

Table of Contents

Deep Learning and Neural Nets	iii
Preface and Acknowledgments	vi
Part I : Highlights of Linear Algebra	1
I.1 Multiplication Ax Using Columns of A	2
I.2 Matrix-Matrix Multiplication AB	9
I.3 The Four Fundamental Subspaces	14
I.4 Elimination and $A = LU$	21
I.5 Orthogonal Matrices and Subspaces	29
I.6 Eigenvalues and Eigenvectors	36
I.7 Symmetric Positive Definite Matrices	44
I.8 Singular Values and Singular Vectors in the SVD	56
I.9 Principal Components and the Best Low Rank Matrix	71
I.10 Rayleigh Quotients and Generalized Eigenvalues	81
I.11 Norms of Vectors and Functions and Matrices	88
I.12 Factoring Matrices and Tensors : Positive and Sparse	97
Part II : Computations with Large Matrices	113
II.1 Numerical Linear Algebra	115
II.2 Least Squares: Four Ways	124
II.3 Three Bases for the Column Space	138
II.4 Randomized Linear Algebra	146

Part III: Low Rank and Compressed Sensing	159
III.1 Changes in A^{-1} from Changes in A	160
III.2 Interlacing Eigenvalues and Low Rank Signals	168
III.3 Rapidly Decaying Singular Values	178
III.4 Split Algorithms for $\ell^2 + \ell^1$	184
III.5 Compressed Sensing and Matrix Completion	195
Part IV: Special Matrices	203
IV.1 Fourier Transforms: Discrete and Continuous	204
IV.2 Shift Matrices and Circulant Matrices	213
IV.3 The Kronecker Product $A \otimes B$	221
IV.4 Sine and Cosine Transforms from Kronecker Sums	228
IV.5 Toeplitz Matrices and Shift Invariant Filters	232
IV.6 Graphs and Laplacians and Kirchhoff's Laws	239
IV.7 Clustering by Spectral Methods and k -means	245
IV.8 Completing Rank One Matrices	255
IV.9 The Orthogonal Procrustes Problem	257
IV.10 Distance Matrices	259
Part V: Probability and Statistics	263
V.1 Mean, Variance, and Probability	264
V.2 Probability Distributions	275
V.3 Moments, Cumulants, and Inequalities of Statistics	284
V.4 Covariance Matrices and Joint Probabilities	294
V.5 Multivariate Gaussian and Weighted Least Squares	304
V.6 Markov Chains	311

Part VI: Optimization	321
VI.1 Minimum Problems : Convexity and Newton’s Method	324
VI.2 Lagrange Multipliers = Derivatives of the Cost	333
VI.3 Linear Programming, Game Theory, and Duality	338
VI.4 Gradient Descent Toward the Minimum	344
VI.5 Stochastic Gradient Descent and ADAM	359
Part VII: Learning from Data	371
VII.1 The Construction of Deep Neural Networks	375
VII.2 Convolutional Neural Nets	387
VII.3 Backpropagation and the Chain Rule	397
VII.4 Hyperparameters : The Fateful Decisions	407
VII.5 The World of Machine Learning	413
Books on Machine Learning	416
Eigenvalues and Singular Values : Rank One	417
Codes and Algorithms for Numerical Linear Algebra	418
Counting Parameters in the Basic Factorizations	419
Index of Authors	420
Index	423
Index of Symbols	432