《矩阵计算》教学大纲

一、课程基本信息

课程名称/英文名称	矩阵计算/Matrix computations	课程代码	SI231B
课程层次	本研一体	学分/学时	4/64
主要面向专业	计算机科学与技术/电子科学与技术/信息与通信工程	授课语言	双语
先修课程		建议先修说明	数学分析/高等数学，线性代数
开课单位	信息科学与技术学院	课程负责人	陆疌

注 1：课程层次填写“本科生课程”、“研究生课程”或“本研一体课程”

注 2：主要填写全校 10 个本科专业（或若干个专业的组合）或“全体本科生”或“全校学生”

注 3：显示课程信息里的“强制先修课程”信息，强制先修课程是本课程的选课强制约束条件；教师在录入课程教学大纲时，该信息显示但不可修改

注 4：可在此填写教师对学生修读本课程之前应具备哪些知识基础的建议

二、课程简介

作为数学工具，矩阵计算在数学学科与其它工程领域有着广泛的应用。在已掌握本科阶段线性代数知识的基础上，本研究生课程可以进一步深化矩阵计算的相关知识，培养学生抽象思维能力、科学计算能力、科学研究能力，从而提高学生解决实际问题的能力。课程在学时设计上为理论课与实践课相结合，课程前 12 周（48 学时）为理论课程，主要以课堂讲授的形式介绍矩阵分析和计算的理论知识，后 4 周（16 学时）为实践课程，安排同学们上机编程实验，熟悉矩阵计算各种算法的实现，并且基于课程知识完成一个课程设计。

三、课程教学目标

知识认知能力：通过课程基本知识的讲授，培养锻炼学生的逻辑思维和抽象思维的能力，在记忆、理解、应用、分析、评价与创造六个层次中提升学生知识水平,使学生深度理解与掌握矩阵计算课程中的核心思想与数学原理。

综合素质能力：具备科学精神和从事研究的基本素养，具备科技报国的家国情怀和使命担当；能进行团队协作，具备合作精神和人际沟通能力。

四、课程教学方法

课堂讲授与讨论：矩阵计算基础知识与核心思想的讲授，在讲解基本知识点的基础上，关注课程重点难点内容的讲授。采用启发式教学方法，引导学生对问题展开思考和讨论。

实践课程：通过上机实践课程，使学生掌握矩阵计算与优化算法的编程方法，通过具体应用案例讲解，加强学生对矩阵计算与优化相关算法的理解。

课后辅导：通过适量的习题课设置与固定答疑时间的安排，巩固学生的基础，强化数学思维。

课程设计：通过使用课程核心内容与数学思想，结合学生从事各研究方向的当前热点领域，提出并设计相关算法，深刻理解与掌握矩阵计算在信息学科与工程中的应用。

五、课程教学内容与安排

章节名称	**主要教学内容** **（主要知识点）**	**教学周**	**学时安排**	**教学方法** **（仅列名称）**
导引	• 课程的主要内容介绍 • 线性代数回顾 • 浮点运算，误差分析，灵敏度分析	第一、二周	8	

线性系统和 LU 分解		• 三角系统 • 高斯消元法 • LU 分解 • 部分选主元的 LU 分解 • LDM 分解， 对称矩阵的 LDL 分解，正定矩阵的 Choleskey 分解 • 其他线性系统，如带状系统	第三、四周	8	
最小二乘和 QR 分解		• 工程应用中的最小二乘问题 • QR 分解 • Gram-Schmidt QR 分解，改进的 Gram-Schmidt QR 分解 • Householder QR 分解，Givens QR 分解 • 基于正规方程法的最小二乘求解 • 基于 QR 分解的最小二乘求解 • 其他最小二乘问题	第五、六、七周	12	
特征值、特征向量、特征分解		• 特征值和特征向量的性质 • 特征分解，Hermitian 矩阵的特征分解 • Schur 分解	第八、九、十周	12	

	• Hermitian 矩阵特征值的变分性质 • 相似变换 • 幂迭代法 • QR 迭代法			
半正定矩阵	• 半正定矩阵的性质 • 矩阵不等式	第十一周	4	
奇异值、奇异向量、奇异值分解	• 奇异值分解，奇异值分解与特征分解的关系 • 奇异值分解的性质 • 矩阵范数 • 基于奇异值分解的线性系统与最小二乘问题的求解 • 伪逆 • 正交投影 • 低秩矩阵近似 • 奇异值不等式 • 奇异值分解的计算	第十二周	4	
实验课程	LU 分解算法、线性系统相关应用的求解	第十三周	4	
实验课程	QR 分解算法、最小二乘相关应用的求解	第十四周	4	
实验课程	特征值分解算法、特征值相关应用的求解	第十五周	4	
实验课程	奇异值分解算法、奇异值相关应用的求解	第十六周	4	

六、考核方式和成绩评定方法

1. 作业，占总成绩的 30%；
2. 期中考试，占总成绩的 40%；
3. 课程设计（包含实验），占总成绩的 30%。

七、教材和参考书目

<table>
<tr><td rowspan="5">参考书目</td><td>教材名称</td><td>教材作者</td><td>教材译者</td><td>ISBN</td><td>教材出版社</td><td>出版日期</td><td>教材版次</td></tr>
<tr><td>Matrix Analysis</td><td>Roger. A. Horn and Charles. R. Johnson</td><td></td><td>978-0521386326</td><td>Cambridge University Press</td><td>1990-02</td><td>2</td></tr>
<tr><td>Matrix Analysis and Applied Linear Algebra</td><td>Carl D. Meyer</td><td></td><td>978-0898714548</td><td>SIAM (Society for Industrial and Applied Mathematics)</td><td>2000-06</td><td>1</td></tr>
<tr><td>Matrix Analysis for Scientists & Engineers</td><td>Alan J. Laub</td><td></td><td>978-0898715767</td><td>SIAM (Society for Industrial and Applied Mathematics)</td><td>2004-12</td><td>1</td></tr>
<tr><td>矩阵分析与应用</td><td>张贤达</td><td></td><td>978-7302092711</td><td>清华大学出版社</td><td>2004-09</td><td>1</td></tr>
<tr><td>推荐教材</td><td>教材名称</td><td>教材作者</td><td>教材译者</td><td>ISBN</td><td>教材出版社</td><td>出版日期</td><td>教材版次</td></tr>
</table>

	Matrix Computations	G. Golub and C. Van Loan		978-1421407944	The Johns Hopkins University Press	2013-02	4

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，如果教师有更具体的要求，请详细列出。）

九、其他说明（可选）

Matrix computations Syllabus

1. Basic Course Information

Course Name	Matrix computations	Course Code	SI231B
Course Level	undergraduate/graduate	Credit/Contact Hour	4/64
Major	CS/EE/IE	Teaching Language:	Bilingualism
Prerequisite		Prerequisite suggestion:	Mathematical analysis/Calculus, Linear algebra
School/Institute	School of Information Science and Technology	Instructor	陆疌

*Notes: *Course level includes undergraduate, graduate, or undergraduate/graduate.*

***If multiple instructors are involved，please list the name of team leader.*

2. Course Introduction

As a mathematical tool, matrix computations have a wide range of applications in mathematics and engineering fields. On the basis of mastering the undergraduate-level linear algebra, students can further deepen the related knowledge of matrix computations, and cultivate their abstract thinking ability as well as scientific computing and scientific research abilities through this graduate course, thereby improving their capabilities of solving real-world problems. The course is designed to combine theory and practice. The first 12 weeks (48 class hours) of the course are theoretical classes, mainly introducing the theoretical knowledge of matrix analysis and computations in the form of classroom lectures. The last 4 weeks (16 class hours) are practical classes, arranging students to conduct computer programming experiments, familiarize themselves with the implementation of various algorithms for matrix computations, and complete a project based on the course content.

3. Learning Goal

Knowledge cognitive ability: Through the teaching of basic knowledge in the course, students' logical thinking and abstract thinking abilities are cultivated and improved, and their knowledge level is enhanced in terms of memorization, understanding, application, analysis, evaluation and creation. The core ideas and mathematical principles in the course of the matrix computations are deeply understood and mastered.

Comprehensive ability: Obtain the scientific spirit and basic literacy for engaging in research, obtain the feelings of family and country and mission to serve the country through science and technology; be able to work in a team, have the spirit of cooperation and interpersonal communication skills.

4. Textbook & Recommended Reading

	Book Title	Author	Translator	ISBN	Pubulisher	Pubulished Date	Edition
Textbook	Matrix Analysis	Roger. A. Horn and Charles. R. Johnson		978-0521386326	Cambridge University Press	1990-02	2
	Matrix Analysis and Applied Linear Algebra	Carl D. Meyer		978-0898714548	SIAM (Society for Industrial and Applied Mathematics)	2000-06	1
	Matrix Analysis for Scientists & Engineers	Alan J. Laub		978-0898715767	SIAM (Society for Industrial and Applied Mathematics)	2004-12	1
	矩阵分析与应用	张贤达		978-7302092711	清华大学出版社	2004-09	1

	Book Title	Author	Translator	ISBN	Pubulisher	Pubulished Date	Edition
Recommended Reading	Matrix Computations	G. Golub and C.		978-1421407944	The Johns Hopkins University	2013-02	4

		Van Loan			Press		

5.Grading Policy

1. assignments (30%)
2. midterm exam (40%)
3. final project (including lab simulations) (30%)

6. Instructional Pedagogy

Classroom lectures and discussions: The basic knowledge and core ideas of matrix computations are taught. On the basis of explaining the basic knowledge points, attention is paid to the teaching of key and difficult content of the course. Use heuristic teaching methods to guide students to think and discuss issues.

Practical courses: Through computer-based practical courses, students can master the programming methods of matrix computations and optimization algorithms. Through explanations of specific application cases, students can strengthen their understanding of matrix computations and optimization-related algorithms.

After-school tutoring: Through the setting of appropriate exercises and fixed time for answering questions, students can consolidate their foundation and strengthen their mathematical thinking.

Course project: By using the core content of the course and mathematical ideas, combined with the current hot areas in various research directions, students will propose and design relevant algorithms, and gain a deep understanding and mastery of the application of matrix computations in information science and engineering.

7. Course Structure

Chapter	Teaching Contents	Week	Contact Hours	Teaching Modes
Introduction	• Main topics we address in this course • Review on basic linear algebra • Floating point arithmetic, error, and sensitivity analysis	Weeks 1-2	8	
Linear systems and LU decomposition	• Triangular systems • Gaussian elimination • LU decomposition • LU decomposition with partial pivoting • LDM decomposition, LDL decomposition (for symmetric systems), Choleskey decomposition (for positive definite systems) • Other special linear systems (banded systems)	Weeks 3-4	8	
Least squares problems and QR decomposition	• Least squares problems in different engineering applications • QR decomposition • Gram-Schmidt QR,	Weeks 5-7	12	

	modified Gram-Schmidt QR • Householder QR and Givens QR • Least squares with method of normal equations • Least squares with QR • Other least squares problems				
Eigenvalues, eigenvectors, and eigendecomposition	• Properties of eigenvalues and eigenvectors • Eigendecomposition and the case of Hermitian matrices • Schur decomposition • Variational characterizations of eigenvalues of Hermitian matrices • Similarity transformation • Power iteration • QR iteration	Weeks 8-10	12		
Positive Semidefinite Matrices	• Properties of positive semidefinite matrices • Matrix inequalities	Week 11	4		
Singular value, singular vectors, and singular value decomposition	• Singular value decompositions and its relation to eigendecompositions • Properties of singular value decompositions	Weeks 12	4		

s	• Matrix norms • Solving general linear system and least squares problems via singular value decompositions • Pseudo-inverse • Orthogonal projections • Low-rank approximations • Singular value inequalities • Computations of SVD				
Lab class	LU decompositions and linear system related applications	Week 13	4		
Lab class	QR decompositions and least squares related applications	Week 14	4		
Lab class	Eigendecompositions and eigenvalue related applications	Week 15	4		
Lab class	Singular value decompositions and singular value related applications	Week 16	4		

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)