

1 Introduction

There is no rational life, therefore, without intelligence, and things are good only in so far as they assist men to enjoy that life of the mind which is determined by intelligence. Those things alone, on the other hand, we call evil which hinder man from perfecting his reason and enjoying a rational life.

Baruch Spinoza

1.1 The Coming of the Age of Intelligent Agents

Imagine one day you (Jack) arrive at work, switch on your computer and hear a pleasant voice from your personal assistant, Janet:

Janet: Good morning sir, can you look at the web camera and let me have a check for authentication, please?

*Jack: Of course (glimpses at the web cam with a smiling face).
(After a couple of seconds ...)*

Janet: Hi, Jack! Good morning to you. You look terrific today. What makes you so happy?

Jack: My best friend George and his family will come to stay with us for a week. I was thinking of where to take them for dinner when they arrive. Do you have any suggestions?

Janet: Sure, let me think Maybe you can try Ichikawa, the Japanese restaurant not far from our office. Some other PAs told me that they serve excellent food. What do you think?

Jack: Sounds good, could you book a table for five at 7:00 pm? By the way, is there anything urgent to handle today?

Janet: Nothing particularly urgent. But you will have a weekly morning briefing with all marketing staff at 10 am in Conference Room 1. I sent voice reminders to them five minutes ago. Also, there will be two meetings in the afternoon, all the related information can be found in your e-tray.

Jack: That's good. How about the deal with our supplier, B&L?

Janet: According to the baselines you gave me yesterday, I had a long negotiation with Tom – their representative agent – for over half an hour. They are seriously considering our counter-offer, and I think the deal is close to completion. Tom will call me later today. By the way, a non-smoking table has been reserved for dinner tonight. A non-smoking table – is that right? Also, the weather may change later today due to a rainstorm approaching Hong Kong, please remember to take an umbrella.

Jack: Thanks Janet. You're great. Let's talk about the strategy for another deal with Jackson International for the afternoon meeting. Do you have any suggestions?

Janet: Let me think ...

Of course, Janet is not a human being, but rather a PA intelligent agent. All of the above events seem to be science fiction, but, technically, they are not. Agent technology (a spin-off of AI technology) seeks to provide all kinds of assistance, not only for business, but also in our daily lives as well.

Starting from the mid-1990s, scientists have tried to build intelligent software objects or devices (what we call *intelligent agents*) that can mimic human intellectual behavior for the purposes of problem solving, scheduling, data mining and generally assisting humans in all of their activities. In the past few years, the developers of agents have implemented various agent systems (Murch and Johnson, 1998), ranging from Auction-Bot for e-auction to our own iJADE Web Miner for intelligent web mining.

However, most of the textbooks and technical references in this field are either too technical and focused only on the technical implementation of agent technology (Bigus 2001) (i.e., without detailed discussions and elaborations of the core AI technologies being adopted in the field of intelligent agents), or are too “application-oriented”, i.e., they are focused too much on the introduction of different kinds of contemporary agent-based systems, and lack complete explanations and discussions of the design and implementation of intelligent agents. Other research-oriented textbooks and references (Weiss 2000; Jain et al. 2002) do provide details on the de-

sign and implementation of contemporary agent-based systems and applications; however, the lack of descriptions of the basic concepts and theory of intelligent agents defeats the research students and college students who would like to learn this new and interesting technology from scratch.

Some classical AI books, such as the remarkable book written by Russell and Norvig (Russell and Norvig 2003), do provide some introductory discussion on agent technology, but these AI books are mainly focused on the description of the classical AI technology (what we call “macroscopic AI”), including predicate logics, logical reasoning, expert systems, rule-based and frame-based AI systems, and so on. However, the main “theme” AI techniques (the so-called *microscopic AI*) such as artificial neural networks, genetic algorithms, fuzzy logics and other advance techniques, such as chaos theory, are never touched upon, let alone the descriptions of the basic concepts and architectures of intelligent agents (both the conceptual and implementation models) and the contemporary R&D of agent-based systems.

In the above scenario agent Janet demonstrates the typical *intellectual activities* that an intelligent agent (IA) might possess, and such intellectual activities include: natural language processing (NLP) skills, negotiation skills, forecasting skills, planning & scheduling skills, and data-mining and knowledge acquisition skills (from her “memory” and “experience”). Of course, “high-level” intelligent agents also possess the skills of adaptive learning and decision making.

As one can see in the above example, most of the so-called *intellectual activities* of the intelligent agents involve highly uncertain (so-called *fuzzy*) and sometime even *chaotic* reasoning and decision making. Typical examples can be found in multi-agent negotiations, severe weather (such as rainstorm) prediction, active vision and invariant face recognition (for automatic user authentication), etc. These can be tackled by applying fuzzy-neuro machine learning and reasoning techniques – one of the feverish topics in contemporary AI, and also one of the main focuses of this book.

Most AI books on intelligent agents are focused mainly on the design and implementation of agent applications, but the fundamental theory, definition and classification of intelligent agents are seldom touched upon. The development and fundamental theory of intelligent agents are closely related to AI, and the human exploration and interpretation of intelligence is a cross-discipline topic involving neuroscience, neurophysiology, cognitive science and even modern philosophy. Moreover, the latest research and development in intelligent agents – the design and implementation of ontological agents (OAs) – is itself a typical topic in the field of modern ontology, one of the major branches of modern philosophy and epistemol-

ogy. All of these “*critical masses*” of agent technology are also covered in this book.

The main objectives of this book are:

1. To provide complete and detailed interpretations and explanations of the concepts and theories of intelligent agents, AI and the search (and research) for human intelligence in terms of computer science, cognitive science, neuroscience, neurophysiology and philosophy.
2. To provide a complete discussion on the design and development models of intelligent agents, and the major requirements and main features of intelligent agents.
3. To discuss different types of agent-based systems.
4. To discuss the major and contemporary AI techniques for the design and implementation of intelligent agents.
5. To provide technical details for the design and implementation of intelligent agents and agent-based systems using iJADK.
6. To discuss the latest research and development of intelligent agents, including the adoption of modern ontology and the concepts, design and implementation of ontology agents.

1.2 The Structure of This Book

For ease of reading, understanding and concept development, the book is organized into two main sections, namely:

Part I: Intelligent Agents – Concepts and Theories

Part II: Applications of Intelligent Agents Using iJADK

Part I is the introductory section, which focuses on the basic concepts and theories of intelligent agents. It discusses the major requirements and main features of an intelligent agent, and contrasts the differences between intelligent agents and other related technologies such as multi-agents, mobile-agents and distributed computing. It also discusses the major and contemporary AI techniques for the design and construction of intelligent agents, especially the fuzzy-neuro and chaotic-neuro AI techniques for agent development.

Part II focuses on the design and implementation of intelligent agents using the iJADK agent development kit. For ease of illustration in the book, the author has chosen five of his latest iJADE applications: iJADE Shopper, iJADE WeatherMan, iJADE Stock Advisor, iJADE Surveillant and iJADE Negotiator. At the end of this part, the author also discusses the latest research in agent technology – the design and development of ontology agents – a fascinating topic originated from modern ontology, a topic

which has drawn the interest of scientists, philosophers and scholars for centuries. In order to provide readers with an in-depth introductory knowledge about this interesting doctrine, this part begins with the history and overview of ontology, especially the philosophical views and ideas from classical philosophy to modern ontology. It discusses the contemporary works and standards of ontology agents and the agent platforms being developed in recent years, and the future development of intelligent agents and related research works to be undertaken.

It is anticipated that this book will not only provide a complete reference and textbook of intelligent agents, but will also serve as a technical and implementation guidebook for the design and implementation of agent-based systems, as well as vital literature for ongoing research in this field.

1.3 Outline of Each Chapter

Chapter 1: Introduction

This is an introductory chapter of the book which gives a general overview of intelligent agents. This chapter gives a brief overview of the organization of the book, the main focus of each section and a roadmap of reading for different categories of readers.

Part I: Intelligent Agents – Concepts and Theories

Chapter 2: The Search for Human Intelligence

This chapter gives an in-depth discussion on the “source” of artificial intelligence (AI) and intelligent agents (IAs), i.e., human intelligence, a foundation research topic which has been developed for over thousands of years, starting with the Age of the Ancient Greeks, and developed by distinguished philosophers including Plato, Aristotle, Descartes, Kant, etc. In this chapter, the author presents a thorough, cross-discipline exploration of this fascinating topic, ranging from the key philosophical schools of thought of human knowledge and intelligence to the contemporary theories and studies on human intelligence in the areas of psychology, cognitive psychology, neuroscience and neurophysiology.

The author also presents his latest theory on intelligence and knowledge – the Unification Theory of Senses and Experience – which provides the foundation works of the latest research on modern ontology and ontological agents.

Chapter 3: From AI to IA – The Emergence of Agent Technology

In the first part of this chapter, the author gives an overview of artificial intelligence (AI) and also presents the contemporary AI architecture and discusses the latest research and applications of AI. In the second part of this chapter, the author gives in-depth information on agent technologies. Firstly, the author gives a general definition of intelligent agents, as well as the basic concepts and requirements. Secondly, the author presents the main features and characteristics of intelligent agents. Thirdly, the author discusses the conceptual models for the design and development of agent-based systems. Lastly, the author introduces contemporary agent-based systems, both commercial applications and the latest research and development.

Chapter 4: AI Techniques for Agents Construction

This chapter focuses on the major AI techniques being adopted in the construction of intelligent agents and agent-based systems. It serves as an extension of Chap. 3 for the discussion of key AI modules for the design and construction of contemporary intelligent agents – the Fuzzy-Neuro Intelligent Module. In this chapter, the author presents the detailed AI components of this module, including artificial neural networks, fuzzy logics, genetic algorithms and the contemporary works on chaos theory. The author illustrates how these contemporary AI techniques can be integrated to solve complex AI problems. In particular, besides the fuzzy-neuro intelligent agents discussed in Part II of this book, the author also presents his latest research on the chaotic neural network in this chapter, and discusses how it can be used to simulate human visual intelligence behavior, which forms the foundation work for the latest research on modern ontology and ontology agents.

Part II: Applications of Intelligent Agents Using iJADK

Chapter 5: The Design and Implementation of Intelligent Agent-Based Systems Using iJADK

This chapter focuses on the design and implementation of agent-based systems using iJADK. Firstly, the author gives a general overview of the iJADE framework and some background information. Secondly, the author presents and discusses the iJADE Model (version 2.0), its architecture and the functions of different logical layers. This is followed by the description

of the different functional modules in the conscious layer (intelligent layer) of the model, which is summarized in a discussion of the latest developments in and implementations of the iJADE applications.

Chapter 6: iJADE WShopper – Intelligent Mobile Shopping Based on Fuzzy-neuro Shopping Agents

This chapter focuses on the design and implementation of a fuzzy logic-based shopping agent system – iJADE Shopper – which provides intelligent agent-based shopping over Wireless Internet.

In particular, this chapter discusses:

- The design and implementation of iJADE WShopper.
- The system architecture of iJADE WShopper.
- The AI technique being adopted in this agent application (fuzzy-neuro technique).
- The implementation details.
- The experimental results and analysis.
- The latest research and development.

Chapter 7: iJADE WeatherMan – A Weather Forecasting Agent Using Fuzzy Neural Network Models

This chapter focuses on the design and implementation of a fuzzy-neuro based weather forecasting agent, iJADE WeatherMan, which provides an intelligent agent-based weather prediction capability over multiple locations.

In particular, this chapter discusses:

- The major considerations and background on weather prediction, as well as the major obstacles and challenges.
- The design and implementation of iJADE WeatherMan.
- The system architecture of iJADE WeatherMan.
- The AI techniques being adopted in this agent application (fuzzy-neuro – the integration of fuzzy logics with feedforward backpropagation neural networks [FFBPN]).
- The implementation details.
- The experimental results and analysis.
- The latest research and development.

Chapter 8: iJADE Stock Advisor – An Intelligent Agent-Based Stock Prediction System Using Hybrid RBF Recurrent Networks

This chapter focuses on the design and implementation of an intelligent agent-based stock prediction and advisory system based on the hybrid RBF recurrent network (HRBFN) for stock prediction.

In particular, this chapter discusses:

- The major considerations and background on stock prediction, as well as the major obstacles and challenges.
- The design and implementation of iJADE Stock Advisor.
- The system architecture of iJADE Stock Advisor.
- The AI techniques being adopted in this agent application (HRBFN).
- The implementation details.
- The experimental results and analysis.
- The latest research and development.

Chapter 9: iJADE Surveillant – A Multi-resolution Neural-oscillatory Agent-Based Surveillance System

This chapter focuses on the design and implementation of a fully automatic and multi-resolution agent-based surveillance system – iJADE Surveillance – based on an innovative neuro-oscillatory model for automatic scene segmentation and object recognition. In fact, it is one of the author's latest works for adopting agent technologies for commercial use.

In particular, this chapter discusses:

- The major considerations and background on the automatic surveillance system, the major obstacles and challenges.
- The design and implementation of iJADE Surveillant.
- The system architecture of iJADE Surveillant.
- The AI techniques being adopted in this agent application.
- The implementation details.
- The experimental results and analysis.
- The latest research and development.

Chapter 10: iJADE Negotiator – An Intelligent Fuzzy Agent-Based Negotiation System for Internet Shopping

This chapter focuses on the design and implementation of intelligent agent-based negotiation agents for Internet shopping. This chapter: (1) presents an innovative negotiation protocol with a data exchange which is not

troublesome to set up beforehand and supports highly dynamic and flexible changes in negotiation attributes; (2) integrates fuzzy logic to compute the utility function and apply the most appropriate strategies to maximize profits; and (3) shows the learning ability and cooperation between negotiator agents.

In particular, this chapter discusses:

- The major considerations and background of the contemporary negotiation strategies and systems.
- The design and implementation of iJADE Negotiator.
- The system architecture of iJADE Negotiator.
- The implementation details.
- The experimental results and analysis.
- The latest research and development.

Chapter 11: Future Agent Technologies – Modern Ontology and Ontological Agent Technology (OAT)

This chapter focuses on the latest and future research on intelligent agents – modern ontology and ontology agents. Basically, this chapter is divided into three main sections. Section 11.1 begins with a general introduction of ontology, including the definition of ontology, the history of ontology, the main concerns in modern ontology, the major relationship issues and differences between ontology and epistemology, and how it is related to contemporary AI and agent technology. This section also focuses on the introduction and summarization of the critical thoughts and theories of ontology investigated by major distinguished philosophers and scholars, including Plato, Aristotle, Kant and Russell.

Section 11.2 focuses on modern ontology and how it impacts modern AI and agent technologies. The questions addressed include: What is conceptualism? What are the major differences between conceptualism and other major ontological theories? What are the major features of conceptualization theory? How can modern ontology be adopted into contemporary AI and agent technologies?

Section 11.3 discusses the latest and future R&D of the iJADE system, which includes the design and development of a self-aware, adaptive and ontological agent platform – Cogito iJADE. First of all, it gives a brief overview of the main ontological concept and theory of Cogito iJADE – the “Cognitron Map” – and discusses its basic mechanisms for ontology learning and knowledge updating. At the end of this chapter, the author gives a general summarization of the future development of Cogito iJADE and its Cogito Agents.

1.4 Readers of This Book

This book has a multi-disciplinary focus, targeting a range of reader/student categories including:

- Computer science students who are taking intelligent agent and related courses. This book will serve as their main textbook and reference.
- Research students and research personnel working in the field of AI, intelligent agents and related disciplines. This book will serve as their major technical reference. The advanced topics “Modern Ontology and Ontology Agents” can also serve as literature reviews on the latest developments in agent technology.
- Agent developers and scientists who are using iJADK as their agent development toolkit. In fact, this book will also serve as a technical reference for those wishing to develop intelligent agent-based systems using iJADK. The intelligent agent-based systems discussed in this book were developed using the author’s intelligent agent toolkit, iJADK (intelligent Java agent-based development kit) version 2.0 (which can be downloaded free of charge from the iJADK official site <http://www.iJADK.org>).

1.5 Concluding Remarks

Before ending this introductory chapter, I would like to make one important observation: In the old days we often heard that intelligence (and hence AI) is the investigation and study of the “rational thinking” of human beings. However, the author believes differently, and, in addition to Spinoza’s quotation at the beginning this chapter, the author believes that:

The most precious of human intelligence is not only its rational and logical thinking, but rather its irrational, and sometimes “fuzzy” or even “chaotic” reasoning, thinking and decision making. I think the beauty of nature is not only its state of “balance,” “harmony” and “completeness” – the state of Prägnanz – but rather it is the “art” and our “act” of handling highly chaotic, fuzzy and even uncertain situations to seek for harmony from the nature of fuzziness and incompleteness.

It is exactly what we (AI workers) should think about for the development of intelligent agents in this millennium.

<http://www.springer.com/978-3-540-21203-4>

Fuzzy-Neuro Approach to Agent Applications
From the AI Perspective to Modern Ontology

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2006, XVIII, 376 p. 126 illus., Hardcover

ISBN: 978-3-540-21203-4