National Institute of Informatics News ISSN 1883-1966 (Print) ISSN 1884-0817 (Online)

NII Today

72
Dec. 2019

National Institute of Informatics News

Feature

Robotics and Informatics

A New Relationship between Human and Robot

NII Interview

Robot Research, Past and Future

Striving to produce innovative, socially beneficial research

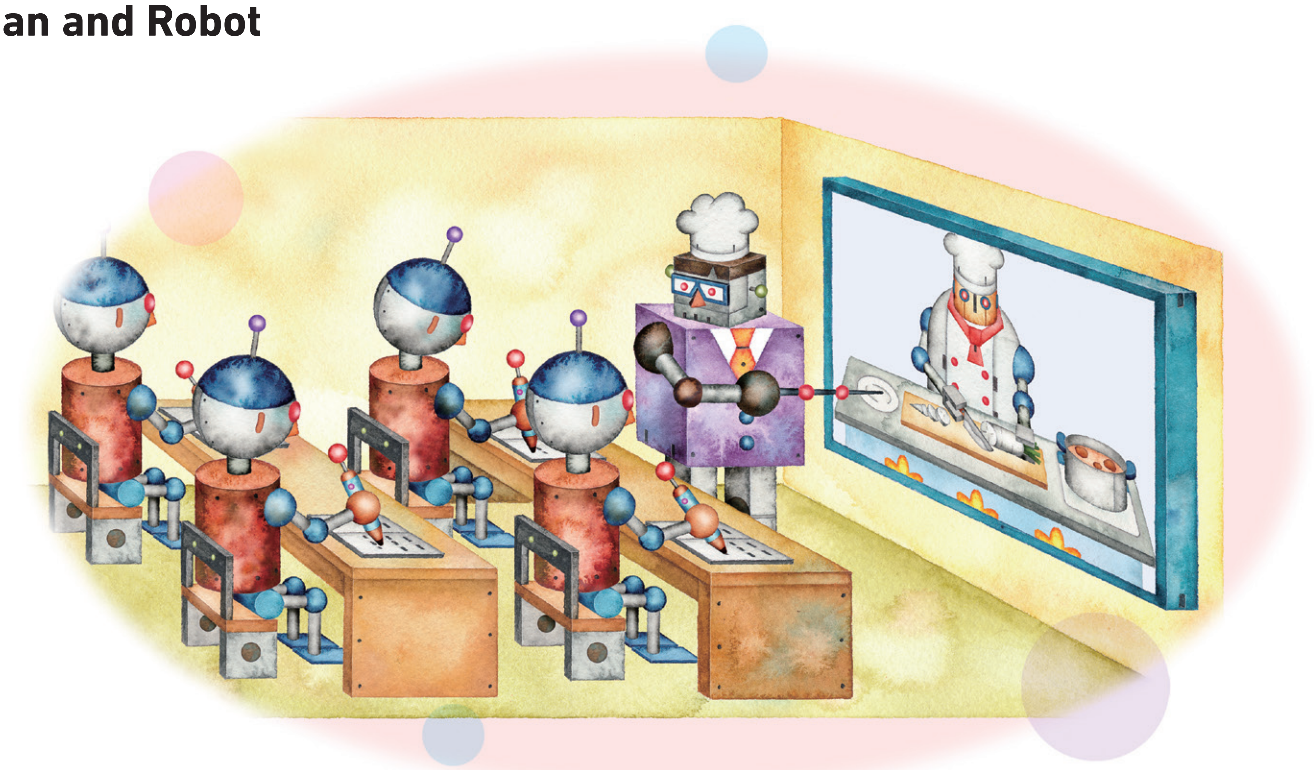
Takeo Kanade [U.A. and Helen Whitaker University Professor, Carnegie Mellon University]

Interacting with Robots in VR to Create Intelligence of Robots

Tetsunari Inamura [Associate Professor, Principle Informatics Research Division]

Unraveling the Mysteries of Human Intelligence from Robots

Shingo Murata [Assistant Professor, Principle Informatics Research Division]



This English language edition NII Today corresponds to No. 86 of the Japanese edition

Robot Research, Past and Future

Striving to produce innovative, socially beneficial research

Takeo Kanade
U.A. and Helen Whitaker University Professor, Carnegie Mellon University
Visiting Professor, National Institute of Informatics
Special Advisor, RIKEN Center for Advanced Intelligence Project

Interviewer: Kyoko Takita
Deputy Managing Editor, Yomiuri Shimbun, Tokyo Headquarters

Are we nearing the days of life with AI-equipped robots? Carnegie Mellon University's (CMU) Professor Takeo Kanade, a robot research expert, answers that question with a resounding "yes." I sat down with Professor Kanade to ask how he envisions robots and human society will interact in the future, and to talk about the allure and prospects of robot research. In the 1970s, Professor Kanade started his pioneering research on what would become robotic eyes: computer vision (image processing and image recognition). In 1995, his team successfully took an autonomous vehicle on a transcontinental trip across the US.

Starting Off with the World's First Processing and Recognition of Facial Images

—— You've been studying computer vision and artificial intelligence (AI) for more than 50 years. How did your initial research start?

Kanade I first heard the term artificial intelligence in my junior year at the Kyoto University School of Engineering. It was in a lecture by Professor Toshiyuki Sakai, a pioneer in speech recognition, that I learned the concept of AI. On my own, I also read books by computer scientists like Alan Turing and Claude Shannon and was absolutely convinced that AI would surpass human intelligence. That belief has never changed.

Human intelligence is calculation. In technical terms, "calculation" is more than just basic arithmetic operations. It encompasses processing of all information, not just numbers but also symbols, conditional judgments and logical calculations, sensor inputs, and executions for the outside world. Through our sensory

Takeo Kanade

Born in 1945, Kanade is the U.A. and Helen Whitaker University Professor at Carnegie Mellon University (CMU), as well as a Visiting Professor at the National Institute of Informatics (NII) and Special Advisor at the RIKEN Center for Advanced Intelligence Project (AIP). Kanade received his Ph.D. in electronic engineering in 1974from the Kyoto University School of Electrical and Electronic Engineering. After serving as an assistant professor at Kyoto University, he joined the CMU Robotics Institute in 1980 and became a senior researcher for their School of Computer Science. From 1992 to 2001, Kanade served as Director of the CMU Robotics Institute. He was awarded the Kyoto Prize in 2016 and pronounced a Person of Cultural Merit in 2019. Professor Kanade has authored several books, including *Originality Is Not Inspiration: Think like an Amateur, Do as an Expert* [in Japanese] (Nihon Keizai Shimbun Press).

organs—the eyes, ears, skin, and so on—we humans take in the state of the outside world as physical signals and process information while referencing memories with our brains, which are physical devices called nerve cell networks. In response, the brain sends electrical signals as orders to our muscles to move our bodies. There's no profoundly mysterious mechanism or power at play. With fewer physical limitations than humans, it's no wonder I thought that computers would surpass us.

—— It was the image recognition program you created in graduate school at Kyoto University that led to your later research on computer vision, right?

Kanade At the 1970 Osaka Expo, there was this collection of more than 1,000 digital images of the Expo visitors. On the advice of Makoto Nagao, who was then an assistant professor in Sakai's laboratory and went on to become president of Kyoto University, for my doctoral thesis, I wrote a program to use a computer to automatically extract and classify features from these images, such as the position and angle of the nose, eyes, and mouth. My research was recognized as the world's first full-scale study in processing and recognition of facial images.

Data Quality Trumps Data Quantity

—— Today, facial recognition is common technology. And the accuracy of recognition is likely to improve for GAFA (Google, Apple, Facebook, Amazon) and other big data-enabled corporate giants, as well as in countries like China where surveillance cameras are widely used to gather information about the public. What's your take on this situation?

Kanade Until around 2000, it was we humans who had to think about what features to use for facial recognition. Today, deep learning is getting smarter and smarter, all by itself, to put it in a good way. Computer networks are learning from thousands of facial images. In that sense, yes, corporations and countries with a lot of facial data do have an advantage, but more data does not necessarily equal more accuracy.

—— So it's not all about big data?

Kanade Data are important; that's no lie. But I don't agree with recent assertions that anything is possible with enough data. What's really important is the quality of the data. It's critical to have data relevant to the problem you want to solve.

Taking autonomous driving as an example, the data you get are going to be roughly the same no matter how many times you drive down a particular road. At a certain intersection, pedestrians will always enter from the right. In rare cases, however, pedestrians may enter from the left. If the data for this intersection assume that pedestrians will only enter the intersection from the right, cases in which pedestrians enter from the left won't be covered, which could lead to accidents in applications.

Now, do you need to consider what to do when a car falls out of the sky? Maybe for roads running under a highway, but generally speaking that would be far-fetched.

Considering too many cases could take up resources unnecessarily and result in dangerous daily driving. Thus, we must discern how much data are needed to achieve autonomous driving.

This is the perspective from which we gather data, or more recently, artificially generate the data, along with answers as to what decisions the autonomous vehicles should make regarding the data. That is the value of high-quality data over poor-quality data.

On His Autonomous Vehicle Successfully Driving Coast-to-Coast across the US in 1995

—— Autonomous driving now attracts attention around the world, but the research started at CMU back in the mid-1980s.

Kanade Research on autonomous driving started as what was called the ALV (Autonomous Land Vehicle) Project, run by the Defense Advanced Research and Planning Agency (DARPA) of the U.S. Department of Defense. In it, a robot car loaded with a camera and computer had to locate the road for itself and drive autonomously.

My first research program started in 1986. We indicated that the vehicle would be able to drive following the road lanes in Year One, to spot obstacles in Year Two, and achieve what we now call level 4 (the vehicle performs all operations without human assistance on highways and under certain other conditions) in Year Four with tentative measures. They (= DARPA) believed our proposal and provided ample funding.

—— When the research started, what technology did you think it would take to achieve autonomous driving?

Kanade Basically the same technology as on today's autonomous vehicles. The basic concept is unchanged: the vehicle uses images and sensors to identify road positions, people, other vehicles, and obstacles, and then determines a safe course on which to drive. Plenty of the parts were crude by today's standards, but the archetype of autonomous driving was already in place.

In 1995, CMU's autonomous vehicle successfully drove from east coast to west, through Pittsburgh to San Diego, without a human touching the steering wheel for 98.2 percent of the 4,500-kilometer trip (see Figure 1). In basic terms, the program

Figure 1 1995 US transcontinental route (top) and NavLab5 autonomous vehicle (bottom)

was a lane keep program as commonly used on highways today. So it couldn't drive in areas without lanes, like construction zones.

Progress in Computers and Sensors Hasten Autonomous Driving

—— **Why is it that we are just now seeing autonomous driving put to practical use on the road?**

Kanade Probably because of significant progress made in each and every technological element of autonomous driving.

First come sensors. Camera performance has significantly improved, particularly in terms of expanding the serviceable range of brightness (dynamic range). If you go outside and the surroundings suddenly go bright, it may take a second, but your eyes will quickly adjust and be able to see. This is more difficult for cameras—with the setting sun in the background, cameras can lose sight of a white oncoming car. From inside a tunnel, the outside world looks white; from the outside, the inside of a tunnel looks black. Research to overcome these weaknesses has made progress. While still imperfect, resolution and dynamic range specifications today are greatly improved.

Another example is LiDAR (laser imaging detection and ranging), a three-dimensional sensor system that measures the state of the outside world as a distance image. When we started, only a few systems with LiDAR existed worldwide, and LiDAR then was low resolution, only capable of measuring several frames per second to a range of 30 meters or so. Today, it covers a full 360-degree radius in real time, up to a forward distance of 100 meters.

Naturally, improvements in computer performance are a major factor. When research started, my Sun Microsystems workstation at the time was considered fast despite being capable of computing at most a few MIPS (million instructions per second). Now we measure computing speed in GIPS (giga = 1 billion) and TIPS (tera = 1 trillion). Computational speed today is a hundred thousand to a million times faster than it was then. Also, GPUs and other computing devices suited to image processing and deep learning are the norm.

In addition to hardware advances in sensors and computing, autonomous driving has been made a reality by dramatic advancements in the ability of recognition programs thanks to deep learning algorithms.

—— **Did you see the age of autonomous driving coming?**

Kanade I thought it was inevitable that computers would take over driving, but I didn't expect it would take this long to be put into practice.

Frankly though, I never imagined the creation of anything like Mobility as a Service (MaaS), in which transportation is optimized by linking cars and public transportation using ICT, or that within that service autonomous vehicles would receive data feedback and improve their capabilities further. At the time, we had no clue that autonomous driving would change not only the way cars are driven but the very structure of society itself.

Social Acceptance Holds the Key to the Spread of Autonomous Driving

—— **What challenges lie ahead for full autonomous driving?**

Kanade Besides the driving technology, I'd probably say modeling human behavior. This is especially true for when autonomous-

driven and human-driven cars share the roads.

Driving is a type of game. It's a trade-off between a positive, getting to the destination quicker, and a negative, causing an accident. The game comes in maximizing the goal of arriving as soon as possible while limiting the likelihood of an accident to below a certain hazard level. Driving is also a multiplayer game in that the drivers around you are also thinking in the exact same way.

When driving a car, you're at a disadvantage if you don't know what the cars around you will do. Deciding who should go first at an intersection is a dance between two drivers. Once all cars are autonomous, it's no problem: the cars will exchange signals and coordinate the next move between them. However, with both autonomous vehicles and human-driven cars sharing the road, the dance breaks down.

Now, autonomous driving will certainly reduce the traffic accident rate on average. Maybe it already has. However, society will not be so quick to accept autonomous driving just because it drops the average accident rate a few percentage points below that for human drivers. Just like for human-driven vehicles, accidents for autonomous vehicles will not fall completely to zero. Cars themselves gained social acceptance because of their overwhelming social benefit and in spite of the unfortunate accidents they create, and even then, acceptance writ large has taken an insurance system covering traffic accidents to achieve. How much lower will the accident rate for fully autonomous driving have to be than that for manual driving for society to accept it? Whether that will take ten percent or one hundredth of a percent, I can't say.

Producing Socially Beneficial Research by "Thinking like an Amateur and Doing as an Expert"

—— **You've been in the US for your research for a long time now. How does the US research environment differ from that in Japan?**

Kanade At American universities and research institutes, researchers care about how their research is used. They're not happy just to write a paper; it's meaningless without making a social impact.

By "impact", I mean how widely the research is used in the world and what kind of a contribution it makes. Also, the universities themselves value how many individuals they have trained to play central roles in changing the world. I definitely want to mention that.

CMU's presence has made Pittsburgh into a major R&D hub for autonomous driving, with companies like Uber Technologies, Argo AI, and Aurora Innovation conducting test drives and trials in the city. These companies have also snatched numerous researchers from us at the university.

In the US, researchers moving back and forth between universities and start-ups build firm ties between the universities and society. Those with doctorates aren't supposed to stay holed up in universities; rather, they should be more interested in what's going on around the world.

—— In short, Japanese researchers should be more socially conscious?

Kanade Many in Japan express their opposition when I say to produce "beneficial research." Some will argue that it's applied research that is beneficial and advocate for the importance of basic research, or even argue that basic research itself isn't beneficial.

We do basic research because it too has meaning. It just seems presumptuous to me to want to research a topic and fund it with tax money, sometimes in large sums, just because it seems interesting but for no specific purpose.

Maybe the word "beneficial" is misunderstood sometimes because it can take the same meaning as "applied" in some cases and "useful" in others? Maybe I should rephrase it as "research of questions worth answering." Finding out what we don't yet understand also qualifies as beneficial research. We need to be able to tell what kind of social impacts such research will have. With that in mind, does that make the research exciting?

Many Japanese research proposals boil down to saying, "This is what we want to research, so please fund our proposal." That's not a proposal. A proposal is writing the points you'd like to clarify in the research and for what purpose, as well as what technical method(s) it will take to achieve this purpose. Also, a proposal will present a reasonable basis for achieving the intended purpose if the research is conducted.

I feel it's important to "think like an amateur and do as an expert." Researchers should think freely without being bound by conventional research wisdom. However, achieving this ideal requires the perspective and skill of a professional.

The Need for Robots that Can Be Fine-Tuned to Match the Situation

—— Where do you see robot research headed in the future?

Kanade So far, the basic idea has been to use robots to reduce human involvement. Autonomous robots have been developed for the purposes of tasking them with work in hazardous locations or to achieve unmanned factories.

Looking forward, I foresee a day when robots and humans work and live together. In addition to their physical ability, there will be robots with superhuman intelligence. The human brain is unable to process all of the information we possess today. There are also limits to how much we can experience in a lifetime. Human ability will reach a saturation point, but robots have no such limitations.

The question to ask is what the best robots will do for us. To this, many would say the best robots will do what we want them to do. My answer is a little different. I'd express it as a formula: What a robot should do equals what the user wants it to do minus what the user can do, plus or minus delta.

If delta is positive, then the robot provides a bit of extra help that the user finds to be useful or kind. If delta is negative, then the robot doesn't help enough, forcing users to bridge the gap themselves. For example, robots could help the elderly or recovering trauma patients to maintain or recover their abilities. Tuning in the negative direction is also important.

I'm spreading this idea under the name Dr. Kanade's Equation. The best robots will bridge the gap between what the user can do and what the user wants to do, with fine-tuning. That's the approach I want to promote in looking forward to life together with robots.

(Photography by Yusuke Sato)

A Word from the Interviewer

As an undergraduate, back when digital images were not available, Dr. Kanade shares that he began programming by making finely graded grids on photos and writing numbers from 1 to 10 to indicate the brightness of each square. He describes editing the massive calculation results on ticker tape with teletype to complete his thesis just before the deadline.

Half a century has passed since the advent of computer vision. I was convinced that both image recognition and autonomous driving would change society through steady effort and successive improvements.

Kyoko Takita

Deputy Managing Editor, Yomiuri Shimbun, Tokyo Headquarters
In 1989, graduated from the Faculty of Foreign Studies, Sophia University, and joined the Yomiuri Shimbun. In 2000, graduated from the Graduate School of Journalism, University of California, Berkeley. From 2002, responsible for science and technology policies, IT, space exploration, environment, disasters, etc., in the Science News Department. After serving as Editorial Writer and Science News Department Director, assumed current role in 2018.

Interacting with Robots in VR to Create Intelligence of Robots

The Significance of Simulators Using Cloud and VR

Tetsunari Inamura

Associate Professor, Principles of Informatics Research Division, The National Institute of Informatics
Associate Professor, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies

NII Associate Professor Tetsunari Inamura believes that simulators can be effectively utilized to create robots that can learn and grow through social and physical experiences by interacting with people in everyday life. A simulation would allow for large quantities of detailed multi-modal data to be gathered at low cost. I talked with Professor Inamura about his lab's efforts to make robots more intelligent by building up interactive experiences with SIGVerse, a cloud-based VR simulation platform for social intelligence research.

Accumulating Learning Data with a Social Intelligence Research Simulator

Today, machine learning sees use in all sectors. In robotics, machine learning has been shown to improve object pick-up and driving skill, and this improvement is expected to accelerate in the future.

Associate Professor Tetsunari Inamura has studied the interaction between humans and robots since his student years. Inamura professes his interest in robots that grow by interacting with humans through conversation and imitating them.

Unfortunately, while one flavor of machine learning, deep learning, would likely make robots more intelligent, there is a bottleneck, namely, no training data for learning can be acquired. Data for object pick-up and autonomous driving can be attained by having multiple robots working in parallel from morning to night or concentrated driving sessions. However, similar approaches prove more difficult for human interaction. Quandaries such as how to hold and lift up a patient in a nursing home or how to serve a customer to increase customer satisfaction in a store, for example, will always involve human interaction.

The challenge in such cases is to accumulate training data through very natural interactions, not through having robots repeating the interaction in a lab with guidance. Inamura's strategy is a robot simulator: SIGVerse.

SIGVerse is a cloud-based VR simulation platform for social intelligence research (Figure 1). In SIGVerse, a simulator runs in a cloud-based VR space, and then robots are operated in the simulator along with a person acting as a virtual avatar so that the avatar and robot can interact. Unlike past experiments, in which people had to physically visit the lab to participate, using the cloud allows for Inamura's lab to conduct many experiments simultaneously by having people log in from around the world through the Internet. "We can experiment on a scale that was unattainable with the conventional style," says Inamura. SIGVerse is already set to log 10,000 hours of activity history.

Extracting Common sense from Actions Observation and Imitation Learning

The programming style of robots as beenchanging recently. The standard methods of robot programming were teaching the robot remotely how to behave using a remote controller. In contrast, more recent research trend is learning by demonstration (LbD), also called imitation learning. In LbD, robots learn by having humans perform the task and then conveying that information to the robots by some means. Inamura and his lab use VR for their LbD.

Tetsunari Inamura

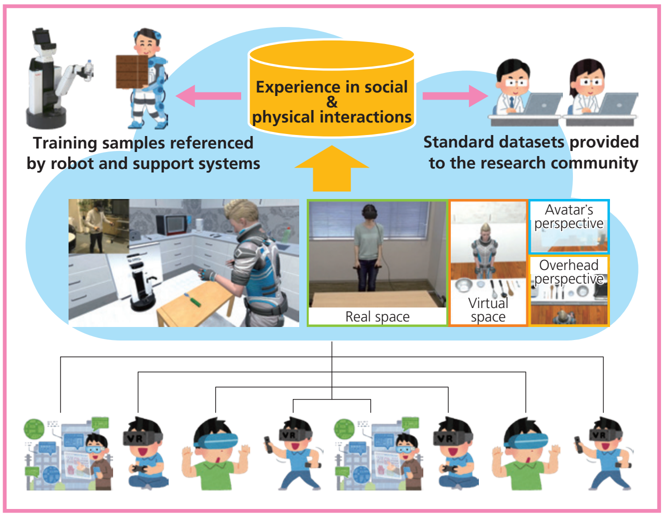


Figure 1 Diagram of the cloud-based VR platform. Users can participate in the experimental system to interact with intelligent robots in the cloud from anywhere. The accumulated social and physical interaction experiences are collected in an open dataset that can be used for robots to learn social intelligence.

For example, say they want to teach robots how humans wash dishes in the kitchen. First, they will have several subjects wash dishes in VR. Their behavior is observed by cameras in VR and then represented as a state transition graph. Each person will have their own dishwashing strategies, such as which hand to hold the sponge with and when to rinse the dishes. In each case, the sequence in which that person touches the objects together is expressed in the state transition graph. The chart clearly shows what transition is made from which action. From there, commonalities can be extracted from the state transition diagrams.

Inamura explains, "If the robot observes that most people hold the sponge with their right hand and dishes with their left, it will determine that, given the high frequency, this is a practice that must be followed. Conversely, it will disregard rare actions, such as throwing a cup in the trash, as noise. Through this process, the robot picks and chooses what it should do."

In this study, conducted jointly with Prof.. Gordon Cheng of the Technical University of Munich (TUM) in Germany, anyone with an environment capable of logging into the VR space and head-mounted display (or HMD) equipment can participate from anywhere.

Interaction is more than just imitated actions. An interactive system can also be built to allow the robots to ask participants questions, or for human participants to give instructions to progressively improve robot skills.

However, robots in their current state do not understand causality or comprehend the ultimate objective of a task. Taking the dish washing example, robots do not understand that the purpose is to clean the dishes; they are merely mimicking the behavior. The fundamental solution to this challenge has yet to be found.

Inamura notes, "Swinging a bat is a simple matter of mimicking joint angles. If the goal is to make contact with a ball to hit a home run though, a robot today will struggle with figuring out for itself what it's supposed to be mimicking."

Similarly, our everyday tasks can be broken down into various levels. Inamura believes that, for now, robots cannot be expected to make all their decisions autonomously. He speaks of the need for a system to both allow humans to input instructions and teaching signals as appropriate and to naturally incorporate those instructions into imitation learning.

A System for Navigating People

Inamura and his lab are also working on building a system that allows robots to interact with humans by creating a competition they call Human Navigation at RoboCup, a robotics competition. Unlike at RoboCon Festival, their aim with the Human Navigation competition was to use VR platforms to create a fairer, low-cost competition free of hardware issues. In real robot competitions, the goal is for the robot to fetch a household object as directed by a human. In the Human Navigation competition, the roles are reversed.: the robot is the one issuing the instructions to a person logged into a VR space.

Problems of moving an object at a specified three-dimensional XYZ-coordinate location to another location, is sent to the robot. Each team in the competition must write a program for converting the three-dimensional coordinates into understandable natural language, such as, "Put the mug on the table in front of you in the kitchen sink." As the humans repeatedly change their orientation, the robot must determine the human's status to word their instructions with directional words such as "up", "down", "left", and "right" from the human-centered coordinates. The better the human is able to follow navigation from the system without wavering, the better that robot will score.

The next Human Navigation competition will be held at RoboCup Asia-Pacific 2021 to be held in Aichi Prefecture in November 2021. A target number for participation is eight teams. Four Japanese teams are scheduled to participate.

Domestic Robots: The Final Challenge

Another facet that Inamura is working on is the ability of robots to make requests of humans. Instead of having robots try to do everything themselves, if the robot thinks it cannot do something itself, it is better that it asks humans to do it.

"The home is the last big challenge for robots. Building new robot-compliant housing from scratch is one thing, but achieving a robot that can wash dishes, fold laundry, or do anything on its own in standard homes is quite a tall order. Given that, one of our ideals is a robot that could say something like, 'I cannot clean; please move this object out of the way.' That way, the robots could do more and our lives would be more comfortable."

In order for robots to ask for help when they cannot do something, they need to be self-aware of what they can do—that is, their physical limitations. Here also, simulation is an important factor. Just like imagination in the human brain, robots need to know exactly what they can and cannot do.

Robots need to be able to build a precise model of the world and update it in real time. Inamura still feels that we are two steps away from this kind of research, but I would love to see his team take on the final challenge: the home. The functions for finding commonalities in navigation and behavior can likely be translated to optimize production sites and service industries as well.

(Interview & Report by Kazumichi Moriyama,
Photography by Yusuke Sato)

Interview

Unraveling the Mysteries of Human Intelligence from Robots

What it takes to read situations and work together

Shingo Murata
Assistant Professor, Principles of Informatics Research Division, The National Institute of Informatics
Assistant Professor, Graduate School of Multidisciplinary Sciences, The Graduate University for Advanced Studies

Has the day come for robots to read situations and support people's lifestyles? Making such a future into reality would require robots to think and judge things for themselves, like humans. In his research on prediction error minimization, NII's Shingo Murata explores the mechanisms of human intelligence and the brain. Some of the results are being applied to robots in attempts to accelerate research.

Human Cognitive Function based on Minimizing Prediction Error

Murata's approach to robots is not to create beneficial robots. As part of his research on human intelligence and the brain, Murata's interest is in utilizing robots to verify the mechanisms of the brain. To him, robots are just a tool for understanding intelligence and the brain. Still, his work could be a shortcut to creating robots with the situational awareness to interact with people naturally.

Murata's research covers prediction error minimization. Although now a cognitive robotics research topic, this principle was originally proposed in the field of cognitive neuroscience.

Murata explains: "When we talk, we predict what kind of response we'll receive. If we get an unexpected response, we're surprised. This is prediction error. Learning is the act of adjusting our synaptic connections to minimize prediction errors accumulated over the long term, and our actions serve the purpose of eliminating prediction errors that occur over the short term. Similarly, perception is also meant to minimize short-term prediction errors. Basically, we learn and act to reduce this error when something goes against our expectations.

"In his proposal for a unified brain theory that he calls the free energy principle, Karl Friston, an authority on cognitive neuroscience, says that this prediction error minimization can explain all of human cognitive function. And so, I'm experimenting with robots to explore the mechanisms behind prediction error minimization."

The Significance of Creating a Robot to Minimize Prediction Error

If minimizing prediction error is tied into all human cognitive

Shingo Murata

function, it explains how an infant learns and makes decisions through interactions with his/her parents, siblings, and others, as well as with his/her surroundings.

Prediction is also an important mechanism when working with others. We act based on our estimations of our partner's intentions. If something unexpected happens, we perceive that and judge accordingly, and then re-estimate our partner's intentions to coordinate our actions based on those estimations.

This is the same for robots that work with humans. For purpose-specific robots, the designers should be able to anticipate possible situations and build in programs and algorithms to run for those situations. However, if attempting to create a robot that can communicate, work with, or read the situation and support people, the robot will need to be capable of making decisions and acting on the fly. If a person's behavior, way of thinking, or work plan changes, the robot will need to recognize and judge these changes for itself in order to provide support. Loading only with programs and algorithms for handling preconceived situations will have its limitations in producing such cognitive robots.

In that sense, cognitive robotics and prediction error minimization research are essential to producing robots of the future to help and support people. According to Murata, "If we can build a robot that can minimize prediction error in all situations, the robots might attain human-like cognitive functions and, as a result, be more useful to us."

In fact, Murata shares that minimizing prediction error can even help in understanding and communicating with people with autism spectrum disorder and other developmental and mental disorders. For example, one cause of autism spectrum disorder is the inability to accurately estimate prediction error. Murata hypothesizes that a robot could be built to behave as if it had autism spectrum disorder by running a learning experiment with his model loaded into the robot.

The higher the confidence in a prediction, the greater the error coefficient when that prediction proves false. Conversely, without confidence, it will not be that surprising if the prediction misses the mark. In other words, behavior can be changed by shifting the error weighting. This is another effort to better understand people. Murata is also exploring this approach in joint research with psychiatric researchers.

Contributions to Informatics and the Ultimate Robot

A form of deep learning called a recurrent neural network (RNN) is an effective means for embedding prediction error minimization into robots. RNNs are neural networks with recursive coupling. Put simply, the system reasons through past situations while manipulating time-series data to perform and output context-dependent predictions.

In robotic applications of RNN, the robot predicts information such as the angle of raising and lowering the arms and vision based on past interactions, allowing it to move its arms in the correct direction and at the correct angle. The robot itself can use historical data to make better predictions and decisions.

Murata shares, "Nine years ago, when I started my graduate study as a senior in undergrad, there were no tools for studying neural networks. I had to start from scratch. The release of the TensorFlow and PyTorch libraries lowered the barriers and made it easier to start research on robot development."

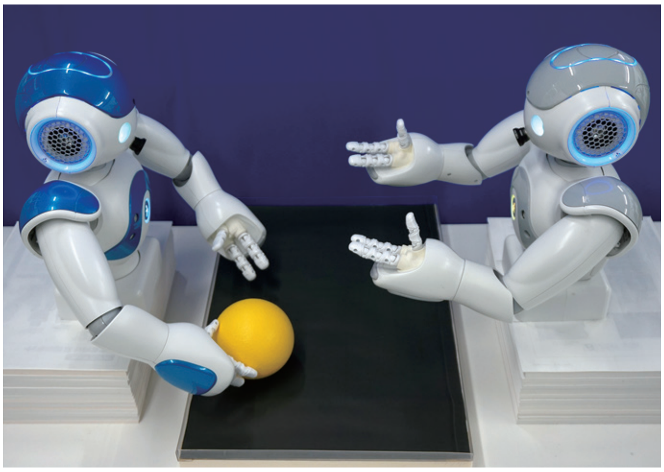


Photo1 Two robots interacting. They are observed to switch autonomously between two learned movements by minimizing prediction error (link to video: https://youtu.be/sQ1u32tQOic).

He also pointed out that combining with core technology in informatics, which deals with multimodal information such as images and audio, may further contribute to robot development.

"For example, for robots with bodies, image recognition helps the robot learn about more than just chairs—through repeated physical experiences, it allows them to learn the concepts that chairs are for sitting and that, in some cases, desk-shaped objects can be used as a chair. If robots can learn these concepts through their physical experience instead of an algorithm needing to be written out for each one by one, they can be utilized effectively as a platform for further evaluation and development."

In his research, Murata is currently experimenting with communication between two robots with prediction error minimization (Photo 1). While facing one another, the robots are being taught only to roll a ball back when it is rolled toward them and, if the ball stops near them, to roll it left and right with both hands. Initially, they roll the ball back and forth. Then when the ball stops near them due to friction or some other reason, they mistakenly predict that the other robot will roll the ball to them. To resolve this prediction error, the robot rolls the ball left and right to reduce the error, and their behavior settles back into rolling the ball back and forth. In this case, the robots are observed to judge the error themselves and resolve the error with a switching action that they have not been taught.

Still, there is quite a way to go yet from current levels to the point of robots with true situational awareness.

Asked what that means, exactly—robots with situational awareness—Murata explained as follows.

"Maybe the ultimate robot could do anything in place of humans. That's still not the same as having situational awareness. Maybe the person actually wants to do something for themselves, even if the robots can do it for them. Or for robots providing rehabilitation support, rather than provide maximum support with everything, the robot will need to encourage people to put in physical effort. Future robots will probably be expected to understand and judge a person's intentions, feelings, and positions."

(Interview & Report by Katsuyuki Okawara, Photography by Yusuke Sato)

NEWS 1

SINET speed between Tokyo and Osaka increased to 400 Gbps

Putting world-leading long-distance, high-volume link into practical operation

NII has constructed a long-distance link with a world-class transmission speed of 400 Gbps between Tokyo and Osaka as part of an academic information network, SINET5, which went into service on December 9. This high-volume link will provide four times the capacity of the current 100-Gbps SINET5 lines connecting all prefectures.

The purpose of constructing this 400-Gbps link is to increase the transmission capacity between the Kanto area centering on Tokyo and the Kansai area centering on Osaka and thereby resolve the tight capacity situation amid soaring demand for data communication between the two regions, where universities, research institutions, and other entities are concentrated. This implementation removes the issue about network resources being occupied by high-volume data communication and ensures stable communication. The updated infrastructure meets demands for further data increases and new super high-volume data transmissions in inter-university collaborations and large research projects.


At a press conference, NII Deputy Director General Shigeo Urushidani (left) and Associate Professor Takashi Kurimoto briefed the press on the 400-Gbps upgrade of SINET between Tokyo and Osaka.

NEWS 2

Cheers at SINET5 VR Experience

At Inter-University Research Institute Corporation Symposium 2019

The "Inter-University Research Institute Corporation Symposium 2019—Tackling the Mystery of Space, Materials, Energy, Life, Information, and Human Culture" was held at the Miraikan in Tokyo's Koto Ward on October 20. At the event, NII and other Japanese inter-university research institutes hosted booths showcasing cutting-edge research and held Researcher Talks sessions for researchers to introduce the appeal of their research and the latest topics.

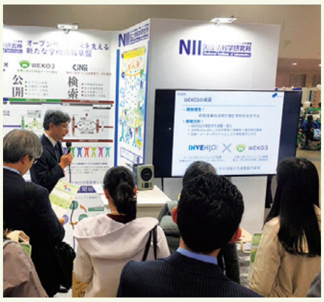
In the opening ceremony, NII Director and President of the Inter-University Research Institute Corporation, Masaru Kitsuregawa, delivered his opening words and introduced the roles and initiatives of the organization.

The NII booth featured a VR activity that allowed visitors to experience the 100-Gbps bandwidth of the Science Information Network (SINET5), built and operated by NII. Gasps of astonishment were heard from visitors who experienced the powerful VR images (photograph). The amount of data flowing was likened to water, with a 100-Mbps residential high-speed network resembling a narrow water pipe, and SINET5, which possesses 1000 times the bandwidth, resembling an immense underground space.

NEWS 3

Introducing Three Research Data Platforms: Management, Publication, and Retrieval

21st Library Fair & Forum



The 21st Library Fair & Forum was held from November 12 to 14 at PACIFICO Yokohama in Kanagawa Prefecture. NII exhibited and presented new academic information infrastructure being developed to support open science: a data management platform (GakuNin RDM), a data publishing platform (WEKO3), and a data retrieval platform (CiNii Research), along with a catalog information system (CAT2020) and the next JAIRO Cloud to be released in 2020 and beyond (photograph).

Staff from the Research Center for Open Science and Data Platform (RCOS) manned the booth for the duration of the event to answer questions from visitors and give presentations.

NII held forums on three themes: "Open Science and Research Data Management," "Open Access to Papers," and "Future Academic Information Systems." Researchers and university library staff passionately discussed the issues surrounding science and technology.

NEWS 4

AI Deciphers *Kuzushiji* Characters

Japanese Culture and AI Symposium 2019

The "Japan Culture and AI Symposium 2019—AI for Reading *Kuzushiji* Is Now Ready!" was held on November 11 at the Hitotsubashi Hall in Tokyo's Chiyoda Ward by the Center for Open Data in the Humanities at the Joint Support-Center for Data Science Research (ROIS-DS), the National Institute of Informatics (NII), and the National Institute of Japanese Literature (NIJL) at the National Institutes for the Humanities.

In Japan, historical materials such as pre-modern books, old documents, and historical records have been preserved for more than a thousand years, and the amount of historical materials is estimated to be hundreds of millions of items, which is rare in the world. Most modern Japanese people, however, are unable to read historical materials written in *kuzushiji* (cursive) characters, which have made reading and understanding a large amount of *kuzushiji* characters an urgently important issue. Thus, ROIS-DS, NII, and NIJS have joined together to study how to use artificial intelligence (AI) to decipher these *kuzushiji* characters.

At the symposium, the winner of "*Kuzushiji* Character Recognition: Opening the Door to a Thousand Years of Japanese Literate Culture" as held on Kaggle, the popular worldwide AI competition platform, made an appearance

to introduce the *kuzushiji* character recognition algorithm they had developed. Other popular exhibits included a demonstration of KuroNet, which automatically reads *kuzushiji* characters and converts them to modern Japanese, by the developer, ROIS-DS Special Assistant Professor and NII Special Researcher Tarin Clanuwat (photograph).

NEWS 5

The Interaction between Finite and Infinite

Lecture by Associate Professor Hasuo at the 3rd “Forefront of Informatics” Public Lecture

On November 7, NII held their 3rd “Forefront of Informatics” public lecture, which was Associate Professor Ichiro Hasuo of the Information Systems Architecture Science Research Division delivering the lecture entitled “Introduction to Theoretical Computer Science—Between Finite and Infinite: From Mathematical Theory to AI and Autonomous Driving” (photograph).

Theoretical computer science is an academic discipline that studies the behavior of computer programs and information systems mathematically. While being infinitely rich in terms of their behavior, computers and programs must be finite in size to actually be created and analyzed. Hasuo explains, “As an important point, theoretical computer science uses mathematics to somehow express the unreachable infinitude in a finite sequence of symbols.” Hasuo illustrated this finite–infinite interaction using automata (mathematical models devised to clarify calculation principles) applied to model tests of various software systems. He told the audience that mathematically proving software product safety is the greatest form of quality assurance, and that in the future AI era, there is great potential for expanding formal methods (mathematical methods for software quality assurance) and applying them to physical information and machine learning systems.

Hasuo also introduced the research project that he personally supervises called the JST-ERATO Hasuo Metamathematics for Systems Design Project. In this project, Hasuo’s lab engages in research and development of modeling, formal and testing methods, and the practical verification and validation (V&V) technology that encompasses these methods, in order to help ensure reliability in design support for autonomous driving systems and other industrial products. According to Hasuo, “Our goal is to envelop AI in a safe logical layer to ensure safety and to create safe, descriptive autonomous driving systems.”

NEWS 6

Robot and Machine Learning Classes

Visiting Lectures at High Schools and Technical Colleges

On November 21, NII held its first visiting lecture for the 2019 year at Toyama High School in Tokyo. This lecture aimed to introduce NII’s research results to high school students and technical college students, who will determine our future, in order to familiarize them with and stoke their interest in informatics.

In the first lecture, Associate Prof. of Principles of Informatics Tetsunari Inamura delivered a lecture entitled “Natural Interaction with Robots: Developing Social and Physical Intelligence” to a freshman class of 36 students. Inamura used simple language to explain his research on how to train robot intelligence and efforts in RoboCup robot competitions, weaving in the history of AI and some practical examples. After the lecture, the students got to experience a VR system developed by Inamura. Each of the students cheered when they donned the VR goggles to experience a variety of simulations.

The second class was held at Kurume College of the National Institute of Technology on December 6. This time, Associate Professor of Principles of Informatics Mahito Sugiyama lectured a class of 28 freshmen on the topic of “How Machine Learning Works.” Mixing in examples from his own research, Sugiyama explained machine learning and data mining, two core AI technologies that have attracted attention in recent years. He explained the purpose of machine learning: to create computer programs that learn from experience to automatically grow smarter. Then, he introduced the class to machine learning applications in a wide range of fields, including autonomous driving, voice recognition, drug discovery, defect detection, and gaming.

[Top] Associate Professor Inamura lecturing at Toyama High School
[Bottom] Visiting lecture by Associate Professor Sugiyama at Kurume College, National Institute of Technology

SNS

“Hey, this is great!” Hottest articles on Facebook and Twitter (September – November 2019)

National Institute of Informatics, NII (official) Facebook
www.facebook.com/jouhouken/

On the exterior wall of the National Center of Sciences, NII is showing a projection celebrating the performance of the Japanese national team at the 31st International Olympiad in Informatics. In this year's competition, held in Azerbaijan August 4 to 11, four Japanese high school students achieved one gold medal and three silver medals. (9/10/2019)

National Institute of Informatics, NII (official) Twitter
@jouhouken

[NII Today, Issue No. 85]
“Taking on Fakes: Seeing through Fraudulent Information” was published. (10/20/2019)

Bit on Twitter! Twitter
@NII_Bit

Here at the ceremony for the 67th Electrical Science and Engineering Promotion Award. Congratulations to Project Researcher Fumihiko Kato and Professor Hideaki Takeda!!!
(11/20/2019)

* Some text edited/omitted.

Essay

Fun with “Sharpening” and “Investigating”

Minoru Asada
Institute for Open and Transdisciplinary Research Initiatives, Osaka University
Symbiotic Intelligent Systems Research Center
Research Professor

From the two characters used to write the word in Japanese [Added context which is apparent to Japanese readers.], I take research as enjoying the process of “sharpening” oneself and “investigating” basic issues. My meetings with so many researchers have been a driving force behind investigating in my research. It started with my study of video images in computer vision, which was then applied to enhanced learning for robots and spawned the idea for RoboCup. Through all my advocating and promoting cognitive developmental robotics and, by extension, the idea of constructive anthropology, these encounters with many people have spurred on my research by helping me to hone in on the question at the core of my research to date [Order changed for purpose of sentence flow.]: What does it mean to be human?

One such encounter was with Dr. Takeo Kanade of Carnegie Mellon University, who headlines this issue. As you already know, Dr. Kanade was pronounced a Person of Cultural Merit in 2019, and as president of the Robotics Society of Japan, I just wrote my congratulations to him in the RSJ journal. After my own mentor, Professor Emeritus Saburo Tsuji of Osaka University, and Ryoji Suzuki, the Professor Emeritus of Biomedical Engineering at Osaka University, to whom I have been so indebted since my graduate thesis work, Dr. Kanade is the third most respected researcher I have met in my research career. In particular, I wholly agree with Dr. Kanade’s approach and motto of “Think like an amateur, do as an expert.”

As I also introduced my final lecture on the anniversary of my retirement in March of this year, a favorite phrase of mine is “out of sight, out of mind.” The common Japanese translation of this means “when someone leaves, we grow further apart everyday,” but another translation would be “that which is not seen doesn’t exist.” In fact, newborns under the age of one perceive this innately as their working memory is not yet developed. The phrase also served as a hint in my thesis work on a system for tracking schools of plotosids, a species of fish. In my research, careful predictions were needed to uncover the fish hiding behind the pack. It was lucky for me to have addressed such an important issue at the beginning of my research. Incidentally, we as adults need to respect this aspect of newborns, as we too tend to ignore (put “out of sight”) inconvenient ideas, both consciously and unconsciously.

Another pet phrase of mine is that “every success starts with a handicap.” Similar to the handicap principle at play in biology, as illustrated by the tailfeathers of peacocks and long-tail chickens, this saying expresses my belief that the quickest path to the heart of an issue is the crisis awareness that just coasting with the tailwind is the most dangerous thing you can do. I have experienced this myself. When I submitted my first paper for RoboCup to a large international conference and got rejected, I was indignant. From there, I turned around and presented about RoboCup at small workshops and study groups to great response, which fueled my confidence. The following year, I submitted the same paper, verbatim, to another large international conference and was selected in the top 10 (the top 1% of applicants!). In the end, my success started with the resentment of being rejected.

For more of my favorite phrases, I have recently started posting a President’s blog entitled “*Mino Tsubu Tanshin* [Mino’s Notes][Added for clarification.]” on the new RSJ website, robogaku.jp. I hope you will follow me there.

Future Schedule

January 21 | “The Forefront of Informatics” 4th Public Lecture: “Manipulating Light with Topology—Can Light Distinguish between a Ball and Donut?” (Speaker: Professor Iwamoto Satoshi, Research Center for Advanced Science and Technology, the University of Tokyo & Research Member in Hybrid Quantum Science, Scientific Research on Innovative Areas)
For registration, go to **https://www.nii.ac.jp/event/shimin/**

Late January to early February | 3rd SPARC Japan Seminar 2019 For more, go to **https://www.nii.ac.jp/sparc/event/**

March 13 | The National Institute of Informatics Top SE Seminar “Implementing Deep Learning using PyTorch”
For more, go to **https://www.topse.jp/ja/seminar.html for more information**

Notes on cover illustration
Robots in the classroom learning to cook via remote learning shown on the display screen. Creating “smart robots” that can imagine being human will require them to imitate human actions or to learn from one another in order to become autonomous enough to judge and act for themselves.

Weaving Information into Knowledge
NII

National Institute of Informatics News [NII Today]
No. 72 December 2019
[This English language edition NII Today corresponds to No. 86 of the Japanese edition.]
Published by National Institute of Informatics, Research Organization of Information and Systems
Address | National Center of Sciences 2-1-2 Hitotsubashi, Chiyoda-ku, Tokyo 101-8430
Publisher | Masaru Kitsuregawa Editorial Supervisor | Ichiro Satoh
Cover illustration | Toshiya Shirotani Copy Editor | Madoka Tainaka
Production | MATZDA OFFICE CO., LTD., Sci-Tech Communications Inc.
Contact | Publicity Team, Planning Division, General Affairs Department
TEL | +81-3-4212-2028 FAX | +81-3-4212-2150 E-mail | kouhou@nii.ac.jp

Bit (NII Character)

https://www.nii.ac.jp/en/about/publications/today/