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My Life Has Been Lucky!

Hello, everyone. Thank you all for coming. It's an honor to be here. Today, I would like to look back on my nearly 70 years as a researcher. As the title says, I truly feel I have been lucky throughout my research life.

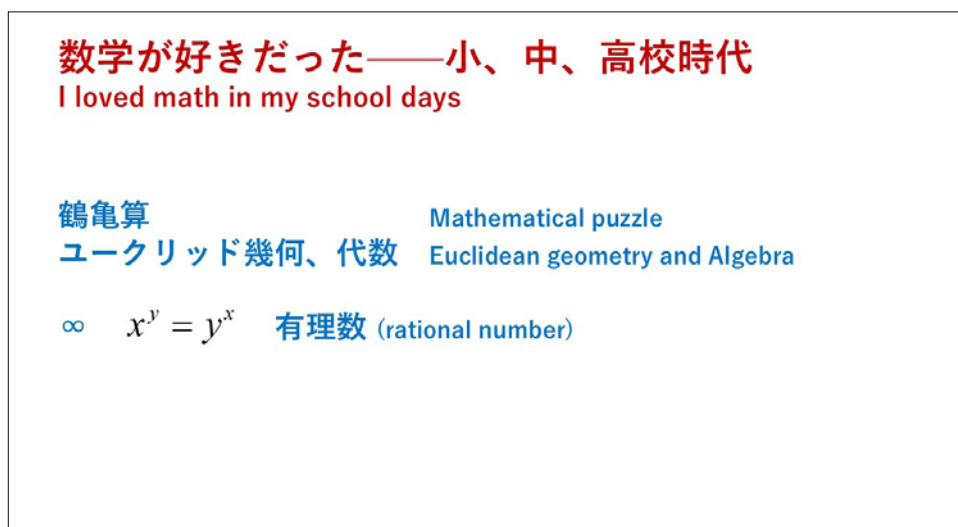


Fig. 1

Going all the way back to my childhood—and I could spend far too long talking about this—I loved math in the elementary school. I was fascinated with a Japanese traditional math puzzle called *Tsuru-Kame-zan*, and I remember being amazed that such interesting concepts existed. This love to math continued in the junior high school. I then went on to Tokyo Metropolitan Toyama High School, where I joined the after-school mathematics club and learned different sorts of intriguing things about the subject (Fig. 1).

One time—and sorry if this story is a bit too technical to follow—our teacher took us to the University of Tokyo's May Festival, where the Mathematics Department had a booth. There were many sorts of math problems on display, and if you solved one, you would win a pencil, which I found very exciting. I spotted a problem that said, "Find all rational numbers that satisfy the equation $x^y = y^x$." I spent two or three hours in the room heavily tackling this problem, but I just couldn't crack it. When I got home, I had dinner, then sat down and racked my brain again. After several hours of concentration, I finally solved it. I was overjoyed, and the next day I went back to the University and claimed my pencil.

When I was asked to give this speech, I thought back to this particular problem and tried to solve it again. To my surprise I found I couldn't. "What?" I thought. "How did I solve it back then?" Please try it for yourselves. $x^y = y^x$: for integers, that's " $2^4 = 4^2$," right? There are other rational numbers that satisfy this condition too. And for real numbers there are, of course, densely many numbers. Well, that was a snapshot of my childhood.



Fig. 2

I entered the university and was vaguely attracted to the idea of life as a researcher, aspiring to become one myself. But in Japan at that time the young generation was burning with passion and idealism, and peace activism and student movements were thriving. In simple terms, these were movements that opposed Japanese government policy and American imperialism. As I became more involved in these movements, I had a sudden realization.

The University of Tokyo requires students to choose an academic major after one and a half years. Your grades at this point determine which department you can enroll in. I looked at my grades and realized they were nowhere near good enough to get into a highly popular department like mathematics, physics, or electrical engineering. I was at a bit of a loss what to do, but then I discovered that the Faculty of Engineering had just created a new course called Mathematical Engineering.

It was a course that aimed to use modern mathematics to get to the root of a variety of engineering problems. So why wasn't it run by the Mathematics Department? Well, back then, the Mathematics Department believed that mathematics had to be pure. Applied mathematics was something for third-rate researchers; in other words, people who had fallen off the "elite" career path. Although the mindset is much different nowadays, this was the attitude at the time. So there was this new Mathematical Engineering course, which was led by four professors and associate professors. The course had an enrollment capacity of five students. Since it was an obscure course in an obscure field called Mathematical Engineering, there weren't many applicants, which meant grades weren't really an issue. So, I managed to slip into this little-known course, which only around five students at most would even apply for. This was really the beginning of my luck (Fig. 2).



Fig. 3

What is Mathematical Engineering? As I just mentioned, it involves tackling problems in engineering and other fields using modern mathematics. So the object of study can be practically anything—the underlying belief is that if there’s an interesting phenomenon, there must be a mathematical structure behind it. There’s actually a backstory to why this new course was created. Before the war, Japan’s aeronautical engineering program was considered the top-tier, and the field attracted the nation’s brightest talent. But after the war ended, the field suffered the misfortune of being banned—Japanese researchers were forbidden to research aeronautical engineering. Years later, when the ban was finally lifted, many scholars happily transferred to the newly established Department of Aeronautical Engineering. But a few said, “Wait a minute—it’s not the time for aeronautical engineering anymore. What we really need is a discipline that allows us to view the world through a much more mathematical lens.” It was these researchers that pioneered the new Mathematical Engineering course.

At the time, the course professors themselves were striving desperately. There was a prevailing mood in the Faculty of Engineering that it was inappropriate for the Faculty to handle such an obscure and incomprehensible subject, so amidst this, the professors were fighting to forge a new, legitimate discipline. As a student in the Mathematical Engineering course, I witnessed their struggles firsthand and realized this is the way to build new disciplines.

I was lucky in the sense that, had I gone into pure mathematics or physics, I would have been overwhelmed by the nation’s brightest minds and unable to accomplish anything of note. And if I had gone into electrical or mechanical engineering, I would have ended up doing work for a professor without being able to pursue my own research. But in this Mathematical Engineering course, the professors were working tirelessly with their backs against the wall. They would tell us students, “Keep your eyes open wide, observe the world around you carefully, and pursue your own studies. I’ll focus on my own research. I don’t need your help.” It was a great experience being able to develop my skills while seeing the professors persevering to energetically forge a new path. My professor stressed to me, “Learning is freedom. Open your eyes wide, and study the various mechanisms in the world around you” (Fig. 3).



Fig. 4

During my graduate studies, I worked on topological analysis of electrical networks, which was a challenging field, as well as the differential geometry of continuum materials and the geometric theory of signal transformations. All this strengthened my confidence from various perspectives (Fig. 4).

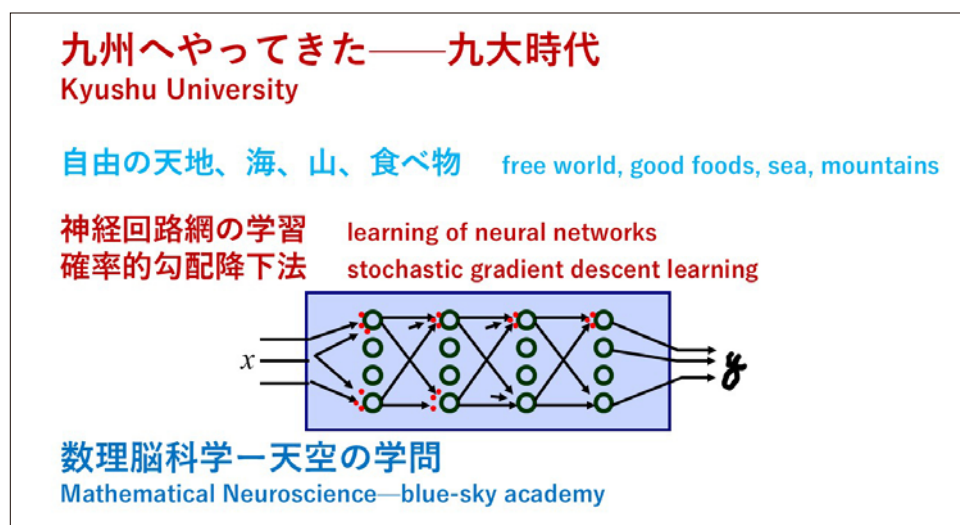


Fig. 5

After completing my Ph.D. degree, I began working at Kyushu University. It was a wonderful place, not just the university itself, but also the Kyushu region. I love Fukuoka, especially Hakata. It was a place where I was free—I would go to the beach, hike in the mountains, enjoy all kinds of delicious food, and generally do whatever that pleased me.

Back then, my interest was drawn to the “perceptron”—a mechanism through which machines could learn by mimicking neural networks in the brain. Although this technology was something of a trend at the time, its learning method was still rather incomplete. I felt it should be possible for machines to learn far more freely and broadly. Much of my time at Kyushu University was spent pondering how to achieve this. Mount Kuju in Kyushu has hot springs at the foot of the mountain, and Kyushu University has a recreational facility there. It was while soaking in these hot springs one day that I had a series of inspirations. I thought I might have found a way to achieve a breakthrough. This is how my journey into machine learning began.

My concept was that, if we could study how the human brain functions, perhaps we could transfer these mechanisms to machines. However, the human brain is much too complex, and although modern science has made considerable progress in understanding its working mechanisms, we still don't fully understand why the brain is capable of things like flashes of inspiration or creative thinking and learning. At the same time, I wanted to explore the brain's information processing and higher-level mechanisms using mathematical engineering, which is my field of expertise. And I thought to myself: Couldn't we use this to create an amazing system that enables machines to learn?

People from the faculty of medicine would say, "Amari-san, what you are doing is blue-sky research. What we're doing is down-to-earth brain research." Even so, I still believe that mathematical neuroscience—this "blue-sky academics"—is also vital for brain research, and I felt still in those days that the influence of this discipline was steadily growing (Fig. 5).

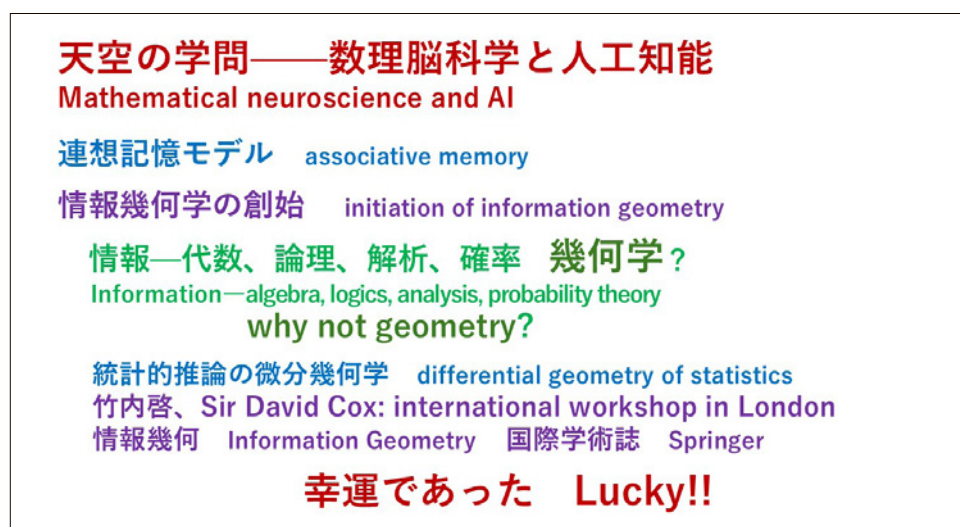


Fig. 6

As part of this "blue-sky academics," I developed the stochastic gradient descent method, one of the most fundamental principles of the machine learning I just mentioned. I also conducted various other research, including the associative memory model.

If you dedicate yourself to such work for ten years or so, creating brain models and elucidating the brain's mechanisms becomes relatively straightforward. However, if the task becomes too easy, you run the risk of simply becoming a skilled craftsman in a single specialized field. You might be capable of doing anything within this field well and produce excellent work, but your growth could plateau there. After all, I still believed that I had a larger, deeper goal in the form of mathematical engineering, an area that held immense potential, and that I needed to keep my eyes open to broader possibilities. This is when I started thinking about the geometry of information.

Informatics naturally employs algebra and logic, as it involves computers, while the control field has long utilized analysis. Shannon's information theory is, of course, based on probability theory. But then I realized that there was no geometry. That's why I felt that it should theoretically be possible to study the geometry of information, and so I began exploring that field. As it turned out, shifting my field of expertise to tackle something new was quite a painful process. For roughly a year and a half to two years, I spent my days silently poring over calculations and thinking, without writing a single paper. It was a good era back then—a time when it was perfectly acceptable for a university professor to spend a year or two without publishing anything. I feel sorry for today's professors. They're weighed down by administrative tasks and under pressure

from ridiculous quotas dictating how many papers they must write or how many reports they must submit. Back then, things were a lot freer.

When I first began studying differential geometry for statistics, Professor Kei Takeuchi in Japan saw the possibilities in my work and told me, “Amari-san, this research is fascinating. You should present it to the Mathematical Society immediately and show it to the world.” He later introduced me to the world-renowned statistician Sir David Cox, who was visiting Japan. He then urged me, “Amari-san, present your work to Sir David.” When I did so, Sir David listened to my explanation with a slightly perplexed expression on his face, and I wondered if he had understood. However, about a month later, a letter from him arrived. It said: “Your theory might help forge a new direction in statistics, and should be examined internationally. To do this, I plan to hold a workshop in London to examine differential geometry in statistical inference. You must be there.” He invited me, a little-known researcher and a novice in statistics, to headline the workshop. Sir David gave me tremendous support—whenever subsequent international statistics conferences were held, he would insist they invite me as a speaker.

That’s when I realized this wasn’t just about statistics—it was a discipline with the broader goal of the geometry of information, as I had originally envisioned. So I named this field “Information Geometry,” and the name stuck. A good name is really important. Today, the field has grown so much that it even has its own academic journal called *Information Geometry* (Fig. 6).



Fig. 7

My English was actually pretty poor—and still poor even now—but back then, I could hardly speak it at all. This was around 1970, before Japan’s bubble economy had started, and at a time when the country was still in the midst of its recovery. There was no chance of going to the US of my own volition. Around this time, a researcher named Michael Arbib was visiting Japan to give a series of lectures. I met him during his visit, and he later sent me a letter telling me: “I’m establishing a program at my university to develop mathematical models of the brain. I would like you to send me one of your most talented postdoc students.” Since I had never been to the US myself, I decided that instead of sending a postdoc student, I would go myself. So I headed off to the US, taking my family with me.

I remember watching a movie on the flight over and not being able to understand English at all. I consoled myself, believing that I would be able to understand everything on the flight back. But nine months later, I watched a movie on the return flight again and still couldn’t understand a thing. I wondered what I did all the time in the US, but at the same time realized I had gained some courage through the experience. When researchers talk to one another, it’s all about the substance,

not how well they speak English (Fig. 7).

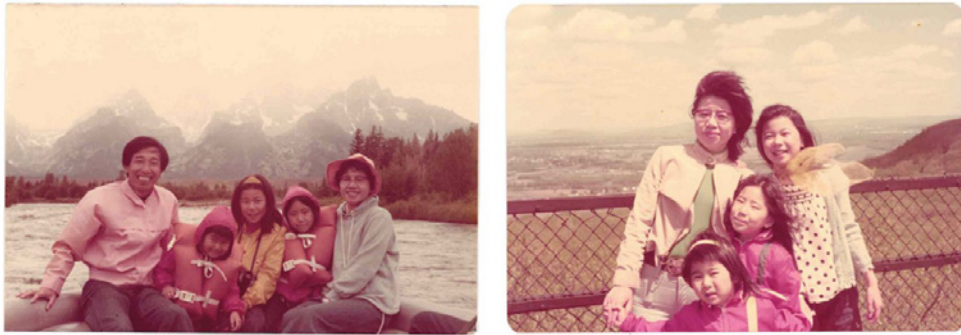


Fig. 8

These are family photos from our time in the US. My wife and three daughters joined me, and the experience broadened our horizons (Fig. 8). Before we left the US, we took a cross-country road trip over three weeks, visiting famous sights along the way. In this photo (Fig. 8, left), we're rafting down the Snake River in Yellowstone National Park.

第2次ニューロブーム Second neuro boom	
冬の時代を抜けて	through neuro winter period
日本は先進国	Japan was an advanced country
国際会議での活躍	activities in international conferences
海外出張	overseas visits

Fig. 9

Looking globally, although the concept of machine learning using neural networks had originated in the US, the field later entered a so-called “winter period.” The consensus was that pursuing such research was completely useless, leading to a sharp decline in the number of researchers worldwide and bringing progress to a near standstill. However, at that time in Japan, academia was under a relatively free environment. Although research funding was being cut in the US, Japan had very little research funding from the start, meaning there was nothing left to cut. While we lacked in funding, we made up for with freedom. Researchers from an engineering background like myself teamed up with pure neuroscientists from medical schools, whose studies were down-to-earth, not just blue-sky concepts. This collaboration allowed us to pursue a wide range of research. As a result, Japan made significant progress in informatics research of the brain from an engineering perspective.

Around this time, the second neural network boom took off in the US, and at this point Japan was an advanced country in neural network study. I was invited to speak at conferences in the US. Meanwhile, I was asked to serve as a board member for a new international society being

established, and eventually became its president. As the president of such a major society's board, I had to chair meetings, which I struggled with due to my poor English (Fig. 9).

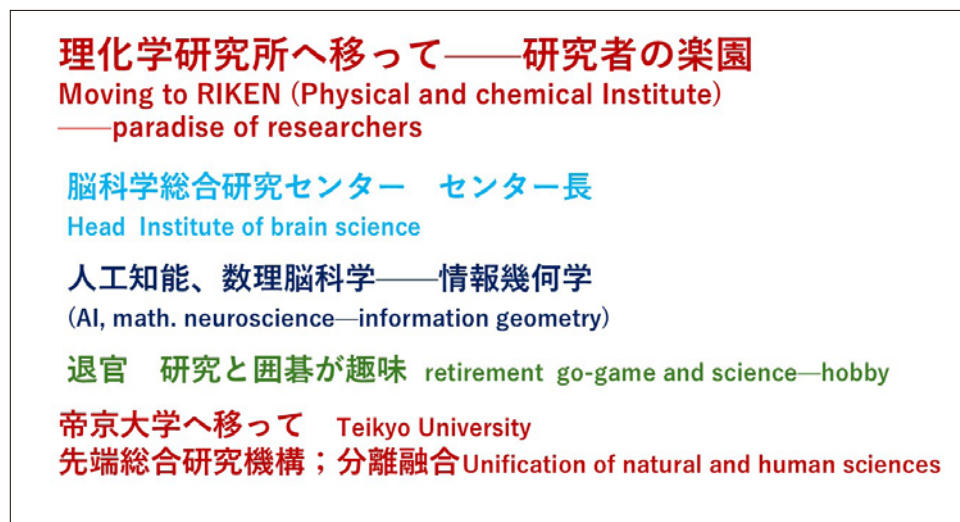


Fig. 10

All that aside, when I reached retirement age at the University of Tokyo, I received an invitation from Dr. Masao Ito, a renowned medical researcher, offering me a position at the RIKEN Brain Science Institute, where I happily continued my academic work. At RIKEN, I focused on using information geometry as a methodological framework to conduct research in fields like artificial intelligence and mathematical neuroscience. Of course, after turning 80, I knew I couldn't stay at RIKEN forever, so I resigned. That's when Teikyo University reached out to me with an invitation, saying, "Amari-san, please come and join us." They were establishing a new research institute focused on ways to integrate knowledge from across science and the humanities. I decided to join the institute that stressed academia needs to address societal challenges by unifying the natural and human sciences (Fig. 10).



Fig. 11

Although AI is a remarkable technology, the human brain is super wonderful, isn't it (Fig. 11)?



Fig. 12

Will AI make our society better? The optimistic scenario is that AI will handle all production, while humans relax and receive a generous basic income, with the key word here being “generous.” Every day, we’ll enjoy delicious food and drink, sipping fine wine and living life at a leisurely pace. But does this represent true happiness? Absolutely not, right?

Humans actually love to work. Of course, they also love to play. So people will never stop working, no matter how much basic income they receive. But rather than everybody toiling away as so-called “professionals” in specialist roles, how about a society where people enjoy life while working as amateur scientists, amateur farmers, amateur athletes, or amateur artists? This would be paradise, but unfortunately, the world doesn’t tend to go that way (Fig. 12).



Fig. 13

Looking at the current state of AI, we see it being used more and more in military applications, increasingly being used to create cheap killing machines. At the same time, there’s intense competition between nations for dominance in AI, and some people are using it purely as a money-making tool. This is the problem—if AI is left unchecked, it risks further widening a disparity in human society.

An even bigger problem is just how incredibly convenient AI is. I imagine many of you already use it. In fact, I use it a bit myself. If I’m asked to write something like a recommendation letter in

English, I'll create a draft in Japanese and then tell the AI, "Translate this into English." It generates incredibly fluent English translation. Although I have struggled studying English for decades, I still can't write a good recommendation letter. I'm amazed that AI can do such a good job. It would be foolish not to use it, so I do encourage you to make effective use of AI. However, I worry that AI might take away the joy and the struggle of thinking from humans. Thinking deeply by your own brain to find a solution can at times be a struggle, but at the same time a source of great joy.

If humans get used to AI doing all their thinking for them, it will end up eroding our very ability to think. And once our ability to think deteriorates, concepts like populism can exploit this vulnerability. This could seriously threaten the very foundations of our modern civilization—the freedom, equality, and democracy we've worked so hard to cultivate. There's a very real danger that dictators could rise to power. So I believe this erosion of our ability to think due to AI is a huge problem. This is what I have referred to previously as the "domestication of humanity."

While many people may believe that they are the masters of AI, never its servants, we are entering a dangerous era in which we may unwittingly lose both the joy and the struggle of thinking for ourselves. This is why education is so crucial at a time like this, and by education I do not simply mean teaching knowledge. Traditionally, education has largely focused on this style of imparting knowledge. But in the future, knowledge can be easily obtained by asking an AI. So what is the future of universities, high schools, middle schools, and elementary schools? I believe they will become places where students learn from the way teachers live their lives, and where they engage in active discussions with peers who hold differing opinions. This will allow them to encounter different perspectives—not necessarily to argue against them, but to understand the diverse viewpoints that exist and to learn to respect others' perspectives. In this way, I think that education will play an increasingly vital role in the coming era.

I recall a poem by the French poet Louis Aragon, "Enseigner c'est dire espérance. (To teach is to talk hope together.) Etudier fidélité. (To study is to engrave faithfulness in your heart.)" He wrote this poem while France was under Nazi occupation. As we move forward, we must avoid the domestication of humanity. As I mentioned earlier, work is both the joy and the struggle. I sincerely hope we move forward into an era where all people can find joy in persevering through hardship to accomplish something meaningful (Fig. 13).

Thank you very much.

The interview held after the commemorative lecture is available on the Kyoto Prize YouTube channel.

(<https://www.youtube.com/watch?v=XTrdbl2JMCI>)