

Matrix Computations, 1st Edition
Golub and Van Loan
Table of Contents

1. Background Matrix Algebra	1
1.1 Vectors and Matrices	1
1.2 Independence, Orthogonality, Subspaces	4
1.3 Special Matrices	6
1.4 Block Matrices and Complex Matrices	8
2. Measuring Vectors, Matrices, Subspaces, and Linear System Sensitivity	11
2.1 Vector Norms	12
2.2 Matrix Norms	14
2.3 The Singular Value Decomposition	16
2.4 Orthogonal Projections and the CS Decomposition	20
2.5 The Sensitivity of Square Linear Systems	24
3. Numerical Matrix Algebra	30
3.1 Matrix Algorithms	30
3.2 Rounding Errors	32
3.3 Householder Transformations	38
3.4 Givens Transformations	43
3.5 Gauss Transformations	47
4. Gaussian Elimination	52
4.1 Triangular Systems	52
4.2 Computing the LU Factorization	54
4.3 Roundoff Analysis of Gaussian Elimination	60
4.4 Pivoting	64
4.5 Improving and Estimating Accuracy	71
5. Special Linear Systems	81
5.1 The LDM^T and LDL^T Factorizations	82
5.2 Positive Definite Systems	86
5.3 Banded Systems	92

- 5.4 Symmetric Indefinite Systems 100
- 5.5 Block Tridiagonal Systems 110
- 5.6 Vandermonde Systems 119
- 5.7 Toeplitz Systems 125

6. Orthogonalization and Least Squares Methods 136

- 6.1 Mathematical Properties of the Least Squares Problem 137
- 6.2 Householder and Gram Schmidt Methods 146
- 6.3 Givens and Fast Givens Methods 156
- 6.4 Rank Deficiency I: QR With Column Pivoting 162
- 6.5 Rank Deficiency II: The Singular Value Decomposition 169
- 6.6 Weighting and Iterative Improvement 179
- 6.7 A Note on Square and Underdetermined Systems 185

7. The Unsymmetric Eigenvalue Problem 189

- 7.1 Properties and Decompositions 190
- 7.2 Perturbation Theory 199
- 7.3 Power Iterations 208
- 7.4 The Hessenberg and Real Schur Decompositions 219
- 7.5 The Practical QR Algorithm 228
- 7.6 Computing Eigenvectors and Invariant Subspaces 238
- 7.7 The QZ Algorithm and the $Ax = \mu Bx$ Problem 251

8. The Symmetric Eigenvalue Problem 267

- 8.1 Properties, Decompositions, Perturbation Theory 268
- 8.2 Tridiagonalization and Symmetric QR Algorithm 276
- 8.3 Once Again: The Singular Value Decomposition 285
- 8.4 Jacobi Methods 295
- 8.5 Some Special Methods 305
- 8.6 More Generalized Eigenvalue Problems 313

9. Lanczos Methods 322

- 9.1 Derivation and Convergence Properties 322
- 9.2 Practical Lanczos Procedures 332
- 9.3 Applications to Linear Equations and Least Squares 342

10. Iterative Methods for Linear Systems	352
10.1 The Standard Iterations	353
10.2 Derivation and Properties of the Conjugate Gradient Method	362
10.3 Practical Conjugate Gradient Procedures	372
11. Functions of Matrices	380
11.1 Eigenvalue Methods	380
11.2 Approximation Methods	387
11.3 The Matrix Exponential	396
12. Special Topics	404
12.1 Some Constrained Least Squares Problems	405
12.2 Subset Selection Using the Singular Value Decomposition	414
12.3 Total Least Squares	420
12.4 Comparing Subspaces Using the Singular Value Decomposition	425
12.5 Some Modified Eigenvalue Problems	431
12.6 Updating the QR Factorization	437