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Raymond S.T. Lee

Fuzzy-Neuro Approach to Agent Applications

From the AI Perspective to Modern Ontology

With 126 Figures

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“Thinking” is the way we ascertain our existence.

“Intuition” is the way we show our differences with Machines.

Raymond Lee, Spring 2004

This book is dedicated to UNICEF and the royalty will be wholly
donated by the author to UNICEF for the
purpose of assisting children
living in poverty to acquire their innate rights for
knowledge and education

*I now want to know all things under the sun, and the moon, too. For
all things are beautiful in themselves, and become more beautiful
when known to man. Knowledge is Life with wings.*

Beloved Prophet, Kahlil Gibran

Preface

“Anything happens must have its own reason”. Although I cannot really recall exactly when I heard of this statement for the first time, it is always in my mind and in fact it has been one of the motivations for me to carry out research and study. When I asked myself again about the purpose of writing this book at the time of writing this preface, several “add-on” reasons that had never occurred to me at the start of writing this book in the spring of 2003 surprisingly came up.

Back then, when I was preparing the progress report for the iJADE (2.0) project, a “fuzzy” idea of whether it was feasible to write a book on intelligent agents came to my mind. This book not only would discuss and deal with the theory but also the “spin-off” applications from the iJADE project, including: the iJADE WeatherMan, the iJADE Stock Advisor, the iJADE Surveillant and the latest works on iJADE Negotiator. The fact that I had to launch the iJADE development kit officially over the Web in the summer of 2003 (<http://www.ijadk.org>) and to arrange courses and seminars to teach and train our undergraduate students to make use of this toolkit further supported the idea and the future use of this book. Hence, the “archetype” of this book emerged.

Different from my previous two books, I started the writing of this book from the second part, the applications of agent technology, instead of writing first the theoretical part. In the course of writing this book I had seriously considered starting with the theoretical concepts of agent technology but I had failed to convince myself of the depth of the concepts that should be discussed in the book. However, after I had started my phase III iJADE project – the Cogito iJADE in the summer of 2003 – such “struggling” had settled down.

The Cogito iJADE project was designed to explore and tackle the “ultimate” problem of agent technology – the ontology of intelligent agents – and focus on the design and construction of highly autonomous, adaptive, self-knowledge ontological agents, and to explore the feasibility of building self-aware agents. This topic is really fascinating in the sense that it not only involves computer science but is also a cross-disciplinary topic involving cognitive science, human psychology, philosophy and metaphys-

ics. In fact, ontology itself is one of the major topics in modern philosophy.

After writing Chaps. 5–9 in July 2003, I immediately started to plan for the integration of Modern Ontology and Ontological Agents as discussed in Chap. 11 of this book. My research into ontology which had started in the mid-2001 had caused a substantial change in my views of AI. In the couple of years of literature reviews and research on ontology, I had the opportunity to “refresh” and “trigger” my thoughts and knowledge on philosophy and epistemology, subjects I had studied in college about 10 years ago. I have to acknowledge that the great thoughts from all the distinguished philosophers – including Plato, Aristotle, Berkeley, Hume, Descartes, Kant, Russell and Wittgenstein – had given me fresh inspiration and new ideas that helped me to consolidate the concepts and theories of AI and human intelligence and to form a solid foundation for the theories of intelligent agents and their ontological aspects.

Different from most of the other contemporary books on agent technologies, ranging from discussions on mobile agents to elaborations of multi-agent systems, this book is totally focused on the theory, the design and implementation of intelligent agents and their corresponding systems. One important feature of this book is that I provide a “structural” discussion on all critical theoretical bases for the understanding of intelligent agents. This book begins with a discussion of the theories of human intelligence and is followed by an overview of research on artificial intelligence and the theories for the development of intelligent agents and agent-based systems. The fact is I strongly believe that AI (including agent technologies) should be closely related to the exploration of the human mind and intelligence, which is in turn a highly complex and critical topic, not only related to computer science but also to cognitive science, neurophysiology, psychology, neuroscience, mathematical science and philosophy. As you will see in the book, my philosophical beliefs and ideas on human knowledge, intelligence and ontology have been strongly influenced by Kant and Russell – the two most influential philosophers in the history of mankind. Also, my religious belief in Zen Buddhism gives me a great deal of inspiration.

As one will see in Chaps. 2 and 3, most of the critical theories of AI and agent technologies are strongly related to the research and study in these disciplines, especially in the topics that relate to the fundamental concepts of AI and the latest development of intelligent agents, ontological agents. Generally speaking, all these basic theories and researches on ontological agents basically originate from the philosophical study of ontology and epistemology. As a matter of fact, my Unification Theory of Senses and Experiences and the fundamental idea of the Cognitron Theory were also

inspired by the great thoughts of those distinguished philosophers and ontologists.

Last but not least, one of the major purposes of writing this book was to provoke my belief that current AI (and agent technologies) should not be limited to research and development in computer science but rather should involve an “alliance” across many different disciplines and faculties. I strongly believe that the contributions in this area should not only benefit academia and industry but also the wider community and all mankind in future! I hope that this *tiny book* can trigger more *great thoughts* on the exploration of human and machine intelligence.

Acknowledgments

I took over a year to write and finish this book and would like to express my thanks to the following people for their support and assistance.

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Last but not least, to all my colleagues in the iJADE development team, including Dr. James Liu, Prof. Keith Chan, Dr. Hareton Leung and Dr. Jane You, for their fruitful academic advice and stimulating discussions.

I am certain that without all the above supports and assistance, the publication of this book would not have been successful.

Spring 2004
Hong Kong Polytechnic University

Raymond Lee

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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