Our world is a large, integrated system of systems. These systems, whether they are ecological, social, or financial are complex and they constantly adapt to their environment. Many of them are essential for our very existence. Because of the intensive interactions among the system components and because they are so complex, they cannot be fully understood by isolating their components or applying simple cause and effect reasoning. These systems, however, can be examined by looking for patterns within their behaviour. Intelligent complex adaptive system (ICAS) research uses systemic inquiry to build multi-disciplinary representations of reality to study such complex systems.

Because the use of ICASs is prevalent across a number of disciplines, papers describing ICAS theory and applications are scattered through different journals and conference proceedings. It is, therefore, important to have a book that broadly covers the state of the art in this highly evolving area. There has been a strong interest among researchers regarding the publication of this book. Forty-nine submissions were received. All papers went through rigid peer review by at least three reviewers and only 23 were accepted for publication, an acceptance rate of just under 50%. Because of size constraints, these papers were published as two volumes. This book focuses on the techniques and applications of ICASs while its sister book *Intelligent Complex Adaptive Systems* emphasises the theoretical side of ICASs. These two volumes cover a broad spectrum of ICAS research from discussion of general theory and foundations to more practical studies of ICASs in various artificial and natural systems. It is important to highlight that a significant portion of contributions come from the social sciences. This will, we believe, provide readers of these books with extremely valuable diverse views of ICASs and also clearly demonstrates the wide applicability of ICAS theories.
The study of ICASs draws richly from foundations in several disciplines, perhaps explaining in part why ICAS research is so active and productive. These diverse fields that contributed to the formation of ICASs included the genetic algorithm (Holland, 1975) and cellular automata (Gardner, 1970; Von Neumann, 1966 in computer sciences, evolution, and predator-prey models (Lotka, 1925) in biology and game theory in economics (Von Neumann & Morgenstern, 1944).

Researchers of ICASs are interested in various questions, but these can be summarised as to how to describe complex systems, and how to describe the interactions within these systems that give rise to patterns. Thus, although researchers from different backgrounds may have very different approaches to the study of ICASs, it is the unique properties of ICASs, such as nonlinearity, emergence, adaptivity, and modularity that form the centre of inquiries. Many of these properties will be thoroughly explored in these two volumes. It is the complexity of ICASs which means that although a variety of techniques which have been employed to study ICASs, computer simulations have become important and widely used. These simulations involve several important computing techniques that may interest readers of these books.

- Evolutionary computation (EC) is a highly active field of research inspired by natural evolution. Essentially, EC models the dynamics of a population of distinctive entities such as chromosomes in genetic algorithms or programs in genetic programming. Thus, while EC has been used as a simplified model to study ICASs, it is also an ICAS itself having wide applicability for solving scientific and engineering problems.

- Cellular automata (CA), and related techniques such as Boolean networks, are common techniques in ICASs. The behaviour of entities that respond to the environment is defined as rules or other forms. Each entity can interact with adjacent ones. The topology of adjacency can be defined in various ways depending on the focus of the research. CA and related techniques have been widely used to study important properties of ICASs such as emergence.

- Multi-agent systems (MASs) are systems composed of several autonomous agents. These agents may use a belief-desire-intention model or other mechanisms to guide their behaviour, respond to the environment, or communicate and interact with other agents. The concept of the MASs model can be directly applied to study a number of ICASs. More often, a computer simulation of MASs is used to understand corresponding ICASs.

ICAS research has applications across numerous disciplines. As we are surrounded by complex systems, and indeed are ourselves a complex system, applications are everywhere. In this preface, we have no intention of providing a complete list of applications of ICASs, although some of the chapters do survey ICAS applications.
in a particular field, but we do wish to highlight the following subjects that are covered by this book and its sister volume.

Because human society is a complex system, comprising a large number of autonomous individuals and entities that are connected by various layers of networks, it has been one of the major fields of applications of ICAS research. As explained in a number of excellent chapters, significant research has been conducted into how disease, information, belief, language, and innovation propagate and diffuse in society.

Economics and finance are also the focuses of applied ICAS research. The economic and financial interactions among the entities of modern society, either at individual or institutional level, are vital to its existence. ICASs have been used to study these interactions and to understand the dynamics that underpin them.

Management can also be understood and further explored with ICAS concepts and methodologies that provide both a novel perspective and an exciting new set of tools. Besides applications to general management, these two books also have chapters dedicated to specific management applications such as military transformation.

And finally, ICASs have been widely used in science and engineering. Complex systems exist almost everywhere in the natural world, from the complex dynamics of the weather to important ecological systems. ICASs play an important role in understanding these systems. Furthermore, it is well known that the robustness and reliability of an ICAS is partially due to the fact that there is usually no centralised control system. This idea has been explored in solving engineering problems.

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**Audience**

Researchers working in the field of ICASs and related fields such as machine learning, artificial intelligence, MASs, economy, finance, management, international relations, and other social sciences should find this book an indispensable state-of-the-art reference. Because of its comprehensive coverage, the book can also be used as complementary reading at the post-graduate level.

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**Organisation**

Papers in this second volume are divided into two sections on techniques (four chapters) and applications (eight chapters). The first techniques chapter by Chiong and Jankovic presents modelling of the economy using agent-based representation and the iterated prisoner’s dilemma (IPD). They create a simulated market environment
with agents acting as firms to perform transactions among each other with chosen IPD strategies, and investigated strategic interactions between different firms were. Following this, De Luca and Quattrociocchi model context-aware interactions in autonomous systems using an agent-based model, complex dynamic system (CDYS). CDYS uses information from multiple perceptions and provides real-time updates and context-specific guidance to state representation and synthesis. The work includes the design of state and ontology-based interaction and context, a set of representations of perception, and a set of rules.

A third techniques chapter by Bossomaier discusses CA as the quintessential complex system and how they can be used for complex systems modelling. Firstly, he considers various theoretical issues relating to the complexity of CA behaviour before discussing the input entropy as a way of quantifying complex rules. Finally, the author contrasts explicit CA modelling of geophysical systems with heuristic particle-based methods for the visualisation of lava flows.

The final techniques chapter by Negrello and colleagues applies dynamical system theory to the analysis of the structures and functions of recurrent neural networks. This approach is exemplified with the dynamical analysis of an evolved network controller for a small robot that maximises exploration, while controlling its energy reserves by resorting to different periodic attractors.

In the second section of this volume, eight reports are grouped together under the title of applications. These chapters begin with a paper by Ratna, Dray, Perez, Grafton, and Kompas in which they apply agent-based modelling to capture the complexity of the diffusion process in medical innovation and consider the classic study on diffusion of the drug tetracycline. They extend a previous model to heterogenous social agents that vary in terms of their degree of predisposition to knowledge and explore the impact of stage-dependent degrees of external influence from the change agent (the pharmaceutical company). Cumulative diffusion curves suggest that the company plays a weaker role in accelerating diffusion when diffusion dynamics are explored with complex agents. Analysis also reveals that the degree of adoption threshold or individual predisposition to knowledge is crucial for adoption decisions.

In the second applications chapter, Satterfield constructs multi-scale “artificial societies” to examine competing first- and second-language acquisition-based theories of Creole language emergence. Sociohistorical conditions and psycholinguistic capacities are integrated into the model as agents (slaves and slave owners) interact. Linguistic transmissions are tracked and grammar constructions are charted. The study demonstrates how a CAS approach offers clear indications for computational solutions to questions of language change and formation.

In chapter VII, Turrini and colleagues present a theory of reputation. Reputation is the result of evaluation spreading through an MAS, and the capacities of agents that spread reputation are decomposed and analysed. They demonstrate how interdisciplinary research can help understand the complex intelligent phenomena among
adaptive social systems. Reschke and Kraus then raise several important issues in
the application of economics, psychology, sociology, and evolutionary theories to
strategic management. They provide a brief survey from an evolutionary complexity
perspective and discuss the evolutionary processes of changes and their implications
for strategic planning and related organizational issues.

Agent-oriented software engineering (AOSE) is the design of distributed software
systems as collections of autonomous and proactive agents. Since software applica-
tions result from the interaction of agents in MASs, this design approach facilitates
the construction of software applications which exhibit self-organising and emergent
dynamics. In chapter IX, Sudeikat and Renz examine the relation between self-
organising MAS and CAS, highlighting the resulting challenges for engineering
approaches. They propose a multi-level analysis to comprehend MAS dynamics
and guide agent design, which may relieve development efforts and bridge the gap
between top-down engineering and bottom-up emerging phenomena.

Two chapters present information concerning several important real-world examples.
In chapter X, Outkin and his colleagues provide an overview of a financial system
model (FinSim) created at the Los Alamos National Laboratory. The model aims
to understand the impacts of external disruptions to the financial system, and how
those impacts are affected by the interactions between the different financial system
components and by individual agent’s actions and regulatory interventions. In chapter
XI, Holloman investigates how the US and others have initiated transformation of
their defensive capabilities to take advantage of recent advances in technologies
and to meet emerging security challenges. Progress has been mixed. The author
examines questions regarding our ability to manage large scale organizational
change and suggests that transformational efforts can be viewed through the lens
of the agent structure, which posits that social change is the outcome of a complex
dialectic between human agents and social structures. It is argued that understand-
ing this dialectic may be significantly enhanced if we examine the theoretical and
empirical insights gained from the study of CAS.

In this volume’s final chapter, Sycara and colleagues use evolutionary game theory
(EGT) to model the dynamics of adaptive opponent strategies for a large popula-
tion of players. In particular, the effects of information propagation through social
networks are investigated. The key underlying phenomenon that the information
diffusion aims to capture is that reasoning about the experiences of acquaintances
can dramatically impact the dynamics of a society. Results from agent-based
simulations show the impact of diffusion through social networks on the player
strategies of an evolutionary game, and the sensitivity of the dynamics to features
of the social network.
Conclusions

This book, and its sister volume, bring together prominent ICAS researchers from around the globe who provide us with a valuable diverse set of views on ICASs. Their work covers a wide spectrum of cutting-edge ICAS research, from theory to applications in various fields such as computing and social sciences, and provides both comprehensive surveys on some topics and in-depth discussions on others. This offers us a glimpse of the rapidly progressing and extremely active field that is ICAS research. More importantly, because of the interdisciplinary background of the contributors, these books should facilitate communications between researchers from these different fields and thus help to further enhance ICAS research. Thus, we hope that these books may help to raise the profile of the contribution that complex adaptive systems can make toward a better understanding of the various critical systems around us. In doing so, this work should encourage both further research into this area and also the practical implementation of the results derived from this area.

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References


