Agent-oriented design has become one of the most active areas in the field of software engineering. The agent concept provides a modeling paradigm for coping with the complexity of software systems. The design of multi-agent systems, however, remains a hard issue because conventional methods find it hard to capture the complex behavior patterns of agents in a multi-agent system. A multi-agent system model should be general enough to address common architectural issues and not be specific to design issues of a particular system. The architectural design of multi-agent systems is one of the most significant areas in the current literature. Research issues include system modeling and specification, specification languages, system derivation and reasoning, and domain-specific issues. Attempts have been made in software architecture, cognitive learning, very high-level languages, and distributed systems literature. Although great advances have been made in the study of architectural design of agent systems, its complexity and multi-disciplinary nature makes it a hard subject in the current technology suite. A compilation of current research results is needed to help bring this premature subject onto the next stage.

This book is an attempt to provide a compilation of current research results in multi-agent systems area that reflects the research trends and serves as a reference for further research. The book covers a wide spectrum of topics in multi-agent systems design, including fundamentals of multi-agent system theories, system models, formal methods and reasoning, knowledge management, and design issues pertaining to specific applications. The book will serve as both an overview on the current state of research on multi-agent systems and an in-depth exposure of theories and state-of-the-art design technologies. By publishing a collection of frontier research results in multi-agent systems, we aim to provide a comprehensive reference for scientists who work in artificial intelligence, programming methodology, software engineering, parallel/distributed computing, computer networking, security, and various research domains of multi-agent system applications.

The contributing authors of the chapters of this book have developed both theoretical and practical issues in multi-agent systems research. Their valuable scholarly work ensures both the breadth and the depth of the presentation of the current literature. The book’s comprehensive coverage will help readers gain a bird’s-eye view of the area and provide guidance for further research. The presentation of the frontier research results will also provide information on the limitation and current challenges when we use agent technology to reach a solution to problems under consideration, as well as on the benefits the agent systems can bring to the community.

The book is organized into four sections. Section I includes chapters that discuss fundamental theories for multi-agent systems; Section II focuses on agent-oriented design technologies of computer systems; Section III presents knowledge and artificial intelligence issues pertaining to agents; and Section IV covers applications of agent technology in various areas. We can find theoretical studies of agent-oriented modeling in Section I. In Chapter I, Dr. Pratik Biswas provides an in-depth analysis of agent concept and compares it to conventional programming models.
such as object-oriented design. In Chapter II, Dr. Wanli Ma, Dr. Dat Tran, Dr. Dharmendra Sharma, Dr. Hong Lin, and Ms. Mary Anderson develop a framework for specifying autonomous agents using the chemical reaction metaphor. Temporal logic is used to reason the properties of the specified system. In Chapter III, Dr. Hiromitsu Hattori, Dr. Tadachika Ozono, and Dr. Toramatsu Shintani use combinatorial auction metaphor to develop a scheme for coordinating agents in solving complex problems. In Chapter IV, Dr. Andre de Korvin, Dr. Plamen Simeonov, and Dr. Hong Lin present a gentle introduction to fuzzy logic and discuss its applications to multi-agent systems.

Section II contains valuable work in developing methodologies for agent-oriented system design. In Chapter V, Dr. Paulo Marques and Dr. Luís Silva propose component-based mobile agent systems to overcome the limitations of traditional platform-based approach for developing mobile agents and demonstrate the effectiveness of their method by two case studies. In Chapter VI, Mr. Daniel Lübke and Dr. Jorge Marx Gómez present an effort to develop a common platform and framework for developing mobile agents that operate on a peer-to-peer network and contain the logic of the network services. In Chapter VII, Dr. Luo Junzhou, Dr. Liu Bo, and Dr. Li Wei develop some algorithms to support dynamic multi-agent scheduling decisions in a network management scenario. The algorithms are developed using functional decomposition strategy, and an experiment has been done and shown promising results. In Chapter VIII, Dr. H. Farooq Ahmad, Dr. Hiroki Suguri, Dr. Arshad Ali, Ms. Amna Basharat, and Ms. Amina Tariq introduce a scalable, fault tolerant agent grooming environment (SAGE) for creating distributed, intelligent and autonomous entities that are encapsulated as agents. SAGE has a decentralized fault tolerant architecture that provides tools for runtime agent management, directory facilitation, monitoring and editing messages exchange between agents, and a built-in mechanism to program the agent behavior and their capabilities. SAGE can be used to develop applications in a number of areas, such as e-health, e-government, and e-science. In Chapter IX, Dr. Lizhe Wang presents methodologies and technologies of agent-based grid computing from various aspects and demonstrates that agent-based computing is a promising solution to bring a scalable, robust, thus tractable, grid. In Chapter X, Dr. Dharmendra Sharma, Dr. Wanli Ma, Dr. Dat Tran, Mr. Shuangzhe Liu, and Ms. Mary Anderson study multi-agent-based information technology (IT) security approach (MAITS) as a holistic solution to the increasing needs of securing computer systems. In their approach, each specialist task for security requirements is modeled as a specialist agent, which has the ability to learn, reason, and make decisions, and an agent interface that enables inter-agent communications.

Section III presents some significant work in the traditional area of agent technology—artificial intelligence. In Chapter XI, Dr. Michael Bowman describes a methodology for modeling expert problem-solving knowledge that supports ontology import and development, teaching-based agent development, and agent-based problem solving. The methodology is applicable to a wide variety of domains and has been successfully used in the military domain. In Chapter XII, Dr. Yang Gao, Mr. Hao Wang, and Dr. Ruili Wang present a general framework of multi-agent reinforcement learning (MARL), which combines three perspectives in order to assist readers to understand the intricate relationships between different perspectives, and a negotiation-based MARL algorithm that enables interaction among cooperative agents and gaming agents. In Chapter XIII, Dr. Maria Salamó, Dr. Barry Smyth, Mr. Kevin McCarthy, Mr. James Reilly, and Dr. Lorraine McGinty present their recent research on critiquing-based recommendation and a comparison between standard and recent proposals of recommendation based on critiquing. Their work leads to conversational recommender agents, which facilitate user navigation through a product space. In Chapter XIV, Ms. Fabiana Lorenzi, Ms. Daniela Scherer dos Santos, Ms. Denise de Oliveira, and Dr. Ana L. Bazzan present an approach inspired by swarm intelligence applied to a case-based recommender system in the tourism domain and show experiment results that, using the proposed metaphor, the system always return some recommendation to the user, avoiding the user’s disappointment.
In Section IV, we can find exciting use of multi-agent systems in various application areas. In Chapter XV, Dr. Hyung Rim Choi, Dr. Hyun Soo Kim, Dr. Yong Sung Park, and Dr. Byung Joo Park develop a multi-agent system that enables the effective formation and management of an optimal supply chain. By means of active communications among internal agents, the multi-agent system for optimal supply chain management makes it possible to quickly respond to the production environment changes such as the machine failure or outage of outsourcing companies and the delivery delay of suppliers. In Chapter XVI, Mr. Ben Tse and Dr. Raman Paranjape present an architecture for an agent-based electronic health record system (ABEHRS) to provide health information access and retrieval among different medical services facilities. The agent-system’s behaviors are analyzed using the simulation approach and the mathematical modeling approach. The key concept promoted by ABEHRS is to allow patient health records to autonomously move through the computer network uniting scattered and distributed data into one consistent and complete data set or patient health record. In Chapter XVII, Mr. Gordon Fraser, Mr. Gerald Steinbauer, Mr. Jörg Weber, and Dr. Franz Wotawa present a control framework that is able to control an autonomous robot in complex real-world tasks. The key features of the framework are a hybrid control paradigm that incorporates reactive, planning, and reasoning capabilities, a flexible software architecture, and the capability for detecting internal failures in the robot and self-healing. The framework was successfully deployed in the domain of robotic soccer and service robots. In Chapter XVIII, Dr. Manolya Kavakli, Dr. Nicolas Szilas, Mr. John Porte, and Mr. Iwan Kartiko discuss the use of multi-agent systems to develop virtual reality training systems and describe the system architecture of a multi-agent system for risk management (RiskMan) to help train police officers to handle high-risk situations.

All chapters included in this book are selected by the following review process: Authors who were interested in contributing a chapter submitted a proposal for review. Those authors whose proposals were selected were invited to prepare the full chapters to be reviewed on a double-blind review basis. Each chapter manuscript was reviewed by three reviewers. Authors of accepted chapter manuscripts were then asked to revise the manuscript to address the issues raised by reviewers. The chapters on which major revisions were deemed necessary went through another review to determine whether the suggested revisions had been performed accordingly. Through this review process, 18 out of 28 submitted manuscripts were selected to be included in this book.