Numerical Methods of Exploration Seismology

With Algorithms in MATLAB

GARY F. MARGRAVE
University of Calgary

MICHAEL P. LAMOUREUX
University of Calgary

CAMBRIDGE
UNIVERSITY PRESS

Contents

Preface *page* ix
Note on Online Resources xi
How to Obtain the MATLAB Codes xi

1 Introduction to MATLAB and Seismic Data 1
1.1 Scope and Prerequisites 1
1.2 MATLAB Conventions Used in This Book 3
1.3 Seismic Wavelets 6
1.4 Dynamic Range and Seismic Data Display 10
1.5 Programming Tools 28
1.6 Programming for Efficiency 35
1.7 Chapter Summary 40

2 Signal Theory: Continuous 41
2.1 What is a Signal? 41
2.2 Crosscorrelation and Autocorrelation 42
2.3 Convolution 48
2.4 The Fourier Transform 55
2.5 Multidimensional Fourier Transforms 90
2.6 Chapter Summary 103

3 Signal Theory: Discrete 104
3.1 Sampling 104
3.2 Interpolation, Aliasing, and Resampling 116
3.3 Discrete Convolution 121
3.4 The Discrete Fourier Transform 136
3.5 Discrete Minimum Phase 149
3.6 Filtering and Spectral Analysis 155
3.7 Time–Frequency Analysis 165
3.8 Multidimensional Discrete Fourier Transforms 171
3.9 Chapter Summary 181

4 Wave Propagation and Seismic Modeling 182
4.1 Introduction 182
4.2 The Wave Equation Derived from Physics 184
4.3 Waveform Changes in Heterogeneous Wave Equation 194

4.4 Waves in an Elastic Medium 195
4.5 Finite-Difference Modeling with the Acoustic Wave Equation 196
4.6 The One-Dimensional Synthetic Seismogram 206
4.7 MATLAB Tools for 1D Synthetic Seismograms 215
4.8 Chapter Summary 244

5 Deconvolution: The Estimation of Reflectivity 245
5.1 The Deconvolution Trace Model 245
5.2 Gain Correction 249
5.3 Frequency-Domain Stationary Spiking Deconvolution 254
5.4 Time-Domain Stationary Spiking Deconvolution 266
5.5 Predictive Deconvolution 276
5.6 Nonstationary Deconvolution 288
5.7 Chapter Summary 306

6 Velocity Measures and Ray Tracing 309
6.1 Instantaneous Velocity: v_{ins} or Just v 310
6.2 Vertical Traveltime: τ 311
6.3 v_{ins} as a Function of Vertical Traveltime: $v_{\text{ins}}(\tau)$ 312
6.4 Average Velocity: v_{ave} 313
6.5 Mean Velocity: v_{mean} 314
6.6 RMS Velocity: v_{rms} 315
6.7 Interval Velocity: v_{ins} 317
6.8 MATLAB Velocity Tools 320
6.9 Apparent Velocity: v_x, v_y, v_z 323
6.10 Snell's Law 326
6.11 Ray Tracing in a $v(z)$ Medium 327
6.12 Ray Tracing for Inhomogeneous Media 343
6.13 Chapter Summary 350

7 Elementary Migration Methods 351
7.1 Stacked Data 352
7.2 Fundamental Migration Concepts 361
7.3 MATLAB Facilities for Simple Modeling and Raytrace Migration 377
7.4 Fourier Methods 389
7.5 Kirchhoff Methods 408
7.6 Finite-Difference Methods 417
7.7 Practical Considerations for Finite Datasets 423
7.8 Chapter Summary 434

References 435
Index 438