

Patricia Jay Shiroma

Efficient Production Planning and Scheduling

An Integrated Approach with
Genetic Algorithms and Simulation

With a Foreword
by Prof. Dr. Gerhard Niemeyer



DeutscherUniversitätsVerlag

Table of Contents

1	Introduction	1
1.1	Motivation	1
1.2	Problem Definition and Extensions	5
1.2.1	Definition of the Standard Job-Based Production Planning Problem	5
1.2.2	Deficiencies in the Standard Problem Definition.....	6
1.2.2.1	Time-Cost Tradeoffs	6
1.2.2.2	Time Aspect of Dynamic Resource Allocation.....	7
1.2.3	Expanded Problem Definition.....	8
1.3	Failure of Traditional Operations Research Methods to Solve Problems with Nonlinear Dependencies	9
1.3.1	Linear Programming	9
1.3.2	Hillclimbing Methods	9
1.4	Simulation	11
1.5	Cybernetic System Theory	12
1.5.1	Automata Theory.....	13
1.5.2	Cybernetics.....	15
1.6	Generation of Input Parameters for Simulation Studies	16
1.6.1	Simple Heuristics	16
1.6.2	Nearest Neighbor.....	16
1.6.3	Balancing Machine Load	18
1.6.4	Expert Systems	19
1.6.5	Enumeration	21
1.6.6	Dynamic Programming	22
1.6.7	Branch and Bound.....	24
1.6.8	Simulated Annealing.....	29
2	The Nature of Evolutionary Algorithms	33
2.1	Evolutionary Programming	35
2.2	Evolutionary Strategies	36
2.3	Genetic Algorithms	37
2.3.1	Selection	38
2.3.2	Crossover.....	39
2.3.3	Mutation	40
2.3.4	Convergence.....	41
2.3.5	Example of a Genetic Algorithm in Pseudo-Pascal	42

3	Theoretical Foundations of Genetic Algorithms.....	43
3.1	Schema Theorem.....	43
3.1.1	Schemata	44
3.1.2	Upper and Lower Bounds on the Number of Schemata Evaluated.....	45
3.1.3	Hyperplane Sampling	45
3.1.4	Effects of Fitness Proportional Reproduction.....	47
3.1.5	Effects of Crossover.....	49
3.1.6	Effects of Mutation	50
3.1.7	Schema Theorem Summarized.....	51
3.2	The Building Block Hypothesis	52
3.3	Interacting Roles of Crossover and Mutation	54
3.4	Self-Organizing Systems and Artificial Life.....	55
3.4.1	Artificial Life	55
3.4.2	The Game of Life	56
3.4.3	Manipulation of DNA to Solve Combinatorial Problems.....	57
3.4.4	Generation of Computer Programs with Natural Selection	59
3.4.5	Simulation of a Market Economy with Autonomous Agents	61
4	Methodology	63
4.1	Classic vs. Hybrid Genetic Algorithms.....	65
4.2	Time Constraints when Combining Genetic Algorithms with Simulation	66
4.2.1	Minimization of the Number of Simulation Runs.....	67
4.2.1.1	Delta Evaluation.....	68
4.2.1.2	Messy Genetic Algorithms.....	68
4.2.1.3	Chromosome Representation	69
4.2.1.3.1	Binary vs. Real Coding Schemes.....	69
4.2.1.3.2	Hierarchical, Dynamic Data Structure	71
4.2.1.4	Modification of Genetic Operators	73
4.2.1.4.1	Selection.....	73
4.2.1.4.1.1	Generational vs.	
Steady State Algorithms.....		74
4.2.1.4.1.2	Fitness Proportional vs.	
Rank-Based Selection		75
4.2.1.4.2	Modifications to the Crossover Operator	77
4.2.1.4.2.1	Multi-Point Crossover.....	77
4.2.1.4.2.2	Uniform Crossover.....	78
4.2.1.4.2.3	Intelligent Crossover	79
4.2.1.4.2.4	Order Crossover	80

4.2.1.4.3	Order-Based Mutation	81
4.2.1.5	Adaptive Feedback Controller to Vary Mutation Rate	82
4.2.1.6	Tabu List of Previously Evaluated Schedules.....	85
4.2.2	Minimization of the Processing Time for Each Simulation.....	86
4.2.2.1	Simulation Model.....	86
4.2.2.1.1	Petri-Nets	87
4.2.2.1.2	Dynamic Agents.....	88
4.2.2.2	Hierarchical, Dynamic Data Structure	89
4.3	Multiobjective Fitness Function.....	91
4.3.1	Hard Constraints.....	91
4.3.2	Soft Constraints	92
4.3.3	Competing Objectives: Minimization of Time and/or Costs	93
5	Feasibility Study: A Hybrid Genetic Algorithm Embedded in AMTOS	97
5.1	AMTOS Simulation Software.....	97
5.2	Feedback Loop Between AMTOS and the Genetic Algorithm	97
5.3	First Experiments with Small Problems.....	99
5.4	Results	101
5.5	Conclusions	102
6	Case Study: Implementation of a Hybrid Genetic Algorithm for Production Planning in a Large Pharmaceutical Company.....	105
6.1	Problem Description.....	105
6.2	Hybridization.....	107
6.2.1	DISYS Object-Oriented Data Management and Logistics System....	107
6.2.2	AMTOS Simulation System.....	110
6.2.3	Genetic Algorithm	110
6.3	Comparison of Two Different Types of Genetic Algorithms	113
6.3.1	Genetic Algorithm Type 1.....	113
6.3.1.1*	Convergence Rate	114
6.3.1.2	Mutation Rate.....	115
6.3.1.3	Optimization According to Different Goals.....	116
6.3.2	Genetic Algorithm Type 2 (with Tabu List)	117
6.3.2.1	Convergence Rate	118
6.3.2.2	Mutation Rate.....	119
6.3.2.3	Optimization According to Different Goals.....	120

6.4	Comparison to Other Stochastic Optimization Methods.....	121
6.4.1	Monte Carlo Random Search	122
6.4.2	Tabu Search.....	123
6.4.3	Evolutionary Strategy.....	125
6.5	Results	126
6.6	Conclusions	134
7	Summary and Plans for Future Research.....	137
7.1	Summary	137
7.2	Plans for Future Research	138
7.2.1	Seeded Genetic Algorithms.....	138
7.2.2	Rescheduling	139
7.2.3	Parallel Genetic Algorithms.....	139
7.2.4	Fuzzy Logic Fitness Functions.....	141
7.2.5	Self-Organizing Systems: Autonomous Agents.....	142
	Bibliography	143