FO	rewoi	rd page	xiii
Pre	eface		xvii
Co	ntrib	utors	xix
		I Computing in Games	
1	Basi	ic Solution Concepts and Computational Issues	3
	Éva	Tardos and Vijay V. Vazirani	
	1.1	Games, Old and New	3
	1.2	Games, Strategies, Costs, and Payoffs	9
	1.3	Basic Solution Concepts	10
	1.4	Finding Equilibria and Learning in Games	16
	1.5	Refinement of Nash: Games with Turns and Subgame Perfect Equilibrium	18
	1.6	Nash Equilibrium without Full Information: Bayesian Games	20
	1.7	Cooperative Games	20
	1.8	Markets and Their Algorithmic Issues	22
	Ack	nowledgments	26
	Bibl	iography	26
	Exer	cises	26
2	The	Complexity of Finding Nash Equilibria	29
	Chri	stos H. Papadimitriou	
	2.1	Introduction	29
	2.2	Is the Nash Equilibrium Problem NP-Complete?	31
	2.3	The Lemke–Howson Algorithm	33
	2.4	The Class PPAD	36
	2.5	Succinct Representations of Games	39
	2.6	The Reduction	41
	2.7	Correlated Equilibria	45
	2.8	Concluding Remarks	49
	Ackı	nowledgment	50
	Bibli	iography	50

and E	Extensive Form	53	5.15 Discussion and Open Problems	131
Bernh	ard von Stengel		Bibliography	132
3.1	Introduction	53	Exercises	133
3.2	Bimatrix Games and the Best Response Condition	54	Communication of Manle 4 Emilibrie has Common Decommon of	135
	Equilibria via Labeled Polytopes	57	6 Computation of Market Equilibria by Convex Programming	133
	The Lemke–Howson Algorithm	61	Bruno Codenotti and Kasturi Varadarajan	125
	Integer Pivoting	63	6.1 Introduction	135
	Degenerate Games	65	6.2 Fisher Model with Homogeneous Consumers	141
	Extensive Games and Their Strategic Form	66	6.3 Exchange Economies Satisfying WGS	142
	Subgame Perfect Equilibria	68	6.4 Specific Utility Functions	148
		69	6.5 Limitations	150
	Reduced Strategic Form	70	6.6 Models with Production	152
	The Sequence Form		6.7 Bibliographic Notes	155
	Computing Equilibria with the Sequence Form	73	Bibliography	156
	Further Reading	75	Exercises	158
	Discussion and Open Problems	75		150
	graphy	76	7 Graphical Games	159
Exerc	ises	77	Michael Kearns	
Lagri	ning, Regret Minimization, and Equilibria	79	7.1 Introduction	159
			7.2 Preliminaries	161
	Blum and Yishay Mansour Introduction	79	7.3 Computing Nash Equilibria in Tree Graphical Games	164
1 74			7.4 Graphical Games and Correlated Equilibria	169
	Model and Preliminaries	81	7.5 Graphical Exchange Economies	176
	External Regret Minimization	82	7.6 Open Problems and Future Research	177
	Regret Minimization and Game Theory	88	7.7 Bibliographic Notes	177
	Generic Reduction from External to Swap Regret	92	Acknowledgments	179
4.6	The Partial Information Model	94	Bibliography	179
4.7	On Convergence of Regret-Minimizing Strategies to Nash			
	Equilibrium in Routing Games	96	8 Cryptography and Game Theory	181
4.8	Notes	99	Yevgeniy Dodis and Tal Rabin	
Biblio	graphy	99	8.1 Cryptographic Notions and Settings	181
Exerc	ises	101	8.2 Game Theory Notions and Settings	187
Carrel		100	8.3 Contrasting MPC and Games	189
	oinatorial Algorithms for Market Equilibria	103	8.4 Cryptographic Influences on Game Theory	191
	V. Vazirani		8.5 Game Theoretic Influences on Cryptography	197
	Introduction	103	8.6 Conclusions	202
	Fisher's Linear Case and the Eisenberg-Gale Convex Program	105	8.7 Notes	203
	Checking If Given Prices Are Equilibrium Prices	108	Acknowledgments	204
5.4	Two Crucial Ingredients of the Algorithm	109	Bibliography	204
5.5	The Primal-Dual Schema in the Enhanced Setting	109	Dionography	204
5.6	Tight Sets and the Invariant	111		
5.7	Balanced Flows	111	II Algorithmic Mechanism Design	
5.8	The Main Algorithm	115	9 Introduction to Mechanism Design (for Computer Scientists)	209
5.9	Finding Tight Sets	117	Noam Nisan	
	Running Time of the Algorithm	118	9.1 Introduction	209
	The Linear Case of the Arrow–Debreu Model	121	9.2 Social Choice	211
	An Auction-Based Algorithm	122	9.3 Mechanisms with Money	216
	Resource Allocation Markets	124	9.4 Implementation in Dominant Strategies	

9.5 Characterizations of Incentive Compatible Mechanisms	225	13.5 Frugality religions I show to M I amend and S.	350
9.6 Bayesian–Nash Implementation	233	13.6 Conclusions and Other Research Directions	354
9.7 Further Models	238	13.7 Notes	357
9.8 Notes	239	Bibliography	358
Acknowledgments	240	Exercises	360
Bibliography	241	14 Distributed Algorithmic Mechanism Design	363
	242	Joan Feigenbaum, Michael Schapira, and Scott Shenker	
Mechanism Design without Money	243	14.1 Introduction	363
James Schummer and Rakesh V. Vohra		14.1 Introduction 14.2 Two Examples of DAMD	366
10.1 Introduction	243	14.2 Two Examples of DANID 14.3 Interdomain Routing	370
10.2 Single-Peaked Preferences over Policies	244	14.5 Interdoman Routing 14.4 Conclusion and Open Problems	379
10.3 House Allocation Problem	253		380
10.4 Stable Matchings	255	14.5 Notes	381
10.5 Future Directions	262	Acknowledgments	381
10.6 Notes and References	263	Bibliography	383
Bibliography	264	Exercises	303
Exercises	264	15 Cost Sharing	385
Combinatorial Auctions	267	Kamal Jain and Mohammad Mahdian	
Liad Blumrosen and Noam Nisan		15.1 Cooperative Games and Cost Sharing	385
11.1 Introduction	267	15.2 Core of Cost-Sharing Games	387
11.2 The Single-Minded Case	270	15.3 Group-Strategyproof Mechanisms and Cross-Monotonic	
11.3 Walrasian Equilibrium and the LP Relaxation	275	Cost-Sharing Schemes	391
11.4 Bidding Languages	279	15.4 Cost Sharing via the Primal-Dual Schema	394
11.5 Iterative Auctions: The Query Model	283	15.5 Limitations of Cross-Monotonic Cost-Sharing Schemes	400
11.6 Communication Complexity	287	15.6 The Shapley Value and the Nash Bargaining Solution	402
11.7 Ascending Auctions	289	15.7 Conclusion	405
11.8 Bibliographic Notes	295	15.8 Notes	406
Acknowledgments	296	Acknowledgments	408
Bibliography	296	Bibliography	408
Exercises Exercises	298	Exercises	410
LACICISCS .	290		
Computationally Efficient Approximation Mechanisms	301	16 Online Mechanisms	411
Ron Lavi		David C. Parkes	
12.1 Introduction	301	16.1 Introduction	411
12.2 Single-Dimensional Domains: Job Scheduling	303	16.2 Dynamic Environments and Online MD	413
12.3 Multidimensional Domains: Combinatorial Auctions	310	16.3 Single-Valued Online Domains	417
12.4 Impossibilities of Dominant Strategy Implementability	317	16.4 Bayesian Implementation in Online Domains	431
12.5 Alternative Solution Concepts	321	16.5 Conclusions	435
12.6 Bibliographic Notes	327	16.6 Notes	436
Bibliography	327	Acknowledgments	437
Exercises	328	Bibliography	437
Drofit Maximization in Machaniana Dasima	221	Exercises	439
Profit Maximization in Mechanism Design	331	AAA Complex Networks - maintains and a second of the contract	
Jason D. Hartline and Anna R. Karlin 13.1 Introduction	221	III Quantifying the Inefficiency of Equilibria	
	331	17 Introduction to the Inefficiency of Equilibria	443
13.2 Bayesian Optimal Mechanism Design 13.3 Prior Free Approximations to the Optimal Mechanism	335	Tim Roughgarden and Éva Tardos	The state of the s
13.3 Prior-Free Approximations to the Optimal Mechanism 13.4 Prior Free Optimal Mechanism Design	339	17.1 Introduction	443
13.4 Prior-Free Optimal Mechanism Design	344	17.1 Introduction	173

~	A 14 1	PRINT	THE T	-
	ON	Maria Maria		
	OT.	AA	17.	R

17.2 Fundamental Network Examples	446	21.6 Notes	565
17.3 Inefficiency of Equilibria as a Design Metric	454	Bibliography	566
17.4 Notes	456	Exercises	567
Bibliography	457		
Exercises	459	IV Additional Topics	
Routing Games	461	22 Incentives and Pricing in Communications Networks	571
Tim Roughgarden		Asuman Ozdaglar and R. Srikant	
8.1 Introduction	461	22.1 Large Networks – Competitive Models	572
8.2 Models and Examples	462	22.1 Earge Retworks Competitive Interests 22.2 Pricing and Resource Allocation – Game Theoretic Models	578
18.3 Existence, Uniqueness, and Potential Functions	468	22.2 Alternative Pricing and Incentive Approaches	587
18.4 The Price of Anarchy of Selfish Routing	472		590
18.5 Reducing the Price of Anarchy	478	Bibliography	
18.6 Notes	480	23 Incentives in Peer-to-Peer Systems	593
Bibliography	483	Moshe Babaioff, John Chuang, and Michal Feldman	
Exercises	484	23.1 Introduction	59.
	40=	23.2 The p2p File-Sharing Game	594
Network Formation Games and the Potential Function Method	487	23.3 Reputation	590
Éva Tardos and Tom Wexler		23.4 A Barter-Based System: BitTorrent	600
19.1 Introduction	487	23.5 Currency	60
19.2 The Local Connection Game	489	23.6 Hidden Actions in p2p Systems	602
19.3 Potential Games and a Global Connection Game	494	23.7 Conclusion	608
19.4 Facility Location	502	23.8 Bibliographic Notes	608
19.5 Notes	506	Bibliography	609
Acknowledgments	511	Exercises	610
Bibliography	511		
Exercises	513	24 Cascading Behavior in Networks: Algorithmic and Economic Issues	61.
Selfish Load Balancing	517	Jon Kleinberg	61
Berthold Vöcking		24.1 Introduction	61
20.1 Introduction	517	24.2 A First Model: Networked Coordination Games	61
20.2 Pure Equilibria for Identical Machines	522	24.3 More General Models of Social Contagion	62
20.3 Pure Equilibria for Uniformly Related Machines	524	24.4 Finding Influential Sets of Nodes	62
20.4 Mixed Equilibria on Identical Machines	529	24.5 Empirical Studies of Cascades in Online Data	62
20.5 Mixed Equilibria on Uniformly Related Machines	533	24.6 Notes and Further Reading	63
20.6 Summary and Discussion	537	Bibliography	63
20.7 Bibliographic Notes	538	Exercises	63
Bibliography		25 Incentives and Information Security	63
Zvoroicoc	540	Ross Anderson, Tyler Moore, Shishir Nagaraja, and Andy Ozment	
Exercises	542	25.1 Introduction	63
The Price of Anarchy and the Design of Scalable Resource		25.2 Misaligned Incentives	63
Allocation Mechanisms	543	25.2 Informational Asymmetries	63
Ramesh Johari		25.4 The Economics of Censorship Resistance	64
21.1 Introduction	543	25.5 Complex Networks and Topology	64
21.2 The Proportional Allocation Mechanism	544	25.5 Complex Networks and Topology 25.6 Conclusion	64
21.3 A Characterization Theorem	551	25.0 Conclusion 25.7 Notes	64
21.4 The Vickrey-Clarke-Groves Approach	559	Bibliography	64
21.5 Chapter Summary and Further Directions	564	Dionography	01

XII CONTENTS

26	Com	putational Aspects of Prediction Markets	651	
	David	l M. Pennock and Rahul Sami		
	26.1	Introduction: What Is a Prediction Market?	651	
	26.2	Background	652	
	26.3	Combinatorial Prediction Markets	657	
	26.4	Automated Market Makers	662	
	26.5	Distributed Computation through Markets	665	
	26.6	Open Questions	670	
	26.7	Bibliographic Notes	671	
		owledgments	672	
	Biblio	ography	672	
	Exerc		674	
27	Mani	pulation-Resistant Reputation Systems	677	
	Eric I	Friedman, Paul Resnick, and Rahul Sami		
	27.1	Introduction: Why Are Reputation Systems Important?	677	
	27.2	The Effect of Reputations	680	
		Whitewashing	682	
	27.4	Eliciting Effort and Honest Feedback	683	
		Reputations Based on Transitive Trust	689	
		Conclusion and Extensions	693	
	27.7	Bibliographic Notes	694	
		ography	695	
	Exerc		696	
28	Spon	sored Search Auctions	699	
	Sébas	tien Lahaie, David M. Pennock, Amin Saberi, and Rakesh V. Vohra		
	28.1	Introduction	699	
	28.2	Existing Models and Mechanisms	701	
	28.3	A Static Model	702	
	28.4	Dynamic Aspects	707	
	28.5	Open Questions	711	
	28.6	Bibliographic Notes	712	
	Biblio	ography	713	
	Exerc	ises	715	
29	Com	putational Evolutionary Game Theory	717	
4	Siddh	arth Suri		
	29.1	Evolutionary Game Theory	717	
	29.2	The Computational Complexity of Evolutionarily Stable Strategies	720	
	29.3	Evolutionary Dynamics Applied to Selfish Routing	723	
	29.4	Evolutionary Game Theory over Graphs	728	
	29.5	Future Work	733	
	29.6	Notes	733	
	Acknowledgments			
	Bibliography			
	Exerc	eises	735	
Inc	lex		737	