

Contents

Preface	v
1 Introduction	1
1.1 Chatter in Machine Tools	1
1.1.1 The Experiment	2
1.1.2 Correlations Among Data Points	4
1.1.3 The Number of Coordinates	5
1.1.4 Prediction of the x displacement of the Cutting Tool	7
1.1.5 Preview of Things to Come	9
2 Reconstruction of Phase Space	13
2.1 Observations of Regular and Chaotic Motions	13
2.2 Chaos in Continuous and Discrete Time Dynamics	15
2.3 Observed Chaos	16
2.4 Embedding: Phase Space Reconstruction	17
2.4.1 Geometry of Phase Space Reconstruction	18
2.5 Reconstruction Demystified	21
3 Choosing Time Delays	25
3.1 Prescriptions for a Time Delay	25
3.2 Chaos as an Information Source	26
3.3 Average Mutual Information	28
3.3.1 Lorenz Model	29
3.3.2 Nonlinear Circuit with Hysteresis	33
3.4 A Few Remarks About $I(T)$	34
4 Choosing the Dimension of Reconstructed Phase Space	39
4.1 Global Embedding Dimension d_E	39
4.2 Global False Nearest Neighbors	40
4.2.1 Lorenz Model	43
4.2.2 Nonlinear Circuit with Hysteresis	45

4.3	A Few Remarks About Global False Nearest Neighbors	47
4.4	False Strands	49
4.5	Other Methods for Identifying d_E	50
4.6	The Local or Dynamical Dimension d_L	51
4.7	Forward and Backward Lyapunov Exponents	53
4.8	Local False Neighbors	58
4.8.1	Lorenz Model; Ikeda Map	61
4.8.2	Nonlinear Circuit with Hysteresis	63
4.9	A Few Remarks About Local False Nearest Neighbors	65
5	Invariants of the Motion	69
5.1	Invariant Characteristics of the Dynamics	69
5.2	Fractal Dimensions	71
5.2.1	D_0 : Box Counting	74
5.2.2	Lorenz Model	75
5.3	Global Lyapunov Exponents	77
5.4	Lyapunov Dimension	82
5.5	Global Lyapunov Exponents from Data	83
5.6	Local Lyapunov Exponents	84
5.6.1	Recursive QR Decomposition for Short Times	86
5.6.2	Smooth Coordinate Transformations	87
5.7	Local Lyapunov Exponents from Data	88
5.7.1	Lorenz Model	89
5.7.2	Nonlinear Circuit with Hysteresis	90
5.8	A Few Remarks About Lyapunov Exponents	92
6	Modeling Chaos	95
6.1	Model Making in Chaos	95
6.2	Local Models	96
6.2.1	Lorenz Model	98
6.2.2	Nonlinear Circuit with Hysteresis	101
6.2.3	A Few Remarks About Local Models	102
6.3	Global Models	103
6.3.1	The Ikeda Map	105
6.3.2	Other Global Methods	105
6.3.3	A Few Remarks about Global Model Making	108
6.4	Phase Space Models for Dependent Dynamical Variables	108
6.4.1	Lorenz Model	110
6.4.2	Nonlinear Circuits	110
6.5	"Black Boxes" and Physics	112
7	Signal Separation	115
7.1	General Comments	115
7.2	Full Knowledge of the Dynamics	117
7.3	Knowing a Signal: Probabilistic Cleaning	123

7.4 "Blind" Signal Separation	129
7.5 A Few Remarks About Signal Separation	131
8 Control and Chaos	133
8.1 Parametric Control to Unstable Periodic Orbits	134
8.1.1 Targeting	139
8.2 Other Controls	140
8.3 Examples of Control	141
8.3.1 Magnetoelastic Ribbon	141
8.3.2 Nonlinear Electric Circuits; Chaotic Lasers	142
8.3.3 Control in Cardiac Tissue	144
8.3.4 Experimental Targeting	144
8.4 A Few (Irreverent) Remarks About Chaos and Control	145
9 Synchronization of Chaotic Systems	147
9.1 Identical Systems	148
9.2 Dissimilar Systems	154
9.3 Mutual False Nearest Neighbors	158
9.3.1 Mutual False Nearest Neighbors; Coupled Roëssler Systems	162
9.4 Predictability Tests for Generalized Synchronization	163
9.4.1 Chaotic Nonlinear Circuits	166
9.5 A Few Remarks About Synchronization	170
10 Other Example Systems	173
10.1 Chaotic Laser Intensity Fluctuations	174
10.1.1 Experimental Setup and Data Preparation	175
10.1.2 Analysis of the Chaotic Laser Data	177
10.1.3 A Physical Model for the Process	188
10.1.4 Predicting on the Attractor	193
10.1.5 A Few Remarks About Chaotic Laser Fluctuations .	195
10.2 Chaotic Volume Fluctuations of the Great Salt Lake	196
10.2.1 A Few Remarks About the Great Salt Lake Volume	207
10.3 Chaotic Motion in a Fluid Boundary Layer	208
10.3.1 A Few Remarks About Chaotic Boundary Layers .	214
11 Estimating in Chaos: Cramér-Rao Bounds	217
11.1 The State Estimation Problem	218
11.2 The Cramér-Rao Bound	219
11.3 Symmetric Linear Dynamics	223
11.4 Arbitrary, Time-Invariant, Linear Systems	226
11.5 Nonlinear, Chaotic Dynamics	231
11.6 Connection with Chaotic Signal Separation	233
11.7 Conclusions	234

12 Summary and Conclusions	237
12.1 The Toolkit—Present and Future	239
12.2 Making ‘Physics’ out of Chaos—Present and Future	244
12.3 Topics for the Next Edition	245
Appendix	
A.1 Information Theory and Nonlinear Systems	249
A.2 Stability and Instability	249
A.2.1 Lorenz Model	251
A.2.2 Logistic Map	252
Glossary	259
References	261
Index	269