

SCIENCE PRESS

edp sciences

What is Intelligence? What is Artificial Intelligence (AI)? Can AI develop autonomous consciousness? Will AI surpass humans in all areas in the near future? Should humans prepare to escape Earth to avoid being dominated by AI machines?

These questions have sparked significant public debate, especially since the release of ChatGPT by OpenAI in 2022. Widespread discussions and concerns about AI's future role in society have led to growing uncertainty, with some fearing that AI might eventually control or harm humanity.

As AI researchers, the authors of this book feel it is their responsibility to address these concerns. They aim to provide clear answers based on deep analysis and expert knowledge, helping people to better understand AI's capabilities and limitations. Their goal is to dispel unfounded fears and encourage the responsible development and use of AI for the benefit of all.

The insights presented in this book are grounded in thoughtful consideration and rigorous research, offering a balanced perspective on the future of AI and its impact on society.

About the authors:

Yixin Zhong, Professor at Beijing University of Posts and Telecommunications, has focused on information science and artificial intelligence research and teaching for half a century. **Huacan He**, Professor at Northwest Polytechnical University, has dedicated his research career to computing, logic, and **AI. Peizhuang Wang**, Professor at Beijing Normal University and Liaoning University of Engineering and Technology, is specialized in statistical mathematics and factor space theory. **Yong Shi**, Chair Professor at the University of Chinese Academy of Sciences, is a leading expert in big data analytics, data mining, knowledge management, and the digital economy. **Xiangfu Meng**, Professor at Liaoning Technical University, is dedicated to AI model research and its applications in medical healthcare. **Yi Qu** is a postdoctoral research fellow at the University of Chinese Academy of Sciences. **Yunong Wang** is a Ph.D. candidate at the University of Chinese Academy of Sciences.

ISBN : 978-2-7598-3725-0

9 782759 837250

edp sciences
www.edpsciences.org

SCIENCE PRESS

Yixin ZHONG, Huacan HE,
Peizhuang WANG, Yong SHI,
Xiangfu MENG, Yi QU and
Yunong WANG

What Is Intelligence?

A General Theory of Artificial Intelligence

SCIENCE PRESS
edp sciences

The main illustration is copyrighted and generated by one of the coauthors, Yunong WANG, using artificial intelligence.

Printed in France

EDP Sciences – ISBN(print): 978-2-7598-3725-0 – ISBN(ebook): 978-2-7598-3726-7
DOI: 10.1051/978-2-7598-3725-0

All rights relative to translation, adaptation and reproduction by any means whatsoever are reserved, worldwide. In accordance with the terms of paragraphs 2 and 3 of Article 41 of the French Act dated March 11, 1957, "copies or reproductions reserved strictly for private use and not intended for collective use" and, on the other hand, analyses and short quotations for example or illustrative purposes, are allowed. Otherwise, "any representation or reproduction – whether in full or in part – without the consent of the author or of his successors or assigns, is unlawful" (Article 40, paragraph 1). Any representation or reproduction, by any means whatsoever, will therefore be deemed an infringement of copyright punishable under Articles 425 and following of the French Penal Code.

The printed edition is not for sale in Chinese mainland.

© Science Press, EDP Sciences, 2025

Introduction

The origin of the universe, the emergence of life, and the mystery of intelligence are questions that continue to be of great interest to modern scientific research and represent a significant challenge when integrating their roles and implications in the development of science and technology.

Research on the origins of our universe is directly related to the macro environment of human survival and development and remains near the forefront of physics research. Although many great scientists, including Copernicus, Galileo, Newton, Einstein, Bohr, Schrödinger, and Hawking, have made significant contributions to studying these topics, many mysteries remain unsolved.

How did life emerge? This research concerns the mechanism of our evolution: where did we come from? Significant progress and contributions have been made in life science and anthropology fields by scientists such as Darwin, Huxley, Lamarck, Mendel, Crick, and others, but many unanswered questions remain.

How was intelligence generated? This research deals with the mystery of human wisdom, a central theme in intelligence science, cognitive science, information science, and artificial intelligence. Turing, McCarthy, Minsky, Newell, Simon, Feigenbaum, Hinton, and others have contributed valuable wisdom, but there are also many mysterious clouds of doubt.

In the last half-century, between the three main topics, human society has given increased attention to the study of intelligence.

This is largely due to the rapid development of information science and technology in the mid-20th century, stimulated by the needs of World War II, which provided a good technical basis for the development of artificial intelligence. As a result, "artificial intelligence" has left the realm of fantasy to become a focal object of scientific research in the academic world and has achieved rapid technological renewal.

However, in recent years, especially after IBM's Deep Blue system defeated the then-world chess champion Kasparov in 1997. Deep Mind's Alpha-Go defeated more

DOI: 10.1051/978-2-7598-3725-0.c901
© Science Press, EDP Sciences, 2025

than 60 of the world's top Go players, including Lee Sedol, in 2016, as well as ChatGPT and GPT-4 in 2023, people's enthusiasm for AI has changed to mixed feelings of expectation but also fear. Those who possess high hopes for AI believe that it is a product of man's successful research and should be used for the benefit of mankind, but others remain cautious regarding the potential harm it may cause. Those who are fearful believe that AI machines are becoming more and more powerful will one day surpass humans in all respects and that the law of survival of the fittest will inevitably eliminate them. Some even speculate that the year 2045 will be the "singularity event" when AI machines will overtake humans!

In the face of these dazzling advances in artificial intelligence and people's deep concern about the future and destiny of humanity, a series of serious questions are posed to science and technology workers: How should we view the development of artificial intelligence over the years? How do we understand the scientific nature of AI? How can we grasp the relationship between artificial intelligence and human intelligence? In particular, where are the breakthroughs and innovations in the basic theory of AI?

As a senior research team in the field of AI, we have the responsibility to express our views for the world's reference. To this end, a special booklet is needed to elaborate our understanding based on the scientific progress and results we have achieved so far.

We will outline our basic ideas in the Introduction section and then expand them in more detail in the main text.

This book argues that, on the one hand, research in artificial intelligence has made remarkable technological progress since the beginning of the 21st century. Thanks to advances in information technology such as big data, cloud computing, cloud storage, the Internet, and the Internet of Things, the implementation of artificial intelligence has been greatly improved, enabling a shift from the "expert systems" of the 20th century to "neural networks" of nowadays. Also, new technologies such as deep neural networks, deep learning, and reinforcement learning have been realized, resulting in the Alpha-Go series and GPT series of artificial intelligence products. These technological advances deserve full recognition.

On the other hand, the technological advances achieved by AI research over the past half-century are basically the results of natural science and technology. However, as we delve further into the scientific subject of simulating human intelligence inspired by "human intelligence", the research of artificial intelligence invokes the profound mystery of human thinking and the laws which govern the human subjective world and human society. These deep questions have become the essence of AI research. Obviously, these deep problems can stretch far beyond the scope of "natural science theory" and belong to the domain of philosophical research topics. Therefore, if the research on AI is limited only to the scope of natural science theory and technology and ignores the guidance of philosophical ideas – especially scientific worldview and methodology (collectively called paradigms) – then such research will lose the correct guidance, and take the path of blind development.

Unfortunately, this is precisely a major flaw that has existed in AI research throughout history. For those that do not believe this to be so, then we provide the following substantive questions:

- What is the scientific worldview that should guide AI research? Is it a "physical view"?
- What is the scientific methodology that it should follow? Is it "divide and conquer" and "formalization"?
- What is the global model reflecting the nature of AI science? Is it an "artificial brain"?
- What is the universal approach to AI? Why is there no unified theory for AI?
- How is the study of artificial intelligence fundamentally different from the study of computers? Is intelligence computation?
- What is the essential difference between artificial intelligence and automated systems? Is intelligence automatic work?
- Can a formal theory of information without content and value factors support the study of artificial intelligence?
- Does the GPT series achieve the organic unity of structuralism and functionalism?
- Do the GPT series based on formalized hollow information really have the ability of understanding?
- Is a system without understanding a truly intelligent system?
- Can existing rigid formal logic theories support the study of artificial intelligence?
- Can the existing probability theory, fuzzy set theory, rough set theory, etc. adequately describe the study of artificial intelligence?

The answers to all these questions ask fundamental questions about people's ideas and, in particular, touch on the scientific worldview and methodology (collectively called paradigmatic) positions of researchers.

This book will explore the mystery of intelligence with a new scientific worldview and new methodology and elaborate the understanding of the above issues. Specifically, this book will uphold the new academic concept of paradigm revolution in the field of artificial intelligence, start our analysis and exposition from three levels: the intelligence generation mechanism of artificial intelligence systems, the universal logic of artificial intelligence and the factor space theory of artificial intelligence, and lay a solid foundation for the establishment of a systematic theory of intelligence science.

This book is convinced that the profound significance of the paradigm revolution in AI can be discovered and recognized only by consciously breaking down the barriers between natural science and philosophy. Only after the paradigm revolution can the research of AI be put on the right track to healthy development, and the general theory of AI can be established. Moreover, only through the use of the "pervasive intelligence generation mechanism", "universal logic theory", and "factor space theory" can the general theory of AI be truly realized. Therefore, whether or not the paradigm revolution in AI is captured and implemented will be the "watershed" between the old and new lines of research in AI.

These are the heartfelt words that this book offers to readers and fellow researchers.

Finally, we will adhere to the principle of "simplicity": to make the theories presented in this book more accessible to a broader audience, we have tried to avoid difficult mathematical derivations and instead use concise language and expressions to describe them. However, the simplicity of language and expressions is not the same as the shallowness of ideas. Look at the expression of Newton's second law of motion $f = ma$ and Einstein's expression of mass-energy conversion $E = mC^2$. How simple they are, and yet how profound the physical meaning they imply! There are also some seemingly simple expressions in this book, such as $P = Int(V, M)$, $Y = \lambda(X, Z)$, etc. We hope that when reading this book, the reader will not only stop at the literal meaning of the words but also think deeply about the profound meanings underlying some of these mathematical derivations.

The book consists of four chapters. The first chapter describes the paradigm revolution in artificial intelligence and its product "mechanism-based general theory of AI", the second chapter describes the logical basis of the mechanism-based general theory of AI – "universal logic theory", and the third chapter describes the mathematical basis of the mechanism-based general theory of AI – "factor space theory". They form the complete system of the mechanism-based general theory of AI, which is the first result of the research on the theory of artificial intelligence in the world literature. Chapter 4 is a concise summary.

In preparing this book, Zhong Yixin provided the introduction and the content of Chapter 1 and made partial contributions to Chapter 4. He Huacan contributed to Chapter 2 and participated in the discussion and revision of Chapter 4. Wang Peizhuang provided the content of Chapter 3 and contributions to Chapter 4. Shi Yong is mainly responsible for Chapter 4 and in the discussion of the structure and content of each chapter. Qu Yi and Wang Yunong are mainly responsible for the content revision, translation, and coordination of the whole book.

We sincerely thank the reviewers for their comments and the publisher for their support, and we welcome readers' discussions and criticisms. We are sincerely grateful to Dr. William Allen Jefferson, who helped us to polish the book. We would also like to thank the National Science Foundation of China (Key Projects: No. 71932008, No. 72231010) for its kind support in doing this meaningful work!

Contents

Introduction III

CHAPTER 1
Paradigm Revolution in the Field of Intelligence 1

1.1 New Explanation of Basic Concepts 1
1.1.1 Human Intellectual Ability 1
1.1.2 Human Wisdom 2
1.1.3 Human Intelligence 2
1.1.4 Artificial Intelligence 2
1.2 New Exploration of Scientific Laws 4
1.2.1 Science and Technology: Why Does It Emerge (Starting Point)? How Does It Develop (Process)? What Role Will It Perform (End Point)? 4
1.2.2 Evolutionary Patterns of Human Capacity Expansion Needs . . 5
1.2.3 Characteristics of the Era of Scientific and Technological Development 5
1.2.4 Paradigm Theory I: New Definitions of Concepts 6
1.2.5 Paradigm Theory II: The Paradigm Formation Period 9
1.2.6 Paradigm Theory III: Mismatch of Paradigm During the Paradigm Formation Period 10
1.2.7 Paradigm Theory IV: The Implementation Framework of the Paradigm Revolution 11
1.3 The Claim "AI Can Surpass Humans in All Aspects" Is Not Valid . . . 12
1.4 Artificial Intelligence: Paradigm Mismatch and Paradigm Revolution . 15
1.4.1 The AI Research So Far: Paradigm Mismatch 15
1.4.2 Steps in Implementing the Paradigm Revolution in AI 19
1.5 Implementing the Universal Intelligence Generation Mechanism and Creating the General AI Theory 30
1.5.1 The Principle of Perception (and Attention): Conversion from "Object Information" to "Perceptual Information" 30

1.5.2 The Principle of Cognition: Conversion from "Perceptual Information" to "Knowledge" . . . 35
1.5.3 The Principle of Memory Expression: Comprehensive Information and Comprehensive Knowledge Representation of the Memory Base . . . 38
1.5.4 The Principle of Strategy Formulation: Conversion from "Perceptual Information – Knowledge – Goal" to "Strategy" . . . 40
1.5.5 The Principle of Strategy Execution: Conversion from Intelligent Strategy to Intelligent Action and Optimization of the Strategy . . . 43

CHAPTER 2
Universal Logics . . . 47

2.1 The Basic Law of Logic's Development . . . 49
2.1.1 The Current Direction of Logic Development . . . 50
2.1.2 Basic Parts in Logic . . . 51
2.2 Basic Properties of the Object of Logic . . . 53
2.2.1 The Basic Property of the Objective World Is Evolution . . . 53
2.2.2 Analysis of the Basic Properties of the Subjective World . . . 54
2.2.3 Intelligence Can Only Be Formed and Evolve in a Realistic Environment . . . 60
2.3 Research and Practice in AI Have Proven that It Requires Universal Logics Support . . . 61
2.3.1 The Original Intention of Establishing the Discipline of AI . . . 61
2.3.2 Over 70 Years of Practical Experience in AI Research . . . 63
2.3.3 Giving Computers More Intelligence Factors . . . 66
2.3.4 AI Research Urgently Needs Logical Paradigm Revolution . . . 68
2.4 Propositional Universal Logics Theory . . . 69
2.4.1 Theoretical Framework of Propositional Universal Logics . . . 69
2.4.2 An Effective Way to Achieve Propositional Universal Logics . . . 70
2.4.3 The Specific Expansion Process of Propositional Universal Logics . . . 73
2.5 How to Apply Positional Universal Logics . . . 80
2.5.1 Robustness Criteria Using Propositional Universal Logics . . . 80
2.5.2 Method for Determining the Parameters of the Logical Operation Model . . . 82
2.5.3 Logical Support for Intelligent Generation Mechanism . . . 83
2.6 Propositional Universal Logics and Deep Neural Network . . . 88
2.7 Summary . . . 89

CHAPTER 3
Factor Space . . . 95

3.1 Factor Space Is a Mathematical Product of the Paradigm Revolution in Intelligence Research . . . 95

3.2 Definition and Properties of Factor Space 96
3.2.1 Factors Are Generalized Variables 97
3.2.2 Definition of Factor Space 98
3.2.3 Background Base 101
3.2.4 Factor Spectrum 102
3.2.5 Factor Encoding – the DNA of Knowledge Ontology 106
3.3 Factor Space Is the Basis for Revolution of Cause and Effect 110
3.3.1 Pearl's "Revolution of Cause and Effect" Theory (Pearl *et al.*, 2018) 110
3.3.2 The Core Idea of Causality Analysis 112
3.3.3 Causality Triangulation Method 115
3.4 Factor Space Theory Is the Mathematical Foundation of Information and Intelligence Science 116
3.4.1 Factor Spaces Provide a Unified Descriptive Platform for All Branches of Intelligent Mathematics 116
3.4.2 Rough Calculation of Sweep Class and Explicit and Implicit Algorithm Using Machine Learning 120
3.4.3 Tentative Algorithm for Supporting Vector Sets 122
3.5 Factor Space Is a Mathematical Tool for Intelligent Incubation 129
3.5.1 Description of Perception Process 130
3.5.2 Intelligence Incubation Project 133

CHAPTER 4
Summary and Outlook 135

4.1 Summary of Basic Principles 135
4.2 A Brief Review of Current AI Research 139
4.3 Outlook 140

Bibliography 143

Chapter 1

Paradigm Revolution in the Field of Intelligence

1.1 New Explanation of Basic Concepts

When talking about artificial intelligence (AI), different people may have different understandings of the concept of AI. As a result, awkward situations can arise due to a lack of shared understanding. Even among experts in AI, the situation is the same. To accurately address the issue of AI, it is first necessary to clarify and standardize a number of relevant underlying concepts.

It is important to note that AI is not an isolated concept but an artificial realization of human intelligence, which in turn is closely linked to the concepts of human intellectual ability and human wisdom. In daily academic exchanges, it is common to find people confusing the concepts of "intelligence" and "wisdom", which leads to many misunderstandings about AI. The most common misunderstanding is the confusion of artificial intelligence with artificial wisdom. Therefore, to examine the concept of AI, it is necessary to begin by examining the concepts and relationships of human intellectual ability, human wisdom, and human intelligence.

1.1.1 Human Intellectual Ability

Human intellectual ability is the counterpart of human constitution and human physical strength, which work together to form human overall ability. Human constitution and physical strength are the basic abilities of human ability in general, and human intellectual ability is the master ability of human overall ability. It can be argued that without intellectual ability, it would be difficult for humans to survive, let alone develop, in a complex environment.

Specifically, human intellectual ability is the ability to "use the *a priori* knowledge to explore the future, identify problems, define problems, designate goals, associate knowledge, solve problems, improve reality and achieve results to achieve the eternal goal of survival and development". Once old problems are solved, new ones are explored, and so on, to continuously improve and optimize the level of survival and development for humans (Zhong, 2023).

DOI: 10.1051/978-2-7598-3725-0.c001
© Science Press, EDP Sciences, 2025

1.1.2 Human Wisdom

Human wisdom is an integral part of human intellectual ability. Specifically, it is the ability to use knowledge to explore the future, identify problems, define them, set goals, relate knowledge, and provide a working framework for problem-solving for the purpose of survival and development (Zhong, 2023).

It follows that human wisdom is heavily tied to human purpose and closely linked to human knowledge. It is easy to understand that without purpose, there can be no wisdom; without knowledge, the level of wisdom is greatly limited. Unfortunately, it is often assumed that artificial intelligence will produce artificial wisdom and thus produce fully superhuman capabilities. If one pays careful attention to the concepts articulated above, one knows that AI has no life, and therefore has no purpose, and it cannot produce artificial wisdom.

1.1.3 Human Intelligence

Human intelligence is also an integral part of human intellectual ability. Specifically, it is the ability of human beings to solve problems, achieve goals and improve reality in accordance with the framework (problem-goal-knowledge) provided by human wisdom for survival and development, guided by goals and constrained by knowledge (Zhong, 2023).

Human intelligence is a component of human capability that is interconnected with, interacts with, and contributes to human wisdom. Human wisdom provides the working framework for human intelligence to solve problems, and human intelligence provides the results of problem solving to human wisdom and facilitates human wisdom to a deeper understanding of the reality. It is worth emphasizing that the working framework for human intelligence to solve problems is provided by human wisdom and that the role of human intelligence is to solve problems within the given working framework.

1.1.4 Artificial Intelligence

Artificial intelligence is human intelligence implemented in an artificial machine, which is the ability of an artificial machine to solve problems, achieve goals and improve reality within the framework of work given by human wisdom (Zhong, 2023).

According to the above understanding, the relationship between human intellectual ability, human wisdom, and human intelligence can be expressed in the model shown in Figure 1.1*a*. It shows that the process of interaction between the human subject and the environmental object (*i.e.*, the object information acts on the human subject, and the human subject generates intelligent action in response to the environmental object) is a continuous process of "human intelligence's" solving problems, improving reality and achieving goals based on the proposed problems, pre-determined goals and *a priori* knowledge provided by "human wisdom".

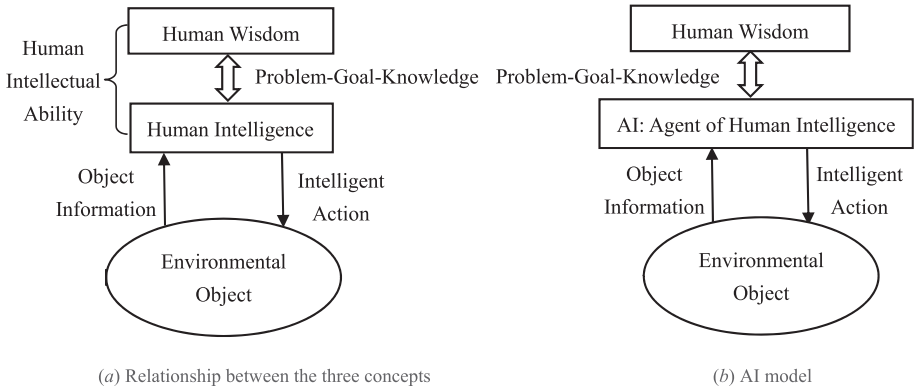


FIG. 1.1 – (*a*) Relationship between the three concepts. (*b*) AI model.

With the above concepts and models, the concept and model of artificial intelligence becomes a natural one (see Figure 1.1*b*) because artificial intelligence is human intelligence realized by man-made machines, and is a machine agent of human intelligence.

Figure 1.1 shows that AI systems are a kind of open, complex information systems that solve problems given by human wisdom through the interconnection, interaction, and mutual facilitation between the machine agents of human subjects and the objects of the environment.

More specifically, according to the "problem" (expressed as "object information" from the external environment) identified by the human subject (specifically implemented by human wisdom), the predetermined problem-solving goal, and the relevant knowledge provided, the task of AI is to perform complex processing and evolution of the "object information" under the guidance of the goal and the constraint of knowledge and to generate intelligent actions that act on the object to solve the given problem and achieve the predetermined goal (Zhong, 2023).

The models in Figure 1.1 look very simple. However, they contain extremely profound meanings of human and artificial intelligence and can scientifically and rationally answer many significant questions about artificial intelligence. For example, what is the nature of artificial intelligence? Why must AI far surpass humans in specific work performance (speed, accuracy, endurance, etc.)? But why is it impossible for AI to surpass humans in overall capabilities (especially innovation)? What is the relationship between artificial intelligence and human beings? How do we understand the ethical issues in AI research? And so on, all of them can be profoundly enlightened by the seemingly simple model. Therefore, the seemingly simple but profound model is a fundamental prerequisite for the scientific study of AI. On the contrary, it would be wrong to regard the model of AI as an isolated and neutral "artificial brain", as usual.