Contents

Abstract iii

Contents v

List of Figures viii

List of Tables x

Acknowledgements xi

1 Introduction 1
- 1.1 Motivation . . . 2
- 1.2 Contributions . . . 3
- 1.3 Outline . . . 4
  - 1.3.1 How to Read this Book . . . 5
  - 1.3.2 How the Book Was Written . . . 6

2 Complexity 9
- 2.1 Introduction . . . 10
- 2.2 Classical Thinking . . . 10
- 2.3 Complexity . . . 11
- 2.4 Indeterminacy . . . 14
- 2.5 Nonlinearity and Chaos . . . 17
- 2.6 Adapting to Complexity . . . 19
- 2.7 Conclusions . . . 21

3 Self-organization 23
- 3.1 Introduction . . . 24
- 3.2 The Representation-Dependent Dynamics of Entropy . . . 24
- 3.3 The Role of the Observer . . . 29
- 3.4 Ontological Issues . . . 30
- 3.5 Self-organization: A Practical Notion . . . 32

3.5.1 Artificial self-organizing systems . . . 33
3.5.2 Levels of abstraction . . . 34
3.5.3 Coping with the unknown . . . 34
3.6 Conclusions . . . 35

4 A General Methodology 37
4.1 Introduction . . . 38
4.2 The Conceptual Framework . . . 38
4.3 The Methodology . . . 44
4.3.1 Representation . . . 44
4.3.2 Modeling . . . 46
4.3.3 Simulation . . . 54
4.3.4 Application . . . 54
4.3.5 Evaluation . . . 55
4.3.6 Notes on the Methodology . . . 55
4.4 Discussion . . . 57
4.5 Conclusions . . . 60

5 Self-organizing Traffic Lights 63
5.1 Introduction . . . 64
5.2 Applying the Methodology I . . . 65
5.3 Experiments: First Results . . . 71
5.4 Applying the Methodology II . . . 78
5.5 Experiments: Second Results . . . 79
5.6 Applying the Methodology III . . . 84
5.7 Experiments: Third Results . . . 86
5.8 Applying the Methodology IV . . . 87
5.9 Discussion . . . 88
5.9.1 Adaptation or optimization? . . . 89
5.9.2 Practicalities . . . 90
5.9.3 Environmental benefits . . . 91
5.9.4 Unattended issues . . . 92
5.10 Conclusions . . . 93

6 Self-organizing Bureaucracies 97
6.1 Introduction . . . 98
6.2 Designing Self-organizing Bureaucracies . . . 100
6.3 The Role of Communication . . . 102
6.3.1 Decision Delays . . . 106
6.4 The Role of Sensors . . . 106
6.5 The Role of Hierarchies . . . 108

6.6 The Role of Context . . . 111
6.7 A Toy Model: Random Agent Networks . . . 112
6.7.1 Using self-organization to improve performance . . . 114
6.7.2 Simulation Results . . . 115
6.7.3 RAN Discussion . . . 117
6.8 Conclusions . . . 125

7 Self-organizing Artifacts **127**
7.1 A Scenario . . . 128
7.2 Requirements for self-organizing artifacts . . . 129
7.3 Achieving self-organization . . . 131
7.4 Learning to communicate . . . 132
7.5 Learning to cooperate . . . 133
7.6 Learning to coordinate . . . 135
7.7 Conclusions . . . 137

8 Conclusions **139**
8.1 Achievements . . . 140
8.1.1 Limitations . . . 141
8.2 Future Work . . . 142
8.3 Philosophical Implications . . . 144
8.3.1 Objectivity or Subjectivity? Contextuality! . . . 144
8.3.2 The Benefits of Self-organization . . . 145

Bibliography **147**

Glossary **169**

Index **173**

List of Figures

1.1 Book map . . . 5

2.1 Is it a duck, a rabbit, or both? . . . 15
2.2 The same sphere seen from different angles . . . 16

3.1 Entropy increases and decreases for the same system . . . 27

4.1 Diagram relating different stages of Methodology. . . . 44
4.2 Detailed diagram of Methodology. . . . 58

5.1 Screenshot of a part of the traffic grid . . . 67
5.2 Results for standard methods . . . 73
5.3 Results for self-organizing methods . . . 74
5.4 Full synchronization . . . 77
5.5 Second results for standard methods . . . 80
5.6 Second results for self-organizing methods . . . 81
5.7 Comparison of initial and average number of cars . . . 82
5.8 Simulation of the Wetstraat and intersecting streets . . . 85
5.9 Wetstraat results . . . 95
5.10 Potential implementation of *sotl-platoon*. . . . 96

6.1 Asynchronous communication . . . 104
6.2 Response delay . . . 105
6.3 Hierarchy represented as a network . . . 110
6.4 Dynamics of a random agent network of $N = 25$, $K = 5$ . . . 113
6.5 RAN self-organization mechanism . . . 114
6.6 Results for $N = 15$, $K = 1$. . . . 116
6.7 Results for $N = 15$, $K = 2$. . . . 118
6.8 Results for $N = 15$, $K = 5$. . . . 119
6.9 Results for $N = 15$, $K = 15$. . . . 120
6.10 Results for $N = 100$, $K = 1$. . . . 121
6.11 Results for $N = 100$, $K = 2$. . . . 122
6.12 Results for $N = 100$, $K = 5$. . . . 123

6.13 Results for $N = 100$, $K = 100$. 124

List of Tables

5.1 Parameters of NetLogo simulations. 72
5.2 Vehicle count per hour, Wetstraat 85
5.3 Emissions by idling engines on Wetstraat 92