Barriers and Bounds to Rationality

ESSAYS ON ECONOMIC COMPLEXITY AND DYNAMICS IN INTERACTIVE SYSTEMS

Peter S. Albin

Edited and with an Introduction by Duncan K. Foley

PRINCETON UNIVERSITY PRESS PRINCETON, NEW JERSEY

Contents

.

.

Preface				xiii			
				xxxiii			
1	Introduction						
	1.1	Dynamical systems					
		1.1.1	Linear dynamical systems	. 4			
		1.1.2	Nonlinear dynamical systems	. 7			
		1.1.3	Cellular automata as models of nonlinear				
			dynamical systems	. 15			
	1.2	Dynan and pl	nical systems in social hysical science	. 17			
		1.2.1	Local and global interaction	. 18			
		1.2.2	Topology and geometry in physical and social models	. 18			
		1.2.3	Time and causality	. 20			
		1.2.4	Identity and diversity	. 21			
	1.3	Econo	mic models of fully rational behavior	. 23			
		1.3.1	The rational choice program	. 23			
		1.3.2	Individual decision models—intertemporal optimization	. 25			
		1.3.3	The finite-horizon Ramsey problem	. 25			
		1.3.4	Market models	. 28			
		1.3.5	Game theory models	. 33			
	1.4	Defini	tions and measures of complexity	. 40			
		1.4.1	Computational complexity	. 41			
		1.4.2	Linguistic complexity	. 42			

CON	TEI	VI	S
-----	-----	----	---

		1.4.3	Machine complexity	44		
		1.4.4	Decidability, computational complexity, and rationality	46		
		1.4.5	Dynamical systems and computational complexity	47		
	1.5	Comp	lexity in cellular automata	48		
	1.0	1.5.1	Complexity types	50		
		1.5.2	Computability, predictability, and complexity in cellular automata	52		
	1.6	Model	ling complex social and economic			
		intera	ctions	53		
		1.6.1	Self-referencing individual agents	53		
		1.6.2	Organizations	55		
		1.6.3	Industries and economies	56		
		1.6.4	Markets	58		
		1.6.5	The local interaction multiperson Prisoners' Dilemma	61		
	1.7	Comp intera	lexity, rationality, and social	64		
		1.7.1	How complex are social systems?	65		
		1.7.2	How smart do agents need to be?	67		
	1.8	Towar and so	rd a robust theory of action	68		
2	The and	e Meta Prop	logic of Economic Predictions, Calculations, ositions	73		
	2.1	Introd	luction	73		
	2.2	and Propositions 2.1 Introduction 2.2 Preliminaries: Automata and structural formations 6.1 Element				
		2.2.1	Finite automata	76		
		2.2.2	Finite formations	77		
		2.2.3	Generalized formations and finite surrogates	79		
		2.2.4	General computation and computability	80		
	2.3	Unde	cidability in generalized formations	83		
		2.3.1	An economy with finite automaton components	84		
		2.3.2	Structural properties of a finite economy	85		
		2.3.3	Archival expansion: An economy with Turing machine components	85		
			• • • • • • • • • • • • • • • • • • • •			

CONTENTS

		2.3.4	Conditional forecasting: Economies with universal machine components	86
		2.3.5	Undecidability propositions	87
		2.3.6	General comments	88
	2.4	Social	welfare evaluations	91
		2.4.1	The decision setting	91
		2.4.2	The political process	94
		2.4.3	The computability of a political program	95
		2.4.4	Predictability of restricted programs	97
	2.5	Conclu	usions	98
	Арр	endix:	Proof of Theorem 2.5	103
_				
3	Mic	roecor	nomic Foundations of Cyclical	105
	31	Introd		105
	3.7	The re	action	100
	0.2	201	The meaning of "chaos" in dynamic systems	100
		3.2.1	Nonlinearities and underlying microeconomic	101
		0.2.2	interactions	110
	3.3	A mod	del of microeconomic interaction	114
		3.3.1	Specification of interaction neighborhoods	114
		3.3.2	Specification of interaction conventions	116
		3.3.3	Simulation of firm behavior	117
		3.3.4	Classification of simulated time series	118
		3.3.5	Preliminary indications	125
	3.4	Interp	retations	127
		3.4.1	The background model	127
		3.4.2	The computation irreducibility hypothesis	131
		3.4.3	Reexamination of economic implications	131
	3.5	Exten	sions and applications	135
	•			
4	Qua "Ri	alitativ ch" D	e Effects of Monetary Policy in vnamic Systems	137
	4.1	Introd	Juction	137
	4.2	The e	xperimental setting	138
	4.3	Comp	lexity classification	
		of dyr	namic behaviors	140

		4.3.1	Qualitative types of dynamic behavior	140
		4.3.2	Projective properties	147
		4.3.3	Modeling considerations	148
		4.3.4	Dynamics and expectations	148
		4.3.5	Industry structure	149
	4.4	Policy	v interventions	149
		4.4.1	Simulating monetary interventions	151
		4.4.2	Properties of the system and experimental	
			protocols	155
	4.5	Result	ts and preliminary interpretations	155
		4.5.1	Incomplete stabilization	156
		4.5.2	Economic implications	156
ĸ	Do	contro	lized Dispersed Exchange without an	
U		tionee	ar. A Simulation Study	157
	51	Introd	luction	157
	5.2		del of dispersed exchange	158
	0.2	591	Findowmonte and utilities	150
		599	Advertising neighborhoods information costs	105
		0.2.2	and trade protocol: The rules of the game	159
	5.3	Strate	egies of agents	161
		5.3.1	Boundedly rational agents of fully rational players .	161
		5.3.2	Truthful disclosure	162
		5.3.3	The agent's computational capacity	162
		5.3.4	The candidate algorithm	163
		5.3.5	The expected gain from signaling	163
		5.3.6	Estimating the likelihood of neighbor actions	164
		5.3.7	Simulation procedures	165
		5.3.8	The coefficient of resource utilization	166
	5.4	Simul	ation results	166
		5.4.1	Reporting format	166
		5.4.2	Illustrative results	167
		5.4.3	Trader accounts	168
		5.4.4	Comment	169
		5.4.5	A second illustrative example	169
	5.5	Inform	nation cost and efficiency	169
		5.5.1	Interactions of advertising cost	
			and neighborhood size	170
		5.5.2	Interpretations	171
	5.6	Concl	luding comments	174

6	Approximations of Cooperative Equilibria in Multiperson				
	Pris	oners'	Dilemma Played by Cellular Automata	181	
	6.1	Introdu	uction	181	
	6.2	The m	odel	183	
		6.2.1	Subgame and sub-subgame structure of MPD	183	
		6.2.2	Threshold conditions for equilibria in repeated play.	188	
	6.3	Strateg	gic equivalence and the complexity of cellular aton rules	190	
		6.3.1	Digression: Study of cellular automaton complexity properties	190	
	6.4	The co	emplexity of bounded-rationality		
		forms		192	
		6.4.1	Classes of strategic equivalence in multiperson games	193	
	6.5	A theo	orem on "Nash-like" equilibria		
		in MP	D	197	
	6.6	A "Na	sh-like" solution to MPD	198	
	6.7	Conclu	isions	204	
	Арр	endix .		205	
7	The Des	Comp	blexity of Social Groups and Social Systems	210	
	7.1	Introd	uction	210	
	7.2	7.2 Directed graphs and their representation: An overview .			
		721	Arbitrary system functions		
			"Structure generators"	216	
		7.2.2	Analysis of the undirected graph	218	
		7.2.3	Parameters of the undirected graph	218	
		7.2.4	The function "rumor transmission with recorded path	"218	
		7.2.5	Complexity of the rumor propagating machine	222	
	7.3	The di	irected graph	231	
		7.3.1	The graph that is less than total	231	
		7.3.2	Complexity measurement for the directed graph	235	
		7.3.3	Case example: Complexity of organizational		
			structures	236	
	7.4	Conclu	usion	241	
W	/orks	Cited		243	