

# MTRN4010

Advanced Autonomous Systems

Term 1, 2022



## Course Overview

### Staff Contact Details

#### Convenors

Name	Email	Availability	Location	Phone
Jose Guivant	<a href="mailto:j.guivant@unsw.edu.au">j.guivant@unsw.edu.au</a>	TBA	Building J17, Room 510D	(02) 9385 5693

### School Contact Information

#### Location

UNSW Mechanical and Manufacturing Engineering

Ainsworth building J17, Level 1

Above Coffee on Campus

#### Hours

9:00–5:00pm, Monday–Friday\*

\*Closed on public holidays, School scheduled events and University Shutdown

#### Web

[School of Mechanical and Manufacturing Engineering](#)

[Engineering Student Support Services](#)

[Engineering Industrial Training](#)

[UNSW Study Abroad and Exchange](#) (for inbound students)

[UNSW Future Students](#)

#### Phone

(+61 2) 9385 8500 – Nucleus Student Hub

(+61 2) 9385 7661 – Engineering Industrial Training

(+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

(+61 2) 9385 4097 – School Office\*\*

\*\*Please note that the School Office will not know when/if your course convenor is on campus or

available

## Email

[Engineering Student Support Services](#) – current student enquiries

- e.g. enrolment, progression, clash requests, course issues or program-related queries

[Engineering Industrial Training](#) – Industrial training questions

[UNSW Study Abroad](#) – study abroad student enquiries (for inbound students)

[UNSW Exchange](#) – student exchange enquiries (for inbound students)

[UNSW Future Students](#) – potential student enquiries

- e.g. admissions, fees, programs, credit transfer

[School Office](#) – School general office administration enquiries

- NB: the relevant teams listed above must be contacted for all student enquiries. The School will only be able to refer students on to the relevant team if contacted

## Important Links

- [Student Wellbeing](#)
- [Urgent Mental Health & Support](#)
- [Equitable Learning Services](#)
- [Faculty Transitional Arrangements for COVID-19](#)
- [Moodle](#)
- [Lab Access](#)
- [Computing Facilities](#)
- [Student Resources](#)
- [Course Outlines](#)
- [Makerspace](#)
- [UNSW Timetable](#)
- [UNSW Handbook](#)

## Course Details

### Units of Credit 6

### Summary of the Course

The course is aimed at learning basic and advanced techniques necessary for sensing and control of autonomous mechatronic systems. Contents covered in this course include Stochastic Processes, State Estimation, Sensor Data Fusion, Common Optimization approaches, Particle Swarm Optimization (PSO), Model Predictive Control (MPC), Dynamic Programming/Dijkstra.

Half of the course is lecture-based. In the other half, students implement processes based on the covered theory.

### Course Aims

The course is aimed at learning basic and advanced techniques necessary for sensing and control of autonomous mechatronic systems. Contents covered in this course include Bayesian state estimation /Sensor data fusion and certain relevant nonlinear control techniques (Dynamic Programming, MPC and PSO). Half of the course is lecture-based. In the other half, students implement and apply those techniques.

In addition to the theory discussed in the lectures, the course is also focused on practical implementation matters, involving implementing processing modules, which are tested with real measurements from sensors, additionally being tested in simulation, in diverse scenarios.

### Course Learning Outcomes

After successfully completing this course, you should be able to:

Learning Outcome	EA Stage 1 Competencies
1. Understand of the general theory of Bayesian Estimation. Understand of the theory and application of the Kalman Filter (KF) and Extended KF (EKF), for solving diverse problems in the area of Engineering.	PE1.3, PE1.2, PE1.4
2. Understand and apply Model Predictive Control (MPC), standard optimization, Particle Swarm Optimization (PSO) and Dynamic Programming / Dijkstra approaches.	PE1.2, PE1.3
3. Be able to develop software for applying the theory, and actually solving related problems. Get experience in using state of the art sensors, used in Field Robotics and Autonomous Systems.	PE2.1, PE2.2, PE2.3

### Teaching Strategies

Teaching of this course is implemented through lectures to cover the theory, tutorial sessions, and project sessions to put those concepts in practice. All laboratory/project work is individual work, and attendance is strongly recommended

The provision of the learning environment in the laboratory is to facilitate students developing confidence in managing laboratory tasks as projects. Demonstrators in the laboratories are there to provide guidance and assistance in solving the projects.

Examples (e.g. source code) for the projects are provided by the Lecturer, to help in the understanding and full implementation of the projects. Project complexity is incremental, to allow the student to finally complete the solution of a complex problem.

Project work is focused on processing measurements acquired from real sensors; in addition, a comprehensive simulator is used, to allow testing concepts which would be difficult to try with a real system.

Lectures have a nominal duration of 2.5 hours. However, the last ½ hour is intended to be dedicated to discussions, and clarification of concepts; and for showing related material, which is useful for helping the understanding of the previously presented material.

## Assessment

The assessment is distributed in evaluating practical and conceptual aspects included in the course.

The practical aspects are evaluated through two projects, which contribute, in total, 46% of the final mark.

Knowledge about the theory and concepts, is evaluated via quizzes (totalizing 22% of the marks) and through a final exam (contributing with 32%).

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Project 1: Processing sensors' data.	23%	Week 7, Tuesday, 11:55PM	1, 3
2. Problems applying Estimation, PSO and MPC.	23%	Week 10, Friday, 11:55PM	1, 2, 3
3. Quizzes during T1	22%		1, 2, 3
4. Final Exam	32%	Not Applicable	1, 2, 3

### Assessment 1: Project 1: Processing sensors' data.

**Assessment length:** 4 weeks

**Due date:** Week 7, Tuesday, 11:55PM

**Deadline for absolute fail:** Week 8, Tuesday, 11:55PM

**Marks returned:** A week after submission.

The students use real and simulated data for implementing a localization process based on LiDAR, IMU and encoder measurements.

#### Assessment criteria

The work is individual. The students implement source code for defined processing tasks. The submitted code must be fully operational, and demonstrated and explained by the students during demonstration time. (Demonstrations take place after submission date).

A minor report about certain components of the project will be required. In that report, the student will explain his/her approach for solving that part of the project.

Please refer to the assignment specification for the breakdown of marks allocated.

#### Additional details

Deadline: Tuesday week 7, 11:55AM

Submitted, electronically, via Moodle.

Results will be released by Wednesday week 8, 11:55PM (for those who had submitted the project in

time).

Absolute fail deadline: Tuesday week 8.

## **Assessment 2: Problems applying Estimation, PSO and MPC.**

**Due date:** Week 10, Friday, 11:55PM

**Deadline for absolute fail:** Week 11, Friday, 11:55PM

**Marks returned:** Friday, week 11

A set of problems to be solved using EKF, MPC and PSO techniques.

### **Assessment criteria**

The work is individual. The students implement source code for defined processing tasks. The submitted code must be fully operational, and demonstrated and explained by the students during demonstration time. (Demonstrations take place after submission date).

A minor report about certain components of the project will be required. In that report, the student will explain his/her approach for solving that part of the project.

Please refer to the assignment specification for the breakdown of marks allocated.

## **Assessment 3: Quizzes during T1**

**Assessment length:** Major Quiz (35 mins), minor quizzes, 6 minutes each.

**Deadline for absolute fail:** Immediately after the quiz close times.

**Marks returned:** Minor quizzes: Immediately; Major Quiz: One week later.

Continuous evaluation during the term, via online quizzes.

There are three minor quizzes (having a relevance of 2 marks each) and a major quiz (relevance 16 marks).

The quizzes are online, via Moodle.

### **Assessment criteria**

There are three minor online quizzes, having each of them a relevance of 2 marks. Quizzes cover fundamental concepts seen in previous weeks, in lectures and in practical work.

A major online quiz takes place on week 8. It has a duration of 35 minutes. It has a relevance of 16 marks.

Results of minor quizzes are provided at the end of the same day.

The result of the major quiz is provided the subsequent week.

## **Assessment 4: Final Exam**

**Assessment length:** 2 hours.

The Final Exam covers all the topics seen during the term.

### **Assessment criteria**

The exam is focussed on concepts (from the covered theory and solved projects) and on solving problems (as those solved in tutorials).



## Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

## Course Schedule

[View class timetable](#)

### Timetable

Date	Type	Content
Week 1: 14 February - 18 February	Lecture	<p>Lecture 1. Part 1:</p> <p>Refreshing necessary concepts: Vectors, matrixes, transformations. Coordinate frames. Rotation matrix.</p> <p>State space models for continuous time system. LTI systems, Linear time variant systems, nonlinear systems.</p> <p>Classic Observers (continuous time, for LTI systems.)</p> <p>Approximate discrete time models. Euler approximation, for non LTI cases.</p> <p>Lecture 1. Part 2:</p> <p>SENSORS (Part 1). 2D LiDAR. Typical characteristics. Real-time demo in class.</p> <p>Typical data (we inspect data, generated in class).</p>
	Tutorial	Tutorial Problems and hand on tutorial (basic processing for LiDAR measurements).
Week 2: 21 February - 25 February	Lecture	<p>Usual Models in Field Robotics: Analog and Discrete time kinematic models of a wheeled platform.</p> <p>SENSORS (Part 2). IMU (Inertial measurement Unit. Description. Relevant technical specifications.</p> <p>Example using real IMUs. We inspect usual measurements, from IMUs operating in real time.</p>

		<p>IMU integration for estimating 2D and 3D attitude. Example source code discussed.</p> <p>Release and explanation of Project 1.</p>
	Tutorial	Hands-on tutorial: implementation of discrete time kinematic models. Basic IMU's gyroscope integration
Week 3: 28 February - 4 March	Lecture	<p>Minor quiz (6 minutes) about topics seen in weeks 1 and 2.</p> <p>Lecture 3. Part 1:</p> <p>SENSORS (part 3). RGB and RGB-D cameras. 3D LiDAR.</p> <p>Description, typical data. We see sensors working in class. We inspect measurements.</p> <p>Lecture 3. Part 2:</p> <p>Refreshing concepts about Statistics: Probability. Probability Density Function (PDF) . Gaussian cases. Multivariate PDFs in 2D and n-dimensions. Probability Mass. Marginal and Conditional PDFs. Statistical independence. Bayes Rule.</p>
	Tutorial	<p>1) Tutorial problems about Gaussian PDFs.</p> <p>2) Time dedicated to work and discuss about Project 1.</p>
	Assessment	Minor quiz (6 minutes, during lecture time) about topics seen in weeks 1,2.
Week 4: 7 March - 11 March	Lecture	Bayesian Estimation. Sensor Data Fusion. Kalman Filter (KF), Extended Kalman Filter (EKF).
	Tutorial	Problems applying KF and EKF.
Week 5: 14 March - 18 March	Lecture	<p>Minor quiz (6 minutes) about topics seen in weeks 3,4.</p> <p>Robot Localization. Localization via EKF</p>

		<p>Sensor data fusion (IMU, encoder, LiDAR)</p> <p>Map based localization.</p> <p>Early Release of Project 2. Introduction to Project 2.</p>
	Tutorial	Session for working and discussions about projects
	Assessment	Minor quiz (6 minutes, during lecture time) about topics seen in weeks 3,4.
Week 7: 28 March - 1 April	Lecture	<p>Minor quiz (6 minutes) about topics seen in week 5.</p> <p>Estimating model parameters (General cases).</p> <p>Estimating UGV model parameters</p> <p>Mapping (Occupancy grids)</p>
	Tutorial	<p>1) Tutorial problems about estimation of model parameters.</p> <p>2) Session for working and discussions about projects.</p>
	Assessment	Submission Project 1.
	Assessment	Minor quiz (6 minutes, during lecture time) about topics seen in week 5.
Week 8: 4 April - 8 April	Lecture	<p>Mid Term Major Quiz (35 minutes).</p> <p>Lecture 8. Part 1:</p> <p>Optimization (common methods)</p> <p>Examples/cases: estimating model parameters (e.g. UGV kinematic model and pendulum model)</p> <p>Lecture 8. Part 2:</p> <p>Particle Swarm Optimization (PSO)</p>
	Assessment	Major Quiz (Online via Moodle, duration: 35

		minutes, during lecture time).
	Tutorial	Solving problem via optimization.
Week 9: 11 April - 15 April	Lecture	Model Predictive Control (MPC). Linear MPC. Nonlinear MPC.  Cases of study: UGV's path follower or Collision avoidance (we choose one.)
	Tutorial	Solving problems using MPC.
Week 10: 18 April - 22 April	Lecture	Lecture 10. Part 1: Dynamic Programming, Dijkstra approach. Path planning example.  Lecture 10. Part 2: Revision.
	Tutorial	Session for working and discussions about projects.

## **Resources**

### **Recommended Resources**

All the academic material is provided by the course (lecture notes, example data, software libraries, example code, and equipment).

Datasets of measurements from real sensors, and a simulator, are provided for allowing the students to perform playback sessions and work at home when needed.

### **Course Evaluation and Development**

Lecture time is now also dedicated to discussing the application of EKF to systems in other areas of Engineering (in addition to the localization problem in the Robotics field)

Week 1 covers a review of concepts which are necessary for dealing with the course's new concepts. These reviewed concepts used to be assumed as well known, however are now reviewed to help students who may not be familiar with them.

A comprehensive simulator is included for better and easier testing of implementations.

Projects have been reorganized for a better adjustment to the trimester modality.

Tutorial sessions are in place, which result in better preparation for solving projects.

Lecture time is spent for more explanations of practical matters.

Relevance of the final exam has been reduced, allowing the students to secure more marks before the exam period.

### **Laboratory Workshop Information**

All tutorial and laboratory sessions can be attended in person or via MS Teams. Each student decides how to attend, at any time

However, there is a limit in the number of students attending in person, due to restrictions related to the COVID pandemic.

# Submission of Assessment Tasks

## Assessment submission and marking criteria

Should the course have any non-electronic assessment submission, these should have a standard School cover sheet.

All submissions are expected to be neat and clearly set out. Your results are the pinnacle of all your hard work and should be treated with due respect. Presenting results clearly gives the marker the best chance of understanding your method; even if the numerical results are incorrect.

Marking guidelines for assignment submissions will be provided at the same time as assignment details to assist with meeting assessable requirements. Submissions will be marked according to the marking guidelines provided.

## Late policy

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of 20 percent (20%) of the maximum mark possible for that assessment item, per calendar day, for a minimum of zero marks.

The late penalty is applied per calendar day (or part thereof), including weekends and public holidays, that the assessment is overdue.

Work submitted after the 'deadline for absolute fail' is not accepted and a mark of zero will be awarded for that assessment item. For example:

- Your course has an assessment task worth a total of **30 marks (Max Possible Mark)**
- You submit the assessment **2 days after the due date**
- The assessment is marked as usual and achieves a score of **20 marks (Awarded Mark)**
- The late policy is applied using **Late Mark = Awarded Mark - (Days\*Penalty per Day)\*Max Possible Mark**. Your adjusted final score is **8 marks** ( $20 - ((2*0.2)*30)$ ).

For some assessment items, a late penalty may not be appropriate. These are clearly indicated in the course outline, and such assessments receive a mark of zero if not completed by the specified date. Examples include:

1. Weekly online tests or laboratory work worth a small proportion of the subject mark, or
2. Online quizzes where answers are released to students on completion, or
3. Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
4. Pass/Fail assessment tasks.

## Examinations

You must be available for all quizzes, tests and examinations. For courses that have final examinations, these are held during the University examination periods: February for Summer Term, May for T1, August for T2, and November/December for T3.

Please visit myUNSW for Provisional Examination timetable publish dates. For further information on

exams, please see the [Exams](#) webpage.

## Special Consideration

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to submitting an assessment or sitting an exam.

UNSW now has a [Fit to Sit / Submit rule](#), which means that if you attempt an exam or submit a piece of assessment, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's [Special Consideration page](#).

**Please note** that students will **not** be required to provide **any** documentary evidence to support absences from any classes missed **because of COVID-19 public health measures such as isolation**. UNSW will **not** be insisting on medical certificates from anyone deemed to be a positive case, or when they have recovered. Such certificates are difficult to obtain and put an unnecessary strain on students and medical staff.

Applications for special consideration **will** be required for assessment and participation absences – but no documentary evidence **for COVID-19 illness or isolation** will be required.

## Special Consideration Outcomes

Assessments have default Special Consideration outcomes. The default outcome for the assessment will be advised when you apply for Special Consideration. Below is the list of possible outcomes:

<b>Outcome</b>	<b>Explanation</b>	<b>Example</b>
Time extension	Student provided more time to submit the assessment	e.g. 1 more week of time granted to submit a report
Supplementary assessment	Student provided an alternate assessment at a later date/time	e.g. a supplementary exam is scheduled during the supplementary exam period of the term
Substitute item	The mark for the missed assessment is substituted with the mark of another assessment	e.g. mark for Quiz 1 applied also applied as mark for Quiz 2, meaning if a student achieved a mark of 20/30 for Quiz 1 and was granted Special Consideration for Quiz 2, a mark of 20/30 would be applied for Quiz 2, etc
Exemption	All course marks are recalculated excluding this assessment and its weighting	e.g. The course has an assessment structure of: - Assignments 30%, - Lab report 30%, - Final Exam 40%. If the Lab report is missed and student is granted Special Consideration, then the assessment structure may be reweighted as follows: - Assignments 50% - Final Exam 50% as though the Lab report did not exist
Non-standard	Course Coordinator is contacted for the outcome when special consideration is granted as the outcome differs on a case-by-case basis	e.g. typical for group assessments where time extension supplementary assessment could be granted to the group member, time extension could be granted to the whole group, etc. Clarify with your Course Convenor for



## Academic Honesty and Plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: [student.unsw.edu.au/plagiarism](http://student.unsw.edu.au/plagiarism). The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis) even suspension from the university. The Student Misconduct Procedures are available here:

[www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf](http://www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf)

## Academic Information

### Credit points

Course credit is calculated in Units-Of-Credit (UOC). The normal workload expectation for one UOC is approximately 25 hours per term. This includes class contact hours, private study, other learning activities, preparation and time spent on all assessable work.

Most coursework courses at UNSW are 6 UOC and involve an estimated 150 hours to complete, for both regular and intensive terms. Each course includes a prescribed number of hours per week (h/w) of scheduled face-to-face and/or online contact. Any additional time beyond the prescribed contact hours should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

### On-campus class attendance

**\*\*T1-2022 UPDATE\*\***

Public distancing conditions must be followed for all face-to-face classes. To ensure this, only students enrolled in those classes will be allowed in the room. No over-enrolment is allowed in face-to-face classes. Students enrolled in online classes can swap their enrolment from online to on-campus classes by Sunday, Week 1. Please refer to your course's Microsoft Teams and Moodle sites for more information about class attendance for in-person and online class sections/activities.

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by [NSW health](#) or government authorities. Current alerts and a list of hotspots can be found [here](#). **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate.** We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed. Further information is available on any course Moodle or Teams site.

In certain classroom and laboratory situations where physical distancing cannot be maintained or there is a high risk that it cannot be maintained, face masks will be considered **mandatory PPE** for students and staff.

For more information, please refer to the FAQs: <https://www.covid-19.unsw.edu.au/safe-return-campus-faqs>

### Guidelines

All students are expected to read and be familiar with UNSW guidelines and policies. In particular, students should be familiar with the following:

- [Attendance](#)
- [UNSW Email Address](#)
- [Special Consideration](#)
- [Exams](#)
- [Approved Calculators](#)

- [Academic Honesty and Plagiarism](#)

## **Image Credit**

Photo by Stephen Blake March 2017, Willis Annexe (J18) Thermofluids lab

## **CRICOS**

CRICOS Provider Code: 00098G

## **Acknowledgement of Country**

We acknowledge the Bedegal people who are the traditional custodians of the lands on which UNSW Kensington campus is located.

## Appendix: Engineers Australia (EA) Professional Engineer Competency Standard

Program Intended Learning Outcomes	
Knowledge and skill base	
PE1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline	
PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline	✓
PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline	✓
PE1.4 Discernment of knowledge development and research directions within the engineering discipline	✓
PE1.5 Knowledge of engineering design practice and contextual factors impacting the engineering discipline	
PE1.6 Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline	
Engineering application ability	
PE2.1 Application of established engineering methods to complex engineering problem solving	✓
PE2.2 Fluent application of engineering techniques, tools and resources	✓
PE2.3 Application of systematic engineering synthesis and design processes	✓
PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
Professional and personal attributes	
PE3.1 Ethical conduct and professional accountability	
PE3.2 Effective oral and written communication in professional and lay domains	
PE3.3 Creative, innovative and pro-active demeanour	
PE3.4 Professional use and management of information	
PE3.5 Orderly management of self, and professional conduct	
PE3.6 Effective team membership and team leadership	