Contents

1.	The	e Challenge of Complex Systems	1
	1.1	What Are Complex Systems?	1
	1.2	How to Deal with Complex Systems	5
	1.3	Model Systems	7
	1.4	Self-Organization	10
	1.5	Aiming at Universality	11
		1.5.1 Thermodynamics	11
		1.5.2 Statistical Physics	12
		1.5.3 Synergetics	13
	1.6	Information	14
		1.6.1 Shannon Information: Meaning Exorcised	15
		1.6.2 Effects of Information	16
		1.6.3 Self-Creation of Meaning	23
		1.6.4 How Much Information Do We Need to Maintain	
		an Ordered State?	29
	1.7	The Second Foundation of Synergetics	33
2.	Fro	m the Microscopic to the Macroscopic World	36
	2.1	Levels of Description	36
	2.2	Langevin Equations	37
	2.3	Fokker-Planck Equation	40
	2.4	Exact Stationary Solution of the Fokker-Planck Equation	
		for Systems in Detailed Balance	41
		2.4.1 Detailed Balance	41
		2.4.2 The Required Structure of the Fokker-Planck Equation	
		and Its Stationary Solution	42
	2.5	Path Integrals	44
	2.6	Reduction of Complexity, Order Parameters and the Slaving	
		Principle	45
		2.6.1 Linear Stability Analysis	46
		2.6.2 Transformation of Evolution Equations	47
		2.6.3 The Slaving Principle	48
	2.7	Nonequilibrium Phase Transitions	49
	2.8	Pattern Formation	51
3.		and Back Again: The Maximum Information Principle (MIP)	53
	3.1	Some Basic Ideas	53
	3.2	Information Gain	57

XII		Contents				
	3.3 3.4	Information Entropy and Constraints Continuous Variables	58 63			
4.	An	Example from Physics: Thermodynamics	65			
5.	Ар	plication of the Maximum Information Principle				
	to S	Self-Organizing Systems	69			
	5.1	Introduction	69			
	5.2	Application to Self-Organizing Systems: Single Mode Laser	69			
	5.3	Multimode Laser Without Phase Relations	71			
	5.4	Processes Periodic in Order Parameters	72			
6.	The Tra	The Maximum Information Principle for Nonequilibrium Phase				
	and	Emerging Patterns	74			
	6.1	Introduction	74			
	6.2	General Approach	74			
	6.3	Determination of Order Parameters, Enslaved Modes, and				
		Emerging Patterns	76			
	6.4	Approximations	77			
	6.5	Spatial Patterns	78			
	6.6	Relation to the Landau Theory of Phase Transitions. Guessing of				
		Fokker-Planck Equations	79			
7.	Infe	ormation, Information Gain, and Efficiency of Self-Organizing				
	Syst	tems Close to Their Instability Points	81			
	7.1	Introduction	81			
	7.2	The Slaving Principle and Its Application to Information	82			
	7.3	Information Gain	82			
	7.4	An Example: Nonequilibrium Phase Transitions	83			
	7.5	Soft Single-Mode Instabilities	84			
	7.6	Can We Measure the Information and the Information Gain?	85			
		7.6.1 Efficiency	85			
		7.6.2 Information and Information Gain	86			
	7.7	Several Order Parameters	87			
	7.8	Explicit Calculation of the Information of a Single	~~			
		Order Parameter	88			
		7.8.1 The Region Well Below Threshold	89			
		7.8.2 The Region well Above Threshold	90			
		7.8.3 Numerical Results	93			
	70	7.8.4 Discussion	94			
	1.9	exact Analytical Results on Information, Information Gain,	05			
		and Efficiency of a Single Order Parameter	93 07			
		7.9.1 The Instability Point	9/ 00			
		7.9.4 THE Approach to Instability	98 00			
		7.0.4 The Injected Signal	100			
		1.7.7 Ino injected signal	100			

		7.9.5 Conclusions	101
	7.10	The S-Theorem of Klimontovich	102
		7.10.1 Region 1: Below Laser Threshold	104
		7.10.2 Region 2: At Threshold	104
		7.10.3 Region 3: Well Above Threshold	105
	7.11	The Contribution of the Enslaved Modes to the Information	
		Close to Nonequilibrium Phase Transitions	107
8.	Direc	t Determination of Lagrange Multipliers	115
	8.1	Information Entropy of Systems Below and Above	
		Their Critical Point	115
	8.2	Direct Determination of Lagrange Multipliers Below, At and	
		Above the Critical Point	117
9.	Unbia	ased Modeling of Stochastic Processes: How to Guess Path	
	Integr	rals, Fokker-Planck Equations and Langevin-Ito Equations	125
	9.1	One-Dimensional State Vector	125
	9.2	Generalization to a Multidimensional State Vector	127
	9.3	Correlation Functions as Constraints	130
	9.4	The Fokker-Planck Equation Belonging to the Short-Time	
		Propagator	132
	9.5	Can We Derive Newton's Law from Experimental Data?	133
10.	Appli	cation to Some Physical Systems	135
	10.1	Multimode Lasers with Phase Relations	135
	10.2	The Single-Mode Laser Including Polarization and Inversion	136
	10.3	Fluid Dynamics: The Convection Instability	138
11.	Trans	itions Between Behavioral Patterns in Biology,	
	An Ex	xample: Hand Movements	140
	11.1	Some Experimental Facts	140
	11.2	How to Model the Transition	141
	11.3	Critical Fluctuations	147
	11.4	Some Conclusions	151
12.	Patter	n Recognition. Unbiased Guesses of Processes:	
	Explic	cit Determination of Lagrange Multipliers	153
	12.1	Feature Selection	153
	12.2	An Algorithm for Pattern Recognition	159
	12.3	The Basic Construction Principle of a Synergetic Computer	161
	12.4	Learning by Means of the Information Gain	163
	12.5	Processes and Associative Action	165
	12.6	Explicit Determination of the Lagrange Multipliers	
		of the Conditional Probability.	
		General Approach for Discrete and Continuous Processes	169
	12.7	Approximation and Smoothing Schemes. Additive Noise	174

12.8	An Explicit Example: Brownian Motion	181			
12.9	Approximation and Smoothing Schemes. Multiplicative				
	(and Additive) Noise	184			
12.10	Explicit Calculation of Drift and Diffusion Coefficients. Examples	185			
12.11	Process Modelling, Prediction and Control, Robotics	187			
12.12	Non-Markovian Processes. Connection with Chaos Theory	189			
	12.12.1 Checking the Markov Property	189			
	12.12.2 Time Series Analysis	190			
13. Quan	tum Systems	195			
13.1	Why Quantum Theory of Information?	195			
13.2	The Maximum Information Principle	197			
13.3	Order parameters, Enslaved Modes and Patterns	203			
13.4	Information of Order Parameters and Enslaved Modes	206			
14. Concluding Remarks and Outlook					
References					
Subject Index					