

## Applied AI

### Utilization of artificial intelligence and implementation of "smartness"

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#### Preface

This book describes what the author saw from the perspective of Applied AI, that is, "applied artificial intelligence," and what the overall picture of the expanding application of artificial intelligence is. Looking back, I have had many opportunities to discuss the dream of artificial intelligence with many people, from those in the field of technology development to those on the front lines of business. I also visited several sites. In about 50 years, a vague dream to artificial intelligence, artificial intelligence! The excitement of creating it, the dream of making IT systems smart, the inevitability of the "waves" of the artificial intelligence boom that occurred many times, and the various young people who have applied it to business up to the present. Expectations, these experiences one after another, motivated me to put together this book.

Artificial intelligence has been discussed since the early days of computers. And it's still going. As an individual, I have worked on technology development research on Lisp processing systems and Lisp dedicated machines, activities related to CommonLisp language specification development committees, especially X3J13 in the United States for over 8 years. Since then, he has been in charge of AI special theory at the graduate school business school, and has been teaching working students who are engaged in entrepreneurship and new service development. These diverse experiences were invaluable. In addition, most of the modern neural network applications are the results of the dreams of those who patiently dreamed of practical application, starting to consider concrete images in the so-called AI winter era in the late 1980s. I also think that it will not happen.

After the year 2000, I started collecting related materials and lecture notes. In the dizzying pace of progress, lecture notes have been forced to improve and revise every year, procrastinating their chances of publication. At last, I recognize that the time has come to clarify the history and path of artificial intelligence, focusing on factual descriptions. As one of the books that tries to touch on the whole picture of AI, I hope that it will be a material for young people who want to apply AI in the future by describing the path they have taken in detail and thinking about the path they should know. ing.

The dreams and efforts of many predecessors have been inherited, and a long history of research and development has given rise to today. At the graduate school level, I realized that it is important not to make ambiguous propaganda statements such as "AI will do" and to avoid creating a society that believes in such vague statements. Many people have their own truths.

In the structure of this book, I am conscious of making the technical commentary available

from the standpoint of the application side, but it is not the main subject. Rather, it focuses on the why, how, and what. The historical position of the artificial intelligence field that the author has experienced is developed in order, and it is composed of natural needs, developments for them, and new elements in each situation.

The era of challenges to artificial intelligence in the early 1960s, the development of programming languages, the accompanying advances in computer science elemental technology, the era of implementation of large-scale IT systems, and the advent of deep learning. It deals with the era in which the parts that were not done until now are compensated, and the problems of the present age. It touches on many personal facts that the author felt should be introduced, and this point leads to a strong motivation for publication. Many of the people involved are already deceased, and the author takes full care in quoting their remarks and materials, and takes responsibility to ensure that their intentions are properly expressed. Therefore, I have decided to incorporate the material as data, hoping that the description of personal experience facts will be as faithful as possible and that the reader will be able to touch on the facts as much as possible. All responsibility for the publication of private material rests with the author. After discussing with the editorial department, we decided to write all names in English. However, for people who are introduced in various contexts in Japan, we decided to add katakana notation at the time of first appearance.

Artificial intelligence is a processing concept and has the recognition that it is a general term for dreams. I believe that by following this realistic path, we will be able to pave the way for the future. The term "engineering algorithm" must come up, but at the same time, I would like to touch on the link between individual issues and stories in individual fields. Things that can be explained by natural science are incorporated into the elemental technologies of IT. Therefore, from the viewpoint of technological development, it is important to know what each element is, but it is not our task to explain it in detail technically. Rather, the policy is to leave a reference material for young people who are trying to open up a new world. Therefore, although there may be a part of the author's lack of understanding, I have omitted unnecessary descriptions for the sake of overall balance, especially those that can only be described as hearsay regarding the author's background and subject area. I intend to narrow it down to those that are related to some kind of fact.

Structure of this document

As a whole, the chapters are organized in a way that traces the history of about half a century. I tried to follow the approximate chronological order.

Chapter 1 describes the beginning of artificial intelligence as an introduction.

Chapter 2 mainly describes the period from the 1950s to the 1980s.

Chapter 3 focuses on descriptions of various swells in the 1980s. I dared to include the fact that the author decided that if he didn't write it, it would be buried as it is.

Chapter 4 describes applications that existed before deep neural nets came to the fore and have evolved to this day.

Chapter 5 describes the emergence of deep neural networks. As much as possible, the description of technical aspects and the flow of applications are separated by section. The period focuses on the growth of the field since the 1980s and the events in individual industrial fields that were highlighted in the 2010s.

Chapter 6 describes the development up to the present day in terms of the fusion of the individual technologies taken up to that point and the resulting successes.

Chapter 7 discusses emerging issues and future themes. Therefore, we have included many open questions that do not lead to the introduction of actual tools and algorithms.

References are provided for each chapter. I also put the URL reference in it. I have checked everything, but I would like to say that I am not referring to the contents at the time of writing.

Finally, the manuscript is closed by supplementing the author's point of view. The author's philosophy should be found in Chapter 7 and "Finally".

**Acknowledgments** The author's activities have been supported by the support and discussion of many organizations and institutions, including his university (at that time), as well as many acquaintances and friends. Interactions with members of the Information Processing Society of Japan's Symbol Processing Study Group, members of the Electronics Association's Lisp Technical Committee, and ANSI X3J13 members supported my early and first half research activities. From the latter half of the 1990s, research that shifted its focus to the application side was supported by educational and lecture activities at Aoyama Gakuin University, to which he belonged. In particular, the students who attended the author's lectures at the Graduate School of International Management always supported the lectures based on the incomplete lecture materials. I could not continue writing this book without the support of my family, who patiently watched over me.

We would also like to thank the following people for confirming and providing us with data and information in compiling this document. A few also agreed to post their photos.

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Masayuki Ida

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## Chapter 1 Expectations for Artificial Intelligence

### 1.1 Changes in the definition of AI and the perspective of Applied AI

#### (1) Exploring what intelligence is and passing on efforts to "artificial intelligence"

It can be said that the term artificial intelligence or AI (artificial intelligence) has permeated the world. Aside from what it is. Needless to say, among specialists, it is taken up in various fields, various social life, the side that makes something related to computers, the side that uses it, and various contexts. At its core is the search for what intelligence is. Sometimes it's used as a key word in science-fiction fantasies, or in real-life tough business competition. These are probably expressions of expectations or fears for something called "artificial intelligence." Then, like waves, they push and pull, making news in the form of booms, repeatedly, changing angles, and appearing in front of us human beings. Gradually, understanding of "artificial intelligence" has become essential as a social worker's education or in the basic academic ability of students.

This book attempts to approach the overall picture of "artificial intelligence" mainly from an engineering and business standpoint. Starting with the past that the author directly understands, it also deals with the prospects that should be passed on to the next generation. Because that is also the responsibility of humans who have struggled with AI.

Since when has "artificial intelligence" been discussed, and what kind of background has its logic been assembled?

The author is not yet in a position to confidently answer this question. In other words, the more I trace the related research, the more I come across the history of the dreams and pursuits of various people and their influence on later generations. I realize that everyone has played a role that can be said to be the father of artificial intelligence research. In other words, I feel that artificial intelligence is a whole set of very big challenges from different angles.

For example, the name of Frank Rosenblatt (Frank Rosenblatt) is a big name for those who have mainly studied neural networks. He is a psychologist born in 1928. He developed the Perceptron in 1958. As for the original model, McCulloch and Pitts' formal neuron model (1943) preceded it. Rather, it is written in Wikipedia that Rosenblatt and Marvin Minsky, who will be introduced later as one of the founders of artificial intelligence, were classmates in high school in the Bronx. Maybe. That being the case, I wonder who taught them at that high school and what kind of environment it was in. You can go back endlessly.

However, what the author thinks is probably the first description of artificial intelligence is Minsky's December 1956 "Heuristic Aspects of the Artificial Intelligence Problem" [1-1] (Fig. 1-1) comes across. It is archived at the Defense Document Center and is an UNCLASSIFIED document. I've thought that one of the keys to understanding the artificial intelligence concepts in this book is the "heuristic", and that's exactly what the early document, and the title of the book, showed. This was another surprise for the author when he faced this material. But I'd like to save that for later, or rather for this book in general.

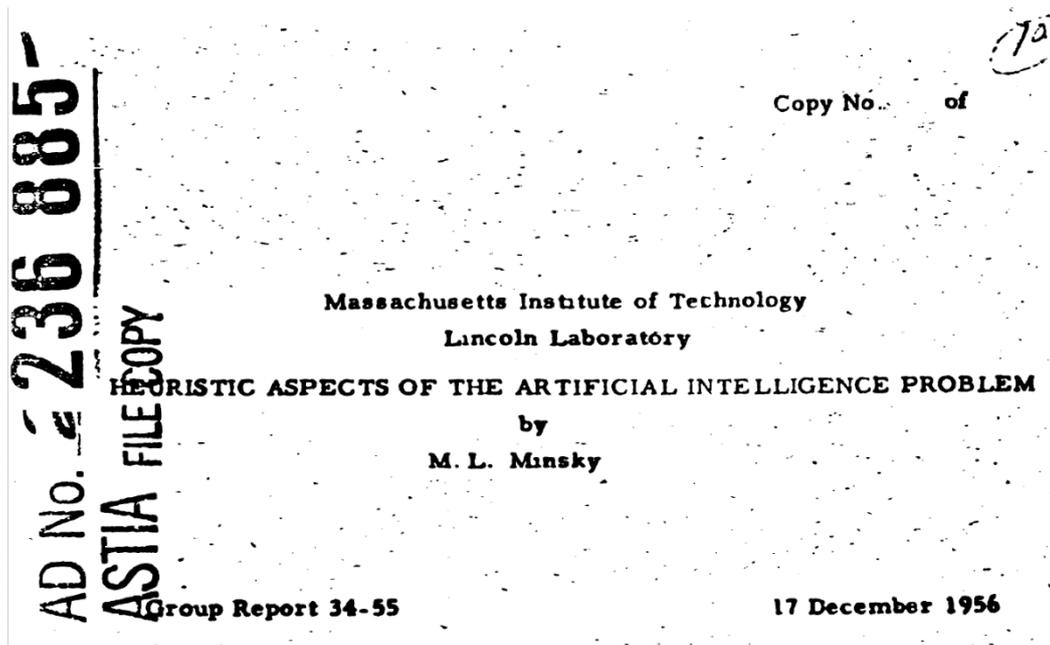


Figure 1-1 From the cover of the 1956 Minsky paper [1-1]

Advances in research in fields other than engineering or business have played a major role in shaping the field of artificial intelligence. I would like to start by pointing out two of them from different fields.

First, we return to the nineteenth and early twentieth centuries and take up the general linguistics lectures of Saussure (Ferdinand de Saussure). Saussure is a linguist born in Switzerland in 1857. He was a man in the field of philosophy of language or semiotics, and would later be classified as the father of modern linguistics. Although his text is difficult to understand, I have the impression that the more I read it, the deeper the implications. He was interested in how he perceived the "signifie". Perhaps someone with an engineering background would have thought so. As he repeatedly touched on Keizaburo Maruyama's explanations and Japanese translations, he came across the design concept of the Lisp processing system. "Language is a system of signs," said Saussure. The author of this book understands the fundamental point that "expression and its concept are integrally linked, and that link is arbitrary." Words are tools for the external expression of intelligence, and the connection between words and concepts differs depending on the language. He recalls that it was more than 40 years ago that the term "symbol" gave him a fresh shock.

The other is the influence of Earl B. Hunt (1933-2016). This man is an American psychologist who has led his research on human and artificial intelligence, in short, artificial intelligence, primarily based at the University of Washington. He seems to be considered a behaviorist psychologist. Is it not well known in Japan? If you search for behaviorist psychology on Wikipedia, as of the winter of 2022, it is one of the approaches of psychology that claims that behavior can be studied scientifically without relying on internal or mental states. Behaviorism can be considered a form of materialism-mechanism. "a. Earl B. Hunt published "Artificial Intelligence" [1-2] in 1975.

The book review is published in SIAM Review [1-3]. I explain the relationship with psychology, but I will quote from it next. This is a description from 1976.

Artificial intelligence is the theory and practice of programming computers to do things considered to require intelligence when done by people. In the nearly two decades of its history, this field of computer science has been enriched by contributions from related areas like decision theory, logic and linguistics. But the strongest tie has been between AI and psychology, in large part because the goals of AI are often inseparable from the objectives of building computer models of human behavior.

For the author, the name of Earl B. Hunt is that the rule-based concept (described later) was already proposed by him in the 1960s, while examining the materials of the 80s after the year 2000. It was only when I discovered my own notebook that I had heard about this that I became conscious of it for the first time.

Also, there was a person next to me who was enthusiastically reading a book on ABA (Applied Behavior Analysis) on a crowded train, and I was tempted to buy the book and read it myself. Although the book was written in the context of the analysis of children with autism, it is trying to deepen our understanding of people by focusing on the <cause> and <result> of human behavior.

Surprisingly, they have a similar context to the theory about rule-based expert systems. It is a set of individual listings of conditions and actions at that time, and clarification with reference to them. Once again, one of the goals of psychology or linguistics is to elucidate human intelligence, and we come across many common contexts.

These linguistic or psychological backgrounds are not taken up further here. I would like interested readers to unravel the respective technical books and introductory books.

## (2) Perspective of Applied AI

To put it simply, Applied AI is about understanding and grasping AI from the standpoint of using and applying it. The term Applied AI is not used much in Japan. The relationship between AI and Applied AI can be compared to mathematics and applied mathematics, or the relationship between science and engineering in the first place. It comes to mind as appropriate for the author. In other words, Applied AI is defined as having a point of view that includes considerations and techniques for actual application. At least, it doesn't stop at AI as a pure technology. Always have an applied perspective. In addition, it is also necessary to grasp the target technology as accurately as possible from that standpoint. I have discussed this point with my acquaintances in the past, but my friends in the United States want to stick to being a developer, or conversely, whether or not the emerging technology can be used in business, and if so, whether it can be used. There were many cases where I wanted to devote myself to cooking a specific technique. Also, there were not many people who wanted to research and write down the big picture of something called AI. Fortunately, the author's position has changed from the 1960s to the present, but I feel that there are many things I have seen and talked about from my own perspective. conclude that there is. Therefore, it is up to the reader's judgment whether the method of summarization here is unique, or whether it can be accepted as a direction. We hope that you will read to the end, or study, and make your own judgment about the perspective of Applied AI.

## (3) Knowledge Representation

The first task is to represent knowledge. And how to make that expression usable. In the history

of the development of artificial intelligence-related fields, classification trees or tree structures, association triplets, semantic nets, frames, rules, predicate logic, etc. have appeared. At first, it is not a computerization, but it starts with expressing with paper and pencils. If it goes forward, it will be made into a form that can be machine processed.

First, as shown in Figure 1-2, tree structures have been used in various contexts and applications as an intuitive representation of hierarchical relationships. For example, Figure 1-2 is a strong representation if it represents a partition where A is B or C. There are various cases with and without strictness, but in order to be subject to mechanical processing, a method that can be converted into another textual expression is required.

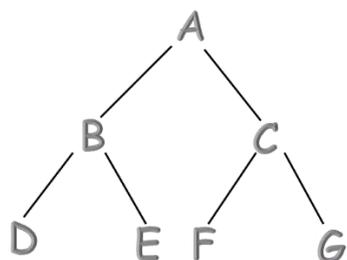


Figure 1-2 Representation by tree structure

In addition, I often tried to express it in the form that a certain thing has several attributes and properties, and each attribute has a value. For example, we write (color, apple, red) that the color of an apple is red. It is a ternary vector, or triplet, (attribute, target, attribute value). At this time, the order or what can be written is not a problem. In any case, the wisdom to organize information in such a way has been nurtured. Information about a certain object is described openly for each element. Then, for example, you can prepare a function called "color" and make it possible to ask for a value as a color (apple). It also allows (?, ?, red) and so on to refer to everything that has a red color.

A semantic net or semantic network is one of the methods of expressing knowledge by a graph data structure. Label concepts and express relationships between them. Given that the tree structure is only hierarchical, we also need to extend this to interrelationships. Moreover, if it is possible to specify what the relationship is, various expressions of the relationship can be reduced here. In the links that connect the concepts that become the nodes of the graph, it is possible to specify the type of relationship such as "is-a" or "has" (Fig. 1-3). There have been other developments to include the notion of procedures, and so on. Semantic networks are attributed to R. Litjens in 1956. In the 1960s, it became known through related studies by multiple researchers. There is a paper by M.R. Quillian in 1968 ("Semantic Memory" [2-3]).

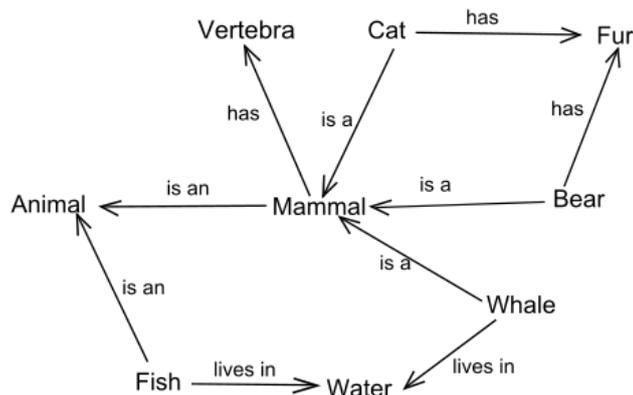


Figure 1-3 "Example of semantic network" from Wikipedia

You can see the affinity with object-oriented design. In other words, it can be understood as early work in object modeling. If we define an element that belongs to that concept by means of a has link, we organize the many links into an object with multiple slots. In addition, as a concrete example belonging to the concept, the idea of placing an instance link also comes up. Another idea is to put a fragment of a program that can be started. It can also be positioned that there is a frame as one arrangement about these. For frames, please see Section 2.2 (2).

Also, the concept of labeling is gradually formed. If a certain knowledge (group) is labeled, then by handling that label (name tag), the entire labeled knowledge can be made the object of operation. Group together information that has some commonality. Not limited to text, these images are defined to have such and such labels, and so on. better outlook. It can also be used arbitrarily. Whether it is a Yes set or a No set is also a label.

The problem is what kind of expression label should be prepared. Semantic analysis requires a moderate level of labels to form groups.

#### (4) "Autonomous Intelligence" and "Making Computers Smart": Advances in Computer Usage

The discussion of "artificial intelligence" can be broadly divided into two streams. One is whether humans can create intelligent beings in future predictions or prospects. And from that point of view, I tried to approach human intellectual ability.

The other is the rapid advancement of computer inventions, technological improvements, and their use, especially since the 1950s, and the theme of making computers "smarter."

The former was sometimes talked about in science fiction novels, etc., and the main topic was intelligent life forms such as "artificial life" and speculation about aliens, but there is a part related to "artificial intelligence", and that part is in this book. It can be said that it is within the scope of the description of Here, for the time being, we will focus on the pursuit of "autonomous intelligence."

The latter is to give or add "smartness" to the computer. That is, devising and utilizing smart processing methods, and pursuing progress in computer configuration technology itself. In particular, when considering the latter, the problem is the ingenuity and mechanism of the current mainstream stored program type digital computer, and the introduction of "artificial intelligence" to the system built on it is the problem. I want to go

The pursuit of machine mechanisms or structures for "autonomous intelligence" exists as a

large field. However, since this book takes the position that the current digital computer is the mainstream, "autonomous intelligence" is treated as a discussion of how to develop its mechanism on the digital computer and its extension. In that case, we think that the information system on the computer can receive the benefit given by those concepts.

The pursuit of artificial intelligence is seen as a conceptual synthesis of advances in computer usage. The accumulation of small steps to make computers smarter will become the limbs of autonomous intelligence.

Of course, the pursuit of a revolutionary computer operating principle is important, and I think it is possible in the future, but when it reaches the stage where it is going to be used in various activities, it will be discussed again.

In this book, the flow related to today's AI as a whole is

A) AI based on symbolic expressions that can be considered an extension of programming  
B) AI based on simulating the mechanisms for autonomous intelligence on digital computers  
There are two things, and as we enter an era in which they merge, further development becomes possible, and the realization of this is sought. First of all, I recognize that history is preceded by A) and followed by B).

### (5)Problem Solving

Consider the application side. On the application side, for example, in the construction and operation of business systems, there is a basic principle that any technology can be used as long as it can achieve its purpose. In other words, is "artificial intelligence" worth adopting as a means?

The theme of "problem solving" has been set since the beginning of the formation of the field of artificial intelligence. The idea is that if a problem can be clarified, it can be solved. Alternatively, it has often been done to fix the original problem, or to cut out only the problem that can be solved, to the problem that can be solved.

Even in the 1960s, problem solving was actively discussed, and well-established books were published. For example, Ranan B. Benerji's Theory of Problem Solving: An Approach to Artificial Intelligence (1969) [1-4], or Nils Nilsson's Problem-Solving Methods in Artificial Intelligence [1-5].

These are developed from topics introduced later as game theory and descriptions of mathematical formulations. Gradually, the problem began to be solved in the realm of practical applications, that is, whether it could be solved by a computer and within practical capacity and speed. In particular, in the business field, cost, operational capability, and processing reliability have come to be questioned, leading to the current state of affairs.

Universal algorithms have been researched and methods for computer programming have been researched and developed, but specific methods for specific problems are measurable and details such as algorithm implementation methods became a problem. What has been regarded as an AI matter will gradually become more computer science-oriented and become established as an IT method. For example, in the 70's around the author, various implementation techniques were tried, such as a hash method that enables high-speed searches for words or variable names. These were initially introduced and studied as novel "smart" tools.

In addition, programs that "work and achieve a purpose" became a topic of discussion, and there were many challenges, such as solving a one-player card game. Furthermore, the method called "discovery method" was often seen as a name given to methods that could not be

supported or proved by natural science, but were effective anyway. Scheduling and assignment problems have been researched, and although the optimal solution is not known, the best solution is aimed at under certain conditions, and some of them have been evaluated for practicality.

There are many notable early AI research and developments in the 1960s, some of which are often labeled as problem-solving or general problem-solving.

#### (6) AI and business areas as IT frontiers

The author believes that there is no technological field that will remain as AI forever. Issues taken up as "current challenges of AI" are words that refer to problems that cannot be solved with conventional techniques and technologies. In other words, if there is a new method that cannot be explained by the conventional classification, there is an aspect that it is called AI for the time being. The author calls this "AI as the frontier of IT". In other words, when it becomes clear that the AI method can be used and its effectiveness is widely recognized, the method itself will be elucidated and improved, forming a new field. Once in that state, it is no longer called an AI. A familiar example is image recognition using deep neural networks. Even if it is said that it is based on deep learning, it will no longer be possible to refer to the word AI one by one, such as "AI recognizes images".

In the business field, I would like to point out that there are two aspects to the issues surrounding the use of AI. One is the gigantic information system and the resulting social life. The other is the emergence of new ideas and the supply of elemental technologies for them as the field advances. That is,

"Operation of growing systems" and "Changes in target areas/Emergence of new situations"

The former results from the fact that it is difficult for humans to always judge the whole picture, which can be said to be the result of the factor of gigantism. If an automated machine does it, we can assume that mistakes will be reduced. If high-speed calculation and large-capacity memory can be used, it will not be a dream to process large amounts of data instantaneously and accurately grasp macroscopic data in real time.

Ultimately, the latter is an issue of clarification of business flow and business procedures. It is assumed that if a clear procedure and flow can be described and it can be operated according to it, the system will become more stable and efficient compared to the days when processing and judgment were done manually. Many of the computer technologies for that are problems of IT techniques rather than AI.

However, a global system that combines local optima in often separated units cannot be said to be globally optimal. When that happens, the entire system needs to be reconstructed, and in doing so, it can be found that an AI-like mechanism that can review the whole from a different perspective is effective. In addition, decisions that were made by humans will be programmed and incorporated into automation. These are also repeatedly applied, and when the common reality is understood, they will be given a name instead of AI.

On the other hand, the construction and clarification of basic theory is indispensable for the fields where AI is challenging, and it is difficult to call it an IT frontier. They are the "basic research fields of AI" in their respective challenging fields. Since this book discusses the perspective of Applied AI, the explanation of the technical details of this "basic research field

of AI" will be dealt with separately.

### (7) Definition of AI and transition of targets

Chapter 2 deals with changes in the definition of artificial intelligence as a historical development. This, as we have seen, represents the eye of the age. That is, what was the frontier of IT. The author believes that the accumulation of small developments and improvements to "make digital computers smarter" will eventually reveal the appearance of "autonomous intelligence", and beyond that, autonomous intelligence that has that appearance. We believe that specific development research is waiting for us. Until then, it is natural that there will be various definitions and changes in the subject. God only knows when the nose will come. Until then, it is necessary to understand various topics that have been collectively referred to as AI, and to cultivate the ability to make accurate judgments in applying them, and we are not assuming just one AI technology. It is also important to accurately understand the meaning and principle of the underlying technology.

In addition, in an era when the distance between business and technology is shrinking, it is thought that the use of machines' "autonomous intelligence" is directly linked to business. In particular, the theme of "machine learning" expresses the fact that AI, which is a variety of "frontiers of IT," is becoming established along with the changes of the times. It can be said that

## 1.2. Modern paradigm shift and expectations for AI

### (1) Changes in the modern information environment and the formation of natural fields

As discussed in the previous section 1.1, this book takes a bird's-eye view of AI from an application perspective, and defines the frontier of IT as AI as a general term. Furthermore, we will analyze AI from that aspect. There are other aspects of the IT frontier, and each technique that can be called AI differs in its degree of establishment and detailed definition, so the definition of AI is still vague. remain.

Furthermore, with the progress of the times, the importance of areas that had not been included in the area of IT utilization until then increased. In particular, expectations for AI adoption in various aspects of commerce have increased. It has been fueled by the spread of the Internet and increased commercial use. For example, the area called e-commerce.

### (2) The new domain of e-commerce

In e-commerce, the issue was how to handle the new tools created by the times. Until the 1990s, the world wide web (WWW), which could not be said to be an elemental technology, has been used commercially, and the existence of mobile devices such as smartphones (smartphones) and tablets (tablet computers), which have achieved remarkable popularity, cannot be ignored. is now required in all IT or information system fields. A new user interface that takes advantage of the device's characteristics has become essential. Also, all interactions between sellers and buyers through these devices and media made a big difference in that they were all based on one-to-one traceable communications.

In a conventional retail store, it is not possible to easily grasp what kind of behavior people

are doing when window shopping, and it is not possible to grasp whether they picked up a product at the store and returned it. . In principle, it is within the possible range via the Internet. In addition, it is possible to introduce new elements from a different angle to the way customers are served. There was a need to introduce clever methods for these, and to take advantage of individual one-to-one TCP communication exchanges.

For example, in the first half of the 1990s, when the 5th generation computer was booming in Japan, the US MCC (Microelectronics and Computer Technology Corporation, established in 1984) CYC (named Encyclopedia As a hint for considering new uses, in the project that is said to be derived from

A door-to-door salesman is about to visit a house.

What should he mainly sell and how should he say it?

was exemplified.

As a common sense reasoning, the main sales story is derived from the general image of the residents of the area, the profile of the individual as far as we can understand, the state of the house, etc. This, of course, involves back-end database lookups, various big data lookups, or even the preferred natural language conversations.

It has become clear that the frontier of IT needs to involve a mechanism for making comprehensive judgments against the background of such specific situations, situations, and specific tools. And the individual techniques used are infinitely different, and the way they are combined is also varied. The tools that can be selected also differ depending on the era. It is unreasonable, then, to try to apply generalities to all individual situations. If it is the existence of problem consciousness, then it is inevitable that it will be a separate argument. In addition, since the information to be processed changes in real time, it is necessary to recognize that what should be done and what is considered good will change over time without the introduction of AI unilaterally bringing about results. Inevitably, the existence of the "problem awareness" of those who are trying to introduce AI, and what it is, will greatly affect the success or failure of the introduction.

### (3) Abstraction is the Culmination of Concrete: Three Roles of AI

In that sense, there is a saying that "abstraction is the culmination of concreteness," and I think that applies to AI well. At that time, there will be a collection of concrete objects that are being handled, and the concept that encompasses them will be called AI. And we are living in an era where, for example, the entry into the Internet age itself will cause a paradigm shift, which will change the real image and expectations of AI.

This is also one aspect of the "age of individuality" or "age of diversity." The pursuit of intelligent processing by computers has made it possible to keep individual figures until the final stage of processing without rounding them up as statistics, and it has become possible to process them individually, which has increased their importance. .

Regarding AI, at this stage, let us summarize the roles of AI into the following three categories.

1. Creation and improvement of information technology: Exploring new and smarter judgment and knowledge processing techniques
2. Information Systems Frontiers: Challenging Uncharted Areas
3. Challenge to Autonomous System: Trying to Establish a Mechanism That Allows "Leaving Hands Off"

Among the various roles, 1. 2. Research and development of elemental technology to supply practical and faster means; 3. Research and development to expand the areas that could not function in the computer system up to that point. is positioned as R&D aiming at "leaving hands" in areas where regular operation is difficult with human ability, and basic R&D related to common foundations common to them.

### 1.3.A natural approach to problem solving and the emergence of artificial intelligence

#### (1)Efforts to solve problems

As attempts were made to apply artificial intelligence, there was a natural search for what it could be used for and how it could be used.

Consequences of "large-scale and large-capacity data processing" and "high-speed calculation function" possessed by computers is.

"Artificial intelligence" in terms of many industrial applications results in expectations here. The problem is how to perform large-scale and large-capacity processing, and how to process it at high speed. Another issue is the user interface for real-time feedback of results.

"Intelligent processing", but if you think about it, you may be calling "artificial intelligence" to quickly execute "some kind of" statistical processing in real time. For example, consider image recognition through deep learning. The mechanism of recognition using a deep neural network has been recognized as an epoch-making mechanism and put into practical use. Train a neural network on a huge number of images and use it to identify an image. Identifies specifics, detects anomalies, or determines what is depicted in the image as scene analysis. The neural network training for this purpose can be regarded as machine learning in the narrow sense. The training does not converge on numerical and mathematical fragments as in conventional statistics, but changes the strength of neuron connections by stacking them according to the frequency of use as the path followed by each training data. To go. Training a neural network simulated on this digital computer with data can be said to be "a kind of" statistical processing of the data used.

Let me explain this by comparison. As an application example of artificial intelligence, let us consider the task of "choosing lunch in the student cafeteria." Consider the problem of computerizing the selection method of students who use the student cafeteria many times a week. In fact, it is a question that has been used many times in lectures.

thought one student. Let's deal with the statistics about the choices so far and the camera footage of the display cabinet in the student cafeteria. Then, when you go to the cafeteria, for the selection presented in front of you, that is, for the menu as visual information, determine the probability from the past selection data, and select the one with the most probable probability. I came up with the idea of choosing.

Another student said otherwise. In a place called the student cafeteria, what kind of choice to make is generally decided. It's difficult to explain, but I decide by judging a little decisive factor. For example, on Mondays, I want to eat properly, so in any case, I have a set meal. It's a set meal even when you skip breakfast. When the rice continues, it will be soba for a while. etc. So it's faster to program it directly.

This is the symbolic case. The former may be a perspective imagining the application of deep neural networks. Interpretation of results involves probabilities. In that sense, it is statistical processing. On the other hand, in the latter, dogmatic "decision" is made. As for whether or not it is objectively justifiable, or whether it is possible to show grounds, there is no objective proof other than that the person himself thinks so. The author sometimes calls this a "discovery decision".

Let's assume that both of these ways of thinking can be programmed. Think about whether it is possible to make it smarter as you use it, and what form it will take.

In the former, from the descriptions of the advantages of deep learning that are generally introduced, it can be imagined that the probability of winning will surely increase as it is used. On the other hand, the latter is basically a mechanism that makes the same judgment no matter how many times it is used. That's basically how software is programmed. If you change the program logic manually, you can change the decision mechanism. In addition, if the program is designed to automatically change the direction of the decision based on the results of use using a decision tree or other method, which will be described later, the accuracy of the decision will be improved as it is used. You can change your judgment.

Let's say you've used each of them many times. Then, if it's the right method for the situation, it gets smarter the more you use it. It can be said that it is the realization of machine learning.

What is the difference between the former machine learning and the latter machine learning? First, the common denominator is that the computer's operation is intended to change with use and without human intervention. The direction of change is in the direction of "getting smarter." There were two ways to do this. In order to change the processing method from the accumulation of data, do you change the program, or do you change the state of some information collection without changing the program? The "something" assumed at the stage of this book is the state of a neural network built on digital computer software.

Therefore, it is divided into a neural network method and a programming method, that is, a conventional method.

In the neural network method, as will be described later, it is not self-evident to logically explain the path through which decisions are made. It may be said that it is not suitable. On the other hand, the method of procedural program development is itself a program, so in that sense it has a logical structure, that is, it becomes the object of logical explanation. Also, in the neural net approach, the conclusion is the choice of which of the prepared choices is the most likely. Therefore, it is a conclusion supported by probabilistic certainty. On the other hand, the programming method is deterministic, and there is no expression that the result may be stochastically different from the result reached. In the programming method, it is possible to describe the method to reach the solution heuristically, so it is possible to directly incorporate the will and hope into the software.

Having the ability to choose between these two broad categories of methods is probably a good way to prepare for a variety of problems. However, historically, the programming method preceded it, and then the neural network method blossomed, leading to the present day.

This book discusses these two approaches in various ways, but before that, Chapter 2 adds further consideration to the characteristics of the field called artificial intelligence. In order to do so, let us summarize what has been said so far in this section.

## (2) Writing Empirical Procedures and Performing Tasks

Furthermore, when given the assignment, "I stood in front of the student cafeteria. I want to decide what I want to eat from the menu." recommend. I will think about many things. Some people may be inexperienced or unfamiliar with the subject of "student cafeteria". In such a case, imagine entering a cafeteria in the city. The menu includes Japanese, Chinese, and Western dishes, and it is inexpensive, and there is almost no absolute signboard menu. Therefore, rather than being prompted by a specific menu, the author believes that it will be a question of what and how you choose in your daily activities.

First, you might take it as writing down a particular experience of one day. In that case, the goal is to write down your actions as accurately as possible.

The next thing to think about is to write down and receive the logic of behavior in response to the pattern of repeated behavior and the question of what is the principle of one's behavior. And it's not going to lead to the only "right" answer all the time, and it probably won't make sense to anyone. If there is a notation of "daily set meal", some people may say that they simply choose it.

Perhaps they would give different answers under similar conditions. After all, your mood for the day will play a role, and if it's lunch, what you have for breakfast will also play a role. It may be different depending on what kind of friends you are with. Also, some choices may be excluded from the beginning because they don't like it or because it's too expensive. However, it is probably not absolute either. And some people will say that they are not bound by the past, and others will say that they will not worry about food and that they will be fine as before.

I believe that the task of describing such procedures can be an introductory example of artificial intelligence programming or an example of designing artificial intelligence software. After reading this book, each sentence in the above section may give you a sense of considerations or branching points for the future design of artificial intelligence software.

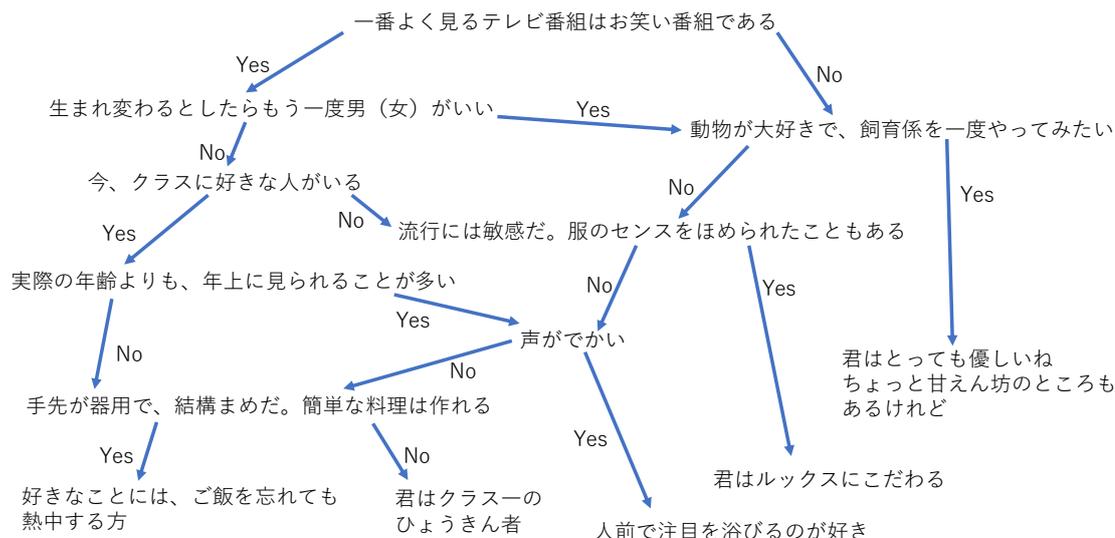
Perhaps if you write not only about the day, but about your behavior in general terms, that element is strengthened.

"Writing out" is the root of symbolic expression, and a program that can be written and used is a good program. This is the position of Applied AI. Also, while using the program and gaining experience, learn the necessary trajectory of the case and become "smart". This is the beginning of machine learning. When symbolic expressions are emphasized, judgments that are not routine or common sense can be reproduced as they are. On the other hand, in a neural network-like mechanism, it doesn't matter what kind of logic it is, but anyway, it becomes good at deriving what the next action is from the accumulation of experience so far.

Parents may pass on or pass on their choices to their children. Having a teacher also matters.

In any case, current artificial intelligence methods are limited to the extent that they can "imitate" or "substitute" human functions based on the accumulation of known situations.

At the same time, I would like to consider the following subject (Fig. 1-4). This is the procedure of the "chart-type personality test" used as an example of programming practice. There is no objective basis for this trend. However, it is an example of becoming a program, and it is also an example of trying to incorporate human judgment into a computer. From here, I tried to make the students feel the beginning of incorporating "smartness" into computers. It's not a special "problem-solving", it's a kind of play. However, it is also human ability to feel something from there.



チャート型性格診断 1988.10井田作成 小四チャレンジ11月号福武書店を参考にして  
「Python・Colab・NLP入門」井田著、近代科学社 2021.11、P50 図2.20に一部掲載

Figure 1-4 Example: "Let's make a personality diagnosis program"

### (3) Problem Solving and Discovery

Problem Solving and Heuristics were treated for some time in the 1960s as state-of-the-art matter in mathematical programming or management engineering. That is, they had already appeared in the context of engineering applications in the business domain.

It is related to trying to find a solution to a problem with complicated conditions using the functions of a computer within the time we can wait. A typical example is the problem of optimizing an objective function under a large number of constraints. For example, if you have a problem with 100 variables, it may be overkill to make them produce results while strictly satisfying all the constraints. A well-referenced example is the traveling salesman problem. This is an example of finding the optimum route for a salesman who tours N cities. As N increases, the time needed to find a solution increases astronomically. In these examples, it often takes time and space to find the exact optimal solution, but there is a real need to get the answer in a certain amount of time. We are faced with the practical situation that it is better to be satisfied with a solution of some level than not to come up with anything at all in time. A traveling salesman visiting 15 cities has 15! You'll have to do some calculations on that order, the amount of time you should spend in each city will be different, and you'll have to think about the actual transportation costs. In some cases, it is possible to break the premise that you must go around the planned number of days in the first place.

I wrote down the cities in the Kanto region (Figure 1-5). There are two railway networks: JR (dotted line) and private railway (solid line). To this there is a motorway network that allows connections different from these. Consider the paths that a traveling salesman might have using these. In practice, operational flexibility exists. In other words, there are various restrictions such as timetables, transfers between cars, where to spend lunch time, and so on, and the reality is to think about them flexibly.

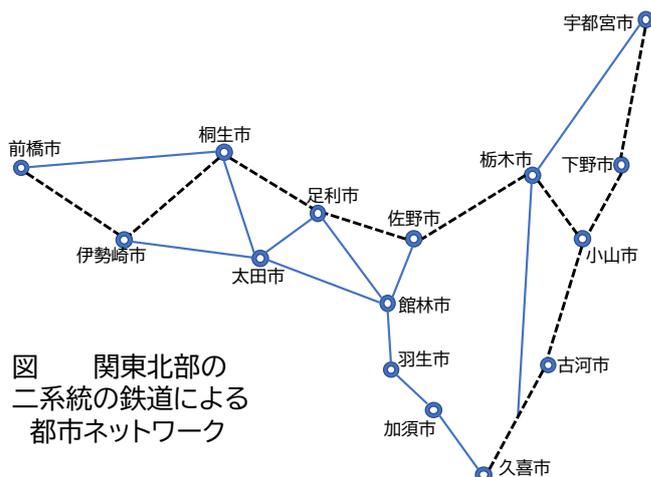


Figure 1-5 City network with two railroad systems in northern Kanto

This kind of situational setting related to "ba" was commonly seen in the field of problem solving.

In such a case, the trump card of computerization in normal usage, the logic of procedurally constructing "exhaustively examining all situations at high speed", no matter how fast the computer is, However, due to the expansion of the scale of the target problem, we always had the problem that the required time was too large and the required memory was too large. .

Then even the best-of-breed, textbook algorithm becomes weak. In such situations, heuristics or heuristics, which are state transition techniques unrelated to the natural scientific representation of the problem, have often brought about significant improvements in execution performance. It is, so to speak, selection from multiple candidates by seemingly irrelevant measures. Even today, there are various discussions, such as the debate over the tofu index, which will be discussed later in Section 7.4.

In the progress of artificial intelligence, these areas have already been treated as major issues since the late 1950s. Nils Nilsson's "Problem-Solving Methods in Artificial Intelligence" [1-5] (Fig. 1-6) is a book that has a title that is easy to understand and that has first-class explanations at the time. Nils Nilsson, who played an active role in the early days of artificial intelligence, is often introduced as a computer scientist. References [1-5] are also part of the computer science series. He has written many books and papers on Artificial Intelligence, but I think it is wise to think that this itself represents the aspect that "Artificial Intelligence is the frontier of IT." The frontier is always on the move. In other words, what was once thought to be the field of "artificial intelligence" has the property of being incorporated into one of the core IT as the situation is clarified and put into practical use. Artificial Intelligence has it. A person who deals with such a field is consistently working as an individual, but in terms of evaluation from the outside, it is not always the case that the last person is thought to be a person who has worked in artificial intelligence. That should be fine.

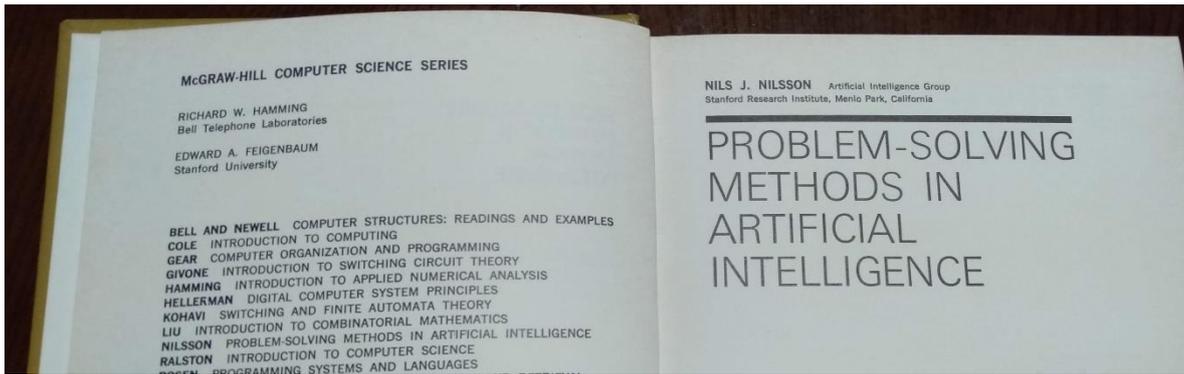


Figure 1-6 From Nils Nilsson [1-5]

Now, let me briefly introduce what is covered in this Problem-Solving Methods in AI. First, as an introduction to basic consciousness, he introduces puzzles and games, and states that problem solving involves the concept of states and operators, or the processing of states, and the reduction of those problems. As a concrete means, in addition to the handling of search-related matters, we have introduced characteristic concepts such as the use of predicate logic, automatic theorem proving, and unification, which will lead to Prolog later. The contents of this book are divided into two parts.

A) It shows the existence of graph and tree representation (subsequent declarative knowledge representation) and non-deterministic program description representation (subsequent procedural knowledge representation) as basic representation methods.

B) Furthermore, as concrete means of problem solving, representations such as state transition diagrams, And/Or graphs, and decision trees, breadth-first search, depth-first search, A\* search, use of heuristic information, and game min/max It summarizes search, alpha-beta techniques, and their general use.

The former A) contains the origin of Logic Programming. Starting with J. McCarthy's Advice Taker[1-6] in the late 1950s and Kowalski's Horn clause in the 1960s, declarative knowledge expressions were studied using Lisp as a realization language. It can be seen that Later, in the fifth generation computer project in Japan, more parallelism was added, and Concurrent Prolog and his KLI were developed and used. They tried to express knowledge declaratively and use that representation to implement QA and theorem-proving type processes. On the other hand, Minsky and others focused on procedural expressions.

The latter B) is an extremely practical method for specific search, not only as a basic technique in computer science, but also used as it is for data processing and strategy theory in the field of management science, and is used as it is from the treatment of artificial intelligence frontiers. was separated.

#### (4)The Concept of the Best Solution and the Genetic Algorithm

As part of an engineering class, I learned that "best" and "optimal" are different. At the time, he was unconvinced. Because he thought it was all about the pursuit of mathematical 'optimality'. The definition of the best solution or best solution is irrelevant here. Let's assume that it is the result of the action of choosing the best one among candidates that have a certain amount of "goodness". When he studied mathematical programming, he learned the concept of ``feasible solutions''. It is not necessarily the optimal solution, but it can be said that it is a

solution that can be used practically and that satisfies the constraint conditions. And I remember my undergraduate days when I was told that the "best solution" was a different concept than this, and I didn't understand. It has an engineering nuance, so the word "best" doesn't include the qualitative adjectives that many people know, such as happy, beautiful, and kind. Since the terms are not used very often here and I do not intend to refer to a fixed concept, I will use the terms "best" and "no."

The "best" solution has nuances that are willing to make engineering compromises. As a result, the optimal solution may be reached, or there may be a solution that does not reach that point and leads to a better ability by continuing to search the search space. The author often feels that problem solving with artificial intelligence has the nature of trying to find the best solution. It is an expression that appeals to the user of the solution that there are important constraints that are not shown in the formula, such as within the upper limit of time, or because the resources that can be used for calculation are finite. Therefore, it is a word that is used in situations that give a sense of reality to "solution."

"Best solution" will often appear in an explanatory context as well. However, I have come across a sentence that directly uses the word "best solution". In many cases, it is an expression related to when a realistic solution is reached while searching for the optimal solution in the search space, and is sometimes seen when defining methods in patent documents and the like. Alternatively, we can see it in sentences such as how to select the best global solution from among many local solutions. These concepts seem to fit the description of artificial intelligence methods.

At the same time, regarding methods that are likely to be able to select the best solution at high speed, there are some that discuss how to find the best solution, even if it is not the best solution. At the top of the list, I would like to point out the genetic algorithm.

Genetic Algorithm (GA) is a technique developed by JH Holland in the 1970s. It is intended to streamline trial and error within the search space. First, a large number of local solution candidates are arranged. This is represented by a set of bit strings. Then, 0 and 1 can express which candidate is selected or not selected. Swap the positions of 0 and 1 using the unit operations provided. Then the overall result is good or bad. Observing this, if you repeat the replacement many times, you will get closer to a better solution. This is also different from a mathematical "approximation". Moreover, it cannot be said that a good solution can be approached only by a fixed replacement method.

Therefore, we define three types of operations. They are selection, crossover (permutation), and mutation. A practical approach is to take two bitstrings and operate between them to find the best string. Efforts have been made to validate and verify the effectiveness of this technique, and attempts have also been made to extend it. However, it is difficult to say that clear usefulness has been found. However, this method is still inherited and attracts the interest of researchers. Patrick Winston, who will be introduced later, devoted a chapter to Chapter 25 Learning by Simulating Evolution in his Artificial Intelligence 3rd edition (1992), and introduced a genetic algorithm method that was not in the 2nd edition. He tried to treat it as one of learning. After that, every time we met, he was asked about success stories of genetic algorithms. And he said he spoke of his desire to put out a fourth edition, including a revision of Chapter 25, which he said was in sight. He too has talked about genetic algorithms and the pursuit of the best solution, but it may have been a wild dream. In any case, it will be one of the issues entrusted to future generations.

## 1.4.Impossible dream and IT frontier

### (1)to various fields

Here are some of the early AI applications to give you an idea of what they were like. In general, if such a section is included, it is likely to be criticized that it is missing or that it was not the case, but in the author's understanding, there are too few specific examples of the past hot era. Therefore, I decided to describe what the author can directly and indirectly understand. And I think they have some hints that lead to the present. As for the era, the 1980s are treated here as the early period. I have four observations:

A) Applications based on the net or distributed type have appeared since the 1990s. Prior to that, it was based on single operation, and had a relatively simple form as an application of artificial intelligence. It focuses on demonstrating the feasibility of conceptual and functional ideas, and does not reach the awareness of the entire related information system.

B) With the development of object-oriented concepts, major changes have occurred in system configuration methods, programming language specifications, and programming styles. Even the surge to Common Lisp starting in the mid-80s is different before and after the adoption of CLOS object-oriented extensions. Enforcing procedural representations of knowledge is a realistic implementation, and techniques that are not inherently procedural, such as those based on declarative representations or those rooted in graphs and other graphical representations, are not procedural. in the form of a mock language, mainly manual implementation and refinement of various technologies

C) Therefore, the artificial intelligence system as a unit was the core system concept in the first place, and at its apex was the highly optimized Lisp machine. The Lisp machine had an architecture suitable for the Lisp language, peaked around 1990, and ended its mission in the mid-90s. And it was mainly implemented by the Lisp language, and as a result, the pursuit of optimization for its execution was inevitable. The Lisp machine was intended to implement it in hardware, and was highly functionalized by specializing in the representation and processing methods peculiar to Lisp. This is effective in application fields such as CG and animation production, which are essentially independent work, and later, the application concept is differentiated into such systems, and the success of being separated from the whole AI. It became the beginning of the field.

D) At that time, almost all natural languages used were English, and although there was awareness of multilingualization of programming languages and artificial intelligence systems, implementation capabilities were scarce. As for the Japanese language, I did not go beyond the fact that there are things that can be used by chance. And it was an English system. The computer system itself was not multilingual, and even printing was at the stage where printing of kanji characters was gradually becoming possible. affected. After that, the aspect of distributed systems utilizing the Internet and the existence of natural language processing as a typical application field rapidly expanded to support a wide range of natural languages and to process information and knowledge based on it. proceeded. However, voice input/output will wait until around 2000.

### (2)theorem proof

Using Lisp, which has been widely used to implement AI since its early days, many studies have been conducted on mechanisms that take the form of proving theorems, partly because of the thought of its creator, John McCarthy. The underlying Lisp 1.5 Programmer's Manual[1-7] describes the Wang algorithm for propositional logic as an example. In addition, the research and development of predicate logic has involved many methods and algorithms that have been applied to AI. John McCarthy himself states that the concepts that Advice Taker [1-6] has been based on are theorem proving and intelligence through declarative knowledge representation. This advice taker will be discussed again in section 2.2 (1). Since then, there have been many studies in the area of "theorem proving".

### (3) Symbol processing

Since the early days of AI, Symbol Processing or Symbolic Computing has been the subject of much research and development as a promising field as a concept paired with theorem proving concept. The theorem-proving concept advanced to declarative knowledge representation, and the root of the symbolic concept advanced to procedural knowledge representation. Symbol Processing literally means processing symbols on a computer, and in the early days, research and development on the character string processing language SNOBOL and text editors as applied technology started in this area.

In March 1966, the ACM (Association for Computing Machinery) held a symposium on Symbolic and Algebraic Manipulation, and several activities followed. One example is Symbol Manipulation Languages and Techniques, edited by Daniel G. Bobrow, published by North-Holland in 1968 as a product of IFIP activities [1-8]. The mechanism based on "list processing" came to be highly evaluated. The Information Processing Society of Japan (IPSJ) established the Symbol Processing Research Committee led by Eiichi Goto. At first, Kazuhiro Fuchi was the chief examiner, and Hozumi Tanaka, Tateaki Sasaki, and Ikuo Takeuchi were the secretaries. From 1984, Eiichi Wada became the chief examiner. Ida served as secretary for three years from 1985.

Symbolic Computing includes formula processing, and there were many activities related to introduction to Japan such as Macsyma and Reduce. In addition, computation at the symbol level became a hot topic as Algebraic Computing. At RIKEN, under the guidance of Eiichi Goto, a computer called FLATS was developed with this field in mind.

### (4) Question answering and natural language input

Since the 1960s, there have been many studies and developments aimed at clear usage of question answering and natural language input. Question answering using the concept of automatic theorem proving was also developed under Advice Taker and several methods were studied. You can see the discussion that becomes the prototype of pattern matching after that.

D.G. Bobrow's 1964 STUDENT[1-9] was the core of his doctoral dissertation and was talked about as being able to solve high school math problems. A natural language question (or problem) is analyzed by logical reasoning with a set of pre-made rules. Therefore, it is also said to be an early case of natural language processing. Wikipedia provides the following example of a question that can be handled.

If the number of customers Tom gets is twice the square of 20% of the number of advertisements he runs, and the number of advertisements is 45, then what is the number of

customers Tom gets?

In addition, Marvin Minsky, in his edited book *Semantic Information Processing* [1-10], discusses various studies from the perspective of handling semantic problems in artificial intelligence using symbolic algorithms. In it, he devotes considerable space to discussing STUDENT. In addition, as an example of the problem that D.G. Bobrow himself explained and solved, in Fig. 3.1,

The distance from New York to Los Angeles is 3000 miles. If the average speed of a jet plane is 600 miles per hour, find the time it takes to travel from New York to Los Angeles by Jet.

introduced such cases. It can be seen that the development of a specific method for a specific image was intended.

Interestingly, Minsky treats this as a study in the category of Natural Language Input. It can be seen that there is a gradual shift in recognition of this area from theoretical research to research on practical knowledge processing capabilities.

In addition, Weizenbaum's ELIZA had an impact on society that became news stories at the time. ELIZA was developed and announced from 1964 to 1966. Assuming that the psychoanalyst was in a separate room and could have a conversation on a terminal, he was asked to have a conversation with the "patient" and test whether it would be tolerable. Wikipedia also has a description. The ability to interact with a computer in natural language attracted social attention and created a sensation, but in reality, it discriminates patterns in the patient's input message and outputs the following message in a parrot-like manner. That was the basis. This logic was introduced in magazines such as BYTE, and even in Japan, readers contributed program examples in Basic language, etc., as subjects for Bit magazine's "Nanopico Classroom." There was much speculation among software engineers because they were able to launch it by typing M-x doctor in the GNU Emacs text editor. In the first place, it is created by choosing the plausibility that can respond like that without inputting specialized knowledge. However, there is also an episode from the era when many people who touched it said that it was an example of artificial intelligence, so experts described it as "artificial incompetence." For natural language sentences, judgment by pattern matching has at least been recognized as a convenient technique. Also, if you know the seeds, it's a compact program that can bring such play into a stressful program. .

#### (5) Will, solidarity and trust

Perhaps, depending on the definition of "will", it may be said that even computers have it. However, in the sense of the author of this book, there is a strong recognition that "will" is "voluntary". I think it probably has something to do with the ability to set goals and goals for yourself and the ability to walk towards them. Many of them are behavioral principles of beings that answer "Because I want to do it" when asked why they do it. Therefore, from today, the robot will begin to think that mountain climbing is its mission, start working toward it, prepare tools, train, choose a destination, and continue while evaluating the results. Once that is done, the author will also recognize the existence of a "computer with a will."

If we collect the essence of today's technology, computers will have "intention", that is, starting from logic given by humans in advance and having expanded logic or other logic. let's admit It is possible for humans to look at it from the outside and check that it is logically structured like this now, and we have entered an era in which there are cases where such a

form is beneficial and effective. This is the form of "machine learning" that the author perceives. This is the first aspect of "making computers smarter." Machine learning is one of the main areas of artificial intelligence. And we will deal with it in this book.

I would like to define "solidarity" as a state in which communication between autonomous beings is functioning on a common task. It is premised that each person's "will" is at work there. Being autonomous, there is no pre-established common goal process for each object of solidarity. "Communication" will be essential for mutual communication, especially communication of ideas. There should be a process in which the participants mutually determine the "common issues" and set them as a common goal.

This "solidarity" is still a dream. The author does not assume that this will be possible in the near future. However, there is a practical prospect for communication technology that allows self-driving cars on expressways to communicate with each other and platoon while maintaining a distance between them. In addition, as a step before that, it has become possible to set and implement distributed processing for a given theme by defining a given communication method and function assignment. But I don't know if we'll ever get to see the adorable scenes of robot soccer team players chaining nice passes together to score goals.

I would like to point out "trust" as something that supports this "will" and "solidarity". "Trust" is sometimes betrayed. However, "trust" between autonomous systems is irreplaceable, and I would like to respect the dream of making it possible someday between computer systems. Because it is also the starting point of technological development that has always existed.

The Applied AI described in this book currently does not include these wills, solidarities, and trusts, nor does it extend beyond what is described. However, I do not deny the view that we are on the way to acquiring them, and I would like readers to share that there is a long history of struggle and joy, and that we are here today.

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## Chapter 2 Historical development and the era of pioneering

### 2.1. von Neumann's View

John Von Neumann, who realized the stored program system that is the basic mechanism of today's digital computers, died in 1957 at the age of 53. He is a mathematician, a genius known for his game theory and participation in the Manhattan Project. He received many invitations to give lectures from Yale University, and the manuscripts he wrote for them were published the following year in 1958. *The Computer and the Brain* [2-1].

I remembered that I had the 1986 reprint at hand (Fig. 2-1). The text can also be viewed online. I write about "computers and brains". I read it again with interest to see what the genius of the 1950s had written.

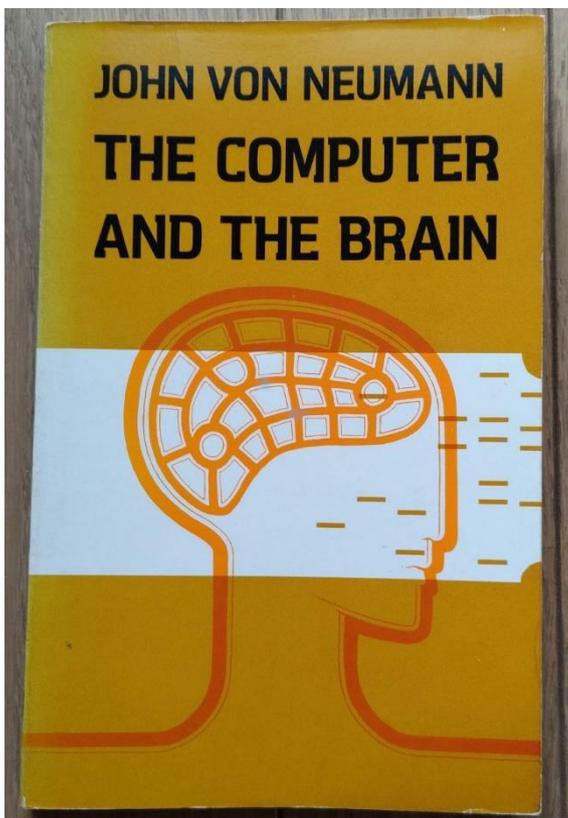


Figure 2-1 The Computer and the Brain [2-1] Cover

The whole is roughly divided into computers and brains, and he describes what he understood in a matter-of-fact manner. Reflecting that era, in the section about computers, digital computers and analog computers are listed side by side. First of all, this was a fresh surprise. It is, so to speak, a reconfirmation of the situation. Regarding digital computers, I wrote about the mechanism that is the starting point of the current flow. The devices used, the size of the memory, and other data at the time are recorded. With regard to analog computers, with Differential Analyzer in mind, we prepared basic calculations using integrators (instead of the four arithmetic operations) for problems that can be represented by differential equations, and numerically (digital), but I am writing about a mechanism to obtain a solution numerically (analog). Depending on the target system, it is overwhelmingly faster than a digital computer.

It can be said that an analog computer is a computer that is established by "similarly" realizing basic operations that a digital computer does not have. It is interesting to read this while keeping in mind things like today's quantum computers. In addition, considering the neural network, as will be described later, if you are considering the design of a computer that directly implements the neural network, it may be useful to foster that image. In any case, the description as a book is closer to listing the summary of the analysis rather than writing the theory.

The description of the brain proceeds in a similar fashion. Neural networks and neurons and their ability to transmit information are described. I feel that some of the points are suggestive. It looks like this:

- What a digital computer can do depends on how the user creates it using the prepared code (note: instruction code).
- Turing showed in 1937 that it was possible to imitate other machines using a prepared instruction set. (For this reason, it is also possible to simply recall another machine, or a description in a high-level language, some system, or human behavior, etc.) as "another machine."
- This story concerns the role of logic and arithmetic in the functioning of complex automata, especially the nervous system.
- An artificial automaton can be used to control complex processes, and has two parts: logical processing and arithmetic processing. The fact is that our habit of expressing thoughts makes it difficult to express truly complex situations without resorting to formulas and numbers. Both arithmetic and logic are important in the nervous system and can be viewed as a computing machine. Its accuracy is low, but it should be emphasized that it works in a reliable manner. The nervous system information transmission system by pulse propagation is based on statistical properties and uses a notation distinctly different from that of mathematical systems. This results in low arithmetic accuracy but high logical reliability. How do you approximate the memory capacity of the human brain? First, assuming that the number of cells in the nervous system is about  $10^{10}$ , the amount of processing per second is  $14 \times 10^{10}$  bit/s. Assuming a life span of 60 years, it will be about  $2 \times 10^9$ , so we can estimate the total to be  $2.8 \times 10^{20}$ . Not all of these will remain or be forgotten. (Ida's note: Peta is  $10^{15}$ , and the unit above it is Exa, which is  $10^{18}$ . This area is currently realistic. I have the impression that the order has become quite close. Neumann was at that time Digital computer memory capacity is up to about  $10^6$ .)

These descriptions, which are said to be genius, are first-class expressions and use the terminology of the time, and are very difficult to understand. But I can say this. He discusses computers and brains separately, but he believes that if we do not lose sight of the essence of arithmetic and logical operations, we can treat these "machines" with different characteristics and operational concepts from a bird's-eye view and cross-sectionally. It can be determined that there are

## 2.2. Exploring Giants in the 1960s: Two Approaches and CS

## (1) Definition of Artificial Intelligence by John McCarthy

What is "artificial intelligence"? Let's search from the words of the people who are considered to be the founders of the current artificial intelligence field. First, John McCarthy stated the following in his 1958 paper "Programs with common sense" [1-6] regarding the motivations and matters to be addressed in artificial intelligence research.

"A machine is instructed mainly in the form of a sequence of imperative sentences, while a human is instructed mainly in declarative sentences describing the situation in which action is required together with a few imperatives that say what is wanted."

Then there is the description of the mechanism of human behavior. Computers work by writing programs and giving them to run. However, if a program that expresses what is required instead of a procedure can be executed, the situation will change. I think he was searching for what kind of mechanism should be provided to do so. First, he states that there are two kinds of sentences. Imperative and Declarative. I dare to quote that part from the relevant part of the 1959 document [1-6] as it is (Fig. 2-2).

### Advantages of Imperative Sentences

1. A procedure described in imperatives is already laid out and is carried out faster.
2. One starts with a machine in a basic state and does not assume previous knowledge on the part of the machine.

### Advantages of Declarative Sentences

1. Advantage can be taken of previous knowledge.
2. Declarative sentences have logical consequences and it can be arranged that the machine will have available sufficiently simple logical consequences of what it is told and what it previously knew.
3. The meaning of declaratives is much less dependent on their order than is the case with imperatives. This makes it easier to have afterthoughts.
4. The effect of a declarative is less dependent on the previous state of the system so that less knowledge of this state is required on the part of the instructor.

Figure 2-2 J. McCarthy, Programs with Common Sense [1-6] P4, 1959

Then, we propose the realization of the Advice Taker system in the paper. In order to be able to implement this, he created a specification called the Lisp language and started working on its realization. Advice Taker expresses facts as follows: I am at my desk, my desk is in my house, and my car is in my house.

```
at(I, desk)
at(desk, home)
at(car, home)
```

Then for problem solving, e.g.

```
at(I, car) → can(go(home, airport, driving))
```

If the proposition is

```
do(go(desk, car, walking))
```

It is said that it leads to actually going to solve it first. It should be noted that detailed

explanations are omitted. This is very close to the example that will appear later as an example of program execution with predicate logic in Prolog. Rather, a characteristic part of Prolog is that it was an implementation of J. McCarthy's Advice Taker in 1959.

After that, he advanced his interest from theorem proving to epistemology, and the "monkey banana problem" became a symbolic topic, and he also visited Japan. It was from May to June 1975. He has given lectures at the Institute for Mathematical Sciences, Kyoto University and at the Uchisaiwai-cho Electrical Testing Laboratory. It was difficult to understand, but the author also participated with interest. He wanted to go to Hakone last weekend, so he acted as a driver (Fig.2-3). He also listened to what the graduate students at the time had to say. He also accompanied me when I asked him to try the tonkatsu. His impression, he felt, was that of a mathematician and philosopher, someone who would ask Shinrabansho "why is it so?"

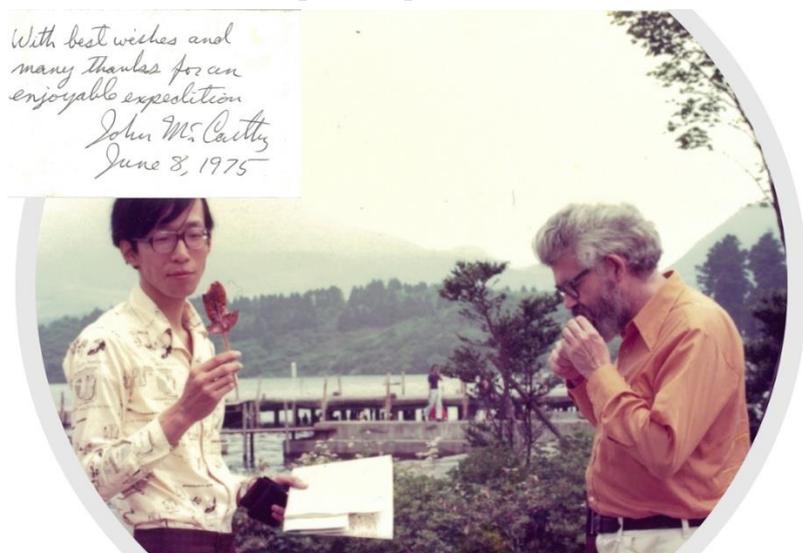


Figure 2-3 At Hakone on June 8, 1975

## (2) Artificial Intelligence by Marvin Minsky

On the other hand, another ancestor, Marvin Minsky, published "Semantic Information Processing" [1-10] in 1968. In it he states:

"Artificial intelligence is the science of making the machines do things that would require intelligence if done by humans"

Both were involved in the creation of the MIT Artificial Intelligence Laboratory, but John McCarthy also played a major role in the creation of the Stanford University Artificial Intelligence Laboratory. Their positions are slightly different. From the very beginning, McCarthy argued that "declarative description" does not directly pursue intellectual behavior, but rather that some action based on that expression, such as the theorem proving process, is the intellectual behavior of a machine. It seems that he thought that it would become

On the other hand, Minsky concentrates on researching implementation methods and mechanisms of realization. "A Framework for Representing Knowledge" [2-2], which he wrote in MIT AI Laboratory Memo 306, summarizes various knowledge representations he considers, and is reproduced in several later books. . Around this time, as director of the MIT AI Lab, he established the general framework of the research center around the "frame concept", and

quickly handed over the position of director to his student, Patrick Winston, and immersed himself in his own research. .

Some of the knowledge representations and themes related to them for which Minsky clarified the framework are as follows. In particular, the concept of a frame is also the basis of many activities, incorporating various ideas related to various knowledge representations and their processing up to that time. He framed not only new mechanisms, but also new mechanisms related to knowledge representation that were being studied elsewhere at the time. In addition, specific issues are collected in References [1-10]. The author of this book was very interested in Semantic Memory [2-3].

Minsky categorizes the concept of frames and the various issues surrounding them in artificial intelligence as frameworks for knowledge representation as follows.

A: Frame, rereading it now, the core idea of object orientation is still there

B: Expression of images, how to convert images captured as images into knowledge

C: Natural language and scenarios, expressions of meaning, expressions of dialogue, work of translation, questions, examples

D: Mechanisms such as learning, memory, paradigm, matching, similarity, class, summarization

E: Control, how to handle these frames in the program

Frames have become one of the methods of knowledge representation in the field of artificial intelligence. A frame has a number of slots to organize information about a certain object. Slots are composed of slots to put "values", slots to put "procedures", and slots to put references to other frames. Figure 2-4 shows a notation example from Reference [2-4]. And it has a hierarchical taxonomy that includes inheritance. Although frames and classes were born separately, they have many commonalities, and in the course of their development, they influenced each other.

```
(FASSERT MINSKY
  (NAME      ($VALUE ( |Marvin Minsky| )))
  (ADDRESS   ($VALUE ( |545 Technology Square, Room 821, Cambridge, MA 02139| )))
  (PUBLICATIONS ($VALUE ( |A Framework for Representing Knowledge.| )))
  (INTERESTS ($VALUE ( REPRESENTATION ))))
```

Figure 2-4 First example of frame (from [2-4])

Subsequent AI research, especially in the vicinity of MIT, can be understood as being described with an explanation of which part of Minsky's framework it is. That's how Minsky had such a strong influence on the system of practical tools for AI.

This is an example from a later date, but since it is easy to read, here is an example of a frame from materials familiar to the author. As a basic figure, you will find that it resembles the basic examples in various object-oriented schemes that followed. Minsky's team put this together in 1976 as the Frame Representation Language[2-4][2-5]. It included concepts such as inheritance, slots and their values, slots with procedures, and auto-invocation of procedures when a value changes. The lower frame inherits the slots of the upper frame. For example, the concept shown in the following diagram (Fig. 2-5) has become widely known, where the wheels of a sports car are defined at the upper level, and the initial value is 4, which is also used at the lower level. Such a mechanism has come to be used [2-6].

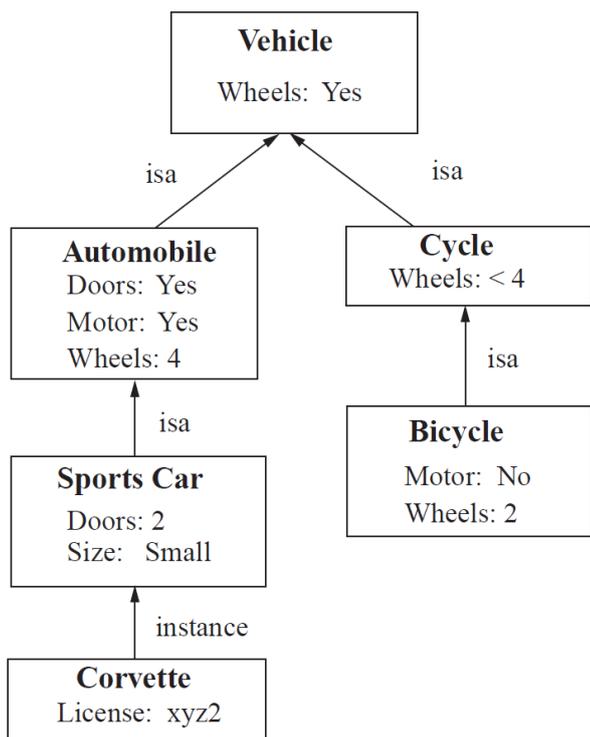


Figure 2-5 Examples of frames [2-6] p81 From Figure 3.1

Look at Automobile in Figure 2-5. In the semantic network (Section 1.1 (3)), this is expressed as shown in Fig. 2-6 below. Such practical improvements are being pursued.

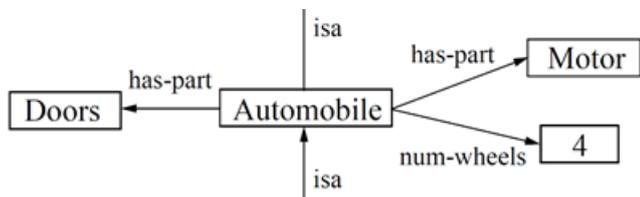


Figure 2-6 An example of representing Automobile in Figure 2-5 with a pure semantic network

Then, Minsky set out a direction oriented toward practical application, and after getting rid of the director’s practice, he wrote the famous *The Society of Mind* [2-7]. It was 1985. It became a worldwide bestseller.

(3)Nils Nilsson was later called a Computer Science Scholar

Nils Nilsson, introduced in Chapter 1, was at Stanford, where McCarthy was welcomed. At Stanford University’s AI Center (at that time), he published several papers in the early 70’s that looked at the big picture of artificial intelligence. For example, [2-8].

Nils Nilsson, in 1971, in [1-5], on the definition of artificial intelligence:

“The goal of work in artificial intelligence is to build machines that perform tasks normally requiring human intelligence”

It has said.

It is worth noting that they arrive at the expression ”task” and that they clearly state the goal

of "making a machine." As the title indicates, this book [1-5] discusses the domain of problem solving, including state space representation and search methods, problem reduction, theorem proving by predicate logic, and application of predicate logic to problem solving. etc. is included in the content.

Stanford and MIT can be said to be the males of the West and the East, and were often contrasted after this.

Minsky, in 1985's "The Society of Mind,"

"Research in Artificial Intelligence started only in the 1950s. This inspired a flood of new ideas about how machines could do what only minds had done previously." Things that could only be done by machines could be done by machines, and new ideas spring up like a flood.)

It has said.

As director of the MIT Artificial Intelligence Laboratory, he led many interesting ideas and initiatives. Both pursued a practical form of artificial intelligence.

#### (4)Patrick Winston's Perspective on Artificial Intelligence

Professor Patrick Winston, who served for many years as director of the Massachusetts Institute of Technology Artificial Intelligence Laboratory (MIT AI Lab) and served several terms as president of the American Society for Artificial Intelligence, defined artificial intelligence in his 1977 book. At the beginning of Chapter 1 The Intelligent Computer of Artificial Intelligence 1st edition [2-9], it is described as shown in Figure 2-7.

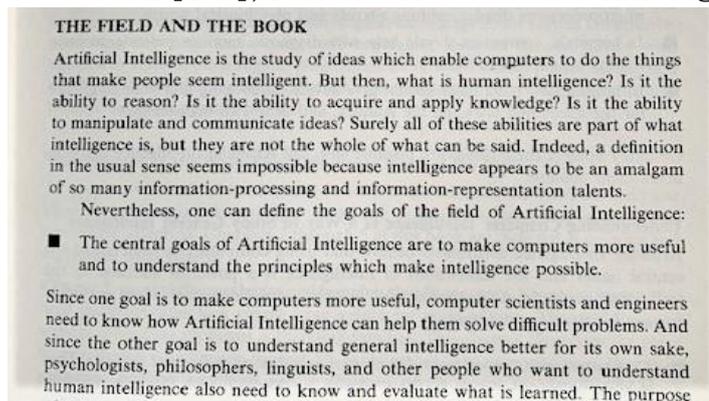


Figure 2-7 From Artificial Intelligence 1st ed. P1, Addison-Wesley

"The central goals of Artificial Intelligence are to make computers more useful and to understand the principles which make intelligence possible."

It can be said that it is extremely practical and has the context of Applied AI referred to in this book.

This definition was revised in the second edition [2-10]. Prefaced with "There are many ways to define the field of Artificial Intelligence. Here is one:", published in 1981. In the second edition of

"Artificial Intelligence is the study of ideas that enable computers to be intelligent."

And put his leadership in the AI lab there. In 1984 he published a revised version of the second edition. Then, in 1989, he published a third edition with a break [2-11]. At this time, he was young, but he was active as the leader of the research institute (Fig. 2-8).



Figure 2-8 Author and Professor Winston March 1985

In parallel with this, he published and revised in parallel a book titled Lisp, also from Addison-Wesley, which discussed the details of the means of implementation [2-12]. He released San Marco Explorer as a learning and execution environment for personal computers, making it convenient for studying. His consistent policy is well represented in his articles [2-13] in the April 1985 Special Issue on Artificial Intelligence in Byte magazine.

And in the third edition [2-11] of 1992, the definition was rewritten as follows.

“Artificial intelligence is the study of the computations that make it possible to perceive, reason, and act. Artificial intelligence excites people who want to uncover principles that must be exploited by all intelligent information processors”

These definitions have given researchers in related fields a certain perspective on artificial intelligence research. We are committed to developing more practical means of exploring intrinsic intelligence. At the same time, the people of cognitive science who began to confirm its existence in parallel also wrote the following words.

“AI researcher attempts to develop and test computer programs that exhibit characteristics of human intelligence. ... AI researcher is always working with an artifact, which is only inferentially related to the human mind and is in many respects a pale substitute for it.”  
p139[2-14]

These views can be interpreted as a desire to move more toward intelligence exploration itself, or an expectation of movement that more closely simulates the mechanics of human intelligence. Later on, we would see neural nets finally bloom into the 21st century. In addition, the beginning will be seen in the latter half of the 80's. We will deal with them one by one.

### 2.3. Exploring AI and Consequences in Some Areas

#### (1) puzzle, game

Programs that played checkers and chess were the subject of much discussion in the 1960s. It mainly fights against human opponents. Several programs have been announced, but the most famous one is MIT's Mac\_Hack chess program. 1966 and 1967 were the years of major achievements. It was made with Maclisp implemented on ITS (Incompatible Timesharing System, PDP-6) as part of Project MAC. Described at [https://www.chessprogramming.org/Mac\\_Hack](https://www.chessprogramming.org/Mac_Hack). In the 70's, it was ported to the PDP-10. In a way, it was also inevitable that a prototype chess

hardware called CHOPS was planned. R. Greenblatt says that these were the precursors to the hardware for competitive games that followed.

As for puzzles, I'll list Trump's solitary play program and how to solve the Hakoiri Musume puzzle in Japan. Calculation, a solitary game, is still a hot topic.

Puzzles and game player programs have come to be known to a wide range of people as representatives of a world that is not software for specific tasks. In addition, it can be said that it showed society in an easy-to-understand manner that, as the use of computers, scientific calculations and clerical work are gradually spreading, there are different genres for the realization of specific functions for specific purposes. .

To unravel the history of computers and chess, we can start with the February 2022 CACM (ACM Journal) paper "Reimagining Chess with AlphaZero" [2-15]. The authors are DeepMind Technologies trio and eight-year world chess champion Vladimir Kramnik since 2000. In it, reference is made to the 1953 paper Digital Computers applied to games by Alan Turing. However, the paper is listed in *Faster Than Thought: A Symposium on Digital Computing Machines* (Editor B. Bowden, Pitman Publishing, p286-310), but the author was unable to confirm the original text.

## (2) Recognition

A computer that could think and operate autonomously was probably in the common mind of many early researchers in the field of artificial intelligence. It depends on the individual's ability to correctly perceive, communicate with, and influence the external environment in which it exists. The visual ability that is absolutely necessary for this will wait for the age of deep learning, which will be described later. The human ability to face the outside world, such as voice conversation, will also wait for that era.

Early researchers did what they could without waiting for them. From 1968 to 1970, Terry Winograd conducted an experimental study known as "the world of building blocks", which was the beginning of scene recognition. It is called SHRDLU (Figure 2-9). Place multiple building blocks on the desk, move them, stack them, and move them out of stacks. Triangular pyramids and cylinders are also included. Recognize when it is physically impossible/possible, and when possible, control as instructed. It can be said that he established various data structure expression methods for such areas that had not existed before. At the same time, it was also a case of natural language input, as it was made to respond to natural language (wind) instructions. At first, it was a text-based exchange, and it was not possible to visually see the world that the program recognized. rice field. After that, screen-based implementation also appeared.

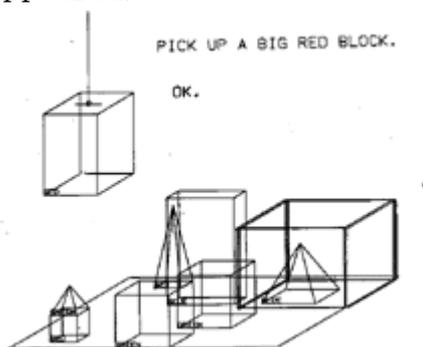


Figure 2-9 When 'Pick up a big red block' is instructed in SHRDLU

(From <https://hci.stanford.edu/~winograd/shrdlu/>)

Handwritten character and number recognition also began to appear in the 70s. In Japan, attempts to put it into practical use have begun, assuming practical applications such as recognizing handwritten postal codes on the address side of postcards. It became the current MNIST standard problem (Section 5.2). At that time, it could not be said that it had reached the level of practical use. Voice input followed.

The first computer input/output interface consisted only of a typewriter with a glyph for each character, but the development of bitmap displays and multilingual input support functions such as kanji input and the bitmap printing functions of laser printers and inkjet printers. had to be accompanied by They will be commercialized and popularized from the 1980s. These have become the basis for a major change in the interface between computers and humans. Artificial intelligence research and development is in a sort of parallel, chase-and-catch race, and the very era of pioneering continued just a few decades ago. It should be noted that some fields are still in such a state.

### (3) Mathematical Programming, PERT/CPM, Traveling Salesman Problem

Along with the progress of business management, there have been expectations for the realization of management problem-solving methods among management practitioners and their staff functions. Mathematical programming, in many ways, called for artificial intelligence techniques. For example, in linear programming, the optimum value of the objective function is obtained while satisfying a plurality of constraint equations, but in using it, the constraints may change according to the situation, which sooner or later becomes a problem. Among the author's involvement, the development of integer programming and dynamic programming is impressive. Interested in the branch and bound method in integer programming, and have created a program. In the mid-1970s, an attempt was made to include integerization conditions in the constraint equations. In the search tree at this time, decide which condition to change next, and compare how the execution including it differs from other cases. Dynamic programming necessarily seeks a feasible solution rather than an exact solution.

Within the business management field, the usefulness of project management or project scheduling was recognized here and there, and practical methods were invented. Figure 2-10 shows a typical situation. PERT (Program Evaluation and Review Technique) was developed in the latter half of the 1950s as a result of the search for a solution to the schedule delays that occurred in the development program for the US Navy submarine-launched ballistic missile "Polaris." Around the same time, there was a project to deal with the problem of process delays at DuPont (chemical industry) in the United States, and the search for a solution to this problem led to the development of the CPM (Critical Path Method). Both were similar solutions to similar problems, but the specific methods were different. In both cases, there was a common understanding that a "smart" method was required for problems that were considered practically impossible due to the enormous number of steps and excessive computation time required for the brute-force method. As the process progressed, it was often necessary to recalculate from there, while it was not necessary to seek a perfect solution. The challenge was how many days to go or how far to go in a day, and Oroanse existed. These were extremely realistic issues, and at the time, they were the subject of discussion as application areas for

artificial intelligence, and were even discussed as the practical application of artificial intelligence. Today, no one would call these applications of artificial intelligence. The method that combined the two came to be called PERT/CPM. In PERT/CPM, it matched the background awareness that heuristic treatment often leads to success in resource constraints. It can be said that there was a sense of familiarity with the practical application of artificial intelligence technology in the field of business administration, where such things came into contact on a daily basis.

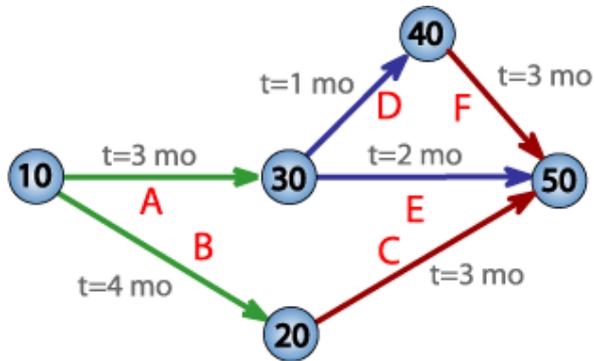


Figure 2-10 Schedule management in scheduling (from Program evaluation and review technique, Wikipedia)

Complexity increases greatly when human elements are included in the operation of large-scale systems. This is because there is absolutely no guarantee that a human will behave as expected. Furthermore, in a large-scale system, related systems based on independent behavioral principles influence each other, so it is necessary to be prepared for plan changes to occur all the time. Combining this with information from many installed devices enables smooth operation.

As a familiar example, consider a transportation system. It is a subject that involves control, management, and mathematical planning. Each railway network and road network has its own problems and difficulties. It also includes the planning, operation, and monitoring of operation plans, including signal control and traffic volume. The wide-area signal control system in the United States in the 1970s led to many issues for smartification, and was also introduced in Japan. Furthermore, air traffic control and airport operations are also difficult systems. Even if there is an accident, it should be operated within the range of movement. These are more of a planning and scheduling issue than a control system.

Let's summarize. What elements were there? First, there is the basis for expectations of heuristics. There is a search for a method other than finding a solution after hitting everything. Second, there is the pursuit of the best solution, feasible solution, and inexact solution in mathematical programming. The pursuit of optimal solutions is expensive. In addition, an attempt was made to draw a clear line from approximate solutions based on calculation formulas, such as statistical rounding. After that, there is the setting of useful KPIs and the source of operations based on them. And, thirdly, there are many jobs that cannot proceed unless they are decided. Accompanied by time constraints, dynamic changes in conditions, etc. Various allocation and scheduling problems come to mind. A typical example is the traveling salesman problem, which is still being debated about the usefulness of quantum computers.

Therefore, at the end of this section, I would like to quote from Wikipedia about the traveling salesman problem so that it will be a hint for those who aspire to this field in the future.

The traveling salesman problem (TSP) is the problem of a traveling route that visits every city exactly once and returns to its starting point, given a set of cities and a travel cost (e.g. distance) between each two cities. This is a combinatorial optimization problem of finding the one with the lowest total travel cost (finding the shortest route when a salesman visits a plurality of predetermined cities only once). The size of the problem example is represented by the number of cities. This problem belongs to a class of problems called NP-hard in computational complexity theory. That is, it is a computationally difficult problem for which it is unlikely to find a deterministic polynomial-time algorithm for the size of the problem instance.

The time complexity of the method to obtain the optimal solution by computing all paths is  $O(n!)$ . It is not realistic to try to find the optimal solution when the number of cities exceeds 20. For relatively small problems within about 2,000 cities, exact solutions can often be obtained within about a day on a personal computer using branch-and-bound methods that combine linear programming and logic trees. Genetic algorithms and other heuristic algorithms that do not strictly guarantee optimal solutions are often used.”[2-16]Wikipedia Text omitted

There are 5040 ways to go around all eight cities. Also, as mentioned in 1.3(3), there are further complications when considering real-world applications. If there is a mechanism that is not like a digital computer, and if we can come up with a solution using it, it will be good news.

A benchmark problem for solving this traveling salesman problem is available at <http://www.math.uwaterloo.ca/tsp/data/art/>.

This has become a matter of stroking a digital image such as the Mona Lisa, represented by 100,000 to 200,000 dots. I'm trying to find the fastest way to do this. The achievements of several Japanese researchers are introduced in this challenge. As of spring 2022 when I checked this site, for example, Yuichi Nagata in 2009 posted that the Mona Lisa image has a record of 5757191 steps. It seems to be the subject of research such as parallel genetic algorithms, but it seems that it requires a large-scale calculation that would take hours even if a supercomputer is used.

In addition, I recall that Professor Eiichi Goto talked about reducing the amount of computation based on computational complexity theory in relation to the development of Lisp processing systems. “For  $O(n)$  problems, the amount of computation increases in proportion to  $n$ . An  $O(1)$  problem means that the computational complexity is constant regardless of  $n$ . Therefore, if we want to be able to solve the target problem practically, we have to develop a smart calculation method, that is, an  $O(1)$  method. ] (The expression is by the author of this book). It reminds me of Mr. Goto's HLISP and his attempt to build a hardware FLATS machine for its execution. I had an image of what to do in order to obtain an exact solution with  $O(1)$  feasibility on a digital computer.

Additionally, there is the job shop scheduling problem. It has departments (job shops) that use independent machines to handle multiple elemental tasks that have a sequence relationship. At this time, it is a problem such as seeking a flow method and a machine operation method that minimizes the creation and processing time of multiple products.

All of these create a network diagram that shows the work required to carry out the project, its preceding relationships, the time required for each work, etc., and schedule the project based on this. The materials, human resources, tools, required time, etc. required for the

elemental work differ from each other. Although combinatorial problems are at the core, it is generally considered difficult to derive optimal solutions for problems of a practical scale using deterministic mathematical methods.

#### (4) expert system

The discussion of expert systems is so important that it will be expanded upon in a new chapter, Chapter 4, Section 4.5.

The basis of what is called an expert system is to try to write down human actions. This is developed into how experts in a certain area are doing. Expert systems were symbolically treated as the core of the artificial intelligence boom of the 80s.

Until then, the driving force behind America's development was mass production using large numbers of low-wage workers. It is the presence of experts and leaders in technology development and operation that makes it possible. There was a major theme of how to keep the abilities accumulated in these people within the organization, and how to inherit and develop them. Writing down empirical skills and making them executable on a computer as they were was a major issue, and the development of artificial intelligence tools was active around this.

The maintenance of steam locomotives would have been a symbolic example among them. As long as steam locomotives are used, there will be a need for people to be involved in repairs and inspections. You can't cut so many, but you need to be careful. Inspection requires the ability to not overlook small symptoms, so skill is required. Let's put it on the computer. If a computerized system can be used, there will be no omission of check items, so there will be no accidental inspection failures, and a constant response system will be created.

Or, in medical diagnosis, don't overlook what patient complaints, measured data, etc. mean. Then, we will properly diagnose, prescribe, and treat. Is it possible to raise this standard to that of a skilled doctor?

The ability to deal with these phenomena from different perspectives in different fields has inspired the development of expert systems, and investments have been made around them. Many things did not bear fruit. Some were worth the challenge, some weren't. Some things have continued to evolve since then.

When an expert's way of thinking and judgment methods are incorporated into the rules of business execution of an organization, documentation and standardization become an inevitable step, creating business rules and acting according to them will create a strong corporate culture and customer trust. , that sort of thing took root.

The author most sympathizes with credit management. In particular, credit management is indispensable for executing settlements of credit cards owned by general consumers, and the circumstances encountered are infinitely different. Moreover, it is common for credit companies to have different standards and settlement limits, and natural scientific general rules no longer exist in response to individual cases. In other words, how does our company make decisions? As the number of cases increases, the instability of decisions made by human authorizers becomes apparent.

This unbridled passion for expert systems gradually subsided. Technologies with stable effects will be incorporated into the technical system collectively known as IT, and will no longer be called AI. Also, the things that didn't work will disappear. These will be described again in Chapter 4.

Figure 2-11 introduces the mechanism of MYCIN as a representative example from Reference

[2-17]. Physicians know the facts of their field and have a stock of speculatively-backed standards for a variety of medical decisions. These are static knowledge. With this expert physician's knowledge held on the computer, the actual attending physician enters patient data and receives decisions from MYCIN. From the static knowledge and patient data, and the recorded history of the interview so far, the next necessary question is generated and matched with the reasoning process.

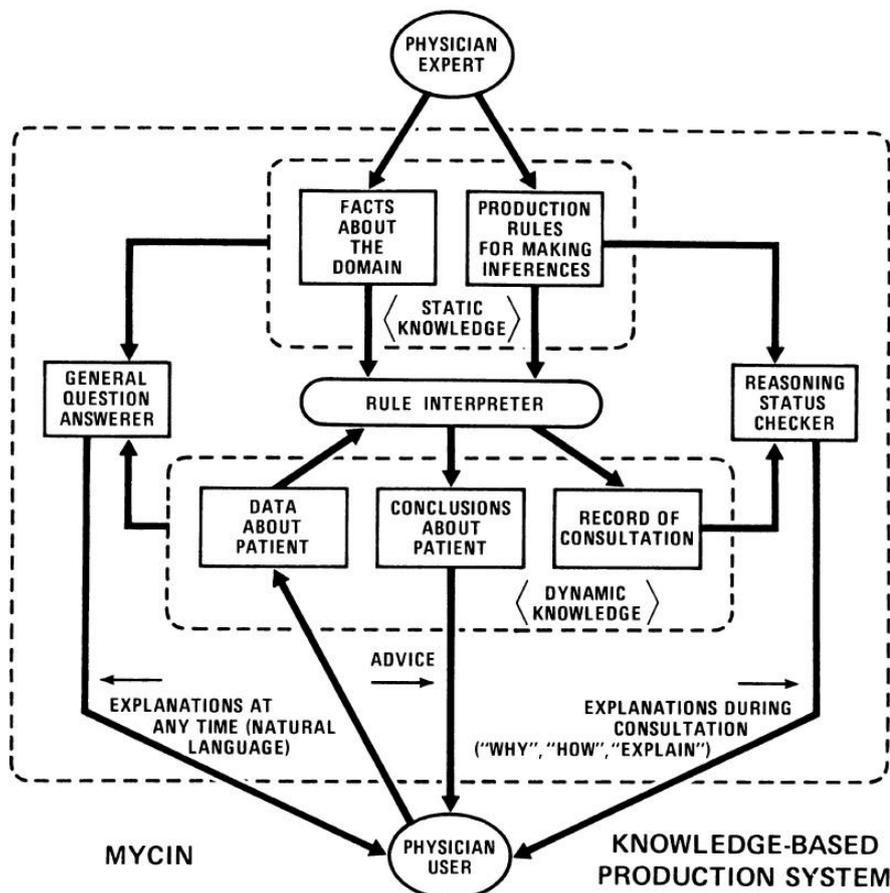


Figure 2 - Diagram summarizing the organization and flow of information within MYCIN. The correlation between this design and the human consultation process depicted in Fig. 1 is discussed in the text. (Figure reproduced from reference 10).

Figure 2-11 Mechanism of MYCIN (Reference [2-17] Figure 2)

It is easier to understand that the concept of fuzzy, which has been attracting attention since the 1990s, is an extension of this expert system. An example of moving toward the adoption of fuzzy logic in incorporating (collectively) qualitative criteria including ambiguity and range, as well as (enumeration of) clear quantitative criteria, such as crisp logic in rules. appeared.

#### (5) Control and process management and monitoring

There is also the aspect that the most difficult thing about control is not the control action itself, but the continuous and stable operation of the control. If you look at the gauge and the value it points to is within the normal range, do nothing. Once an abnormal value is shown, a response must be decided instantly. Also, when there is a complicated situation, what appears on the

instrument display is just the tip of the iceberg, and the situation of other related devices may be more important to deal with.

For large systems, there will be many instruments to check. Automatic control will make use of technology that has been researched and developed to deal with such situations. In any event, various attempts have been made to avoid human visual oversight and relegation of troubleshooting situations to emergency procedures. In the first place, humans cannot stand continuous monitoring and control 24 hours a day, 365 days a year. Moreover, it is difficult to make an accurate judgment in an instant. It wasn't even ten years ago that software agents were reported to have beaten skilled pilots in aerial combat shooting game competitions. And it's not a good idea to force judgment on top of long-term tension. At the beginning of artificial intelligence, there were voices that computers should take over this task.

In the 1980s, expert systems related to such control were also announced. For example, Houston Electric Power's power generation control became a big topic. The target value for the amount of power generation itself changes from morning to night even during the day. There are also seasonal variations. There are also sudden changes due to incidental circumstances. In the power generation plan, the relationship with cost also affects. It is also necessary to quickly respond to failures and troubles. There was no report of a control system that took all of these things into account, but I was able to hear about the effort from Houston Electric Power officials. In addition, process control in the manufacturing industry, etc., has a large element of scheduling based on plans, and the cooperation of each station is also a major factor. The PICON system of LMI (Lisp Machine Incorporated) was developed and marketed as a process control system to deal with such situations.

These early systems did not necessarily show great results, but at least they showed that one of the major applications of artificial intelligence is the field of response systems, including continuous monitoring, which is difficult for humans to do. gave. If we can detect the occurrence of noise, which indicates an abnormality in equipment, at an early stage, we can take action quickly and minimize troubles. In this area as well, development is still progressing as a major issue after the era when methods using neural networks appeared.

In order to improve control accuracy, it was important to collect and classify features from (all) actual data, that is, to analyze the features of the controlled object in advance. After that, in actual operation, it was a traditional method to judge while detecting which pattern it will be. By analyzing abnormal situations and abnormal values indicated by instruments in advance, automation of control and improvement of control accuracy were maintained. In the learning method by deep learning that will appear later, it is possible to simply detect things that are "different", so it is possible to change the approach and detect unexpected abnormalities in normal operation in automatic control. Easier. Replacing the preliminary steps of feature extraction and classification with a neural network made it easier to introduce a general framework of non-panic and mostly successful. It can be said that it is one smart, full of cleverness.

In addition, autonomous driverless driving of automobiles has come to the stage where practical application can be seen. The level of automated driving is set by the SAE standard, and as of January 2022, a system that reaches the 4th level of 5 stages has reached the entrance of commercialization. Experiments on public roads are also underway in several cases, including the DMV (Department of Motor Vehicle) in California, USA. The installation of

stereoscopic vision in unmanned helicopters and cruise missiles at several universities, the quadrupedal robot that can carry luggage on uneven terrain, and the success of Honda's autonomous humanoid robot walking in Japan have had a great impact. Gave. Climbing stairs, running, and recent achievements have made remarkable progress.

In addition, control adjustment called microscopic motion planning has great practical value. For example, the movement of a magic hand is determined by a combination of basic movements such as 6-axis or 8-axis. For example, in three-dimensional motion, in order to move straight toward an object, it is necessary to change the motion of each axis in parallel. With simple teaching tools or programming techniques, it is difficult to learn smooth multi-axis movements, whether manually or automatically.

Many systems have multiple control systems that manage sub-functions. There is a large-scale control system that requires distributed control rather than a system that supervises them all. This is generally the case with large-scale plants as well as with traffic control. Consider the control of the human body. In other words, not everything is controlled by the cerebrum. The realization of these concepts has also been taken up as a field of artificial intelligence. The concept and realization of distributed control systems has been advanced since the 1970s. DCCS (Distributed Computer Control System) is one example, and in Industrial Automation in particular is still being treated as an ongoing issue. Basic operation is measurement and warning at each point. In the early days, there was no monitoring by cameras, and devices such as sensors were mainly assumed. Also, the communication function was not able to exchange information with a large granularity.

The idea of putting intelligence in partial functions was developed by Rod. Brooks, former director of the AI Research Institute and one of the founders of iRobot, for example, Subsumption Architecture, which was also used in the development of NASA's lunar robots.

## (6) image recognition

In the field of image recognition, since the 1970s, it has become possible to handle camera images on computers, and in particular, with digitization, concrete research and development has progressed. Fundamentally, the concept of feature extraction has advanced the capture of objects in images. Recognition by procedurally walking through a 2D color bitmap file was inherently no match for the neural net approach. Practical fields such as recognizing objects in images, separating and identifying multiple objects in succession, reading handwritten characters, such as handwritten postal codes, and reading OCR characters, etc. It was studied while intersecting with the field of pioneering. Then, as an image synthesis or advanced recognition, a challenge was taken, such as whether the face in the image is smiling. Scene analysis and face recognition have come to be seen as practical achievements. These are the results of dramatic technological progress using deep neural networks. We are very close to a situation in which computers can be said to have eyes. Along with this, many surveillance cameras have been installed in every corner of the city, and the problem of securing and using photos posted on SNS has become a social awareness problem.

In this field, feature extraction approaches were actively tested, but in the 2000s, along with the success of deep learning, the previous methods gradually fell out of use. However, as image processing technology continued to advance, comparisons with those before that were clearly empathetic to many people.

### (7) natural language processing

The field of natural language processing (NLP) has long had various struggles, accumulations and applications. It involved dealing with a variety of natural languages, question-answering, or any practical tool for getting close to the 'concepts' and intelligence expressed in the underlying linguistic expressions. If you take out the root part, analysis of words, comprehension of meaning, understanding of context, And natural language dialogue that deals with relationships with other facial expressions necessary for communication

And so on. In question answering, we are looking forward to an era in which artificial intelligence can answer questions about reasons and meanings. Today in the 21st century, I feel that machine translation is reaching a practical level.

One of the great interests of the 1970s was the link with linguistic research on grammar and syntactic rules. N. Chomsky's phrase structure grammar was the topic of discussion. Semantics and syntax were also dealt with, and even going back, general linguistic theory of the early 20th century was often mentioned. In the expression "understanding" of natural language, many attempts were made to understand the meaning of the given description in natural language. In addition, based on grammatical analysis, research and development related to automatic translation has also started.

On the other hand, the field of NLP (Natural Language Processing), which began with instructions to computers using text input in natural language, has progressed to speech recognition and response, and understanding of sentences using general natural language descriptions.

Penetration into the business domain has increased in importance as the ability to process multimedia documents has increased. Experimental workstation technology originating from ALTO, etc., gave birth to STAR at Xerox, and WYSWYG was brought about. Along with the slogan of office automation, sound and color processing has dramatically improved the capabilities of office equipment since the 1980s. improved to STAR gave birth to J-STAR, which was translated into Japanese, became the mother of Unicode, and formed the core of Xerox's XINS.

In historical order, I would also like to mention multilingual text editors at ILA from the early 80's. Not only did it support many languages, but it also had better glyph display using bitmaps, and editing and input functions for right-to-left text such as Arabic. It was also a "living document" mechanism supported by the Lisp environment. The result was the implementation of BBN Slate (Fig. 2-12) that can handle multimedia documents. Subsequent natural language processing packages began with multilingual text editing, morphological analysis, understanding the meaning of words, etc., and have come to support the functions required for today's analysis and business operations.



Voice annotations, multimedia composition, text management, and printing in six languages highlight the BBN/Slate, Release 1.1.

## BBN/Slate 1.1 Package Adds Voice Annotation

Integrates Spreadsheets, Text, and Graphics

BY MARTIN MARSHALL

The addition of voice recordings

1.1 also adds multilingual text editing, management, and printing in six languages, including

Figure 2-12 From BBN/Slate Release 1.1 [2-18]

Advances in NLP since the 1970s have had a major impact on document processing in business. Broadly speaking, the direction can be divided into Document/Stream analysis and attribute/identification analysis.

Document analysis has elements such as document summarization, extraction, document entailment, clustering, and trend recognition. Being Stream aware means being aware of and supporting real-time volatile text streams. It progresses to contemporary roles such as techniques and applications such as Topics, Category, Sentiment, Semantic Similarity.

Attribute/identification analysis is a deep analysis that also includes word or sentence level. Attributes include analyzes such as Entity, Property, and Implication, and Name Matching for identification.

And technical operations such as Extraction, Linking, Relationship, Matching and their applications are being used in various fields.

We are now in an era where we can see applications of various scales, from the backends of large-scale search engines such as Google to small hand-made programs.

Let's switch gears a little and talk about the old days. Practicing small tricks can lead to big hints and achievements. In that sense, programming practice is very important.

ELIZA is known to play an ancestral role in the parrot-backed natural language response mechanism known as artificial incompetence. In 1981, Bit magazine P1257 Nanopico Class, contains sample code(s) of readers for the task of creating an ELIZA-inspired parrot-flip program. One of the posted execution examples is introduced below. The actual text is written in katakana, and the print is difficult to read, so I transcribed it again.

(Computer) What's wrong?

(Human) I am Superman.

(Computer) It must be difficult with Superman.  
(Human) I hate computers  
(Computer) Since when do you hate computers?  
(Human) It's because I can't fly in the sky  
(Computer) Tell me more  
A (human) monster bullied me  
(Computer) Is there a monster?  
(Human) yes, yes  
(computer) please continue  
(Human) I'm afraid of monsters  
(Computer) Since when are you afraid of monsters?  
(Human) Three years ago.  
(Computer) Tell me more  
(Human) Because I am weak  
(Computer) You are weak.

...

The program that does this returns a simple pattern-matching rule and the resulting transformation of the last-minute human input.

For example, as a rule

I'm X is Y

If you know that the input is

Since when will X become Y?

and set to return. Program these rewriting rules. If the user misinterprets this as thinking that the computer is intelligent and that the story has context, it succeeds.

The purpose of chatbots and the like is often to give advice as a reply to a user's question, so it cannot be said that the purpose is long dialogue. Moreover, if it is useful for the work, the user will be satisfied, so it can be said that there is utility value even in the present age.

## 2.4. Role of Lisp

When Lisp appeared and began to spread, it was used by highly specialized professionals such as software developers, especially language processor developers, and those who were close to the early application fields but were not satisfied with the existing methods. I think it was a time when strong people started looking for new challenges. In order to explain the features of Lisp and its role at that time as concisely as possible, I have transcribed it again.

First, Lisp, for which it is named, is a language based on "list processing". List Processor. "List processing" can be recalled as a list of "items", and it is the grouping of multiple items and the general processing for them. For example, write it as (a b c). This represents a lump of three terms a, b, and c. It's called a list representation. A list is an ordered pair and the position in the list is meaningful. (a b c) and (b a c) are not considered identical. This means of expression is consistently used for both the data to be processed and the description of the processing procedure. There may be lists within lists. This realizes a hierarchical structure.

Second, not only the notation but also the actual storage method is implemented accordingly. The external representation matches the internal structure. The internal structure is laid out in

a space that is united by "cells" rather than in the usual addressable memory space. A "pointer" to the cell is used to locate the cell. An indivisible cell that is a constituent element is called an atom cell. So-called variables and the like are included in it. Anything else is called a "cons cell". As a special atom cell, we place the existence of the symbol NIL, which represents nothing. When using a pointer to indicate whether it is true or false, NIL indicates false, and everything else indicates true. A cons cell is a cell that joins two cells. Also called dot pair. In other words, it is a sequence of two pointers. The front part is called the car part, and the rear part is called the cdr part. When there is an operation to create a cons cell, one cell is assigned and two pointers are created there. To put a pointer to another cell in the cdr part and indicate that there is nothing beyond it, put a pointer to NIL to make it an internal representation of the list. The elements of the list put pointers in their respective car parts. Cells are consumed as the program operation progresses. There is a parallel process of keeping track of available cells, so that when there are no more available cells or at an appropriate point in time, the consumed cells that are not referenced by others can be reclaimed and reused. This is called garbage collection.

This kind of explanation of the management of cells, which is the internal structure, and expressions using it is also an operational concept explanation of the invention of an autonomous memory management mechanism. When a computer program is executed autonomously, it is necessary to be able to rearrange the program itself, change and expand the program logic, and change the processing target in memory through some mechanism without stopping. In other words, it can be said that this is the beginning of machine learning. And since resources are finite, a mechanism for collecting and reusing them will probably be essential. Alternatively, automatic regeneration or scale expansion of resource space is required. However, there is an upper limit.

Figures 2-13 show the internal representation of the program procedure, beyond the representation of the data. By expressing in this way, it is possible to have an internal expression that matches the external expression and to place it in the same space as the target data. Dynamic changes are also possible.

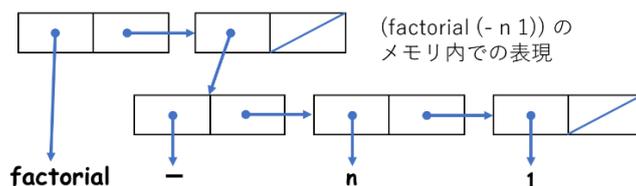


Figure 2-13 Representation in memory of (factorial (- n 1))

Third, Lisp programs are written based on functional notation and execution techniques. A program is handled by a series of function calls  $f[x,y]$  or a nested structure such as  $f[g[x], h[y]]$ . Since it's a function, basically every Lisp program execution returns a value. Then, the program is described as a list whose first element is a pointer to the function to be executed, such as  $(f (g x) (h y))$ . Putting these promises, we put all the processing objects and processing procedures into the framework of the list processing. The fact that the value of a variable changes can also be expressed by collectively managing it by connecting the cons cells of the pointer pointing to the "variable" and the pointer pointing to the "value". In order to improve the performance of the system, basic functions and frequently used functions are developed in advance (prepared in machine language, etc.) and associated with symbols that serve as names

that refer to them.

Execution of a function is based on calculating the actual value of the specified argument and then calling it. On the other hand, prepare what is called "form" or special form, special form, etc., and also prepare a form that does not perform "calculation of value" in advance, which is called evaluation. The function responsible for executing the "form" is passed the list of arguments as is. Only necessary parts are traced in the list according to a prescribed method, and execution proceeds while evaluating them.

A form called "McCarthy conditionals" was first provided as a form of basic conditional execution, and its existence became common knowledge, called the COND form. As a simplification of that, if was prepared in many processing systems. Using the if form, the factorial calculation, with its name factorial, can be defined as follows:

```
(if (= n 0) 1 (times n (factorial (- n 1))))
```

Such a form can be stored in memory in this form. Basically, you can call yourself in your own definition, and you can write processing concepts that are suitable for recursive expression. This was groundbreaking for the situation at the time. In addition, since each branch performs the same processing of the search tree and tracing it, recursive program description was indispensable for such algorithms.

It is important to be able to write, to be able to express, to be able to work anyway, and to be able to process it as a processing target if necessary. It was a problem after that. Many people were fascinated by this dream challenge, which enabled computers to do things that had not been possible before. At the forefront of research at places such as the Massachusetts Institute of Technology and Stanford University, attempts have been made to implement artificial intelligence concepts using this Lisp. "Dialects" of Lisp, with various modifications and improvements, were created and used in many places.

## 2.5. The People Called Hackers and the Massachusetts Institute of Technology Artificial Intelligence Laboratory

In the 1960s and 1970s, there were many people who leveraged their imagination and execution to push the world of computers beyond data-processing machines into never-before-seen directions. Following in the footsteps of these people is of great significance in tracing the history of artificial intelligence.

Hackers: Heroes of the Computer Revolution, 1984, by Steven Levy, focuses on these people. Wikipedia also has an overview. The activities of people on the west coast who created the prototype of today's personal computers that appeared in that era, Bill Gates, Steve Jobs, Stephen Wozniak, etc. appearing around Altair, Apple II, IBM PC, PDP-1, etc. are famous. Hackers begins with the MIT model railroad club in the 1960s, introduces MIT-affiliated Hackers, and concludes with a description of Richard Stallman in the final chapter. It is written. The history of the MIT Artificial Intelligence Laboratory, which became the parent body, is placed on one axis. Various events at the AI Lab, revisions to the driver software for Lisp machines and installed equipment, etc., were the major starting points for the Free Software Foundation's origins. The author also helped for about 10 years. Concepts such as GNU and copyleft were

born, and activities to disseminate and permeate them were carried out (Fig. 2-14). It was also called VP for Japan. Also, Emacs, GCC, etc. were developed at the Free Software Foundation. There's a lot to say about these, but I'll stop here in the context of Applied AI.

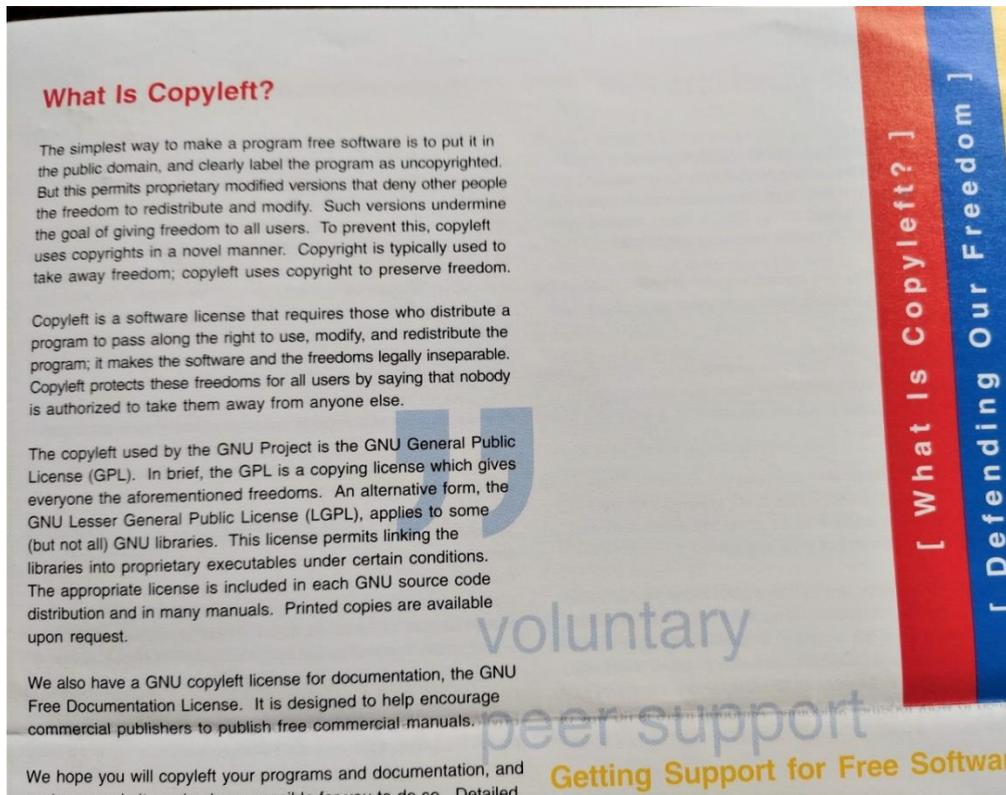


Figure 2-14 From the FSF pamphlet created and used in the 1990s (photographed by the author)

If stereotyped data processing programming is called deterministic programming, programming that attempts to exploit these various areas is non-deterministic programming, as Nils Nilsson called these areas. There were many people who, so to speak, pioneered programming in uncharted territory through their own abilities. In the field formation that followed, and in the sense of putting the intelligence that these people have on computers, we can call them early attempts at artificial intelligence.



Figure 2-15 The building where the MIT AI Lab was located in Tech Square (1986)

The Massachusetts Institute of Technology Artificial Intelligence Laboratory (MIT AILab) was established in 1970 and located in Tech Square (Fig. 2-15). A well-contrasted research institution is the Artificial Intelligence Laboratory at Stanford University. In 2003 AILab merged with the Computer Science Laboratory (LCS) to form CSAIL. Since both AILab and LCS are based on Project MAC, which started in 1963, it can be said that they were back in their original sheath in 2003. In AILab and its predecessor, there were many challenges in the artificial intelligence field, and the field was formed. In neural network research, it was not necessarily the most advanced, and at that time it was before the current breakthrough. Around that time, CSAIL moved into a newly constructed building and was busy getting it into orbit (Fig. 2-16). The author received a room as a Visiting Scientist for one year in 1993 and half a year in 2002. The three months in 2012 will be the last period of stay, but since 1985 we have continued exchange almost every year.



Figure 2-16 MIT Stata Center Building containing current CSAIL (2014)

Marvin Minsky, Patrick Winston (1972-97) and Rodney Brooks (1997-2003) served as directors.

Professors who are members of this research institute give lectures at undergraduate and graduate schools such as EECS (Electrical Engineering and Computer Science), host laboratories that accept students, introduce external funds, and conduct research commissioned by US government agencies. Since the researchers who stayed at this institute for a fixed period were solely for research purposes, they were not assigned the role of visiting professor, and their official title was visiting scientist. The author himself conducted research on the introduction of external funds during his stay, which was also evaluated as an achievement. As for the obligation of undergraduate education, I was able to hire lecturers with my own research funds and apply them to a certain extent. It all depends on whether the research is outstanding or advances the field.

Because of this kind of climate, the graduate students who were accepted were also researchers at the institute, and there was no division between ranks and ranks, and lively discussions and personnel exchanges took place. Almost every day, seminars, lectures, and young debates were held in the open space. The atmosphere was full of discussions about what I would have thought if it were me. These aspects influenced the free software activity and the emergence of various ideas mentioned above. The days when the Director was wearing a suit implicitly meant that there would be visits by key figures from sponsoring government officials and cooperating companies. It is difficult to maintain such an atmosphere every day for many years. But it continued. Director Winston used to say that the power of the director was to raise a few big projects so that individual researchers didn't have to worry about small funding. And he silently apportioned the staff's resources. In addition, he served as chairman of the federal government's research planning committee for the entire United States, and made significant behind-the-scenes contributions. He also served several terms as president of the AAAI (American Association for Artificial Intelligence). I think it was around until the early 2000s. He was also a good listener. I made a memo to understand it, and sometimes used it as a reference to summarize it. Figure 2-17 is a memo that he compiled after discussing what he

would say in his 2017 lecture on Japan. He discovered its existence after his death. Surprisingly well put together. In the daily life of artificial intelligence researchers, we often try to test our own actions and judgments as examples in research subjects. I also remember discussing how it would be nice to have slides automatically created after making something like this. You can see that every work for him is a hint to artificial intelligence research. He was in charge of the How to Speak lecture every year. It was a famous lecture that gathered students and researchers from various fields. Also, as his last work of his own, he was about to put together a book called Communication and put it out into the world. It is a pity that it is incomplete. The author of this book also naturally gave lectures on business negotiations and presentations assuming them, and attracted attention for several years before retirement, gained a large number of students, and also gave regular intensive lectures at Hanoi University of Science and Technology. I was in charge of the subject.

## Outline suggestions from Masayuki

Future of Artificial Intelligence through my view with 40 years of experiences

AI has long history of research and development  
and Deep net is one of the results from the history

MIT AI lab played various roles on AI such as...  
I led various activities such as... as the director and as a researcher...

Many times I was involved with outside activities such as...  
government level, and civil level,

I was once AAAI president, my role/feeling/aim was...

I think current AI situation is ...

Then,  
Messages to current AI developers and researchers  
Messages for academic people,  
Messages for commercial people,  
Messages to the people who are interested in AI but no knowledge, and no experiences

Figure 2-17 Professor Patrick Winston's lecture memo (discovered after his death in the materials received)

When viewed as a whole, there were many studies and experiments that never saw the light of day during the activities of the AI Lab. For example, in 1993, an experiment was conducted using a real object, in which a camera and a magic hand were used to search for a specific item from a stack of keys randomly placed on a desk. Move the cursor on the bitmap display that started to be introduced, and when you pass through the part that is a hot spot, it will be highlighted. There were also people who said, It also reminds me of the sight of a minicar running down the corridor and the multilingual text editor.

After the Great East Japan Earthquake, the first robot to walk around the reactor core of a nuclear power plant was a robot that could move around on its own while recognizing its surroundings, a dream that Director Rodney Brooks had dreamed of since the early 1980s. A spin-off, iRobot, has launched the Roomba.

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