课程详述

COURSE SPECIFICATION

以下课程信息可能根据实际授课需要或在课程检讨之后产生变动。如对课程有任何疑问，请联系授课教师。

The course information as follows may be subject to change, either during the session because of unforeseen circumstances, or following review of the course at the end of the session. Queries about the course should be directed to the course instructor.

1.	**课程名称 Course Title**	控制工程基础与设计 Fundamentals of Control Engineering and Design
2.	**授课院系** **Originating Department**	系统设计与智能制造学院 School of System Design and Intelligent Manufacturing
3.	**课程编号** **Course Code**	SDM314
4.	**课程学分 Credit Value**	3
5.	**课程类别** **Course Type**	专业核心课 Major Core Courses
6.	**授课学期** **Semester**	秋季 Fall
7.	**授课语言** **Teaching Language**	中英双语 English & Chinese
8.	**授课教师、所属学系、联系方式（如属团队授课，请列明其他授课教师）** **Instructor(s), Affiliation& Contact** **（For team teaching, please list all instructors）**	吴元庆，助理教授 系统设计与智能制造学院（设计智造学院） WU Yuanqing, Assistant Professor School of System Design and Intelligent Manufacturing（SDIM） Email: wuyq@sustech.edu.cn
9.	**实验员/助教、所属学系、联系方式** **Tutor/TA(s), Contact**	待公布 To be announced
10.	**选课人数限额(可不填)** **Maximum Enrolment** **（Optional）**	待公布 To be announced

11.	授课方式 Delivery Method	讲授 Lectures	习题/辅导/讨论 Tutorials	实验/实习 Lab/Practical	其它(请具体注明) Other（Please specify）	总学时 Total
	学时数 Credit Hours	32	0	32	0	64

12.	先修课程、其它学习要求 Pre-requisites or Other Academic Requirements	SDM283 设计力学 SDM283 Mechanics for design
13.	后续课程、其它学习规划 Courses for which this course is a pre-requisite	无 NIL
14.	其它要求修读本课程的学系 Cross-listing Dept.	无 NIL

教学大纲及教学日历 SYLLABUS

本课程介绍了设计和分析反馈系统的基本原理和工具。它旨在为有兴趣了解和利用物理、生物、信息和社会系统中的反馈控制原理的学生提供较为全面的信息渠道和专业训练。本课程的主要目标是对反馈和控制系统中的知识提供一个简洁而不失深度的观点。在开发本课程时，我们试图通过强调基本概念来浓缩不断膨胀的自动控制知识体系。 重要的是要培养学生理解为什么反馈有用，了解控制的语言和基本数学工具，并掌握过去半个世纪控制理论发展史上的关键范例。课程通过作业、MATLAB 仿真、实验、项目等手段培养学生有效利用快速的定性分析解决简单的反馈问题，对控制系统的基本局限性等抽象概念形成内化的理解。

知识点包括：

- **简介和课程概述** - 自动控制，使用原因和地点（示例）的主要概念概述：反馈与开环控制，性能度量，模拟和数字控制。
- **拉普拉斯（Laplace）变换** - 回顾方法和标准结果，线性微分方程，传递函数，框图的解决方案。
- **动态模型及属性** - 系统模型的微分方程，传递函数，状态空间形式；类型之间的转换；框图和原型反馈控制系统，性能指标，标准的一阶、二阶系统，脉冲和阶跃响应，极点和零点的影响，稳态误差。
- **PID 控制** - 定义，比例增益、积分增益和微分增益的影响，简单情况下的增益选择，Ziegler-Nichols 方法。
- **根轨迹方法** - 特征方程，根轨迹（RL）的定义，绘制 RL 的规则，使用根轨迹技术的控制系统设计，超前和滞后补偿器，Matlab RLTOOL，预补偿器和灵敏度函数。
- **频率响应方法** - 频率响应函数，波特图，奈奎斯特图，稳定性条件，增益和相位裕量，相对稳定性，M 圆，超前/滞后补偿器设计。
- **状态空间控制** - 稳定性，全状态反馈，可控制性，控制规范形式，极点位置，状态观测器，观测器规范形式和观测器极点位置，以及线性最优控制的介绍。

该课程广泛使用 Matlab 来表示和模拟控制系统。课程中包含有关控制系统设计的小组最终项目；利用 Matlab 和 Simulink

进行仿真和设计。

This course introduces the basic principles and tools for the design and analysis of feedback systems. It is intended to serve a diverse audience of scientists and engineers who are interested in understanding and utilizing feedback in physical, biological, information and social systems. A major goal of this course is to present a concise and insightful view of the current knowledge in feedback and control systems. In developing this course, we have attempted to condense the current knowledge by emphasizing fundamental concepts. We believe that it is important to understand why feedback is useful, to know the language and basic mathematics of control and to grasp the key paradigms that have been developed over the past half century. It is also important to be able to solve simple feedback problems using back-of-the-envelope techniques, to recognize fundamental limitations and difficult control problems and to have a feel for available design methods.

Topics include:

- **Introduction and course overview** – automatic control, why and where is it used (examples) overview of main concepts: feedback vs. open loop control, performance measures, analogue and digital control.
- **Laplace transforms** – review of methods and standard results, especially the solution of linear differential equations, transfer functions, block diagrams.
- **Dynamic modeling and model properties** - differential equations, transfer functions, state-space forms of system models; conversion between types; block diagrams and prototype feedback control systems, performance metrics, standard first-order and second-order systems, impulse and step responses, effect of poles and zeros, steady-state error.
- **PID control** – definition, effects of the proportional, integral and derivative terms, choice of gains in simple cases, Ziegler-Nichols methods.
- **Root locus methods** – characteristic equation, definition of the root locus (RL), rules for sketching the RL, control system design using root locus techniques, lead and lag compensators, Matlab RLTOOL, pre-compensators and sensitivity function.
- **Frequency response methods** – frequency response function, Bode plots, Nyquist plots, stability conditions, gain and phase margins, relative stability, M-circles, lead/lag compensator designs.
- **State-space control** – stability, full state feedback, controllability, control canonical form, pole placement, state observer, observer canonical form and placement of observer poles, introduction to linear optimal control.

  The course makes wide use of Matlab to represent and simulate control systems. A group final project on control system design is included in the course; this makes use of Matlab and Simulink for simulation and design.

External reference:

- SUSTech ME307: Fundamentals of control engineering
- SUSTech ME331: Robot modeling and control
- UMICH ME461: Automatic control
- MIT 2.14: Analysis and Design of Feedback Control Systems

16. 预达学习成果 Learning Outcomes

Through lectures, lab sessions and final project, students should have mastered the following abilities:

- Find differential equation and transfer function of single-input, single-output mechanical system.
- Draw feedback system block diagram and find closed-loop transfer function.
- Translate time-domain specifications into frequency-domain requirements.
- Determine steady-state error to step and ramp inputs and disturbances.
- Given a system transfer function, find time-domain behavior (impulse, step and frequency response).
- Design PI, PD, PID, lead, and lag compensators to meet control goals.
- Use software tools to design state-space controllers to meet control goals.
- Use software tools to translate continuous-time controllers into digital equivalent.
- Find closed-loop transfer function, system poles, frequency response using software tools.
- Simulate system behavior using software tools.

17. **课程内容及教学日历 （如授课语言以英文为主，则课程内容介绍可以用英文；如团队教学或模块教学，教学日历须注明主讲人）**
Course Contents (in Parts/Chapters/Sections/Weeks. Please notify name of instructor for course section(s), if this is a team teaching or module course.)

Course Schedule

Week	In-class		Out of class	
	Lecture Title	Hour	Tutorial / Lab Practice	Hour
1	反馈原理 Feedback principles	2	MATLAB Simulink 仿真练习 1 MATLAB Simulink practice I	2
2	系统建模 System modeling	2	MATLAB Simulink 仿真练习 2 MATLAB Simulink practice II	2
3	动态特性 Dynamic behavior	2	迷你项目 1：倒立摆 Mini project 1: Inverted pendulum	2
4	线性系统 Linear systems	2		2
5	状态反馈 State feedback	2		2
6	输出反馈 Output feedback	2	迷你项目 2：球盘仪 Mini project 2: Ball and plate	2
7	传递函数 Transfer functions	2		2
8	频域分析 Frequency domain analysis	2		2
9	PID 控制 PID control	2	期末项目 Final project	2
10	频域设计 Frequency domain design	2		2
11	鲁邦特性 Robust performance	2		2
12	基本限制 Fundamental limits	2		2
13	系统架构设计 Architecture and system design	2		2
14	选学内容 1 Additional topics 1	2		2

15	选学内容 2 Additional topics 2	2		2
16	选学内容 3 Additional topics 3	2		2

18. 教材及其它参考资料 Textbook and Supplementary Readings

References:

- Åström, Karl Johan, and Richard M. Murray. *Feedback systems: an introduction for scientists and engineers*. Princeton university press, 2021.
- Liu Qiu, Kemin Zhou. Introduction to Feedback Control. Pearson.
- Ogata, Katsuhiko. *Modern control engineering*. Prentice hall, 2010.
- Messner, William, and Dawn Tilbury. *Control Tutorials for Matlab and Simulink: A Web-Based Approach*. Addisson Wesley, 1999.

课程评估 ASSESSMENT

19.

评估形式 Type of Assessment	评估时间 Time	占考试总成绩百分比 % of final score	违纪处罚 Penalty	备注 Notes
出勤 Attendance				
课堂表现 Class Performance				
小测验 Quiz				
课程项目 Projects	小项目 1-8 周 Mini projects Week 1-8	20	逾期提交惩罚 Overdue penalty applies	动手技能 Hands-on skills
	期末项目 Final project	30	逾期提交惩罚 Overdue penalty applies	系统分析和设计能力 System analysis and design abilities
平时作业 Assignments	书写作业 1-13 周 Written assignments Week 1-13	20	逾期提交惩罚 Overdue penalty applies	基础知识及能力 Fundamentals
	学习笔记 1-16 周 Study notes Week 1-16	10	逾期提交惩罚 Overdue penalty applies	课外延伸 Learning beyond class
	Matlab 作业 1-13 周 Matlab assignments Week 1-13	20	逾期提交惩罚 Overdue penalty applies	仿真学习 Simulation studies
期中考试 Mid-Term Test				

期末考试 **Final Exam**				
期末报告 **Final Presentation**				
其它（可根据需要改写以上评估方式） **Others (The above may be modified as necessary)**				

20. 记分方式 **GRADING SYSTEM**

☑A. 十三级等级制 **Letter Grading**
☐ B. 二级记分制（通过/不通过） **Pass/Fail Grading**

课程审批 REVIEW AND APPROVAL

21. 本课程设置已经过以下责任人/委员会审议通过
This Course has been approved by the following person or committee of authority