School of Chemical Engineering

UNSW Engineering

CEIC8102

Advanced Process Control

Term 3, 2022

Course Overview

Staff Contact Details

Convenors

Name	Email	Availability	Location	Phone
Jie Bao	j.bao@unsw.edu.au	By appointment, Teams messages/emails and Teams discussion forum	Room 301 SEB	x56755

School Contact Information

For assistance with enrolment, class registration, progression checks and other administrative matters, please see the Nucleus: Student Hub. They are located inside the Library – first right as you enter the main library entrance. You can also contact them via http://unsw.to/webforms or reserve a place in the face-to-face queue using the UniVerse app.

If circumstances outside your control impact on submitting assessments, Special Consideration may be granted, usually in the form of an extension or a supplementary assessment. Applications for Special Consideration must be submitted online.

For course administration matters, please contact the Course Coordinator.

Course Details

Units of Credit 6

Summary of the Course

Concepts of linear Multi-Input Multi-Output (MIMO) systems, state-space representation of process systems, linear spaces and linear operators, controllability and observability analysis, Lyapunov stability analysis, stability of interconnected systems, linear optimal control, frequency-domain analysis and controller synthesis for MIMO process systems. Introduction to model predictive control, system identification, robus control, decentralised control. In addition, there will be a project component on an individual study basis. The individual study project is to be chosen in the areas identified by codes A-Artificial Intelligency, F-Computer Modelling and Design and Q-Process Control advanced (see School for details).

This course assumes that you have an appropriate background in process control at undergraduate level. If this is not the case, please consult your program authority about the possibility of taking the undergraduate course CEIC3006 as one of your program electives, prior to attempting CEIC8102.

Course Aims

The aim of the subject is to equip the students with the basic knowledge of some of the key advanced process control techniques widely applied in process industries and develop skills to analyze multivariable process dynamics and design multivariable control systems, including linear optimal control, robust control and model predictive control.

Course Learning Outcomes

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

Learning Outcome	EA Stage 1 Competencies
1. Ability to develop dynamic models for multivariable processes in the state-space representation and analyse process dynamic features using frequency response techniques.	PE1.1, PE1.2
2. Ability to analyse process controllability, observability, operability and robustnes from process models in early stages of process design to ensure the controllability of process designs.	PE1.1, PE2.1, PE2.2, PE2.3
3. Understanding the basic theory of the following modern control techniques and their strength and limitations: multivariable optimal control approaches (including Linear Quadratic Regulator, Linear Quadratic Gaussian control) and model predictive control.	PE1.1, PE1.3, PE2.1, PE2.2
4. Ability to design multivariable controllers using Linear Quadratic Regulator, Linear Quadratic Gaussian control and model predictive control approaches.	PE1.1, PE1.3, PE2.3

Teaching Strategies

This subject is about quantitative and rigorous control analysis and development, based on mathematical derivations. Therefore, the philosophy behind mathematical theory will be emphasized in lectures, such as, what motivates the approach, how it works and why. The relevance of this subject to chemical engineering practice will also be highlighted. In order to encourage a deep-approach to learning, emphasis is placed on the understanding of the control theory via problem solving. This subject has three main components: lectures, tutorials and a design project (including lab sessions):

- The key theory and concepts will be taught during lectures (4 hours per week).
- Deeper understanding of the theory will be achieved via solving workshop questions (2 hours per week) and assignment problems.
- The students will have an opportunity to gain more thorough understanding of the techniques they have learned in this subject by implementing them judiciously in a control project. The description of the major project will be released in Week 7. The project is about controlling a multivariable process (e.g., a distillation column). The theoretical aspect of the project (system analysis and theoretical design) will be covered in some tutorial classes and assignments. You can use any method taught in this subject or their combination. You will perform the control system design using Matlab and simulate your design using Simulink. You will compare the performance of different control designs and assess their cost-effectiveness. Your report will be assessed based on the critical analysis of your results and control methods.

Students are expected to enter CEIC8102 having developed competencies in all the material covered in the pre-requisite courses, at least. Little time is available to remediate any deficiencies in your knowledge of those topics. Over the course of the term, you will be developing new competencies and to illustrate the standards we expect.

Additional Course Information

This course is concerned with quantitative system analysis and control design for multivariable processes. The prerequisite of this course is CEIC3006 Process Dynamics and Control or an equivalent entry-level process control subject. Focused on the key concepts of modern control theory, this subject is suitable for students who are interested in the career of process control engineers/consultants or researchers in the field of control theory.

Assessment

Assignment problems are designed to ensure that lecture material is comprehended through personal practice and hence achievement of indicated learning outcomes. Individual work. While working in groups is permitted, independent reporting (distinct to each student) is required.

The project gives the students an opportunity to use the techniques they learned in this subject to design a multivariable control system.

All written work will be submitted for assessment via Moodle unless otherwise specified. If you are unable to submit the work via Moodle, you should email the work to the project coordinator as soon as possible. The time the email is received will be considered the submission time. If the content is too big to email, you can share it via your UNSW OneDrive.
Some assessments will require you to complete the work online and it may be difficult for the course coordinator to intervene in the system after the due date. You should ensure that you are familiar with assessment systems well before the due date. If you do this, you will have time to get assistance before the assessment closes.

When you submit work through Moodle for assessment you are assumed to be assenting to the standard plagiarism declaration. A copy of the plagiarism declaration is available from this course's Moodle page. You should not include a plagiarism declaration with your submissions as it will lead to false positives in the plagiarism detection system.

Submissions received after the due date and time will be penalised at a rate of 5% per day or part thereof. No submission will be accepted 3 days after the deadlines.

Timely, constructive, and meaningful feedback will be provided to student within two weeks of assessment submission. The assessment tasks and marking rubrics are designed to reflect the expected learning outcomes specified in "Professional Outcomes" section. You are expected to pass this course if you demonstrate good understanding of the key concepts of multivariable system representation and analysis, and the basic ideas, strength and limitations of the control methods and application of these techniques. You are expected to achieve higher scores if you demonstrate deep understanding of the above concepts and the ability of applying these concepts in solving process control problems. The teaching staff will apply these marking guides fairly and provide you with feedback so you can continue to improve over the term and beyond.

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Assignments	30%	Week 3 and Week 7	1, 2, 3, 4
2. Quiz	40%	Week 9	1, 2, 3, 4
3. Design Project	30%	Week 10	1, 2, 3, 4

Assessment 1: Assignments

Due date: Week 3 and Week 7

Assignment problems are designed to ensure that lecture material is comprehended through personal practice and hence achievement of indicated learning outcomes, including (but not limited to): analysis of multivariable system dynamics, frequnecy response, operability, controllability, observability and robustness; state estimator design; control design using Linear Quadratic Regulator (LQR), Linear Quadratic Gaussian (LQG), robust control (H-inifinity) and model predictive control (MPC).

Assessment 2: Quiz

Due date: Week 9

Students will demonstrate their understanding of concepts of system and control analysis and ability to perform control design using the methods learned in this course, including: analysis of multivariable system dynamics, frequnecy response, operability, controllability, observability and robustness; state estimator design; control design using Linear Quadratic Regulator (LQR), Linear Quadratic Gaussian (LQG), robust control (H-inifinity) and model predictive control (MPC). The quiz is open-book and online.

Assessment 3: Design Project

Due date: Week 10

The project gives the students an opportunity to use the system analysis and control design techniques that they learned in this subject to design a multivariable control system and implement it using computer simulation.

Assessment criteria

The assessment criteria will be provided in the project description.

Attendance Requirements

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

Course Schedule

There are 4 hour lectures and 2 hour workshop classes every week, which cover the contents detailed in the course schedule.

[View class timetable]

Timetable

Date	Type	Content
Week 1: 12 September - 16 September	Lecture	Introduction and background; signal and systems; frequency response analysis; Bode plots; multivariable systems - state space representation; transfer function matrices
	Workshop	
Week 2: 19 September - 23 September	Lecture	Multivariable analysis; Poles and zeros of multivariable systems
	Workshop	
Week 3: 26 September - 30 September	Lecture	Lyapunov stability; internal stability; controllability analysis; Process operability analysis based on frequency responses; operability analysis for multivariable processes
	Workshop	
	Assessment	Assignment 1 due
Week 4: 3 October - 7 October	Lecture	Controller design: Linear Optimal Control (LQR)
	Workshop	
Week 5: 10 October - 14 October	Lecture	Controller design: State observer (observability) and LQG control
	Workshop	
Week 6: 17 October - 21 October	Blended	Flexibility week
Week 7: 24 October - 28 October	Lecture	Robustness analysis and Introduction to robust control
	Workshop	
	Assessment	Assignment 2 due

Week 8: 31 October - 4 November	Lecture	Introduction to Model Predictive Control
	Workshop	
Week 9: 7 November - 11 November	Project	Design project
	Workshop	Design project
	Assessment	Quiz
Week 10: 14 November - 18 November	Project	Design project
	Workshop	Design project
	Assessment	Design Project

Resources

Prescribed Resources

Online resources

The following recourses are available on Moodle or MS Teams:

- Lecture recordings (on MS Teams)
- Lecture slides (on Moodle)
- Lecture notes and suggested readings (on Moodle)
- Tutorial exercises and solutions (on Moodle)
- Links to other online resources (on Moodle)
- Online discussion forum (on MS Teams)

These will be progressively released as the semester progresses OR These are all currently available on the course website.

Prescribed text

Skogestad, S. (2nd Ed). Multivariable Feedback Control - Analysis and Design. John Wiley & Sons. ISBN(0470011688) (paperback).

The textbook is available from the University bookshop and the UNSW library:

https://www.bookshop.unsw.edu.au/details.cgi?ITEMNO=9780470011683

You can also use the older edition (Edition 1, 1996).

Computer software

You need to use Mathowrks MATLAB software to do control design and perform computer simulations in this course.

You can download MATLAB through: https://www.it.unsw.edu.au/students/software/matlab.html

You need sign up a mathworks account with your UNSW email. @student.unsw.edu.au

https://au.mathworks.com/academia/tah-support-program/eligibility.html

Once you have a mathworks account you can access the MATLAB Onramp training via the self-paced courses in a browser. https://matlabacademy.mathworks.com/

For the Simulink training you will need to access this via the Desktop/Laptop version of your downloaded MATLAB. Once in the program you can click on ‘Simulink’ and ‘Simulink Onramp'.

MATLAB and Simulink are also available online through https://www.myaccess.unsw.edu.au/.

Computers with Matlab (including toolboxes of control systems, MPC and Simulink) are required in the quiz.

Other resources

You can access the full text of online resources available from the UNSW library using the UNSW VPN Service (https://www.it.unsw.edu.au/staff/vpn/#AccessingLibraryJournals).

You can download MATLAB through: https://www.it.unsw.edu.au/students/software/matlab.html

You should sign up a mathworks account with your UNSW email. @student.unsw.edu.au

https://au.mathworks.com/academia/tah-support-program/eligibility.html

Once you have a mathworks account you can access the MATLAB Onramp training via the self-paced courses in a browser. https://matlabacademy.mathworks.com/

For the Simulink training you will need to access this via the Desktop/Laptop version of your downloaded MATLAB. Once in the program you can click on 'Simulink' and 'Simulink Onramp'.

MATLAB and Simulink are also available online through https://www.myaccess.unsw.edu.au/.

Computers with Matlab (including toolboxes of control systems, MPC and Simulink) are required in the quiz.

Course Evaluation and Development

Course delivery is influenced by student feedback in order to ensure continuous improvement. This is done through the administration of UNSW's myExperience questionnaire during the course, the student/staff meetings held by the School, as well as direct feedback to the lecturer/tutors from time to time. Several improvements of this course, for example, greater emphasis on control applications, increased tutorial hours and a better assessment scheme have been made based on previous student feedback. Your constructive suggestions would help in securing a better teaching and learning experience for future students.

Submission of Assessment Tasks

In the School of Chemical Engineering, all written work will be submitted for assessment via Moodle unless otherwise specified. Attaching cover sheets to uploaded work is generally not required; when you submit work through Moodle for assessment you are agreeing to uphold the Student Code.

Some assessments will require you to complete the work online and it may be difficult for the course coordinator to intervene in the system after the due date. You should ensure that you are familiar with assessment systems well before the due date. If you do this, you will have time to get assistance before the assessment closes.

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 penalties

Unless otherwise specified, submissions received after the due date and time will be penalised at a rate of 5% per day or part thereof (including weekends). For some activities including Moodle quizzes and Team Evaluation surveys, extensions and late submissions are not possible.

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 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.

Note: UNSW does not require a medical certificate for COVID-related absences of 7 days or less, however you must provide formal evidence from your local/state health provider (e.g. NSW Health) that clearly states your name and the date you tested positive (i.e. confirmation of your RAT registration, PCR test result). Longer absences due to extended self-isolation or COVID-related illness will still need documentation such as a medical certificate.

Applications for special consideration **will still be required** for assessment and participation absences related to COVID-19. Special consideration requests should not be lodged for missing classes if there are no assessment activities in that class.

Academic Honesty and Plagiarism

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits: honesty, trust, fairness, respect, responsibility and courage (International Center for Academic Integrity, 'The Fundamental Values of Academic Integrity', T. Fishman (ed), Clemson University, 2013). At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.

Further information about academic integrity and plagiarism can be located at:

- The Current Students site
- The ELISE training site

The Conduct and Integrity Unit provides further resources to assist you to understand your conduct obligations as a student: https://student.unsw.edu.au/conduct.

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism. Further information about referencing styles can be located at https://student.unsw.edu.au/referencing.

For assessments in the School of Chemical Engineering, we recommend the use of referencing software such as Mendeley or EndNote for managing references and citations. Unless required otherwise specified (i.e. in the assignment instructions) students in the School of Chemical Engineering should use either the APA 7th edition, or the American Chemical Society (ACS) referencing style as canonical author-date and numbered styles respectively.

Academic Information

To help you plan your degree, assistance is available from academic advisors in The Nucleus and also in the School of Chemical Engineering.

Additional support for students

- Current Student Gateway
- Engineering Current Student Resources
- Student Support and Success
- Academic Skills
- Student Wellbeing, Health and Safety
- Equitable Learning Services
- IT Service Centre

Course workload

Course workload is calculated using the 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

Physical distancing recommendations must be followed for all face-to-face classes. To ensure this, only students enrolled in those classes will be allowed in the room. Class rosters will be attached to corresponding rooms and circulated among lab demonstrators and tutors. No over-enrolment is allowed in face-to-face class. Students enrolled in online classes can swap their enrolment from online to a **limited** number of on-campus classes by Sunday, Week 1.

In certain classroom and laboratory situations where physical distancing cannot be maintained or the staff running the session believe that it will not be maintained, face masks will be designated by the course coordinator as **mandatory PPE** for students and staff. Students are required to bring and use their own face mask. Mask can be purchased from IGA Supermarket (Map B8, Lower Campus), campus pharmacy (Map F14, Middle Campus), the post office (Map F22, Upper Campus) and a vending machine in the foyer of the Biological Sciences Building (Map E26, Upper Campus).

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 advice can be found here. Do not come to campus if you have any of the following symptoms: fever (37.5 °C or higher), cough, sore throat, shortness of breath (difficulty breathing), runny nose, loss of taste, or loss of smell. If you need to have a COVID-19 test, you must not come to campus and remain in self-isolation until you receive the results of your test.

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

Note: This course outline sets out 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 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 (as updated in Moodle), the description in the Course Outline/Moodle applies.

Image Credit

Dr Peter Wich

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	