Contents

Cr	edits (and Aci	knowledgments	page xv		
			the Latest by American Table	xvii		
1	Diet	ributo	d Constraint Satisfaction			
			ing distributed constraint satisfaction problems	1 2		
			ain-pruning algorithms	4		
			stic search algorithms	8		
			The asynchronous backtracking algorithm	9		
		1.3.1	A simple example	11		
			An extended example: the four queens	11		
			problem	13		
			Beyond the ABT algorithm	15		
			ry and references	17		
		111310	Later in Consumpose managing 144	17		
2	Dist	ribute	d Optimization	19		
	2.1	Distri	buted dynamic programming for path planning	19		
			Asynchronous dynamic programming	19		
			Learning real-time A*	21		
	2.2	Actio	n selection in multiagent MDPs	23		
	2.3		tiation, auctions, and optimization	27		
			From contract nets to auction-like optimization	27		
			The assignment problem and linear programming	29		
		2.3.3	The scheduling problem and integer programming	36		
	2.4	Social	l laws and conventions	43		
	2.5	Histor	ry and references	45		
3	Intr	oductio	on to Noncooperative Game Theory: Games in Nor	mal		
	Form					
	3.1	Self-in	nterested agents	47		
			Example: friends and enemies	48		
		3.1.2	Preferences and utility	49		
	3.2	Game	s in normal form	53		
		3.2.1	Example: the TCP user's game	54		
			Definition of games in normal form	55		
			More examples of normal-form games	56		
		3.2.4	[] [] [전 : [[[[[[[[[[[[[[[[[58		
	3.3	Analy	zing games: from optimality to equilibrium	60		

viii	Contents
VIII	Contents

		3.3.1	Pareto optimality	60
		3.3.2	Defining best response and Nash equilibrium	61
		3.3.3	Finding Nash equilibria	62
		3.3.4	Nash's theorem: proving the existence of Nash equilibria	64
	3.4	Furthe	er solution concepts for normal-form games	71
		3.4.1	Maxmin and minmax strategies	72
		3.4.2	Minimax regret	75
		3.4.3	Removal of dominated strategies	77
		3.4.4	Rationalizability	79
		3.4.5	Correlated equilibrium	81
		3.4.6	Trembling-hand perfect equilibrium	83
		3.4.7	ϵ -Nash equilibrium	83
	3.5	Histor	ry and references	85
4	Con	nputing	Solution Concepts of Normal-Form Games	87
	4.1		outing Nash equilibria of two-player, zero-sum games	87
	4.2	Comp	outing Nash equilibria of two-player, general-sum games	89
		4.2.1		89
		4.2.2	An LCP formulation and the Lemke–Howson algorithm	91
			Searching the space of supports	99
			Beyond sample equilibrium computation	101
	4.3		outing Nash equilibria of n-player, general-sum games	102
	4.4		outing maxmin and minmax strategies for two-player, al-sum games	105
	4.5		fying dominated strategies	106
			Domination by a pure strategy	106
			Domination by a mixed strategy	107
		4.5.3	Iterated dominance	109
	4.6	Comp	outing correlated equilibria	110
	4.7	Histor	ry and references	111
5	Gar	nes wit	h Sequential Actions: Reasoning and Computing with	
	the		ive Form	113
	5.1	Perfec	ct-information extensive-form games	113
		5.1.1	Definition	113
		5.1.2	Strategies and equilibria	115
		5.1.3	Subgame-perfect equilibrium	117
		5.1.4	Computing equilibria: backward induction	119
	5.2	Imper	fect-information extensive-form games	125
		5.2.1	Definition	125
		5.2.2	Strategies and equilibria	126
			Computing equilibria: the sequence form	129
			Sequential equilibrium	136
	5.3	Histor	ry and references	139

Contents ix

		_	resentations: Beyond the Normal and Extensive	141
			ted games	142
	0.1		Finitely repeated games	143
			Infinitely repeated games	144
				144
		0.1.3	"Bounded rationality": repeated games played by automata	1.47
	60	Canalan	automata stic games	147
	0.2	6 2 1	Definition Definition	153
				153
			Strategies and equilibria	154
			Computing equilibria	155
	6.3		an games and section 14.0.4	156
			Definition Company of the Property L.A.	157
		6.3.2	Strategies and equilibria	160
		6.3.3	Computing equilibria	163
		6.3.4	Ex post equilibrium	165
	6.4	Conge	stion games	166
		6.4.1	Definition	166
		6.4.2	Computing equilibria	167
		6.4.3	Potential games	168
		6.4.4	Nonatomic congestion games	170
		6.4.5	Selfish routing and the price of anarchy	172
	6.5		utationally motivated compact representations	176
			The expected utility problem	177
		6.5.2	Graphical games	179
		6.5.3	Action-graph games	181
		6.5.4	Multiagent influence diagrams	183
		6.5.5	GALA	186
	6.6		y and references	187
7	Lea	rning a	nd Teaching	189
	7.1	Why th	he subject of "learning" is complex	189
	,		The interaction between learning and teaching	189
			What constitutes learning?	190
			If learning is the answer, what is the question?	192
	7.2			192
	7.2		ous play	
	7.3		al learning	200
	7.4		orcement learning	204
			Learning in unknown MDPs	205
			Reinforcement learning in zero-sum stochastic games	205
			Beyond zero-sum stochastic games	208
			Belief-based reinforcement learning	209
	7.5		gret learning and universal consistency	209
	7.6	-	ed learning	211
	7.7		ionary learning and other large-population models	212
		771	The replicator dynamic	213

Contents

		7.7.2 Evolutionarily stable strategies	216
		7.7.3 Agent-based simulation and emergent conventions	219
	7.8	History and references	221
8	Com	nmunication	223
	8.1	"Doing by talking" I: cheap talk	223
	8.2	"Talking by doing": signaling games	227
	8.3	"Doing by talking" II: speech-act theory	229
		8.3.1 Speech acts	229
		8.3.2 Rules of conversation	230
		8.3.3 A game-theoretic view of speech acts	232
		8.3.4 Applications	235
	8.4	History and references	238
9	Aggi	regating Preferences: Social Choice	241
	9.1	Introduction	241
		9.1.1 Example: plurality voting	241
	9.2		242
	9.3	Voting Company & Arriver House	244
		9.3.1 Voting methods	244
	2.7	9.3.2 Voting paradoxes	246
	9.4		247
		9.4.1 Social welfare functions	248
		9.4.2 Social choice functions	251
	9.5		255
	9.6	History and references	258
10		cocols for Strategic Agents: Mechanism Design	261
	10.1	Introduction	261
		10.1.1 Example: strategic voting	261
		10.1.2 Example: buying a shortest path	262
	10.2	Mechanism design with unrestricted preferences	263
		10.2.1 Implementation	264
		10.2.2 The revelation principle	265
		10.2.3 Impossibility of general, dominant-strategy	265
	10.2	implementation	267
	10.3	Quasilinear preferences	268
		10.3.1 Risk attitudes	269
	10.4	10.3.2 Mechanism design in the quasilinear setting	271 276
	10.4	Efficient mechanisms	276
		10.4.1 Groves mechanisms 10.4.2 The VCG mechanism	280
		10.4.3 VCG and individual rationality	282
		10.4.4 VCG and weak budget balance	283
		10.15 D. 1. 1. CYGG	284
		10.4.5 Drawbacks of VCG 10.4.6 Budget balance and efficiency	288
		10.4.0 Dauget balance and efficiency	200

10.0

E81

281

Contents xi

	10.4.7	The AGV mechanism	288
		efficiency	289
	10.5.1	What else can be implemented in dominant strategies?	290
		Tractable Groves mechanisms	292
10.6	Compu	tational applications of mechanism design	293
		Task scheduling	294
		Bandwidth allocation in computer networks	296
		Multicast cost sharing	298
		Two-sided matching	301
10.7	Constra	ined mechanism design	307
		Contracts Targette J. E. C.	308
	10.7.2	Bribes Bribes	309
	10.7.3	Mediators	310
10.8	History	and references	311
11 Prot	ocols for	Multiagent Resource Allocation: Auctions	315
der no 11.1	Single-g	good auctions a lease of 2.1.1	315
		Canonical auction families	316
	11.1.2	Auctions as Bayesian mechanisms	318
		Second-price, Japanese, and English auctions	319
	11.1.4	First-price and Dutch auctions	321
	11.1.5	Revenue equivalence	323
	11.1.6	Risk attitudes	326
	11.1.7	Auction variations	327
	11.1.8	"Optimal" (revenue-maximizing) auctions	328
		Collusion	330
	11.1.10	Interdependent values	333
11.2		it auctions	336
	11.2.1	Canonical auction families	336
	11.2.2	Single-unit demand	337
		Beyond single-unit demand	340
		Unlimited supply: random sampling auctions	342
		Position auctions	344
11.3	Combin	atorial auctions	346
	11.3.1	Simple combinatorial auction mechanisms	348
	11.3.2	The winner determination problem	349
	11.3.3	Expressing a bid: bidding languages	352
	11.3.4	Iterative mechanisms	357
	11.3.5	A tractable mechanism	359
11.4	Exchang	ges vertice by high vipped (AT)	361
	11.4.1	Two-sided auctions	361
	11.4.2	Prediction markets	362
11.5	History	and references	364

12	Teams of Selfish Agents: An Introduction to Coalitional Game	216
	Theory	367
	12.1 Coalitional games with transferable utility	367
	12.1.1 Definition	368
	12.1.2 Examples	368
	12.1.3 Classes of coalitional games	370
	12.2 Analyzing coalitional games	371
	12.2.1 The Shapley value	372
	12.2.2 The core	374
	12.2.3 Refining the core: ϵ -core, least core, and nucleolus	378
	12.3 Compact representations of coalitional games	381
	12.3.1 Weighted majority games and weighted voting games	381
	12.3.2 Weighted graph games	382
	12.3.3 Capturing synergies: a representation for superadditive games	384
	12.3.4 A decomposition approach: multi-issue representation	385
	12.3.5 A logical approach: marginal contribution nets	386
	12.4 Further directions	388
	12.4.1 Alternative coalitional game models	388
	12.4.2 Advanced solution concepts	389
	12.5 History and references	390
13	Logics of Knowledge and Belief	393
	13.1 The partition model of knowledge	393
	13.1.1 Muddy children and warring generals	393
	13.1.2 Formalizing intuitions about the partition model	394
	13.2 A detour to modal logic	396
	13.2.1 Syntax	398
	13.2.2 Semantics	398
	13.2.3 Axiomatics	399
	13.2.4 Modal logics with multiple modal operators	399
	13.2.5 Remarks about first-order modal logic	400
	13.3 S5: An axiomatic theory of the partition model	400
	13.4 Common knowledge, and an application to distributed systems	403
	13.5 Doing time, and an application to robotics	406
	13.5.1 Termination conditions for motion planning	407
	13.5.2 Coordinating robots	410
	13.6 From knowledge to belief	412
	13.7 Combining knowledge and belief (and revisiting knowledge)	413
	13.8 History and references	418
14	Beyond Belief: Probability, Dynamics, and Intention	421
	14.1 Knowledge and probability	421
	14.2 Dynamics of knowledge and belief	425
	14.2.1 Belief revision	426

Contents		

Index

		14.2.2 Beyond AGM: update, arbitration, fusion, and friends	430			
		14.2.3 Theories of belief change: a summary	430			
	14.3	Logic, games, and coalition logic	436			
		Towards a logic of "intention"	438			
		14.4.1 Some preformal intuitions	438			
		14.4.2 The road to hell: elements of a formal theory of intention	440			
		14.4.3 Group intentions	443			
	14.5	History and references	445			
		The planting in the partners of Care connections in				
	App	endices: Technical Background	447			
A	Probability Theory					
	A.1	Probabilistic models	449			
	A.2	Axioms of probability theory	449			
	A.3	Marginal probabilities	450			
	A.4	Conditional probabilities	450			
В	Line	ear and Integer Programming	451			
	B.1	Linear programs	451			
	B.2	Integer programs	453			
C	Mar	kov Decision Problems (MDPs)	455			
	C.1	The model	455			
	C.2	Solving known MDPs via value iteration	455			
D	Clas	sical Logic	457			
	D.1	Propositional calculus	457			
	D.2	First-order logic	458			
3ib	liogra	aphy	459			

xiii