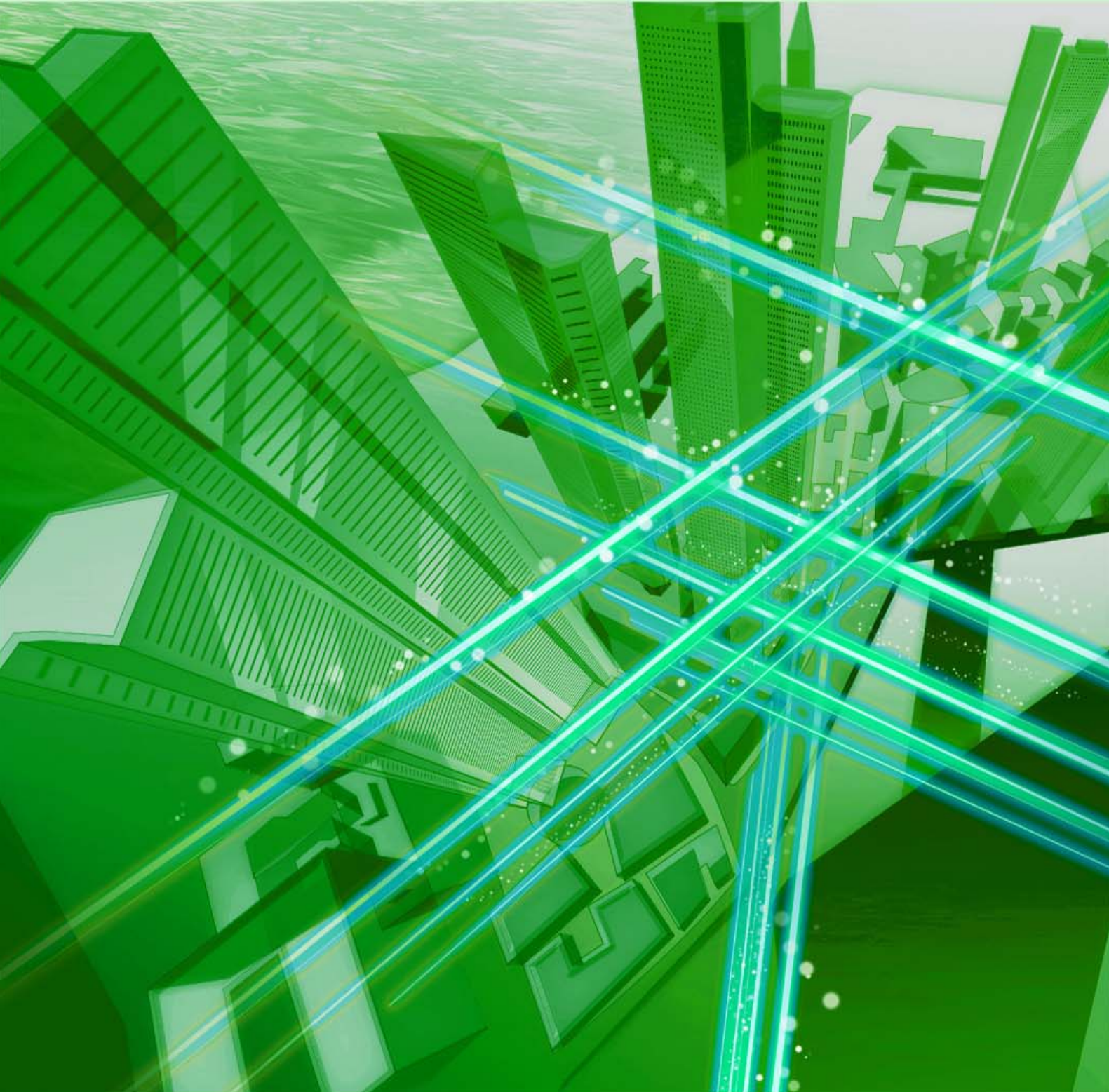


NTT Technical Review

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External Awards/Papers Published in Technical Journals and Conference Proceedings

Boldly Taking the Helm to Be “Your Value Partner” Now and into the Future



Motoyuki Ii

Senior Executive Vice President and Head of Technology Planning, NTT

Overview

Innovation in digital technologies is disrupting existing industries while creating new value. At the same time, social phenomena such as an aging population with a declining birthrate and a shrinking labor force continue to have a major impact on consumer lifestyles and corporate activities in Japan. NTT has formulated a digital transformation strategy in the face of such social issues. We asked NTT Senior Executive Vice President Motoyuki Ii, a driving force behind this strategy, to tell us how he plans to deal with these issues as Chief Digital Officer.

Keywords: digital transformation, disruption, R&D

Put employees at ease, accumulate small successes, and pursue bold changes

—NTT Group’s Medium-Term Management Strategy has recently been announced. How do you plan to implement this strategy as Senior Executive Vice President and Chief Digital Officer?

The theme of this Medium-Term Management Strategy is bringing about a major transformation in NTT and the NTT Group. There are four pillars making up this strategy, two of which promote our customers’ digital transformations and our own digital transformation. This is my mission as Chief Digital Officer (CDO). The position of CDO was newly established in August 2018 not only in the holding company but also in major NTT Group companies including NTT EAST, NTT WEST, NTT Communications, NTT DOCOMO, and NTT DATA. Each company’s CDO has the job of maximizing the

use of data and information and communication technology (ICT) to revolutionize business processes and make human intervention minimal. In other words, each CDO has the role of bringing about a major transformation in management. Here, *transformation* means changing existing processes, or to put it another way, to disrupt the current way of doing things. There will naturally be some resistance from people who have been working in the same way for years, so to bring about a transformation, it is essential that a CDO “take the helm” with good negotiating skills and courage without yielding to that resistance. Although the original meaning of “D” in “CDO” is *digital*, it can also stand for *disruptive*, reflecting the role of the CDO as the person with ultimate responsibility for disruptive innovation.

—A CDO takes on the heavy responsibility of overseeing a digital transformation, but to push such change through, won't a good understanding of current conditions be needed?

A CDO can also be appointed from the outside. That person would have to have a detailed knowledge of ICT and be proficient in business analysis, and should also be quite familiar with the way things have been done up to now. A company is a living thing, so it is essential that a CDO understand the present way of doing things and be able to establish a strategy for determining how things must change going forward. For this reason, the NTT Group is appointing CDOs from among people who have held responsible positions requiring an extensive understanding of business and work and who have much and varied experience in their backgrounds. On top of all this, a CDO must pursue major changes while accumulating small successes over big ones to put employees at ease. A “quantum leap” in the way things are done can be stressful for anyone, so employees are more likely to oppose such change than to give their approval. It is vitally important here to draw up a goal that everyone can commit to and to then move toward that goal one step at a time. To repeat, people are bound to show resistance to change, so a CDO must understand how to get employees to move forward to achieve transformation.

That being said, I have been involved in all sorts of work since entering NTT about 35 years ago, including technology development, international procurement, plant planning, personnel affairs, NTT reorganization, and corporate sales, and I have experienced many successes and failures, all of which should serve me well as a CDO.

The mission of a CDO is to promote the use of new technologies and systems to automate various types of business processes from a management perspective. It is precisely for this reason that a CDO who cannot grasp where manpower is realistically and specifically being applied will not produce effective results. As a CDO, I believe I can put my experiences in problem solving in many different areas to good use.



There is no such thing as unfinished work. The only recourse is to face a problem with resolve, honesty, and sincerity.

—You said you have faced many situations involving problem solving, but can you tell us what area of your work taught you the greatest lesson?

Let me tell you about a matter that I think I can call one of the biggest crises in my life. It occurred during the four years that I served as an NTT EAST senior executive vice president and head of corporate sales. It involved the use of digital technology to make a major change to the system of a certain university. We were using new technology that we were not yet fully adept at, and as a result, we missed the delivery date and were unable to achieve some functions we promised, all of which caused our customer a great deal of trouble. Repairing the system would require a period measured in years, and the whole project ended up in the red.

Although this work involved collaboration with NTT Group system integrators and participating companies such as vendors, NTT EAST was the prime contractor, making us responsible for the project; we could not blame anyone else. In such a situation, the only approach was to be honest and sincere with the customer. Making excuses did not erase the fact that the problem was caused by a lack of technical competence and that the deadline could not be met. We gave the customer an honest assessment as to what efforts or measures we were taking, what problems still remained, and about how much time would be needed to rectify those problems. I took this action thinking that it was very important that I be viewed as an honest person and as someone who could be

trusted. In addition, as leader of this project, I made an effort to cheer up and embolden members of my staff who were working for days on a major problem and being yelled at by the customer. This was truly a long battle that could not have been won without the strong bonds of a team that would not give up. Lost time cannot be recovered, so the only thing to do is move forward. Convinced that we could solve the problem and be accepted by the customer once and for all, all the members of this team confronted this situation with great resolve. It was a good opportunity to gain hands-on experience about learning from failure.

—I can sense a terrible experience by just listening to your story. All of your challenging experiences should prove to be useful in your upcoming work.

I believe that experience is the driving force behind one's personal growth. It is important to have many experiences and make maximum use of them. However, the number of experiences one can have is limited, so reading can make up for that shortfall as pseudo experiences. Incorporating the experiences that others have had can deepen one's knowledge, so I encourage my employees to read as many books as possible.

I use as a reference the many conflicts that arose during Japan's Muromachi period (1338–1573) and beyond when feudal warlords vied for political power, and I am also inspired by historical novels that depict peaceful times during the Edo period (1603–1867) when culture flourished. In particular, I find it deeply interesting how Hojo Soun established the foundation for the Hojo clan. Similarly, the Edo

period originates with Tokugawa Ieyasu, Toyota Motor Corporation with Sakichi Toyoda, and Matsushita Electric Industrial Co., Ltd. (now Panasonic Corporation) with Konosuke Matsushita. Stories about people known as a *chukonosho*, who helped to make a corporation thrive, serve as a reference in my work.

I also find books that make predictions about the future quite interesting. For example, I recommend "Homo Deus: A Brief History of Tomorrow" by the bestselling author Yuval Noah Harari, also known for "Sapiens: A Brief History of Humankind." I also liked "The Singularity Is Near: When Humans Transcend Biology" by the American scientist Ray Kurzweil. Now 70 years old, Ray Kurzweil was placed in charge of developing artificial intelligence at Google six years ago. From these books, I learned that as science and technology develops, humans themselves will undergo dramatic changes as they assimilate those advances. This refers not only to the growth of humans as a species from the perspective of natural science but also to changes in individual humans due to science and technology that we ourselves created. Given the view that 2045 will mark a transition from Homo sapiens to post-humanism, it can be seen that we are living in a period in which mankind itself is undergoing a transformation. On taking charge of transforming the company in such a period and thinking about the best approach to changing the way we work and the role of the company, I feel that it is also necessary to consider the transformation in human beings.

In this way, I think it's important that we compensate for any lack of experience by putting the knowledge of trailblazers and researchers to good use in our work. One man alone cannot achieve a successful transformation, so I am taking up the challenge together with the CDOs of the other NTT Group companies. To begin with, we will undertake a transformation achieved through software and robotics by analyzing work processes and introducing ICT. However, making immediate and straightforward improvements to work processes will not be the end of our efforts. Our ultimate objective is to create an ecosystem in which work is completed without human intervention.

I am beginning this endeavor by sharing a roadmap and goals among all CDOs. Perhaps there are some people who imagine that this is going to be a very difficult endeavor based solely on the documents describing these goals. Nevertheless, I would like to describe this dream in the form of specific goals and



to consider how best to achieve them. I envision these goals to be achieved around the year 2050. In general, such plans for the future should be made, say, 100 years in advance, but as can be seen from the development of smartphones, technical innovation can bring about changes that occur too fast to predict. Taking such speed of technical development into account, I think we can set goals about 30 years in advance.

Supporting people who take on difficult themes and creating an appealing workplace for employees

—What is “work” from your point of view?

As I mentioned in my last interview (October 2016 issue), there is a difference between *work* and *tasks*. Work is making discoveries on one’s own and opening up new possibilities. Carrying out something that is simply given to you is not work. The action of thinking about what problems exist and what goals to set, and aiming for those goals are what constitutes work. Anything else we can regard as tasks. To put it another way, work is taking up the challenge of a more difficult theme and making an effort that can lead to results.

I like the attitude of doing whatever it takes without giving up and making an all-out effort with not only the results in mind. If such an attitude can be maintained, some sort of achievement will be forthcoming. A theme can sometimes appear by chance, and some themes can be difficult to achieve, while other themes can be easy to achieve. It’s simple to evaluate things only based on the results, but I want to support those who do not avoid difficult themes but rather confront them head on. I am always telling those under me that such passion is what makes a company grow.

I think that a person in top management cannot succeed without having skills in expressing one’s vision and without having decisiveness and courage. Although one method is to allow for proposals from subordinates in a bottom-up approach, I feel that presenting a clear direction from the top is one way of making it easier for subordinates to do their work. Failure to clearly indicate direction from the top forces subordinates to guess what that direction is and leads to a company on shaky ground. It is essential that top management take a bold stance in presenting direction. To execute that direction, it is necessary for subordinates to have the attitude in which they believe “I must think of another way to do this instead



of giving a reason for not being able to do it.” There is no top executive who will listen to a reason for not being able to do something. For instance, with mountain climbing as an example, there are usually many paths to the top, so a good one can be searched for, and if by chance there are no paths, one can be created. A quick ascent may be possible if one is skillful, or a struggle may ensue. Either way, it is important that one does not give up on reaching the top.

—Mr. Ii, what would you like to say to our researchers?

To begin with, I’d like to point out that I am concurrently serving as Chief Technology Officer with the responsibility of establishing the NTT Group technology strategy, research and development (R&D) direction, and a strategy for determining how to apply our intellectual property to what kinds of services. In recent years, technology in the information technology field has been advancing exponentially. However, people tend to think of things in a linear manner, resulting in a gap with technology development. In this regard, a mainstay of NTT R&D has been the creation of intellectual property on its own. However, creating intellectual property in an independent manner may broaden that gap instead of closing it up. Therefore, I would like to ask researchers to be proactive in adopting a co-innovation approach, which means finding and incorporating intellectual property of value, integrating it with NTT’s own intellectual property, and creating new value. As I just mentioned, technology is advancing at an exponential rate, so I would like to promote co-innovation and new value creation so that we can ride the wave of technology development.

Globalization is progressing not only in business

but also in the field of R&D, resulting in a broadening of researchers' activities. Amid this development, international headhunters have been targeting our researchers. In one sense, this is gratifying since it offers proof that NTT has superior, top-notch researchers. We are therefore revising our personnel system to persuade such top researchers to stay at NTT despite such invitations.

At the same time, NTT is opening research laboratories outside Japan and establishing environments in which our researchers can work together with top international researchers. This represents a major change in direction for NTT R&D. In addition, opportunities for joint research are expanding with sites that promote cutting-edge research or so-called "crazy research" not only in Japan but also in Europe, the United States, and Israel. Such research activities can increase the appeal of NTT, and conversely improve the chances that NTT researchers are selected as partners in joint research. Achieving impressive research results is important, but what we also really want to do is to create an attractive company for researchers.

—Finally, could you leave a message for all NTT employees?

Yes, I would like to ask everyone to have a variety of experiences. Be curious about all sorts of things in relation to work and play. And by all means, read books to make up for what your experiences do not

cover. The knowledge contained in books can inspire and enlighten you. When Internet searches leave you unsatisfied, you can find what you need in books. A book compiles the personal experiences and thoughts of the author, and as such, it can stimulate and motivate the reader. I believe that obtaining information and reading books are completely different worlds. Of course, it's difficult to make time when you are busy, but life passes by quickly. I wouldn't say one book a day, but if you can read one book a week, that would be about 50 books worth of inspiration a year. Please give it a try!

Interviewee profile

■ Career highlights

Motoyuki Ii joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1983. After becoming Manager of NTT EAST Niigata branch office in July 2007, he became NTT EAST Senior Vice President and concurrent Executive Manager of the Plant Department and Strategy Planning Department, Network Business Headquarters, in June 2011. He then became NTT EAST Senior Executive Vice President and Senior Executive Manager of Corporate Sales Promotion Headquarters in June 2016. He took up his present position in June 2018.

Bringing the Smart World to Life

Jun Sawada
President and Chief Executive Officer,
NTT



Overview

This article introduces an NTT Group effort in new value creation to bring the *smart world* to life. The contents of this article are based on a lecture presented by Jun Sawada, NTT President and Chief Executive Officer, at NTT R&D Forum 2018 Autumn held November 29–30, 2018.

Keywords: smart world, B2B2X, cognitive foundation, Your Value Partner 2025

1. Smart city

An NTT Group objective is to help create a prosperous and happy future for everyone. With the aim of achieving smart cities, we have been working for some years on creating new value by utilizing data together with the cities of Sapporo, Fukuoka, and Yokohama through collaborations with industry, government, and academia. In this article, I will introduce NTT Group initiatives for the City of Las Vegas, where smart city initiatives are taking root and evolving, and new initiatives toward urban development and problem solving in Japan.

1.1 City of Las Vegas

The NTT Group has been conducting joint trials on smart city solutions in the City of Las Vegas in partnership with Dell Technologies since September 2018 [1]. Our aim here is to construct a system that can detect the occurrence of incidents and help prevent crime by networking many cameras and sensors installed in downtown Las Vegas and analyzing pedestrian and traffic patterns.

This system is based on a model that combines elements that perform recognition and detection at the network edge and elements that analyze and predict trends by artificial intelligence (AI). It features a variety of advanced technologies from the NTT laborato-

ries including sensing technologies. A new software platform called Cognitive Foundation[®] has been prepared to interconnect these hardware and software elements (**Fig. 1**). The plan going forward is to expand the lineup of system functions to include solutions, traffic monitoring, and other functions that can provide an even higher level of public safety. We are also working on smart city initiatives in the State of Nevada [2]. Going forward, we plan to roll out smart city solutions throughout the United States in collaboration with Dell Technologies and NTT Group sales teams in the United States.

The NTT Group has been promoting the business-to-business-to-X (B2B2X) model as shown in **Fig. 2**. In this model, the NTT Group and its partners, which correspond to the first ‘B’ in B2B2X, seek to create new value by supporting main players, the second ‘B’ in B2B2X.

The City of Las Vegas corresponds to the second ‘B,’ and NTT and Dell Technologies, the first ‘B,’ do not own the collected data. The City of Las Vegas owns and utilizes such data, and our role is to support the creation of new value. Michael Sherwood, Director of Information Technologies for the City of Las Vegas, explained that the reason for selecting NTT and Dell Technologies was not only our specialized know-how in new data-use fields such as cybersecurity and data management, which Las Vegas needs for

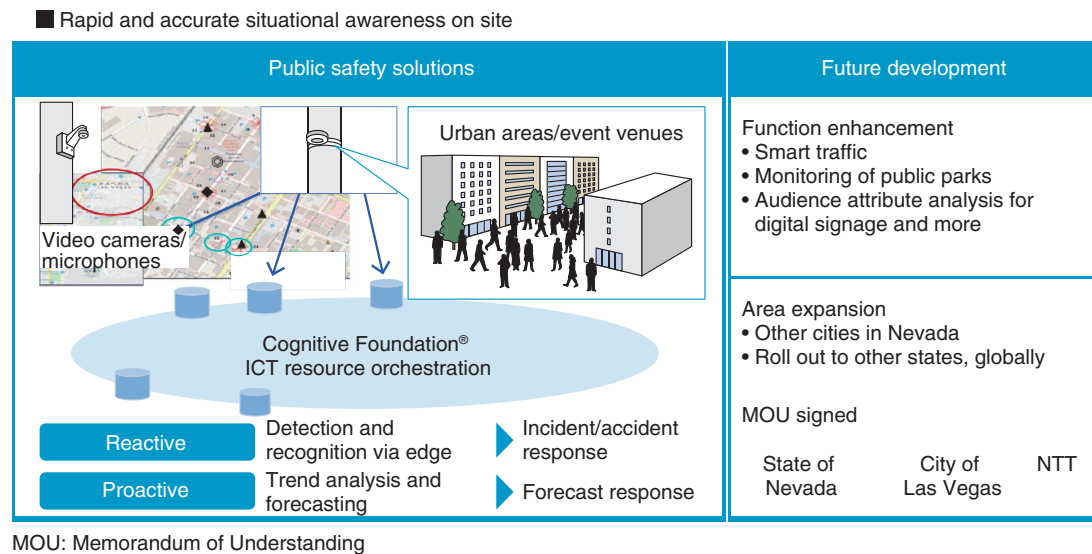


Fig. 1. Smart city initiative with City of Las Vegas.

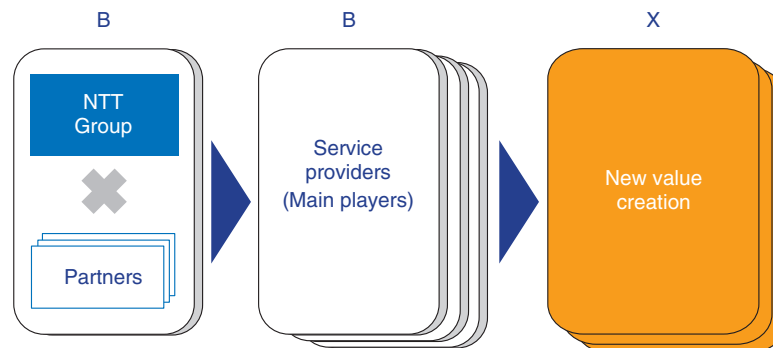


Fig. 2. Direction of initiatives for B2B2X model.

development, but also our proposal that the City of Las Vegas be a main player (an owner of the collected data). Data will be a basic resource for business and services, indeed for everyday life in society. In Japan, I think it should be local governments that own and control such data. I would like to roll out our smart city initiatives with this approach to data ownership on a global scale.

1.2 Urban solutions company

NTT completed its tender offer bid for NTT Urban Development Corporation, enabling NTT to acquire 95.2% of the company’s shares. Our aim here is to assist in urban development by combining the urban development expertise of NTT Urban Development

and the construction- and power-related solutions of NTT Facilities with NTT Group assets and other technologies. We hope to achieve diversity, innovation, resilience, and communities by using information technology (IT) and communications as essential tools. I believe that by assisting in urban solutions in this way and broadening our scope as a business entity, we can contribute to society and the world at large.

2. Smart world

I introduce some examples concerning the smart world here.

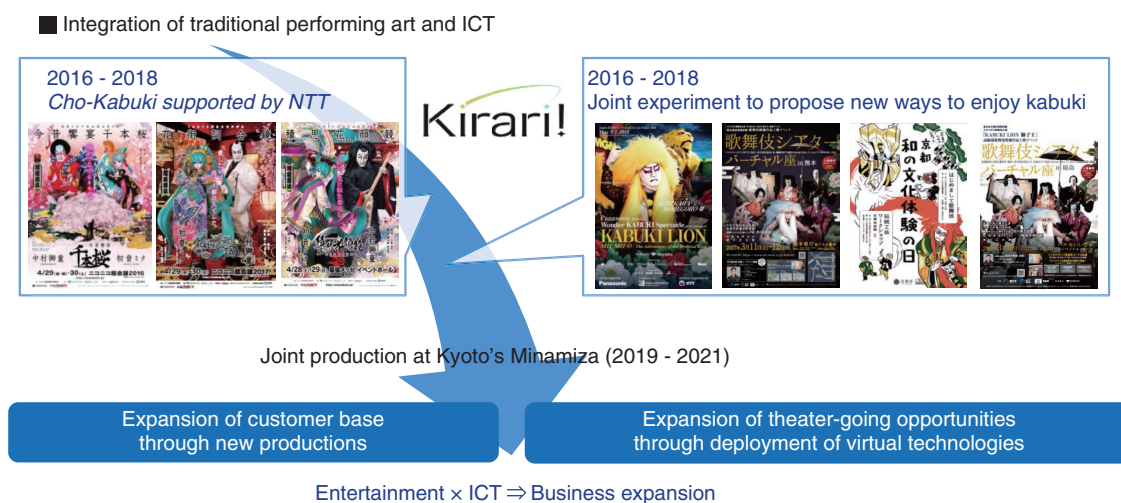


Fig. 3. Smart entertainment with Shochiku.

2.1 Smart entertainment

In the field of smart entertainment, we are aiming at providing a new sports viewing style in collaboration with J.League, Japan's professional soccer league. We are also pursuing the integration of traditional Japanese performing arts with information and communication technology (ICT) in collaboration with SHOCHIKU Co., Ltd., a company engaged in motion pictures and theater operations, including *kabuki* (Fig. 3).

Kyoto's Minamiza Theatre, famous for its kabuki plays, reopened on November 1, 2018, with equipment supporting NTT's Kirari! immersive telepresence technology. The plan is to co-produce performances at this theater starting in the summer of 2019. Although the Minamiza Theatre has a long and rich tradition, our attempt is to fuse new traditions and new arts.

2.2 Smart manufacturing

We are undertaking a variety of projects in the field of smart manufacturing. For example, we are working on smart plants with JSR Corporation, remote control of construction and mining machinery with Komatsu Ltd., data usage at manufacturing sites with FANUC CORPORATION, and detection and response support for unknown cyber-attacks on industrial control systems with Mitsubishi Heavy Industries, Ltd.

Our project with JSR on smart plants involves a collaboration with Accenture Japan Ltd. on digitizing explicit knowledge using AI, voice recognition, and sensors (Fig. 4). Going forward, we aim to connect all

sorts of things through Internet of Things (IoT) technology as a connected value chain and to create a structure that enhances added value not in a partial manner but throughout the industrial complex. Doing so, however, is an extremely difficult task since batteries cannot be used. A short circuit in a battery can result in an explosion, which is why there are regulations prohibiting the use of batteries in petrochemical complexes. For this reason, we are using explosion-proof sensors developed by NTT Advanced Technology and inQs Co., Ltd. that incorporate dye sensitization technology for generating electric power using infrared light.

2.3 Smart mobility

In the field of smart mobility, we are working with Toyota Motor Corporation on fundamental technologies for achieving autonomous driving, with NYK Line and MTI Co., Ltd. on ship safety and environmental initiatives, and with East Japan Railway Company on seamless transportation.

(1) Toyota

Full-scale verification testing with Toyota toward autonomous driving began in December 2018. Up to now, trials involving the running of one or two cars have taken place at various locations, but in the future, a platform that can process data on a scale of several tens of millions of vehicles will be essential. With this in mind, our initial experiments will assume the operation of five million vehicles. These experiments will test a connected car platform that can process the data collected from cars at a datacenter

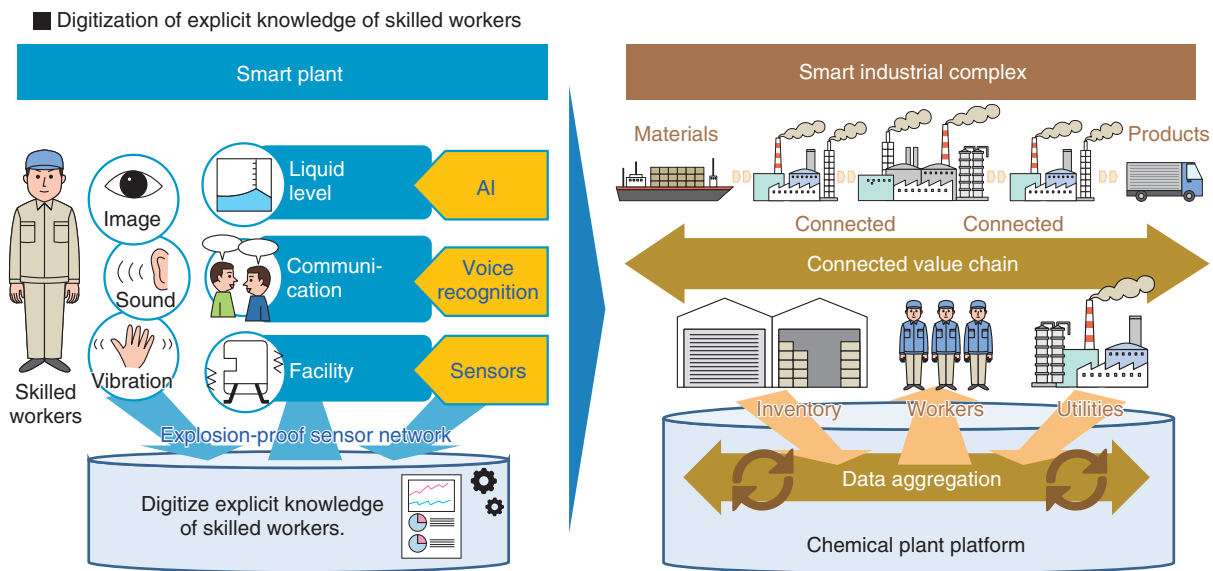


Fig. 4. Smart manufacturing with JSR.

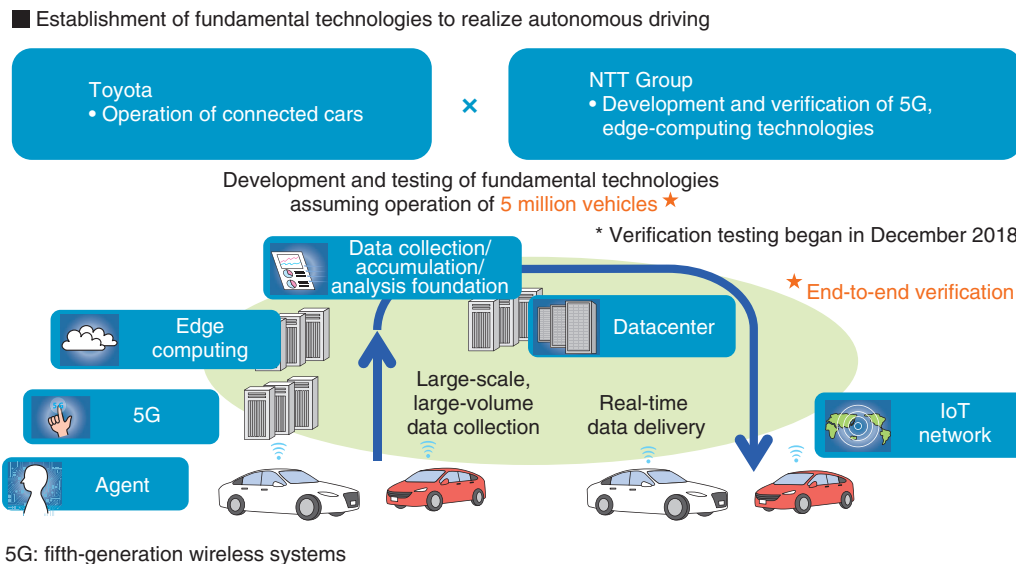


Fig. 5. Smart mobility with Toyota.

and transfer the data processing results to other vehicles in the field to achieve an end-to-end data flow (Fig. 5). The plan is to continue with these tests during specific time periods and assuming a variety of cases. I would like to turn this platform that we are creating together with Toyota into a model that can be used by other companies throughout the world, including other automobile companies.

(2) NYK Line and MTI

We are working with NYK Line and MTI on a smart ship initiative involving an onboard IoT platform that can improve fuel economy, achieve preventive maintenance, and enhance safety by collecting onboard data and managing that data even from land using satellite communications (Fig. 6). I would like to apply this platform to container ships and other

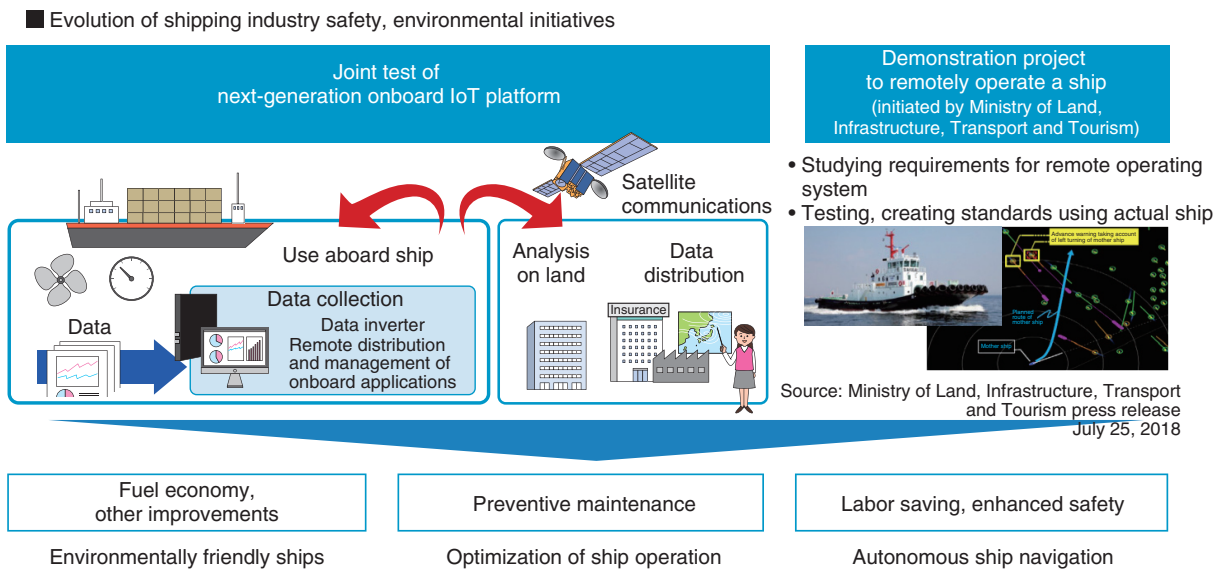


Fig. 6. Smart ships with NYK Line and MTI.

types of vessels with the aim of achieving a ship-to-ship connected world.

3. NTT Group Medium-Term Management Strategy: Your Value Partner 2025

In autumn 2018, I announced The NTT Group Medium-Term Management Strategy called *Your Value Partner 2025*. Around that time, the Japanese government was promoting the separation of handset and network charges in the mobile communications market. To remain a market leader, I therefore asked NTT DOCOMO to announce a cut in mobile phone fees and incorporated the reduction in revenue in our Medium-Term Management Strategy.

In retrospect, the separation of terminals also took place in 1985 when competition was introduced in the fixed telephone (landline) market, or public switched telephone network (PSTN). This separation of telephone sets and networks in the PSTN resulted in a significant expansion of the telephone-set market. Similarly, the separation of mobile handsets should stimulate competition in the mobile communications and handset markets, which I think is healthy all in all. On the other hand, this presents a challenging situation for NTT DOCOMO, but by entering into such a situation on our own initiative, we can face this issue with the intention of becoming a company that can provide our customers with even better services while remaining the market leader.

3.1 Future trends

The Medium-Term Management Strategy envisions 3-year, 5-year, and 7-year milestones. Here, the fifth-generation wireless system (5G) is scheduled to commence within three years, and the PSTN is scheduled to complete its migration to Internet protocol (IP) telephony in seven years. At the same time, it appears that globalism and *bloc-ism* in society will continue to coexist for some years. Amid these trends, Osaka City was selected to host the World Expo in 2025. The NTT Group as well is promoting a variety of initiatives with the aim of supporting the Tokyo Olympic and Paralympic Games a year and a half from now and the Osaka Expo in seven years.

There are also key trends taking place in the world of IT. Given the imminent end of Moore’s law, the need has arisen for new architecture and systems, and meanwhile, it is predicted that robots will replace half of the workforce in seven years. To put it another way, this means that each and every person will be able to engage in more enriching work and cultural activities. I think that we can expand our market by supporting people in these endeavors.

3.2 Further phase changes

In regard to phase changes as a communications and IT operator, NTT’s business model is making a transition from business-to-consumer (B2C) to B2B2X, as I mentioned earlier. We can also expect all-out competition as mobile handsets and the

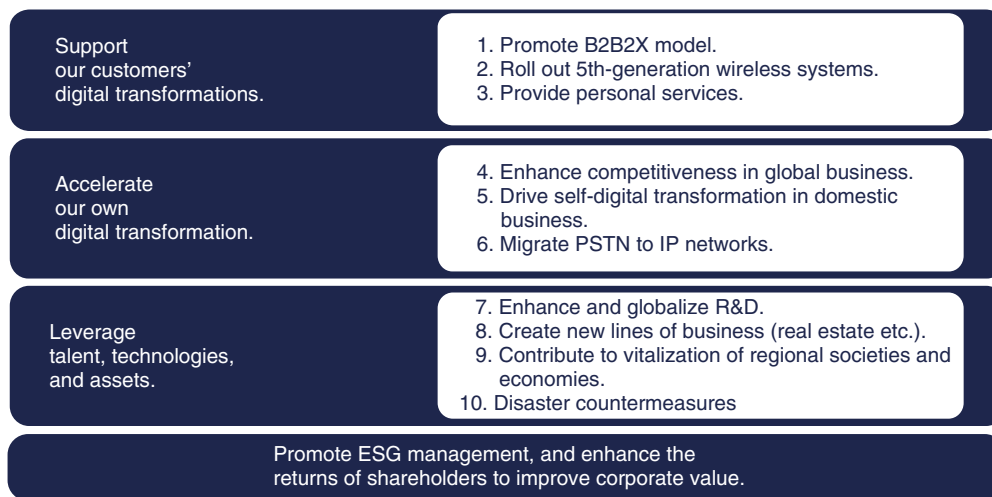


Fig. 7. Medium-Term Management Strategy.

network come to be separated, as well as shifts from communications services to digital services, from the cloud to virtualization and AI-based infrastructures, and from mobile/FTTH (fiber to the home) to 5G and smart devices in access networks.

3.3 Outline of Medium-Term Management Strategy

NTT seeks to become Your Value Partner that customers continue to select. To this end, the Medium-Term Management Strategy calls for both growth investment and cost reductions to increase profits, and introduces return on invested capital (ROIC) as a key performance indicator.

The strategy declares the NTT Group mission to be resolving social issues and the NTT Group vision to be embodied by the *Your Value Partner* concept. By pursuing this mission and vision, we would like to contribute to achieving a sustainable society by meeting SDGs (Sustainable Development Goals) initiated by the United Nations and to the realization of Society 5.0 proposed by the Japanese government [3]. I believe that our mission is to solve social problems through collaboration with our business partners while maintaining a healthy balance between the roles of a public utility and private company that the NTT Group has had from the beginning.

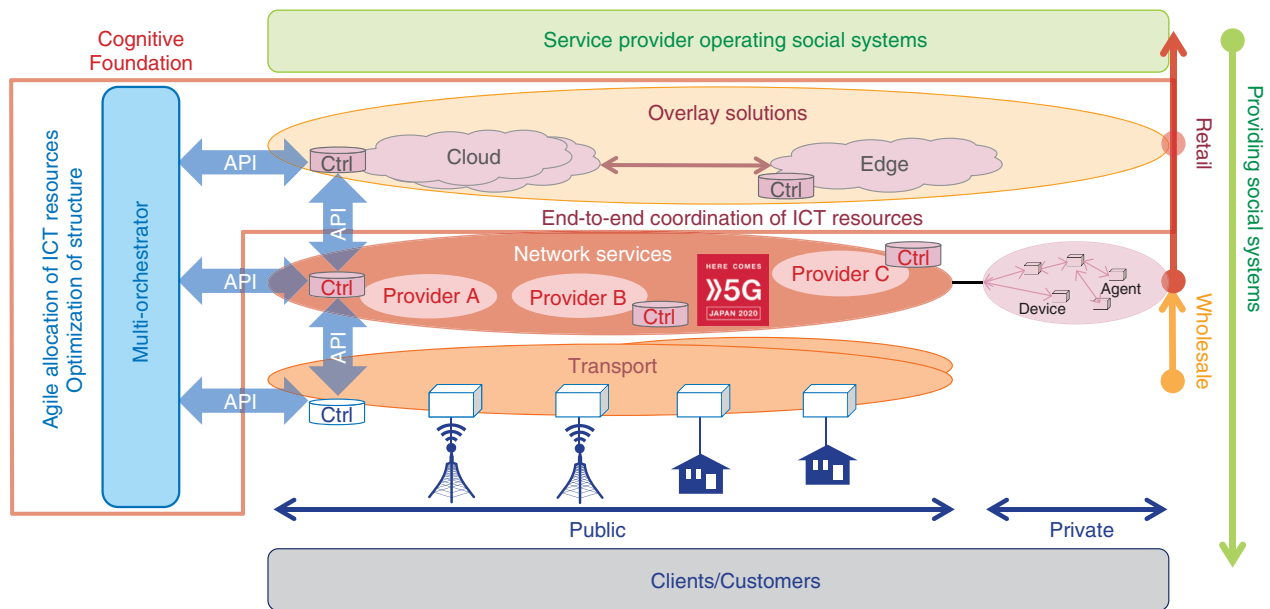
While we are aiming to be Your Value Partner, the main figure of the NTT Group vision is *people*. In the end, it is people that drive innovation, technology development, and research and development (R&D), and the values shared among people are *connections*,

trust, and *integrity*. The idea of *connections* in this case does not refer to network connections but rather to the connection of things by IoT and the connection of systems going forward. It also includes the concept of helping people to connect with each other and connecting the present with the future.

The NTT Group Medium-Term Management Strategy consists of four elements (**Fig. 7**). To begin with, we will support our customers' digital transformation by accelerating our own digital transformation. At the same time, we will pursue growth by leveraging talent, technologies, and assets. Finally, at the base of these elements, we will promote ESG (environmental, social, and governance) management and shareholder return. We have established ten measures to achieve these goals. Here, I would like to highlight the measures related to R&D.

(1) Roll out 5G services

The 5G system is slated to be the next network. Given that it is a public network, end-to-end services will be achieved by adding private networks and functions and systems within factories, on vehicles, and in other areas. The three-layer model shown in **Fig. 8** features overlay solutions at the top, but to provide such solutions as social systems, various types of things will have to be coordinated within the network-services layer. Additionally, 5G aside, an optical fiber network will run as far as base stations, which means a transport layer at the bottom of this model that will also require coordination. In other words, it is necessary to deploy functions that can orchestrate and manage all three layers, and these



API: application programming interface
Ctrl: controller

Fig. 8. Roll out 5G systems (3-layer model).

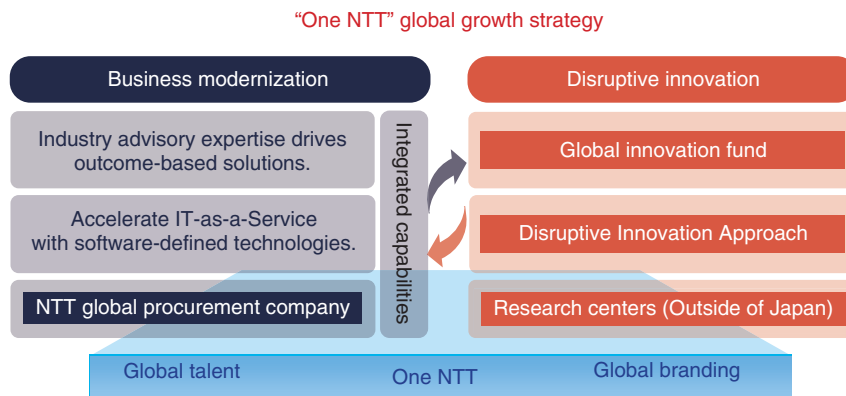


Fig. 9. Enhance competitiveness in global business.

functions will be achieved through software-defined technologies. One example of an overlay solution here is the Cognitive Foundation platform we are working on in the City of Las Vegas.

(2) Enhance competitiveness in global business

We are planning to reorganize the NTT Communications Group and Dimension Data Group into two companies, one focused on the global market and the other on the Japanese market, by July 2019. As a corporation reorganized under the One NTT brand, I

would like to support the modernization of our customers' businesses (Fig. 9). To this end, we will provide a variety of integrated solutions from datacenter services to applications, and we will do this through outcome-based solutions driven by industry expertise, IT-as-a-Service using software-defined technologies, and efficiency gains via an NTT global procurement company.

However, our customers' digital transformations cannot be achieved by this alone. There will be no

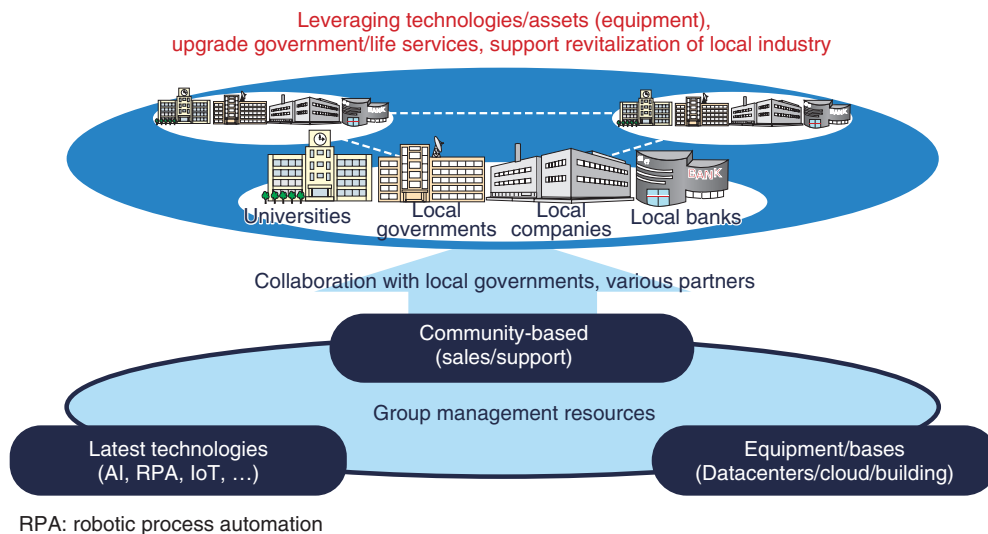


Fig. 10. Contribute to revitalization of regional societies/economies.

appealing solutions without including disruptive innovation. For this reason, we have established global R&D centers for long-term development projects and created a global innovation fund. The purpose of this fund is not to launch new businesses but rather to connect people who wish to pursue new business ventures and support them through medium-term incubation. The fund was launched in the United States with an American as head. Additionally, the Disruptive Innovation Approach team will enhance our advisory functions. This team will propose a digital or smart world to our customers in the short term. In this way, we plan to incorporate long-term, medium-term, and short-term initiatives within our solutions.

(3) Enhance and globalize R&D

We will strengthen our joint R&D. I think that communications and IT should be and will be *natural* things—if not, they would not be usable. We would like to conduct more research on natural awareness, techniques, and methods of use. In addition, I would like to expand basic research beyond present levels at overseas bases in such areas as super-secure certification technology, quantum computation theory, and biomedical technology. To this end, we will increase our R&D investment in high-growth areas by about 10% to 2 trillion yen over the next five years. Apart from this, we will invest 1 trillion yen over the next five years in 5G infrastructure build-out.

(4) Contribute to revitalization of regional societies/economies

The Cabinet Office of Japan is advocating a Super City initiative, while the Ministry of Land, Infrastructure, Transport and Tourism is promoting the concept of Compact Cities. For Japan, city development is a major issue going forward. In this regard, I think that we can support various regions in Japan using the latest technologies, facilities, and sites of the NTT Group (**Fig. 10**). Recent years have seen a confrontation between movements in socialism (nationalism, bloc-ism) and in liberalism (globalism, borderless world). While nationalism and bloc-ism are determined by a *de jure* standard, globalism and the borderless world are determined by a *de facto* standard. From here on, however, if we devise the solution of problems together with local communities, the concept of *glocalism*, which combines the meanings of global and local, will no doubt become pronounced in society. This will result in a structure 70–80% of which is dominated by *local*, and in this case, I believe that *glocalism* will be determined by a consensus standard (**Fig. 11**).

(5) Disaster countermeasures

Finally, I would like to talk about disaster countermeasures. In Japan, 2018 was a year of many disasters. Up to now, we have been striving to improve the reliability of the communications network, to secure critical communications, and to achieve prompt restoration. From here on, we must further reinforce the communications infrastructure. This will require proactive disaster responses using AI and other measures. Furthermore, taking into account the growing

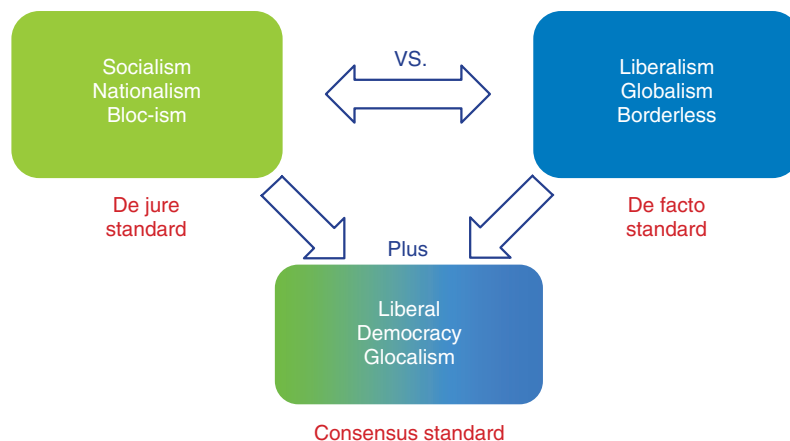


Fig. 11. Global + Local.

number of international visitors to Japan, we must work on disseminating helpful information in foreign languages as well.

3.4 Medium-term targets

The Medium-Term Management Strategy sets medium-term financial targets that we seek to meet by executing the measures I have just described. These include a 50% increase in earnings per share (EPS) and cost reductions of at least 800 billion yen in five years. I would like to achieve this EPS growth by increasing profit. Thus, I want to increase overseas (outside Japan) sales from US\$18 billion to \$25 billion and raise overseas operating income margin from 3% to 7%. Here, we set ROIC to 8% to aim for an efficient return on investment.

NTT’s total revenue stands at \$106 billion, so its global revenues are still about 19% of the total. NTT is ranked 55th on the Fortune Global 500. It provides network services in over 190 countries and regions and ranks second in the world in datacenter space. NTT employs about 300,000 employees worldwide.

4. Accelerate our own digital transformation to become Your Value Partner

In 1985, NTT’s revenues from PSTN business accounted for 83% of total revenues, but today, with

voice revenues from cell phones included, it accounts for only 18%. In other words, all other sources of revenue have expanded substantially. This is a change that took about 30 years to occur. From here on, I would like to accelerate our own digital transformation to become Your Value Partner, meaning that our customers continue to choose us over others. As a consequence of this endeavor, our business portfolio will undergo great changes. I ask for everyone’s support in determining what the new NTT should become, and I look forward to promoting business development while holding discussions with our customers and other stakeholders.

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Making the World Smart and Technology Natural

Katsuhiko Kawazoe

Senior Vice President, Head of Research and Development Planning, NTT



Overview

This article introduces NTT's latest research and development activities based on a lecture presented by Katsuhiko Kawazoe, NTT Senior Vice President, Head of Research and Development Planning, at NTT R&D Forum 2018 Autumn held November 29–30, 2018.

Keywords: smart world, highly realistic communication, artificial intelligence

1. Transformation of the world with B2B2X

Until the present time, the NTT laboratories have engaged in research and development (R&D) mainly to support NTT's services and systems. NTT has shifted its business strategy to the business-to-business-to-X (B2B2X) model, thus placing greater emphasis on R&D for value creation with partners. We have been able to develop groundbreaking co-innovations in collaboration with numerous parties.

For example, in 2014, Mitsubishi Heavy Industries, Ltd. and NTT agreed to work together on R&D for *social infrastructure* × *ICT*, which refers to the integration of social infrastructure and information and communication technology (ICT). The two companies are engaged in different business fields, but one technology linked them, and this connection led to a discovery that transformed the manufacturing industry. From the wide-ranging research results produced by NTT, Mitsubishi Heavy Industries set its eye on one technology, one that NTT had never imagined would catch their attention. They took an interest in optical fiber technology.

The photonic crystal optical fiber, which was an NTT first, was characterized by having air holes inside the fiber, and light propagated through these

holes while being confined in them (**Fig. 1**). By changing the hole diameter and the spacing between the holes, we can finely control the refraction index of the light in the fiber and achieve optical transmission characterized by extremely high output and unparalleled quality.

Application of this optical fiber technology for communication to laser beam machining is the key objective of the cooperation between the two companies. However, because the light energy level required for laser beam machining was more than 10,000 times higher than that required for communications, we faced a number of new challenges. We solved these problems, and optical fiber technology for communications found a new application in laser beam machines for cutting and welding.

It had not previously been possible to transmit a high-power single-mode laser beam for machining over more than a few meters. The application of NTT's technology made it possible to extend the distance by several dozen times. The people at Mitsubishi Heavy Industries discovered new value in our technology that those at NTT could never have envisaged on their own. This is a prime example of co-innovation through B2B2X. The case involving Mitsubishi Heavy Industries originated from our attempt to

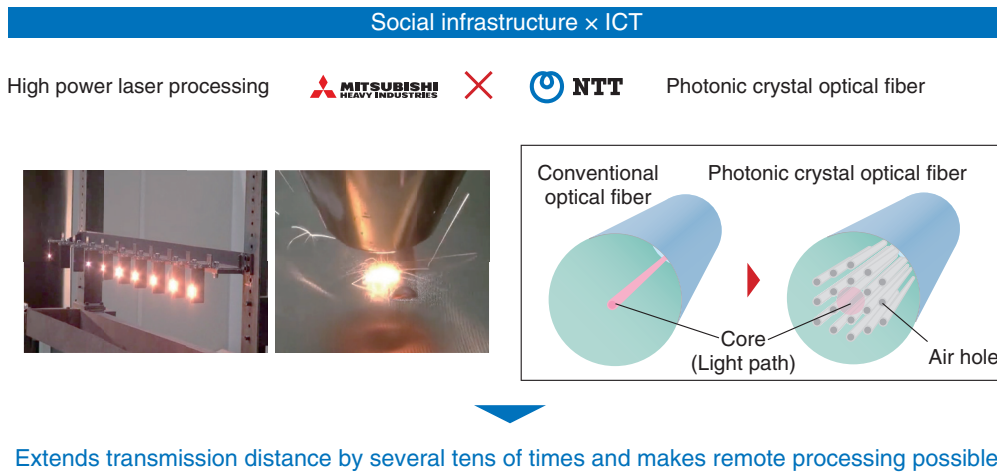


Fig. 1. Technology transforming the manufacturing industry.

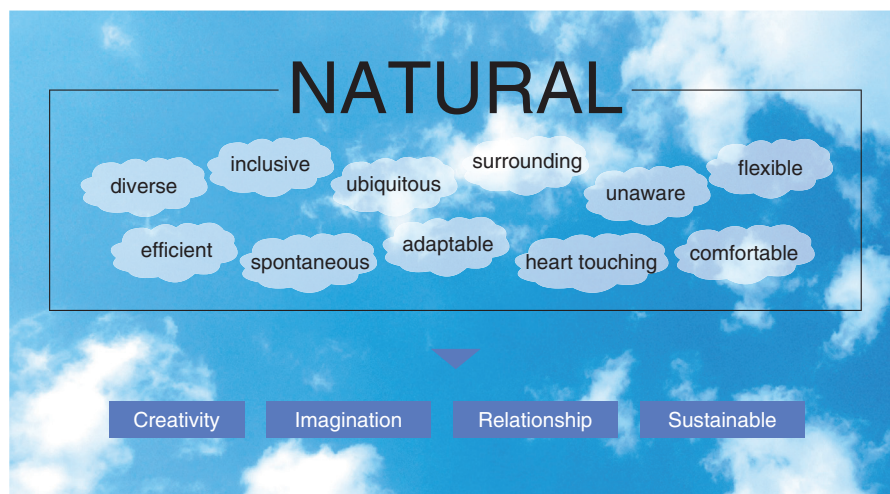


Fig. 2. The concept of *natural* in digital transformation.

solve a problem besetting their business. In the end, we have produced a result that will dramatically transform the manufacturing industry. Looking back, we realize that this constituted a transformation of the world.

2. Keyword for making smart world a reality: *natural*

NTT has innovative technologies that originated in its R&D—technologies that have been the best in the world, the first in the world, and that have amazed the world. With these technologies and through co-inno-

vation with a range of partners, we will push digital transformation in society and industry to solve the problems they face, and thereby make a smart world a reality. To do this, we will strengthen our involvement in a wide range of technical fields.

How should we advance these technologies and push digital transformation so that everyone regardless of nationality, age, or background can benefit from technology? We believe the keyword for this endeavor is *natural* (Fig. 2). We are aiming at the creation of a world in which technology keeps *caring eyes* on the lives of people from all walks of life without them being aware of it; a world in which technology

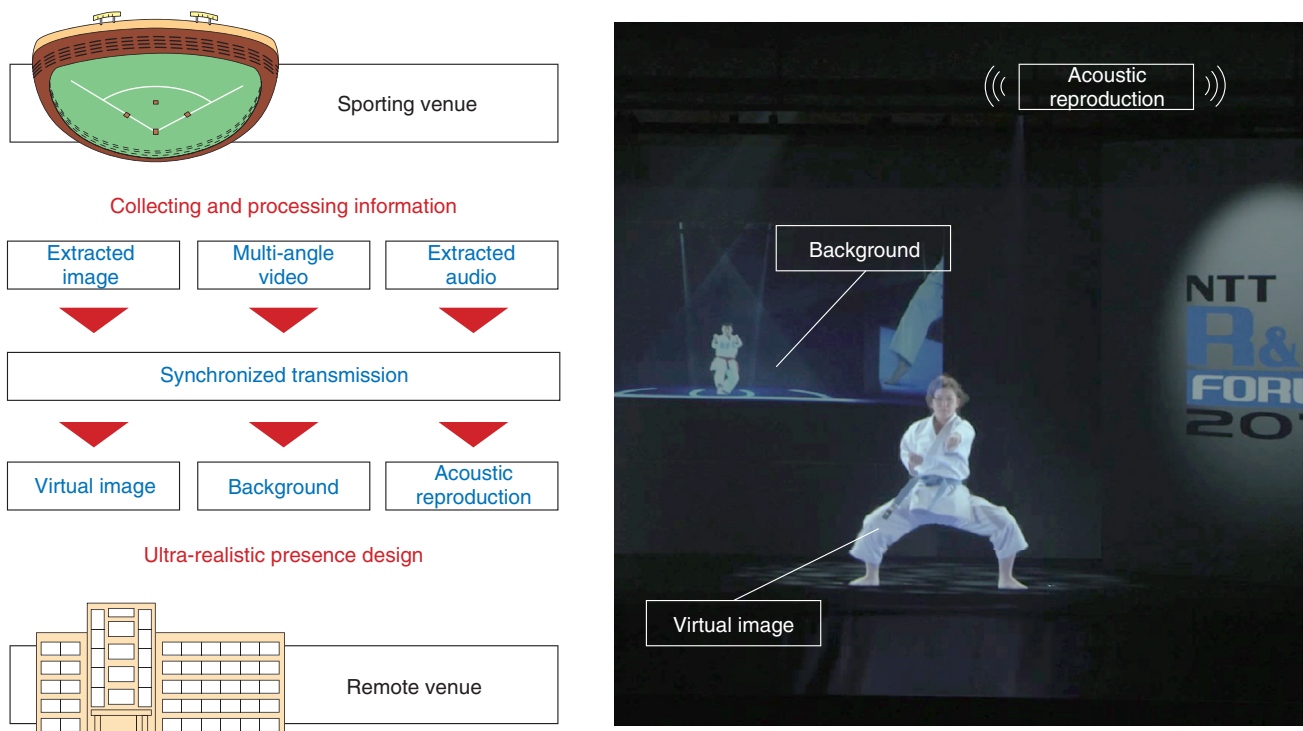


Fig. 3. Ultra-realistic communication that conveys excitement.

sometimes helps people do things more efficiently and appeals to their feelings; a world in which technology provides an environment that is friendly to both people and the earth. This initiative will lead to a world in which people can engage in human-centered activities. Let me introduce some of our activities that are aimed at making such a world come true.

3. Ultra-realistic communication that conveys excitement

The long-awaited regular broadcasting of 4K and 8K television (TV) started on December 1, 2018, in Japan. Its high definition of video images will offer a higher than ever sense of excitement. As the next step, we want to realize a world in which people transcend time and space and experience excitement as if they were at the site where an event was unfolding. This is the ultra-realistic communication that NTT is aiming at (Fig. 3).

For example, in the fashion show Tokyo Girls Collection 2018, which was held at the Yokohama Arena on March 31, 2018, scenes from the show were transmitted to a remote live viewing site in real time, enabling a large number of people to view the scenes

happening at the event site. Kirari!’s ultra-wide video synthesis technology stitched together a number of 4K videos in a natural manner in real time to produce a video that allowed the audience to enjoy a high sense of reality.

In addition, the videos shown on long vertical screens, three-dimensional (3D) and virtual reality videos, and multi-angle videos displayed on tablets were synchronized precisely using Kirari!’s advanced media streaming and synchronization technology called Advanced MMT*. Kirari! is an ultra-realistic communication technology that enables people at any location to enjoy the sensation of being at an event venue. It brings to remote sites the excitement and sensation of tension that usually only those at an event venue can enjoy. The ability to share in the excitement of a game or event is what we aim to achieve with Kirari!.

Kirari! has been continuously evolving since the

* Advanced MMT: Extended protocol of the MPEG Media Transport (MMT) undergoing standardization in ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) Study Group 16 Immersive Live Experience. The MMT is an optimized protocol for synchronous data transmission developed by the Moving Picture Experts Group (MPEG).

concept behind it was announced in 2015. Initially, viewers' attention is captured by its quasi-3D image display, but what is more important is that Kirari! creates a natural and highly realistic space by decomposing a scene into elements such as the objects' video and audio streams, transmitting them separately, and recomposing them in a way that is best suited to the conditions at the viewing site.

I was once deeply moved by the performance of a figure skater in a top-level competition. Her entry into this event was to be the culmination of her long efforts, but she lagged well behind in the short program. Despite that, her performance in the free program the next day was outstanding, gaining her sixth place in the end. I believe that many people around the world were also moved when they witnessed her complete her performance, look up, and start to cry. Why were we so moved at that time? I believe that we were impressed not just by her performance but also because the images of the path she had followed from childhood, her aspirations for that contest, and her errors in the short program ran through our minds like fragments of a story and were multiplied by the video.

Kirari! will evolve further with the aim of not only transmitting the video and audio faithfully but also evoking deep emotions in the hearts and minds of viewers based on a relevant story, such as past experiences and knowledge. Ultra-realistic communication that conveys deeply felt emotions. That is the *naturalness* that we aim at.

4. Artificial intelligence (AI) that guesses what you think

Technologies for listening and speaking AIs are now being incorporated into home appliances and are commonly used in our everyday lives. If we are to convey human feelings in a natural manner without causing the person involved to be conscious of interacting with a machine, it is essential to make further advances in speech dialogue technology. For example, if AI can handle unstructured chatting, which makes up a good part of our conversation, it can communicate with people naturally. Therefore, research on chat technology is underway at the NTT laboratories.

We are developing an AI system that can converse more naturally by giving it a distinct character and, consequently, friendliness. In order to initiate and sustain a pleasant conversation, we have developed a function that responds with not just words but also through gestures such as nodding in agreement, a

verbal function whereby appropriate responses are made that indicate agreement with what you say or think, and a function whereby a follow-up question or a question relating to what you have said is asked. We have incorporated these into Totto, the android of Ms. Tetsuko Kuroyanagi, Japanese actress and TV presenter [1].

Viewing AI that recognizes objects in the surroundings and the current situation will also become more natural. NTT has been researching robust image recognition technologies. They include, for example, robust media search technology that requires only a few reference images in order to determine that an object in question is identical to the object in the reference images, and change point detection technology that instantly locates change points in observational photos taken from a satellite.

In addition, we have developed angle-free rigid and non-rigid object recognition technology that is expected to advance image recognition technology dramatically (**Fig. 4**). Things that AI needs to recognize are not necessarily limited to rigid objects. This new recognition technology can tell that an object with a shape that can change, such as a product in a bag, is identical to the object in the reference image. This ability is expected to significantly expand the application areas of image recognition AI.

The performance of AIs when listening, speaking, and viewing things is improving. The time will come when it is more than adequate. We believe that at some stage in the future, *thinking AI* that supports human thought processes and leads to co-creation by people and AI will become more important than ever (**Fig. 5**). The current technology for Totto is still at a stage where the distinct character of Ms. Kuroyanagi has been incorporated into the robot. In the future, AI needs to incorporate her values and personality. The AI we are aiming for at NTT is one that incorporates various values and personality traits and helps people to consider complicated problems for which there is no single answer.

In the future, we will aim for AI that, while conforming to commonly accepted rules and morals, absorbs all of the perceptions of value that may arise out of geographical regions or customs. Such AI could be called *generous AI* or *sincere AI*.

5. Stress-free device

When we think of the next personal communication device that will go beyond the evolution of cell phones and smartphones, we think that what is needed

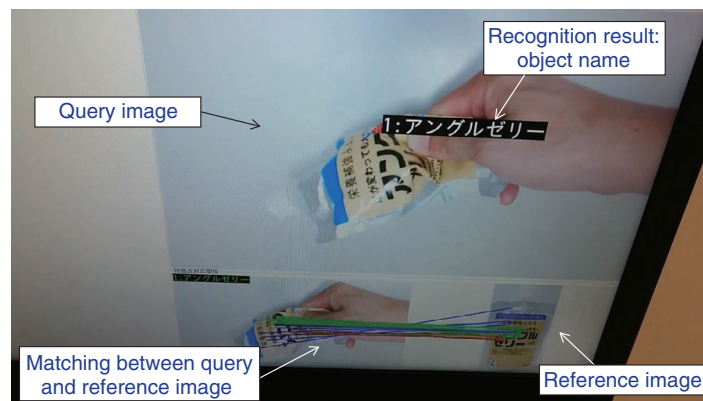


Fig. 4. Angle-free rigid and non-rigid object recognition technology.

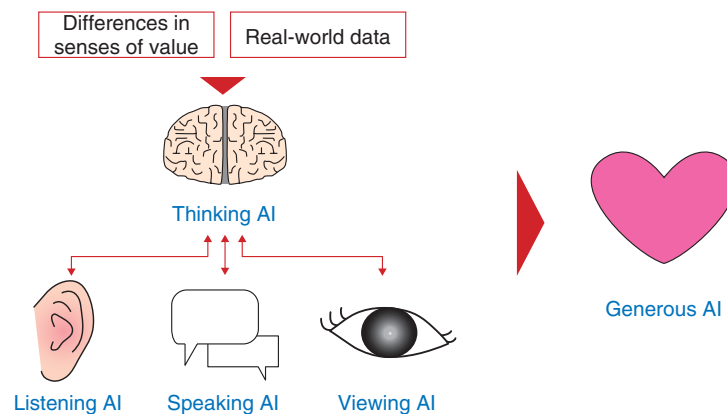


Fig. 5. AI that guesses what you think.

is a terminal or device that frees people from being dominated by applications and settings.

CUzo is a device that can be operated very naturally just by pointing it at something such as a person or a landmark. You can get information about something just by pointing the device at it. For example, CUzo will present information about a tourist spot in the user’s own language on its transparent display, provide easy-to-understand navigational advice in an unfamiliar street, or enable people from different countries to have a face-to-face conversation by looking at translations that appear on the display (Fig. 6). We want to enable people to have a natural experience by doing away with annoying tasks such as activating and operating applications, and having the device provide services in response to prompts conveyed by an individual’s natural actions.

We have developed this system in collaboration

with Panasonic Corporation. It uses device function virtualization technology developed by NTT, which virtualizes the processing functions conventionally performed within a device such as a smartphone, and places them in a cloud or on an edge computer. This technology makes it possible to provide advanced services even with simple devices.

After we have made it possible to use devices without the conscious effort of setting up and operating applications, what will come next? We foresee a future in which we no longer need to be conscious of visible devices, and various things around us look after our lives. For example, several ICT devices in a room work together and provide an illusion that a raincoat hung on the wall appears to be trembling and the floor looks wet, thereby letting the resident know in this natural manner that it is going to rain today (Fig. 7). This is one of the manifestations of naturalness.

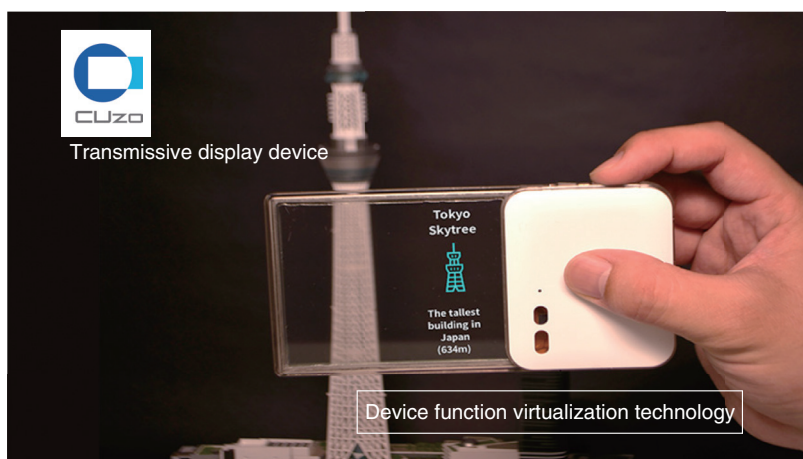


Fig. 6. Stress-free device.



Fig. 7. A world where we no longer need to be conscious of visible devices.

To pursue this concept, we plan to launch a new project called Point of Atmosphere. Please follow what we do in this field in the coming years.

6. Future network that blends seamlessly into society

Networks support various services. They will also evolve to become more natural.

A next-generation network will integrate various functions and roles across different layers. It will understand social order and priority and operate in a natural manner without humans being required to make conscious efforts to select the optimal choice. A mechanism we are working on for this purpose is the Cognitive Foundation[®]. It manages and operates various resources in different layers in an integrated manner. In the public safety solution in the City of Las Vegas, the Cognitive Foundation manages various ICT resources such as cameras, sensors, edge computers, networks, and clouds, as necessary in an optimal and integrated manner in order to flexibly adapt video monitoring resources to what is needed at a particular time.

At the current stage, the Cognitive Foundation only performs basic operations automatically, but our aim is that as the network AI continues to learn, it will execute globally optimal control in real time in a constantly changing environment and achieve advanced coordinated operations. The Cognitive Foundation will expand its coverage area to people, towns, transport and energy, work with enterprises involved in various layers of society and applications, and

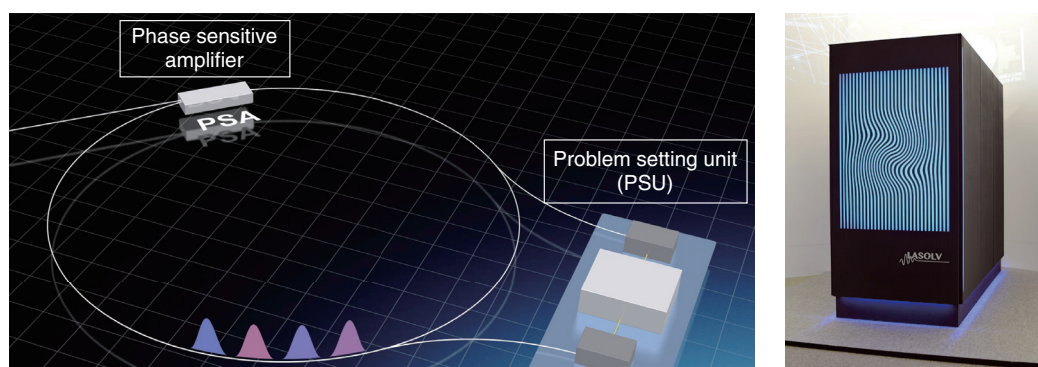


Fig. 8. Computer that solves challenging problems with light.

orchestrate everything from services to devices, thereby achieving optimization of the entire society in a natural manner. For this purpose, we will work on scalable data processing infrastructure and super-secure authentication infrastructure technologies.

7. Computer that solves challenging problems with light

If we are to enable people to lead a better life in a natural manner, we must boost the power of computers. To overcome the limitations of conventional von Neumann computers, the NTT laboratories are developing LASOLV, a computer that solves challenging problems with light (Fig. 8). Conventional digital computers solve a problem by turning it into a mathematical problem. LASOLV solves a problem not as a mathematical problem but as a physical problem. This has made it possible to solve hard problems that could not be cracked by conventional digital computers.

LASOLV is implemented using leading-edge optical communication devices and optical parametric oscillator pulses generated by phase sensitive amplifiers, both of which have been developed by the NTT laboratories over many years. A series of optical pulses flow in a 1-km-long optical fiber ring. LASOLV expresses inter-pulse interactions using an optical parametric oscillator and a problem-setting unit. This has made it possible to solve the problems associated with optimizing large-scale combinatorial models.

To date, LASOLV has been able to solve relatively simple grouping problems. It has now become possible for LASOLV to expand its targets to a wider variety of problems such as the Japanese map coloring problem and scheduling problems. For example,

assume that the possibility for a town consisting of residential, commercial, industrial, and green sections to grow to become a better town is predicated on the condition that sections belonging to the same category should not exist side by side. Let us consider a simulation of town development that meets this condition. The beauty of LASOLV is that it can solve a problem incredibly quickly that conventional digital computers cannot solve in a short time.

We are now considerably expanding the libraries of LASOLV software and advancing its software development environment so that not only experts but also general programmers can make use of it.

In addition, we will increase the number of bits in hardware from 2048 to 100,000 so that LASOLV can be applied to a wider variety of fields. One example is drug development. At the basic research stage of searching for chemical compounds that can be used therapeutically, LASOLV has the capacity to quickly identify good combinations of chemical compounds so that new drugs can be developed in a short time. To solve traffic jams and city planning, LASOLV will suggest a better route by calculating a recommended route from one point to another or the most efficient route when it is necessary to visit several places. In the field of AI, LASOLV will have the ability to find from a data set to be used in machine learning, a sample that is the closest to the data being sought. This will lead to more robust learning.

8. Activities to accelerate innovation

I have so far introduced our R&D results and the direction we are taking. Let me reveal the details of our new measures designed to accelerate further innovation. The underlying policy is globalization of

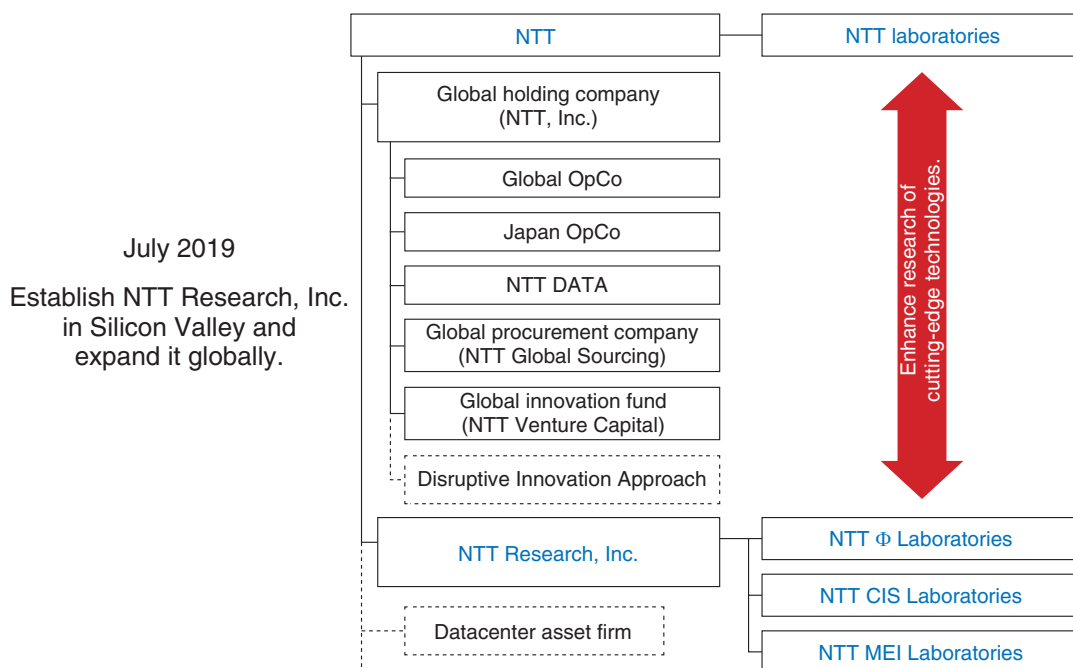


Fig. 9. Establishment of research organizations outside Japan.

our R&D. We are taking the following three measures to achieve this:

The first is global utilization of R&D results. We will take the R&D results of the NTT laboratories outside Japan and deploy them in ways adapted to individual regions.

The second is globalization of research targets. We will strengthen R&D that is adapted to global needs.

The third is establishment of research organizations outside Japan (Fig. 9). There is apprehension today that basic science and technology, the very source of innovation, are declining in Japan. We believe that basic research that serves as the foundation supporting the activities I have outlined above is the key that will allow us to take the next leap forward. To expand and strengthen basic research, we will establish a basic research organization overseas. It will be called NTT Research, Inc.

Three laboratories will be established within NTT Research, Inc. The first is NTT Φ Laboratories. This facility's mission is to make new discoveries and develop new technologies that will dramatically transform the world in the area of quantum science and computing, which is a co-creation area encompassing both physics and informatics. We came up with the idea of using PHI or Φ from the Greek alphabet—as an acronym of physics and informatics—for

the name of the laboratories. The focus at Φ Labs will be on basic research in the field of quantum theory, which will lead to future quantum computing technology and the formulation of completely new theories, including the application of quantum theory to information processing. We will invite Professor Yoshihisa Yamamoto, professor emeritus of the National Institute of Informatics and of Stanford University and the project manager of ImpACT (Impulsing Paradigm Change through Disruptive Technologies Program), which has collaborated with us in the development of LASOLV, to become the director of Φ Labs.

The second is NTT CIS Laboratories. This organization will work on advanced cryptographic theory and encryption, and information theory, which is the basic theory underlying secure information exchange in a complicated distributed environment. The director of CIS Labs will be Dr. Tatsuaki Okamoto, NTT Fellow and last year's recipient of the RSA Conference Award, which is one of the most prestigious awards in the area of cryptography.

The third is NTT MEI Laboratories. They will be engaged in medical and health information processing, which will assist the establishment of a natural relationship between people and ICT. To head MEI Labs, we will invite Dr. Hitonobu Tomoike, medical doctor

and advisor to the Sakakibara Heart Institute. He has considerable influence both in Japan and abroad as a physician expert in the cardiocirculatory system and is also well-versed in ICT.

The key aspect of these appointments is that all three individuals are active globally in their respective fields of expertise and thus have wide-ranging international human networks.

We will first establish NTT Research, Inc. in Silicon Valley, California, where research in these fields is advancing, and then extend its geographical presence to other parts of the world. Through R&D at global sites focusing on basic research, and in collaboration with universities, both at home and abroad, and with other partners, we will aim for the summit of basic research and produce unparalleled research results that will bring about game-changing innovations.

9. Future outlook

The NTT laboratories have shown the potential of new technologies well in advance of their rivals. We will aim to achieve impactful technical innovation, keep abreast of the changing times, and open up the next frontier.

NTT R&D will look ahead and paint a picture of what lies beyond the near future. With a view to bringing about a future characterized by naturalness and to realizing a smart world, we will continue to pursue research that will transform the world.

Reference

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Ensuring Greater Safety for Our Firefighters and Our Communities: Integrating FLAIM Trainer™ and hitoe™

Tamir Levin, Simon Chessum, James Mullins, Nobutomo Yoshihashi, and Katsuyoshi Hayashi

Abstract

FLAIM Trainer™ is an immersive, virtual reality (VR) firefighter training simulator with biosensing and real-time scenario analytics. It was developed in Australia through research at Deakin University and incorporates a patented digital biosensing fabric developed by NTT called hitoe™. The hitoe material provides real-time data readings of biomedical signals, for example, electrocardiogram or electromyogram signals. FLAIM Trainer revolutionizes the way emergency services train and prepare to fight fires. The immersive VR, haptics feedback, and breathing simulation provide firefighters with the ability to train for dangerous scenarios that are hard to reproduce in reality, expensive, and environmentally harmful.

Keywords: wearable sensor, electrocardiogram, biomedical signal monitoring, haptics, immersive virtual reality, firefighting, emergency services

1. Introduction

NTT subsidiary Dimension Data and FLAIM Systems Pty Ltd., a start-up wholly owned by Deakin University (Melbourne, Australia), have collaborated on the integration of biometric data capture and feedback as part of an immersive virtual reality (VR) firefighting simulator called FLAIM Trainer™. This has created an enhanced training experience and improved the health and safety of trainees and ultimately their *fitness to fight* in emergency situations. Under a co-innovation agreement, Deakin University and Dimension Data have integrated NTT's hitoe™ material (**Fig. 1**) [1] into FLAIM Trainer. The hitoe biosensing nanofiber material is worn as a vest by the trainee, which tracks electrocardiogram (ECG) readings and transmits the data in real time for analysis of firefighters' heart rate, stress level, and fatigue during

training. The FLAIM Trainer system includes an HTC VIVE VR headset, personal protective clothing with heat generation components, a breathing apparatus simulator, and a patented haptics feedback hose system that provides a unique training experience. With the complementary layer of hitoe, instructors can monitor the trainee's vital signs as well as physiological response and performance during training. Dimension Data's Cloud Analytics Platform is used to aggregate the hitoe data with the data captured from the FLAIM Trainer system during training. The data is then displayed alongside the visuals of the training scenario being undertaken (**Fig. 2**). As the captured data and training session are recorded and stored in a cloud environment or integrated into a learning management system, results can be benchmarked, and instructors can review and track performance over time.



Fig. 1. hitoe™ smart shirt and transmitter.



Fig. 2. Screen for instructors and trainers.

This innovation is unparalleled in the world of VR-based training systems and will have a much broader application in the future for other industry uses. The system not only captures, integrates, and presents live feedback from all devices and sensors, including hitoe, but also enables the trainee and instructor to see how a set of actions (firefighting technique, hose and water or foam use, oxygen consumption and any simulation or scenario-related activity) correlates with and affects performance via heart rate and stress. This will lead to new insights into how we fight fires and better manage the health and safety of our emergency workers.

The FLAIM Trainer solution was announced and

demonstrated at the launch of Dimension Data's first Client Innovation Centre (CIC) in Sydney in August 2018. The CIC showcases a number of technologies and solutions developed and co-innovated with the NTT Group and the wider Australian business, government, and academic community [2].

2. FLAIM Trainer design

FLAIM Trainer is a highly configurable and mobile training system that can be easily transported and set up at different locations. The hardware (**Fig. 3**) consists of:

- Industry-standard personal protective helmet and

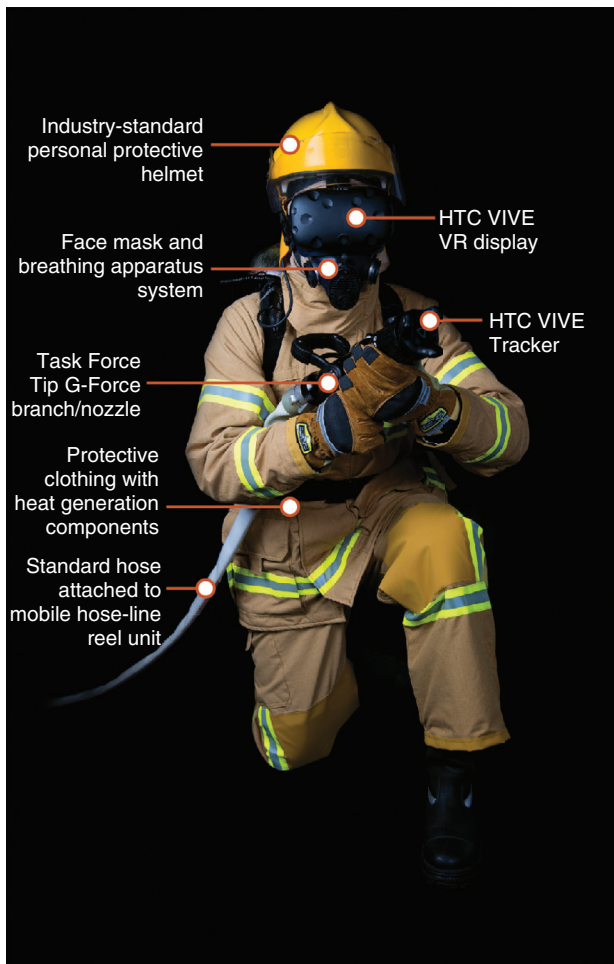


Fig. 3. FLAIM Trainer™ hardware.

clothing with heat generation components;

- An NTT hitoe vest and transmitter that tracks heart rate, heat stress, and ECG and transmits data via bluetooth;
- A head-mounted HTC VIVE VR display integrated into a full-face cover, and a customized oxygen tank that replicates the breathing apparatus used by firefighters;
- A mobile hose-line reel unit and Task Force Tip G-Force branch/nozzle that can be customized with haptic feedback, generating up to 300 N of force;
- A VIVE Tracker mounted on the tip of the nozzle and two VIVE Base Stations; and
- Support equipment including an operator control tablet, charging systems, ancillary support tools, and storage and transport cases.

FLAIM Trainer’s VR simulation produces realistic

renders of smoke, fire, water, and foam effects and precisely matches the physical nozzle settings and performance, with five detent flow positions from an optimal straight stream to a fog pattern displayed in the headset for the trainee and on screen for the instructor. The nozzle’s selectable 100/200/300/400/500 l/min @ 500 kPa (5 bar) water pressure control, combined with the flow type, is reflected in the physical force feedback for the trainee created by the haptics system.

The mask and breathing apparatus system, worn as an oxygen tank on the trainee’s back, contains all of the electronics and processing to capture and measure the respiration rate of the trainee, the amount of oxygen consumed and whether or not they are communicating effectively during the exercise.

The heat suit realistically replicates the heat that would be felt by the trainee in the simulation scenario, including the direct or radiant heat from the fire itself. The heating elements are controlled via the FLAIM Systems software that determines the proximity and orientation to the fire, and other heating effects, and how that affects the individual.

From a software and systems perspective, there are five standard scenarios available, with additional and customized scenarios available via subscription to users. These base scenarios and skills training cover hose use, compartment (kitchen) fire, aircraft (foam), gas cylinder cooling (BLEVE: boiling liquid expanding vapor explosion), and vehicle and size-up fires (Fig. 4). In each scenario, data feeds from the various components of the VR simulation and hitoe vest are captured and presented on screen for the instructor in real time. The data is also captured in Dimension Data’s Cloud Analytics Platform, with data sets stored and analyzed to provide measurement against benchmarks, that is, to determine best practices, and for training results to be logged in each trainee’s training record, either in a stand-alone application or the organization’s own learning management system or other professional development or training system. Individual or group feedback and recommendations can then be provided by the instructor based on the reports generated (Fig. 5).

FLAIM Systems has a team of roboticists, modelers, software developers, machinists, fabricators, and engineers who can develop customized solutions and scenarios for specific training exercises and requirements.



Fig. 4. Rendered image of standard scenarios.

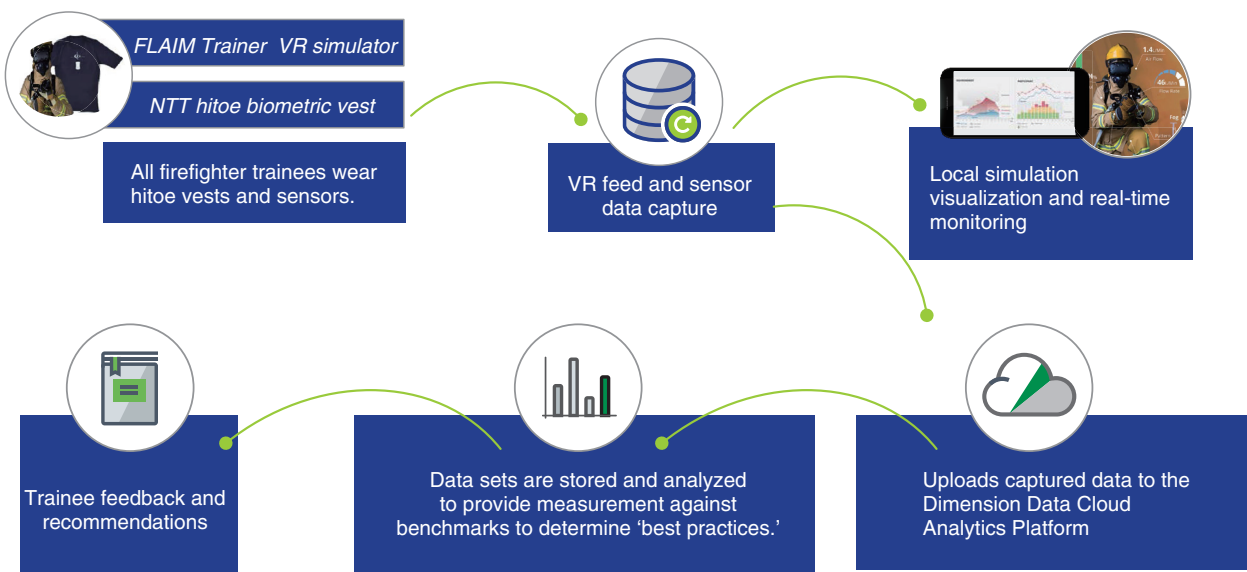


Fig. 5. FLAIM Trainer - How it Works.

3. Stress calculations from hitoe

The calculations of the trainee’s level of physiological stress are completed on the hitoe device and reported to the FLAIM Trainer application as a value of 0 – ~2.3. The FLAIM Trainer software then converts this to a six-bar visual stress indicator, displayed as part of the instructor’s dashboard (Fig. 6).

The stress estimation logic calculates the ratio of high- and low-frequency oscillations (LF/HF) values as one of the feature values employing inter-beat (RR) interval values (RRI) representing the fluctuation of heartbeats. LF: total power of 0.04–0.15 Hz when performing spectral analysis on RRIs; HF: total power of 0.15–0.40 Hz when performing spectral analysis on RRIs; LF/HF: increases when sympathetic

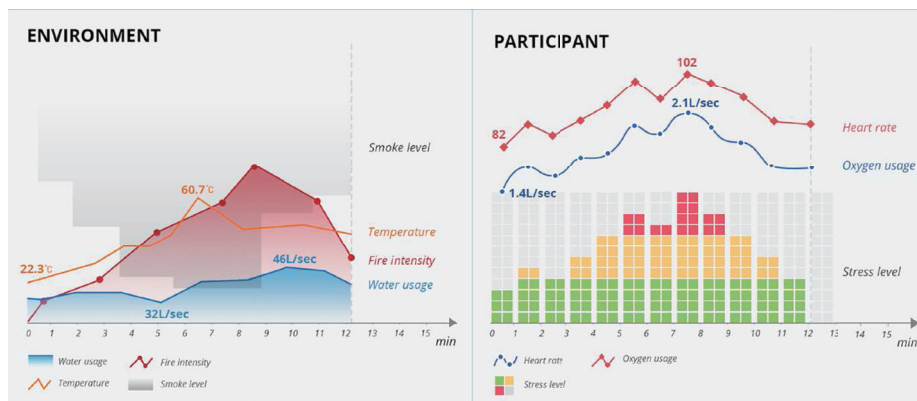


Fig. 6. Fit to fight analysis.

nerve activity is activated.

4. Cost and difficulty of traditional training

One of the key challenges that FLAIM Trainer addresses is the cost and difficulty of training, which limit the scale and frequency of firefighting training. Those costs include establishing and maintaining purpose-built training facilities, personnel, and travel time and costs for trainees to attend training sessions. For the more complex or extreme scenarios, for example, an aircraft fire, setting these up in a real training facility are virtually impossible or prohibitively expensive. FLAIM Trainer also provides an opportunity for the community and potential recruits to experience what it is like to fight a fire—all at a low cost, in a quick timeframe, and at any possible location.

“The Virtual Reality roadshow is underway and is more than likely coming to a location near you! This Virtual Reality tool will help volunteers train for incidents that they may not see on a regular basis.”—Country Fire Authority (CFA) News & Media [3].

Training members of the world’s navies, for instance, has historically been difficult—logistical constraints mean that naval members cannot fully train at sea, as they are constrained in the use of training smoke or the use of fire hoses in the middle of a vessel. Using industry standard equipment and real-world systems in a virtual environment such as with FLAIM Trainer removes those constraints and allows users to train more, train better, and train anywhere.

“A big push for the future will be to get Sea Training Group to take FLAIM Trainer to sea, so Navy members get the chance to practice with a greater level of realism in their ships.”—Commander

Graeme Bacon, Royal Australian Navy [4].

5. Reduced environmental impact

By complementing physical training with a fully immersive set of virtual scenarios, FLAIM Trainer can reduce the environmental damage caused by real-life training. It also enables training for scenarios that are no longer possible to carry out due to environmental, community, or regulatory constraints. Traditional firefighter training can cause extensive environmental harm. In a country such as Australia, where many areas are suffering from water shortages and drought conditions, high volume water usage for training purposes can be problematic in that it takes precious and limited water resources away from more essential needs.

By-products of traditional training activities such as smoke and other pollutants released through the process of burning substances can have a damaging effect on the surrounding environment and air quality and also contribute to atmospheric damage. Apart from water, the long-term effect of other substances such as per- and polyfluoroalkyl substances (PFAS) used in firefighting foams, has caused contamination of the surrounding areas and health side-effects for populations around the world. The Australian government reported that there are a number of specific sites across Australia where run-off from the historical use of PFAS-containing firefighting foams has resulted in increased levels of PFAS in surrounding soil and water. As an indication of the seriousness of this issue, the Australian Government has set up a dedicated website to provide the community with more information on PFAS contamination [5].

Many jurisdictions around the world have banned or are phasing out the use of firefighting foams containing PFAS chemicals. A number of physical training sites have been closed down due to PFAS contamination across Australia, increasing the cost and availability of firefighter training, and also limiting the amount of training that can be conducted safely with firefighting foams. Furthermore, the potential health impacts associated with exposure are being investigated by an Expert Health Panel for PFAS established to advise the Australian Government [6].

6. Trainee health and safety

The use of firefighting foams in training exercises also has a direct impact on the trainees themselves. When these training exercises are replaced with virtual scenarios, there is less exposure over the long term for firefighters to the potentially damaging effects of the chemicals used in firefighting foams. For example, in 2013, Airservices Australia tested 150 firefighters for exposure to toxic chemicals and found that some firefighters had levels of PFOS (polyfluoroalkyl substances)—a type of PFAS chemical—from 10 to nearly 20 times higher than the general population [7].

However, firefighting training in and of itself is inherently dangerous to the health of trainees. With the biosensing data supplied by hitoe, instructors are able to monitor the trainee's health and safety during the training exercise, alerting them to immediate risks to the trainee's wellbeing or to underlying health issues that can then be treated to avoid potential harm to the person in future training scenarios or in the field.

Training-related injuries and fatalities are a serious concern in the emergency services sector. For instance, the United States Fire Administration (USFA) reported that approximately 11% (141 out of 1305) of the line-of-duty deaths that occurred from 2001 to 2013 were training-related. The leading cause of training-related deaths was heart attacks (50%) followed by traumatic injury (31%). The remaining 19% were other types of cardiovascular disease and other diverse circumstances [8].

During 2001 to 2013, the National Institute for Occupational Safety and Health (NIOSH) investigated 77 training-related fatalities through the Fire Fighter Fatality Investigation and Prevention Program [8] and reported that of those fatalities, 62 (80%) were cardiac-related and 11 (14%) were trauma-related. The investigations included 38 deaths

due to physical fitness activities, 23 deaths due to apparatus/equipment drills, 10 deaths due to live-burn exercises, and 5 deaths due to other training associated circumstances.

In 2017, the situation in the United States had only improved marginally. The National Fire Protection Association reported that ten deaths had occurred during training activities. Sudden cardiac death claimed the lives of seven of the firefighters. Three of those seven were engaged in physical fitness training; two were involved in search and rescue training; one was training on vehicle extrication, and one was involved in hose training. Two of the other three training deaths resulted from traumatic injuries. One of those firefighters fell from an aerial ladder during above ground fire training. Another was involved in a motor vehicle crash while traveling to an off-site drill. One firefighter died shortly after developing complications from a recent medical procedure while he was attending a refresher class at the fire station [9].

7. Societal benefits

With firefighters facing long periods of inactivity and fighting fewer fires than ever before, the co-innovation initiative between Dimension Data, Deakin University, NTT, and FLAIM Systems will significantly boost the fitness and effectiveness of firefighters all around the world and put them in the best possible position to stay safe and protect our communities. The combination of FLAIM Trainer and hitoe has proven to be a safe, low cost and mobile solution that can simulate a range of fire events and conditions, enabling firefighters to train more easily and more frequently. This will make our firefighters better prepared and better able to deal with a wider range of emergency situations and fire scenarios that they might face in the real world, which will ultimately result in better community safety. At the same time, with virtual training supplementing real-life training, there are better health and safety outcomes for our firefighters, and a reduced impact both on our environment and on the health and welfare of our communities.

CFA News and Media reported that FLAIM Trainer could be used to engage the community and let them feel what it was like to be a firefighter in a fire scenario [10]. Steve Warrington, Chief Officer of the CFA in Victoria stated in a news broadcast that the technology enables firefighters to monitor their own health and wellbeing and to find out how they will react in the heat [11].

8. Future development

FLAIM Trainer is currently commercially available in Australia and the United States, and there are plans to launch the product into other worldwide markets. FLAIM Trainer can be used in fire departments and defense forces, firefighter training schools, and other training providers for emergency services. The innovations demonstrated with FLAIM Trainer and hiteo have applications across a range of different industries and professions where health and safety is an issue, and where effective training and emergency response readiness are important.

The use of technology applied to the challenge of training firefighters to be fit to fight also creates a platform for the ongoing enhancement of current VR simulations and the development of future training scenarios.

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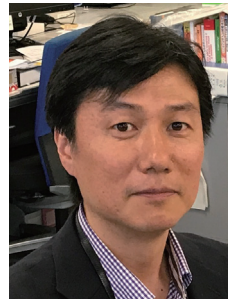
He has an engineering degree with a major in robotics and a Ph.D. in medical simulation. He has worked in the robotics and technology sectors for over 20 years and has a strong focus on commercializing cutting edge technologies into domains including defense, medical, fire, and manufacturing. FLAIM Systems is a start-up from Deakin University delivering next generation training opportunities for first responders. He has 25 years of experience as a CFA volunteer and is currently serving as the 1st Lieutenant at the Grovedale chapter outside Melbourne, Australia.



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Utilization of NTT's R&D Technology in the Financial Industry

Rika Miyahara, Fumi Enomoto, Yoshihisa Koike, Seiichiro Kitamaki, Takashi Miyatake, and Takashi Tominaga

Abstract

The financial industry is currently going through major transformations owing to a technological innovation called *fintech* (i.e., finance and technology). The NTT laboratories have been researching and developing a number of technologies that contribute to the promotion of fintech such as concealment technology for blockchain, artificial intelligence technology for automated responses to customers, and robotic process automation technology for improved operational efficiency, and we have been able to introduce these technologies via various NTT Group companies. This article introduces some collaborations with Mitsubishi UFJ Financial Group, Inc., in cooperation with NTT Communications, that we have been implementing since fiscal year 2017. The future utilization of NTT technology in the field of fintech is also discussed.

Keywords: fintech, digitization, teleconference

1. Background

In the financial industry, the development of digital financial technology called *fintech* has been greatly transforming financial operations. Technological innovations are being made across a wide range of applications; some examples are credit screening by artificial intelligence (AI), automated responses to customer inquiries by chatbot, and international remittances with cryptocurrency using a new information infrastructure technology called blockchain.

NTT and Mitsubishi UFJ Financial Group, Inc. (MUFG) have been jointly studying digitization transformation for about a year, in cooperation with NTT Communications. By introducing various technologies developed by the NTT laboratories and jointly investigating the possibility of utilizing those technologies in the banking business, we are aiming at mutually accumulating knowledge for creating business by utilizing our research results in the future.

The technological innovation achieved through NTT's research and development (R&D) that attract-

ed the interest of MUFG is our immersive telepresence technology called Kirari!. Kirari! comprises an array of technologies that transmit high-reality images in a manner that makes viewers feel like they were seeing the objects of the images in person even when the objects are in remote locations. We have been developing Kirari! with the aim of applying it to relay broadcasts of entertainment such as sports, *kabuki* plays (traditional Japanese performing art), and concerts. When we introduced this technology to MUFG, we received proposals to apply it for handling situations such as external events, conferences, and customer visits to branches. We subsequently began a joint study in a wide range of areas on the possibility of utilizing the technologies of the NTT laboratories in order to provide new banking services at MUFG.

Currently, to improve management efficiency, megabanks and other banking institutions are aiming to increase the number of next-generation branches at which customers handle various procedures themselves and to offer new banking services by which various procedures are completed in customers'

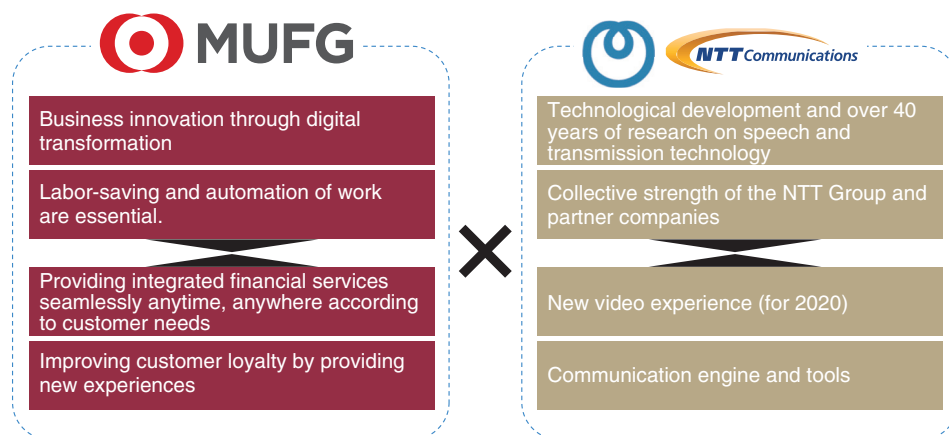


Fig. 1. Joint study on realizing a future vision of banking services.

homes. Using ordinary video calls to customers who visit branches is one approach; however, communication via ordinary video calls might be perceived as cold and unwelcoming by customers. MUFG thought that applying NTT's advanced technologies such as Kirari! and corevo[®] AI technology would make it possible to respond to customers from a remote location while maintaining warmth and a sense of connection with people.

2. Collaboration with MUFG

In fiscal 2017, we held a workshop-style discussion to explore a joint study on the theme of realizing the future vision of banking services. About 20 members from MUFG participated in regular meetings, mainly from the Digital Transformation Division, who are promoting digital transformation of the banking business. The scale of the joint study became very large as various studies were initiated and discussed in eight meetings in total.

In these studies, we exchanged views on introducing NTT's technology and the possibility of utilizing it with two major points of focus, namely, a new video experience, and a communication engine and tools.

To illustrate the first point, a new video experience, we held a joint exhibition using a television-size viewing box on how to use Kirari! with customers when they visit branches. This conceptual exhibition provided exhibition visitors with a hands-on experience in which a virtual agent (a character mascot representing MUFG) was projected in a pseudo-three-dimensional manner by Kirari! technology to

deal with customers. This exhibition received a favorable reception at the Singapore FinTech Festival 2017 and CEATEC JAPAN 2017.

For the second point, a communication engine and tools, we introduced our research accomplishments in speech technology cultivated by NTT over many years, for example, speech recognition, speech synthesis, and intelligent microphones, and discussed how to utilize these technologies in the banking business. For example, we hypothesized that linking the intelligent microphone and speech recognition with speech-to-text technology would enable voice data recorded while dealing with visiting customers to be converted to text, which could then be accumulated and analyzed. Sharing good responses to customer inquiries as examples among branches would make it possible to improve customer satisfaction and work efficiency.

We also introduced our annotation technology, which displays operational explanations and messages regarding issues needing attention on the system screen without affecting the existing system. Accordingly, we were able to obtain opinions on specific usage scenarios stating that the technology can be utilized as a system to support operations by elderly people and foreign customers as banking procedures continue to advance toward being paperless and are handled by customers themselves.

From this point on, we will continue to strengthen our relationship through a series of joint-study sessions in order to promote digital transformation in the financial industry (**Fig. 1**).

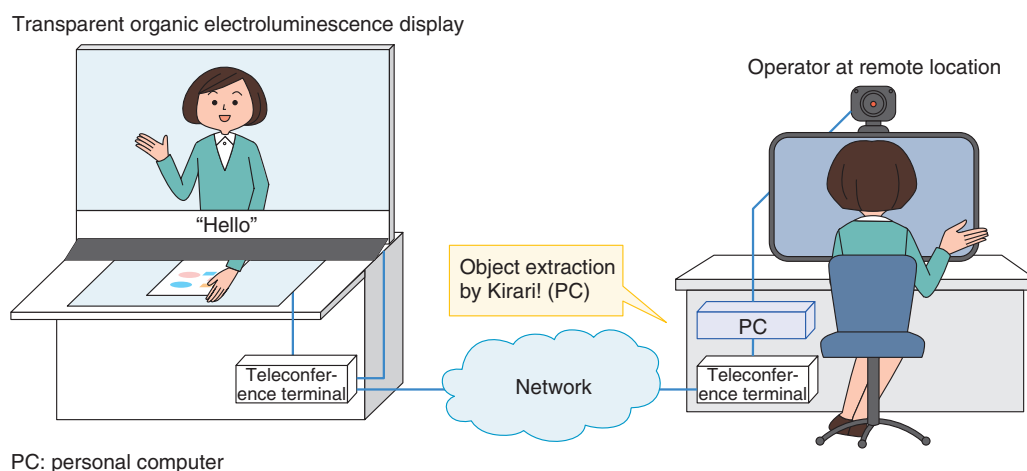


Fig. 2. Prototype of customer reception system.

3. Utilization of latest technologies

NTT and NTT Communications are making full use of the knowledge gained through these studies to commercialize products and services.

3.1 Speech recognition

The joint study enabled us to recognize the possibility of utilizing the speech-recognition and Japanese-language-analysis technology of the NTT laboratories in MUFG operations. As a result, the application of this technology is being considered for call centers as well as in other scenarios such as at storefronts, for outside visits, and for recording the minutes of meetings at banks to improve work efficiency by combining technologies that can *visualize* the customer's voice by speech recognition and can carry out thorough searches by using robust media search technology. As the first step of one study, MUFG's outbound call center is utilizing ForeSight Voice Mining to evaluate the possibility of applying it for purposes such as emotion analysis and summarization.

3.2 COTOHA Translator™

Automatic-translation technology based on COTOHA Translator™ is proving advantageous with the globalization of the banking industry. It is increasing the number of opportunities to translate materials and serve customers in multiple languages in scenarios such as dealing with inbound visitors to banks. COTOHA Translator achieves high translation accuracy without changing the slide layout of Microsoft PowerPoint documents; consequently, it is gaining

popularity as it leads to significant improvement in work efficiency, and we are presently evaluating it at MUFG. To diversely utilize these corevo AI technologies of language recognition and analysis processing in the financial business, we will promote joint studies aimed at providing new banking services by leveraging NTT's comprehensive technical capabilities such as the fusion of corevo and Kirari!.

3.3 Kirari!

At the NTT Communications Forum 2018 held in October 2018, a terminal capable of displaying glassless three-dimensional images was exhibited. This terminal uses Kirari! technology and an aerial-imaging plate provided by NTT Communications in cooperation with Dai Nippon Printing Co., Ltd. We are working to offer the terminal at a reasonable cost and in a size used at financial institutions and other branches, and are planning to commercialize the terminal in the future.

In addition, the NTT laboratories exhibited a prototype of a customer reception system at the NTT R&D Forum 2018 Autumn (Fig. 2). This system connects the object extraction technology used in Kirari! with a general-purpose teleconference system and uses a transparent organic electroluminescence display. It can provide a realistic sensation by Kirari! in a general broadband environment such as that provided by a FLET'S Internet access service. We want to make the system available to a wide range of industries—starting with the banking industry—that must deal with customers in remote locations.

4. Future directions

The NTT laboratories are researching and developing cutting-edge technologies such as blockchain and

quantum computers that are expected to be used in the fintech field. We will continue to strive to derive the best practices through collaboration with MUFG and other financial institutions.

Cooperation with NTT Group and future expectations

At MUFG, digitization is one of the pillars of the structural reform outlined in our medium-term business plan, and the Digital Transformation Division is playing a role in developing and promoting wide-ranging initiatives for improving top-line results and streamlining processes. In regard to those initiatives, NTT Communications has introduced new technologies of the NTT Group in cooperation with NTT researchers through workshops, tours of the Musashino and Yokosuka R&D Centers, NTT Communications Forums, etc., and we have received many ideas on new things we can do.

We are currently working with NTT Communications on converting voice data into text at outbound call centers. I expect to see more proposals that will lead to a reduction in workloads by making full use of the NTT Group's advanced speech and transmission technologies.

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Director, Digital Transformation Division,
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From left: Yoshihisa Koike, Manager, Marketing, Third Sales Division, NTT Communications Corporation; Fumi Enomoto, Senior Account Executive, Financial Industry Sales Group, Third Sales Division, NTT Communications Corporation; Rika Miyahara, Senior Manager, Financial Industry Sales Group, Third Sales Division, NTT Communications Corporation; Seiichiro Kitamaki, Account Supervisor, Financial Industry Sales Group, Third Sales Division, NTT Communications Corporation



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Initiatives in the Primary Industries (Agriculture, Forestry, and Fisheries) Utilizing Advanced Technology of the NTT Group

Yoshikazu Kusumi

Abstract

Currently in Japan, primary industries such as agriculture are facing problems including a shrinking working population, an aging working population, and a decreasing area of agricultural land. *Agritech*—which utilizes the Internet of Things, big-data analysis, artificial intelligence (AI), and robot technology in the agricultural industry—is attracting attention as a trump card to solve these problems. In this article, concrete initiatives involving agritech, focusing on utilization of the NTT Group’s AI-related technology called *corevo*[®], are introduced, and future directions are discussed.

Keywords: agritech, AI, animal husbandry, rice cultivation

1. Increased focus on *Agritech*

Japan’s agriculture industry is facing problems such as a shortage of labor due to a decrease in the number of agricultural workers and low productivity. In recent years, attention has been paid to *agritech*^{*1}—which utilizes the Internet of Things (IoT), big-data analysis, artificial intelligence (AI), and robot technology in the agricultural industry—as a key to solving these problems.

In particular, efforts utilizing AI have started both in Japan and abroad as support for and substitution of the *eyes* and *brains* of agricultural professionals (exemplary farmers), whose numbers are steadily decreasing. The NTT Group is also engaged in research and development and service creation of agritech unique to telecommunications carriers by utilizing its AI-related technology called *corevo*[®]. We are exploring its use for verification and demonstration purposes in the areas of rice cultivation, dry-field farming, and livestock farming as well as promoting social implementation of our agritech services.

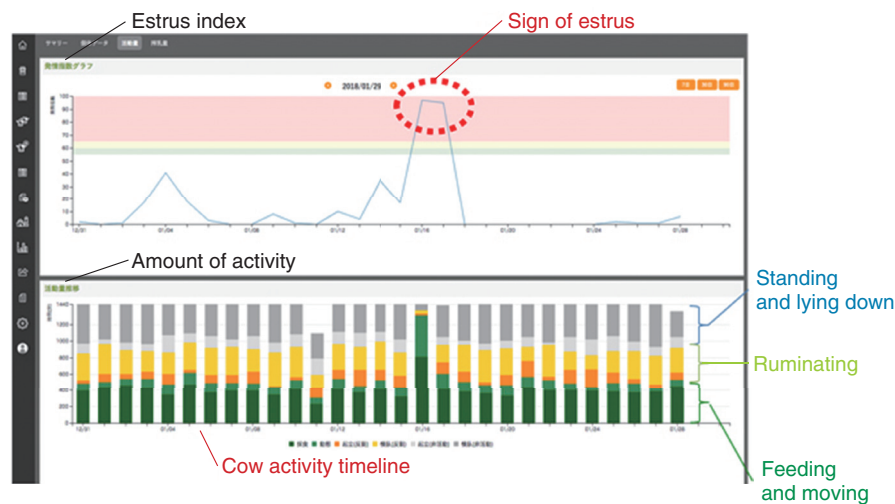
2. Technology applications in the animal husbandry field

Applications of NTT technology in farming have been ongoing for some time, and one important area is animal husbandry. Two examples of such applications are described in this section.

2.1 Technology use in breeding cows

In farm management, it is very important to grasp livestock information on individual animals and herds such as the state of health and signs of estrus and labor required for efficient breeding in a timely manner. NTT TechnoCross is providing real-time visualized information via a data-analysis platform called IoT Data Analysis Suite—which identifies seven key behaviors (i.e., feeding, drinking, ruminating, moving, standing up, lying down, and standing still) from sensor information recorded by tags attached to cows—as part of a service called *U-motion*[®] provided by *desamis Co., Ltd.*, a leader in

*1 Agritech: The combination of agriculture and technology.



Source: Created using materials of desamis

Fig. 1. Screen shot of U-motion®.

the animal husbandry field.

We also provide a service to notify the farmer of a cow's condition in terms of signs of estrus, disease (poor condition), and difficulty in standing up at appropriate timings by analyzing the accumulated data (Fig. 1). In particular, the effect of an alert function that promptly detects cows with standing difficulty (which risk sudden death if they cannot stand up) is significant in the beef cattle industry, in which individual animals are traded at 1 to 1.5 million yen (8000 to 13,000 US dollars). As the introduction of U-motion advances, more cases of cattle with standing difficulty are being detected and accumulated, and analysis accuracy is improving accordingly.

Moreover, if a dairy cow becomes sick, milk yield will be affected. Utilizing U-motion makes it possible to promptly detect and deal with diseases, and it is thus expected to have various beneficial effects such as minimizing decreases in milk yield.

Pastures of cow-feed grass also have a major impact on the amount and quality of milk. For example, when fog forms at the time the grass is being cut, the grass moistens, and the quality of feed for the livestock deteriorates; occasionally, all of the feed must be discarded. Also, if the feed has poor quality as a result of that moisture, the cows lose their appetite, and milk output falls. However, it is difficult to grasp the generation of fog because it is difficult to distinguish it from clouds, so expectations for new technology in the livestock field have increased.

Accordingly, NTT Communication Science Laboratories (hereafter, CS Labs), HALEX Corporation of the NTT DATA Group, the Japan Meteorological Agency, the Hamatonbetsu Evergreen TMR (total mixed rations) Center in Hokkaido (a cow-feeding-service center), and other bodies have collaborated in integrating weather-related big data collected from the meteorological satellite *Himawari* using techniques such as spatio-temporal data analysis by CS Labs (part of the corevo AI technologies) and the expertise of HALEX as a private weather company. The aim of this integration is to predict the risk of fog development and support decision making at grass harvest time before fog forms (Fig. 2).

2.2 Application to breeding pigs

There are various challenges involved in the breeding of pigs. One crucial issue is weight control before shipping because pig prices are determined by the weight of a pig at the time of shipment. Accurately grasping the pig's weight is also important in managing a pig's health. The required feed changes as piglets grow into pigs, and if the appropriate feed is not given at the appropriate timing, the pig's health and the quality of its meat will be affected. Consequently, it is necessary to give feed that matches the body weight of the pig.

The method of weighing pigs at the time of shipment is to use scales exclusively designed for pigs to weigh pigs individually or to conduct a collective

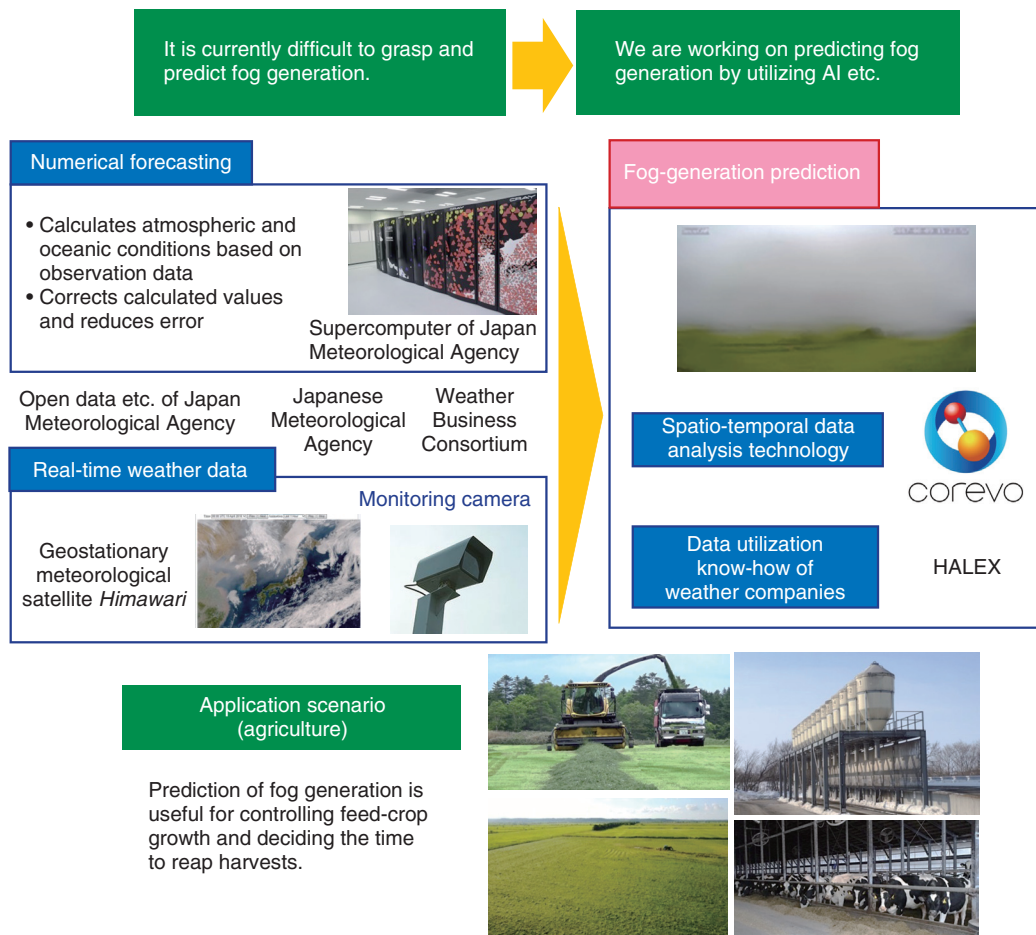


Fig. 2. Conceptual diagram of predicting risk of fog generation.

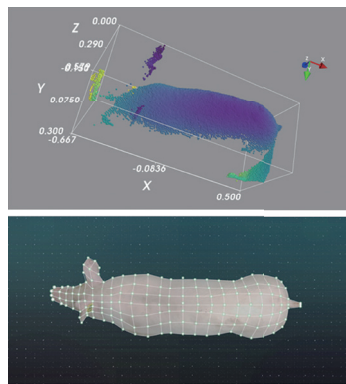
measurement. However, both methods are costly and troublesome and place a burden on pig farmers. Until now, the timing of shipping has been determined according to the age of the pig (in months) and the skilled eye (called *mekan* in Japanese) of an expert, so more experience of skilled people was needed.

In collaboration with ITOCHU Feed Mills Co., Ltd., NTT TechnoCross is developing Digital Mekan—which applies measurement logic incorporating corevo AI image-recognition technology to accurately estimate the weight of pigs (Fig. 3). Although Digital Mekan was originally developed as an application for smartphones, it is currently being developed as a packaged solution including dedicated hardware. It is almost complete, and a dedicated unit is being developed and set for early release.

3. Applications to rice cultivation

The agriculture, forestry, and fisheries industries operate in step with nature, and consequently, they can suffer from damage peculiar to the natural world. One such example is damage from pests. On a global scale, it is said that 20–30% of agricultural production capacity is lost because of damage caused by pests and weeds. A loss on that scale amounts to a quantity of food for hundreds of millions of people, equivalent to the hunger population of the world. Meanwhile, the burden on farmers to come up with countermeasures such as dealing with climate change, diversifying cultivated crops, and guarding against invading pests from overseas as a result of internationalization of agricultural distribution, are getting ever heavier.

As a member of a project of the Ministry of Agriculture, Forestry and Fisheries of Japan, NTT DATA



Source: NTT TechnoCross document

(a) Measured image



Source: NTT TechnoCross document

(b) Displayed image

Fig. 3. Digital Mekan for estimating pig's weight.

CCS (hereafter, DATA CCS) is working with Nihon Nohyaku Co., Ltd. to develop a diagnostic system to identify pests and weeds in rice fields. By combining image analysis utilizing AI technology of DATA CCS, the knowledge and expertise of Nihon Nohyaku on pesticide manufacturing, and the large amount of pest images possessed by Nihon Nohyaku, we are aiming to construct a system to provide real-time feedback of information such as potential pests, their respective countermeasures, and recommended pesticides to farm workers. This system, for example, will enable a farmer or an agricultural advisor to match a photo of a pest taken with a smartphone with images stored in a pest database (Fig. 4).

In addition, as a new initiative, we are developing a mechanism for discriminating the growth stage of paddy rice by using deep learning with images, focusing on changes in the shape of paddy rice. The rice-growing cycle is roughly divided into five stages: tilling, panicle differentiation, meiosis, heading, and ripening. To raise the yield, taste, and quality of rice,

it is necessary to know precisely the timing of the start of panicle differentiation and to provide additional fertilizer^{*2} at the appropriate time. However, that timing is presently determined based on the long experience and intuition of exemplary farmers or by a more scientific approach such as microscopic examination. These approaches, however, are accompanied by the twin problems of a shortage of successors and the large amount of labor required.

In collaboration with Ibaraki Prefectural Agricultural Experiment Station, DATA CCS has taken the initiative in constructing a mechanism to determine the start of differentiation of panicles by employing deep learning (a kind of nondestructive testing). In particular, each growth stage is classified using images taken by a fixed camera, and the shape of the rice at the time of capturing the image is determined. We are currently expanding this mechanism to cover other crops and deploying it in a wider region. We have already applied for international patents on this system.

4. Future development

Agritech is moving from the verification and demonstration phase to the social implementation phase. Under these circumstances, companies in the NTT Group have been individually promoting product development and deployment. From now onwards, however, we will accelerate the construction of a mechanism for linking each product and accumulated data in such a manner that will strengthen our competitiveness.

For example, with regard to rice cultivation, by linking together the above-mentioned mechanisms for pest and weed disease diagnosis, growth diagnosis, sensing technology and weather and map information of the NTT Group, and future forecasting technology under development in our laboratories, we aim to establish a total diagnosis and prediction service for rice cultivation (Fig. 5). Moreover, by coordinating the rice production utilizing ICT (information and communication technology) with the NTT Group's digital food value chain linking agriculture and food [1], we are establishing a mechanism for supporting people involved in agriculture in terms of sales as well as production. By doing so, we aim to create agriculture that is profitable from the aspects of both saving labor and increasing profit.

*2 Additional fertilizer: Fertilizer applied after seeding or transplantation.

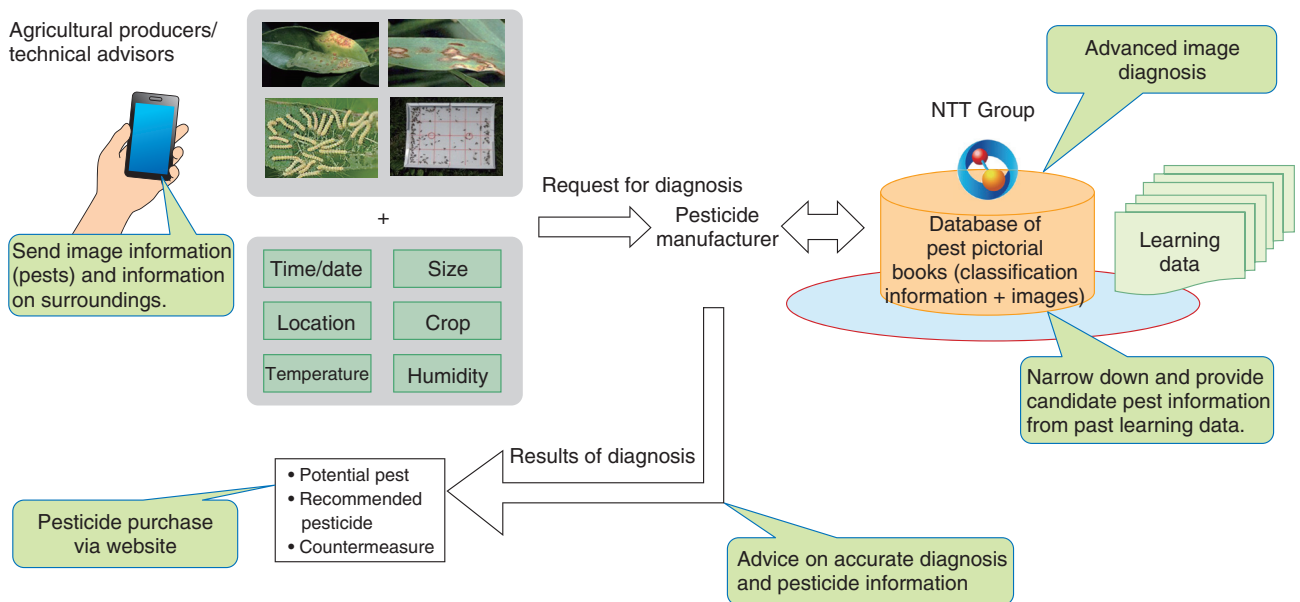


Fig. 4. Illustration of pest diagnosis system.

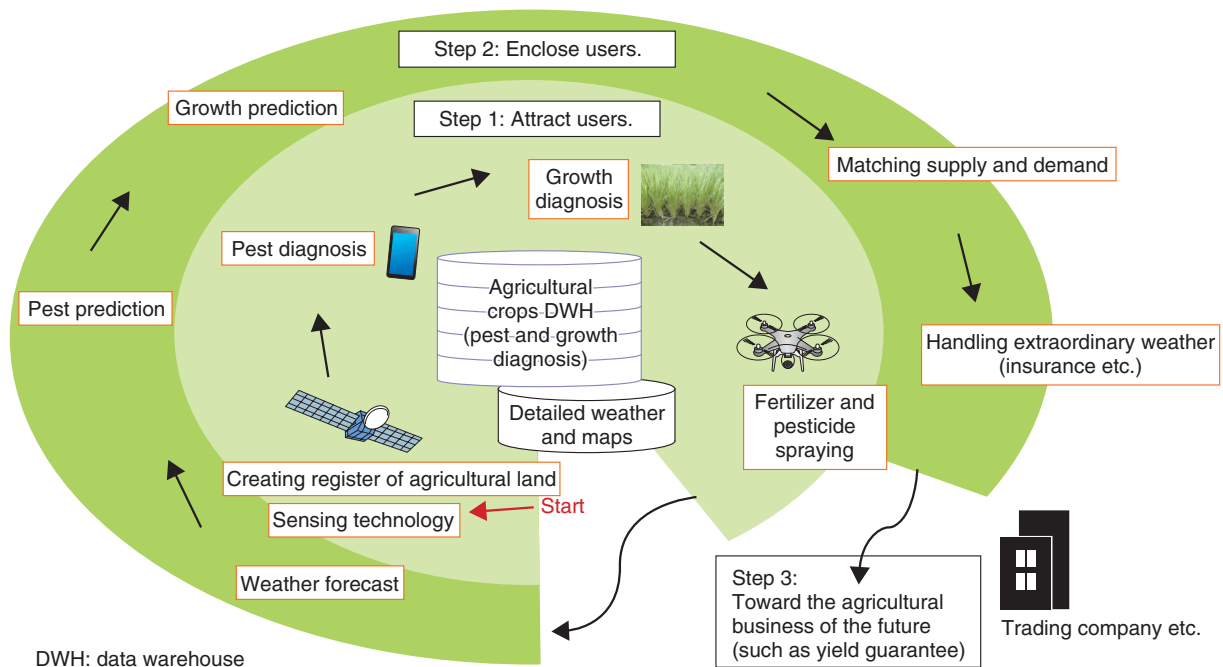


Fig. 5. Illustration of total support service for rice cultivation.

Furthermore, we are thinking beyond simply exporting rice produced in Japan and are planning to expand into Asian countries where rice cultivation is as prosperous as in Japan. That is, we aim to roll out

the above-mentioned rice production support mechanisms created in Japan under the concept of *Made by Japan*.

From now onwards, we will continue to contribute

to the development of primary industries with a view to globalization with the aim of making the NTT Group a *value partner* that will continue to be selected by numerous companies.

Reference

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Improving Amenities at Narita International Airport—Utilizing High-precision Indoor Maps and Geomagnetic Positioning to Facilitate the Movement of Visitors

Tomohiko Murakami, Hitoshi Seshimo, Wataru Kondo, Tomo Inaba, Mitsuaki Takaishi, Shinji Yarinome, and Shinnosuke Nakamura

Abstract

The number of international visitors to Japan has been soaring. At Narita International Airport, the gateway to Japan, we aim to create airport services that allow everyone to spend time comfortably via the concept of a *smart airport*. In September 2018, a service called NariNAVI—Japan’s first high-precision indoor navigation application introduced at an airport—was launched. This application utilizes geomagnetic positioning as indoor-positioning technology. To display the map, we adopted a 2.5D (two-and-a-half-dimensional) map, which stereoscopically expresses spaces inside complex airport terminals spanning multiple floors. Providing such a map that is intuitive and user-friendly supports customers’ smooth movement inside the airport.

Keywords: NariNAVI, geomagnetic positioning, 2.5D map

1. Current status and issues concerning Narita International Airport

In 2018, Narita International Airport (Narita Airport, hereafter) celebrated its 40th anniversary since starting operations. It is one of Japan’s busiest airports, so it is necessary to ensure that it is capable of handling the influx of visitors that continues to increase each year.

1.1 Increasing number of international visitors

In anticipation of the international sports event being held in Japan in 2020, the country has made good progress in regard to national tourism policy. The number of inbound visitors has increased from

8.36 million in 2012 to 28.69 million in 2017, more than a threefold increase, and the government has set the target of 40 million visitors in 2020.

Narita International Airport Co., Ltd. (NAA) has been promoting a three-year NAA Group medium-term management plan—Innovative Narita 2018—since 2016. This plan aims to retain and reinforce Narita’s position as a top-class international hub airport in Asia while striving to become an airport providing the world’s highest standard of quality and service for customers. By creating the world’s highest-level *smart airport* by utilizing state-of-the-art information and communication technology, NAA is striving to impress customers by providing them with exciting and unexpected experiences while setting the

smart airport initiative as its aim to improve customer convenience and the overall comfort of Narita Airport.

1.2 Utility of high-precision indoor electronic map

The space in an airport is vast. As well as acting as a transportation node for buses and railways, it functions as a complex commercial facility. People come from all over the world to visit Japan, and our experience tells us that the needs of those passengers are changing. For example, access to the city center, Wi-Fi service, and souvenir shops are just some of the needs to be met. We cannot respond to these diversified needs with only a simple unified map, so we therefore decided to create a high-precision indoor electronic map.

Creating electronic mapping of existing buildings takes time and effort because the points where maps of indoor areas and outdoor areas connect differ depending on the map data sources, and there is no unified standard for map data. NAA prepared an electronic map in compliance with the guidelines created through the High Accuracy Positioning Society Project initiated by the Ministry of Land, Infrastructure, Transport and Tourism of Japan.

In October 2017, we developed a form of digital signage called infotouch, which utilizes a high-precision map, and digitizing that map has made it possible to reflect changing terminal information in a timely manner. In addition, we introduced a mechanism for continuously displaying pictograms on the map of the facilities frequently used by customers (toilets, smoking areas, etc.) so that customers do not need to search for such facilities. Furthermore, the universal design approach was incorporated from scratch in various aspects of the designs of colors, buttons, and other details. We are installing four infotouch units in Terminal 1 and plan to expand the installation to cover all airport buildings by the end of fiscal 2019.

As a new initiative, we simultaneously developed an application programming interface (API) that makes it possible to use high-precision electronic maps in other operations and by airline companies. We surmised that other businesses located at the airport would use the API to provide information displayed by infotouch on mobile devices and thereby improve customer convenience. By using location information in this manner, we can offer new ways to spend time at the airport.

1.3 Creation of NariNAVI

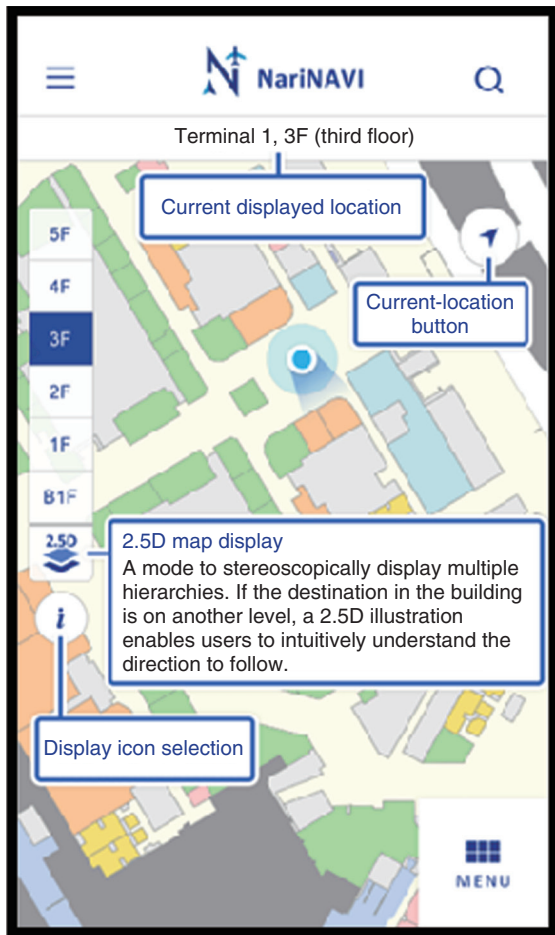
Development of the navigation application called NariNAVI (**Fig. 1**) started with the above-mentioned idea in mind. There are two important factors regarding information displayed via the application: the accuracy of the user's position (self-location) and the ease of setting the destination. Various technologies are available for indoor positioning. We selected iBeacon since it is being adopted internationally as a mainstream technology for airport infrastructure. We installed about 1500 iBeacons at Narita Airport, and we combined the use of the iBeacons with geomagnetic positioning to determine location. Although installing the iBeacons in the proper position and height was difficult due to constraints such as passenger flow lines, we overcame that difficulty by reconsidering the typical geomagnetism survey method. It seems natural, but specifying a self-location indoors in places that GPS (Global Positioning System) cannot reach is actually quite groundbreaking.

We implemented a predictive conversion function in the destination setting of NariNAVI. Although most search logics provided by facilities will ask for a search by formal name, we created a dictionary that also supports several variations so that users can search for a target facility without entering its official name. This feature makes it possible to search for flight information and shop facilities more easily.

Another feature of NariNAVI is that it can be used with web browsers other than Android and iOS applications. It is displayable by web browsers, so it is easy to link with various web services via homepages. Moreover, by extending NariNAVI to robotics and chatbots (which are progressing in parallel with services based on location information), NAA wants to offer new services to everyone who uses Narita Airport.

2. Technology of NariNAVI

Two NTT Group technologies were adopted in NariNAVI to accurately determine indoor location and intuitively represent maps in the complex layout of a multilevel airport. One is high-precision indoor-location technology using geomagnetism, and the other is two-and-a-half-dimensional (2.5D)-map platform technology. Geomagnetic positioning is a function of a cloud service called high-precision location information provided by NTT DATA, and it utilizes technology jointly developed by NTT DATA and GiPStech. The 2.5D-map platform technology



(a) Top screen



(b) 2.5D map

2.5D: two and a half dimensional

Fig. 1. NariNAVI.

was developed by NTT Service Evolution Laboratories and is used to express and transmit maps. NTT DATA is developing the NariNAVI application, and they have incorporated the above-mentioned technologies in the application.

2.1 High-precision indoor location-information service

The high-precision indoor location-information service provided by NTT DATA is a cloud service providing map distribution, indoor positioning, and route-search functions, which are basic functions for creating navigation services in indoor spaces. By using this service, customers who wish to create indoor guidance services can focus on developing higher-level applications.

The mechanism of indoor positioning provided by this service involves calculating the optimal balance between radiowaves emitted by various kinds of equipment such as Wi-Fi and BLE (Bluetooth Low Energy) routers and other beacons installed in customer facilities and the geomagnetism in the building, and that calculation makes high-precision positioning possible. The high-precision indoor location-information service provided by NTT DATA was selected since NAA aimed to enable high-precision indoor positioning by effectively utilizing already installed iBeacons.

As its name suggests, geomagnetic positioning is positioning using the Earth's magnetism. Indoors, where geomagnetism is distorted by structures such as steel frames of buildings, the characteristic

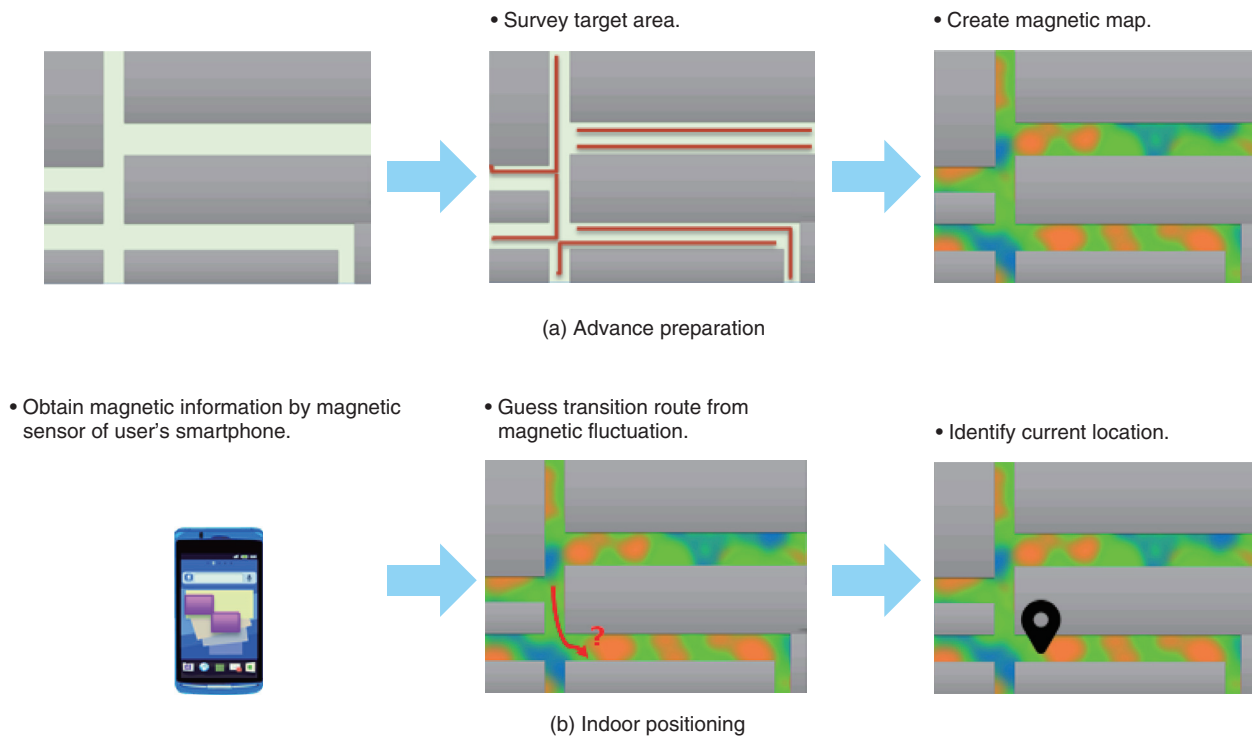


Fig. 2. Mechanism of geomagnetic positioning.

strength or weakness of magnetism is easily manifested; geomagnetic positioning technology utilizes that characteristic. The intensity of geomagnetism was measured by conducting a survey on foot at the site, and the collected data were used to create a database. Position is determined by matching the database values with the magnetic value measured by the magnetic sensor installed as standard in most smartphones (Fig. 2).

Once the geomagnetic data have been measured, there is no need to remeasure the data as long as there are no major structural changes such as large-scale construction, and this feature enables stable positioning on a continuous basis.

At Narita Airport up until now, indoor maps and a geomagnetic-positioning environment were created in a series of development phases. In other words, the foundation of highly accurate indoor position information was laid. By utilizing this foundation, various services can be developed in the future. In addition to providing infotouch and NariNAVI, we will continue to collaborate with NAA to further improve services at airports by, for example, analyzing the behavioral history of users from log information, improving the work processes of airport staff, and managing goods

such as luggage carts and strollers.

Also, from a user's viewpoint, expanding the area in which users can be guided indoors would enable the same service to be received anywhere, leading to improved user convenience. NTT DATA intends to roll out this service at other airports and public transportation facilities in the future.

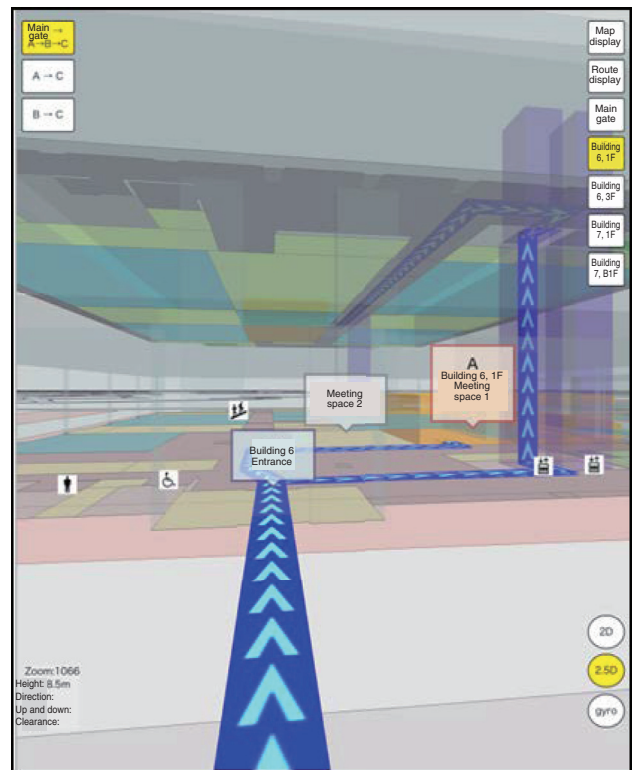
2.2 Advanced 2.5D-map platform technology

At NTT Service Evolution Laboratories, we have been carrying out research and development aiming to achieve navigation services that provide safe and convenient support for movement of a diverse group of people including those using wheelchairs and strollers, elderly people, and international visitors to Japan. That research resulted in the development of 2.5D-map platform technology, which enables seamless transmission and display of outdoor and indoor hierarchical maps (i.e., planar maps with floor and height information).

Unlike automobiles, which basically move in a planar manner, people move in a stereoscopic manner. Movements of people include coming and going indoors and outdoors as well as movements up and down stairs and elevators. With conventional map



(a) Indoor 2D map



(b) Indoor 2.5D map

*Map data source: NTT EAST

Fig. 3. Automatic generation of 2.5D map.

services, this situation was handled by switching overlapping planar (2D) maps; however, with that approach, it is difficult to see one's present location and a destination on different floors from a bird's-eye view, and the guided route is cut off at each level, making it difficult to understand the route intuitively.

With these circumstances in mind, we simply added height information (i.e., the number of levels in each floor, ceiling height, etc.) as an extra *half dimension* (+ 0.5D) to indoor 2D floor maps aligned on a conventional outdoor 2D map to create a way to automatically generate, transmit, and present simple stereoscopic maps, referred to as 2.5D maps (Fig. 3). Changing the map to a stereoscopic representation from 2D to 2.5D, as mentioned previously, makes it possible to view the positional relationships between different levels connected by staircases and elevators, and a guided route can be confirmed at a glance at any time. As a result, the user can see the route clearly ahead of time and, for example, decide whether to go left or right before going up the stairs. It is also pos-

sible to display walls or floors transparently, so the user can foresee things that cannot be seen in the real world.

Although it does not express images as elaborately or realistically as a 3D map does, it reduces the time and cost of creating maps by utilizing existing planar maps and indoor floor maps, and the amount of data read by the user terminal and its processing load can also be curtailed. This makes it possible to provide services on a web-browser basis regardless of whether a personal computer or mobile device is being used. In fact, the maps displayed on infotouch are used as a common mechanism for map display on both the application and browser versions of Nari-NAVI.

At NTT Service Evolution Laboratories, we have been working on new research and development while receiving feedback on demonstration tests conducted with the Ministry of Land, Infrastructure, Transport and Tourism since 2016, joint demonstrations with private companies, and commercial

introduction of the technologies described in this report. For example, creating indoor 2D maps (which are the source of the 2.5D maps) currently requires a lot of manual labor, so we are studying whether it is possible to automatically generate 2.5D maps with existing data used by building-design systems.

Since economization is considered to be one of the key objectives when rolling out technology, we hope to increase the efficiency of map-production work as much as possible by using technology and to improve indoor maps at low cost and in a short period of time.

Moreover, regarding efforts concerning the ease of understanding the navigation while making maximum use of 2.5D map data, we are also studying guidance methods that do not rely on visual representations (such as maps) for those who are not good at reading maps.

Trademark notes

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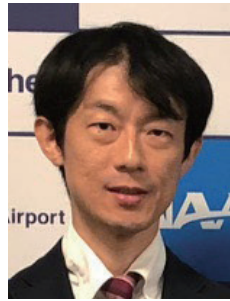
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Creating Value from Deep Learning Technology and Its Business Applications

Kunihiro Moriga, Takeharu Eda, Masashi Toyama, Keita Mikami, Yutaka Hirokawa, Yuji Yamada, Sanae Muramatsu, Taku Sasaki, Shin'ya Yamaguchi, and Katsuo Inaya

Abstract

NTT has positioned the utilization of artificial intelligence (AI) as an important business strategy. NTT Software Innovation Center has been engaged in research and development aimed at creating value from the AI technology known as *deep learning*. In this article, we explain how the deep-learning inference environment can be optimized for business applications, namely by speeding it up, making processing lightweight, and saving labor. We also report on verification activities concerning the image-analysis business opportunities (such as surveillance-camera image analysis) generated by using that technology.

Keywords: deep learning, cloud-based inference, optimization

1. Deep learning: entering the disillusionment phase

Artificial intelligence (AI) is currently said to be in its third boom. The Hype Cycle for Emerging Technologies, 2018 [1] published by Gartner Inc. in August 2018, predicted that deep learning would be at a *peak of inflated expectation* in its second consecutive year. In other words, it would soon enter a *disillusionment phase*.

Conditions such as PoC (proof of concept) and precedent cases and best practices were published by cutting-edge companies; however, the persons and departments in charge might be feeling the difficulty of solving problems using deep learning technology by themselves.

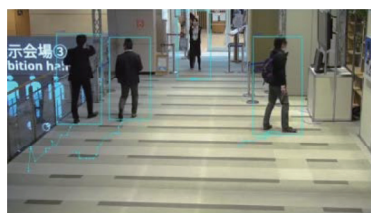
During the peak of inflated expectations phase, the results and utility that everyone imagined and expected cannot be obtained, and the people who are in charge become disappointed as they face the real situation; this is the beginning of the disillusionment

phase. However, that situation can be said to be the beginning of true business applications. From now onwards, implementation and peripheral technologies of deep learning will catch up, and deep learning will gradually be adopted in actual business operations.

The technology developed by NTT Software Innovation Center that can analyze images of people in real time is an example of such technology that is approaching the stage of business application.

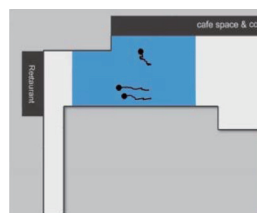
2. Analysis of images captured by multiple surveillance cameras at high speed in real time

Since deep learning became a topic of research in about 2011, it has succeeded in giving something akin to a *person's eyes and ears* to computers. Moreover, as of 2018, it is no exaggeration to say that at the purely technical level, it has already passed beyond the human eyes and ears ability. Real-time person tracking developed by NTT Software Innovation



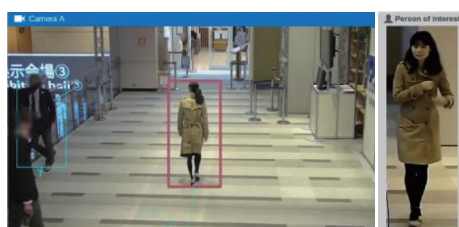
When people are detected in the video image, they are enclosed in a blue frame. The line extending from the bottom of the blue frame is the estimated trajectory.

(a) People detection



As shown in the figure above, if a plan view of the room is prepared in advance, it is possible to map the trajectory onto the plan view.

(c) Trajectory recognition



After people are detected in the video image by the people detection function, if a photo (as shown on the right side of the figure) of a person being looked for is specified, when the specified person is detected in the image, the blue frame switches to a red frame, which indicates that the specified person has been found. Moreover, in this video, it is possible to identify the same person even with a backward-looking video by performing the whole-body collation function described in section 2.1.

(b) Person re-identification

Fig. 1. Functions of real-time person tracking.

Center is a form of deep learning packaged as image-analysis technology [2]. It analyzes images captured by a large number of surveillance cameras installed in a facility in real time and instantly detects and tracks target persons (suspicious persons, prominent persons, people needing care, lost children, etc.) in those images. Real-time person tracking is enabled by combining the following seven functions (**Fig. 1**):

- (1) People detection: Only people are extracted from an image (Fig. 1(a)).
- (2) Attribute recognition: The gender and age group of a person are estimated.
- (3) Detailed attribute recognition: Attributes associated with specific body parts are recognized. For example, a person is searched for on the basis of detailed attributes concerning their appearance, colors of clothing, and presence of personal items such as a bag (e.g., having long hair and wearing a white shirt, jeans, and sunglasses).
- (4) Person re-identification: Whole-body collation is applied to determine whether the detected person is the target person (Fig. 1(b)).
- (5) Trajectory recognition: The trajectory of a person walking is estimated from video images (Fig. 1(c)).
- (6) Multiple camera compatibility: Functions (1) to (5) are supported even if the target person crosses the views of multiple cameras.
- (7) Real-time analysis: The results of (1) to (6) can be analyzed in real time.

2.1 Achievement of whole-body collation ahead of our competitors

We achieved function (4), person re-identification, by employing whole-body collation ahead of our competitors, which makes it possible to extract people even if the person is facing backwards. Automatically

extracting features from a large number of pairs of images of people by using deep learning technology made it possible to match the images with higher precision than rule-based judgment using human-set characteristics (body type, clothing color, hairstyle, etc.).

The person-search service provided by NTT Communications called Takumi Eyes—which incorporates part of our real-time person-tracking technology—was awarded the 20th Automatic Recognition System Grand Prize by the Japan Automated Identification System Association in 2018 [3]. Winning the award indicates that this technology is highly evaluated by the market.

2.2 Results of collaboration between Panasonic Group and NTT Group

Whole-body collation is not perfect by itself. A whole-body check is difficult to perform if a person's appearance changes such as when they take off outerwear (coats etc.) that they were wearing. We devised a solution to this problem in collaboration with our partner.

A business alliance agreement with Panasonic Corporation in 2015 [4] triggered efforts to greatly improve recognition accuracy by combining our whole-body-collation technology with Panasonic's face-recognition technology [5]. Created as a result of the combined technologies was real-time person tracking, which can match people with high accuracy from camera images shot under various angles and conditions. Until now, we were not aware of any other services that combined full-body collation technology and face authentication using deep learning in this manner. At the present time, only the person re-identification is achieved by whole-body collation plus face authentication; however, the technology can be combined with additional detection functions, such as detecting the gait of a person, in response to the needs of our customers.

3. Video monitoring market forecasted to be 160 billion yen by 2030

This section focuses on the business potential of the above-described real-time person tracking using deep learning technology.

The image-analysis business is a promising sector with the highest growth rate in the AI market. It is expected to grow more than one-hundred-fold, namely, from 1.3 billion yen in 2015 to 160 billion yen in fiscal year 2030 [6]. It is expected that the market for

analyzing images shot by surveillance cameras will increase.

A use case of an actual implementation is described in the following subsection.

3.1 Utilization of surveillance cameras at convenience stores: person re-identification

An example that is easy to imagine as a use case involving surveillance cameras is the use of surveillance-camera images taken in convenience stores. Having surveillance cameras in present-day convenience stores enables people to confirm what actually happened from past images after an incident or accident has occurred. A convenient function in such a case is person re-identification.

In the case of a crime occurring at a convenience store equipped with surveillance cameras, it is possible to quickly find when the perpetrator entered the store by specifying the image of the person from the video at the time of the crime and then searching from other past video images. In addition, it is possible to quickly find out if the crime was planned or impulsive by retrieving the perpetrator's past images in order to determine the history of their store visits—if they had been to the store to check it out in the past. Moreover, person re-identification is even more effective in the case of large facilities such as apartment blocks or shopping malls fitted with multiple surveillance cameras.

Scenes in television crime dramas in which a police detective spends a long time checking surveillance camera videos will surely be a thing of the past once this technology is put into service. Furthermore, utilizing this technology will eliminate oversights due to human error.

3.2 Utilization of surveillance cameras in commercial facilities: finding lost children by combining attribute recognition, color search, and person re-identification

Finding lost children is an expected use case for larger-scale commercial facilities. When shopping at department stores or shopping malls, we sometimes hear announcements about lost children. Announcements such as, "A mother is looking for her five-year-old daughter (name), who is wearing a pink dress." are commonly heard on busy weekends at commercial facilities. Such announcements, however, may no longer be necessary once this technology is put into service. The child's age is specified by a technique called attribute recognition, and the color of the child's clothes is specified and searched for via a

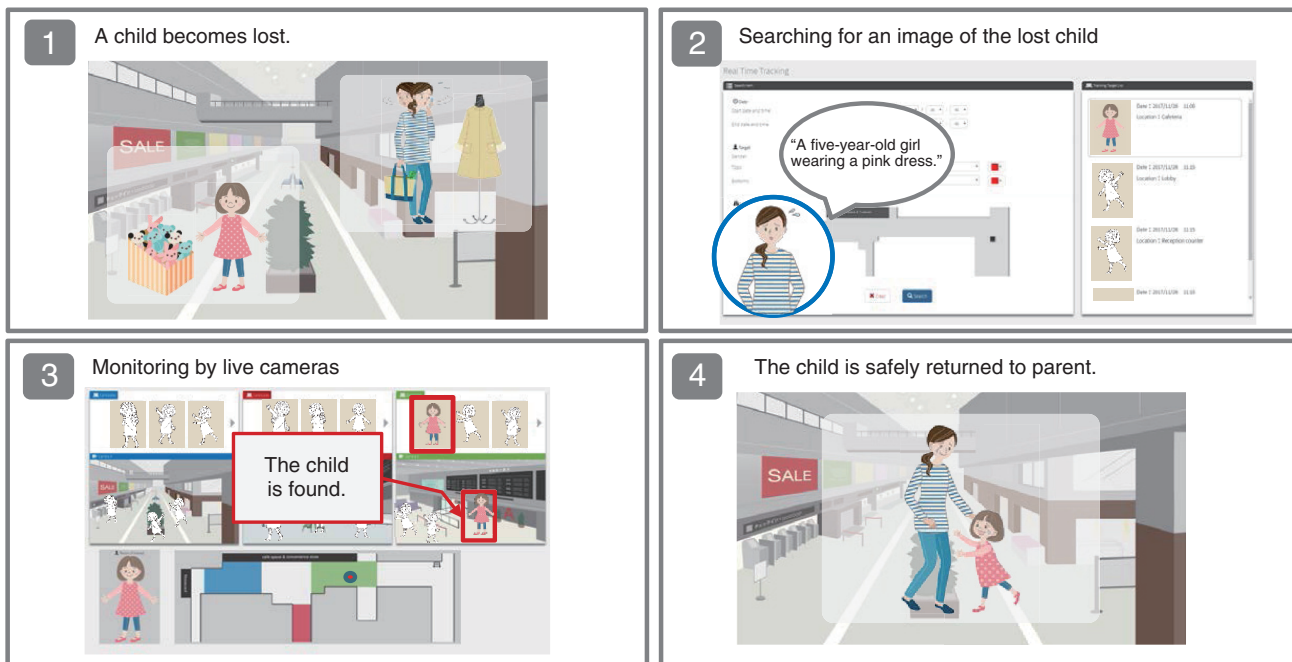


Fig. 2. Use of surveillance cameras in commercial facilities to look for a lost child.

color search. From the images captured by nearly 100 surveillance cameras, the most-recent captured image of the child can be displayed, and the lost child can be pinpointed from that image (Fig. 2). Such a system is likely to be essential for future large-scale theme parks and other such facilities that do not implement measures for announcing lost children.

3.3 Search for wandering citizens for municipalities

The example mentioned in the previous section is a use case concerning a lost child in a commercial facility, but it can also be applied to finding elderly people who wander away from home. With one photo of the elderly person who has wandered away, it is possible to promptly find that person from the images captured by multiple surveillance cameras operated by municipalities. The person re-identification function can find people in a much shorter time compared to manually checking surveillance-camera images with the human eye. Using this technology as a human assistant makes it possible to promptly find the wandering elderly person and thereby reduce the probability of that person being involved in an accident. The news footage of people in local municipalities, including hundreds of local police and fire fighters, simultaneously searching for elderly people who

have wandered away may not be very common after this technology is put into service.

3.4 Use in marketing: combining person re-identification, attribute recognition, and trajectory recognition

This real-time person-tracking technology can also be used for purposes other than crime prevention, namely, marketing. It may also be useful for analyzing and outputting the number of visitors and their attributes in a time slot from surveillance camera images as well as analyzing the flow of customers. It will be possible to analyze data and determine how to arrange shelves and goods in a limited store space. Other applications are also possible. For example, although a logic program is required for detecting objects or people, by preparing training data and learning from it, it will be possible to extract items that customers had taken from a shelf but returned to the shelf (that is, products that a customer seemed interested in but did not purchase). With the introduction of such technology, it will be possible to obtain information that cannot be extracted from cash-register POS (point of sales) data.

4. Core technology that enables real-time processing

One particular core technology is important for establishing real-time processing. That technology is a technique for optimizing the deep-learning inference environment. This optimization technology makes it possible, for example, to detect and classify objects in video images at high speed and process them in real time. By combining the world's latest technologies listed below according to the type of deep learning processing (i.e., detect and classify) that is executed, we have increased the processing speed by more than 10 times.

- Image-analysis algorithm for detecting and matching people with high accuracy
- Reduction of parameter size
- Implementation technology for optimizing inference processing of deep learning

When the person-tracking service was introduced for the first time in the world as Takumi Eyes, the main service was searching for past images by using images captured by surveillance cameras. Since then, real-time processing has become possible by researching and combining optimization techniques for deep-learning inference environments over time.

5. Future development

After developing the video-analysis technology that enables real-time processing, we plan to focus our research on distributed processing of video-analysis technology. Specifically, we are planning to conduct research on distributed processing that

enables systems (including central offices and data-centers of telecommunication companies as well as cloud services) to be constructed and the functions required at each location (edge) to be provided. We call this processing a *two-layer edge model*. We will work to make the operation of edge devices more efficient, lower in cost, and with the maximum savings of power and memory.

From now onwards, the NTT Group will continue to work towards applying its AI technology called corevo[®] and implementing it in society in cooperation with various partners in order to improve the lives and businesses of many customers.

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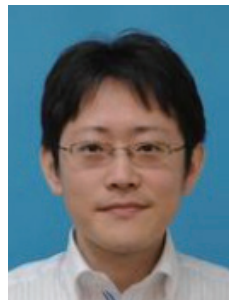
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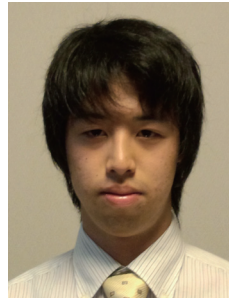
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Highly Efficient Gate Controllability of Rashba Spin-orbit Interaction in a Gate-all-around InAs Nanowire MOSFET

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Abstract

Indium arsenide (InAs) is a III-V semiconductor with high mobility that has attracted much attention as a next-generation semiconductor to replace the current silicon technology. At the same time, InAs is known to have a large spin-orbit interaction that causes electron spin precession even without an external magnetic field. Here, we report on an InAs nanowire metal-oxide-semiconductor field-effect transistor (MOSFET) with a gate-all-around structure, where the gate electrode is arranged coaxially with the InAs channel. We not only show that our device has good FET properties such as a high ON/OFF ratio and high mobility but also demonstrate that the Rashba spin-orbit interaction is largely controlled with a small gate voltage range, with its efficiency being ten times larger than those obtained for previously reported III-V semiconductor MOS and Schottky FETs. This indicates that our FET is promising as a prototype of a low-power-consumption spin FET, in which transistor ON/OFF is controlled as a consequence of electron spin flips.

Keywords: nanowire, spin-orbit interaction, spin FET

1. Introduction

Group III-V semiconductors such as indium arsenide (InAs) and InGaAs (indium gallium arsenide) have been extensively studied as next-generation high-mobility semiconductors that can replace the current silicon (Si) technology. Another direction of research on III-V semiconductors that has been of fundamental interest for decades is their large spin-orbit interaction, which acts as an effective magnetic field and thus can rotate electron spin even in the absence of an external magnetic field.

As these two research directions merged, a concept of the spin field-effect transistor (FET) was proposed by Datta et al. in 1990 [1]. In contrast to a normal transistor, in which transistor ON/OFF is defined by

the changing electrical current using gate voltage, a switch for a spin FET relies on reversed spin direction in the channel, which is controlled via the spin-orbit interaction using gate voltage. The required key effect is the Rashba spin-orbit interaction, which is proportional to the applied electric field. With this interaction, the spin precession can be accessed by the gate voltage, and the device can consequently be used as a spin transistor.

A spin FET is conceptually shown in **Fig. 1**. The spin FET is composed of ferromagnetic electrodes and an electron channel formed in a semiconductor that has a strong spin-orbit interaction. When spin is injected from one of the ferromagnetic electrodes and rotated by π via the spin-orbit interaction, the spin becomes antiparallel to the spin on the other side of

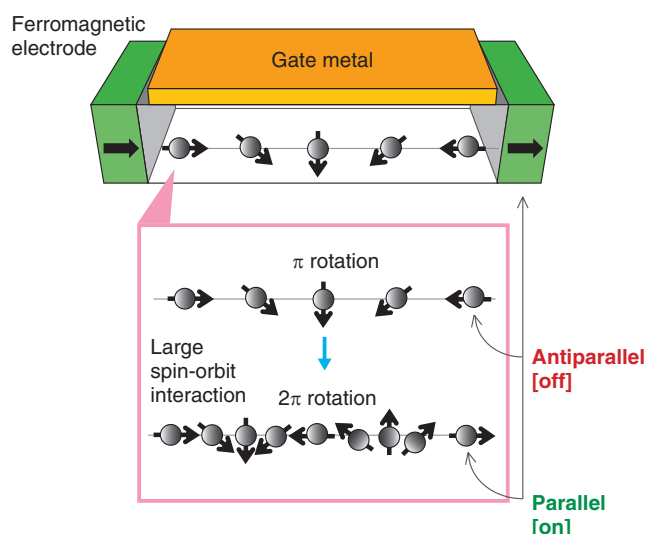


Fig. 1. Concept of a spin FET. The spin flip in the channel is controlled by the gate voltage via spin-orbit interaction.

the ferromagnetic electrodes, indicating that electrical current is no longer flowing.

In contrast, when the electron spin rotates up to 2π due to the varied spin-orbit interaction, the spin turns so it is parallel to the spin in the other electrode, indicating that electron current has started to flow. This transistor operation resulting from spin precession can be realized by changing the gate voltage if we can use the Rashba spin-orbit interaction.

This type of spin FET is expected to provide many benefits in engineering as well as to continue to be of fundamental interest. For instance, we can expect to achieve a lower-power-consumption transistor when the spin flip voltage is lower than the pinch-off voltage in normal transistors. In addition, when the spin-orbit interaction is large enough, we can integrate the spin FETs using the present Si technology.

Based on this background, various III-V semiconductors have been investigated to examine whether spin-orbit interaction is indeed controlled by the gate voltage. Nitta et al. demonstrated for the first time that the spin-orbit interaction is varied by the gate voltage using two-dimensional electron gas formed in a III-V semiconductor quantum well [2]. Later, Koo et al. demonstrated that spin injection and gate control of the spin-orbit interaction occurred simultaneously for the same device [3]. Moreover, much smaller devices have been developed from quantum wire [4] and bottom-up nanowires [5–9] with the aim of achieving lower power consumption and high integration. However, the Schottky FETs and metal-

oxide-semiconductor field-effect transistors (MOSFETs) used in the previous reports have not greatly improved the gate controllability of spin-orbit interaction.

In this article, we report that a gate-all-around (GAA) InAs nanowire MOSFET that we recently developed has superior gate controllability of the spin-orbit interaction, which is ten times higher than that obtained for MOSFET or Schottky FETs [10]. Our demonstration will open the way toward developing low-power-consumption spin FETs.

2. Experimental

The GAA InAs nanowire is schematically shown in Fig. 2(a). The InAs nanowire was grown using the vapor-liquid-solid method [11]. The diameter of the nanowire is about 100 nm, and the gate length is about 3.3 μm . The GAA structure was prepared as follows. We first grow $\text{Al}_2\text{O}_3/\text{HfO}_2$ (aluminium oxide: 2 nm/hafnium oxide: 4 nm) as a gate insulator around the nanowire and then put it on a pre-patterned SiO_2 (silicon dioxide)/Si substrate and deposit the gate metal by an electron beam. A coaxial gate structure using a thin high-k gate insulator enables us to apply a strong electric field to the nanowire channel. The details of the fabrication procedure are described in other reports [10, 12, 13].

A TEM (transmission electron microscope) image of our device is shown in Fig. 2(c). We can see that a thin gate insulator and surrounding gate metal are

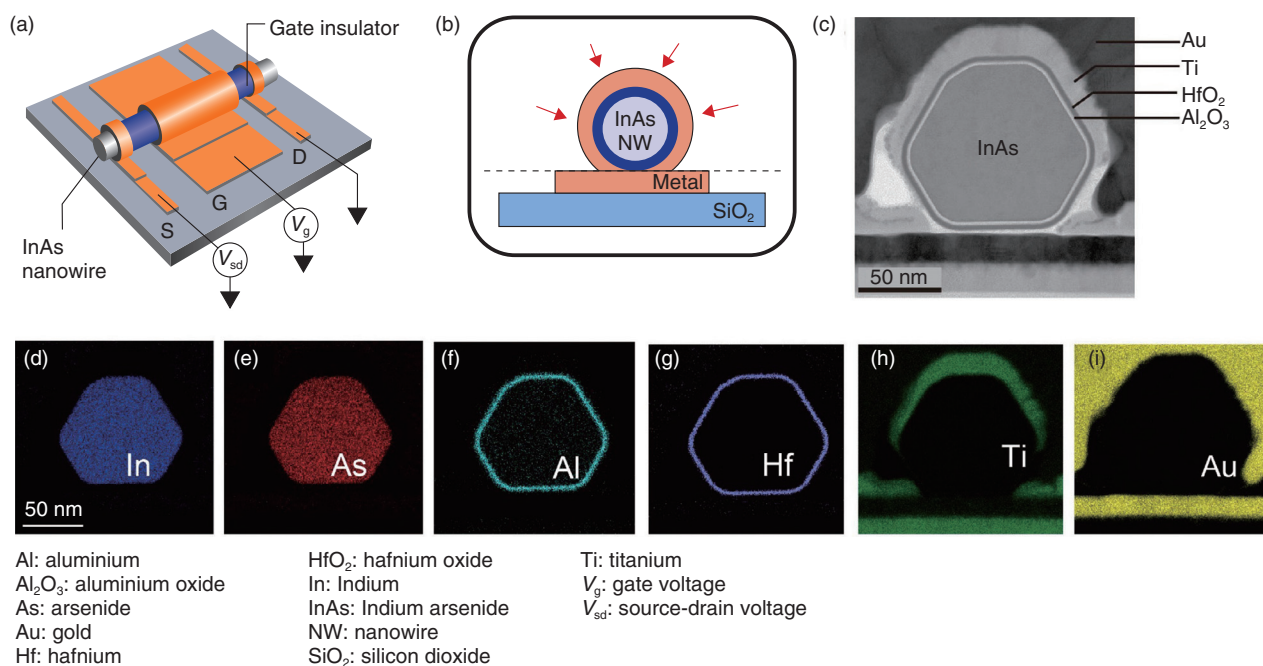


Fig. 2. (a) Schematic illustration of our GAA InAs nanowire MOSFET. (b) Schematic cross section of our device. (c) TEM (transmission electron microscope) image of the cross section of our device. (d)–(i) EDS (energy dispersive X-ray spectroscopy) images taken at the same time as image shown in (c). These images correspond to each element in the device.

formed around the nanowire. These geometries were confirmed by energy dispersive X-ray spectroscopy, which also indicates that there are no notable impurities or migration. The measurements were performed at temperatures ranging from room temperature to 1.5 K.

3. Results and discussion

In this section, we report the results of our experiments and explain their significance.

3.1 FET characteristics

The transfer and output characteristics obtained at room temperature and 1.5 K are presented in Fig. 3(a)–(d). As shown in Fig. 3(a) and (c), the electrical current increases rapidly as the gate voltage increases, indicating that the device is acting as a transistor. The ON/OFF ratios extracted from these data are 10^4 and 10^5 at room temperature and 1.5 K. The subthreshold swing defined as $SS \equiv dV_g/d\log(I_{sd})$ is 350 mV/dec and 25 meV/dec at room temperature and 1.5 K. The mobility ranges from 400 to 1200 cm^2/Vs . These values are comparable to those reported for back-gated InAs nanowires fabricated by other

groups [14–16]. This demonstrates that our GAA InAs nanowire device shows good FET performance.

3.2 Gate controllability of spin-orbit interaction

We next investigate the strength of the spin-orbit interaction and its gate controllability. For this aim, we measure magnetoconductance to examine whether weak localization and weak antilocalization effects are observed for our device. Weak localization (anti-localization) is a quantum correction effect, which happens in the absence (presence) of the spin-orbit interaction. When the spin-orbit interaction is negligibly small, time-reversal symmetry is protected at zero magnetic field, and thus, electron waves propagating in the clockwise and anticlockwise directions produce constructive interference, leading to a weak localization. Then when the magnetic field is applied, time-reversal symmetry is broken, and the conductance is increased with the increasing magnetic field.

In contrast, the opposite behavior occurs when the spin-orbit interaction is strong. At zero magnetic field, the spin flips due to the spin-orbit interaction, and thus, destructive interference occurs rather than constructive interference. This is known as a weak antilocalization effect, which results in decreasing

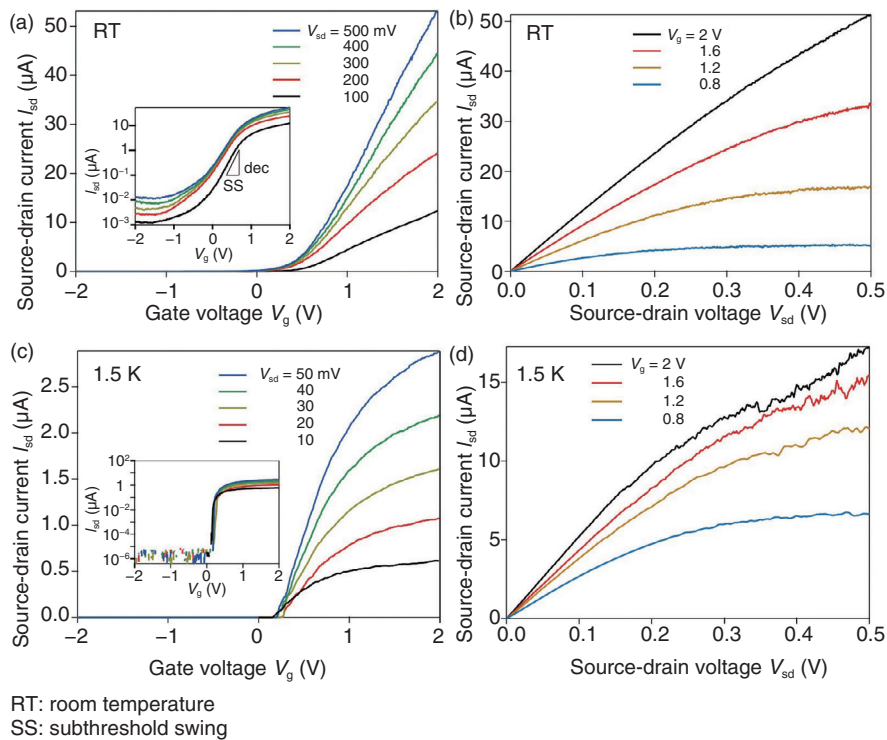


Fig. 3. (a), (c) Transfer characteristics and (b), (d) output characteristics, which were obtained at room temperature and 1.5 K.

magnetoconductance with the increasing magnetic field.

Such weak localization and antilocalization effects were first considered in two-dimensional electron systems by Hikami et al. [17] and are now observed in various two-dimensional materials that possess strong spin-orbit interaction. Moreover, these effects are also observed with one-dimensional systems. In disordered one-dimensional systems, magnetoconductance (defined here as the difference ΔG from the zero-field conductance) is described with the following equation:

$$\Delta G = -\frac{2e^2}{hL_g} \left[3 \left(\frac{1}{l_\phi^2} + \frac{4}{3l_{so}^2} + \frac{W^2}{3l_B^4} \right)^{-1/2} - \frac{1}{2} \left(\frac{1}{l_\phi^2} + \frac{W^2}{3l_B^4} \right)^{-1/2} \right], \quad (1)$$

where h is Planck's constant, L_g is the gate length, l_ϕ is the phase relaxation length, l_{so} is the spin-orbit length, W is the nanowire diameter, and l_B is the magnetic length given by $l_B = \sqrt{\hbar/(2\pi eB)}$ (e : electron charge, B : magnetic field).

The data are analyzed using this model. In Fig. 4(a),

ΔG is shown as a function of B for various values of gate voltage V_g . We can see that ΔG with respect to B shows a dip-to-peak structure with increasing gate voltage, corresponding to the transition from weak localization to weak antilocalization. Moreover, the mean free path obtained for our device is about 10 nm and is much smaller than the nanowire diameter of approximately 100 nm, so the system indeed satisfies the condition in which the model can be applied. The lines in Fig. 4(a) indicate that our data fit nicely with the one-dimensional model described by Eq. (1). From this fitting, we can extract l_{so} and l_ϕ , which are plotted as a function of V_g as shown in Fig. 4(b). This clearly shows that l_{so} varies significantly with V_g and that l_{so} becomes smaller than l_ϕ around the crossover from weak localization to weak antilocalization.

3.3 Comparison with previous reports

Next, we compare our results with those obtained for previously reported III-V semiconductors with various sample geometries. The dependence of l_{so} on V_g measured for various InAs nanowires is summarized in Fig. 5(a). Our results plotted in different colors (blue and orange) are obtained for the same sample

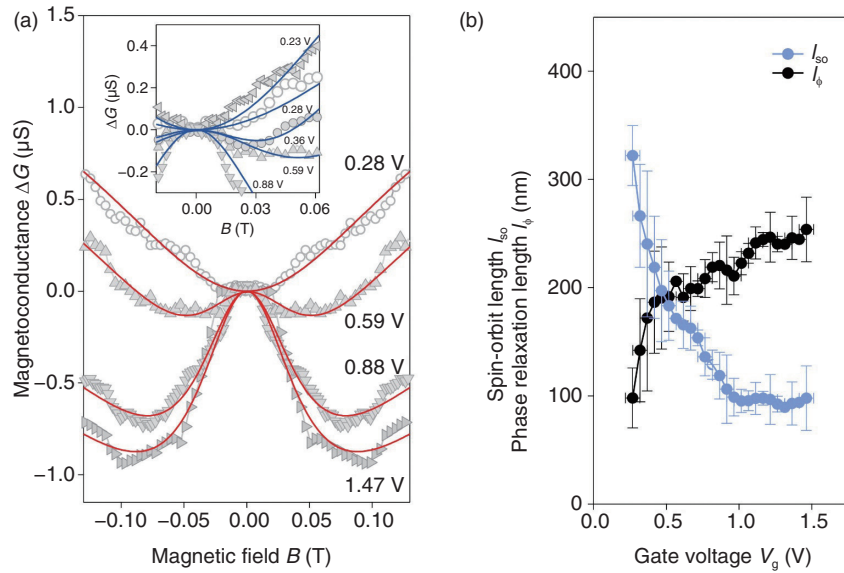


Fig. 4. (a) Magnetoconductance with respect to magnetic field for different gate voltages. (b) Spin-orbit length and phase relaxation length as a function of gate voltage.

with different cooling times, which confirmed the robustness of the sample as well as reproducibility after thermal cycles. We can see that there is little modulation in l_{so} for InAs nanowires with conventional back gate or top gate structures [5–9], even if a gate voltage over 10 V is applied.

In contrast, our GAA and the ion-gated device developed by Liang et al. [18] show large modulation in l_{so} within a much smaller V_g range. This is because the GAA and ion-gated structures can change the electric field over a wide range, indicating that the Rashba spin-orbit interaction, which is proportional to the electric field, varies widely with a small gate voltage.

We then deduce the Rashba coupling parameter α_R from l_{so} . Here, α_R is defined in the Hamiltonian representing the Rashba spin-orbit interaction,

$$H = \frac{\alpha_R}{\hbar} \sigma \cdot (p \times \hat{z})$$

(\hbar : Planck's constant divided by 2π , p : momentum, \hat{z} : direction parallel to the electric field). We can intuitively understand that an effective magnetic field, which occurs in the direction perpendicular to the momentum and electric field, interacts with spin; consequently, the strength of the spin-orbit interaction is determined by the size of α_R . Here, α_R can relate with l_{so} in the formula, $\alpha_R = \frac{\hbar^2}{2m^*l_{so}}$ (m^* : effective mass).

In Fig. 5(b), α_R obtained for our device is com-

pared with those reported for one-dimensional and two-dimensional FETs that have been investigated in the context of spin FETs. The gate modulation efficiency of α_R for our device is more than ten times larger than those obtained for back-gated InAs nanowire [5] and Schottky FETs fabricated from various III-V semiconductor quantum wells [2, 3]. Although our GAA MOSFET is a bit less effective than the ion-gated device, our device has great significance in that it demonstrates that such high controllability and large Rashba parameter are obtained using a MOSFET, which is much faster and more stable than ion-gated devices.

We finally note the electric field E_R associated with the Rashba spin-orbit interaction, which is given by $E_R = \alpha_R/(\alpha_0 e)$ (α_0 : Rashba coefficient, $\alpha_0 = 1.17 \text{ nm}^2$ for InAs [19]). We obtain the ratio to the peak electric field E_0 that is expected from the gate geometry. The results of E_R vs. E_0 obtained for our GAA device and the ion-gated device are plotted in Fig. 5(c). With both devices, E_R is reduced more than E_0 is. The ratio stays at 5% for the entire V_g range (Fig. 5(d)). This indicates that the screening effect due to the interface states that may be included in the devices is nearly the same for both devices.

4. Summary

We demonstrated that our GAA device has higher

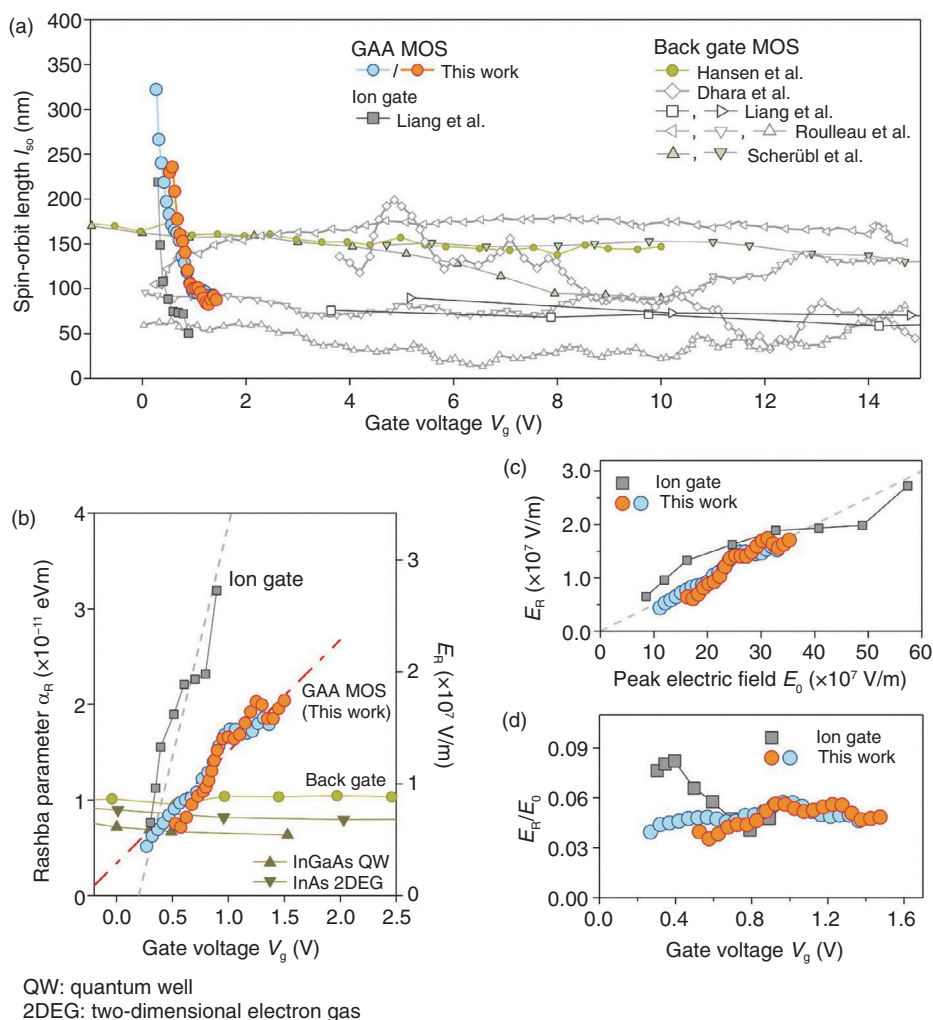


Fig. 5. (a) Comparison of dependence of l_{so} on V_g for our device and those reported previously [5–9]. (b) Comparison of the Rashba parameter vs. gate voltage for our device and previously reported III-V semiconductor devices [2, 3, 5, 18]. (c) E_R as a function of E_0 for our device and the ion-gated device reported by Liang et al. [18]. (d) E_R/E_0 ratio as a function of V_g for the devices in (c).

gate controllability of the spin-orbit interaction than those obtained for standard MOS or Schottky FETs fabricated from one- and two-dimensional III-V semiconductors. The biggest advantage is that high gate controllability and the large Rashba spin-orbit interaction are obtained at a small gate voltage using a MOSFET structure. This opens the way toward realizing nanoscale spin FETs.

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New Standardization Trends at GlobalPlatform—Secure Components for the IoT Era

Eikazu Niwano

Abstract

GlobalPlatform, which was founded as an international standardization organization targeting smart cards, has expanded its scope of standardization to include a variety of Secure Elements, Trusted Execution Environments, and devices. Furthermore, in the light of current trends surrounding the Internet of Things (IoT) and ecosystems, GlobalPlatform is broadening the functions it provides from application management to device trust management. This article introduces new initiatives toward the IoT and ecosystem era at GlobalPlatform, which has recently restructured its organization.

Keywords: IoT security, tamper resistant module, secure chip

1. GlobalPlatform

Smart cards have elements similar to those of a computer such as a CPU (central processing unit) and memory and are secure components with hardware characteristics robust to external attacks, making them tamper resistant. They can be used for security processes and safe data management as in user authentication and data encryption.

Smart cards are presently being used in many fields including payment systems (smart credit cards etc.), communications (subscriber identity module (SIM) cards), transportation (Suica train/bus cards etc.), workplace/access management (employee identification (ID) cards), and public services (electronic passports, My Number (social security and tax number) cards, etc.).

GlobalPlatform [1] was founded in 1999 as an international standardization organization targeting the management of application programs embedded within smart cards (Fig. 1). It is the world's leading industry standardization organization in the field of secure components that enable remote and secure loading/managing of applications in smart cards via collaboration between smart card issuers and service providers after smart card issuance [2].

Since its founding, GlobalPlatform has expanded the range of secure components targeted for standardization from smart cards to various types of Secure Elements (SEs) [3], including embedded SIMs (eSIMs), and to Trusted Execution Environments (TEEs) [4] within a device independent of the device operating system (OS). Of particular importance here is that GlobalPlatform is now extending its target of management as far as the device level. In addition, its scope of standardization continues to expand to include the updating of SE firmware and the creation of an SE/TEE certification program.

Consequently, in addition to contributions from traditional SE-related operators such as chip and card manufacturers for smart card systems as well as telecom operators and others, proactive contributions from mobile-device chip manufacturers such as ARM and mobile-device-related operators such as Apple, Samsung, and Qualcomm in recent years have become an important trend. At present, about 100 companies from around the world are participating in GlobalPlatform as stakeholders.

Meanwhile, a wide variety and massive number of low-to-high-end Internet of Things (IoT) devices are coming to be dynamically added, connected, coordinated, and controlled in ever-expanding IoT environments

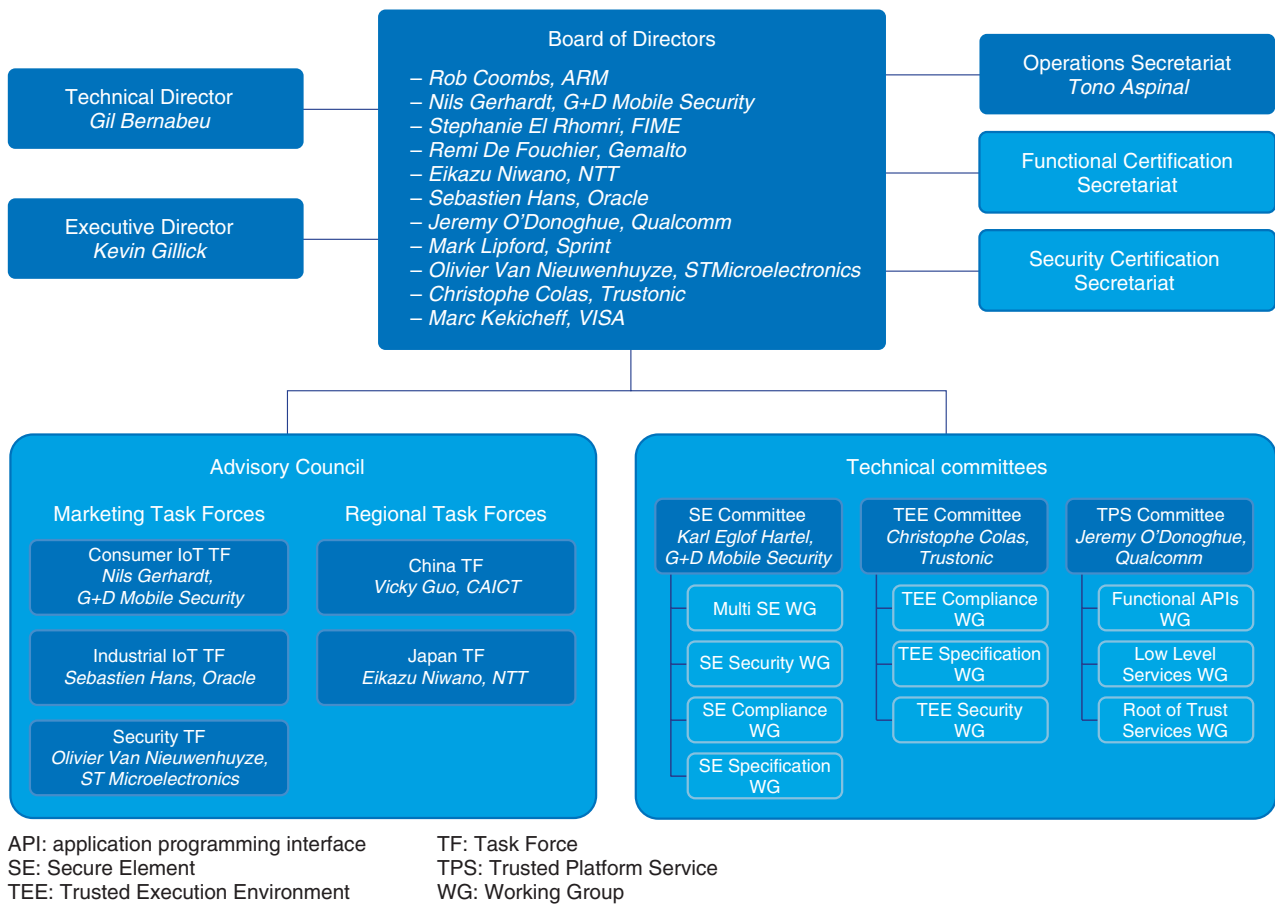


Fig. 1. GlobalPlatform organizational structure.

that drive the formation of ecosystems.

With the appearance of such complex and dynamic environments, much evidence and many incidents in relation to cyber-attacks are starting to be reported, revealing the vulnerability of IoT devices. These include the hijacking of a connected car and the malicious manipulation of its steering wheel, unauthorized operation of medical equipment, and DDoS (distributed denial of service) attacks using home digital cameras as a springboard.

Consequently, much attention is being focused on how to guarantee device trustworthiness as a critical issue, such as in determining the authenticity of the huge variety of interconnected IoT devices.

Against this background, GlobalPlatform seeks to enable a wide range of device manufacturers and digital service providers to collaborate in performing highly reliable and secure device management, and to this end, it is working to expand the role of secure components from user authentication to device

authentication.

Studies have therefore begun on IoT/device authentication at the requirements level, and in conjunction with the first reorganization of technical committees since the founding of GlobalPlatform in 1999, the Trusted Platform Services (TPS) Committee has been established to decide on technical specifications for device authentication.

2. Advisory Council

GlobalPlatform has established an Advisory Council as a forum for discussing requirements before formulating technical specifications. At present, the Advisory Council consists of market and regional task forces.

There are three market task forces: Consumer IoT, Industrial IoT, and Security. These task forces hold discussions on issues respectively concerning the consumer IoT field such as wearable devices, the

industrial IoT field such as Industry 4.0, and Root of Trust (RoT), Chain of Trust, and support for the latest encryption schemes (diverse and advanced encryption schemes, lightweight encryption schemes for specific devices, etc.).

The regional task forces, meanwhile, are established considering where GlobalPlatform members are based. The regional task forces share GlobalPlatform information and regional circumstances, study regional conditions and deployment issues, and hold discussions on region-originating technology. At present, there are two regional task forces: China and Japan.

3. Technical committees

The GlobalPlatform bodies that decide on technical specifications are the technical committees. Some name changes of these committees have occurred in order to reflect the state of study concerning secure components, which continue to expand from smart cards. The Card Committee is now the SE Committee, and the Device Committee is now the TEE Committee. Additionally, as mentioned above, the most noteworthy change here is the establishment of the TPS Committee to study the trustworthiness of devices. Here, the study theme is the trustworthiness of devices that use secure components.

Through these committees, GlobalPlatform aims to facilitate collaboration between device manufacturers and digital service providers and provide secure digital services regardless of the market sector or device type. To this end, it has technologies for authentication, connectivity, privacy, and security that enable it to provide the following services:

- (1) Protection of digital services
- (2) Secure remote management of digital services
- (3) Certification of secure components

4. Protection of digital services

Protection of digital services implements GlobalPlatform's technology designed to protect digital services and assets that use secure components. It provides protection of digital assets (credentials such as fingerprints and authentication/encryption keys) and associated security services (authentication etc.).

This protection is achieved by standardizing two types of secure component technologies—SE and TEE—supporting diverse market needs, as described below.

4.1 SE

This is a secure element consisting of tamper-resistant hardware such as a smart card. It includes smart cards and USB (universal serial bus) tokens that link with a terminal from the outside through a reader or writer. Another type of SE includes SIM, smartSD (Secure Digital memory card), and embedded SEs (eSIM, embedded universal integrated circuit cards (eUICCs), etc.) used inside mobile devices, as well as integrated SE (iSE) integrated with a SoC (system on chip).

Standardization of access to multiple SEs within a mobile device is also progressing. Here, an Open Mobile API (OMAPI) is being specified as an application programming interface (API) for accessing an SE from a mobile application. Furthermore, given that mobile devices support proximity communication technology called near-field communication (NFC)*¹, GlobalPlatform is also engaged in joint studies with the NFC Forum and the European Telecommunications Standards Institute (ETSI) on Host Card Emulation as an emulation environment targeting mobile-device cards that use NFC and on Contactless Card Emulation Environments as a mechanism for accessing various types of SEs. Studies are also progressing on the updating of SE firmware and specifically on a mechanism called Virtual Primary Platform as a new study item that separates the iSE OS into upper and lower sections as requested by the GSM Association (GSMA)*².

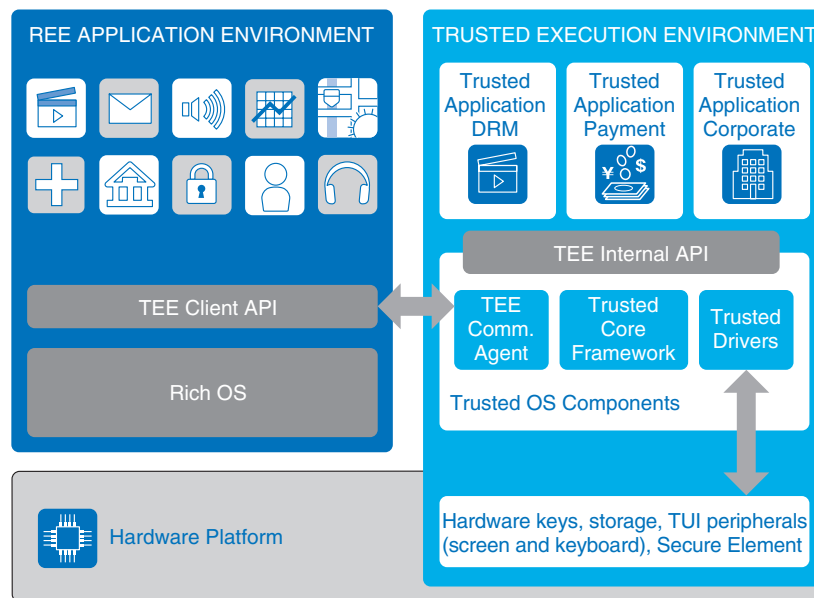
At present, about 22 billion GlobalPlatform-conforming SEs have been deployed (41% of the SE market). It is noteworthy in relation to IoT that GSMA has released remote provisioning specifications for eUICCs that use GlobalPlatform technologies, and that the automobile industry is adopting this mechanism.

4.2 TEE

In addition to tamper-resistant hardware such as SEs, GlobalPlatform is also moving forward with the standardization of TEEs (**Fig. 2**) to provide a secure execution environment independent of the existing OS in devices such as mobile phones and to guarantee a level of security higher than that of the device OS.

*1 NFC: A wireless communications standard that includes existing contactless smart card communication standards. It enables the use of a contactless smart card function, reader/writer function, and inter-device (peer-to-peer) communication function.

*2 GSMA: An industry group made up of mobile communications operators and related companies that have adopted the GSM mobile phone system.



Source: GlobalPlatform

DRM: digital rights management
 REE: Rich Execution Environment
 TUI: trusted user interface

Fig. 2. TEE architecture.

A TEE executes only authorized software known as *trusted applications* and guarantees end-to-end security such as the protection of privacy and data access rights.

A TEE includes interfaces with applications, the device OS, and SEs and provides a trusted user interface (TUI) environment to prevent a man-in-the-browser attack.

At present, TEEs are being used for applications requiring a high level of security such as biometric authentications, digital rights management (DRM) for video content, and payments. The TEE secure component has been mentioned, for example, in IoT Security Guidelines ver. 1.0 [5], specified by the IoT Acceleration Consortium,^{*3} which reflects its ongoing deployment.

4.3 Four features of digital services protection

The following describes four features provided by the SE and TEE secure components to protect digital services and resources (Fig. 3).

The first feature is the provision of a secure execution environment isolated from the device OS by managing the RoT within the secure component.

The second feature is end-to-end secure execution

of application management within the secure component through multi-actors (device manufacturers, digital service providers, etc.). Here, SE firmware is also targeted as a managed resource.

The third feature is the ability to add and provide security services common to multiple market sectors on the same secure component in a flexible manner.

Finally, the fourth feature is the ability of multiple digital service providers to respectively manage an isolated and independent area on the same secure component.

5. Secure remote management of digital services

Another GlobalPlatform technology is remote management. In an IoT environment, IoT devices including sensors are installed in all sorts of places, so on-site management of these devices over the long term is hardly realistic. A remote management function is extremely important under these circumstances.

*3 IoT Acceleration Consortium: A body established in Japan for the purpose of constructing a system for developing and demonstrating IoT technologies and creating new business models through the participation and collaboration of government, industry, and academia.

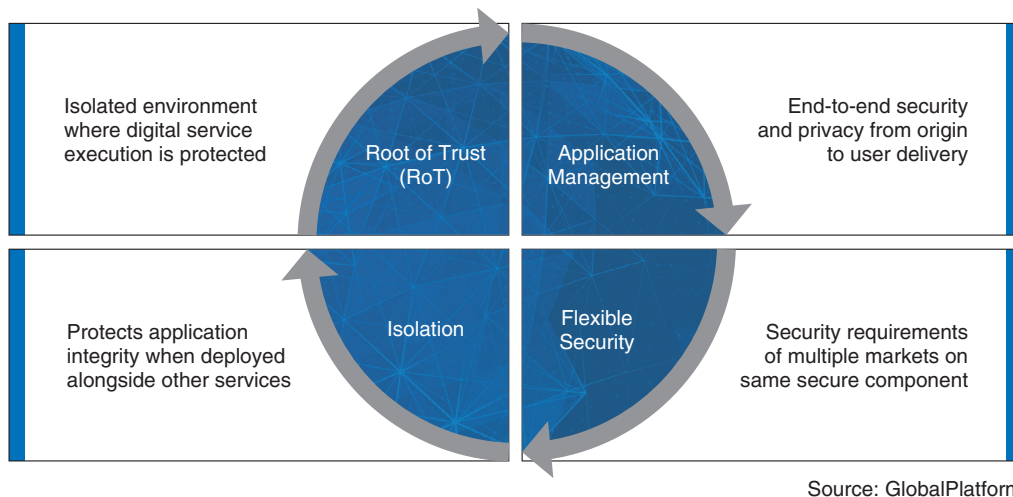


Fig. 3. Four features of digital services protection.

This technology enables secure end-to-end, remote management of SEs such as eSIMs embedded in IoT devices.

6. Certification (authentication) of secure components

GlobalPlatform provides a program for performing functional certification of SE/TEE products and security certification of TEE products. In this regard, GlobalPlatform has begun to collaborate with the FIDO Alliance,^{*4} an organization that promotes the standardization of multi-factor authentication including biometric authentication. Discussions have begun on how to configure and manage FIDO applications (keys, applications) in an internal device environment including secure components and on the necessity of security certification in relation to this configuration.

Furthermore, in relation to cybersecurity and the problem of supply chains for parts in ever-growing ecosystems, lively discussions are taking place in various organizations around the world on the importance of having a certification mechanism that includes hardware. This certification program is expected to become increasingly important in conjunction with security-by-design principles as the IoT/ecosystem era arrives.

7. Device protection—Device Trust Architecture

This section focuses on device protection as the latest initiative taken up by GlobalPlatform. It is an

extremely important key to achieving cybersecurity considering the future expansion of IoT and ecosystem environments.

Device protection is a mechanism related to device trustworthiness, including the authentication of device authenticity. Technical specifications for device protection will be specified by the TPS Committee.

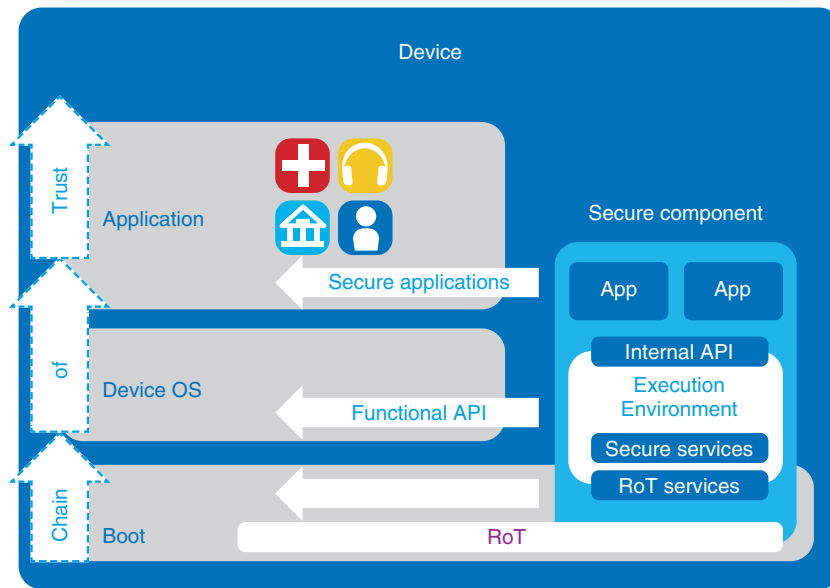
In relation to device protection, the Trusted Computing Group (TCG)^{*5} has been standardizing solutions using the Trusted Platform Module (TPM) for some time as part of trusted computing, but GlobalPlatform seeks to develop IoT devices as a general-purpose mechanism using secure components.

As stated above, a key feature of secure components is that they enable device manufacturers and digital service providers to remotely add or update a variety of applications including security functions (and firmware in the case of SEs) regardless of the market sector or device type. Using secure components in this way enables the provision of services such as device RoT, chain of trust, and remote device identification and attestation, which, in turn, enables trustworthy, safe, and flexible device management in a multi-actor environment [6].

This device protection mechanism is called Device Trust Architecture (DTA) [7]. The plan is to promote studies of DTA as architecture integrated with secure

*4 FIDO Alliance: A standardization organization targeting multi-factor authentication including biometric authentication.

*5 TCG: An organization promoting the study of TPM having a secure boot function.



Source: GlobalPlatform

Fig. 4. Device Trust Architecture.

components for protecting digital services (Fig. 4).

8. Future outlook—Toward the IoT era

A major strength of GlobalPlatform is its collaboration with many standardization organizations. In addition to standardization organizations targeting conventional fields such as smart cards, finance, and communications, it has recently initiated collaboration with GSMA/OneM2M^{*6} in the IoT field and the Car Connectivity Consortium (CCC)^{*7} in the automotive field. Furthermore, in relation to other types of tamper-resistant hardware, studies are beginning on a mechanism for generalizing secure boots such as RoT and chain of trust in collaboration with TCG to assure device trustworthiness, and work is beginning on defining the relationship of secure components with the Hardware Security Module used for key management and encryption processing in server systems.

With the coming of the IoT/ecosystem era, the trend toward collaboration must be promoted even further. In the IoT security field, however, needs differ according to industry and region due to differences in systems and cultural backgrounds, so it will become increasingly important to analyze the needs and use cases of individual industries and regions and to form tie-ups with standardization organizations in

each of those industries and regions. From here on, standardization and certification through cross-sector × cross-region efforts as in the case of smart city initiatives will be essential. Collaboration with other organizations related to tamper-resistant hardware according to such industry/regional characteristics will also be important.

Furthermore, in terms of technology, given an environment that dynamically and dispersedly connects such an array of stakeholders (developers, operators, service providers, users) and various types of devices and systems (and their constituent elements), research and development and standardization will be required for an ID component that manages ID/entity information. Key themes will be how to structure and arrange an ID component using a secure component, how to manage and certify authenticity/trustworthiness of ID components, and what mechanism to use to evaluate and authenticate ID components.

Finally, NTT to date has made contributions to the management of secure components using the public key infrastructure scheme. Going forward, we plan to make further contributions to the IoT security and cybersecurity fields through the application of such

*6 OneM2M: A joint project and standardization organization formed to promote the standardization of IoT platforms.

*7 CCC: An industry group working on the standardization of in-vehicle smartphone connections.

distributed security technologies.

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He received a B.S. and M.S. in mathematics from Waseda University, Tokyo, in 1987 and 1989. He joined NTT in 1989 and has studied distributed system architecture including mobile (messaging)/agent/ubiquitous systems, secure chips, and social information platforms with information security. During 2002–2005, he was the general manager of the European office of the NTT laboratories in Paris, and during 2008–2017 he served as producer at the Research and Development Planning Department of NTT. He is currently studying and planning strategies for IoT security, with a focus on secure components.

He received the Information and Communication Technology Award (the Minister of Internal Affairs and Communications Award) from The Telecommunication Committee in Japan in 2018. He is a member of the board of directors and chairman of the Japan Task Force in GlobalPlatform. He is also a Fellow and member of the board of directors of the Next Generation Ic Card System Study group (NICSS) in Japan. He is a member of the Institute of Electrical and Electronics Engineers (IEEE), the Institute of Electronics, Information and Communication Engineers (IEICE), and the Information Processing Society of Japan (IPSI).

Investigation of the Cause of Disconnection of Call Parking on a Business Phone

Technical Assistance and Support Center, NTT EAST

Abstract

Network-interface engineers at the Technical Assistance and Support Center are providing technical support for local maintenance personnel who deal with customers using IP (Internet protocol) services and public switched telephone network related services. This article describes a problem concerning the disconnection of call parking in business phones. This is the fiftieth article in a series on telecommunication technologies.

Keywords: call park, business phone, line monitoring system

1. Introduction

Network-interface engineers at the Technical Assistance and Support Center are providing technical support for local maintenance personnel who deal with customers using Internet protocol (IP) services such as FLET'S HIKARI NEXT and public switched telephone network (PSTN)-related services such as analog lines. This support ranges from conducting investigations by on-site testing to proposing ways to handle technical difficulties in order to solve problems whose causes are difficult to identify.

Customers use services in diversified ways, and thus, two approaches are used to investigate the causes of any technical problems. First, to investigate the Ethernet segment used by IP services, a method for analyzing IP packets based on packet capture is utilized. Second, to investigate analog and ISDN (Integrated Services Digital Network) lines used by PSTN-based services, a method for analyzing signals using an oscilloscope and protocol analyzer is utilized. We are also utilizing the tools developed by the Technical Assistance and Support Center to investigate terminals such as business phones. These tools

include the α line monitoring system capable of collecting the unique signals of business phones.

The problem described in this report concerns the disconnection of call parking in business phones. We explain how this kind of problem was analyzed by utilizing the above-described analysis methods and the tools developed by the Technical Assistance and Support Center.

2. Summary of problem and survey method

The call-park function is used as follows. All incoming calls on an external line to the customer's main phone number are received by a multifunction telephone installed at the reception desk. After determining who to connect each call to, the receptionist uses the call-park function to hold the calls and then transfers the calls to the appropriate staff member, each of whom carries a digital cordless phone.

However, the following event occasionally occurred. When an incoming call on an external line was held using the call-park function to be accepted by a staff member, the line was put into an active call state (the line being engaged) while the staff member

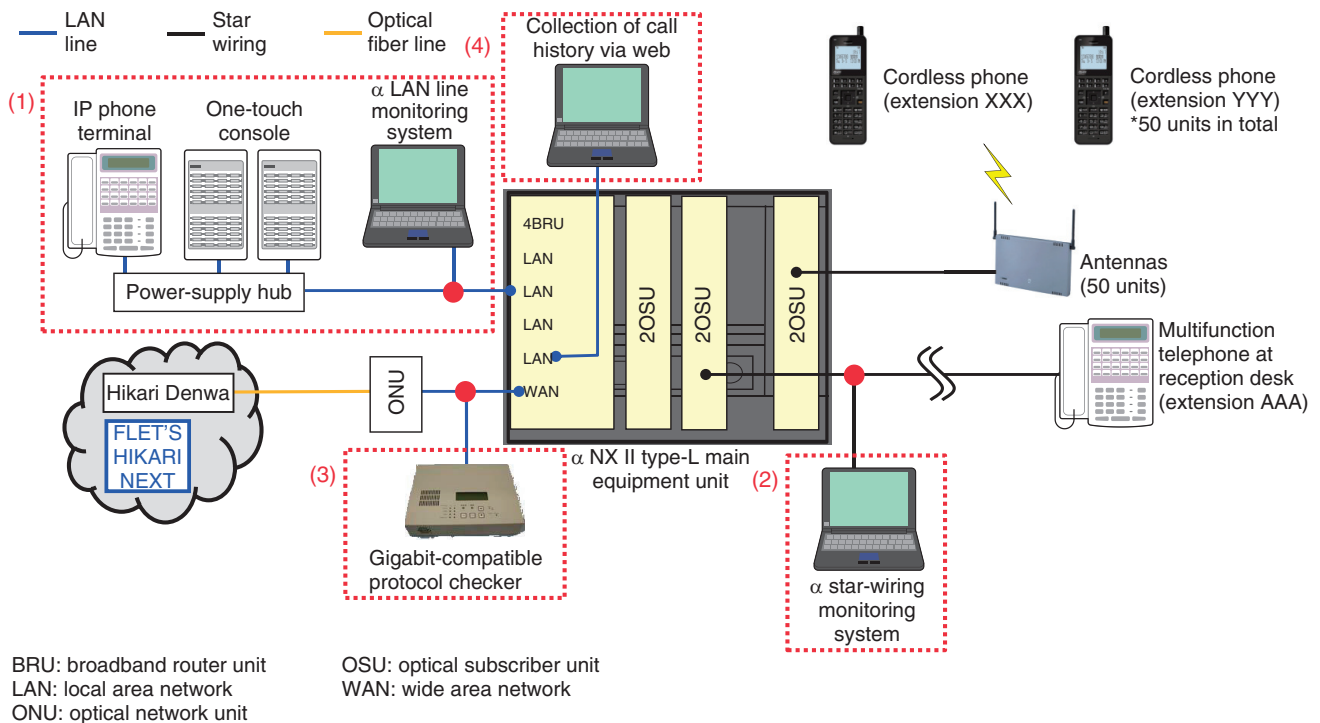


Fig. 1. Configuration of customer's equipment.

who should answer the call was being called.

The customer explained that the status of the LED (light-emitting diode) indicator of the call-parking line on the multifunction telephone (at reception) when the event occurred changed from blinking (call-park state), to continuously lit (call state), and, after a while, to unlit (disconnected state). When the status of the caller of the external-line incoming call where the problem occurred was checked, it became clear that the status in which there was no answer to the call (after the call-park function was initiated) continued for a while, before the line was eventually disconnected from the caller side.

To conduct normal call operations, the customer set all digital cordless phones carried by staff members to respond to all call-park calls via line keys. Local maintenance personnel checked and/or changed the setting of the main equipment unit or replaced some terminals, however, these countermeasures did not solve the problem. Accordingly, the Technical Assistance and Support Center conducted an on-site investigation.

The configuration of the customer's equipment is shown in **Fig. 1**. We considered the possibility of misoperation or failure of the multifunction tele-

phone and digital cordless phones occurring, so in our on-site investigation, we added the following four functional elements to the customer's system: (1) call-park response status monitoring for 50 digital cordless phones combining an α LAN (local area network) line monitoring system and IP telephone/one-touch console; (2) operation status monitoring for the multifunction telephone (reception) using an α star-wiring monitoring system; (3) IP packet capture by a gigabit-compatible protocol checker, and (4) records (call history obtained via web) of call information of all calls, including extensions and external lines of the main equipment unit.

To monitor the call-park response status of all 50 digital cordless phones, one IP phone for monitoring incoming calls on an external line and two one-touch consoles for monitoring the response status of the digital cordless phones were newly registered in the main equipment unit, and the terminal response data were acquired by the α LAN line monitoring system. The response state of the incoming calls on an external line and the time when a call was incoming can be determined from the terminal response data of the IP phone, and the call-park response state and the time that the line was switched to the call-park state of

Table 1. Terminal status according to α LAN line monitoring when the call-park problem occurred.

Time	Terminal	Status (operation etc.)	Remarks
16:42:31	Extension AAA (reception)	Calling	
16:42:36	Extension AAA (reception)	Responding	Answer with multifunction telephone
16:42:50	Extension AAA (reception)	Call parking	
↓			Conveying message to extension XXX while on hold
16:43:16	Extension XXX (staff member A)	Call-park response	Answering with digital cordless phone
↓			Talking
16:44:00	Extension XXX (staff member A)	Call parking	Putting on hold once
↓			On hold
16:44:32	Extension YYY (staff member B)	Call-park response	Answering with digital cordless phone
↓			Extension YYY: No answer to the call
16:46:37	Calling terminal	Disconnection	
↓			
16:47:12	Extension YYY (staff member B)	Disconnection	

each digital cordless telephone can be understood from the terminal response data of the one-touch consoles. In this way, we constructed a measurement system to clarify the call-park response state by analyzing these data.

3. Analysis of collected data

We analyzed the data collected in our investigation as follows.

3.1 α LAN line monitoring system*1

When we checked the park-hold response state of the 50 digital cordless phones when the park-hold problem occurred, we confirmed that a different digital cordless phone (staff member) from the destination phone was responding to the park hold. The operational status of each terminal when the park-hold problem occurred is listed in **Table 1**. Although calls transferred from extension AAA (reception) to the digital cordless phone of extension XXX (staff member A) are temporarily parked at 16:44:00, at 16:44:32, a park-hold line was responded to with the digital cordless telephone of extension YYY (staff member B), that is, not extension XXX. After that, the caller disconnected at 16:46:37, and at 16:47:12, extension YYY (staff member B) disconnected the line.

3.2 α star-wiring monitoring system*2

The results of checking the data collected by the α star-wiring monitoring system revealed that the multifunction telephone at reception was correctly oper-

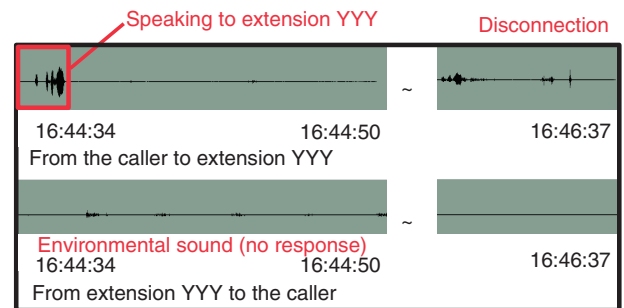


Fig. 2. Audio waveform when extension YYY does not answer the call.

ated to transfer incoming calls via the call-park function.

3.3 Gigabit-compatible protocol checker

An audio-data waveform constructed from packet-capture data when the call-park problem occurred (only after the call-parking line was responded to by extension YYY) is shown in **Fig. 2**. Although the caller is speaking to extension YYY, the voice waveform from extension YYY to the caller cannot be confirmed because there is no verbal response to the caller's utterance from extension YYY. The amplitude of the sound was barely confirmed after the

*1 α LAN line monitoring system: A monitoring system dedicated to LAN lines compatible with business phone α series.

*2 α star-wiring monitoring system: A monitoring system dedicated to star wiring handling the business phone α series. (A monitoring system for bus wiring also exists.)

call-park response was confirmed except for a rustling sound—as if something was rubbing against something else—or the sound of the surrounding environment.

3.4 Call history obtained via web

We found that the NX II type-L main equipment unit was operating normally because the call information recorded in the call history provided via web and the number of calls to and from the external line clarified from the packet-capture data were in accord.

4. Estimation of the cause of call-park problem

When staff members carry a digital cordless phone at work, they often put the phone in their breast pocket; as a result, it is conceivable that the line key flashing in the call-park state might be accidentally pushed by another object (e.g., a pen), and the phone might unintentionally respond to a parked call. For that reason, it is presumed that the staff member who responded to a parked call did not notice that the digital cordless phone was in a call state (accounting for the rubbing or environmental sound rather than a verbal response from extension YYY), and there was no response to a call from a caller.

5. Countermeasures

Since the customer's setting was to respond to all parked calls by pressing the line key of all their digital cordless phones, the above-described unintended call-park response occurred. Because of the fact that users often put their digital cordless phones in their breast pockets along with other objects, we proposed the following three measures to prevent the unintentional call-park response.

1. Utilization of *key lock* function

By releasing the key unlock every time an operation is required, it is possible to prevent erroneous responses to parked calls by unintended button pressing.

2. Utilization of *individual on-hold* function

By using the individual on-hold function (i.e., pushing the hold button) of the multifunction telephone (reception), it is possible to prevent digital cordless phones other than the destination phone from entering a state in which a hold cannot be responded to.

3. Utilization of *park-hold* function

When sending an external-line call from the digital cordless telephone, the customer was pressing the line key to acquire the line and then pressing the destination telephone number. In such an operation, there is a risk that when a staff member unconsciously presses a line key in an attempt to make an external-line call, he/she will inadvertently respond to a parked call. Therefore, the staff member with a digital cordless phone uses the park-hold function that is provided separately from the call park key, it is possible to prevent a false reply to a parked call.

6. Concluding remarks

In the case presented in this report, the problem concerning the disconnection of call parking in business phones was solved by using a measurement system utilizing an α LAN line monitoring system to monitor the operational condition of 50 digital cordless phones. From now onwards, the Technical Assistance and Support Center will analyze the signals and data using various tools at each interface and contribute to the resolution of problems.

Report on NTT R&D Forum 2018 Autumn

Takashi Ikebe, Hideo Kato, Atsuyuki Muramoto, Masaki Hisada, Kentaro Hotta, and Norio Sakaida

Abstract

NTT R&D Forum 2018 Autumn was held at NTT Musashino R&D Center November 26–30, 2018. (November 26 and 27 were set aside solely for the press and NTT Group employees.) This article provides an overall summary of the forum.

Keywords: R&D forum, smart world, digital transformation

1. Forum overview

The NTT Group, as *Your Value Partner*, aims to resolve social issues in collaboration with its partners. We believe that being able to resolve social issues will help to make a smart, digital society a reality. At NTT R&D Forum 2018 Autumn, lectures and exhibits were held on the latest research results designed to help create this emerging society. The concept of the forum was Transforming Your Digital Visions into Reality.

2. Lectures and workshops

On November 28, NTT President and Chief Executive Officer Jun Sawada gave a keynote address entitled “Bringing the Smart World to Life” (**Photo 1**). He declared that NTT would work with its partners to bring about the emergence of a *smart world*. These efforts are designed to resolve local issues from a global perspective (thus, *glocal* activities) through digital transformation.

He then introduced current NTT activities in different industries: promotion of the smart city in the City of Las Vegas using leading-edge technologies in collaboration with Dell Technologies; smart entertainment, an endeavor with SHOCHIKU Co., Ltd. to integrate traditional performing arts with information

and communication technology (ICT); the smart manufacturing of JSR Corporation, which is improving the productivity of its industrial complex, a venture in which we are partnered with Accenture Japan Ltd.; and smart mobility, which includes collaboration with Toyota Motor Corporation in the development of basic technologies for automated driving and collaboration with Nippon Yusen K.K. and MTI Co., Ltd. in the development of an Internet of Things (IoT) platform for the shipping industry.

In connection with the NTT Group’s Medium-Term Management Strategy called *Your Value Partner 2025*, President Sawada described the NTT Group’s global business growth strategy, which has been designed to strengthen the group’s global competitiveness. He announced that NTT will support its customers to evolve their businesses, undertake innovative creation, and strengthen and globalize its research and development (R&D). He ended his address with a declaration that NTT will make all-out efforts to achieve its own digital transformation goals and become *Your Value Partner*.

The president’s keynote address was followed by a speech delivered by NTT Senior Vice President, Head of Research and Development Planning, Katsuhiko Kawazoe (**Photo 2**). With the title “Making the World Smart and Technology Natural,” he stated that NTT’s R&D policy of developing *natural* technologies was

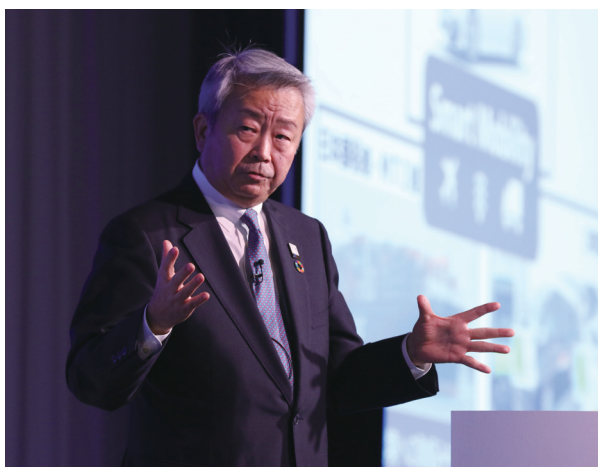


Photo 1. Keynote address by Jun Sawada, President and Chief Executive Officer, NTT.



Photo 3. Special session by Debra Bordignon, Chief Technology Officer, Dimension Data Australia.



Photo 2. Keynote address by Katsuhiko Kawazoe, Senior Vice President, Head of Research and Development Planning, NTT.

motivated by the desire to create a world in which people can engage in human-centric activities while technologies provide an environment that is friendly to both people and the earth. As an activity symbolic of this initiative, he announced his plan to launch a new project called Point of Atmosphere. The aim of the project is to help create a world in which things surrounding a person work together autonomously and interact with the individual in a natural manner.

He then introduced NTT's activities related to "R&D for a SMART WORLD." NTT intends to

achieve a smart world by working with partners to solve issues associated with the digital transformation of both society and industry using technologies that have grown out of its R&D and to generate "the world's best, the world's first, and the world's amazement."

Finally, he presented three R&D measures to accelerate innovation: global utilization of R&D results, globalization of research targets, and establishment of research organizations outside Japan. He announced that based on these measures, three laboratories specializing in basic research will be established overseas: NTT Φ Laboratories, which will study quantum computing science; NTT CIS Laboratories, which will work on cryptography and information theory; and NTT MEI Laboratories, which will address biological information processing.

Two special sessions were held at this forum, the first on November 29 and the second on November 30. First, Debra Bordignon, Chief Technology Officer, Dimension Data Australia, introduced activities at the Client Innovation Centre (CIC) designed to create new value with partners in Australia under the title of "Co-Innovating to Accelerate Transformation and Create New Value" (Photo 3). In collaboration with Deakin University, FLAIM Systems, and Dimension Data, CIC incorporated the NTT-developed hitoe™ material into FLAIM Trainer™, a firefighter training simulator that uses virtual reality to enable training in a situation similar to an actual fire. Use of firefighters' physiological data collected via hitoe has made it possible to train firefighters effectively without

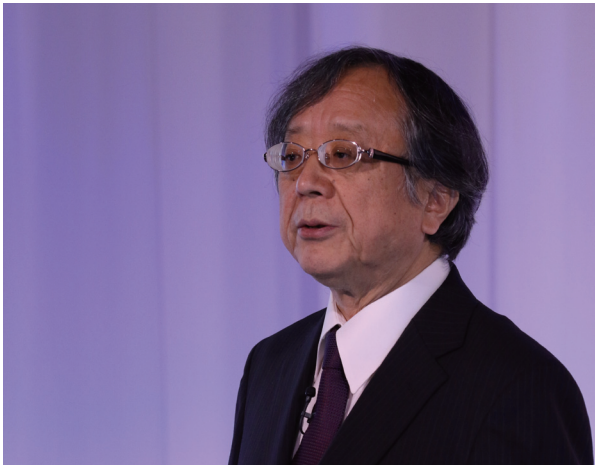


Photo 4. Special session by Dr. Tatsuaki Okamoto, NTT Fellow.



Photo 5. Special session by Dr. Pratish Datta, NTT Secure Platform Laboratories.

exposing them to danger.

Following her lecture, Dr. Tatsuaki Okamoto, NTT Fellow, gave a talk entitled “Diversity and COE—Cryptologic Research in NTT: Talk with Dr. Datta, a Visually Handicapped Researcher” (**Photo 4**). Dr. Okamoto explained that NTT Secure Platform Laboratories is a center of excellence (COE) with a global reputation in the field of cryptography and that diversity is the key to this excellence. Since 1988, when the Laboratories first invited researchers from outside NTT, each year they have accepted many researchers from both inside and outside Japan. If we count only those since 2015, 55 researchers from more than 20 countries have resided there.

Then, Dr. Pratish Datta went to the podium and spoke of his first encounter with Dr. Okamoto, the research environment of NTT, and his life at the Laboratories (**Photo 5**). He explained that he is able to conduct his research in an excellent environment with top-notch cryptography researchers from around the world and that they voluntarily help each other out. Dr. Datta, who has visual and hearing disabilities, added that he has been receiving sufficient support for his research activities and that he will continue his research at NTT to develop theoretically and practically refined cryptography.

The next day, under the title of “Leading in the Age of Digital Disruption,” Marc Alba, Chief Disruption Officer at everis, elaborated on his perception that all industries in the world today, from banking, medical care, automobiles, to retailing, are in the process of reinventing themselves, and that what is needed is



Photo 6. Special session by Marc Alba, Chief Disruption Officer, everis.

disruptive innovation for solving core issues rather than improvement of existing technologies (**Photo 6**). Based on this perception, he proposed that, as part of its disruptive innovation initiatives, the NTT Group create new businesses by returning the ownership of personal data—which have traditionally been entrusted to service providers—to individuals and then using such personal data.

The lectures were an introduction to the activities of NTT R&D and the NTT Group, and were warmly received by the audience.



Photo 7. Media and UI.

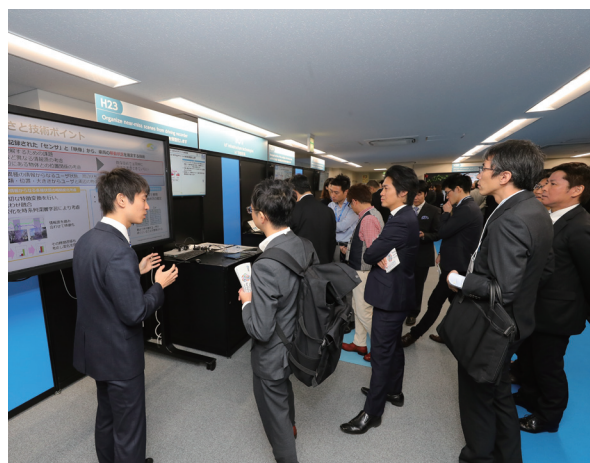


Photo 8. AI.

3. Exhibition of research results

At the forum venue, 124 of the latest research results were on display under six categories: media and user interface (UI), artificial intelligence (AI), IoT, network, security, and basic research. Thus, the exhibition covered a wide range of research findings, from technologies being developed by the NTT Group to outcomes resulting from collaboration with partner companies, and from basic research to already commercialized technologies.

To enable visitors to see the results of R&D more effectively, we created for the first time an exhibition site dedicated to introducing smart world-related activities that cut across different exhibit themes, in addition to the exhibition sites dedicated to specific topics. At these sites, visitors were able to see well-designed demonstrations and exhibits.

3.1 Media and UI

(1) Media technology for providing new user experience

The ultra-realistic communication technology Kirari! was introduced in a lineup of four presentations, each adapted to a specific usage, along with associated elemental technologies. The first and main one was a theater-type exhibit aimed at creating a whole new level of excitement. The second was “Kirari! for Arena,” which transmits images of an entire competition space and enables the audience at a remote site to view the space from all directions in real time. The third was a highly realistic reception window. The fourth presentation featured broadcast-

ing of sports on a wide screen using synthesized and economized four 4K video streams (**Photo 7**).

(2) UI technologies targeted at 202X

An introduction was given of technology enabling low-cost collection and updating of barrier-free information needed by elderly or handicapped people for walking, as well as walking guide technology, with a view to achieving diversity navigation, which makes daily-life activities safe and convenient for those with mobility issues. In addition, technology that enables robots to present information more naturally was on display.

3.2 AI

(1) AI that supports people

The following technologies were introduced: Totto, the interviewer robot, which accurately recognizes what someone is saying and engages in a natural dialogue; RexSense[®], an engine that recognizes non-verbal information (a speaker’s attributes, feelings, and intentions) from speech; and technology that understands a conversation between a customer and an operator, infers the customer’s situation from their responses, and extracts predefined key issues such as the subject matter and the customer’s reason for calling, in real time (**Photo 8**).

(2) AI that supports society

Also on display were AI technologies able to perform optimal control based on the numbers and flows of people in and out of a site. They included technology that uses AI to control air conditioning of a large

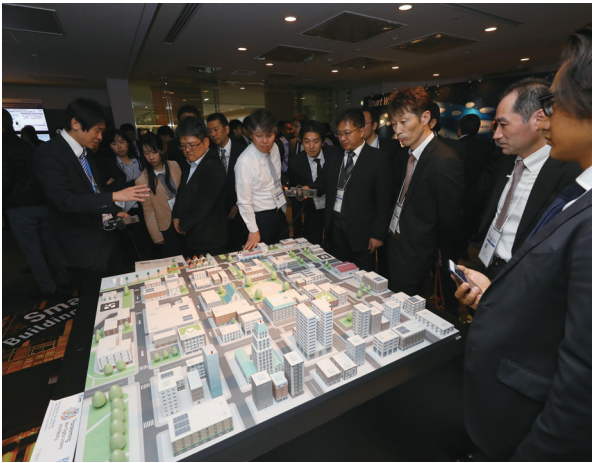


Photo 9. IoT.



Photo 10. Network.

commercial facility with an unspecified number of people coming in and out in order to reduce air conditioning costs while keeping the facility comfortable, and technology that uses a learning simulator to predict flows of people and thereby generate a guidance plan for various places such as an event site, a tourist spot, or a transportation facility.

(3) Fundamental technologies

Also presented were fundamental learning technology to accelerate deep learning, technology that converts and compresses a large volume of spatial data into a group of images, and technology able to deliver AIs to appropriate points within a network and make them operate in coordination.

3.3 IoT

(1) Sense, connect and drive

Technologies that digitize and transmit data that are read out from various objects were introduced, for example, technology for the sensing fabric, hitoe, which is being employed in a wide range of fields including healthcare; and technology for reliably collecting data from sensors in places where reception of mobile radio waves is weak.

(2) Data and software logistics

On display were IoT data exchange technology that achieves high-speed data exchange between a variety of machines and applications in the fields of manufacturing, automobiles, and ships, and edge computing technology that achieves real-time distributed processing for handling a large volume of data with low latency.

(3) Analytics and prediction

The latest research results that combine big data analysis and deep reinforcement learning were introduced (**Photo 9**). They included a public security solution that quickly detects and deals with an incident through analysis at a micro-datacenter located in the vicinity of the monitored area and technology that predicts where and when incidents that require an emergency response are likely to occur and optimally allocates rescue teams.

3.4 Network

(1) Flexible and high-speed networks

A wide range of network technologies for increasing network capacity or for optimizing network functions to suit different service requirements were showcased (**Photo 10**). These included wireless transmission technology for the post-5G (fifth-generation wireless communication networks) era and network slice technology for generating a network suitable for different needs.

(2) Networks that rapidly restore and provide services

The following technologies were introduced: operation technology that maximizes the scope of zero-touch operations and planned maintenance by determining how to handle various operational events such as service applications from customers and faults, based on an SLA (service level agreement), and technology that uses Network-AI to assist operators in different phases, from monitoring, analysis, and control to recovery, with the aim that in the future it will



Photo 11. Security.



Photo 12. Basic research.

be possible to handle faults that occur in ICT systems automatically.

(3) Network/IT (information technology) solutions

Solutions that utilize network functions and technologies that can be employed immediately for service development were exhibited. They included the API (application programming interface) orchestrator, which supports the public security solution in Las Vegas, and solutions that were the result of collaborations with partner companies.

3.5 Security

Unknown cyber-attack detection technology and personal information anonymization technology were exhibited (**Photo 11**). These consist of leading security technologies—some defensive and some offensive—that strengthen measures against cyber-attacks and will lead to the early realization of a data-centric society.

3.6 Basic research

Results of leading-edge basic research aimed at creating new principles or concepts in the coming years were introduced (**Photo 12**). They included a

transparent battery that will enable researchers to create a device that is virtually invisible; child language development analysis technology, which identifies the characteristics of late talkers; middleware and applications for LASOLV, a quantum neural network that solves challenging problems at an extraordinary speed; and coating-type deterioration sensing technology, which detects anomalies in structures simply by coating them.

4. Conclusion of the forum

To enable many people, including those from abroad, to come to the forum, we moved the forum dates from spring, when it was formerly held, to autumn. Consequently, we were able to welcome more than 15,000 visitors. We believe that what lies behind this large number of visitors, many from overseas, is their high expectation for NTT's R&D. In fact, visitors to the exhibit sites and those who took the questionnaire survey clearly expressed the expectations they had for our R&D. To live up to their high hopes, we will redouble our efforts in all areas from basic research to the development and deployment of new technologies.



Authors (from left): Atsuyuki Muramoto, Manager, R&D Planning, NTT Research and Development Planning Department; Hideo Kato, Manager, R&D Planning, NTT Research and Development Planning Department; Takashi Ikebe, Manager, R&D Vision Group, NTT Research and Development Planning Department; Norio Sakaida, Manager, Research Planning Department, NTT Science and Core Technology Laboratory Group; Masaki Hisada, Manager, R&D Management, Planning Department, NTT Service Innovation Laboratory Group; and Kentaro Hotta, Manager, Planning Department, NTT Information Network Laboratory Group

Controlling Nuclear Magnetic Resonance with a Micromechanical Oscillator—A Novel Technique to Individually Manipulate Nuclear Spins in Integrated Devices

1. Introduction

NTT and the National Institute of Advanced Industrial Science and Technology (AIST) have developed a novel device technology to control solid-state nuclear magnetic resonance (NMR) with a micromechanical oscillator. Quantum memory has received much attention in recent quantum technology research for applications to quantum computers, quantum communications, and quantum sensors. Quantum computers are expected to perform ultrafast computation, while quantum communications can provide absolutely secure communications protocols, and quantum sensors promise to drastically improve sensor performance.

Quantum memory's ability to store quantum superposition states for a long period of time could improve the performance of these quantum technologies. One of the most important candidates for quantum memory is nuclear spin because of its extremely long spin lifetime. NTT and AIST experimentally demonstrated that the NMR frequency in a mechanical oscillator can be controlled by strain induced by its mechanical motion. This method enables us to control the quantum state of a nuclear spin in a desired mechanical element in an integrated array and will play an essential role in the development of solid-state-based quantum memory.

This demonstration was made possible through a collaboration between NTT, which performed device fabrication and measurements, and AIST, which performed data analysis based on precise theoretical modeling. The results were published in *Nature Communications* on August 28, 2018 [1]. This work was

partly supported by a Grant-in-Aid for Scientific Research on Innovative Areas (KAKENHI) from the Japan Society for the Promotion of Science, specifically by the research project of Science of Hybrid Quantum Systems.

2. Research background

Nuclear spin is the rotation of an atomic nucleus, and it shows a precessional motion under a magnetic field. Nuclear spin can sustain precessional motion for a long period of time and is expected to be used in various applications such as quantum memory to store a quantum superposition state and high-performance magnetic field sensors. NMR is generally used to manipulate the nuclear spin state, where an electromagnetic wave at the NMR frequency is applied under a magnetic field to modify the precessional motion. However, it is hard to use standard NMR techniques for integrated devices because the magnetic field and electromagnetic wave are simultaneously applied to all the devices. Therefore, a novel method to manipulate nuclear spins in individual devices is in high demand.

3. Research results

The NMR frequency is highly sensitive to the strain applied in a solid, and this property was used to locally manipulate nuclear spins in this experiment. Artificially generating strain at a desired position in a material allows the control of NMR in individual integrated devices. A micromechanical oscillator fabricated using state-of-the-art nanofabrication technology

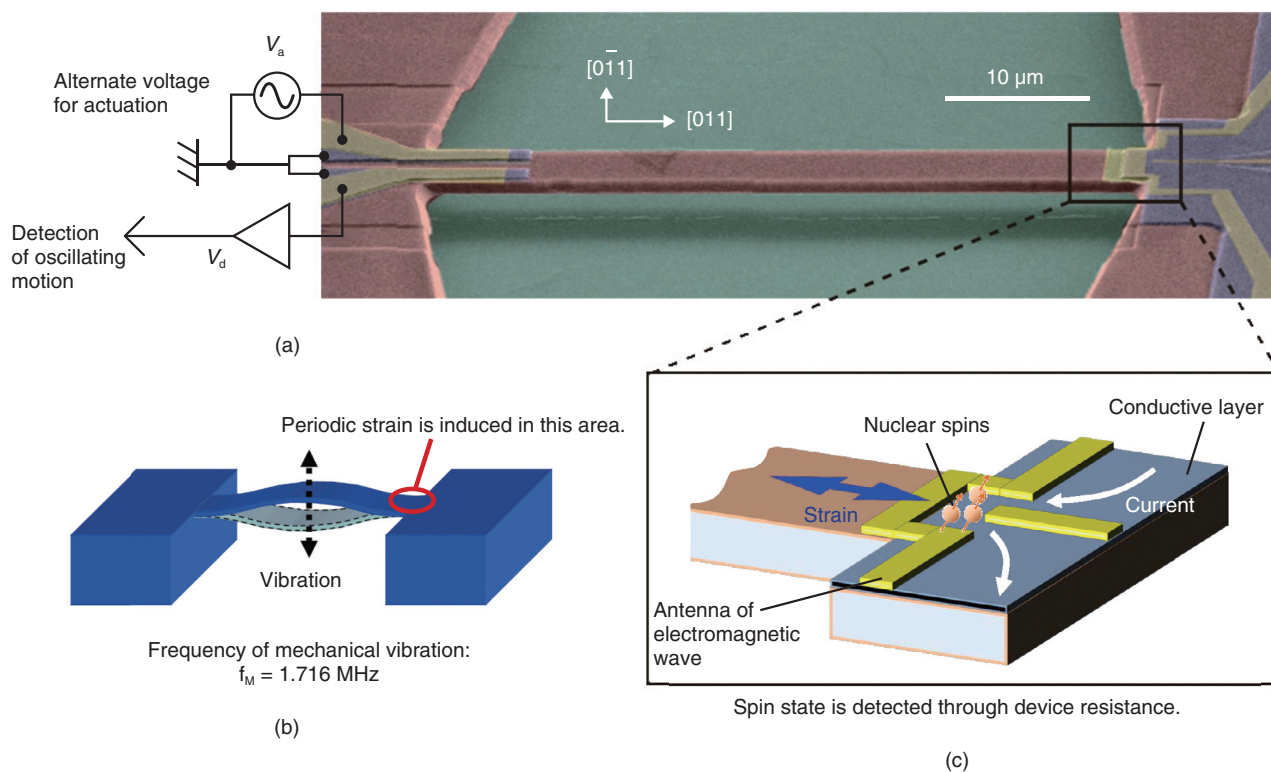


Fig. 1. Mechanical oscillator used in this study. (a) Electron microscope false-color image of a micromechanical oscillator used to apply strain on nuclear spins. The mechanical flexural motion is induced by applying an alternate voltage on the surface electrode (shown in yellow). (b) Schematic drawing showing the generation of strain. The flexural motion of a 50- μm -long beam induces periodic strain on the clamping area. (c) Magnified schematic image of strain area of the oscillator. An antenna radiating electromagnetic waves generates an oscillating magnetic field and induces nuclear magnetic resonance. The change in the nuclear spin state is detected as the change in resistance.

was used to locally generate large strain, and the NMR frequency was controlled with oscillating strain using the resonator's mechanical motion. As a result, we observed not only the modulation of the NMR frequency but also a novel kind of NMR called sideband resonance, which were induced by the mixed effect of electromagnetic waves and oscillating strain.

4. Experimental details

The mechanical oscillator (**Fig. 1(a)**) has the shape of a doubly clamped beam and was fabricated by processing GaAs (gallium arsenide), which is a piezoelectric semiconductor. The mechanical oscillation can be electrically induced through the piezoelectric effect. The motion generates periodic strain at the clamping point (**Fig. 1(b)**) and modifies the dynamics of nuclear spins in the strained region. In the experiments, we observed not only a shift in the

NMR frequency but also sideband resonances, where the resonance was also confirmed at two shifted frequencies: blue- and red-detuned from the original NMR frequency. The theoretical calculation factored in the effect of oscillating strain on nuclear spin dynamics and showed good agreement with the experimental results, proving that the observed phenomenon can be well explained by the effect of mechanical oscillation.

5. Outlook

The mechanical oscillators are fabricated using semiconductor nanofabrication technology and can be integrated on a tiny semiconductor chip. We can utilize this scheme as a novel platform to integrate quantum memories and sensors by demonstrating nuclear spin control in individual arrayed devices.

Reference

- [1] Y. Okazaki, I. Mahboob, K. Onomitsu, S. Sasaki, S. Nakamura, N. Kaneko, and H. Yamaguchi, "Dynamical Coupling Between a Nuclear Spin Ensemble and Electromechanical Phonons," Nat. Commun., Vol. 9, 2993, 2018.

For Inquiries

Public Relations,

NTT Science and Core Technology Group

<http://www.ntt.co.jp/news2018/1808e/180828b.html>

External Awards

38th CHEMINAS Poster Award

Winner: Hiroki Miyazako, Tetsuhiko Teshima, and Yuko Ueno, NTT Basic Research Laboratories

Date: November 1, 2018

Organization: Society for Chemistry and Micro-Nano Systems (CHEMINAS)

For “Direction of Topological Defects in Cell Population by Computer-aided Design of Geometrical Boundaries.”

Published as: H. Miyazako, T. Teshima, and Y. Ueno, “Direction of Topological Defects in Cell Population by Computer-aided Design of Geometrical Boundaries,” 38th CHEMINAS, 1P28, Sapporo, Japan, Oct./Nov. 2018.

APMC 2018 Prize

Winner: Hiroshi Hamada, Takuya Tsutsumi, Hiroki Sugiyama, and Hideyuki Nosaka, NTT Device Technology Laboratories

Date: November 9, 2018

Organization: 2018 Asia-Pacific Microwave Conference (APMC 2018)

For “High-output-power and Reverse-isolation G-band Power Amplifier Module Based on 80-nm InP HEMT Technology.”

Published as: H. Hamada, T. Tsutsumi, H. Sugiyama, and H. Nosaka, “High-output-power and Reverse-isolation G-band Power Amplifier Module Based on 80-nm InP HEMT Technology,” Proc. of APMC 2018, Kyoto, Japan, Nov. 2018.

Papers Published in Technical Journals and Conference Proceedings

Merlin-Arthur with Efficient Quantum Merlin and Quantum Supremacy for the Second Level of the Fourier Hierarchy

T. Morimae, Y. Takeuchi, and H. Nishimura

Quantum, Vol. 2, p. 106, November 2018.

We introduce a simple sub-universal quantum computing model, which we call the Hadamard-classical circuit with one-qubit (HC1Q) model. It consists of a classical reversible circuit sandwiched by two layers of Hadamard gates, and therefore it is in the second level of the Fourier hierarchy. We show that output probability distributions of the HC1Q model cannot be classically efficiently sampled within a multiplicative error unless the polynomial-time hierarchy collapses to the second level. The proof technique is different from those used for previous sub-universal models such as IQP, Boson Sampling, and DQC1, and therefore the technique itself might be useful for finding other sub-universal models that are hard to classically simulate. We also study the classical verification of quantum computing in the second level of the Fourier hierarchy. To this end, we define a promise problem, which we call the probability distribution distinguishability with maximum norm (PDD-Max). It is a promise problem to decide whether output probability distributions of two quantum circuits are far apart or close. We show that PDD-Max is BQP-complete, but if the two circuits are restricted to some types in the second level of the Fourier hierarchy such as the HC1Q model or the IQP model, PDD-Max has a Merlin-Arthur system with quantum polynomial-time Merlin and classical probabilistic polynomial-time Arthur.

Development and Evaluation of an Applause and Hand-clapping Sound Feedback System to Improve Realistic Feeling on Live Viewing

A. Fujimori, K. Kawahara, Y. Kamamoto, T. G. Sato, M. Nishikawa, A. Omoto, and T. Moriya

IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. J101-A, No. 12, pp. 273–282, December 2018 (in Japanese).

Considering the increasing popularity of public viewing, improvement of immersive content is becoming an important issue. This paper presents APRICOT: APplause for Realistic-Immersive COntents Transmission system as one of the solutions for enhancing the quality of live-viewing services. APRICOT detects the sounds of applause and hand-clapping at a remote site, transmits the information as meta-data, and represents the data at the host site. Since hand-clapping is the most common response for an audience and is simple to replay, the system can transmit the excitement in real time with low delay. Experiments indicate that feedback of the applause and hand-clapping enhances the immersive sound, especially at the host site.

Impossibility of Blind Quantum Sampling for Classical Client

T. Morimae, H. Nishimura, Y. Takeuchi, and S. Tani
arXiv:1812.03703 [quant-ph], December 2018.

Blind quantum computing enables a client, who can only generate or measure single-qubit states, to delegate quantum computing to a remote quantum server in such a way that the input, output, and

program are hidden from the server. It is an open problem whether a completely classical client can delegate quantum computing blindly. In this paper, we show that if a completely classical client can blindly delegate sampling of sub-universal models, such as the DQC1 model and the IQP model, then the polynomial-time hierarchy collapses to the third level. Our delegation protocol is the one where the client first sends a polynomial-length bit string to the server, and then the server returns a single bit to the client. Generalizing the no-go result to more general setups is an open problem.

A Supervised Learning Approach to Granger Causality Inference

Y. Chikahara and A. Fujino

IPSI Transactions on Mathematical Modeling and Its Applications, Vol. 11, No. 3, pp. 58–73, December 2018 (in Japanese).

Granger causality is one of the definitions of temporal causality between variables, and inferring Granger causality is an important task in time series analysis. Traditional methods use regression models for this task. Since the inference accuracies of these methods depend largely on whether or not we select an appropriate regression model for each time series data element. However, it is not easy because such selection of regression models requires a deep understanding of data analysis. This paper proposes a supervised learning framework that utilizes a classifier instead of regression models. Our proposed method employs a feature representation that utilizes the distance between the conditional distributions given past variable values. We experimentally show that the feature representation gives sufficiently different feature vectors for time series with different Granger causality.

FiveStar VR: Shareable Travel Experience through Multisensory Stimulation to the Whole Body

K. Shimizu, G. Sueta, K. Yamaoka, K. Sawamura, Y. Suzuki, K. Yoshida, V. Yem, Y. Ikei, T. Amemiya, M. Sato, K. Hirota, and M. Kitazaki

Proc. of the 11th ACM SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia (SIGGRAPH ASIA 2018), Tokyo, Japan, December 2018.

We have developed a multisensory virtual reality system, FiveStar VR (five senses theater for VR), that enables participants to relive or share each other's behavior through well-designed simultaneous stimulation to multiple modalities. FiveStar VR consists of somatosensory displays in addition to the conventional audio-visual VR setup. In the FiveStar VR, the body parts of the participant are forced to move, which is synchronized with those of an avatar in the VR space, resulting in inducing a strong perception of presence at the past walking behavior of someone else. By taking advantage of the cyclic nature of walking, the arms, the lower limbs, and the body are

synchronously moved to simulate the sensation of real walking. These motion profiles do not completely follow the measured data of real walking, but each gain of magnitude of the modalities is adjusted on the basis of the subjective intensity of motion impression, mainly due to the lack of the sensory suppression from the motor command of the participant. The demonstration of our exhibition booth presents a virtual trip to tourist sites in Toronto and Niagara Falls, Canada. A short-time experience of walking around the area is relived/shared by the attendee.

Leg-Jack: Generation of the Sensation of Walking by Electrical and Kinesthetic Stimuli to the Lower Limbs

H. Kaneko, T. Amemiya, V. Yem, Y. Ikei, K. Hirota, and M. Kitazaki

Proc. of SIGGRAPH ASIA 2018, Tokyo, Japan, December 2018.

We developed a neurosensory and kinesthetic stimulation system that generated a walking sensation for a seated user. An electrical stimulus was applied to the Achilles' and tibialis anterior tendons with a kinesthetic stimulus generated by a lower limb device driven synchronously with an egocentric visual scene during virtual walking. The system works as part of an experience replication scheme that aims to receive the physical activity of another (person, entity, etc.). As a common bodily activity of humans, walking motion was focused on. The evaluation experiment has shown that walking sensation was increased by each stimulation at a 1% significance level. In this demonstration, the user on a chair can feel as if he/she is walking in a haunted house. The user can move the upper body freely to look around with a virtual flashlight; however, the lower body is possessed by the other entity. The user walks into the house despite his/her intention. The work gives the user a realistic experience which was not sufficiently generated with only a movie and sounds.

Channel Code Using Constrained-random-number Generator Revisited

Jun Muramatsu and S. Miyake

IEEE Transactions on Information Theory, Vol. 65, No. 1, pp. 500–510, January 2019.

A construction of a channel code by using a source code with decoder side information is introduced. The encoder and decoder pair of any source code can be used for the construction. Constrained-random-number generators, which generate random numbers satisfying a condition specified by a function and its value, are used to construct stochastic encoders and decoders. The result suggests that we can divide the channel coding problem into the problems of channel encoding and source decoding with side information.