Online Research Seminar Syllabus

1. Overview

<table>
<tr><td>Title</td><td colspan="3">Control Systems in Robotics and Digital Technologies</td></tr>
<tr><td>Mode</td><td colspan="3">Leading Instructor Sessions & Teaching Fellow Sessions</td></tr>
<tr><td rowspan="4">Prerequisites</td><td rowspan="2">High School Students</td><td>Required course/Knowledge</td><td>High-school calculus and linear algebra. Familiarity with ordinary differential equations, integrals, and matrices.</td></tr>
<tr><td>Recommended Materials for preparing for the course</td><td>Modern Control Systems, R.C. Dorf and R.H. Bishop, 13th Edition (Available Online Free)

Read Chapter 1 + 2 to prepare.</td></tr>
<tr><td rowspan="2">College Students</td><td>Required course/Knowledge</td><td>Introductory undergraduate courses in differential equations and linear algebra.</td></tr>
<tr><td>Recommended Materials for preparing for the course</td><td>Modern Control Systems, R.C. Dorf and R.H. Bishop, 13th Edition (Available Online Free)

Read Chapter 1 + 2 to prepare.

Familiarize self with Python or MATLAB ODE simulation and plotting tools.</td></tr>
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2. Program Introduction and Objectives

Course Description	This course will introduce engineers to the principles of control automation and digital technologies, allowing them to apply control in their own work in fields including electrical, mechatronic, robotic, and digital systems engineering. Students will build an understanding of discrete control, a highly important discipline which describes the analysis and design approach for controllers

	when implemented in digital technologies such as communication and robotic systems. The course will cover background on control approaches, mathematical analysis of control systems, control design approaches, implementation of discrete control systems, and applications in control of digital systems in robotics and communications. Our goal is to prepare participants for successful careers in academic study and industry research by providing them the most important skills necessary for 21st century engineers. The course will be presented by a leading international expert in the field, with over a decade of experience in control design and practical implementation including at the world's leading universities and companies.
Software/Tools (if any)	

3. **Program Schedule**

Week		Leading Instructor Session	Teaching Fellow Session (lab/case study, etc.)	Assignment	Reading Materials
1	**Topic**	**Introduction to robotics and control**	**Introduction to basic theory and applications of the project**		Modern Control Systems, R.C. Dorf and R.H. Bishop. **Chapters 3.1-3.7 and 4.1-4.8**
	Detail	Introduce techniques for control application, analysis of design. Modelling of feedback controllers in the time and frequency domains using the Laplace Transform. Analysis of control performance and stability.			
2	**Topic**	**Introduction to discrete control systems.**	**Simulation for Solid Mechanics with Comsol**		Modern Control Systems, R.C. Dorf and R.H. Bishop. **Chapters 13.1-13.5**
	Detail	Properties and use of the z-Transform for analysis and design of discrete controllers for robotic and experimental systems.			
3	**Topic**	**Discrete control system performance and application**	**Simulation for Electric Currents with Comsol**		Modern Control Systems, R.C. Dorf and R.H. Bishop. **Chapters 5.1-5.7 and**
	Detail	System specification and			

		performance of discrete control systems. Discrete control in the state space form for analysis of robotic dynamics.			**13.6-13.8**
4	**Topic**	**Robotics and Digital Control**	**Simulation for multi-field coupling with Comsol**		Systems, R.C. Dorf and R.H. Bishop. **Chapters 13.9-13.10**
	Detail	Applications and practical analysis of control systems engineering in Robotics and Digital Technologies. Focus on discrete and digital control skills developed in Weeks 1-3.			
5	**Topic**	**Research Workshop Group 1: Continued discussion of research workshop (remaining students/groups).**	**Research Workshop Group 1: Continued discussion of research workshop (remaining students/groups).**		
	Detail	Worked examples of control challenges/questions with instructor.	Discuss the idea of the final project with each group		
6	**Topic**	**Research Workshop Group 2: Continued discussion of research workshop (remaining students/groups).**	**Research Workshop Group 2: Continued discussion of research workshop (remaining students/groups).**		
	Detail	Further worked examples and discussion of scientific papers. Group discussion.	Mock for the final presentation, and discuss with each group		
7	**Final Oral Presentation and Written Reporting**				

4. Problem Sets/Written Assignments/Quizzes

Total Number of Assignments	3 Assignments: 1st assignment – Challenge on Week 1+2 topics 2nd assignment – Challenge on Week 3 topics. 3rd assignment –Challenge on Week 4
Submission Deadline	Due at start of Weeks 3/4/5

5. Final Oral and Written Project

Detailed requirements of the final project:

Goals:

The objective of this project is for students to conceptualize, design, and analyze a feedback control system for a specific digital or robotic device or technology. Through this process, students will gain a deeper understanding of the principles and techniques involved in feedback control systems, as well as develop their mathematical and simulation skills. Below are the key aspects that should be addressed in the project.

Key Requirements:

Device or Technology Selection: Choose a device or technology for which you want to design a feedback control system. This could be a physical system, an electronic device, or any other system that can benefit from feedback control. It could be a system that already has feedback which you wish to improve, or a new system to add control to. Examples could be a robotic manipulator, HVAC system, agricultural process, bioreactor, electric car or drone, or others.

Mathematical Analysis: Develop a basic mathematical model of the chosen system using ordinary differential equations (ODEs) or other relevant mathematical tools (for example, approximation and 2nd order ODE system). Analyze the system's behavior under various conditions, including stability and performance. Use this analysis to inform your control system design.

Control System Design: Design a discrete feedback control system for your chosen device or technology, considering factors such as stability, robustness, and performance. Incorporate the knowledge gained from your mathematical analysis to optimize the system.

[Extension for advanced groups] Simulation: Create a simulation of your control system to verify its behavior and performance using software of your choice (e.g. Python/MATLAB). Analyze the results to ensure your control system meets the desired specifications.

Business case and application: Research the state-of-the-art technology for devices similar to the one you design. Compare your approach to the existing market devices and describe why yours may make a valuable invention for further development. Investigate the safety and regulatory requirements for your technology, both of which must be understood when bringing a new product from invention to sales.

Report: Write a report discussing your work, including the device or technology selection, mathematical analysis, control system design, simulation results, and expected performance and benefits. Ensure that your report includes both technical aspects and a high-level summary of your findings, suitable for a general audience.

Outcome:
By completing this assignment, students will have demonstrated their ability to apply feedback control principles to a real-world problem. They will have built their skills in modeling, discrete control system design, simulation, and technical communication. The final research report and presentation will showcase their work, highlighting their understanding of the subject matter, as well as the practical applications and benefits of their chosen feedback control system.

5.1 Final Oral Presentation

Presentations will be held in week 7. Each group will have 15 minutes to present and 5 minutes for questions.

Presentations should begin with a brief introduction to the sector the group worked on. Presentations should then *briefly* present each of the key requirements of the research project (including the Simulation Extension for groups that attempt this), including key equations, parameters, and technical analyses, and ideas for future work.

Marking criteria will include the structure of the presentation, clarify of communication, and the detail and technical achievement shown by the results.

5.2 Final Written Report

Groups are requested to present a short, maximum 1500 word report which communicates the key results and analyses performed in the project. Like the presentations, the report should begin with a brief introduction to the sector or device the group worked on. It should then *briefly* present each of the key requirements of the research project (including the Simulation Extension for groups that attempt this), using illustrations/graphs/equations to help explain the work.

6. Suggested Future Research Fields/Direction/Topics

The course will prepare students for successful careers in academic study and industry research relating to digital and robotic systems. Future research directions include robotics, IT

Technologies, Networking/communications, power grids, electric and automated vehicles.

7. Instructor Introduction

Instructor Title

Professor Harrison

Instructor Bio

Harrison is an Associate Professor of Engineering Science at the University of Oxford. His work is at the interface of control engineering, synthetic biology, and robotics, building technologies that combine electronic and biological components applies to address scientific questions as well as industrial and environmental applications. He is also founder of a Bioreactor platform venture (https://chi.bio) used widely in academia and biotechnology start-ups, and is science advisor to several start-ups in areas including biomanufacturing, environmental remediation, and development of new biomedical therapeutics. His work has attracted international recognition, won over $2M in funding and prizes, and has been featured in major news outlets and exhibitions. Prof. Steel has previously worked and studied at the University of Sydney, University of California Berkeley, NASA's Ames Research Centre, and DESY.

Instructor Profile Photo