Title: Artificial Intelligence Used in Financial Markets

Artificial intelligence used in financial markets

Artificial intelligence-based technologies are also used in the financial markets. As will be discussed later, artificial intelligence has its strengths and weaknesses, and there are not as many things it is good at in the financial markets as in other areas, but there are still examples where artificial intelligence is being used. Before introducing these examples, I will first explain why I am writing this report now that the boom is over, that the period of the boom has nothing to do with the period of rapid progress or diffusion of the technology, and what the term "artificial intelligence" means in the first place.

In this report, we have provided a lengthy explanation of how artificial intelligence works and a very brief explanation of its application areas. This is because if you don't know how it works, you won't know why it can be used there, while if you know how it works, you will be able to judge for yourself where it can be used. Please understand that this report is written according to this policy.

Misconceptions during the boom

As stated in my profile, I have been the secretary of the Financial Informatics Research Group*1 of the Japanese Society for Artificial Intelligence since FY2016 (currently the lead secretary), and I have been presenting my research since 2008, when this research group was established. This is the only research group that specializes in finance among the research groups belonging to the Japanese Society for Artificial Intelligence, and is probably the only place in Japan where the application of artificial intelligence to the financial field is discussed in a specialized and academic manner. When it was first established in 2008, artificial intelligence was not considered by the general public and was in a so-called "winter period," but in 2016, when I became secretary, the artificial intelligence boom in the general public had just begun. I think this boom lasted for about three years, until around 2018. According to the research firm Garthner, artificial intelligence is currently in a "period of disillusionment.

During this boom, I spoke at various places such as the Bank of Japan*3, but now the only time I speak about artificial intelligence itself is when I give guest lectures at Kyoto University*4. At times, much of my lecture time was spent trying to counteract the claims that artificial intelligence that surpasses human brains in every field would soon emerge, that there would be massive unemployment, or, in

extreme cases, the extinction of the human race*5. Unfortunately, there are not a few people who never talked about it before the boom, but when the boom came, they spoke eloquently as if they were very knowledgeable in the field, and when the boom went away, they stopped talking about it again, spreading many misconceptions in the public.

Therefore, if you write a report like this during the boom period, you have to devote a lot of text to deny such misconceptions that can normally be ignored, and the report must be less informative than the amount of text. In addition, when reading the report after the boom, one might wonder why they devoted so much text to denying such a silly theory, and it was possible that knowledge of the historical background would be required to understand the structure. Now, you don't need to touch on such matters to that extent. That is why I decided to write this report now that the boom has ended*6.

● Mystery why the boom came at this time: nothing to do with technological progress or diffusion

This is true of any boom, but there is little relationship between the time of the boom and the time when the technology develops dramatically or the use of the technology becomes widespread*7. In particular, there is little relationship between the time of the boom in the general public and the time when the technology really becomes widespread. Among those who specialize in research and development, there is even a question, "Why is this boom happening now? The end of the boom in the general public has had little impact on the actual progress of the technology or the speed of its diffusion.

Rather, the fact that the boom has passed is the flip side of the fact that it has begun to be used as a matter of course in general society. It is no longer necessary to say that it is artificial intelligence. For example, when an advertisement for an image processing application advertises a function that removes people from a landscape photo, it is no longer necessary to say "using artificial intelligence. In the stock market, the IT bubble of the early 2000s is often referred to as the Internet bubble, but I think it is similar to the fact that after the bubble burst, more people used the Internet and the world without the Internet became unthinkable. The spread of artificial intelligence is probably only just beginning.

What is the nature of what is called artificial intelligence?

What is artificial intelligence anyway? We can get an idea of what areas artificial

intelligence can be used in if we know how it works. If you simply ask for a list of where it is used, you will not know whether it can be used in the areas not listed, but if you know how it works, you will be able to judge for yourself where it can be used, and you will be able to avoid suggesting things that cannot be done with artificial intelligence at all.

The website of the Japanese Society for Artificial Intelligence (JSAI) has a page explaining "Artificial Intelligence Research" *8, which says, "Artificial Intelligence (AI) is a machine with intelligence. There are two types of AI: strong AI, which is a truly intelligent machine, and weak AI, which is a machine that appears to be intelligent, i.e., does some of the same intelligent activities as a human. " and lists technologies that use computers to process data, such as genetic algorithms, expert systems, speech and image recognition, machine learning, natural language processing, and information retrieval, as examples of research areas.

In the general public, these computer data processing technologies are currently referred to as "artificial intelligence. Although the term "weak artificial intelligence technology" would be more accurate according to the above definition, this report will also refer to it simply as "artificial intelligence. The term "artificial intelligence" has a very broad meaning, but it is also a very ambiguous term. It can be said that by making it ambiguous, it is a research field that has given birth to many ideas based on flexible thinking without limiting the research area. On the other hand, however, the overly strong image of the word has sometimes led to excessive expectations and disappointment in this field.

To put it very simply and without fear of misunderstanding, artificial intelligence is a new data processing method by computers in general. Therefore, as things that used to be called "artificial intelligence" become more widespread, they are no longer called "artificial intelligence" in every case. The information retrieval listed above is now simply called "search," and refers to the technology used to search for keywords when looking up something on the Internet. 9, but nowadays, even if the technology is based on what used to be called artificial intelligence, it is simply called "search.

How Artificial Intelligence Works

First of all, I would like to say that although we call it artificial intelligence, the way it processes data is completely different from that of humans. The approach is completely different from that of humans. Moreover, as technology develops, we are not getting closer to it, in fact, we are even moving away from it. For example,

in automatic translation technology, the current mainstream technology ignores grammar and word types and simply converts them into numerical values before processing. It is better to assume that there are many things that are easy for humans but completely impossible for artificial intelligence, rather than most of them. Conversely, there are a few areas where artificial intelligence can do things that are difficult for humans with ease. It is important to understand how it works in order to understand where those areas are.

In 2016, news of a top Go player being defeated by an artificial intelligence shocked the general public*11. Here, we will take a look at how artificial intelligence works, specifically using Go as an example. Please note that there may be some parts that are not strictly correct, as I am trying to explain this in a way that is easy to understand without fear of misunderstanding.

Suppose now that the situation is as shown in Diagram 1*12, where White is considering whether to place in the position shown in the diagram. In the case of a human player, he or she would have to think about joseki, the overall situation, and reading the situation ahead of time. In the case of an artificial intelligence, however, it would place the figure there for the time being, and then calculate the win rate after trying to develop the figure by itself a great number of times in a battle. If it is not overwhelmingly victorious, it will consider a different location. If we repeat this a great number of times, we can cover many of the possible future developments and calculate the winning rate when we place them there.

In the fight against itself, artificial intelligence does not need to be strong from the beginning. In the beginning, it is fine to just place it in the right place, and if the probability of placing it in a place where it is likely to win increases little by little, that is all that is necessary. This is a huge task, but in fact, it does not require any knowledge of Go. Even I, who do not know Go, would be able to find a move that would astonish professionals in about 5,000 years. This kind of simple but repeated process is what artificial intelligence is good at. And while artificial intelligence generally requires a large amount of data, in some cases, such as in the case of Go, it can generate game data through its own games.

How Neural Networks Work

Let me attempt to explain in a little more detail. I will explain very briefly, without fear of misunderstanding, how neural networks, one method of machine learning, work. Deep learning (deep learning), which became known to the general public during the boom, is an innovative way to successfully connect and coordinate a

large number of neural networks.

See Figure 2. This figure and the following explanation is a concise version of Steven Miller's site*13, so please refer to it for details. Let's assume that the leftmost column is input data and shows the location of stones in Go. Since the Go board is 19 x 19 = 361, 361 0s or 1s in this column would represent the presence or absence of stones on the board. Since there are black and white stones in Go, 361 x 2 = 722 0s or 1s are enough to represent the complete board.

Now, the data of 1 is entered in the upper left corner, and it is multiplied by the weight 0.8 to proceed to the top hidden layer in the second column. The input data below that is also 1, with a weight of 0.2, so it is multiplied by this to proceed to the hidden layer. These add up to 1 x 0.8 + 1 x 0.2 = 1. We work on processing this number using something called a sigmoid function, and the result is 0.73. Since there should originally be 722 input layers, we multiply the 722 input data by the weights and add them together to finally get the top number of the hidden layer. If there were 100 hidden layers, this process would have to be repeated 100 times before all the hidden layers are finally obtained. The rightmost column is the output layer, but only one, and the results of the 100 hidden layers are added together with the same weights and rounded to the nearest hundred. This is the output value.

The answer to this output value. The answer is the board situation entered and then set to 1 if white is winning and 0 if white is losing. This answer does not have to be the result of the actual game, but can be the result of a battle between the artificial intelligence and itself. This time the answer is 0 and the output value is 0.77, so reducing the output value will bring us closer to the answer. See Figure 3. Adjust the weights so that the output value is reduced. Note that we do not adjust the weights to be completely 0 here, but to be slightly smaller. This is because the data that white lost earlier is not absolute, but only that there were such cases. There are cases where White wins even in the same situation, and the data from many such games will be collected and gradually adjusted in the correct direction.

This adjustment is called "learning. This is why neural networks are called a type of machine learning. When you hear the word "learning," you may have an image of acquiring some knowledge or experience independently. However, when we talk about learning in the field of artificial intelligence, we are talking about this kind of numerical adjustment that brings us closer to an answer. What we are doing is very different between human learning and artificial intelligence learning. Also, learning in artificial intelligence requires a lot of data. Humans can learn from a single experience by thinking about what is relevant, but this is not possible with artificial

intelligence.

What Artificial Intelligence is Good at and Bad at

The mechanisms of artificial intelligence we have seen so far show what it is good at and what it is not good at. Artificial intelligence is good at Go because the rules and the size of the board are predetermined, the same thing happens repeatedly, and it can be tried many times. Even if a Go player is not very smart, he or she can cover many cases by repeating the game a frightening number of times. Go can be reduced to a simple task if it is very subdivided. If the rules change over time, or if the board size changes, or if the same thing happens over and over again, it becomes impossible to cover a large number of cases in a large number of repetitions, because it becomes impossible to try again and again.

Artificial intelligence is not inherently smarter than humans; it classifies and analyzes patterns in past data. It is not creating anything new. Conversely, humans are unusually strong for the number of games they have played. Humans can learn from their limited experience through thinking, but artificial intelligence cannot. Artificial intelligence cannot create something from no data, it cannot create the game of Go, and it does not know whether Go is fun or not. Artificial intelligence is a useful tool for humans.

In summary, Artificial Intelligence is not smarter than humans, but it can process large amounts of data faster, without getting bored, and it is good at problems that can be practiced repeatedly by one person, that have a pre-determined scope to handle, and that have the stability of the same thing happening over and over again.

Can also "process" sentences

Here is how artificial intelligence processes sentences. So far, we have seen an explanation of how artificial intelligence works, and you may be asking yourself, "Can't it only handle numerical data? Can you handle sentences?" Many people may think that this is a good idea. However, just as the Go board is converted into numerical values, text can also be "processed" by converting it into numerical values. I would like to emphasize that this is "processing" of sentences. It does not mean that we understand the "meaning" of the text. However, I would like to show that even if you do not understand the meaning, you can perform a variety of useful processing through the accumulation of a great number of simple processes.

The books "Human Language, Machine Language "*14 and "The Weasel Who Doesn't Want to Work and the Robot Who Understands Language "*15 by Dr. Ai

Kawazoe provide a very clear picture of how artificial intelligence processes text. The book is written in an easy-to-understand manner. Artificial intelligence excels at sentence processing, which includes speech recognition with a limited range of topics, aimless chatter, answering oddly maniacal questions, displaying what is in a video, and determining whether a sentence is right or wrong, which can be reduced to a logical formula that does not require prerequisite knowledge or situational understanding.

What artificial intelligence is not good at is understanding common sense situations and reading the speaker's intentions. For this reason, strictly written sentences that are difficult for humans to read, specialized and exacting talk that can only be understood by drawing on a technical dictionary, and conversely, chatter that has no right or wrong answer at all, are the easiest to process. Let's look at how the process of answering an oddly maniacal question is handled here.

●The process of answering oddly maniacal questions

For example, "Who founded the Edo shogunate in 1603?" Consider the question. In the case of a human being, you may think, "Since this is the beginning of the Edo Period, he must have been the winner of the Sengoku Period that preceded it. Or, you may answer by recalling a scene from a historical drama, and many people have memorized it. However, the method of artificial intelligence is completely different.

First, determine what is being asked. Here it is "Who?" We know that a person is being asked because he or she is being asked, "What do you want to do? There are many techniques to get to this point, but we will not go into them here. Next, we do a search. The search keywords are "1603" and "Edo Shogunate. Here, we do not consider what period "1603" is or what political form "Edo Shogunate" refers to. Anyway, we will search with these keywords. You can imagine that you are doing a normal search on the Internet. Then, a very large number of pages will come up as candidates. For example, "The Edo Shogunate was a warrior government of the Tokugawa clan based in Edo Castle, which was established in Edo by Ieyasu Tokugawa, who was appointed barbarian general in 1603, and ran the government of Japan for 265 years until the 15th shogun, Yoshinobu Tokugawa, returned the government to the Imperial Court. A human being would be able to tell from this one sentence alone that the answer is "Tokugawa Ieyasu opened the door", but an artificial intelligence cannot understand the meaning of the sentence and cannot judge that the answer is written in the same way as a human being (nor does it

understand the meaning of the question in the first place). Therefore, the answer cannot be determined from this sentence alone. The answer is derived by statistically processing a large number of pages containing these keywords.

These large numbers of pages naturally contain "1603" and "Edo Shogunate," and we extract the persons placed near these keywords. As in the example above, we can see that "Tokugawa Ieyasu" and "Tokugawa Yoshinobu" are often found near these keywords, but we create a ranking of the people who appear with the highest probability or who were placed most frequently and most closely, and then synthesize them to derive "Tokugawa Ieyasu". The "Tokugawa Ieyasu" is determined based on the fact that he appears more frequently and more closely together than the "Tokugawa Yoshinobu".

- I'm not good with general sentences with answers.

Therefore, artificial intelligence is not good at questions that have general sentences with answers already written in the text and that cannot be found by searching the Internet. For example, "Fukuko-san picked up a newspaper in her living room and went through the kitchen to her work room. Where is the newspaper now?" (An example of this sentence can be found in the book*15 mentioned above.) A human being would immediately know that the answer is "workroom. However, an artificial intelligence does not know the meaning of the sentence, so it does not know the answer. Think of it in the same way as the procedure explained above.

First, we see that what is being asked is location. Next, we search for keywords such as "workroom," "living room," and "newspaper. Then, many pages of property listings, etc. will be returned. It is natural that you cannot find the answer in these pages. It is unlikely that "work room" will appear near these keywords more often than others. Of course, it is impossible for there to be many pages explaining something as obvious as "If a person picks up a newspaper and goes through the kitchen to the workroom, the newspaper is in the workroom. This is because they don't bother to explain such an obvious thing. This is different from the case of "Tokugawa Ieyasu" mentioned earlier. There are many pages that explain that "Tokugawa Ieyasu established the Edo Shogunate," so it is easy for an artificial intelligence to derive the answer. On the other hand, this "Fukuko-san" problem is very difficult for artificial intelligence.

- Inability to grasp the situation with common sense and read the speaker's

intentions

What is easy for humans but extremely difficult for artificial intelligence is the common sense understanding of the situation and reading the speaker's intentions. As another example from the book*15 mentioned above, when a person is told to "hang the laundry out to dry," a human being would try to hang out all the laundry that is there. A human being would not hang out one or two loads of laundry and then leave the rest to dry. An artificial intelligence, however, does not know how many sheets to hang out to dry.

On the other hand, when asked to bring a plate from the kitchen, a human being would bring only the necessary number of plates. A human being would not bring all the plates in the kitchen. However, artificial intelligence does not know how many plates to bring. A human knows what the task is and can compensate for any ambiguity. Artificial intelligence, on the other hand, does not know that, so it cannot compensate for even the slightest ambiguity. Therefore, artificial intelligence is better at very strictly written texts, such as legal and patent information.

● Artificial intelligence used in financial markets: tools to assist investors and in peripheral areas

Now I will write about artificial intelligence used in the financial markets. When you hear about artificial intelligence in the financial market, you may have an image of artificial intelligence automatically trading. Of course, there is such a thing, but the activity of artificial intelligence is rather more in the tools and peripheral areas that assist investors. Thanks to this long preamble, I think you can see why this is an area where artificial intelligence excels. In fact, I think many of you may have figured out the areas in which it can play an active role without the explanation from here on.

Although financial markets seem to have a lot of data at first glance, the behavior of trading participants, trading systems, and historical backgrounds differ from period to period, and the same thing does not happen exactly over and over again like in the game of Go. As mentioned in a previous report, the uniformity of the same thing happening over and over again is even questionable*17, and moreover, it is impossible to generate new data in a battle among ourselves. In this sense, the financial market is an area where artificial intelligence is not good at, but there are many areas where it can play an active role, including peripheral areas.

Thanks to the long preface, I can almost skip the explanation of how it works from here on, so I will be brief. I have identified the areas where artificial intelligence is

active in the financial markets as "text processing," "algorithmic trading," "enforcement of unfair trading," and We organize them into four main categories, "Institutional Design." Institutional Design" is my specialty and is a discussion of regulations and rules using artificial markets. I will discuss this in a separate report in the next issue.

Processing of sentences

There are many texts in the financial markets. In fact, the largest number of research presentations at the Society for Artificial Intelligence (SIA) Financial Informatics Research Group*1, of which I am the secretary, are on the processing of sentences. There are so many sentences in the financial markets that it is impossible to read them all, and processing them well seems to be a skill in high demand.

For example, there is the extraction and summarization*18 of important parts of financial statements. By summarizing sentences that describe a company's business and words that are often used to describe business performance in advance, and then extracting the important parts that apply well compared to the sentences in the financial statements, we can extract the parts that are important to the business performance. If you combine them well, you can create a summary of the earnings report. Since the sentences expressing business performance are stable and do not differ greatly from company to company, this is a field in which artificial intelligence excels. Recently, there seems to be a demand for processing integrated reports and texts related to ESG*19.

The ability to summarize also means that if there is an original text, the text can be created from it. In some cases, news articles immediately after a company announces its financial results are already written by artificial intelligence based on the text of the earnings report*20. This is what they are good at. As we will discuss later, some algorithmic trading involves reading the freshly generated text to make trading decisions. So the world is already coming to a point where artificial intelligence writes sentences, and artificial intelligence reads those sentences and makes buying and selling decisions.

Others include classification of stocks. It seems that the system determines how similar stocks are to each other from the text and creates, for example, industry classifications*21 or automatically generates investment themes and lists related stocks.

Although it is out of the realm of finance, articles written by artificial intelligence

are being used by major newspapers for first-hand reporting of sports results, etc.*22 There are also tools for checking contracts and other legal texts, etc.*23 Automatic translation of foreign languages has also recently been improving in accuracy. In fact, the mainstream method used to be to try to use the same methods as humans, such as grammar analysis, but around 2017, a method appeared that completely ignores such methods, quantifies everything, and translates based on statistical similarity alone, resulting in a dramatic increase in accuracy*10. This is a good example of how performance can sometimes be improved.

Algorithmic Trading

As we have discussed in our previous report*24 on algorithmic trading, artificial intelligence is sometimes used in this area. When placing an order for a large number of shares, the order is divided into smaller orders so as not to have a large impact on the market, and this is done automatically by a machine, an execution algorithm. The execution algorithm uses artificial intelligence to determine whether a stock is likely to rise or fall in the short term, such as within a few minutes, based on the condition of the board, and then hastens or slows down the buying process*25. This is an area where artificial intelligence excels, as similar patterns can be seen repeatedly.

Artificial intelligence alone is not often used to automate stock selection and trading, but it is used in some cases for factor investing. Factor investing is a method of holding many stocks based on a certain quantitative index, for example, buying many stocks with low P/B ratio (market capitalization/equity capitalization). In most cases, it is a synthesis of a large number of factors. Artificial intelligence seems to be used to create new factors and to change the weighting of the factors over time*26.

Also, as mentioned in a previous report*24, there used to be an artificial intelligence that automatically analyzed the text informing the results of the Bank of Japan's monetary decision meeting and instantly made transactions*27.

Enforcement of Unfair Trade Practices

Artificial intelligence is playing a major role in crime control, not only in the financial sector, but also in the analysis of surveillance camera images. Determining whether or not the criminal's photo and the person in the security camera are the same person, i.e., whether or not the faces are similar, and detecting suspicious

movements, which are very common, are areas in which artificial intelligence excels. This area of policing is certainly one of the areas that will benefit the most from the widespread use of artificial intelligence, and it is also the area where abuse is of greatest concern*28.

The use of artificial intelligence to control unfair trading was introduced in a previous report*24. For example, there is technology to find posts on the Internet that are intended to manipulate the market. It searches the vast Internet space for posts that have similar characteristics to past posts intended to manipulate the market. Processing such a large amount of data is one of the areas where artificial intelligence excels, and it is also an area where it can play an active role because the posts have typical characteristics. The Financial Services Agency is already using such technology to assist in enforcement*29, and the Tokyo Stock Exchange is also using artificial intelligence to find trades with similar characteristics to past unfair trades from the vast amount of board data*30.

On the other hand, there is also concern about unfair trading conducted by artificial intelligence. As discussed in detail in a previous report*31, there is research that shows that artificial intelligence can discover trading strategies called market manipulation even when the creators and users of such intelligence do not intend to do so*32. Some may exploit this fact to get away with saying, "Artificial intelligence did it on its own. Discussion of legal reform is needed.

● Artificial intelligence used in the financial market: a useful tool

Artificial intelligence has very different strengths and weaknesses from humans. What humans are good at is done by humans, and what artificial intelligence is good at is processed using artificial intelligence; in other words, it is used by humans as a convenient tool. Artificial intelligence itself is not good or bad. Like scissors, whether it is used in a good or bad way depends on the people who use it. The boom in artificial intelligence has ended, but its spread is far from over. Let us pay attention to how the application fields will expand in the future.

(*1) The Japanese Society for Artificial Intelligence, Financial Informatics Research Group Website
https://sigfin.org/

(*2) Gartner, "Gartner, "Hype Cycle for Future-Oriented Infrastructure Technology in Japan: 2020", 2020.
https://www.gartner.co.jp/ja/newsroom/press-releases/pr-20200910

(*3) Takanobu Mizuta, "Short Presentation: Application of AI in the Market and Future Possibilities", Bank of Japan, Settlement Mechanisms Department and Financial Markets Department Joint Conference "AI and Financial Services and Financial Markets", Part 2: Panel Discussion "AI and Financial Impact on Markets," Bank of Japan, April 13, 2017.
http://www.boj.or.jp/announcements/release_2017/rel170412c.htm/

(*4) Lecture materials are available below.
https://mizutatakanobu.com/20210118.pdf

(*5) The spread of such misconceptions seems to have been worse in the West than in Japan. For example, the following book states that many (non-professional) celebrities claimed that artificial intelligence would destroy the human race.
Jean-gabriel Ganascia, "Le mythe de la singularite", Le Seuil, 2017
(Japanese translation by Naoko Ito, supervised by Shigehiro Kobayashi, "It's time to talk about the truth of artificial intelligence," Hayakawa Shobo, 2017)
https://www.hayakawa-online.co.jp/shopdetail/000000013576/

(*6) Of course, it is important for experts to work to clear up misconceptions. The Journal of the Association for Artificial Intelligence published a special issue on the boom in 2017, and in the description of that special issue below, it points out that it is important for researchers to engage in activities to clear up misconceptions. In the case of artificial intelligence, this is the third boom, and many researchers must have realized that it is important to clear up misconceptions in order to avoid the great disappointment caused by the end of the previous boom in the 1980s.

Fujio Toriumi, "On "Artificial Intelligence from the Viewpoint of Mass Media," a small special feature," Journal of Artificial Intelligence, November 2017.
https://doi.org/10.11517/jjsai.32.6_927

Incidentally, it is known that the public's excessive expectations of artificial intelligence during the three booms were similar: during the first boom in the 1950s

and 1960s, people were told that "robots will take many jobs" and "cars will be fully automated. Newspaper articles such as "Driving will become a reality" were seen.

Shigeo Kawashima, "Document 1: Kawashima, Member, Presentation Material," AI Network Society Promotion Council, Ministry of Internal Affairs and Communications, Subcommittee Meeting, November 9, 2017.
https://www.soumu.go.jp/main_sosiki/kenkyu/ai_network/02iicp01_04000117.html

(*7) Of course, this is not entirely irrelevant. A lot of data can now be collected, and there have been cases where the challenge of artificial intelligence seemed amazing to the general public at the time, for example, a top professional Go player lost to artificial intelligence. Now that Go and Shogi research has come to a close, research on "clearing a video game," which is even more difficult for artificial intelligence, has become popular, but it is undeniable that it seems easier and less exciting to the general public than winning against a top professional Go player. For example, there are the following studies.

Tim Salimans, Jonathan Ho, Xi Chen, Szymon Sidor, Ilya Sutskever, "Evolution Strategies as a Scalable Alternative to Reinforcement Learning", arXiv, 2017
https://arxiv.org/abs/1703.03864

(*8) Website of the Japanese Society for Artificial Intelligence, "Artificial Intelligence Research."
https://www.ai-gakkai.or.jp/whatsai/AIresearch.html

(*9) A non-"robot search" is a "category search" in which each homepage is manually categorized into a category and then searched using that category.

(*10) Katsuhito Sudo, "Progress in Neural Machine Translation - Evolution of Sequence Transformation Models and Their Applications -," Journal of Artificial Intelligence, July 2019
https://doi.org/10.11517/jjsai.34.4_437

(*11) "Weaknesses of Artificial Intelligence Exposed by Overwhelming 'Go AI'," Nihon Keizai Shimbun, March 17, 2016.

https://www.nikkei.com/article/DGXMZO98496540W6A310C1000000/

(*12) The author does not know Go, so he does not know if this is a realistic phase or not.

(*13) Steven Miller , "Mind: How to Build a Neural Network (Part One)", 2015
https://stevenmiller888.github.io/mind-how-to-build-a-neural-network/

(*14) Ai Kawazoe, "Human Language, Machine Language", Kadokawa Shinsho, 2020.
https://www.kadokawa.co.jp/product/321909000011/

(*15) Ai Kawazoe, "Itachi who doesn't want to work and a robot that understands language: 'People and language' from the perspective of artificial intelligence," Asahi Press, 2017.
https://www.asahipress.com/bookdetail_digital/9784255010038/

(*16) https://nihonshimuseum.com/edo-bakufu/

(*17) Takanobu Mizuta, "Are Markets Efficient? 50 Years Spent Testing Untestable Hypotheses", Sparks Asset Management Special Report, December 22, 2020.
https://www.sparx.co.jp/report/special/3118.html

(*18) Hiroyuki Sakai, Yuko Nishizawa, Shogo Matsunami, and Yasunori Sakachi, "Extracting Performance Factors from PDFs of Corporate Financial Statements," Transactions of the Japanese Society for Artificial Intelligence, vol. 30, no. 1 pp. 172-182, 2015
https://doi.org/10.1527/tjsai.30.172

(*19) For example, the following studies are available

Ryota Dobashi and Kazuhide Nakata, "Extracting ESG-related statements from securities reports using BERT," 26th Annual Conference on Financial Informatics, 2021.
https://sigfin.org/026-02/

Yoshiaki Maehara, Atsushi Kugyu, and Yoshiyuki Nagabe, "Visualization" of Decarbonization-Related Patent Technologies Using Patent Domain-Specific BERT," 27th Annual Conference on Financial Informatics, 2021.
https://sigfin.org/027-06/

(*20) Nihon Keizai Shimbun, "Financial Summary".
https://www.nikkei.com/promotion/collaboration/qreports-ai/

(*21) T. Isogai, "Empirical Analysis on the Estimation of Dynamic Correlation of Stock Prices," Bank of Japan Working Paper Series, 2015.
https://www.boj.or.jp/research/wps_rev/wps_2015/wp15e07.htm/

(*22) "AI instantly creates high school baseball game review articles, developed by Asahi Shimbun", Asahi Shimbun, August 15, 2018
https://www.asahi.com/articles/ASL890GLKL88ULZU011.html

(*23) "Contract Time Battle," a competitive event in which two opponents negotiate in real time to their advantage in a contract editing contest within a limited time frame, pitted an artificially intelligent body against a human in 2018.

"Can AI beat humans! ?LegalForce's Challenge," December 10, 2018.
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(*30) "Introduction of Artificial Intelligence into Trading Examination Operations", Japan Exchange Group, March 19, 2018
https://www.jpx.co.jp/corporate/news/news-releases/0060/20180319-01.html
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Hiroki Sashida, "Application of Artificial Intelligence to Trading Examination Operations," 20th Annual Conference on Artificial Intelligence in Financial Informatics, 2018.
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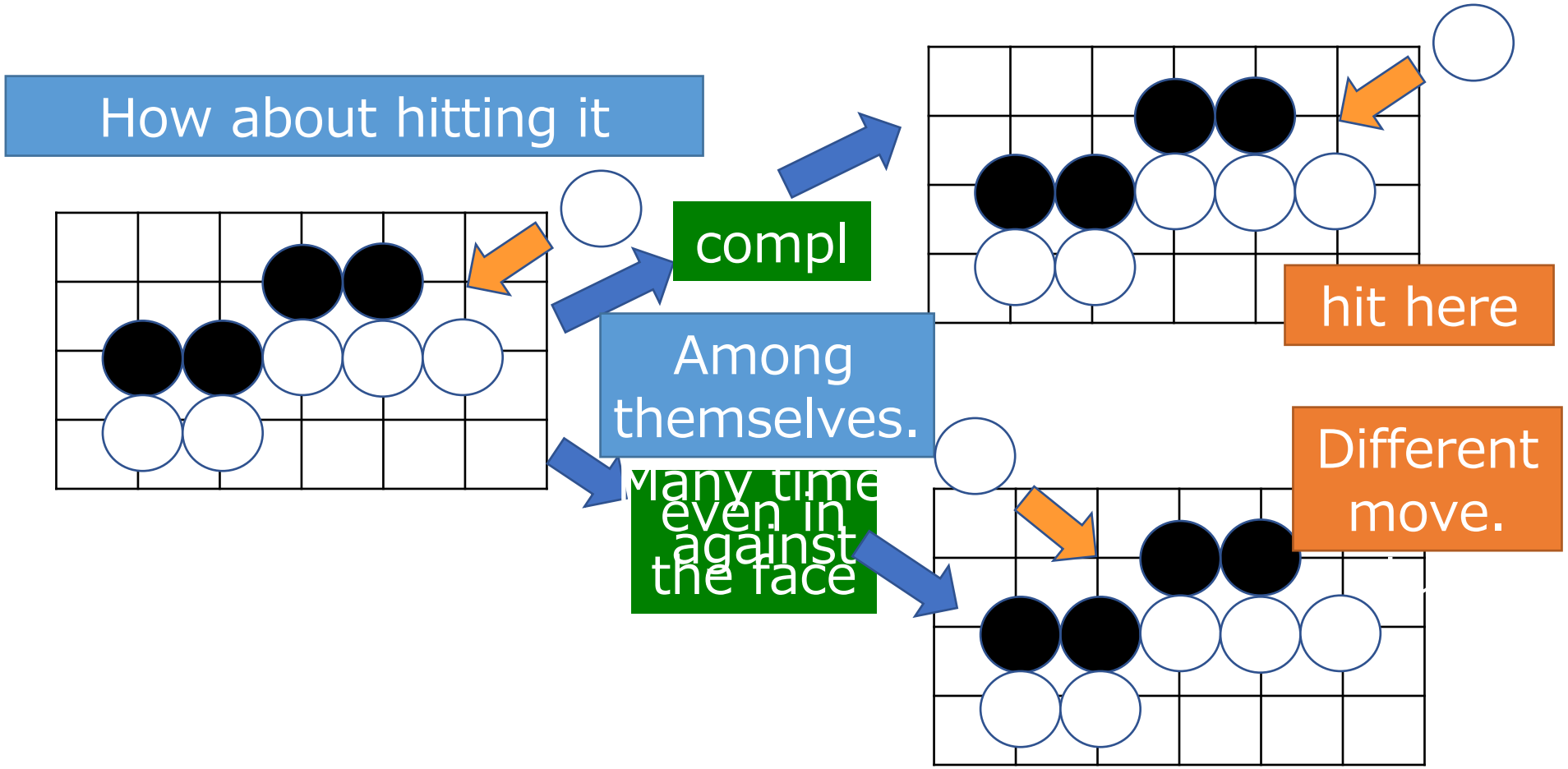

Figure 1: Artificial intelligence searching for good moves in Go.

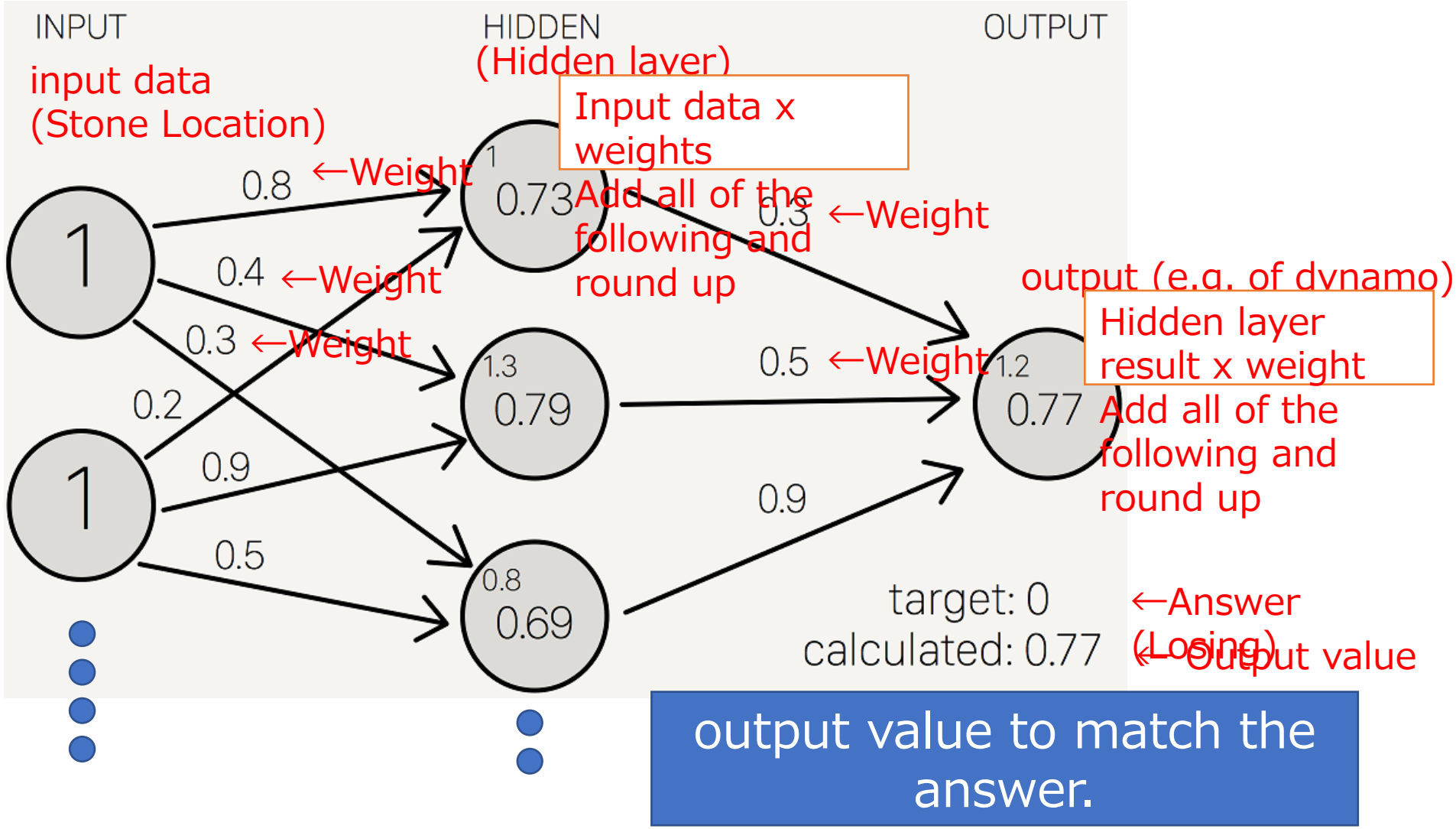

Figure 2: Process of artificial intelligence to find the best answer (1)

(Source: Modified by the author from https://stevenmiller888.github.io/mind-how-to-build-a-neural-network/)

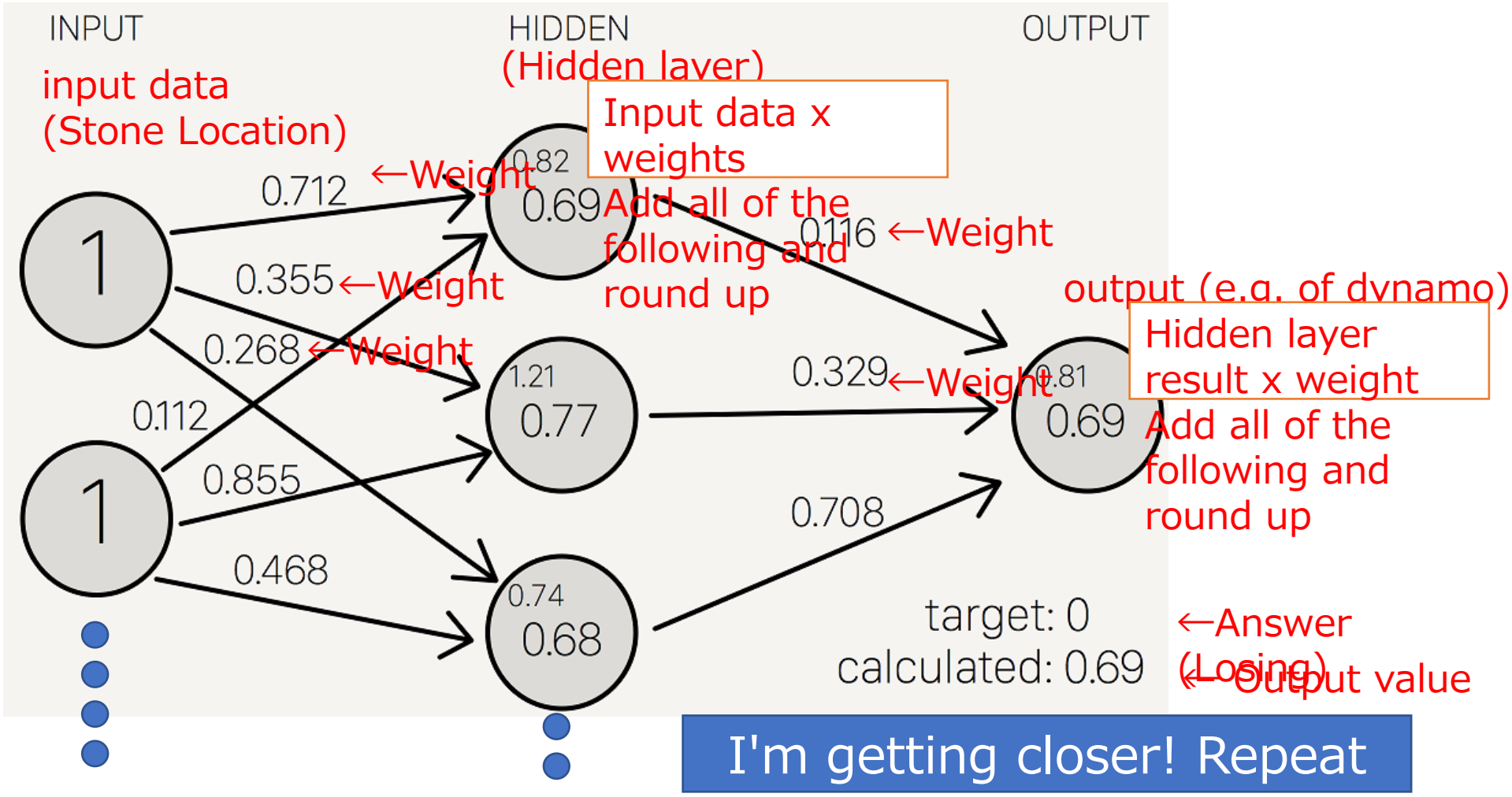

Figure 3: Process of artificial intelligence to find the best answer (2)

(Source: Modified by the author from https://stevenmiller888.github.io/mind-how-to-build-a-neural-network/)