

Numerical Computing with MATLAB

Cleve B. Moler
The MathWorks, Inc.

siam

Society for Industrial and Applied Mathematics
Philadelphia

Contents

Preface	ix
1 Introduction to MATLAB	1
1.1 The Golden Ratio	1
1.2 Fibonacci Numbers	7
1.3 Fractal Fern	13
1.4 Magic Squares	18
1.5 Cryptography	26
1.6 The $3n + 1$ Sequence	31
1.7 Floating-Point Arithmetic	33
1.8 Further Reading	41
Exercises	41
2 Linear Equations	53
2.1 Solving Linear Systems	53
2.2 The MATLAB Backslash Operator	54
2.3 A 3-by-3 Example	54
2.4 Permutation and Triangular Matrices	56
2.5 LU Factorization	57
2.6 Why Is Pivoting Necessary?	58
2.7 <code>lutx</code> , <code>bslashtx</code> , <code>lugui</code>	60
2.8 Effect of Roundoff Errors	63
2.9 Norms and Condition Numbers	66
2.10 Sparse Matrices and Band Matrices	72
2.11 PageRank and Markov Chains	74
2.12 Further Reading	81
Exercises	82
3 Interpolation	93
3.1 The Interpolating Polynomial	93
3.2 Piecewise Linear Interpolation	98
3.3 Piecewise Cubic Hermite Interpolation	99
3.4 Shape-Preserving Piecewise Cubic	100
3.5 Cubic Spline	102

3.6	<code>pchiptx</code> , <code>splinetx</code>	105
3.7	<code>interpGUI</code>	108
	Exercises	110
4	Zeros and Roots	117
4.1	Bisection	117
4.2	Newton's Method	119
4.3	A Perverse Example	121
4.4	Secant Method	122
4.5	Inverse Quadratic Interpolation	123
4.6	<code>zeroin</code>	124
4.7	<code>fzerotx</code> , <code>feval</code>	124
4.8	<code>fzerogui</code>	129
4.9	Value Finding and Reverse Interpolation	132
4.10	Optimization and <code>fmintx</code>	132
	Exercises	135
5	Least Squares	141
5.1	Models and Curve Fitting	141
5.2	Norms	143
5.3	<code>censusGUI</code>	144
5.4	Householder Reflections	145
5.5	The QR Factorization	147
5.6	Pseudoinverse	152
5.7	Rank Deficiency	154
5.8	Separable Least Squares	156
5.9	Further Reading	159
	Exercises	159
6	Quadrature	167
6.1	Adaptive Quadrature	167
6.2	Basic Quadrature Rules	168
6.3	<code>quadtx</code> , <code>quadGUI</code>	170
6.4	Specifying Integrands	173
6.5	Performance	175
6.6	Integrating Discrete Data	177
6.7	Further Reading	179
	Exercises	179
7	Ordinary Differential Equations	187
7.1	Integrating Differential Equations	187
7.2	Systems of Equations	188
7.3	Linearized Differential Equations	189
7.4	Single-Step Methods	191
7.5	The BS23 Algorithm	194
7.6	<code>ode23tx</code>	196
7.7	Examples	199

7.8	Lorenz Attractor	202
7.9	Stiffness	204
7.10	Events	208
7.11	Multistep Methods	212
7.12	The MATLAB ODE Solvers	212
7.13	Errors	213
7.14	Performance	217
7.15	Further Reading	219
	Exercises	219
8	Fourier Analysis	237
8.1	Touch-Tone Dialing	237
8.2	Finite Fourier Transform	241
8.3	ffftgui	242
8.4	Sunspots	244
8.5	Periodic Time Series	248
8.6	Fast Finite Fourier Transform	249
8.7	ffttx	250
8.8	fftmatrix	251
8.9	Other Fourier Transforms and Series	252
8.10	Further Reading	254
	Exercises	254
9	Random Numbers	257
9.1	Pseudorandom Numbers	257
9.2	Uniform Distribution	257
9.3	Normal Distribution	260
9.4	randtx, randntx	263
	Exercises	265
10	Eigenvalues and Singular Values	269
10.1	Eigenvalue and Singular Value Decompositions	269
10.2	A Small Example	272
10.3	eigshow	273
10.4	Characteristic Polynomial	275
10.5	Symmetric and Hermitian Matrices	276
10.6	Eigenvalue Sensitivity and Accuracy	277
10.7	Singular Value Sensitivity and Accuracy	283
10.8	Jordan and Schur Forms	284
10.9	The QR Algorithm	285
10.10	eigsvdgui	287
10.11	Principal Components	289
10.12	Circle Generator	293
10.13	Further Reading	298
	Exercises	298

11 Partial Differential Equations	307
11.1 Model Problems	307
11.2 Finite Difference Methods	308
11.3 Matrix Representation	310
11.4 Numerical Stability	312
11.5 The L-Shaped Membrane	314
Exercises	319
Bibliography	327
Index	332