UNSW Course Outline

MTRN4010 Advanced Autonomous Systems - 2024

Published on the 08 Feb 2024

General Course Information

Course Code : MTRN4010
Year : 2024
Term : Term 1
Teaching Period : T1
Is a multi-term course? : No
Faculty : Faculty of Engineering
Academic Unit : School of Mechanical and Manufacturing Engineering
Delivery Mode : Multimodal
Delivery Format : Standard
Delivery Location : Kensington
Campus : Sydney
Study Level : Postgraduate, Undergraduate
Units of Credit : 6

Useful Links

Handbook Class Timetable

Course Details & Outcomes

Course Description

The following assumed knowledge is expected for students undertaking this course:

MMAN3200, MATH2089 and MTRN2500.

The course is aimed at learning basic and advanced techniques necessary for sensing and control of autonomous systems. Contents covered in this course include Stochastic State Estimation, Sensor Data Fusion and Optimization and certain planning approaches. Half of the course is lecture-based; in the other half, students will work on problems related to autonomous platforms.

Course Aims

The course is aimed at learning basic and advanced techniques that necessary for sensing and control of autonomous mechatronic systems. Contents covered in this course include Bayesian state estimation / Sensor data fusion, and certain relevant techniques (Dynamic Programming, Optimization, 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.

Relationship to Other Courses

Part of the concepts that are introduced in this course relate to two other courses. First, the concept of state observer seen in MMAN3200 (Linear Systems and Control) and posteriorly in MTRN3020, is extended by including stochastic estimation, through approaches such as Kalman Filtering (KF). In addition, as the course also includes the extended KF (EKF), it naturally allows state estimation for time variant and nonlinear processes which is an extension to MMAN3200 and MTRN3020 whose contents are constrained to LTI systems.

MTRN4010 does include Optimization, which is also applied to parameter identification, a topic that complements modelling.

The concept of Sensor Data Fusion and Estimation is relevant for subsequent courses in Robotics.

Course Learning Outcomes

Course Learning Outcomes
CLO1 : Analyse the theoretical underpinnings of Bayesian Estimation and demonstrate advanced proficiency in implementing the Kalman Filter to address diverse engineering challenges.
CLO2 : Apply critical analysis to optimization techniques, demonstrating the ability to strategically employ them in solving complex engineering problems.
CLO3 : Evaluate and integrate Sensor Data Fusion methodologies for vehicle localization and other engineering challenges, demonstrating a mastery of their application.
CLO4 : Design and implement software solutions for solving complex engineering problems, critically assess the performance of applied approaches, and gain experience with typical sensors utilized in Field Robotics and Autonomous Systems.

Course Learning Outcomes	Assessment Item
CLO1 : Analyse the theoretical underpinnings of Bayesian Estimation and demonstrate advanced proficiency in implementing the Kalman Filter to address diverse engineering challenges.	• Assignment 2: Sensor Data Fusion, via EKF and via Optimization. • Tests • Final Exam
CLO2 : Apply critical analysis to optimization techniques, demonstrating the ability to strategically employ them in solving complex engineering problems.	• Assignment 1. Sensor data fusion, via deterministic approach. • Assignment 2: Sensor Data Fusion, via EKF and via Optimization. • Tests • Final Exam
CLO3 : Evaluate and integrate Sensor Data Fusion methodologies for vehicle localization and other engineering challenges, demonstrating a mastery of their application.	• Assignment 1. Sensor data fusion, via deterministic approach. • Assignment 2: Sensor Data Fusion, via EKF and via Optimization. • Tests • Final Exam
CLO4 : Design and implement software solutions for solving complex engineering problems, critically assess the performance of applied approaches, and gain experience with typical sensors utilized in Field Robotics and Autonomous Systems.	• Assignment 1. Sensor data fusion, via deterministic approach. • Assignment 2: Sensor Data Fusion, via EKF and via Optimization.

Learning and Teaching Technologies

Moodle - Learning Management System | Microsoft Teams | Kahoot and Youtube

Learning and Teaching in this course

Teaching of this course is implemented through lectures to cover the theory, problem solving sessions,
and project sessions to put those concepts in practice. All laboratory/project work is individual work, and
attendance is strongly recommended.
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 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 hours. However, the last ½ hour is intended to be dedicated to discussions, and clarification of concepts; and
for showing additional material, which is useful for helping the understanding of the previously presented
material.

Additional Course Information

The students who enrol in this course are required to have prior knowledge from MMAN3200 Linear Systems and Control or a similar course. In addition, programming skills (such as those acquired in MTRN2500) are necessary. We use Matlab plain programming language in our implementations. Basic knowledge about Statistics (from MATH courses) is also necessary.

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Assignment 2: Sensor Data Fusion, via EKF and via Optimization. Assessment Format: Individual	25%	Start Date: Release: Early week 5 (or before) Due Date: Deadline for project submission: Week 9, Friday, 23:55
Assignment 1. Sensor data fusion, via deterministic approach. Assessment Format: Individual	23%	Start Date: Release: Early week 2 (or before) Due Date: Deadline for project submission: Week 5, Friday, 23:55
Tests Assessment Format: Individual	22%	Start Date: Multiple quizzes (weeks 2,4, and 8) Due Date: Not Applicable
Final Exam Assessment Format: Individual	30%	Start Date: Not Applicable Due Date: Not Applicable

Assessment Details

Assignment 2: Sensor Data Fusion, via EKF and via Optimization.

Assessment Overview

The students implement sensor data processing, from IMU and LiDAR measurements, for localizing a robotic platform. They base the processing on EKF, and on Optimization.

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

Course Learning Outcomes

- CLO1 : Analyse the theoretical underpinnings of Bayesian Estimation and demonstrate advanced proficiency in implementing the Kalman Filter to address diverse engineering challenges.
- CLO2 : Apply critical analysis to optimization techniques, demonstrating the ability to strategically employ them in solving complex engineering problems.
- CLO3 : Evaluate and integrate Sensor Data Fusion methodologies for vehicle localization and

other engineering challenges, demonstrating a mastery of their application.
- CLO4 : Design and implement software solutions for solving complex engineering problems, critically assess the performance of applied approaches, and gain experience with typical sensors utilized in Field Robotics and Autonomous Systems.

Detailed Assessment Description

The detailed assessment description will be provided in the Assignment Specification that will be released to the students. This specification will be posted on Moodle, jointly with additional material for the project.

Submission notes

Program files and reports are submitted to Moodle

Assessment information

Deadline for project submission: Week 9, Friday, 23:55

Submitted, electronically, via Moodle.

In addition to the project submission, students need to demonstrate it working, in a brief session (10 minutes)

Individual demonstrations take place on Week 10, during lab_tutorail time.

Results will be released by Tuesday week 11, 14:00 (for those who had submitted the project in time, and had demonstrated it on week 10).

Criteria with marking rubric

Criteria: Please refer to the rubric that is described in the project release.

Fail - Please refer to the rubric that is described in the project release.

Pass - Please refer to the rubric that is described in the project release.

Credit - Please refer to the rubric that is described in the project release.

Distinction - Please refer to the rubric that is described in the project release.

High Distinction - Please refer to the rubric that is described in the project release.

Assignment submission Turnitin type

Not Applicable

Assignment 1. Sensor data fusion, via deterministic approach.

Assessment Overview

The students implement sensor data processing, from IMU and LiDAR measurements, for localizing a robotic platform. They apply determinintic approaches, for that purpose.

Assessment criteria

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.

Course Learning Outcomes

- CLO2 : Apply critical analysis to optimization techniques, demonstrating the ability to strategically employ them in solving complex engineering problems.
- CLO3 : Evaluate and integrate Sensor Data Fusion methodologies for vehicle localization and other engineering challenges, demonstrating a mastery of their application.
- CLO4 : Design and implement software solutions for solving complex engineering problems, critically assess the performance of applied approaches, and gain experience with typical sensors utilized in Field Robotics and Autonomous Systems.

Detailed Assessment Description

The detailed assessment description will be provided in the Assignment Specification that will be released to the students. This specification will be posted on Moodle, jointly with additional material for the project.

Submission notes

Program files and reports are submitted to Moodle

Assessment information

Deadline for project submission: Week 5, Friday, 23:55

Submitted, electronically, via Moodle.

In addition to the project submission, students need to demonstrate it working, in a brief session

(10 minutes)

Individual demonstrations take place on Week 7, during lab_tutorail time.

Results will be released by Tuesday week 8, 14:00 (for those who had submitted the project in time, and had demonstrated it on week 7).

Criteria with marking rubric

Criteria: Please refer to the rubric that is described in the project release.

Fail - Please refer to the rubric that is described in the project release.

Pass - Please refer to the rubric that is described in the project release.

Credit - Please refer to the rubric that is described in the project release.

Distinction - Please refer to the rubric that is described in the project release.

High Distinction - Please refer to the rubric that is described in the project release.

Assignment submission Turnitin type

Not Applicable

Tests

Assessment Overview

Assessment length: One Major Quiz (duration = 30 minutes), two minor quizzes, (10 minutes and 15 minutes duration respectively.)

Three quizzes, which take place during the term.

Quiz 1, 10 minutes duration, relevance 2 marks (out of the course's 100 marks).

Quiz 2, 15 minutes duration, relevance 4 marks.

Quiz 3, 30 minutes duration, relevance 16 marks.

Assessment criteria

Questions may be conceptual, or brief problems whose answer will need to be calculated.

Some questions (calculated answers or multiple choice or about programming) may be automatically marked by Moodle.

Some questions, in quiz #3, may need to be answered by writing, as in traditional "in person" exams.

Course Learning Outcomes

- CLO1 : Analyse the theoretical underpinnings of Bayesian Estimation and demonstrate advanced proficiency in implementing the Kalman Filter to address diverse engineering challenges.
- CLO2 : Apply critical analysis to optimization techniques, demonstrating the ability to strategically employ them in solving complex engineering problems.
- CLO3 : Evaluate and integrate Sensor Data Fusion methodologies for vehicle localization and other engineering challenges, demonstrating a mastery of their application.

Detailed Assessment Description

Dates for the tests and for the release of results.

Minor quiz 1: In person, week 2, Thu 17:00 - 17:15. Results available: Thursday, week 3.

Minor quiz 2, In person, week 4, Thu 17:00 - 17:15. Results available: Thursday, week 5.

Major test, In person, week 8, Thu 17:00 - 17:30. Results available: Thursday, week 9.

Assessment Length

One Major Quiz (duration = 30 minutes), two minor quizzes, (10 and 15 minutes, respectively)

Assessment information

In case of not attending a quiz, under approved special consideration (SC), the mark of the missed quiz will be substituted by the mark of a posterior test (quiz or final exam).

Only cases in which SC has been approved will have the option to be substituted.

Automatic marking of certain questions. Some questions (calculated answers or multiple choice or about programming) would be automatically marked by Moodle.

Assignment submission Turnitin type

This is not a Turnitin assignment

Final Exam

Assessment Overview

Assessment length: 2 hours

Final Exam (during exam period)

Course Learning Outcomes

- CLO1 : Analyse the theoretical underpinnings of Bayesian Estimation and demonstrate advanced proficiency in implementing the Kalman Filter to address diverse engineering challenges.
- CLO2 : Apply critical analysis to optimization techniques, demonstrating the ability to strategically employ them in solving complex engineering problems.
- CLO3 : Evaluate and integrate Sensor Data Fusion methodologies for vehicle localization and other engineering challenges, demonstrating a mastery of their application.

Detailed Assessment Description

The final exam is held in the formal end-of-session examination period, and is two hours and 10 minutes long. The exam will be invigilated and held on UNSW's Kensington campus. The exam will be conducted in School computer labs. Details about format, required materials and how to prepare for this exam will be posted on Moodle by Week 10.

Assessment Length

NA

Assignment submission Turnitin type

Not Applicable

General Assessment Information

Late submission rules for projects (Assignment 1 and Assignment 2): Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of eighteen percent (18%) of the maximum mark possible for that assessment item, per calendar day. The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day.

Deadline for absolute fail: implicitly defined by the rule for late submission.

Grading Basis

Standard

Requirements to pass course

Obtain at least 50 out of 100 available marks.

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 1 : 12 February - 18 February	Lecture	Review of necessary concepts : State space models. LTI, Linear Time variant, and nonlinear cases. MIMO systems. State observers. Discrete time approximation for continuous time state equations. Coordinate frames / transformations. Programming using Matlab (Examples).
	Tut-Lab	Solving problems related to state space modelling , to programming, and to coordinate frames.
Week 2 : 19 February - 25 February	Lecture	Kinematic Models. Sensors: 2D LiDAR. IMU. Dead reckoning. Explanation Project 1.
	Tut-Lab	Solving problems related to models. Programming. First steps working on Project 1.
	Assessment	Minor quiz (10m).
Week 3 : 26 February - 3 March	Lecture	Using Optimization. Map-based localization.
	Tut-Lab	Solving problems by applying optimization. Programming. Working on Project 1.
Week 4 : 4 March - 10 March	Lecture	Review of Statistics, including concepts such as random variables (RV), probability density function (PDF), joint PDF, marginal PDF, conditional PDF, statistical dependence, white noise, and Bayes' Rule. Introduction to Bayesian Estimation.
	Tut-Lab	Hints about programming. Working on Project 1.
	Assessment	Minor quiz (15m).
Week 5 : 11 March - 17 March	Lecture	Topics include Gaussian random variables (RVs), handling high-dimensional cases, covariance matrix, Bayesian estimation under Gaussian assumption, Kalman Filter (KF), Extended Kalman Filter (EKF), and practical examples of application.
	Tut-Lab	Solving Problems. Working on Project 1.
	Assessment	Submission Project 1, Friday, 23:55.
Week 6 : 18 March - 24 March	Tut-Lab	Optional: Students do have access to the Lab for working and consulting teaching staff.
Week 7 : 25 March - 31 March	Lecture	State augmentation. Estimating parameters in real-time via EKF. Discussion about Project 2.
	Tut-Lab	Solving problems related to estimating parameters in real-time via EKF. Working on Project 2.
	Presentation	Students demonstrate their previously submitted project 1.
Week 8 : 1 April - 7 April	Laboratory	Alternative optimization approaches. PSO. GA.
	Tut-Lab	Working on Project 2.
	Assessment	Major quiz. 30m. Thu 17:00 - 17:30
Week 9 : 8 April - 14 April	Lecture	Dynamic Programming. Dijkstra's approach.
	Tut-Lab	Working on Project 2.
	Assessment	Submission Project 2, Friday, 23:55.
Week 10 : 15 April - 21 April	Lecture	Revision. Discussion about Exam. Contingency time.
	Tut-Lab	Students demonstrate their previously submitted project 2.

Attendance Requirements

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

General Schedule Information

Each week students are expected to attend the lecture (two hours duration) and the lab_tutorial sesssion in which they are enrolled (two hours duration).

Course Resources

Prescribed Resources

Example code, datasets, videos and lecture material are provided via Moodle.

Course Evaluation and Development

Provided more time between release and submission dealine for Project 2.

Lecture hours reduced from 2.5 hours to 2 hours.

Extended weekly consultation time.

More explanation of solutions for problems and related to program implementations, provided in lecture time and via prerecorded videos.

API for helping implemenation of software solutions has been extended.

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
Convenor	Jose Guivant		J17 / 510D	93855693	Through appointment, and via weekly consultation sessions.	No	Yes
Lecturer	Jose Guivant		J17 / 510D	93855693	Through appointment, and via weekly consultation sessions.	No	No

Other Useful Information

Academic Information

I. Special consideration and supplementary assessment

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, or within 3 working days of, submitting an assessment or sitting an exam.

Please note that UNSW has a Fit to Sit rule, which means that if you sit an exam, 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.

II. Administrative matters and links

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

- Attendance
- UNSW Email Address
- Special Consideration
- Exams
- Approved Calculators
- Academic Honesty and Plagiarism
- Equitable Learning Services

III. Equity and diversity

Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course convener prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Equitable Learning Services. Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

IV. Professional Outcomes and Program Design

Students are able to review the relevant professional outcomes and program designs for their streams by going to the following link: https://www.unsw.edu.au/engineering/student-life/student-resources/program-design.

Note: This course outline sets out the description of classes at the date the Course Outline is published. The nature of classes may change during the Term after the Course Outline is published. Moodle or your primary learning management system (LMS) should be consulted for the up-to-date class descriptions. If there is any inconsistency in the description of activities between the University timetable and the Course Outline/Moodle/LMS, the description in the Course Outline/Moodle/LMS applies.

Academic Honesty and Plagarism

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. 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.

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 or contract cheating) even suspension from the university. The Student Misconduct Procedures are available here:

www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

Submission of Assessment Tasks

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of five percent (5%) of the maximum mark possible for that assessment item, per calendar day.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day. This is for all assessments where a penalty applies.

Work submitted after five days (120 hours) will not be accepted and a mark of zero will be

awarded for that assessment item.

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

- Weekly online tests or laboratory work worth a small proportion of the subject mark;
- Exams, peer feedback and team evaluation surveys;
- Online quizzes where answers are released to students on completion;
- Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date; and,
- Pass/Fail assessment tasks.

Faculty-specific Information

Engineering Student Support Services – The Nucleus - enrolment, progression checks, 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

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)

School-specific Information

Short Extensions

Short extensions are not currently applicable to Mechanical and Manufacturing Engineering Courses.

Review of Results

The purpose of a review of results is if there was a marking error. Review of results is for when you have cause to believe that there is a marking error. Review of Results cannot be used to get feedback. If you would like feedback for assessments prior to the final exam, you are welcome to contact the course convenor directly. No feedback will be provided on final exams.

Use of AI

The use of AI is prohibited unless explicitly permitted by the course convenor. Please respect this and be aware that penalties will apply when unauthorised use is detected, such as through Turnitin. If the use of generative AI, such as ChatGPT, is allowed in a specific assessment, they must be properly credited, and your submissions must be substantially your own work.

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