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NII's New Director on the Future of NII

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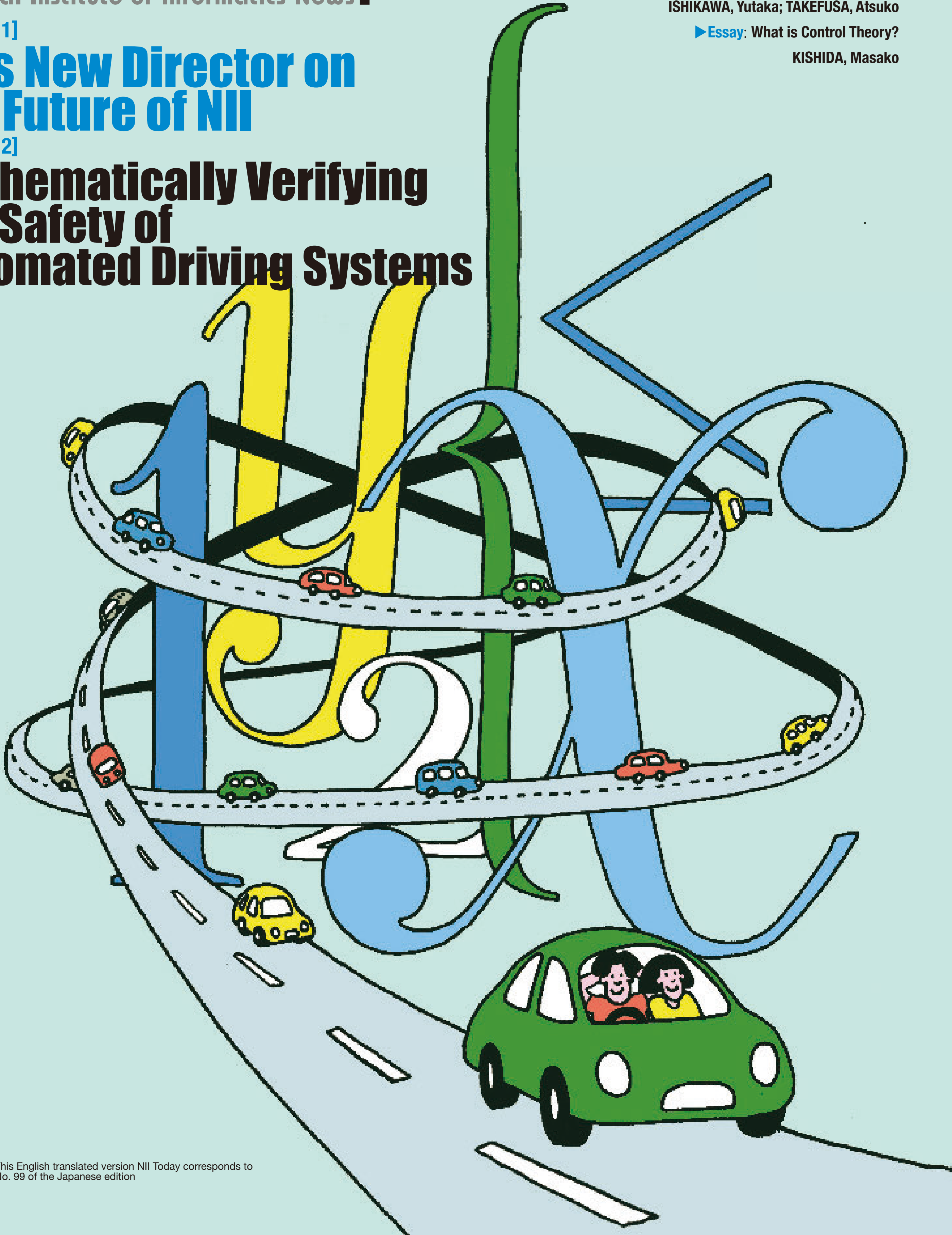
Mathematically Verifying the Safety of Automated Driving Systems



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How Informatics is Shaping Society

Director-General, NII
KUROHASHI, Sadao

Interviewer
MASUTANI, Fumio
Editorialist & Senior Staff Writer
The Asahi Shimbun

In April 2023, KUROHASHI, Sadao took office as the new Director General (DG) of the National Institute of Informatics (NII).
Dr. KUROHASHI, one of Japan's foremost experts in artificial intelligence (AI), is a professor at NII, as well as a program-specific professor at the Kyoto University Graduate School of Informatics. His research has centered on teaching "language" to computers. We asked about how he plans to lead NII and how he sees the prospects of AI.

From data platform to knowledge platform

— To begin, could you please say a few words about your background?

I was born and raised in Kyoto, where I studied at Kyoto University under the guidance of Prof. NAGAO, Makoto, who was a world-leading specialist in machine translation. I was appointed as an assistant professor at The University of Tokyo in 2001 and a professor at Kyoto University in 2006.

My specialty is natural language processing. I have studied methods of teaching computers "natural language," i.e., everyday human use language.

I've worked hard trying to get computers to understand the Japanese language.

Neural networks and large-scale language models have recently drawn huge interest. Making use of these technologies, I hope to keep exploring the new world of AI over the coming years.

— What are your goals as head of NII?

My main goal for NII is to bring about a shift from data platform to knowledge platform. Professor KITSUREGAWA, my predecessor, was a database expert, so he gave a lot of importance to data from the start of his tenure. He pushed the development of a research data platform at NII. I want to build on that foundation to build a "knowledge" platform.

The importance of data in the 21st century, both in academia and society more generally, is well recognized. Scientifically, we've made much progress in terms of creating data from all kinds of observations and measurements, digitizing and making the data widely available for discussion and other uses. Thanks in large part to NII, Japan has an advanced, high-speed "science information network" (latest version SINET6), as well as a highly capable research data platform.

However, the challenges of today are increasingly complex, so they cannot be overcome by any one academic discipline. Collaboration between different fields of research is difficult, however, since experts in one field tend to be amateurs in others. Also, it's not easy to directly utilize data across a diversity of fields.

To go deeper with academic research to establish the comprehensive knowledge needed to solve complex social problems, it is essential to develop a knowledge platform for automatically interpreting, interrelating, and systematizing data, as well as supporting the generation of new knowledge across disciplines.

Now that we have a research data platform in place, we want to set up a knowledge platform for interpreting data, and interrelating and systematizing knowledge from different fields via large-scale language models. In these ways, we want to support the creation of new knowledge and the resolution of social issues.

How data benefits society

— Data have been called the "lifeblood" of an information

We need a mechanism to facilitate collaboration between experts

society.

Due in part to the cautious nature of the country, a lot of data in Japan have not yet been made available.

By distributing greater amounts of data, we can make the world more livable. The adoption of AI is also likely to enhance the circulation of the data in Japan. Consider the medical field! Anonymization is an issue, but AI will allow us to process huge amounts of medical data.

The need for academic infrastructure like that provided by NII and for a knowledge platform has been pointed out for more than 10 years. Now that we have the data platform, the value of opening data up is starting to be recognized. Given that large-scale language models originating from machine translation research are now enabling sophisticated interpretation of academic papers and multimedia data, I think we can finally aim seriously at building a knowledge platform. On the other hand, building large-scale language models requires enormous computational resources, which are increasingly dominated by a few foreign companies. This is a significant problem. We need to set up a system for R&D and operation of large-scale language models and to establish a knowledge platform under a coordinated national effort.

—— What will be the positive impact of opening up data and establishing a knowledge platform?

Analyzing large quantities of anonymized medical data will make it possible to deliver medical care that is better optimized for individuals.

Currently, we classify a patient's symptoms as a typical case and say, "OK, take this medication." Since the world of medicine progresses so rapidly, judgments are often made based on slightly outdated knowledge.

Advances in research using "big data" will make it possible to determine the characteristics of a patient more specifically and precisely, enabling more effective treatment. By taking advantage of the constantly updated information on treatments and medications, we can increase the probability of curing the ailments of individual patients.

NII is becoming more important than ever

—— I often hear people from the university community say that the DX Symposiums for Educational Institutions*1 that NII began running in 2020 have been very helpful. Are you planning to continue them?

When the COVID-19 pandemic

Addressing the demands of society in an era of rapid change

began, many universities were trying to start up online classes with zero experience. Someone from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) appeared at each meeting to provide the latest information on things like special measures for copyrights. Over time, we also presented information on the metaverse and the much-hyped ChatGPT. We feel that the symposiums were very successful.

However, we are now thinking of holding the symposium jointly with the Research Organization of Information and Systems (ROIS), NII's parent body. One reason is that there have been strong calls for my predecessor Prof. KITSUREGAWA, who is now heading ROIS, to keep MCing the symposiums. We also want to reduce the burden on the NII staff, who have tended to overwork themselves to ensure that the meetings go smoothly.

—— What are your thoughts about the evolution of NII in the years ahead?

If we utilize informatics skillfully, then we can help to shape a better society. That's why I believe that the role of NII will become more vital than ever.

It's good that universities compete among themselves in some ways, but sharing is also good in some areas. For research, we have a shared data platform, supported by NII. There are also resources, like academic affairs, online classes, and hospitals, that could be shared more. We are wondering whether we can offer a somewhat broader IT system from the perspective of joint university use. Right now, when universities across Japan adopt cloud services, we provide them with information on what kinds of services are available and their relative pros and cons. I think that we can do more to help universities share this information with each other.

However, as expectations have risen, everyone at NII has become extremely busy. We want to meet those expectations as best we can within the limits of our staffing and budget, but we also want to create a more comfortable working environment at NII.

The amazing rise of generative AI

—— Just as you are taking up your new role, ChatGPT is taking the world by storm. The timing is quite interesting, isn't it?

ChatGPT appeared in November of last year, a few months after my appointment was decided in June (2022).

In March of this year (2023), GPT-4*2 was released. I could never have foreseen such developments. While people see the sudden, widespread focus on AI as a "tailwind" that will help me in my job, to me it seems more like a "hurricane."

Even the government has been moved to respond to the situation, but being new to the job I'm still trying to figure it all out. It would have been nice to have had a year or so to settle into the job before dealing with this AI craze.

ChatGPT as an "intelligent partner"

—— ChatGPT has attracted massive worldwide interest. Could you help us to understand it a little better? How is it different from a search engine like Google?

Search engines match queries to web text based on parameters such as word frequency. They only show associated documents; the rest is up to human interpretation.

Before ChatGPT, AI dialogue systems seemed to work with the limited knowledge they were fed. They were not all-knowing entities.

ChatGPT is different. It is essentially a language model that works by predicting the next words, but this makes it very smart in various ways.

By analyzing the words used in long sentences, you can predict the subsequent words that will appear with a high degree of certainty. I believe the latest version of the model, GPT-4, generates answers based on about a novel's worth of text.

— What were your impressions of using ChatGPT?

It really is smart. If you ask it to create a summary of a topic, in Kansai dialect, using junior high school-level language, it can do a very good job.

As an example, I help foreign students to write applications for scholarships and tuition exemptions in Japanese, but some unnatural wording always remains. I used to spend a lot of time polishing texts. But now, if I ask ChatGPT to "turn this into natural Japanese," it fixes the issues instantly.

ChatGPT can also serve as a partner for intellectual work with whom you can discuss. Even if it doesn't come up with anything amazing, it can help you to organize your ideas or generate new ones.

These are things that machine learning has not been able to do before now. Even as an AI expert, I don't fully understand how it's possible.

Opening up the world of AI

— So, not even the experts understand it?

Only a handful of companies, like OpenAI (the developer of ChatGPT) and Google in the U.S., and Baidu in China, are capable of this level of research and experimentation.

If this situation persists, I think it will be unfortunate for humanity. Who knows what might happen behind closed doors? This technology should not be kept confined and shrouded in mystery, because its potential impact is so huge.

— Will ChatGPT and generative AI continue to evolve? Are there any limits in sight?

The evolution of ChatGPT will not be a linear process. It will keep on learning constantly until a point where some kind of explosive leap occurs. In my opinion, the future consequences are unimaginable.

— What do people who use ChatGPT or other generative AI tools need to be aware of?

The technology will continue to advance rapidly, so it's important to maintain a flexible attitude rather than a fixed view.

Also, since tools like ChatGPT can explain things in smooth, well-written texts, there is a risk of assuming that their answers are always correct. It is therefore absolutely vital to exercise critical thinking when using AI services.

In this era of rapid social change, NII, as an Inter-University Research Institute and Japan's core informatics institution, must address the demands of society in the spheres of both research and business. We are committed to pursuing comprehensive informatics research, from basic theory to leading-edge implementation, as well as furthering our academic network and research data platform projects. At the same time, we will strive step by step to build a knowledge platform that can serve as fertile ground for academic research collaboration.

*1 DX (Digital Transformation) Symposiums for Educational Institutions: Online meetings held weekly or bi-weekly starting at the end of March 2020 for sharing information about distance learning and the adoption of digital technologies at universities and other institutions.

*2 GPT-4: Acronym of "generative pre-trained transformer 4," announced in March 2023. It enables ChatGPT to handle about eight times more words than its predecessor, GPT-3.5.

A Word from the Interviewer

Just as ChatGPT is making waves around the world, an AI expert is appointed as the new NII Director General (DG). The timing seems almost too good to be true. The new DG laughs it off, seeing the fuss about ChatGPT more as a "hurricane" than a "tailwind." Nevertheless, the new DG will be a reassuring presence for NII, the university community, and government alike. Whether or not its use is restricted, ChatGPT is likely to remain a hot topic in the education and research fields for some time to come.

As if replacing the COVID-19 pandemic, a new concern that threatens radical social change has emerged. Even the new DG feels unable to predict the changes we will see in the coming years. How will AI reshape our society?

MASUTANI, Fumio

Editorialist & Senior Staff Writer, The Asahi Shimbun

Born in Utsunomiya City. After graduating from Osaka City University, joined the Asahi Shimbun in 1994, working in Tokyo, Osaka, Nagoya, Sendai, and Kyoto. Since 2005, has spent eight years or so intermittently covering higher education. Since April 2020, has worked as a senior staff writer on higher education and since October 2020, as an editorialist on general education.

Photography by IMAMURA, Takuma (pages 3-4)

Rigorously verifying the safety of automated driving systems–Under the ERATO Metamathematics for Systems Design Project (ERATO MMSD),*1 a Strategic Basic Research Program of the Japan Science and Technology Agency (JST), a team led by Prof. HASUO, Ichiro of NII's Information Systems Architecture Science Research Division has developed a new mathematical method for assuring the safety of automated driving systems. This method has the potential to significantly change the methodology used to ensure the safety of the self-driving vehicles now in development worldwide.

[Feature 2]

Mathematically Verifying the Safety of Automated Driving Systems

Proposing a method of explainable "safety and security"

Professor,
Information Systems Architecture
Science Research Division, NII
HASUO, Ichiro

Interview and Writing
Senior Staff Writer, Nikkei Inc.
YOSHIKAWA, Kazuki

Scenarios that fit real-life driving situations

The development of automated driving systems*2 is currently advancing in two directions. One is next-generation mobility as a service (MaaS)-type autonomous transport systems that operate on fixed routes. These often consist of driverless, self-driving vehicles that are remotely monitored and operated. A typical example is a new transport service, set to launch in Eiheiji-cho, Fukui Prefecture in 2023, featuring seven-passenger vehicles. It is the first “Level 4” automated driving system approved in Japan.

The second direction is self-driving passenger cars and other vehicles designed to run on public roads. Progress is focused on improving and expanding the functions of so-called advanced driver assistance systems (ADAS). As an example, in 2020, Honda’s Legend luxury car became the world’s first “Level 3” self-driving production car certified for use on public roads. When this car encounters traffic congestion on the expressway and its speed drops below 30 km/h, full control of the vehicle is taken over by the autonomous system.

The conditions that define the operation of autonomous operation, such as driving routes and speed limits, are known as “operational design domains” (ODDs).*3

Both for MaaS and private cars, the goal is to eventually achieve “Level 5” fully automated driving in all situations, by progressively relaxing the ODDs over the coming years.

The widespread implementation of automated driving systems is expected to reduce the incidence of traffic accidents, by eliminating human errors. However, even if AI

Mathematics offers a convenient framework for automated driving systems

takes over all driving, it will not be possible to cut accidents to zero under the framework of autonomous driving. As ODD conditions are relaxed and automated systems are more widely adopted, ensuring safety will become more difficult.

Another challenge with self-driving vehicles is the difficulty of striking a balance between safety assurance and driving comfort. If the driving scenarios that a car's safety depends on are too cautious, the car's movement will be sluggish and the ride will be far from comfortable.

If driving scenarios that have been proved to be safe can be prepared for a wide range of situations, this challenge can be overcome. The research findings of Prof. HASUO's team address this need. Making inventive use of mathematics and logics, they have devised a method for developing driving scenarios that can be rigorously verified to be safe and that conform closely to real-life driving situations.

The concept of RSS for isolating safety conditions

Some examples of the driving scenarios developed by the team are as follows. A car is traveling in the passing lane of a two-lane (each way) expressway. It then moves back into the slow lane, maintaining a safe distance from surrounding cars (other cars) before stopping safely in the emergency lane to the left of the slow lane.

This is one of the most important scenarios for automated driving systems. It applies in a variety of situations, e.g., if the car needs to stop to use a roadside emergency phone for some reason, or if the driver is not ready to take over control when it is time to switch from autonomous to human control.

A common pattern in such cases is to adjust the speed and wait for the right moment to change lanes and fall behind another car in the left (slow) lane. It also happens that the right moment to stop the car is missed, because a lane-change cannot be safety executed due to being too wary of the risk of getting close to another car.

To address these kinds of situations, the developed scenarios allow for smoother driving. By judging speed and position relative to other vehicles, the system can change lanes at the right time. Also, in some cases, it will accelerate instead of slowing down to move ahead of a car to the left when it changes lane. This may seem like a risky maneuver, but the scenario is safe because it is verified to avoid any dangerous situation involving other cars.

The methodology employed to prove this safety is known as "responsibility-sensitive safety" (RSS). The idea is to formulate a set of responsibility rules for each car to ensure that it drives appropriately in response to the situation, in terms of accelerating, decelerating, changing lanes, etc. With the certainty of a mathematical proof, the assumption that these rules are followed represents a strict guarantee that no collision can occur.

RSS is a verification of safety under the given conditions, but it does not mean that accidents can be completely prevented. For example, a vehicle can always end up in an accident due to the reckless driving of another vehicle. The idea of RSS is to isolate conditions that cannot be avoided by responsibility on the part of the vehicle, and to rigorously assure safety within those conditions.

Extending RSS with mathe-

matics and formal logic

This approach to safety verification based on preconditions offers significant benefits. If an accident occurs under a prepared driving scenario, we can conclude that one of the vehicles involved did not follow the rules, clearly indicating the locus of responsibility. Professor HASUO stresses that, “RSS also offers a convenient framework for advancing the design of systems for the spread of automated driving, including laws and regulations, nonlife insurance mechanisms, and industry standards.”

RSS was originally proposed in 2017 by researchers at Mobileye, an Israeli company affiliated with U.S. chip maker Intel, but Prof. HASUO saw a lot of room for using mathematics and logic to enhance the method. The company’s example of RSS rules was limited to the simple case of avoiding rear-end collisions between cars moving in the same direction.

Professor HASUO and his team have examined the theoretical basis of RSS and generalized the concept to make it freely applicable to complex driving scenarios. They have also tried to extend RSS using formal logic, a branch of mathematics. The work of formalizing the proofs of RSS was performed, work which, simply put, is like using a computer to do mathematical proofs that were previously only done by people on paper.

The team has extended the reasoning system “Hoare logic,” which is well known in software research, to create a formal logic system referred to as “differential Floyd-Hoare logic (dFHL).” This new method of analyzing the complex action plans of self-driving vehicles in a segmented and sequential manner has successfully enabled the team to greatly expand the scope of RSS applicability. This new, extended method is called “goal-aware RSS” (GA-RSS).

The research team has also collaborated with Mazda to investigate the implementation of RSS in the controllers of self-driving vehicles. The system switches between two controllers, “normal” and “safety,” depending on the situation. Normal mode takes advantage of the vehicle’s performance to enable comfortable driving, and it is switched to safety mode in situations where the priority is on safety. RSS rules are also applied to this switching system.

A new framework with the potential to break new ground

How many of these driving scenarios would be necessary for real-world automated driving? Professor HASUO estimates that whether on fixed routes or expressways, there are probably hundreds of applicable scenarios. In addition to formulating new driving scenarios, the project is also conducting research aimed at automating scenario creation.

Quantity of data is said to be a key factor in the development of automated driving systems. Companies that are developing such systems are collecting vast amounts of AI learning data, both by running experimental vehicles under a wide variety of conditions and conducting driving simulations in virtual reality (VR) spaces. In these efforts, Japan is trailing far behind the international pacesetters.

When it comes to safety assurance (the protection of human life through collision avoidance), however, it is difficult to convincingly demonstrate safety to users and to public opinion through driving tests, simulations, or references to statistics on past accidents. This difficulty could hinder widespread adoption of automated driving technologies, but the completely new safety and security framework that is emerging in Japan has the potential to break through this impasse.

***1 ERATO Metamathematics for Systems Design Project (ERATO MMSD):** This research project is funded by the Japan Science and Technology Agency (JST) under its Exploratory Research for Advanced Technology (ERATO), a Strategic Basic Research Program. The project is focused on the study of quality assurance methods for cyber physical systems, which are a pillar of Society 5.0. Automated driving systems are seen as a high-priority field of application.

***2 Automated driving system:** A system that automatically performs the three essential functions of driving a vehicle: recognition, judgment, and operation. Vehicle operation is enabled by monitoring the surrounding conditions using on-board sensors. In accordance with the standards of the Society of Automotive Engineers (SAE), the Japanese government classifies the degree of automation from Level 1 (Driver Assistance) to Level 5 (Full Driving Automation).

***3 Operational design domain (ODD):** A design condition that is assumed for normal operation of an automated driving system. ODDs include a wide range of conditions, such as whether the vehicle is on an expressway or normal road, whether the road has multiple lanes (each way), geographical conditions such as urban or rural area, environmental conditions such as weather and intensity of sunlight, whether there is a safety operator on board, and speed limits.

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Senior Staff Writer, Nikkei Inc.

After graduating from Kyushu University, joined Nikkei Inc. Following stints in the Industry Department and the Seoul Bureau, headed the Science and Technology Department, and served as president of Nikkei Science, Inc. Since 2015, has covered science and technology as a senior staff writer. From 1997 to 98, participated in a science journalism fellowship at the Massachusetts Institute of Technology (MIT) in the U.S.

A Novel Extension of a Mathematical Method of "Formal Verification"

A theorem for avoiding collisions

Professor,
Information Systems Architecture Science Research Division, NII
HASUO, Ichiro

Interview and Writing
Senior Staff Writer, Nikkei Inc.
YOSHIKAWA, Kazuki

A novel extension of a mathematical method of "formal verification"

This research by Prof. HASUO, Ichiro and his team has shown that the safety of automated driving systems can be rigorously verified. The skillful application of mathematical techniques at each step of verification has led to some fruitful findings. Firstly, as a key framework, the team adopted the method of "responsibility-sensitive safety" (RSS). Since safety verification is difficult due to system complexity, this method was used to isolate certain preconditions to attempt a "conditional safety proof."

When proving a theorem in mathematics, an auxiliary proposition known as a "lemma" (auxiliary theorem) may be used as a stepping stone to the full proof. To prove that "no collision will occur" in the case of RSS, this theorem is divided into the assumption that "each car follows the RSS rules" and the lemma that "if each car follows the RSS rules, no collision will occur." Following this procedure, proving this lemma means proving the theorem that "no collision will occur."

Benefit of "recycling" proofs

The "RSS rules" that emerge are rules described as mathematical expressions or software programs. These are not simple mathematical expressions: they include complex control programs involving differential equations and the like. The development of a method to reliably prove contents described solely by such symbols using a computer is a remarkable achievement.

The term "mathematical proof" usually calls to mind the kinds of proofs worked out on paper and taught in high school math classes. Numerical formulas and words (natural language) such as, "since A is true, B is true," are written down one line at a time. Such paper-based proofs are prone to errors, however, and it is also difficult to check the correctness of proofs mechanically. It is obvious that this approach is unsuitable for an application like assuring the safety of an automated driving system.

The method used by Prof. HASUO's team is "formal verification." The entire verification process is coded and formulated to enable computer processing. Since a validity check algorithm can be used to show that a proof written on a computer is correct, the integrity of the proof and the developed system can be guaranteed. Another benefit is that once a proof is written, it can be "recycled" for similar operation scenarios.

What is the formal system of "Hoare logic"?

In their research, Prof. HASUO and his team proposed a system of formal logic they call "differential Floyd-Hoare logic" (dFHL) to derive RSS rules for the safety of automated driving systems. This is their original extension of Hoare logic, a formal system of logical rules for reasoning rigorously about the validity of software.

The central feature of Hoare logic is an expression consisting of three elements: {A}c{B}. The central element c is the program, A is the property that is true before program execution (precondition), and B is the property that is true after execution (postcondition). In the actual process of deriving a proof, many of these "Hoare triples" (e.g., {A}c{B}) are combined, and reasoning then proceeds step by step. With this new method, all the mental reasoning and logic work done in the case of a proof on paper is expressed in symbols and automatically processed.

This new dFHL system of formal logic proposed by Prof. HASUO and his team expands on Hoare logic by adding two features. The first one is the ability to handle differential equations. This makes it possible to incorporate physical dynamics, such as a vehicle driving controller, into driving scenarios.

The second feature adds a third "safety condition" (S) (on top of the precondition (A) and postcondition (B) of Hoare logic) that must always be guaranteed during program execution. This is expressed as {A}c{B}:S. Expanding the Hoare triples of the original Hoare logic to "Hoare quads" makes it possible to guarantee the safety of a vehicle while it is running.

Accurately demonstrating the safety of complex driving scenarios

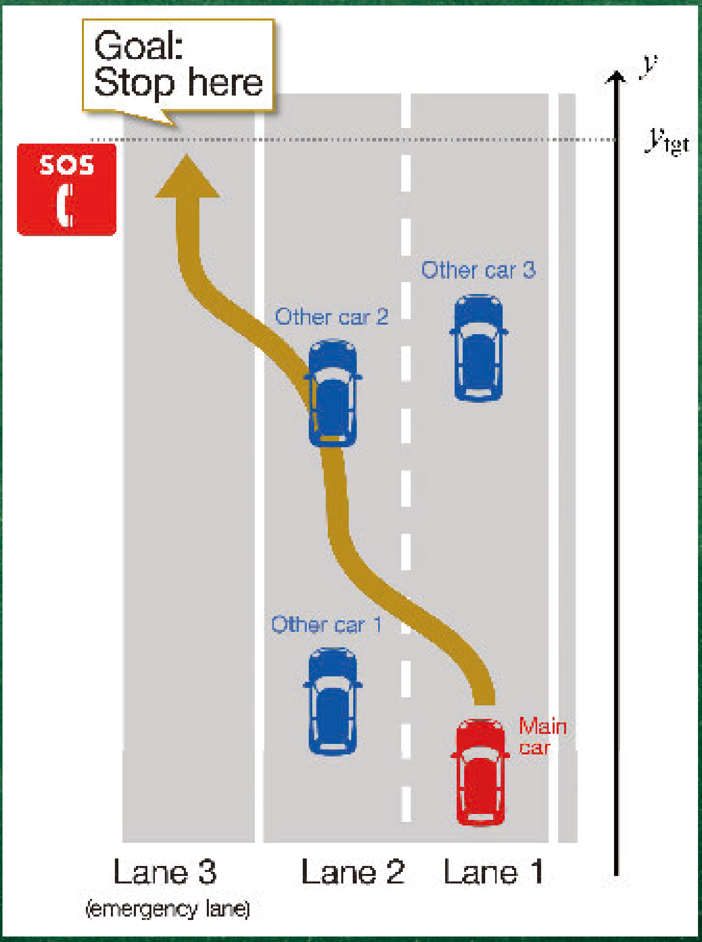
As explained in the article on page 6, the research currently focuses on a typical driving scenario. A car traveling in the passing lane of a two-lane (each way) expressway moves back (to the left) into the slow lane and then comes safely to a stop on the shoulder.

How does the basic formula {A}c{B}:S, which represents the Hoare quad of the dFHL method, align with this scenario? Precondition A corresponds to the "RSS condition," program c to the "appropriate vehicle response," and safety condition S to the "requirement to avoid a collision." If postcondition B is "stop at the designated position in the emergency lane," then the goal of the scenario, to stop at the side of the expressway, is guaranteed.

There is another benefit of expanding the Hoare logic system. A novel feature of Hoare logic is the "ability to verify by divide-and-rule" (in the words of Prof. HASUO). After proving each "component" of a program, the results can be combined to verify the validity of the whole program.

In relation to the current driving scenario, the whole scenario is divided into four sub-scenarios: "Prepare to change lane," "Change lane," "Move into emergency lane," and "Stop in emergency lane." After each of the sub-scenarios is proved, the results are combined. This process, called "sequential derivation," makes it possible to reliably verify the safety of even complex driving scenarios.

[Stop in emergency lane scenario]



The Potential of Mathematical "Safety Verification"

TAKADA, Hiroaki

Professor, Nagoya University (NU)
Director, Global Research Institute for Mobility in Society, Institutes of Innovation for Future Society (NU)
Director, Center for Embedded Computing Systems, Graduate School of Informatics (NU)

TAKADA, Hiroaki

After earning a Master's in Information Science from The University of Tokyo, worked as an assistant professor at Toyohashi University of Technology before becoming a professor at the Nagoya University Graduate School of Information Science. Has served in current role since 2014. Also leads the TOPPERS Project focused on developing open-source real-time OS technology.

"In the age of self-driving vehicles, mathematics may become our road traffic laws." This is how Prof. TAKADA, Hiroaki of Nagoya University, a leader in embedded software research who also works on the development of automated driving technology, sums up the potential of the ERATO MMSD project. We asked him about the difficulties of defining the safety of self-driving vehicles and the possibilities of using mathematics to verify safety.

—Please tell us about your field of specialization.

Basically, it's the design and study of operating systems (OSes) for embedded systems, but I'm also very involved in developing technology for embedded systems for automobiles. Starting with OSes, I also do research on the functional safety of networks and systems, and on security and self-driving vehicles. Much of my research is focused on cars, but I also work on space-related projects. Our lab developed the TOPPERS/HRP kernel, a highly reliable real-time OS (RTOS) for spacecraft that has been used in several launches for rocket control.

—What are the difficulties of an OS for in-vehicle embedded systems?

The safety of vehicle systems has to be assured within the framework of an activity called "functional safety analysis." For example, in failure mode and effects analysis (FMEA), the vast number of parts in a vehicle are analyzed to determine what malfunctions will occur when any part fails, and what accidents can result. This makes it possible to design systems that are free of unacceptable risks and that do not suffer serious accidents. For software, we need to analyze what happens if a module malfunctions and take suitable countermeasures. At the same time, since it's not possible to eliminate all software bugs, we make steady adjustments to ensure that even if an individual module malfunctions, its function is covered in an alternative way.

—How do you avoid collisions while vehicles are in motion?

In the case of ordinary passenger vehicles, the driver is basically responsible for ensuring safety. However, as car systems have become increasingly electronic, the focus of technology has shifted to ensuring adequate safety in the event of a system failure or malfunction.

In the case of self-driving vehicles, it becomes difficult to define "safety," because the human driver is replaced by a computer. To train an AI system to drive safely, a large quantity of learning data need to be collected in the machine learning database of the system. In a rule-based system, you need to write all the rules for a variety of model cases. This makes it easier to understand what happens under different conditions compared to machine learning, but the rules become so complicated that it gets very difficult to verify the accuracy of the rules and check for oversights.

Historically, the main focus of safety in car development has been "collision safety" (passive safety). That is, creating a safe car body to protect human life even in the event of a crash. "Active safety" in the form of electronic systems that automatically apply the brakes in anticipation of a possible collision is a relatively new technology.

—In this context, how can the mathematical safety verification

of the ERATO MMSD Project be applied to self-driving cars?

My understanding is that Prof. HASUO's research aims at proving a safety theorem that states that "no collision can occur if mathematically verifiable responsibility-sensitive safety (RSS) rules are followed," and that "all cars follow those rules." If an accident occurs, a vehicle must have deviated from a rule, thereby showing where the responsibility lies. When I first heard about this, it sounded like a road traffic law written in the language of mathematics.

Getting back to functional safety, even if we can ensure that a vehicle follows all RSS rules, what happens if the system fails? Imagine that the driving system of a self-driving car on the expressway suddenly fails. Due to the risk of a rear-end collision, it would be dangerous to stop suddenly. Therefore, to take over driving from the system, a minimum risk maneuver (MRM) is performed by decelerating safely and bringing the car to a stop at the edge of the road with minimum risk. There is no definition of "safe deceleration" under the law, however. If there were a definition that is verified to enable roadside stopping at a safe speed under "goal-aware" RSS (GA-RSS), an extension of RSS developed by Prof. HASUO and his team, things would be much clearer for automated driving system designers.

However, for the time being, self-driving vehicles must share public roads with bicycles and pedestrians, so there are still many hurdles to overcome before such automated driving technology can be widely deployed.

—— Professor HASUO is working to complete the accumulation of RSS rule-based safety verification scenarios by 2035.

In the case of self-driving vehicles, it is impractical to test for every possible situation and case. Even with computer simulation testing, it is impossible to cover everything. The search-based testing*1 proposed by Prof. ISHIKAWA, Fuyuki of the ERATO MMSD Project is a method of mechanically searching for test patterns that shorten the distance between vehicles, to find dangerous patterns. I think this is an efficient approach to the problem that skillfully applies current technology. As the performance of computers continues to improve, there is no doubt that we will see useful methods of automatically generating test configuration for software testing. Some students in our lab are working on this.

My impression is that the MMSD Project is skillfully applying mathematics in a powerful way. I don't believe there can be one all-powerful tool, so as various techniques are developed, we will see more clearly where they are easy or difficult to apply. But the mathematical techniques of safety verification have been very effective here. I think that the utilization of RSS and the work on GA-RSS are very important, particularly in the sense that they are like a road traffic law written in the language of mathematics.

[Outline of autonomous driving levels]

Autonomous driving level	Name	Conditions, etc.	Entity monitoring and responding to ensure safe operation
0	No Driving Automation	Driver performs all dynamic driving tasks.	Driver
1	Driver Assistance	System performs a limited range of subtasks.	Driver
2	Partial Driving Automation	Hands off, eyes on: Hands-off driving is possible. Remote driving is possible. Limited areas.	Driver
3	Conditional Driving Automation	Hands off, eyes off: Inattentiveness allowed. Sleeping not allowed. Remote driving allowed. One person can drive multiple vehicles. Limited areas.	System (driver if there is difficulty)
4	High Driving Automation	Hands off, eyes off, brain off: Dozing is allowed. Remote person does not have to be the driver. Supervisor required. Limited areas.	System
5	Full Driving Automation	System performs all dynamic driving tasks. Unlimited areas.	System

*1 Search-based testing: A method of finding optimal tests (simulation configurations) for a given purpose, in which tests (simulation configurations) characterized by high defect detection capability and diversity are recursively developed by a process of "evolutionary computation" that mimics the evolution of living organisms through repeated selection and hybridization.
Related releases:
Mar. 23, 2020: A method of automatically detecting dangerous motion in automated driving from route planning programs
Nov. 15, 2021: A technique for detecting critical problems in automated driving through simulation
Apr. 12, 2021: A technique for automatically finding simulation configurations that are difficult to test for
See also https://www.nii.ac.jp/news/release/

Created based on materials by Prof. TAKADA, Hiroaki and the Public-Private ITS Initiative/Roadmaps (https://cio.go.jp/sites/default/files/uploads/documents/its_roadmap_20210615.pdf), created by the Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society (IT Strategic Headquarters), Cabinet of Japan based on the SAE J3016 standard and the Study Group for the Promotion of ASV.

Interview/Written by KAJIWARA, Maiko

[Interview]

Engineerable AI (eAI) to Drive Industrial Innovation

Associate Professor,
Information Systems Architecture Science Research Division, NII

ISHIKAWA, Fuyuki

Tailoring AI to specific needs

**AI is now being utilized in a wide variety of settings.
When it comes to using AI to help develop industrial technology, there are still many challenges, particularly in relation to quality.
In this interview, we learn about the development of technologies that lead to real-world engineering enterprises and the Engineerable AI Project, an initiative aimed at helping to improve the safety of automated driving systems.**

Beyond "explainable AI" to AI that can be tailored to specific needs

——What is the Engineerable AI (eAI) Project?

The eAI Project was launched to address the challenges that arise when AI is applied to industry. Around 2018, many companies started thinking seriously about applying AI to their businesses. However, when they tried it, they often ran into stumbling blocks, such as a lack of data for learning and the huge amount of time required to obtain the desired results. We thought that Engineerable AI (eAI) technology might help to solve these problems.

——How can eAI solve these problems?

The most difficult part of adopting AI is the "explanation." Although it's no longer difficult to create an AI that works to some degree, it's impossible to explain why it works the way it does, since the AI process is hidden within a black box. Consider a product that has always been known for its quality. Due to the opaqueness of AI, it may no longer be possible to guarantee its quality. This is a serious issue. As an attempt to solve this problem, Explainable AI (XAI) was developed. With XAI, the AI's decision-making process, previously obscured by a black box, is made visible and "explainable."

However, when AI is used in business, it is not enough that the process be explainable; to obtain the desired results, it is also important to modify and adjust the AI. In fact, from surveys and discussions with more than 200 business operators, we heard many complaints to the effect that they did not get the desired results from AI, did not understand how to go about making corrections, and found that collecting the huge quantity of data needed to train the AI was too difficult.

We named this technology for tailoring AI to meet the specific needs of users "Engineerable AI" (eAI). We now have eight research institutes and universities participating in the eAI Project. Numerous companies and hospitals are also collaborating with us.

Strengths in the medical and automated driving fields

——What is the eAI Project working on more specifically?

The eAI Project is tackling two major themes.

The first is technology for building AI tools that deliver reliable results even with a limited amount of data. We are demonstrating this in the medical field. A team centered around Prof. SUZUKI, Kenji of Tokyo Institute of Technology is doing R&D aimed at using AI to detect disease cases that are easy to overlook.

Previously, it took around 100,000 data sets for AI to identify a particular case, but for rare diseases, it can take years to

eAI is a technology that tailors AI to meet the specific needs of users

collect even hundreds of cases. As a solution, we are developing technology for building AIs with embedded human knowledge that can perform better than existing AIs with small amounts of data.

The second focus of the project is applications subject to many errors that need to be prevented. We are developing technology that only corrects the output of targeted parts of an AI, without affecting other outputs. This is being demonstrated in the field of traffic control. NII, Kyushu University, and Fujitsu are working on R&D aimed at ensuring the safety of AI systems by narrowing down millions of parameters to identify sets of parameters that can cause errors. The goal is to develop technologies for automatically correcting AI errors in order to improve recognition accuracy in the areas that are prone to significant safety risks in vehicle and pedestrian images.

eAI technology for targeted improvements

—Medicine and traffic control are two fields where failure is unacceptable.

That's right! Take, for example, an AI that is used to forecast stock prices with the goal of making a profit. Adjusting the AI parameters may yield mixed results, increasing the prediction accuracy in some cases while reducing it in other cases, but if the ultimate outcome of AI correction is a higher profit, the AI can be considered successful.

On the other hand, in fields like traffic control and medical care, safety and reliability are the paramount concerns, so even if the overall accuracy of the AI system is increased by adjusting parameters, any error on a high-priority question that was previously answered correctly is unacceptable.

Thus, the aim of eAI technology is not so much to increase the overall percentage of accurate answers but rather to deal with situations in which certain kinds of errors cannot be tolerated, or when it is necessary to prioritize the degree to which errors can be tolerated.

Neural networks, a method of mathematical modeling used in AI, perform "learning" by adjusting multiple weight parameters to vary the AI outputs.

Neural networks are generally

trained by updating all the weight parameters according to the given data. Therefore, even when there is overall improvement, if a targeted part cannot be improved, or if there is deterioration in some parts (compared to before learning), this is a problem.

In particular, such an AI cannot be applied when multiple specific conditions need to be satisfied while achieving an overall improvement.

In contrast, the eAI Project is working to develop AI correction technology that identifies and selectively modifies sets of parameters that affect specific targets by analyzing the input/output and internal behavior of neural networks. This is a key feature of eAI technology.

Efficient AI correction technology

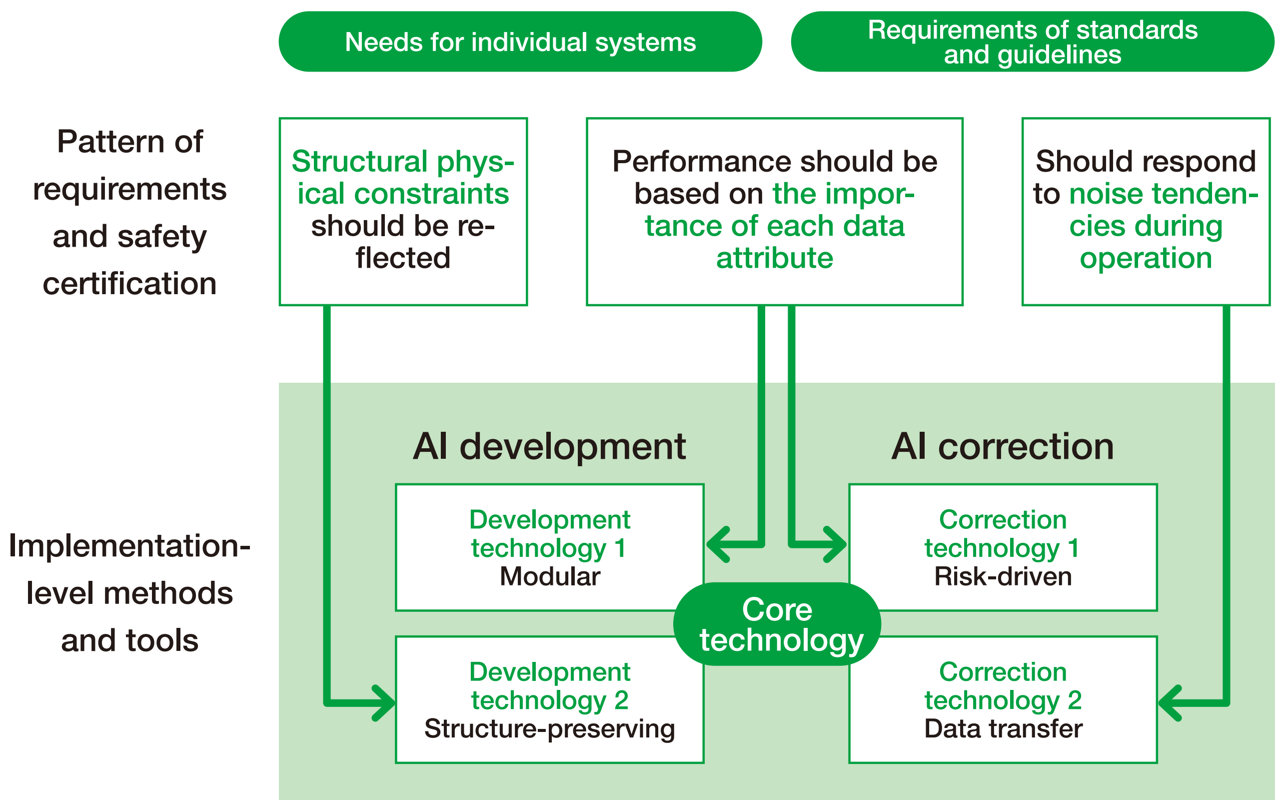
—What method does the eAI technology use for this selective modification?

For example, when correcting various errors made by AI, the eAI technology classifies the errors as precisely as possible and then narrows down the sets of weight parameters that contribute to each error. Next, it searches for the appropriate values of the weight parameters for correcting each error. Once the sets of parameters that can be corrected for all the errors are found, an overall balancing is performed. The final weight parameters are determined by performing this overall balancing based on the probability of each error occurring and the magnitude of the risk. This is why eAI is likely to be most useful in fields and industries in which accuracy and reliability are important.

There is a variety of patterns in the "detailed needs" addressed in the eAI Project. The AI correction techniques described so far are designed to improve prediction performance according to the importance of specific data attributes, such as "pedestrian nearby." As shown in the upper part of the figure, there are other patterns for different needs, for example, the need to avoid making impossible predictions that violate the rules of the physical world, or to deal with noise distribution during operation.

The eAI Project is working on technologies for developing and modifying AI, as shown in the lower part of the figure. Overall, by analyzing the needs of individual systems with respect to standards and guidelines, the project will offer a streamlined framework for uti-

[eAI Project Framework]



The eAI Project, aimed at enhancing the safety of cognitive functions, complements mathematical safety verification

lizing AI technology appropriately.

Complementing mathematical safety verification

—What is the relationship between the eAI Project and the “Metamathematics for System Design Project” that Prof. HASUO is working on?

Professor HASUO’s research is focused on the safety of automated driving system designs. In this research, it is assumed that cognitive information is input from the external environment, and it is important to know what kind of cognitive information it is.

The eAI Project is pursuing research on the “safety of cognitive functions.” As an example of application to automated driving, this work leads to recognizing external conditions and formulating low-risk driving plans.

Another thing is that not all situations that arise in the real world can be proved mathematically to be safe. For complex mathematically unverifiable environments, simulations can be used to verify safety. Therefore, by working on simulations, the eAI Project complements Prof. HASUO’s project.

“Open” project in collaboration with companies

—The eAI Project, which launched in 2021, has made some significant achievements in areas relevant to real-world applications. You have two years left until March 2025, when this phase of the project ends. Overall, how do you think the project has progressed up to now, and what has particularly impressed you?

The eAI Project started out with two major objectives: developing technology to facilitate continuous improvement of AI, and applying this technology to the field of traffic control. We’ve successfully developed technology for improving AI continuously, and we’ve also been able to confirm its suitability for the applications we selected with auto makers, so we have set up a technological foundation for expanding eAI’s scope of application.

In the sphere of academic research, which tends to be closed, the deployment of new technologies is typically expanded slowly, starting with simple applications. In the eAI Project, however, we are working from the outset on real-world applications that can be immediately implemented by companies. Although we had some worries due to this different approach, it’s been an interesting challenge and a very good experience.

Expectations of industrial applications

—What do you plan to work on next?

For the next two years, we are considering two main initiatives.

The first one is to prepare and release some eAI tools by effectively integrating what we’ve developed so far in our multiple basic research efforts. We want people outside the project to have access to these kinds of tools, so the tools can be put to use in the industrial world.

The second focus is to apply our developed technology to the wide range of challenges faced by different companies. So far, we have worked on the applications that were of greatest interest to the companies we consulted with. In practice, though, specific applications always have different assumptions and objectives, so we want to keep doing R&D that will help companies make wider and more effective use of eAI technology in their industries.

Interview/Written by ICHINOSE, Syun / Photography by IMAMURA, Takuma

[Dialogue]

"ZERO TRUST" FOR ESTABLISHING SAFETY

ISHIKAWA, Yutaka
Professor, Information Systems Architecture Science Research Division, NII

TAKEFUSA, Atsuko
Professor, Information Systems Architecture Science Research Division, NII

The impact of formal verification in defining the "behaviors" of systems

In the era of IoT, not just smartphones and tablets but even home appliances and cars are connected to the Internet. In the face of heightened risks, we need to determine how to maintain system reliability. To find out, we set out to learn about the "safety" achieved by the "Zero Trust IoT by Collaboration of Formal Verification and System Software" research project (principal investigator: TAKEFUSA, Atsuko), funded by a Japan Science and Technology Agency (JST) CREST grant.

Guaranteeing safety with the help of formal verification theory

Formal verification theory underpins "zero trust"

— As expectations of automated driving technologies mount, there are also growing concerns about their safety and reliability. What is your research focused on?

TAKEFUSA: Our goal is to create software system technology for creating safe IoT systems, using the power of formal verification theory.

— How did the two of you come to get involved in this field of study?

TAKEFUSA: I majored in information science at university. I was able to choose from a wide variety of subjects to study, from mathematics and theory, to programming and engineering-oriented tasks. The Internet was just going mainstream at that time, so I got interested in network computing and did my graduation thesis on it. My lab at the university was doing joint studies on industrial and real-world applications with research institutes and other universities. This inspired me to pursue research on grid computing and super-distributed processing.

In this area, there was a concept called “sensor grid,” which meant collecting data by networking all objects and experimental devices. In a way, today’s research on cloud computing and IoT started at that time.

ISHIKAWA: I was interested in system software and operating systems. At first, I worked on UNIX mainframe systems, but in the late 1980s, it became possible to run UNIX on PCs, leading to the worldwide Linux boom of the 1990s. Around 1997, it became possible to combine PCs and high-speed networks with optimized system software, to achieve performance levels comparable to supercomputers. When we demoed our system software and PC clusters at a conference in the U.S., we drew a huge amount of attention.

Our software was being used in a variety of places at the time. By natural progression, I continued to work on the development of supercomputers, serving as leader of the Fugaku supercomputer development project. In the late 1980s, I also got interested in verification technology, but it wasn’t mature enough to be useful for system software development, so I lost touch with it.

— The complexity of today’s computer systems and the potential impact if they can’t be controlled are literally orders of magnitude greater than before.

TAKEFUSA: Over the years, IoT devices, which are often out of sight, and computing devices that are not directly controlled by people have been vulnerable to external breaches, resulting in serious damage. With the advent of self-driving cars, the risks will be even greater. The fact that it’s hard to counter the risks means we need to make very sure that systems are safe.

In terms of what kind of controls we need in order to make them safe, first we need to have a clear idea of everything that’s on the network, how it needs to be protected, and how to keep the network secure. We also need to keep track of the system and make sure that it continues to be reliably accessible. This is our approach to guaranteeing security.

— Is total protection against unknown dangers possible?

ISHIKAWA: Whether a danger can be dealt with depends on the vulnerability of the system and the threats that can exist. Even if there is no vulnerability, an attack from outside might affect some network services, degrading performance. The question is how to diagnose this and respond. We need to examine and decide in advance.

With a self-driving vehicle, if a service is unrelated to driving, it can simply be turned off, leaving driving unaffected. In the case of Level 3 autonomy, if the system detects a risk that could adversely affect driving, one response could be to disable automation and get the driver to take over. In practice, we need to do an analysis at the system design stage and take countermeasures based on the results.*1 Together with Prof. HASUO and his team, we are investigating formal verification theory for this purpose.

— It’s clear that a “zero-trust” approach, not trusting

Sustaining system reliability is also important

anything on the network, is essential for security, but doesn't that sacrifice performance?

TAKEFUSA: Of course there is a tradeoff between performance and safety. The system creator initially considers what to make secure and to what degree, but after the system starts operating, various changes may occur or be introduced. That kind of change is one of the things we are currently studying.

Firstly, the system is modeled. Then, after the model has been proved to be secure, the model is reflected in the system implementation. However, if the system changes, the model also changes. If the security of the modified model is verified before the model is reflected in the system, the system should continue to operate securely.

Pure research supports real-world development

— Quality assurance at the initial design stage seems to be important for ensuring continued security in response to changes made after the start of operation.

ISHIKAWA: Although we don't make products or services, we aim to support real-world development by conducting pure research to create reliable methods and dependable analysis tools. That is our mission. Consider self-driving vehicles that are connected to the Internet and utilize a variety of services over the network. The network service providers and the car itself are both running all kinds of software. If a car is attacked due to a cybersecurity vulnerability, we need to ask whether the vulnerability was there from the start. We analyze these cases using formal verification methods in order to develop tools that are released over time. On the platform side, my team is collaborating with Prof. TAKEFUSA's team.

TAKEFUSA: Although it's not always possible to make the required responses for all changes, it is still very important to detect changes.

There are two basic ways to think about disaster countermeasures. One is to try to prevent every kind of potential disaster in advance; the other is to accept that it's impossible to totally prevent disasters and focus on limiting the damage and facilitating recovery in the event of a disaster. We are taking the second approach, by aiming to make IoT systems resilient. Although it is important to anticipate and prepare for risks, it is also vital to respond securely, reliably, and with a broad flexibility when risks that cannot be prevented or foreseen arise. We believe that we can achieve this with system software.

— I understand that formal verification through the power of mathematics plays an important role in this.

ISHIKAWA: Formal verification is the mathematical process of formulating and verifying a system model, as well as verifying all the possibilities that the model can generate. The concept has been around for a long time and used in some fields, but the scope of its application is now gradually expanding.

Since all possibilities are identified and verified, in models of real-world systems of realistic size and complexity, a "combinatorial explosion" tends to occur. Thankfully, the availability of high-performance computers with abundant memory now allows us to do verification even in the case of a combinatorial explosion, at least to some degree, so the question is how far can we progress in verifying large complex models that reflect reality while suppressing combinatorial explosions. We're not sure yet, but we want to find out in the coming years.

TAKEFUSA: There's a big difference between setting up and verifying a model, and creating and executing a program. How can we bridge the gap and correct this? In other words, how can we make the modeling methods developed by formal verification researchers available to system software researchers? This is another challenge.

The important thing is to seriously ask "is this OK here and now?"

Research findings improve the services provided by NII

— What are some of the possibilities for new, unprecedented applications? Are there any "dreams" you are likely to realize in the near future?

TAKEFUSA: NII provides various services to academic institutions, including middleware for IoT systems.*2 The findings of our current research will be integrated and used for this, but above all, we want to help academic institutions create secure IoT systems.

The range of IoT applications is very broad. For example, if every household were equipped with a smart meter, that information could be used to reduce the electricity consumption on a city basis. The first challenge is to implement IoT as a fundamental technology for Society 5.0.

This will make it possible to optimize an entire power supply system without disclosing information about each household. It may be possible, for example, to use such a system for automatically and conveniently saving electricity on a local municipality basis. In addition to IoT system development at academic institutions, promoting joint research with companies can help to disseminate this technology and allow it to take root.

In any case, it's difficult to predict the future because nobody can know what changes may be caused by external factors. However, we feel that it's important both to steadily pursue this research and steadily promote the diffusion of this technology.

— As expectations grow, inevitably some public apprehension about this kind of technology will remain.

TAKEFUSA: That's precisely why we talk about "zero trust." We can't respond to everything by saying, "this will be OK"; instead we need to seriously ask, "Is this OK here and now?" The technology developed from our research on IoT devices can be applied to servers and a wide range of other applications. For example, the development of software and "zero trust" security for IoT devices, which are often small and unable to be managed by human intervention, could be applied in a broad variety of areas.

Mathematics for modeling system behavior

ISHIKAWA: Our research also demonstrates the power of mathematics. Mathematically modeling the behavior of a system and describing it in abstract terms together make it possible to clearly understand its behavior and identify the possibilities of cyberattacks. Identifying the risk of a cyberattack then allows us to examine methods of defense and modify the system design. We can then keep verifying the behavior of the modified system in the same way until the system has been proved to be free of vulnerabilities. We believe that validating systems in this way with accountability and without any omissions or carelessness is very valuable.

To achieve this, developers need to be able to properly abstract and verify the behavior of systems. This is the difficult part, but developers can make use of the tools we are creating to describe how the assets to be protected (e.g., the data handled by IoT devices) are handled. Up to now, the safety of systems was verified by interviewing the developer to understand and model the system behavior. Now, the ability of developers to confidently guarantee the security of their software has the potential to make a very positive impact.

— It seems like we can confidently expect the software systems and self-driving vehicles of the future to be increasingly safe and secure.

*1 For automobiles, analysis is based on international design and evaluation standards.
*2 See https://sinetstream.net.

Verification through mathematics is very valuable

Interview/Written by MIWA, Yoshiko / Photography by IMAMURA, Takuma

News & Topics

NII NEWS TOPICS

Period **February 1 (Wed.) to August 30 (Sun.), 2023**

More details about news items are available online.

www.nii.ac.jp/en/news/2023/

Facebook
https://www.facebook.com/jouhouken/

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YouTube
(audio will play)

https://www.youtube.com/user/jyouhougaku

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https://twitter.com/NII_Bit

NEWS RELEASE 2023

Apr. 7 Field demonstration of CADDE (Connector Architecture for Decentralized Data Exchange), a system for discovering and using data across disciplines, is conducted with release of external specifications.

Mar. 30 NACSIS-CAT/ILL Catalog Information Service for University Libraries and Other Institutions: A new system advances the international distribution of metadata one step forward

Mar. 29 RIKEN, NII, and NTT collaborate to promote large-scale data use for research using IOWN

Mar. 17 Techniques for effectively and efficiently mitigating risks by misperception of image recognition AI: Verified effective according to safety benchmarks in automated driving systems

AWARD 2023

Mar. 22 Prof. ECHIZEN, Isao (Information and Society Research Division), Prof. YAMAGISHI, Junichi (Digital Content and Media Sciences Research Division), Dr. Trung-Nghia LE (former Project Assistant Professor), Dr. Canasai KRUENGKRAI (Project Assistant Professor, Digital Content and Media Sciences Research Division), Dr. Huy Hong NGUYEN (Information and Society Research Division) received a 38th Telecom Interdisciplinary Research Award, Telecommunication Advancement Foundation for a journal feature article.

Mar. 1 Assistant Professor KOBAYASHI, Taisuke (Principles of Informatics Research Division) received a 2022 Japan Society of Mechanical Engineers Young Engineers Award (Research).

EVENT 2023

▶ www.nii.ac.jp/event/2023

- □ Jun. 19-23 Japan Open Science Summit (JOSS2023) (Online)
- □ Jun. 2-3 NII Open House 2023 (public presentation of research findings)(Partially online)
- □ May 29 NII Open Forum 2023(Hybrid event)
- □ May 12 [65th] DX Symposium for Educational Institutions (online)
- □ Apr. 21 [64th] DX Symposium for Educational Institutions (online)
- □ Mar. 29 [63rd] DX Symposium for Educational Institutions (online)
- □ Mar. 25 10th NII Shonan Conference Commemorative Lecture(Hybrid event) "Digital Twins that Extend the Experience of Humans and Robots"
- □ Mar. 22 & 24 NII FY2022 Retirement Commemorative Lecture (Partially online) Director General KITSUREGAWA, Deputy DG YONEDA, Assistant DG OYAMA, Professor ABE
- □ Mar. 3 [62nd] DX Symposium for Educational Institutions (online)

- Feb. 17 Research Data Management (RDM) Information Session 2022 in Kanazawa (Feb. 2023)
- Feb. 17 SPARC Japan Seminar 2022, “Current Status and Challenges of Open Access in the Face of E-Journal Transformative Agreements and APC Issues”
- Feb. 3 [61st] DX Symposium for Educational Institutions (online)

INFORMATION 2023

Apr. 12 Registration opens for NII Open House 2023 (public presentation of research findings)

Apr. 11 NII public lecture series 2022, No. 4, “How to Build a Supercomputer?: Without Software, It’s Just a Box,” by ISHIKAWA, Yutaka is posted online for public viewing.

Apr. 10 Second (additional) call for applications for NII Open Collaborative Research 2023

Apr. 7 Field demonstration of CADDE (Connector Architecture for Decentralized Data Exchange), a system for discovering and using data across disciplines is conducted, with release of external specifications.

Apr. 3 1st call of 2023 "NII International Internship Program"

Apr. 1 National Institute of Informatics Summary 2023 (Japanese) is published.

Mar. 31 National Institute of Informatics Annual Report 2021 is published.

Mar. 30 NACSIS-CAT/ILL Catalog Information Service for University Libraries and Other Institutions: A new system advances the international distribution of metadata by one step

Mar. 29 RIKEN, NII, and NTT collaborate to promote large-scale data use for research using IOWN

Mar. 25 NII public lecture series 2022, No. 6, “Collecting Huge Amounts of Data to Solve Real-world Problems: Collecting and Utilizing IoT (Internet of Things) Data,” by TAKEFUSA, Atsuko is posted online for public viewing.

Mar. 20 Delegation from the Interdisciplinary Institute for Artificial Intelligence of the Côte d’Azur University (France) visits NII.

Mar. 17 Techniques for effectively and efficiently mitigating risks by misperception of image recognition AI: Verified effective according to safety benchmarks in automated driving systems

Mar. 15 PR magazine “NII Today” No. 98, “A World Driven by Informatics: 10 Years of challenges and advances” is published.

Mar. 6 NII public lecture series 2022, No. 5, “Improving Research Transparency and Efficiency Through Appropriate Data Management: What is GakuNin RDM, a Tool for Researchers?” by KOMIYAMA, Yusuke is posted online for public viewing.

Feb. 14 “Kobe University Japanese-Chinese Comparative MRI Movies corpus” (KU-JC-MRI) is now available.

We welcome your comments!

Please feel free to share your comments about NII Today magazine with us. We look forward to hearing from you!

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Click link below for registration and other details (Japanese)
https://www.nii.ac.jp/event/openhouse/2023/

[Essay]

What is Control Theory?

KISHIDA, Masako

Associate Professor,
Principles of Informatics Research Division, NII

For those in the field of computer science, the term "control theory" may be somewhat familiar, but its core remains a mystery. Just because a research paper or project has the term "control" in its title doesn't necessarily mean that it is directly related to "control theory". Even if the title is "XX control theory", it may actually be a theory of "control of XX" that has nothing to do with "control theory". In such cases, even experts need to read the abstract or check the keywords and bibliography to see its relevance.

Control theory is a discipline that primarily uses differential equations (or difference equations) to describe dynamic systems or processes to analyze the characteristics of these dynamic systems. It mathematically and theoretically proposes what kind of inputs should be applied to the system to achieve desired outputs. To do this, control theory uses various mathematical tools, including linear algebra, graph theory, real analysis, complex analysis, functional analysis, and mathematical optimization, and develops theories and presents proposals in the form of theorems and proofs.

Control engineering is another field of study that includes the term "control". Control engineering is the study of designing, building, and operating systems using control theory to make actual systems, such as automobiles, aerospace, robotics, and power systems, perform as desired.

Thus, although control theory and control engineering are different fields of research, they are closely related and connected in a gradient manner. Consequently, there are researchers who specialize in control theory, those who specialize in control engineering, and those who do both.

Control theory is also closely related to artificial intelligence (AI). For example, the concepts of feedback and optimal control in control theory can be considered the basic concepts behind neural networks and reinforcement learning algorithms. Moreover, it is possible to derive the conditions necessary to guarantee the convergence and stability of learning algorithms from the theories known in control theory. For this reason, control theory researchers are actively involved in the development of machine learning and AI algorithms.

The appeal of control theory lies primarily in the ability to conduct research using only pen and paper. Since a computer is needed mainly for gathering information and writing manuscripts, a standard computer is sufficient. There are no limitations in terms of time, place, or budget since no special equipment is required. Another attractive aspect is that the diverse mathematical skills acquired in control theory can be applied to a wide range of research areas, allowing you to combine your strengths with research in other fields. Furthermore, it is important to note that control theory is unambiguous and concise, and the theories developed here are easy to visualize the substance.

In summary, the answer to the question posed in the title, "What is control theory?" is "behind-the-scenes but an important and fascinating area of theoretical research in mathematics".

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Weaving Information into Knowledge
NII

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