
Chaotic dynamics

an introduction

SECOND EDITION

GREGORY L. BAKER

*Academy of the New Church College
Bryn Athyn, Pennsylvania*

AND

JERRY P. GOLLUB

*Haverford College, Haverford, Pennsylvania and
University of Pennsylvania, Philadelphia, Pennsylvania*



CAMBRIDGE
UNIVERSITY PRESS

Contents

	<i>Preface</i>	page xi
	<i>Acknowledgments</i>	xiv
CHAPTER ONE	Introduction	1
CHAPTER TWO	Some helpful tools	7
	2.1 Phase space	7
	2.2 Poincaré section	21
	2.3 Spectral analysis of time series	27
	Problems	35
CHAPTER THREE	Visualization of the pendulum's dynamics	39
	3.1 Sensitivity to initial conditions	41
	3.2 Phase diagrams and Poincaré sections	43
	3.3 Time series and power spectra	59
	3.4 Basins of attraction	59
	3.5 Bifurcation diagrams	66
	Problems and simulations	72
CHAPTER FOUR	Toward an understanding of chaos	74
	4.1 The logistic map	76
	4.1.1 Period doubling	77
	4.1.2 The periodic windows	81
	4.1.3 Lyapunov exponents	84
	4.1.4 Entropy	86
	4.1.5 Stretching and folding	88
	4.2 The circle map	89
	4.3 The horseshoe map	96

	4.4 Application to the pendulum	100
	Problems	105
CHAPTER FIVE	The characterization of chaotic attractors	109
	5.1 Dimension	110
	5.2 Lyapunov exponents	119
	5.3 Lyapunov exponents and dimension	123
	5.4 Information change and Lyapunov exponents	126
	Problems	129
CHAPTER SIX	Experimental characterization, prediction, and modification of chaotic states	133
	6.1 Characterization of chaotic states	133
	6.1.1 Experiment and simulation	135
	6.1.2 Reconstruction of the attractor	137
	6.1.3 Time-delay coordinates	139
	6.1.4 Choosing the time delay	143
	6.1.5 Embedding dimension and attractor dimension	145
	6.1.6 Lyapunov exponents	150
	6.1.7 Summary	152
	6.2 Prediction of chaotic states	152
	6.2.1 Method of analogues	153
	6.2.2 Linear approximation method	156
	6.3 Modification of chaotic states	159
	6.4 Conclusion	163
	Problems	164
CHAPTER SEVEN	Chaos broadly applied	166
	7.1 Chaos in lasers	166
	7.2 Chaotic chemical reactions	168
	7.3 Chaos in fluid dynamics	170
	7.4 Spatio-temporal chaos in fluids	172
	7.4.1 Spatio-temporal chaos in thermal convection	173
	7.4.2 Spatio-temporal chaos on a rotating fluid film	176
	7.5 Spatio-temporal intermittency in model equations	178
	7.6 Strong turbulence	179
	7.7 Chaotic mixing in fluids	180
	7.8 Complex dynamics of interfacial growth: artificial snowflakes	181
	7.9 Chaos in earthquake dynamics	184
	7.10 Chaos and quantum physics	185

7.11 Foundations of statistical mechanics	187
7.12 Conclusion	189
<i>Further reading</i>	190
<i>Appendix A Numerical integration – Runge-Kutta method</i>	193
<i>Appendix B Computer program listings</i>	196
<i>Appendix C Solutions to selected problems</i>	242
<i>References</i>	246
<i>Index</i>	253
<i>Diskette order information</i>	256