

Contents

1	Introduction	1
	Tetsuya Sakuma and Toru Otsuru	
1.1	Computational Simulation for Sound Environment Design	1
1.2	Progress of Computational Acoustics	3
1.2.1	Advent of Wave-Based Acoustic Analysis	3
1.2.2	Features of Numerical Methods	4
1.2.3	Application to Sound Environmental Simulation	5
	References	6
 Part I Methods of Wave-Based Acoustic Simulation		
2	Finite-Difference Time-Domain Method	11
	Shinichi Sakamoto, Hideo Tsuru, Masahiro Toyoda and Takumi Asakura	
2.1	Fundamentals	12
2.1.1	Basic Equations	12
2.1.2	Boundary Conditions	14
2.1.3	FDTD(2, 4) Method	16
2.1.4	Stability and Dispersion Error	18
2.1.5	Absorbing Boundary Condition	20
2.2	Techniques for High Accuracy	25
2.2.1	Compact Finite Difference	25
2.2.2	Improvement of Time Integration	32
2.3	Application to Vibroacoustic Problems	33
2.3.1	Solid Modeling	35
2.3.2	Plate Modeling	42
	References	50
3	Finite Element Method	53
	Toru Otsuru, Takeshi Okuzono, Noriko Okamoto and Yusuke Naka	
3.1	Fundamentals	54
3.1.1	Sound Field Formulation by FEM	54
3.1.2	3-D Acoustic Elements	57

3.2	Efficient Computation with Iterative Solvers.	61
3.2.1	Linear System of Equations and Solvers	61
3.2.2	Estimation of Required Memory	64
3.2.3	Convergence of Iterative Methods.	65
3.3	Application to Exterior Problems.	69
3.3.1	Approaches to Exterior Problems	70
3.3.2	Dirichlet-to-Neumann Method	70
	References	76
4	Boundary Element Method.	79
	Yosuke Yasuda and Tetsuya Sakuma	
4.1	Fundamentals	79
4.1.1	Frequency Domain BEM	80
4.1.2	Time Domain BEM.	88
4.2	Indirect Method and Domain Decomposition Method	92
4.2.1	Indirect BEM	92
4.2.2	Domain Decomposition Method	96
4.3	Application of Fast Multipole Method	100
4.3.1	Application of Iterative Method to BEM	100
4.3.2	Fast Multipole Method	101
4.3.3	Fast Calculation of Matrix-Vector Products	105
4.3.4	Implementation Considerations	110
	References	112
5	Alternative Time-Domain Methods.	117
	Takuya Oshima, Takashi Ishizuka and Kan Okubo	
5.1	Linearized Euler Equation Method	118
5.1.1	Governing Equations	118
5.1.2	Discretization	118
5.1.3	Computational Setup	121
5.1.4	Results.	122
5.2	Constrained Interpolation Profile Method	122
5.2.1	Formulation	124
5.2.2	Implementation.	126
5.2.3	Boundary Conditions.	129
5.2.4	Perfectly Matched Layer	130
5.3	Finite-Volume Time-Domain Method	133
5.3.1	Finite-Volume Formulation	134
5.3.2	Rigid Boundary Conditions	136
5.3.3	Computational Setup	136
5.3.4	Results and Discussion	138
5.3.5	Computational Loads.	139
	References	140

Part II Applications to Architectural and Environmental Acoustic Problems

6 Room Acoustics Simulation	145
Reiji Tomiku, Shinichi Sakamoto, Noriko Okamoto, Yosuke Yasuda, Yoshinari Horinouchi and Kazuma Hoshi	
6.1 Auditoria	146
6.1.1 Application of FDTD Method.	146
6.1.2 Application of FEM and BEM	150
6.2 Seating Rows	154
6.2.1 Analysis with Layer Model Admittance.	155
6.2.2 Analysis with Seat Top Section Admittance.	160
6.3 Reverberation Rooms.	163
6.3.1 Comparison with Measurement Results	163
6.3.2 Descriptors for Diffuseness of Sound Fields.	164
6.4 Vehicle Cabins	168
6.4.1 Boundary Conditions.	168
6.4.2 Numerical Analysis of Impulse Responses.	171
6.5 Partitions	172
6.5.1 Insulation Effect of Arrayed Partitions.	174
References	177
7 Noise Propagation Simulation.	179
Masahiro Toyoda, Takuya Oshima, Takatoshi Yokota, Tomonao Okubo, Shinichi Sakamoto, Yosuke Yasuda, Takashi Ishizuka, Yasuhito Kawai and Takumi Asakura	
7.1 Outdoor Noise Propagation.	180
7.1.1 Influence of Wind.	180
7.1.2 Efficient Calculation of Long-Range Propagation	183
7.1.3 Chained Simulation of CFD and LEE Method	188
7.2 Noise Barriers.	194
7.2.1 2.5-D Analysis Using BEM	195
7.2.2 Numerical Examples	196
7.2.3 Notes on Absorbing Boundaries	200
7.3 Depressed Roads.	200
7.3.1 2-D Analysis Using FDTD Method.	200
7.3.2 2.5-D Analysis Using FDTD Method	204
7.3.3 3-D Analysis Using FMBEM	206
7.4 Building Façades.	211
7.4.1 2-D Analysis Using BEM	211
7.4.2 3-D Analysis Using FMBEM	217
7.5 Building Windows.	220
7.5.1 Flanking Propagation Between Apertures.	220
7.5.2 Propagation Through Facing Apertures	225

7.6	Floor Impact Sound	231
7.6.1	Solid Modeling	232
7.6.2	Plate Modeling	238
	References	240
8	Acoustic Property Simulation for Building Components	243
	Takumi Asakura, Yasuhito Kawai, Hisaharu Suzuki, Naohisa Inoue, Tetsuya Sakuma, Hirofumi Onitsuka and Takayuki Masumoto	
8.1	Absorbers	244
8.1.1	Assumption of Locally Reacting Condition	244
8.1.2	Area Effect	246
8.1.3	Simple FDTD Model	252
8.1.4	Layered Material FE Model	257
8.2	Diffusers	268
8.2.1	BE Analysis of Surface Scattering	269
8.2.2	Calculation of Surface Scattering Indicators	272
8.3	Insulation of Windows	273
8.3.1	Analysis Using BEM	275
8.3.2	Analysis Using FDTD Method	279
8.4	Acoustic Radiation from Loudspeakers	283
8.4.1	Calculation Procedure	285
8.4.2	Numerical Examples	287
	References	293
9	Auralization	295
	Takatoshi Yokota, Takumi Asakura and Takayuki Masumoto	
9.1	Room Acoustics	296
9.1.1	Multichannel Reproduction System with FDTD Method	296
9.1.2	Simulation of Room Impulse Responses	297
9.1.3	Effects of Sound Diffusers in Rooms	299
9.1.4	Auralization of “Roaring Dragon”	300
9.2	Noise Propagation	303
9.2.1	Auralization Method	303
9.2.2	Simulation Results	305
9.3	Head-Related Transfer Functions	308
9.3.1	Basic Examination	309
9.3.2	Simulation Results	313
	References	317
	Index	319

Computational Simulation in Architectural and
Environmental Acoustics

Methods and Applications of Wave-Based Computation

Sakuma, T.; Sakamoto, S.; Otsuru, T. (Eds.)

2014, XIV, 324 p. 237 illus., 38 illus. in color., Hardcover

ISBN: 978-4-431-54453-1