CEIC8102

Advanced Process Control

Term 3, 2021
Course Overview

Staff Contact Details

Convenors

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Availability</th>
<th>Location</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jie Bao</td>
<td><a href="mailto:j.bao@unsw.edu.au">j.bao@unsw.edu.au</a></td>
<td>By appointment or Teams messages/emails</td>
<td>Room 301 SEB</td>
<td>x56755</td>
</tr>
</tbody>
</table>

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

This course introduces the concepts and knowledge of some of the key advanced process control techniques applied in process industries to chemical engineers. It covers the concepts of linear time invariant Multi-Input Multi-Output (LTI MIMO) systems, state-space representation of process systems, controllability and observability analysis, Lyapunov stability analysis, frequency-domain multivariable analysis, stability analysis for interconnected systems, linear optimal control and state observers (soft sensors). An introduction to robust control and model predictive control is also provided, with an emphasis on the philosophy and applications of these approaches.

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:

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>EA Stage 1 Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ability to develop dynamic models for multivariable processes in the state-space representation and analyse process dynamic features using frequency response techniques.</td>
<td>PE1.1, PE1.2</td>
</tr>
<tr>
<td>2. Ability to analyse process controllability, observability, operability and robustness from process models in early stages of process design to ensure the controllability of process designs.</td>
<td>PE1.1, PE2.1, PE2.2, PE2.3</td>
</tr>
<tr>
<td>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.</td>
<td>PE1.1, PE1.3, PE2.1, PE2.2</td>
</tr>
<tr>
<td>4. Ability to design multivariable controllers using Linear Quadratic Regulator, Linear Quadratic Gaussian control and model predictive control approaches.</td>
<td>PE1.1, PE1.3, PE2.3</td>
</tr>
</tbody>
</table>

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 tutorial (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 6. 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 10% per day or part thereof.

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.

<table>
<thead>
<tr>
<th>Assessment task</th>
<th>Weight</th>
<th>Due Date</th>
<th>Course Learning Outcomes Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Major Project</td>
<td>30%</td>
<td>28/11/2021 11:55 PM</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>2. Quiz</td>
<td>40%</td>
<td>Week 9</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>3. Assignments</td>
<td>30%</td>
<td>Week 4 and Week 7</td>
<td>1, 2, 3, 4</td>
</tr>
</tbody>
</table>

Assessment 1: Major Project

Due date: 28/11/2021 11:55 PM

The project gives the students an opportunity to use the techniques they learned in this subject to design a multivariable control system and implement it in the process control laboratory.
Assessment 2: Quiz

Due date: Week 9

The course learning outcomes include a significant level of technical learning which can be effectively assessed in an exam environment and because exams have high reliability.

Assessment 3: Assignments

Due date: Week 4 and Week 7

Assignment problems are designed to ensure that lecture material is comprehended through personal practice and hence achievement of indicated learning outcomes.
Attendance Requirements

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

Course Schedule

View class timetable

Timetable

<table>
<thead>
<tr>
<th>Date</th>
<th>Type</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1: 13 September - 17 September</td>
<td>Blended</td>
<td>Introduction and background; signal and systems; Multivariable systems - state space representation; transfer function matrices; Frequency response analysis; Bode plots</td>
</tr>
<tr>
<td>Week 3: 27 September - 1 October</td>
<td>Blended</td>
<td>Multivariable analysis; Poles and zeros of multivariable systems</td>
</tr>
<tr>
<td>Week 4: 4 October - 8 October</td>
<td>Blended</td>
<td>Lyapunov stability; internal stability; controllability analysis; Process operability analysis based on frequency responses; operability analysis for multivariable processes</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Assignment 1 due.</td>
</tr>
<tr>
<td>Week 5: 11 October - 15 October</td>
<td>Blended</td>
<td>Controller design: Linear Optimal Control (LQR)</td>
</tr>
<tr>
<td>Week 6: 18 October - 22 October</td>
<td></td>
<td>Flexibility week</td>
</tr>
<tr>
<td>Week 7: 25 October - 29 October</td>
<td>Blended</td>
<td>Controller design: State observer (observability) and LQG control</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Assignment 2 due</td>
</tr>
<tr>
<td>Week 8: 1 November - 5 November</td>
<td>Blended</td>
<td>Robustness analysis and Introduction to robust control</td>
</tr>
<tr>
<td>Week 9: 8 November - 12 November</td>
<td>Blended</td>
<td>Introduction to Model Predictive Control</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Quiz</td>
</tr>
<tr>
<td>Week 10: 15 November - 19 November</td>
<td>Project</td>
<td>Design project</td>
</tr>
<tr>
<td>Study Week: 20 November - 25 November</td>
<td>Assessment</td>
<td>Design project due</td>
</tr>
</tbody>
</table>
Resources

Prescribed Resources

Online resources

The following resources are available on Moodle or MS Teams:

- Lecture recordings (videos)
- Lecture slides
- Lecture notes and suggested readings
- Tutorial exercises and solutions
- Links to other online resources

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

Prescribed text


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


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

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
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.

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.
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](https://student.unsw.edu.au)
- The [ELISE training site](https://student.unsw.edu.au/)

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](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](https://student.unsw.edu.au/referencing).

For assessments in the School of Chemical Engineering, we recommend the use of referencing software such as [Mendeley](https://www.mendeley.com) or [EndNote](https://www.endnote.com) 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 a list of hotspots 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-
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

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.
## 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 |