

Contents

<i>Foreword</i>	<i>page</i> xiii
<i>Preface</i>	xvii
<i>Contributors</i>	xix

I Computing in Games

1 Basic Solution Concepts and Computational Issues	3
<i>Éva Tardos and Vijay V. Vazirani</i>	
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
Acknowledgments	26
Bibliography	26
Exercises	26
2 The Complexity of Finding Nash Equilibria	29
<i>Christos H. Papadimitriou</i>	
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
Acknowledgment	50
Bibliography	50

3 Equilibrium Computation for Two-Player Games in Strategic and Extensive Form	53
<i>Bernhard von Stengel</i>	
3.1 Introduction	53
3.2 Bimatrix Games and the Best Response Condition	54
3.3 Equilibria via Labeled Polytopes	57
3.4 The Lemke–Howson Algorithm	61
3.5 Integer Pivoting	63
3.6 Degenerate Games	65
3.7 Extensive Games and Their Strategic Form	66
3.8 Subgame Perfect Equilibria	68
3.9 Reduced Strategic Form	69
3.10 The Sequence Form	70
3.11 Computing Equilibria with the Sequence Form	73
3.12 Further Reading	75
3.13 Discussion and Open Problems	75
Bibliography	76
Exercises	77
4 Learning, Regret Minimization, and Equilibria	79
<i>Avrim Blum and Yishay Mansour</i>	
4.1 Introduction	79
4.2 Model and Preliminaries	81
4.3 External Regret Minimization	82
4.4 Regret Minimization and Game Theory	88
4.5 Generic Reduction from External to Swap Regret	92
4.6 The Partial Information Model	94
4.7 On Convergence of Regret-Minimizing Strategies to Nash Equilibrium in Routing Games	96
4.8 Notes	99
Bibliography	99
Exercises	101
5 Combinatorial Algorithms for Market Equilibria	103
<i>Vijay V. Vazirani</i>	
5.1 Introduction	103
5.2 Fisher’s Linear Case and the Eisenberg–Gale Convex Program	105
5.3 Checking If Given Prices Are Equilibrium Prices	108
5.4 Two Crucial Ingredients of the Algorithm	109
5.5 The Primal-Dual Schema in the Enhanced Setting	109
5.6 Tight Sets and the Invariant	111
5.7 Balanced Flows	111
5.8 The Main Algorithm	115
5.9 Finding Tight Sets	117
5.10 Running Time of the Algorithm	118
5.11 The Linear Case of the Arrow–Debreu Model	121
5.12 An Auction-Based Algorithm	122
5.13 Resource Allocation Markets	124

5.14	Algorithm for Single-Source Multiple-Sink Markets	126
5.15	Discussion and Open Problems	131
	Bibliography	132
	Exercises	133
6	Computation of Market Equilibria by Convex Programming	135
	<i>Bruno Codenotti and Kasturi Varadarajan</i>	
6.1	Introduction	135
6.2	Fisher Model with Homogeneous Consumers	141
6.3	Exchange Economies Satisfying WGS	142
6.4	Specific Utility Functions	148
6.5	Limitations	150
6.6	Models with Production	152
6.7	Bibliographic Notes	155
	Bibliography	156
	Exercises	158
7	Graphical Games	159
	<i>Michael Kearns</i>	
7.1	Introduction	159
7.2	Preliminaries	161
7.3	Computing Nash Equilibria in Tree Graphical Games	164
7.4	Graphical Games and Correlated Equilibria	169
7.5	Graphical Exchange Economies	176
7.6	Open Problems and Future Research	177
7.7	Bibliographic Notes	177
	Acknowledgments	179
	Bibliography	179
8	Cryptography and Game Theory	181
	<i>Yevgeniy Dodis and Tal Rabin</i>	
8.1	Cryptographic Notions and Settings	181
8.2	Game Theory Notions and Settings	187
8.3	Contrasting MPC and Games	189
8.4	Cryptographic Influences on Game Theory	191
8.5	Game Theoretic Influences on Cryptography	197
8.6	Conclusions	202
8.7	Notes	203
	Acknowledgments	204
	Bibliography	204

II Algorithmic Mechanism Design

9	Introduction to Mechanism Design (for Computer Scientists)	209
	<i>Noam Nisan</i>	
9.1	Introduction	209
9.2	Social Choice	211
9.3	Mechanisms with Money	216
9.4	Implementation in Dominant Strategies	222

9.5	Characterizations of Incentive Compatible Mechanisms	225
9.6	Bayesian–Nash Implementation	233
9.7	Further Models	238
9.8	Notes	239
	Acknowledgments	240
	Bibliography	241
10	Mechanism Design without Money	243
	<i>James Schummer and Rakesh V. Vohra</i>	
10.1	Introduction	243
10.2	Single-Peaked Preferences over Policies	244
10.3	House Allocation Problem	253
10.4	Stable Matchings	255
10.5	Future Directions	262
10.6	Notes and References	263
	Bibliography	264
	Exercises	264
11	Combinatorial Auctions	267
	<i>Liad Blumrosen and Noam Nisan</i>	
11.1	Introduction	267
11.2	The Single-Minded Case	270
11.3	Walrasian Equilibrium and the LP Relaxation	275
11.4	Bidding Languages	279
11.5	Iterative Auctions: The Query Model	283
11.6	Communication Complexity	287
11.7	Ascending Auctions	289
11.8	Bibliographic Notes	295
	Acknowledgments	296
	Bibliography	296
	Exercises	298
12	Computationally Efficient Approximation Mechanisms	301
	<i>Ron Lavi</i>	
12.1	Introduction	301
12.2	Single-Dimensional Domains: Job Scheduling	303
12.3	Multidimensional Domains: Combinatorial Auctions	310
12.4	Impossibilities of Dominant Strategy Implementability	317
12.5	Alternative Solution Concepts	321
12.6	Bibliographic Notes	327
	Bibliography	327
	Exercises	328
13	Profit Maximization in Mechanism Design	331
	<i>Jason D. Hartline and Anna R. Karlin</i>	
13.1	Introduction	331
13.2	Bayesian Optimal Mechanism Design	335
13.3	Prior-Free Approximations to the Optimal Mechanism	339
13.4	Prior-Free Optimal Mechanism Design	344

13.5	Frugality	350
13.6	Conclusions and Other Research Directions	354
13.7	Notes	357
	Bibliography	358
	Exercises	360
14	Distributed Algorithmic Mechanism Design	363
	<i>Joan Feigenbaum, Michael Schapira, and Scott Shenker</i>	
14.1	Introduction	363
14.2	Two Examples of DAMD	366
14.3	Interdomain Routing	370
14.4	Conclusion and Open Problems	379
14.5	Notes	380
	Acknowledgments	381
	Bibliography	381
	Exercises	383
15	Cost Sharing	385
	<i>Kamal Jain and Mohammad Mahdian</i>	
15.1	Cooperative Games and Cost Sharing	385
15.2	Core of Cost-Sharing Games	387
15.3	Group-Strategyproof Mechanisms and Cross-Monotonic Cost-Sharing Schemes	391
15.4	Cost Sharing via the Primal-Dual Schema	394
15.5	Limitations of Cross-Monotonic Cost-Sharing Schemes	400
15.6	The Shapley Value and the Nash Bargaining Solution	402
15.7	Conclusion	405
15.8	Notes	406
	Acknowledgments	408
	Bibliography	408
	Exercises	410
16	Online Mechanisms	411
	<i>David C. Parkes</i>	
16.1	Introduction	411
16.2	Dynamic Environments and Online MD	413
16.3	Single-Valued Online Domains	417
16.4	Bayesian Implementation in Online Domains	431
16.5	Conclusions	435
16.6	Notes	436
	Acknowledgments	437
	Bibliography	437
	Exercises	439
 III Quantifying the Inefficiency of Equilibria		
17	Introduction to the Inefficiency of Equilibria	443
	<i>Tim Roughgarden and Éva Tardos</i>	
17.1	Introduction	443

17.2	Fundamental Network Examples	446
17.3	Inefficiency of Equilibria as a Design Metric	454
17.4	Notes	456
	Bibliography	457
	Exercises	459
18	Routing Games	461
	<i>Tim Roughgarden</i>	
18.1	Introduction	461
18.2	Models and Examples	462
18.3	Existence, Uniqueness, and Potential Functions	468
18.4	The Price of Anarchy of Selfish Routing	472
18.5	Reducing the Price of Anarchy	478
18.6	Notes	480
	Bibliography	483
	Exercises	484
19	Network Formation Games and the Potential Function Method	487
	<i>Éva Tardos and Tom Wexler</i>	
19.1	Introduction	487
19.2	The Local Connection Game	489
19.3	Potential Games and a Global Connection Game	494
19.4	Facility Location	502
19.5	Notes	506
	Acknowledgments	511
	Bibliography	511
	Exercises	513
20	Selfish Load Balancing	517
	<i>Berthold Vöcking</i>	
20.1	Introduction	517
20.2	Pure Equilibria for Identical Machines	522
20.3	Pure Equilibria for Uniformly Related Machines	524
20.4	Mixed Equilibria on Identical Machines	529
20.5	Mixed Equilibria on Uniformly Related Machines	533
20.6	Summary and Discussion	537
20.7	Bibliographic Notes	538
	Bibliography	540
	Exercises	542
21	The Price of Anarchy and the Design of Scalable Resource Allocation Mechanisms	543
	<i>Ramesh Johari</i>	
21.1	Introduction	543
21.2	The Proportional Allocation Mechanism	544
21.3	A Characterization Theorem	551
21.4	The Vickrey–Clarke–Groves Approach	559
21.5	Chapter Summary and Further Directions	564

21.6	Notes	565
	Bibliography	566
	Exercises	567

IV Additional Topics

22 Incentives and Pricing in Communications Networks 571

Asuman Ozdaglar and R. Srikant

22.1	Large Networks – Competitive Models	572
22.2	Pricing and Resource Allocation – Game Theoretic Models	578
22.3	Alternative Pricing and Incentive Approaches	587
	Bibliography	590

23 Incentives in Peer-to-Peer Systems 593

Moshe Babaioff, John Chuang, and Michal Feldman

23.1	Introduction	593
23.2	The p2p File-Sharing Game	594
23.3	Reputation	596
23.4	A Barter-Based System: BitTorrent	600
23.5	Currency	601
23.6	Hidden Actions in p2p Systems	602
23.7	Conclusion	608
23.8	Bibliographic Notes	608
	Bibliography	609
	Exercises	610

24 Cascading Behavior in Networks: Algorithmic and Economic Issues 613

Jon Kleinberg

24.1	Introduction	613
24.2	A First Model: Networked Coordination Games	614
24.3	More General Models of Social Contagion	618
24.4	Finding Influential Sets of Nodes	622
24.5	Empirical Studies of Cascades in Online Data	627
24.6	Notes and Further Reading	630
	Bibliography	631
	Exercises	632

25 Incentives and Information Security 633

Ross Anderson, Tyler Moore, Shishir Nagaraja, and Andy Ozment

25.1	Introduction	633
25.2	Misaligned Incentives	634
25.3	Informational Asymmetries	636
25.4	The Economics of Censorship Resistance	640
25.5	Complex Networks and Topology	643
25.6	Conclusion	646
25.7	Notes	647
	Bibliography	648

26 Computational Aspects of Prediction Markets	651
<i>David M. Pennock and Rahul Sami</i>	
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
Acknowledgments	672
Bibliography	672
Exercises	674
27 Manipulation-Resistant Reputation Systems	677
<i>Eric Friedman, Paul Resnick, and Rahul Sami</i>	
27.1 Introduction: Why Are Reputation Systems Important?	677
27.2 The Effect of Reputations	680
27.3 Whitewashing	682
27.4 Eliciting Effort and Honest Feedback	683
27.5 Reputations Based on Transitive Trust	689
27.6 Conclusion and Extensions	693
27.7 Bibliographic Notes	694
Bibliography	695
Exercises	696
28 Sponsored Search Auctions	699
<i>Sébastien Lahaie, David M. Pennock, Amin Saberi, and Rakesh V. Vohra</i>	
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
Bibliography	713
Exercises	715
29 Computational Evolutionary Game Theory	717
<i>Siddharth Suri</i>	
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	734
Bibliography	734
Exercises	735
<i>Index</i>	<i>737</i>