

Contents

<i>Preface</i>	<i>page xi</i>
1 Overview	1
1.1 Aspects of Networks	2
1.2 Central Themes and Topics	7
 Part I Graph Theory and Social Networks	
2 Graphs	21
2.1 Basic Definitions	21
2.2 Paths and Connectivity	23
2.3 Distance and Breadth-First Search	29
2.4 Network Data Sets: An Overview	35
2.5 Exercises	39
3 Strong and Weak Ties	43
3.1 Triadic Closure	44
3.2 The Strength of Weak Ties	46
3.3 Tie Strength and Network Structure in Large-Scale Data	51
3.4 Tie Strength, Social Media, and Passive Engagement	54
3.5 Closure, Structural Holes, and Social Capital	58
3.6 Advanced Material: Betweenness Measures and Graph Partitioning	62
3.7 Exercises	74
4 Networks in Their Surrounding Contexts	77
4.1 Homophily	77
4.2 Mechanisms Underlying Homophily: Selection and Social Influence	81
4.3 Affiliation	83
4.4 Tracking Link Formation in Online Data	88
4.5 A Spatial Model of Segregation	96
4.6 Exercises	103

5 Positive and Negative Relationships	107
5.1 Structural Balance	107
5.2 Characterizing the Structure of Balanced Networks	110
5.3 Applications of Structural Balance	113
5.4 A Weaker Form of Structural Balance	115
5.5 Advanced Material: Generalizing the Definition of Structural Balance	118
5.6 Exercises	132

Part II Game Theory

6 Games	139
6.1 What Is a Game?	140
6.2 Reasoning about Behavior in a Game	142
6.3 Best Responses and Dominant Strategies	146
6.4 Nash Equilibrium	149
6.5 Multiple Equilibria: Coordination Games	151
6.6 Multiple Equilibria: The Hawk–Dove Game	154
6.7 Mixed Strategies	156
6.8 Mixed Strategies: Examples and Empirical Analysis	161
6.9 Pareto Optimality and Social Optimality	165
6.10 Advanced Material: Dominated Strategies and Dynamic Games	167
6.11 Exercises	179
7 Evolutionary Game Theory	189
7.1 Fitness as a Result of Interaction	190
7.2 Evolutionarily Stable Strategies	191
7.3 A General Description of Evolutionarily Stable Strategies	196
7.4 Relationship between Evolutionary and Nash Equilibria	197
7.5 Evolutionarily Stable Mixed Strategies	199
7.6 Exercises	204
8 Modeling Network Traffic Using Game Theory	207
8.1 Traffic at Equilibrium	207
8.2 Braess's Paradox	209
8.3 Advanced Material: The Social Cost of Traffic at Equilibrium	211
8.4 Exercises	219
9 Auctions	225
9.1 Types of Auctions	225
9.2 When Are Auctions Appropriate?	226
9.3 Relationships between Different Auction Formats	228
9.4 Second-Price Auctions	229
9.5 First-Price Auctions and Other Formats	232
9.6 Common Values and the Winner's Curse	233
9.7 Advanced Material: Bidding Strategies in First-Price and All-Pay Auctions	234
9.8 Exercises	242

Part III Markets and Strategic Interaction in Networks

10 Matching Markets	249
10.1 Bipartite Graphs and Perfect Matchings	249
10.2 Valuations and Optimal Assignments	253
10.3 Prices and the Market-Clearing Property	255
10.4 Constructing a Set of Market-Clearing Prices	258
10.5 How Does This Relate to Single-Item Auctions?	261
10.6 Advanced Material: A Proof of the Matching Theorem	262
10.7 Exercises	270
11 Network Models of Markets with Intermediaries	277
11.1 Price Setting in Markets	277
11.2 A Model of Trade on Networks	280
11.3 Equilibria in Trading Networks	286
11.4 Further Equilibrium Phenomena: Auctions and Ripple Effects	290
11.5 Social Welfare in Trading Networks	294
11.6 Trader Profits	295
11.7 Reflections on Trade with Intermediaries	297
11.8 Exercises	297
12 Bargaining and Power in Networks	301
12.1 Power in Social Networks	301
12.2 Experimental Studies of Power and Exchange	304
12.3 Results of Network Exchange Experiments	305
12.4 A Connection to Buyer–Seller Networks	309
12.5 Modeling Two-Person Interaction: The Nash Bargaining Solution	310
12.6 Modeling Two-Person Interaction: The Ultimatum Game	312
12.7 Modeling Network Exchange: Stable Outcomes	314
12.8 Modeling Network Exchange: Balanced Outcomes	317
12.9 Advanced Material: A Game-Theoretic Approach to Bargaining	320
12.10 Exercises	327

Part IV Information Networks and the World Wide Web

13 The Structure of the Web	333
13.1 The World Wide Web	333
13.2 Information Networks, Hypertext, and Associative Memory	335
13.3 The Web as a Directed Graph	340
13.4 The Bow-Tie Structure of the Web	344
13.5 The Emergence of Web 2.0	347
13.6 Exercises	349
14 Link Analysis and Web Search	351
14.1 Searching the Web: The Problem of Ranking	351
14.2 Link Analysis Using Hubs and Authorities	353
14.3 PageRank	358

14.4	Applying Link Analysis in Modern Web Search	363
14.5	Applications beyond the Web	366
14.6	Advanced Material: Spectral Analysis, Random Walks, and Web Search	368
14.7	Exercises	378
15	Sponsored Search Markets	385
15.1	Advertising Tied to Search Behavior	385
15.2	Advertising as a Matching Market	388
15.3	Encouraging Truthful Bidding in Matching Markets: The VCG Principle	391
15.4	Analyzing the VCG Mechanism: Truth-Telling as a Dominant Strategy	395
15.5	The Generalized Second-Price Auction	398
15.6	Equilibria of the Generalized Second-Price Auction	401
15.7	Ad Quality	404
15.8	Complex Queries and Interactions among Keywords	406
15.9	Advanced Material: VCG Prices and the Market-Clearing Property	407
15.10	Exercises	420

Part V Network Dynamics: Population Models

16	Information Cascades	425
16.1	Following the Crowd	425
16.2	A Simple Herding Experiment	427
16.3	Bayes' Rule: A Model of Decision Making under Uncertainty	430
16.4	Bayes' Rule in the Herding Experiment	434
16.5	A Simple, General Cascade Model	436
16.6	Sequential Decision Making and Cascades	440
16.7	Lessons from Cascades	442
16.8	Exercises	444
17	Network Effects	449
17.1	The Economy without Network Effects	450
17.2	The Economy with Network Effects	453
17.3	Stability, Instability, and Tipping Points	456
17.4	A Dynamic View of the Market	457
17.5	Industries with Network Goods	462
17.6	Mixing Individual Effects with Population-Level Effects	465
17.7	Advanced Material: Negative Externalities and the El Farol Bar Problem	470
17.8	Exercises	476
18	Power Laws and Rich-Get-Richer Phenomena	479
18.1	Popularity as a Network Phenomenon	479
18.2	Power Laws	481
18.3	Rich-Get-Richer Models	482

18.4	The Unpredictability of Rich-Get-Richer Effects	484
18.5	The Long Tail	486
18.6	The Effect of Search Tools and Recommendation Systems	489
18.7	Advanced Material: Analysis of Rich-Get-Richer Processes	490
18.8	Exercises	493

Part VI Network Dynamics: Structural Models

19	Cascading Behavior in Networks	497
19.1	Diffusion in Networks	497
19.2	Modeling Diffusion through a Network	499
19.3	Cascades and Clusters	506
19.4	Diffusion, Thresholds, and the Role of Weak Ties	509
19.5	Extensions of the Basic Cascade Model	512
19.6	Knowledge, Thresholds, and Collective Action	514
19.7	Advanced Material: The Cascade Capacity	517
19.8	Exercises	532
20	The Small-World Phenomenon	537
20.1	Six Degrees of Separation	537
20.2	Structure and Randomness	538
20.3	Decentralized Search	541
20.4	Modeling the Process of Decentralized Search	543
20.5	Empirical Analysis and Generalized Models	546
20.6	Core-Periphery Structures and Difficulties in Decentralized Search	552
20.7	Advanced Material: Analysis of Decentralized Search	554
20.8	Exercises	564
21	Epidemics	567
21.1	Diseases and the Networks That Transmit Them	567
21.2	Branching Processes	569
21.3	The SIR Epidemic Model	572
21.4	The SIS Epidemic Model	576
21.5	Synchronization	578
21.6	Transient Contacts and the Dangers of Concurrency	582
21.7	Genealogy, Genetic Inheritance, and Mitochondrial Eve	585
21.8	Advanced Material: Analysis of Branching and Coalescent Processes	590
21.9	Exercises	602

Part VII Institutions and Aggregate Behavior

22	Markets and Information	607
22.1	Markets with Exogenous Events	608
22.2	Horse Races, Betting, and Beliefs	609
22.3	Aggregate Beliefs and the “Wisdom of Crowds”	615
22.4	Prediction Markets and Stock Markets	618
22.5	Markets with Endogenous Events	622

22.6	The Market for Lemons	623
22.7	Asymmetric Information in Other Markets	627
22.8	Signaling Quality	631
22.9	Quality Uncertainty Online: Reputation Systems and Other Mechanisms	632
22.10	Advanced Material: Wealth Dynamics in Markets	635
22.11	Exercises	641
23	Voting	645
23.1	Voting for Group Decision Making	645
23.2	Individual Preferences	646
23.3	Voting Systems: Majority Rule	649
23.4	Voting Systems: Positional Voting	654
23.5	Arrow's Impossibility Theorem	657
23.6	Single-Peaked Preferences and the Median Voter Theorem	658
23.7	Voting as a Form of Information Aggregation	663
23.8	Insincere Voting for Information Aggregation	665
23.9	Jury Decisions and the Unanimity Rule	668
23.10	Sequential Voting and the Relation to Information Cascades	672
23.11	Advanced Material: A Proof of Arrow's Impossibility Theorem	673
23.12	Exercises	678
24	Property Rights	681
24.1	Externalities and the Coase Theorem	681
24.2	The Tragedy of the Commons	685
24.3	Intellectual Property	688
24.4	Exercises	691
	<i>Bibliography</i>	693
	<i>Index</i>	711