplus {}^{C}\xi_B$$

$$\xi_F \oplus {}^{F}\xi_R = {}^{0}\xi_R$$

    and each equation represents a loop in the graph.
  - Both sides of the equation start and end at the same node.



Properties of a Relative Pose

- There are just a few algebraic rules:

  $\xi \oplus 0 = \xi$, $\xi \ominus 0 = \xi$

  $\xi \ominus \xi = 0$, $\xi \oplus \xi = 0$

  where 0 represents a zero relative pose.

- A pose has an inverse $\ominus {}^{x}\xi_{Y} = {}^{Y}\xi_{X}$ which is represented graphically by an arrow from Y to X.
- Relative poses can also be composed or compounded

  $${}^{X}\xi_{Y} \oplus {}^{Y}\xi_{Z} = {}^{X}\xi_{Z}$$

- It is important to note that the algebraic rules for poses are different to normal algebra and that composition is not commutative

  $\xi_1 \oplus \xi_2 \neq \xi_2 \oplus \xi_1$ with the exception being the case where $\xi_1 \oplus \xi_2 = 0$.

- A relative pose can transform a point expressed as a vector relative to one frame to a vector relative to another

  $${}^{x}\boldsymbol{p} = {}^{X}\xi_{Y} \cdot {}^{y}\boldsymbol{P}$$

Pointers and Recap

To recap:

- A point is described by a coordinate vector that represents its displacement from a reference coordinate system;
- A set of points that represent a rigid object can be described by a single coordinate frame, and its constituent points are described by displacements from that coordinate frame;
- The position and orientation of an object's coordinate frame is referred to as its pose;
- A relative pose describes the pose of one coordinate frame with respect to another and is denoted by an algebraic variable ξ;
- A coordinate vector describing a point can be represented with respect to a different coordinate frame by applying the relative pose to the vector using the $\cdot$ operator;
- We can perform algebraic manipulation of expressions written in terms of relative poses.

The remainder of this chapter discusses concrete representations of ξ for various common cases that we will encounter in robotics and computer vision.

References

- [1] Robotics, Vision and Control. Peter Corke

- [2] Why Asimov's Three Laws Of Robotics Can't Protect Us
  Read more at https://www.gizmodo.com.au/2016/04/why-asimovs-three-laws-of-robotics-cant-protect-us/#ePkMlzk8SxTMUvEF.99