《基础信息论》教学大纲

一、课程基本信息

课程名称/英文名称:	基础信息论/Fundamentals of Information Theory	课程代码:	EE142
课程层次:	本科生课程	学 分/学 时:	4/64
主要面向专业:	电子信息工程 , 计算机科学与技术	授课语言:	中英文
先修课程:	无	建议先修课程说明:	Linear Algebra,Probability and Statistics
开课单位:	信息科学与技术学院	课程负责人:	吴幼龙

二、课程简介

该课程主要介绍信息论的基本概念和应用，涉及信息的度量、数据存储和传输的极限等问题。该课程将首先介绍信息论的常用度量工具熵和互信息，并分析它们的物理意义以及数学性质，然后以此为基础介绍香农三大定理：信源压缩定理，信道编码定理，信源-信道分割定理。同时，我们介绍信息论如何在其他领域的发挥作用，如运用信息瓶颈理论来分析机器学习的黑盒问题，运用有损信源编码来缓解分布式计算的通信瓶颈问题，运用互信息来分析赛马投资问题等。本课程以黑板板书为主，辅以课堂游戏和电影来帮助大家了解书本中的概念和算法。该课程要求学生具备基本概率论和高等数学知识。

三、课程教学目标

通过本课程的学习，学生将掌握信息论的常用度量如熵和互信息，并能以信息论角度和工具来分析通信领域的极限问题，如数据压缩极限和数据传输极限问题。此外，学生将通过课程教授和课程项目深入了解信息论如何在其他领域（如生物信息，机器学习，博弈论等）发挥作用。

四、课程教学方法

通过PPT+板书的形式进行授课，辅以课后作业、课程项目来帮助巩固和串联知识点。授课过程中，某些知识点还将通过课堂游戏和电影剪辑视频等方式来帮助学生深入了解。通过课后作业，项目以及期末考试来对学生成绩进行综合评价。

五、课程教学内容与安排

以教学周方式安排教学内容

教学周	章节名称	主要教学内容 （主要知识点）	学时安排	教学方法 （仅列名称）
1	第1章　介绍和概览	介绍信息论所研究的基本问题和其他领域的交叉应用	2 学时	课堂教学、作业
1～3	第2章 熵、相对熵和互信息 2.1 熵 2.2 联合熵和条件熵 2.3 相对熵和互信息 2.4 熵与互信息的关系 2.5 熵、相对熵和互信息的链式法则 2.6 Jensen不等式及其结果 2.7 对数和不等式及其应用 2.8 数据处理不等式 2.9充分统计量 2.11 Fano不等式	介绍熵、相对熵和互信息的定义和物理意义。证明信息论中常用的不等式，并介绍其在后续章节中起到的作用。	10学时	
3～4	第3章 渐近均分性 3.1 渐近均分性的定义 3.3 高概率集与典型集	介绍和推导渐近均分性的定义和性质，浅谈其在信源编码中的作用。	4学时	课堂教学、课后作业
4	第4章 随机过程的熵率 41 马尔可夫链 4.2 熵率	介绍随机过程的熵率定义和物理意义。	2学时	课堂教学、课后作业

5～6	第5章 数据压缩 5.1 有关编码的例子 5.2 Kraft不等式 5.3 最优码 5.4 最优码长的界 5.5 惟一可译码的Kraft不等式 5.6 赫夫曼码	介绍常用的信源编码，如定长码，非前缀码，赫夫曼码，并证明赫夫曼码的最优性。	8学时	课堂教学、课后作业
7～9	第6章 信道容量 6.1 信道容量的例子 6.2 对称信道 6.3 信道容量的性质 6.4 信道编码定理预览 6.5 汉明码 6.6 反馈容量 6.7 联合信源信道编码定理	介绍信道容量的定义、计算、以及推导证明。	10学时	课堂教学、课后作业
9～10	第7章 微分熵 7.1 定义 7.2 连续随机变量的AEP 7.3 微分熵与离散熵的关系 7.4 联合微分熵和条件微分熵 7.5 相对熵和互信息 7.6 微分熵、相对熵以及互信息的性质	介绍连续变量的微分熵、联合微分熵、条件微分熵、互信息的定义和相关性质。	4学时	课堂教学、课后作业
10～12	第8章 高斯信道 8.1 高斯信道的定义 8.3 有限带宽信道 8.4 并联高斯信道 8.5 彩色高斯噪声信道	推导高斯章 高斯信道的信道容量。介绍注水法功率分配策略。介绍信道噪声，信道功率，信道带宽对信道容量的影响。	10学时	课堂教学、课后作业
12	第9章 网络信息论 9.1 定义 9.2 切割集界	介绍入门的网络信息论部分，以及广泛的切割集界。	2学时	课堂教学、课后作业

13～16	课程项目	学生阅读信息论相关论文、撰写报告并做演讲阐述	12学时	撰写并陈述报告

六、考核方式和成绩评定方法

成绩占比：作业 20%，项目30%，期末考试50%。最终成绩按照相对成绩排名来决定成绩等级，不是按照绝对的分数来决定。
关于项目：
1到2位同学为一组，阅读信息领域相关文献后撰写并陈述报告。

七、教材和参考书目

(一)、推荐教材

书名	作者	译者	出版社	出版年月	ISBN	版次
基础信息论(第二版)	T. Cover, and J. Thomas	阮吉涛等	机械工业出版社	2008-01	9787111220404	第二版

(二)、参考书目

书名	作者	译者	出版社	出版年月	ISBN	版次
Network Information Theory	A. El Gamal, and Y. H. Kim					
Elements of Information Theory	T. Cover, and J. Thomas				9780471241959	
Information Theory and Network Coding	Raymond W. Yeung					

八、学术诚信教育

本课程高度重视学术诚信，严禁抄袭、作弊等行为。
“在学习、科研、实习实践等活动中，学生应恪守学术道德，坚守学术诚信，保护知识产权，坚持勇于创新、求真务实的科学精神，努力培养自己严谨求实、诚实自律、真诚协作的科学态度，成为良好学术风气的维护者、严谨治学的力行者、优良学术道德的传承者。”
（具体请参见《上海科技大学学生学术诚信规范与管理办法（试行）》文件要求）

九、其他说明(可选)

《Fundamentals of Information Theory》 Syllabus

1.Basic course information

course name	Fundamentals of Information Theory	course code	EE142
Course Level	Undergraduate	Credit/Contact Hour:	4/64
Major:	Electronic Information Engineering , Computer Science and Technology	Teaching Language	Chinese and English
Prerequisite	NULL	Prerequisite suggestion	Linear Algebra,Probability and Statistics
School/Institute	School of Information Science and Technology	Instructor	wuyoulong

2.Course Introduction

This course mainly introduces the basic concepts and applications of information theory, including how to measure the quantity of information measurement, and the fundamental limits of compressing and transmitting information. This course will first introduce the commonly used measurement tools of information theory (entropy and mutual information) and analyze their physical meaning and mathematical properties, and then introduce Shannon's three famous theorems: Source codng theorem, Channel coding theorem, and Source-channel segmentation theorem. Besides, we will introduce how information theory plays a role in other fields, such as the use of information bottleneck theory to analyze the black-box problem of machine learning, the use of lossy source coding to alleviate the communication bottleneck problem of distributed computing, and the use of mutual information to analyze horse racing investment Problems etc. This course is mainly based on blackboard writing, supplemented by classroom games and movies to help everyone understand the concepts and algorithms in the book. This course requires students to have basic probability theory and mathematics knowledge.

3.Learning Goal

Through this course, students will master the measures of information theory such as entropy and mutual information, and can analyze the fundamental problems in the field of communication from the perspective of information theory, such as the fundamental limit of data compression and data transmission. In addition, students will gain an in-depth understanding of how information theory works in other fields, such as bioinformatics, machine learning, game theory, etc.

4.Instructional Pedagogy

Classes are taught in the form of PPT+ blackboard writing, supplemented by homework and course projects to help student consolidate and connect knowledge points. Besides, we will use classroom games, movie clips and videos in the course to help students gain in-depth understanding of some concepts and algorithms. Evaluation of student performance is based on homeworks, course project and the final exam.

5. Course Content and Schedule

Course Structure by Week

Week	Chapter	Teaching Contents	Contact Hours	Teaching Modes
1	**1. Introduction**	Introduce the basic problems researched by information theory and the cross-applications in other fields	2 hours	Teaching and homework
1～3	**2. Entropy, Relative Entropy, and Mutual Information** 2.1 Entropy 2.2 Joint Entropy and Conditional Entropy 2.3 Relative Entropy and Mutual Information 2.4 Relationship Between Entropy and Mutual Information 2.5 Chain Rules for Entropy, Relative Entropy, and Mutual Information 2.6 Jensen's Inequality and Its Consequences 2.7 Log Sum Inequality and Its Applications 2.8 Data-Processing Inequality 2.9 Sufficient Statistics 2.10 Fano's Inequality	Introduce the definitions and physical meanings of entropy, relative entropy and mutual information. Prove several commonly used inequalities in information theory and introduce their roles in subsequent chapters.	10 hours	Teaching and homework

3～4	**3. Asymptotic Equipartition Property** 3.1 Asymptotic Equipartition Property Theorem 3.2 Consequences of the AEP 3.3 Typical Set	Introduce and derive the definitions and properties of AEP, and talk about its role in source coding.	4 hours	Teaching and homework
4	**4. Entropy Rates of a Stochastic Process** 4.1 Markov Chains 4.2 Entropy Rate	Introduce the definition and physical meanings of entropy rate of stochastic process.	2 hours	Teaching and homework
5～6	**5. Data Compression** 5.1 Examples of Codes 5.2 Kraft Inequality 5.3 Optimal Codes 5.4 Bounds on the Optimal Code Length 5.5 Kraft Inequality for Uniquely Decodable Codes 5.6 Huffman Codes	Introduce various types of source codes, such as fixed-length code, non-prefix code, and Huffman code, and prove the optimality of Huffman code.	8 hours	Teaching and homework

7～9	**6.Channel Capacity** 6.1 Examples of Channel Capacity 6.2 Symmetric Channels 6.3 Properties of Channel Capacity 6.4 Channel Coding Theorem 6.5 Hamming Codes 6.6 Feedback Capacity 6.7 Source-Channel Separation Theorem	The definition, calculation, and derivation of channel capacity. The definition and related properties of differential entropy, joint differential entropy, conditional differential entropy and mutual information of continuous variables are introduced.	10 hours	Teaching and homework
9～10	**7. Differential Entropy** 7.1 Definitions 7.2 AEP for Continuous Random Variables 7.3 Relation of Differential Entropy to Discrete Entropy 7.4 Joint and Conditional Differential Entropy 7.5 Relative Entropy and Mutual Information 7.6 Properties of Differential Entropy, Relative Entropy, and Mutual Information	Introduce definitions of information measures for continuous random variables, including differential entropy, joint differential entropy, conditional differential entropy and mutual information of continuous variables are introduced.	4 hours	Teaching and homework
10～12	**8. 8. Gaussian Channel** 8.1 Definitions 8.2 Bandlimited Channels 8.3 Parallel Gaussian Channels 8.4 Channels with Colored Gaussian Noise	Derive the channel capacity of the Gaussian channel. Introduce the power distribution strategy of water-filling method. Introduce the influences of channel noise, channel power, and channel bandwidth on channel capacity.	10 hours	Teaching and homework

12	**9. Network Information Theory** 9.1 Definition 9.2 Cutset bound	Introduce small part of network information theory of introductory part, as well as a wide range of cutting boundaries.	2 hours	Teaching and homework
13～16	**10. Projects and Presentation**	Students read papers on applying information theory to other fields, write report and give presentation.	12 hours	Technical Report and Presentation

6.Grading Policy

Homework: 20%, Project 30%, Final Exam: 50%.
About the project:
Each group submits a technical report and gives 15min presentation.

7. Textbook & Recommended Reading

(1) Textbook

book name	author	translator	press	publication time	ISBN	edition
基础信息论(第二版)	T. Cover, and J. Thomas	阮吉涛等	机械工业出版社	2008-01	9787111220404	第二版

(2) Recommended Reading

book name	author	translator	press	publication time	ISBN	edition
Network Information Theory	A. El Gamal, and Y. H. Kim					
Elements of Information Theory	T. Cover, and J. Thomas				9780471241959	
Information Theory and Network Coding	Raymond W. Yeung					

8.Academic Integrity

This course highly values academic integrity. Behaviors such as plagiarism and cheating are strictly prohibited. Please list more if you have more specific requirements.

9.Other Information (Optional)