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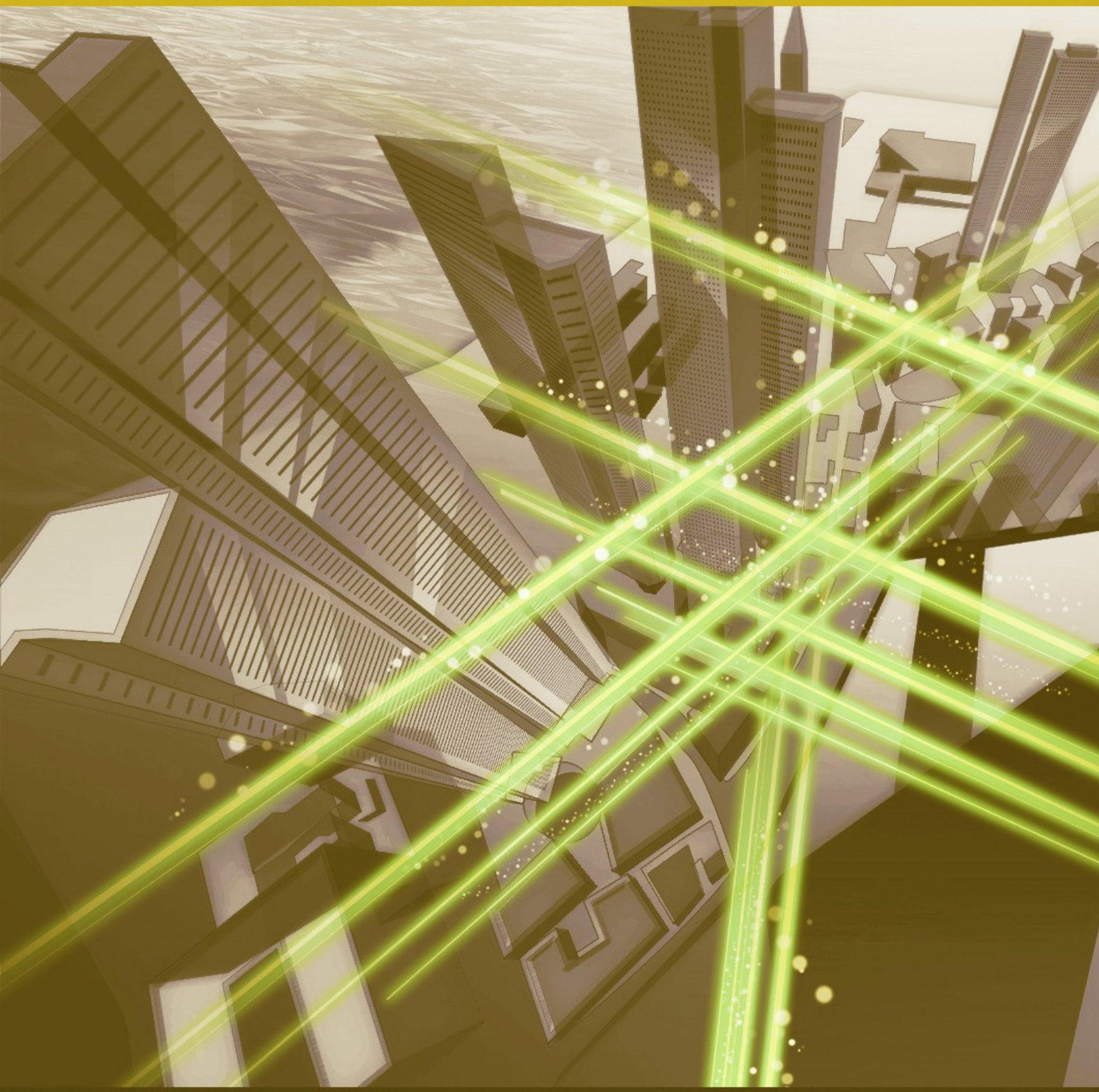

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Elucidating the Implicit Brain Functions that Enable Flexible Human Behavior

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Overview

Advances in information and communication technology (ICT) and artificial intelligence are transforming all areas of society. Brain science is no exception to this transformation, and rapid progress in this area is being made along with advances in measurement technology and analysis methods. Moreover, the subjects of brain research have spread to real-world problems. We asked NTT Fellow Makio Kashino of NTT Communication Science Laboratories what the objective is of the research termed "ICT × brain science" and how it will change our lives.

Keywords: sports brain science, implicit brain functions, autism spectrum disorder

Unravelling implicit brain functions

—First of all, could you tell us a little more about your research?

The research that has been consuming most of my time recently has been focused on sports brain science, which aims to clarify an athlete's brain function and improve his or her performance. I started to work on this research in earnest when the Sports Brain Science Project [1] was officially launched in January 2017. Exercise physiology and biomechanics were (and still are) the mainstream subjects, so our research was a peculiar addition to the field of sports research. My area of specialty was originally brain mechanisms such as hearing that are involved in perception and cognition [2], and I am continuing that research now. Several years ago, developmental disorders such as autism spectrum disorder (ASD) were also included in the study [3].

Although it may seem like I was putting up my hand in a very different field, within myself, I intended to base my research on a consistent awareness of issues. In general, humans can act extremely flexibly and adaptively in various environments and situations, and it is problem awareness that makes that ability possible. Recent progress in artificial intelligence (AI) has been remarkable; however, at present, it can be said that it only works for limited targets or situations. For example, within the specific rules of the board game *go*, a system that can beat a go master is completely useless elsewhere.

In contrast, people make a huge number of decisions and carry out various activities from the moment they wake up to the moment they go to bed. Even brushing one's teeth with the appropriate

pressure, running to the train station while avoiding cars and other people, and talking in noisy bars are actually extremely difficult when viewed as information-processing tasks. Nevertheless, the person performing those tasks doesn't feel as if he or she were doing anything difficult. That is, we are totally unaware, and we cannot explain why we can do such things. It is often difficult for AI to do things that human beings do unconsciously. So how does the brain enable a person to work on a very difficult information-processing task without trying hard? This is the problem awareness that prevails in each research theme.

One of the most sophisticated forms of such flexible human information processing is the performance of top athletes. In martial arts and ball games, the state of the bout or game changes rapidly, and while that's happening, it's necessary to achieve—in an instant—the optimum physical movement according to the situation on the spot, the behaviors of the opponent and the ball, and so on. Given the variety of situations, the required accuracy, and the shortness of time allowed, it is easy to imagine how difficult performing those tasks is. Top athletes achieve high performance as a result of solving those difficult tasks; it therefore follows that if we study their brain functions, we should reveal a concrete algorithm.

At the same time, the findings of such a study may also be useful to the athlete. The higher the level of the match or bout gets, the less likely it is that the result will be determined by physical ability alone. For example, in the case of professional baseball, there are some first-string players considered to be ace level even though their pitching speed is not very fast, while other players may get stuck with the second-string players even though they throw a good fast ball. Physical training alone is not enough to fill in this gap between these types of players, and cognitive training is essential. Establishing these methodologies specifically and systematically is one of the goals of our research on sports brain science.

Meanwhile, in contrast to top athletes, some people cannot easily do certain tasks that many people think can be done effortlessly. One group of such people consists of those with the developmental disorder ASD. ASD is caused by peculiarities of the innate brain function. It is characterized by the fact that a person with ASD cannot communicate with others well or that his or her interests and activities are significantly biased. The so-called "inability to read the situation," that is, the inability to speak or act according to the situation, or to panic in an unfamiliar situation, makes everyday life difficult for people with ASD. This condition may be related to the implicit brain function that adapts flexibly to various situations. Some ASD sufferers are very intelligent and may exert extraordinary abilities in certain areas. However, it is difficult for many of them to do things that other people can do roughly or unconsciously.

In some way, this state of affairs may be partly reminiscent to the current state of AI. If we study such an example, we will be able to clarify—from a different angle to that of the case of top athletes—the principle of achieving flexible behavior according to the situation. Of particular interest are the characteristics of the human sensory and motor systems. Some ASD sufferers are often troubled by hypersensitivity, such as feeling strong discomfort in the presence of certain sounds, or having the ability to hear sounds normally in a hearing test but not being able to hear a conversation in their daily environment.

Moreover, some of them show movement characteristics such as clumsy hands or very awkward movements. These facts indicate the possibility that the "body," namely, a device that takes in information from the outside world and outputs actions back to the outside world, plays an essential role in flexibly adapting to the situation. In this respect, research on ASD is linked to that on athletes. I think that linking research on those topics from now on will give us some hints for expanding the scope of the application of AI.

Understanding individuality and valuing diversity

—What kind of findings have been achieved in the research on sports brain science over the last two years?

I am currently conducting research focusing on baseball and softball. Thanks to the cooperation of professional baseball teams from Japan and the United States, semi-professional baseball teams, university baseball teams, the Japan Softball Association (Japan Women's National Team), and teams from the Japan Women's Softball League, we have gathered a considerable amount of data on top-level players (**Fig. 1**). Many parts of the data cannot be announced yet owing to contractual and other reasons, but the results of this cooperation are pretty exciting because the difference between top-level players and players that do not reach that level is clearly visible to a greater extent than we expected.

The use of devices such as wearable sensors, cameras, and radar makes it possible to measure the behavior of a person's body movement and biometric signals in a duel between a pitcher and a batter.

Fig. 1. Image of the smart bullpen.

As an example, I'll explain some research on batting in baseball and softball. In an actual game, the pitcher skillfully throws balls with various trajectories so that the batter cannot easily hit the ball. Unlike when a batter practices swings and hits with a batting tee, where it is usually only necessary to produce a fixed swing, hitting actual pitched balls requires a very flexible response. To reveal the details of this response, we conducted an experiment in which the pitcher randomly threw two kinds of balls at different ball speeds to the batter. The batter was instructed to hit the ball if the pitched ball was a *strike* (in the strike zone) and not to hit it if it was a *ball* (outside the strike zone).

The participants were women's softball players including ones representing Japan. The participants wore wearable sensors, enabling us to obtain data from their movements. Analysis of the batters' body movements clearly distinguished the batters who were able to adjust the timing of their bat swing in response to the speed of the ball from batters who could not do so (**Fig. 2**). It was estimated from the analysis results that in the former case, the timing of the batter's swing is determined on the basis of visual information (i.e., pitching form before and after release of the ball or the trajectory of the ball immediately after release) that was obtained about 0.1 seconds after the ball was released.

To further specify the visual information used for judgment, we used virtual reality (VR) to create a condition in which the information concerning the actually measured pitching form and that concerning ball trajectory were interchanged (as if a slowball (changeup) was pitched by a pitcher in the form of a fastball or vice versa), and after that informational interchange, we tried to measure the batter's behavior in the manner described.

Batters who were able to cope with the combination of information concerning the original pitching form and ball trajectory by varying their batting tempo became unable to cope when the combination of pitching form and ball trajectory was interchanged. This result is clear evidence that the batter who can respond at will to the ball uses the pitching-form information to predict the speed of the ball.

Even more interesting to us was the discovery that those batters were completely unaware of the fact that they were using information concerning pitching form. One of Japan's top batters said, "With this pitcher, I can't determine the type of ball from the pitching form." However, contrary to her words, the experimental result clearly showed that she was unconsciously aware of the difference in pitching form.

In this way, the true worth of our research is to reveal what people cannot consciously notice about themselves by using objective data. Consequently, we made full use of various kinds of information and communication technology such as wearable sensors, computer vision, biometric signal processing,

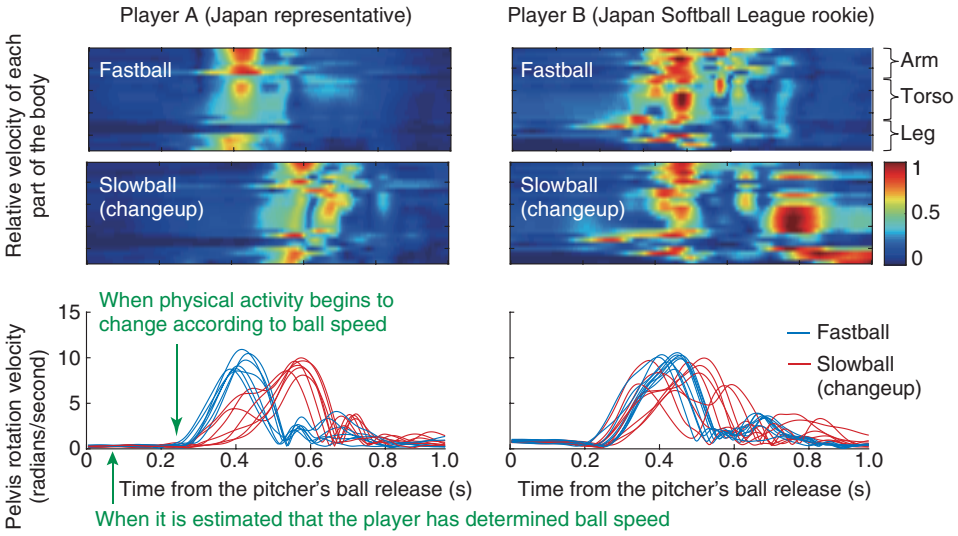

Fig. 2. Example of feature analysis of the physical movement of a batter.

machine learning, and VR and tried to estimate the state of the brain or mind from information that could be observed from the outside. The subjectivity of a person is important, but it is often the case that only having subjective information is not enough to reach the truth.

Through this kind of analysis, it has become possible to objectively understand what people have said in the past, for example, from the player's viewpoint, that something can be done somehow, and the body moves unconsciously, and from the coach's viewpoint, that a player has talent. It was also found that the performance of players in the above experiment, the index of coordination ability obtained in the experiment, and the batting averages in official games corresponded well. Furthermore, when we tried the same experiment with candidates for the under-14 (14 years old and under) Japanese national team, we learned that at that age, some players can already respond to different ball speeds, and some cannot. This means that the path to evaluating players and discovering talent based on objective data is being opened up.

—It feels harsh to be declared "talentless" at a younger age.

That is often said. However, I think it's rather the opposite. That is to say, whether a player is superior or inferior is persistently evaluated on a certain axis, and in fact, there are many such evaluation axes for athletes. It is important to know exactly what profile a player has in relation to many evaluation axes. There is more than one ideal type of batter.

According to the player's profile, the player can try to maximize their strengths and overcome their weaknesses. For example, a certain women's softball player was very successful as a long-distance hitter right up through high school; however, she has not yet become a regular in the Japan Women's Softball League. She boasts the best swing speed of the team when hitting at a batting tee. However, in a mixed-ball (slowballs and fastballs) experiment, her average hitting speed was in the slow category. In other words, if she faces a good pitcher, she will not be able to swing fast enough to hit the ball. Analysis revealed that she was unable to determine the type of ball from visual information from the start. That is, she can try to determine the type of ball, but no matter how much she practices swinging the bat, the practice will not be effective.

Alternatively, as another approach, it might be better to give up on unconsciously determining the type of ball and instead try to improve the ability to *read* the game situation and swing only at certain types of pitches. She shouldn't worry if her reading is off and she swings and misses. As far as the pitcher is concerned, it is far worse to give up a home run. In fact, even some of the best players are ones who swing only at certain types of pitches.

The challenge for coaches is to provide uniform instruction while ignoring individual profiles. If the

player doesn't train according to his or her aptitude, the training might be ineffective and even worse, it might ruin the player's potential. However, under the current state of affairs, the profiles of individual players at the top level are not accurately understood, and it seems that coaches often give subjective guidance based on their past playing experience. If coaches and players play differently, or the type of brain processing behind the way they play differs, they may not share images in their minds and may not even understand what each other is saying. After all, even a good player doesn't really know why he or she can play the way they do. Good use of objective data will help fill those gaps.

Research on sports and ASD is, ultimately, a study of human diversity. The more I study, the more I realize that there are many types and subtypes of physical and cognitive aspects. In contrast, from the traditional viewpoint of human beings, which also applies to basic research in brain science, there has been an assumption of a "standard" human being, with individual differences considered as variations from that standard. That is, there was an implicit premise for understanding individual differences as the mean and variance of normal distributions. This way of thinking tends to lead to valuing the majority or judging value on a particular axis.

However, even the same characteristics can have advantages and disadvantages depending on the goal and environment. Although the idea of curbing individual diversity and approaching a "standard" (i.e., the majority) is becoming prevalent everywhere, it needs to be given caution. In any field, having a multidimensional and objective understanding of characteristics is the starting point of understanding the difficulties faced by the minority and enabling them to maximize their individuality. Once the starting point and goal to be achieved by a person are defined, he or she should be able to see a way to solve a problem. I hope our research will be able to help people solve problems and achieve their goals in any situation.

—What was the trigger for your journey as a researcher?

My father taught organic chemistry at a university, and when I was in primary school, I lived in an official residence on the university campus, so the daily life I observed was the life of a researcher. I chose to be a researcher as a profession without any particular reason; I just thought that's the way it was. To be honest, I just couldn't picture myself working in a company, doing business with customers, or any other profession. I've been interested in a wide range of topics such as insects, astronomy, architecture, and archeology from an early age, and I get the feeling that I arrived here by being guided by my interests at the time.

I am interested in hearing because for as long as I can remember, listening to sounds has aroused strong emotions in me. For example, when I was little, I picked up vacuum tubes from discarded televisions and stereos and threw them onto the concrete surface, and when they shattered, I felt unbelievable pleasure from the sound they made. In contrast, I felt tremendous fear when I hit the bass keys on a piano keyboard. Moreover, I was very fond of Japanese popular songs for adult audiences, and listening to certain songs made me shiver inside. I used to wonder if other people felt the same way when they listened to music.

In elementary school and junior high school, I made my own radio and audio equipment to listen to music. I wasn't taught by anyone, and the parts I used came from broken televisions and other appliances. Gradually, through trial and error, I naturally learned the basics of experimenting and measurement as well as the theories of electricity and sound. I think that my attitude rather than the knowledge that I acquired through that process is the basis of my research up until now.

Some of my favorite reads at that time were the Japanese and Chinese classics. In particular, I read essays such as "Tsurezuregusa" and "Hojoki," military tales such as "The Tale of the Heike" and "Taiheiki," as well as those from "The Hundred Schools of Thought," and it was the ancient Chinese philosopher Zhuang Zhou who particularly affected me. On reading many fables such as "The Butterfly Dream" and "The Death of Chaos," I was reminded of the limit of human recognition as well as epistemological problem awareness, such as the concept that the world in front of our eyes is not actually as steadfast as we naturally think. It is dangerous to believe in a single viewpoint and set of values, and yet it is impossible to completely recognize all viewpoints and values. So what should we do? Such questions are always on my mind.

When deciding my major in the third year of university, I chose the field of hearing because that field is where my interest in sound, epistemological problem awareness, and methodology of experiments intersected. However, that does not mean that professors

who specialized in hearing were teaching at the university. Although I learned the basics from professors in fields such as vision and neurophysiology, and also from mathematical models, I had no choice but to manage on my own in regard to what and how to study hearing.

Nevertheless, everything I learnt originally came in a trial-and-error manner in my own way, and I didn't really like being lectured to very much, so I considered this environment rather cozy. That being the case, I think I took many detours. If I had selected my area of expertise in a laboratory with a lot of talented leaders from the beginning, I could have efficiently studied core themes of the research community by using advanced methodologies, and I would have published more papers. Since that was not the case, it might have made me somewhat unique. Even in everyday life, I rarely enter a shop if there is a line of people waiting outside; that is my personal nature, which is both good and bad.

Follow one's own interests and nature's providence, and do not overstate the social value of research.

—You have focused on your interests and unique character. Finally, please give us your message for researchers.

People around me often find me amazed when things such as life's most important matters are easily taken for granted. In the same manner, I changed my major to another research field; accordingly, the methodology and knowledge that I had cultivated up to that point and the results and personal connections I had accumulated in the research community often got reset. I'm often asked how I can take such risks (like losing what I cultivated by changing majors) or am told I'm very decisive. To be honest, I'm not thinking like that at all. It is more accurate to say that I cannot think like that. I lack the ability to worry about the future, and I only focus on my current interest and problem awareness. I think people would be unhappy to end up doing things that they are not interested in as a result of thinking too much.

I cannot say that I'm able to read every situation or other people's feelings well. Because I belong to an organization, I should probably compromise and accept situations where I'm not completely satisfied; however, I am lucky to be in a work environment in which I was able from the beginning to get involved in basic research and my approach was accepted. If a standard for judging the "goodness" or "badness" of what you are doing exists, the only question is whether it suits the providence of nature. Although judging the value of a certain matter may change according to the situation and standpoint, being suitable for natural reasons remains until the end. I think that basic research is that which does not go against the laws of nature.

As long as you are engaged in work for which you receive research expenses and are provided with a research environment, human resources, etc. (in other words, you are not just pursuing a personal hobby), it will naturally be necessary to explain what kind of value that work brings to society. When I explain that value to society, what I most care about is not to overstate the value. That is different from fabrication of data, which is also bad.

Overstating the value means, for example, in the introduction of research proposals, etc., writing "This is useful for such things" without proper grounds. There are some papers written with statements like "for the elderly" or "for disabled persons," without knowing the real problems faced by those people and there are also papers that have a huge leap between what is said to be useful and specific research contents. I try to listen to the words of athletes and ASD sufferers as much as possible so as not to exaggerate my research's value. That is why we have narrowed the scope of our research to some extent. By listening to people carefully, we will find real problems and find ways to dig deep and solve them as basic research. Because our research can affect the lives of athletes and ASD sufferers, the above-mentioned process or the results achieved by the process cannot be neglected. And if research findings are truly valuable, people will recognize that, and business opportunities will be created accordingly.

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■ **Interviewee profile**
Makio Kashino
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He received a B.A., M.A., and Ph.D. in psychophysics from the University of Tokyo in 1987, 1989, and 2000. He joined NTT in 1989. From 1992 to 1993, he was a visiting scientist at the University of Wisconsin (Prof. Richard Warren's laboratory), USA. He is currently a specially appointed professor in the School of Engineering at Tokyo Institute of Technology. He has been investigating functional and neural mechanisms of human cognition, especially auditory perception, cross-modal and sensorimotor interaction, and body-mind interaction. More information can be found at http://www.kecl.ntt.co.jp/people/kashino.makio/.

Technology for Smart Coordination of ICT/Network Resources and Services

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Abstract

In the near future, things and applications will be connected across companies and industries to help people enjoy new innovative services. This article introduces technology for coordinating ICT (information and communication technology)/network resources and services to help us prepare things and applications only as needed.

Keywords: orchestration, AI, IoT

1. Introduction

Service providers in various industries are developing their own things and applications in order to launch new services powered by the Internet of Things (IoT) and artificial intelligence (AI). By *things*, we mean all kinds of objects such as sensors, devices, and others covered in the IoT. In the near future, service providers will be combining various things and applications provided across different companies/industries to make their services more innovative. To support those service providers, we are developing a new information and communication technology (ICT) platform for reusable things and applications (**Fig. 1**). Our aim is to enable service providers to easily select resources only as needed. A coordination mechanism is necessary to do this. We call this *smart coordination*.

As shown in Fig. 1, the smart coordination platform has two technical features (directions): (1) flexibility and (2) intelligence. For the first feature (flexibility), there will be various use cases when combining services. This refers to when we need flexibility to accommodate a huge number of different cases. The key features are a coordinated operation function and an advanced assurance function. The coordinated operation function provides one-stop service building to easily deploy things and applications. The architecture including this function can handle increasing amounts of data and diverse demands for various services. The latter function (advanced assurance function) will support the coordinated operation function. Operation processes are modularized by this assurance function to flexibly meet users' needs.

The second feature (intelligence) involves applying AI technologies to provide more attractive services. AI can support an optimal combination of services to meet the requirements of large numbers of users. AI also provides an environment in which services are optimally configured and executed to meet each user's situation.

2. Research and development (R&D) of flexibility and automation

Our objective is to develop technology enabling flexibility and automation of functions. In this section, we explain some of the R&D that is being

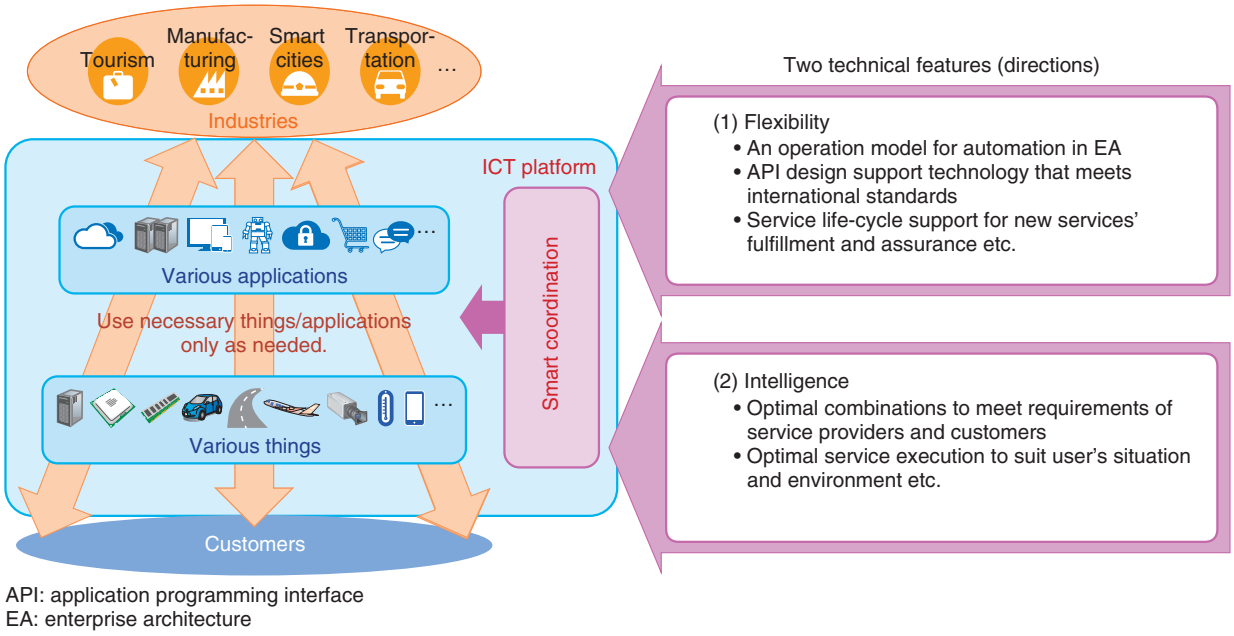


Fig. 1. Future of ICT platform and its technical features.

carried out to achieve this.

2.1 Catalog-driven orchestration and operation model

Service providers have been taking it upon themselves to combine existing resources/functions in order to build services. However, to accelerate rapid service development (namely cloud-first), such a conventional style should be changed. In fact, resources and functions are publicly available as application programming interfaces (APIs). Service providers can thus combine them to provide a new service (federated service, hereinafter).

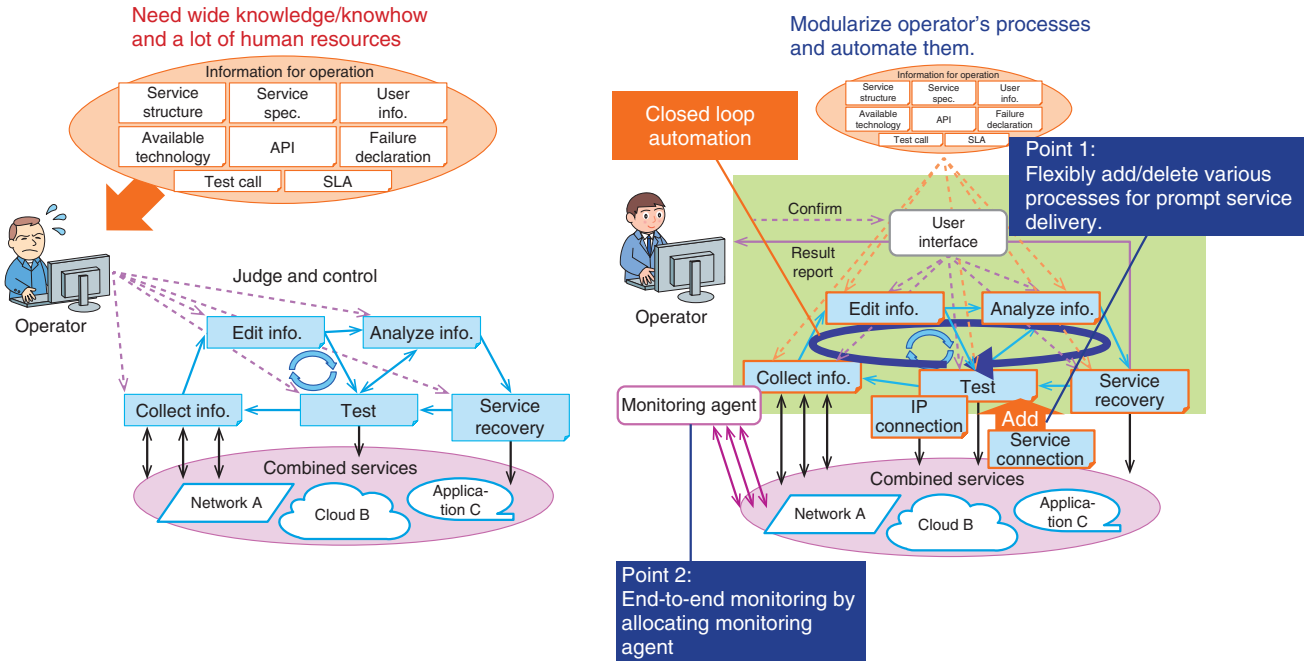
For service providers or resource providers who are trying to provide a federated service, easy coordination of various resources/functions in the federated service will be necessary to meet users' needs. Such federated services are built upon many configurations. Therefore, we have made use of a current catalog-driven orchestration technology [1]. This technology simplifies configuration in the form of a catalog and coordinates various resources/functions flexibly. We set public cloud services and mobile services as our target for one-stop configuration using commercially available APIs. We conducted a proof of concept in Las Vegas, USA, in 2018 as the result of our research [1]. Part of the artifact was used for one-stop building of the services environment.

Automation of operation will also be necessary for on-demand provision of resources/functions. Even though automation technologies are already widespread in cloud service operation, network service operation is not yet sufficiently automated. However, there are concerns that automation will have an impact on many existing systems in networks. The emergence of virtualization techniques such as software-defined networking to address such concerns is gaining attention because virtualization enables on-demand equipment provision. Thus, our ICT platform uses such a virtualization technique for automation of operations.

Regarding automation, we are also studying business processes for service management, order management, and customer management. For automation of various business processes, we need to define an operation model of the business process and the relationships between the operation function APIs. TM Forum [2] has been leveraging the trend in increased use of APIs and redefining business processes, data models, and functions. We are taking such standardization and market trends into consideration as we carry out our research on the operation model.

2.2 API design support technology

As we study operation function APIs, we are also taking the use of public APIs into consideration. In



(a) In the past

(b) One step ahead

SLA: service level agreement

Fig. 2. Advancement of service operation.

public APIs, request/response description rules and authentication methods are often different for each service provider. This complexity of API specifications is confusing for service providers. If there are no rules for API descriptions, the API designs can become confusing. Therefore, we are developing API description rules by taking industry standards into account.

In addition to such rules, we are developing a function to check whether a designed API conforms to the API description rules. We used the Swagger Specification [3], which is widely used for API specification description, to implement a method of generating a template in which service providers only need to answer some simple questions.

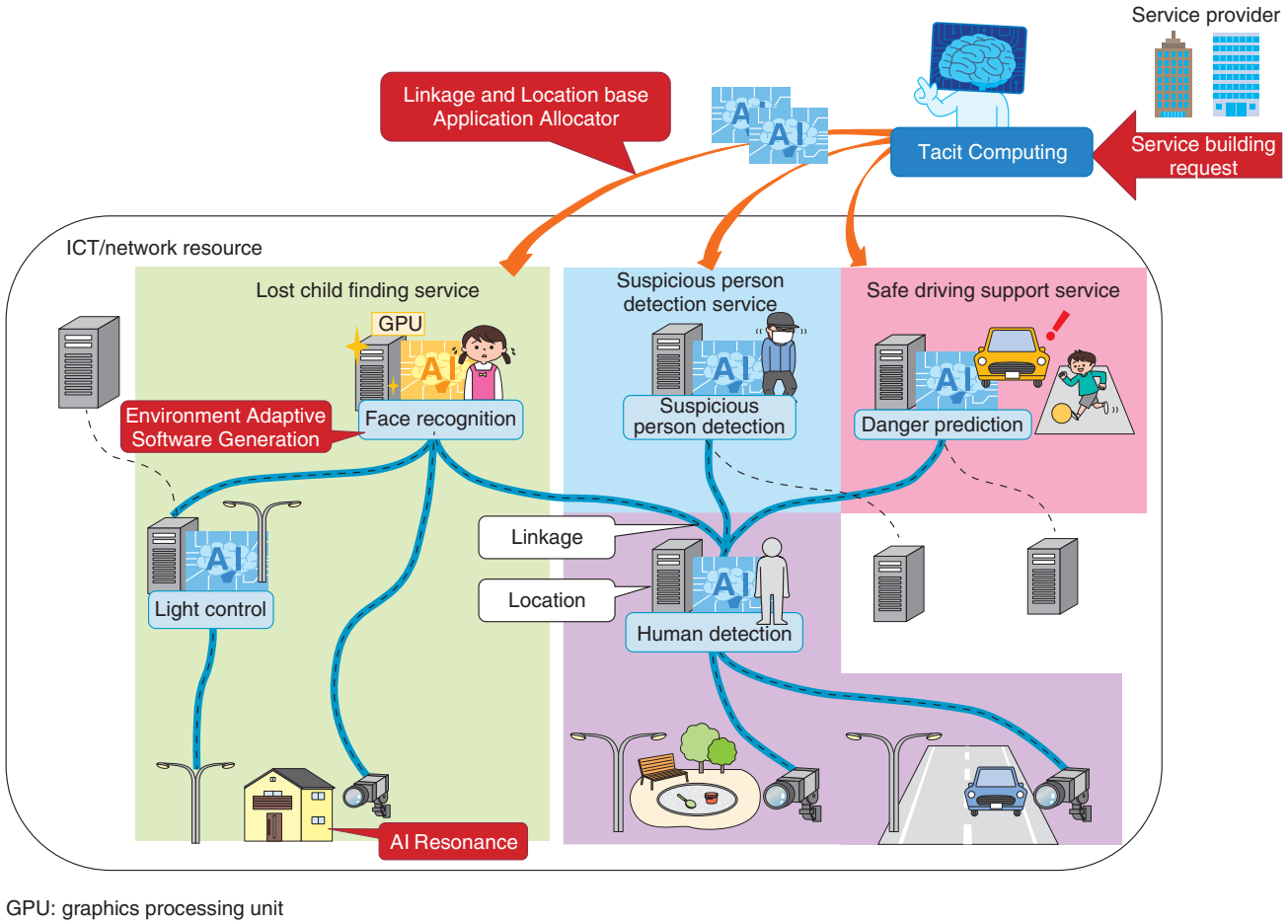
2.3 Advanced assurance function

When a service provider creates a federated service, a huge burden is placed on the operation personnel. This is because the operation personnel need to understand the relations of multiple resources/functions that constitute the federated service (**Fig. 2(a)**). Thus, assurance automation is important. Among various automation technologies, we have paid much attention to closed loop [4]. This refers to a loop of processes that ensures that services follow a specific sequence of steps: (1) collect and manage information on the operation status of wholesale services, → (2) analyze the collected information and make decisions, → (3) control wholesale services, → return to (1) and repeat.

A service use case includes such a closed-loop process. Providing a federated service means that many individual event cases are to be supported. For individual event cases, one closed loop might be needed. Consequently, assurance automation for a federated service requires the same number of closed loops as there are event cases. Furthermore, closed loops will also be needed for various service use cases, which would lead to many closed loops. Designing such a huge number of closed loops one by one is too laborious and time-consuming to be feasible.

To solve this problem and facilitate new service creation, as shown in **Fig. 2(b)**, we have been researching an advanced assurance function technology that can automate the processes operators use in a federated service. There are two points of this technology.

The first point is architecture. The architecture includes modularized assurance functions that autonomously judge and share information among other



GPU: graphics processing unit

Fig. 3. Tacit Computing.

functions via messaging. For example, this enables us to add new assurance tasks to existing closed loops without designing a new closed loop. It can also support a wide variety of assurance processes of each federated service.

The second point is enhancement of monitoring technology. The study of the architecture described above revealed that collecting as much information as possible is most essential for closed loop automation. Information on network/cloud services has often been published via an API recently, but this is not enough information to identify the cause of failures. To solve this problem, the monitoring technology allocates an agent that collects detailed information such as flow information of each user. Therefore, it can add new types of information for analysis and judgement. Thus, we enable end-to-end monitoring of federated services that combine resources/applications of different service providers.

3. R&D on intelligence

We have been developing Tacit Computing to provide sophisticated services. Tacit Computing is a generic name for IoT and AI service technologies produced by NTT Network Service Systems Laboratories. Certain functions are necessary to build services by combining devices, computers, and software on demand. Such functions need to grasp the status of these components in real time, match them with service requirements, and coordinate them properly.

To implement such functions, we have been developing a means of automatic device behavior analysis [5] to automatically identify the types and models of devices in the network. We have also been developing three elemental technologies for building service systems by appropriately combining devices and software (**Fig. 3**). We introduce these three elemental technologies in this section.

3.1 Linkage and Location base Application Allocator

The Linkage and Location base Application Allocator is technology for selecting appropriate devices, software, and a network from many candidates in order to build services. To guarantee the quality of service, a large number of services must use devices, computers, and networks at the same time without overloading them. This technology can find what data and processing are common to multiple services. Then it aggregates them to make the overall processing more efficient. Furthermore, it selects the appropriate computer's location for each processing step based on network bandwidth, transmission delay, and service characteristics. For example, when the allocator executes a suspicious person detection service and a lost child finding service at the same time, it can extract images of people, which is a common processing function of both services. Then the detection is efficiently executed on one computer near the camera.

3.2 AI Resonance

AI Resonance is technology that automatically coordinates multiple devices and software programs upon request. To build a service, it is necessary to choose appropriate settings that suit the type of device, its location, and software. For example, let us assume an outdoor lost child finding service that consists of a camera and a nighttime light. The light intensity should be suitable for video analysis depending on the location and the software. The conventional way is to manually set the appropriate settings. However, we can assume that this will be impossible in the future because the combination of devices and software will be enormous and will dynamically change.

To solve this problem, the technology automatically evaluates an operation result of the device and applies the appropriate setting in real time. For example, in a lost child finding service, lights that can make camera images clear are automatically selected from the network and adjusted to the appropriate intensity. The technology eliminates the need for service providers to carry out manual design settings and adjustments and also enables the provision of multi-device services on demand.

3.3 Environment Adaptive Software Generation

Environment Adaptive Software Generation is technology that automatically optimizes source code depending on the hardware specifications. Some computers in the network have special hardware such as a graphics processing unit (GPU) or field programmable gate array. To produce sophisticated services, it is necessary to demonstrate high performance regardless of the computer that is selected as the software execution environment. This technology automatically converts the source code into the appropriate code for the execution environment from the viewpoint of performance. As an example, we confirmed that the technology automatically found the part of a code that was suitable for the GPU in video analysis software. The automatically generated program performed about four times faster than the original program for the central processing unit. In the future, we aim to adapt it to various types of hardware such as IoT devices and quantum computers.

4. Future work

In this article, we introduced two features to achieve smart coordination of ICT/network resources and services. The first is the architecture of the coordinated operation function that has flexibility and intelligence. The other is the advanced assurance function. The development of these features contributes to a value-added solution for the ICT platform. In the future, we will also continue to develop Tacit Computing for resource selection and configuration automation. Then we will expand its application to various IoT resources and services.

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Failure Point Estimation Using Rule-based Learning

Naomi Murata, Fumika Asai, Taisuke Yakawa, Satoshi Suzuki, Haruo Oishi, and Akira Inoue

Abstract

NTT Access Network Service Systems Laboratories aims to achieve smart and advanced network operations supporting the digital transformation of the NTT Group. This article introduces a means of failure point estimation using rule-based learning that immediately presents potential failure points at the time of a failure. This estimation technique is based on technology for autonomously deriving cause-and-effect relationships (rules) between failure points and alarms.

Keywords: rule-based learning, failure point estimation, Network-AI

1. Introduction

The occurrence of a failure in a large-scale network generates many alarms. A skilled maintenance operator must then analyze the large number of alarms and isolate the failure point by testing or other means. We are researching and developing failure point estimation technology using rule-based learning with the aim of shortening this analysis and troubleshooting work and reducing the burden of carrying out maintenance tasks through prompt failure recovery (**Fig. 1**). The use of this technology is expected to lead to reduced operating expenses.

2. Failure point estimation using rule-based learning

In this section, we describe the key features of our failure point estimation technology.

2.1 Reduction of operator analysis/troubleshooting work

Failure point estimation using rule-based learning is technology based on decision-making using rules. A *rule* is an *if-then* construct that expresses a conclusion derived when a certain condition holds in the form of "*if* condition *then* conclusion." When such rules are applied to network failures, a rule is defined with the *if* portion designating a combination of events (event group) such as alarms and log information originating in network equipment at the time of a

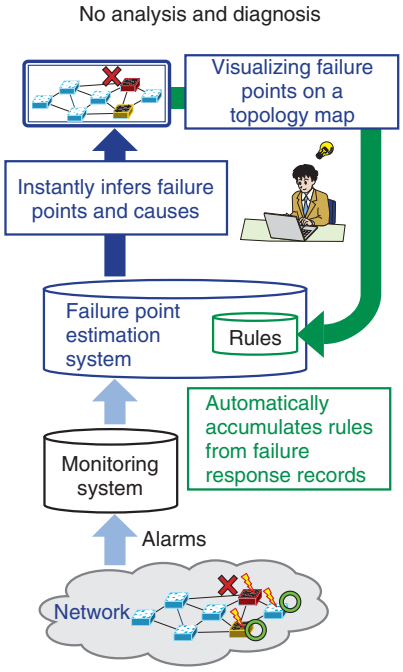

Fig. 1. Prompt recovery from failure.

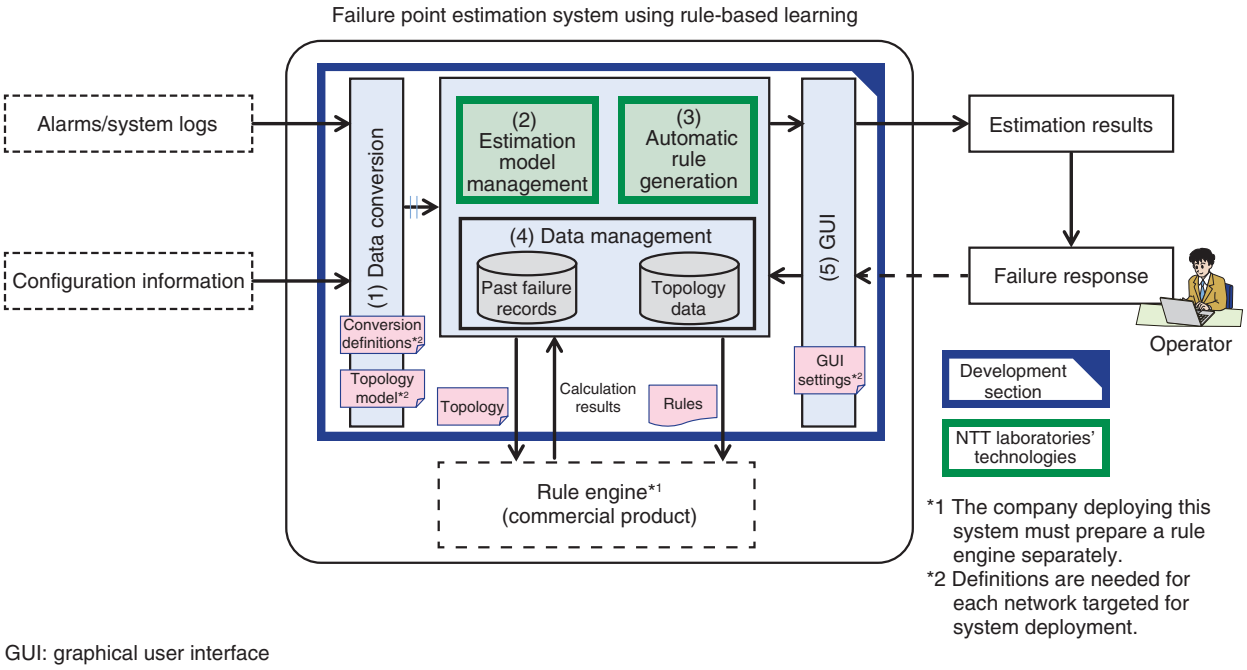

Fig. 2. Failure point estimation system using rule-based learning.

failure, and the *then* portion designating the cause and location of that failure. When a failure occurs, comparing alarm conditions with such rules enables efficient derivation of points (candidates) in the network causing that failure. A maintenance operator can then mount a response to that failure based on the failure point candidates derived. This reduces the workload associated with time-consuming alarm analysis and troubleshooting-related diagnosis while offering the potential of failure response independent of operator skills.

2.2 Systemization

We constructed a failure point estimation system using rule-based learning with high accuracy by combining this technology with a commercially available rule engine (an engine that performs processing based on *if-then* rules), as shown in **Fig. 2**. This system maintains configuration information targeted for management as topology data in a data format that the system can analyze. At the time of a failure in the target environment, the system processes an event group consisting of alarm and log data as input data and presents the operator with the results of estimating failure points based on rules. If no rules corresponding to the current failure case have been registered, the operator can input information on the correct cause of failure through a graphical user interface, thereby saving that case as an example of a past failure ready for rule learning.

Here, rule learning not only serves to add a new rule but also to use added rules as a basis to examine whether all stored failure examples from the past can be used to make correct judgments on current failures. Past failure examples include an event group made up of alarm and log data plus the cause and point of failure for each failure case. Since the know-how of maintenance operators who perform actual failure analysis and troubleshooting is learned in the form of rules, this system can also contribute to the conversion of failure-response actions (operator know-how) into knowledge.

3. Future outlook

Going forward, we plan to study ways of improving the accuracy of failure point estimation by using enhanced learning algorithms and to expand the application scope of the proposed technology.

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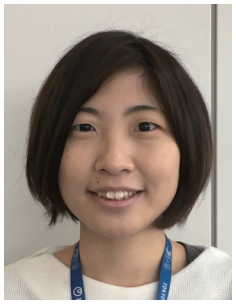

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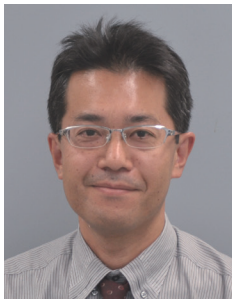

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Deep Learning Based Anomaly Detection Technology for ICT Services—DeAnoS: Deep Anomaly Surveillance

Keishiro Watanabe, Kengo Tajiri, and Yuusuke Nakano

Abstract

In this article, we outline a deep learning based anomaly detection technology called Deep Anomaly Surveillance (DeAnoS). The NTT laboratories have been developing this technology with the aim of enabling proactive maintenance operations for ICT (information and communication technology) services. The present situation regarding verification of DeAnoS at NTT Group companies is also explained.

Keywords: Network-AI, network and service operations, anomaly detection

1. Introduction

NTT Network Technology Laboratories is developing a deep learning based anomaly detection technology called Deep Anomaly Surveillance (DeAnoS), which utilizes an autoencoder (AE) to promptly detect changes in the state of an ICT (information and communication technology) service [1–3]. In this article, we explain the technical issues concerning DeAnoS, which was exhibited at NTT R&D Forum 2018 Autumn held in November 2018.

2. Overview of DeAnoS

An AE, as used in DeAnoS, is a type of deep learning based neural network that enables the learning of complicated structures inherent in data. Attention is now being focused on the use of AEs in technology for detecting anomalies. When an AE is used, the dimensionality of data in the middle layer of the AE is reduced by setting the dimensionality of the middle layer to be less than that of the input and output layers and by learning the parameters for reproducing the data of the input layer in the output layer. Anomaly detection using an AE is based on the premise that normal data are distributed in the input-data space around certain manifolds that can express low dimensions. Specifically, as shown in **Fig. 1**, at the time of learning, a *normal* state is learned by using various kinds of data observed during normal operation of the system, and at the time of the test (i.e., anomaly detection), the current data are input to the AE that has learned the normal state as described above, and the distance between vectors of the input and output layers is output as the anomaly degree. When the degree of anomaly exceeds the threshold, the state is detected as an anomaly.

In addition to numerical data such as resource and traffic information based on SNMP (Simple Network Management Protocol)/MIB (Management Information Base) and flow data based on Netflow, the network data to be entered also include the syslog of routers and servers (text information). With text logs such as syslog, identifiers (IDs) are created by using syslog-analysis technology [4] for each syslog line, and the text log is converted to numerical data by using the appearance frequency of each ID. This process enables learning of information including syslog.

We are also working on not only detecting anomalies

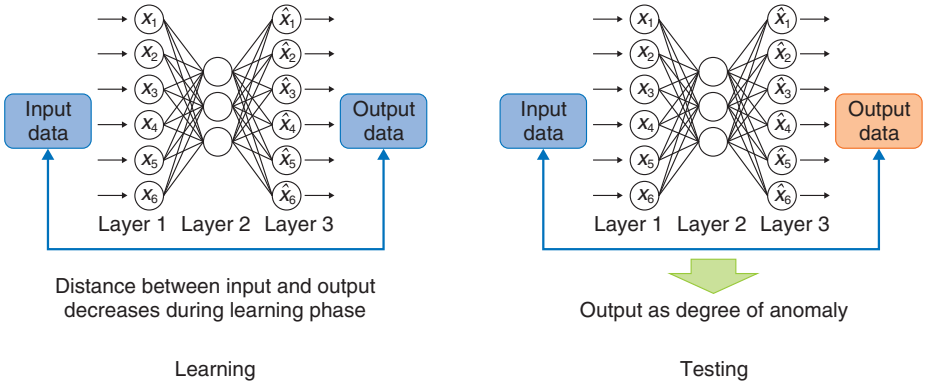
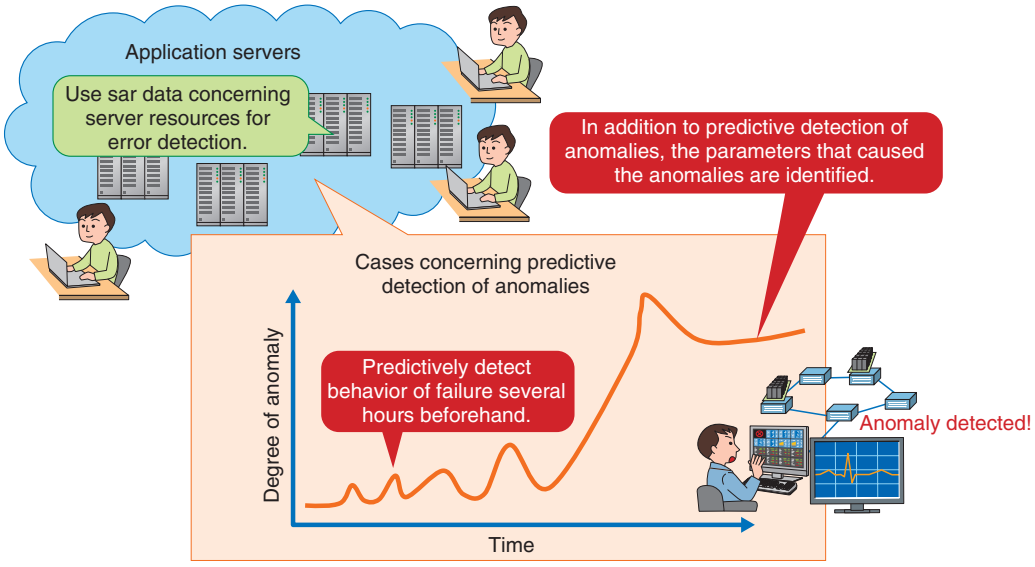


Fig. 1. How an AE works.



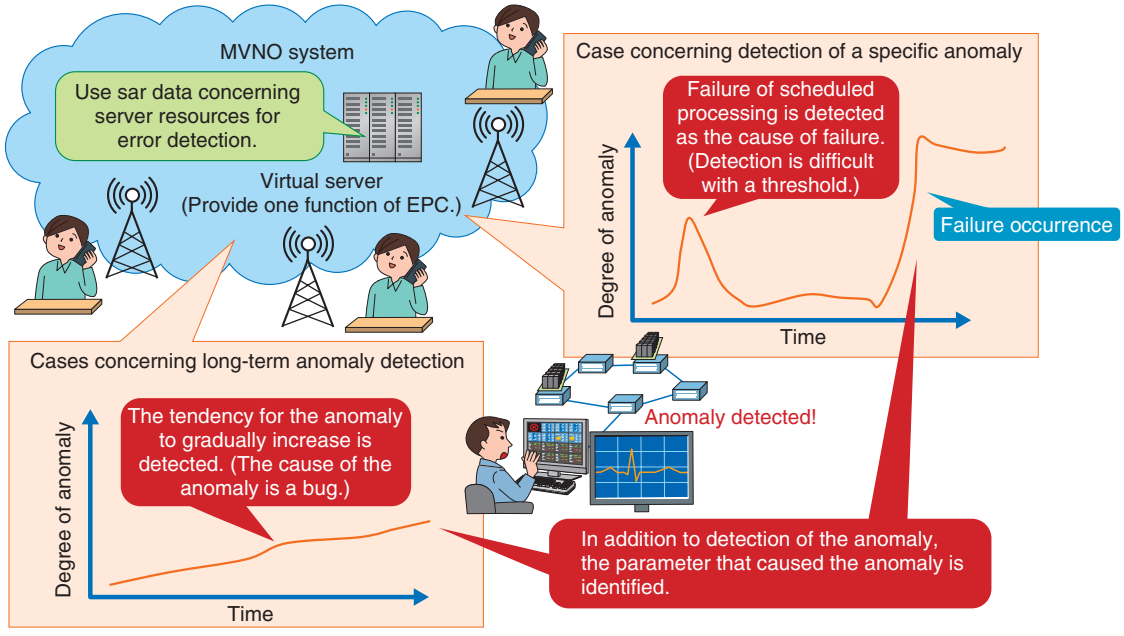
sar: system admin reporter

Fig. 2. Initiative with Strategic Network Management Department of NTT EAST.

but also estimating their cause at the time they are detected [5, 6]. Specifically, we are investigating a method using sparse optimization for estimating which input dimension causes the anomaly degree to become higher when an anomaly is detected by the AE. With this technology, the degree of contribution of each input dimension to the degree of anomaly is calculated; accordingly, it is expected to improve the efficiency of investigation after detection of anomalies.

3. Status of verification of DeAnoS at NTT Group companies

In cooperation with NTT Group companies, we are presently verifying DeAnoS on the basis of operational data acquired from actual services, and we are assessing the effectiveness of this technology and extracting the issues for practical use. Our initiatives with the Strategic Network Management Department of NTT EAST and the Network Services Department of NTT Communications are shown in **Figs. 2** and **3**, respectively. First, in cooperation with the Strategic



EPC: evolved packet core
MVNO: mobile virtual network operator

Fig. 3. Initiative with Network Services Department of NTT Communications.

Network Management Department of NTT EAST, we confirmed the effectiveness of DeAnoS in detecting anomalies in application servers and estimating the parameters that caused them. Second, in an initiative with the Network Services Department of NTT Communications, we confirmed a case in which it was possible to estimate the causal parameter in addition to detecting the anomaly by analyzing changes in specific events and long-term trends.

4. Future prospects

In this article, the deep learning based technology DeAnoS, which NTT Network Technology Laboratories has been developing, was outlined, and the situation regarding its verification at NTT Group companies concerning network-anomaly detection technology was described. We will continue to fine tune DeAnoS by proceeding with its technology verification with the aforementioned companies and improve the environment for utilizing DeAnoS in the real world. Future tasks regarding technology for detecting network anomalies are to (i) improve the interpretability of main causes when an anomaly is detected and (ii) adapt such technology to various environments. Accordingly, we will continue our research and development to address those issues.

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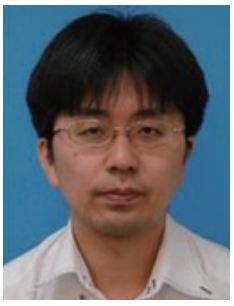

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Automatic Generation of Recovery-command Sequences

Takehiro Kawata, Yoichi Matsuo, Hiroki Ikeuchi, and Yuka Hashimoto

Abstract

We describe technology for automatically generating recovery-command sequences, which is intended to support quick recovery actions by system operators and to achieve automatic recovery from ICT (information and communication technology)-system failures.

Keywords: recovery-command sequence, seq2seq, automation

1. Introduction

In current large-scale ICT (information and communication technology) systems, troubleshooting has become more complicated due to the diversification of the causes of network failures. The increase in operational costs has also become a serious problem. We are developing technology for automatic generation of recovery-command sequences that is designed to help system operators recover from failures quickly and achieve automated recovery operations [1].

2. Overview of technology

An overview of our technology is shown in **Fig. 1**. Sequences of recovery commands are estimated by using a sequence-to-sequence technique (seq2seq) [2], which is a neural-network model that learns the relationship between an input sequence and an output sequence (**Fig. 2**).

Seq2seq is widely used in translation systems and dialog tasks. In our technology, we use a sequence that consists of a series of log identifiers (IDs) as an input sequence. The log IDs are generated by associating system logs and alarms related to system failures with unique numbers [3]. We also use a sequence of words that consists of a recovery-command sequence as an output sequence. Learning the relationship between the input sequence and the output sequence makes it possible to estimate a command sequence that will restore the system when a new failure occurs.

When the command sequence estimated in this method is executed, it is necessary to measure the reliability of the estimation and the impact on the system of the command sequence. In our technology, we define the reliability of a command sequence by multiplying the generated probabilities of each word that composes the recovery-command sequence. Thus, the reliability can be regarded as a probability of the system recovery when the obtained command sequence is executed. Moreover, we can define the impact on the system by using the information about the impact on performance of the system when recovery-command sequences were executed in past failures. These indicators (i.e., reliability and impact) can be used to decide whether to execute the obtained command sequence.

3. Future work

We will continue to work on verifying our technology by using data obtained from commercial systems and improving the accuracy of the estimated recovery-command sequences. We will also improve the definitions of the reliability and the impact from the viewpoint of practical system operation to achieve automated recovery operations.

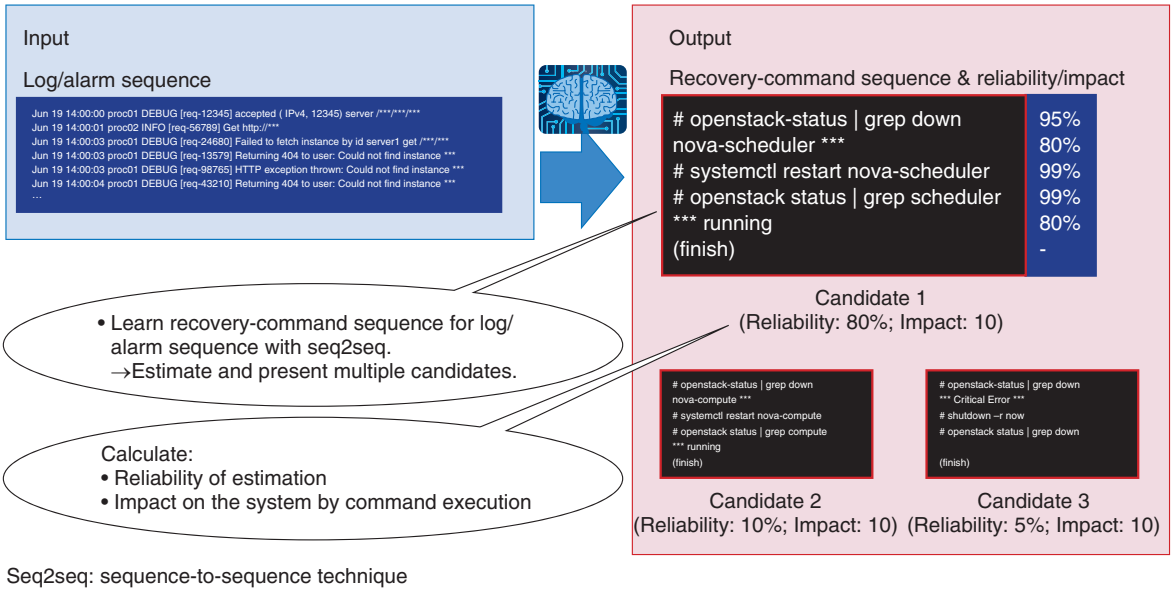

Fig. 1. Outline of automatic generation of recovery-command sequences.

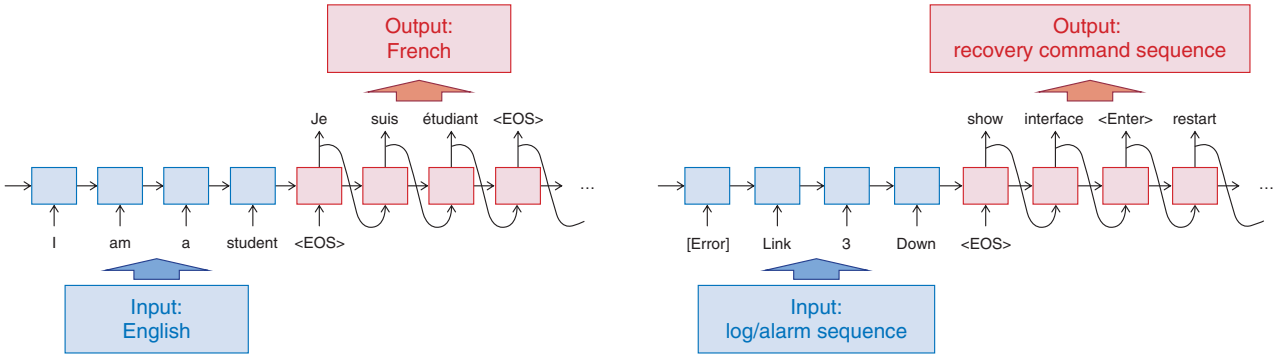

Fig. 2. Estimation by seq2seq.

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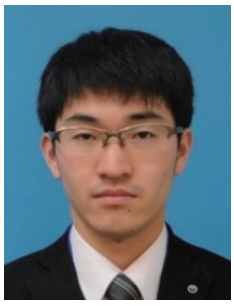

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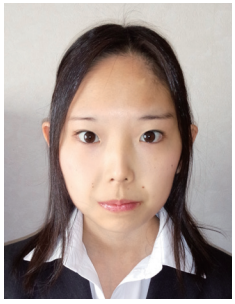

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Failure Localization in Optical Transmission Networks

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Abstract

The core network is the backbone of society's telecommunications infrastructure, and it therefore requires rapid failure localization in order to handle diverse types of failures. This article introduces a failure localization method being studied by NTT Network Service Systems Laboratories in collaboration with an NTT Group company.

Keywords: core network, failure localization, optical parameters

1. Introduction

The core network continues to increase in capacity to support a wide variety of services, and consequently, rapid failure localization is necessary when a failure occurs. The traditional role of the network operator has been to understand signal quality within the network by monitoring alarms issued by transmission equipment and performance monitor (PM) information, to identify the failure location based on that information whenever a failure occurs, and to carry out facility restoration.

However, there are times when isolating the location of a failure from alarms and PM information can be difficult. For example, if the mechanism that adjusts the optical power of wavelength division multiplexing signals for each optical path should fail, the optical power of a certain optical path may increase. This increase in optical power on that path can intensify the nonlinear effects of the optical fiber and degrade signal quality, which can spread to other optical paths propagating along the same optical fiber. This degradation in signal quality can be detected at a transponder (TRPD) where optical signals terminate, but since the site that raises the alarm differs from the actual location of the failure, time is needed to determine the failure's impact and to troubleshoot the cause, and even more time is needed to completely restore facilities.

2. Failure localization method

NTT Network Service Systems Laboratories in cooperation with an NTT Group company is studying a method to enable rapid failure localization based on actual examples of anomalies and major failures. The proposed failure localization method is overviewed in **Fig. 1**. We envision the case in which transmission equipment implementing the optical power adjustment mechanism has failed within one of NTT's many central offices making up the core network. First, in Step 1, a failure is detected based on temporal degradation in signal quality as monitored by a TRPD. Next, the correlation between signal quality and high-resolution time-series data of optical parameters is analyzed. These parameters include phase, amplitude, frequency, and polarization, which are newly monitored using this method.

The correlation analysis is done to identify which parameters are contributing to the degradation in signal quality. Since the optical parameters are related to the state of transmission links, this information can be used to infer the cause of failure. The result of Step 1 (inference result) is forwarded to the network control

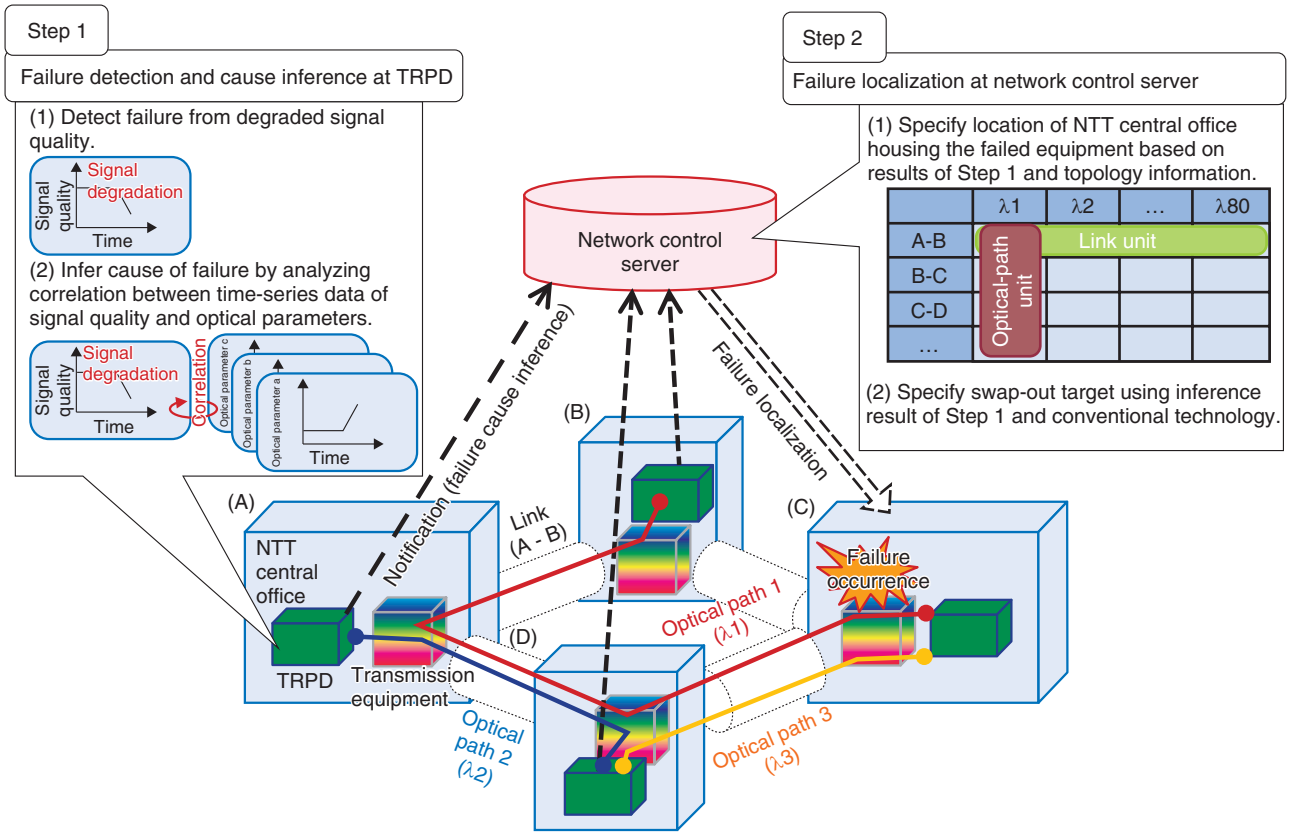


Fig. 1. Failure localization method.

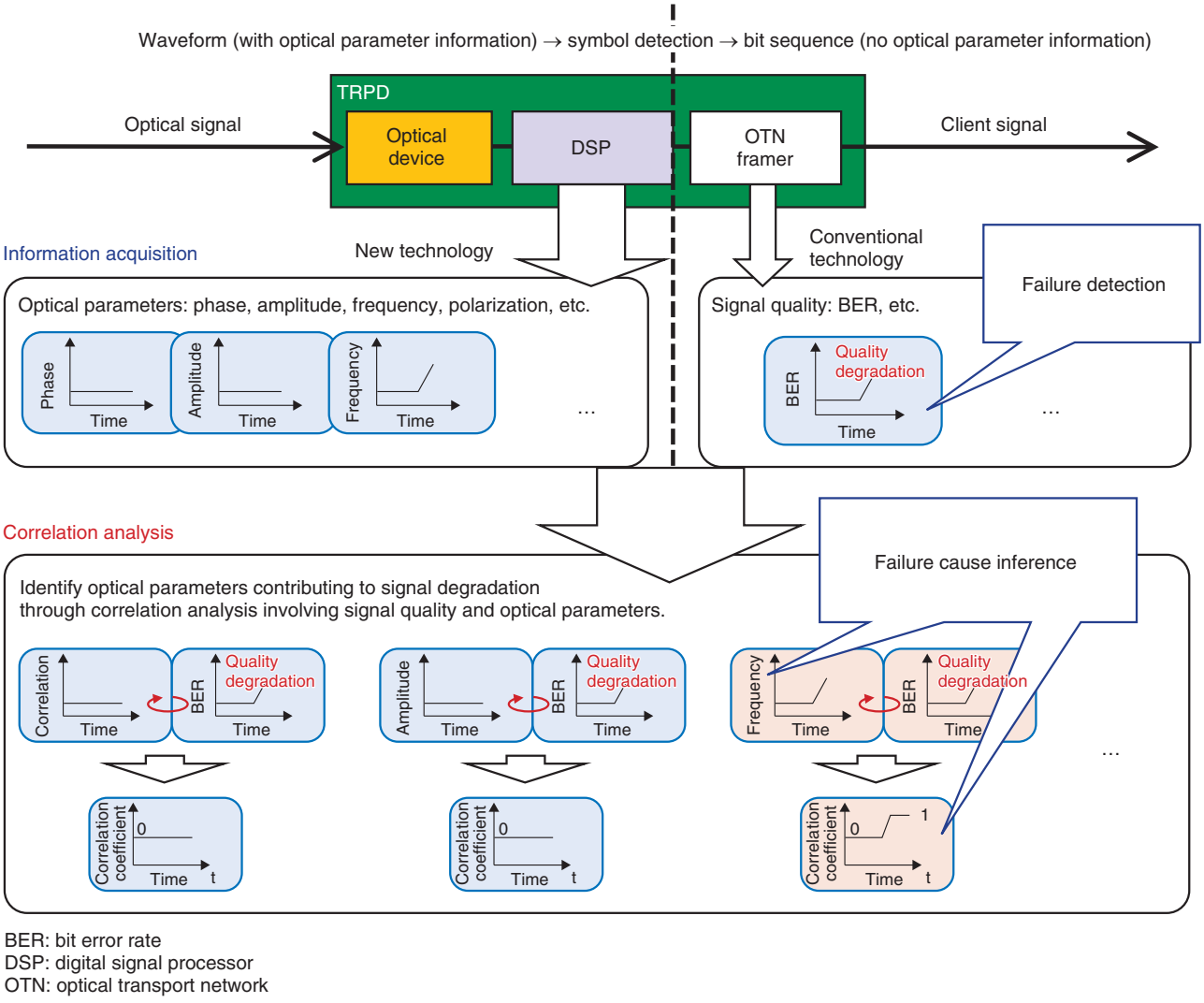
server from the TRPD that terminates the optical paths with degraded signal quality.

Although Step 1 could be performed on the network control server, the flow of a massive amount of data into the data communication network (DCN)—the IP (Internet protocol) network used for monitoring and control purposes—situated between the transmission equipment and the network control server, would create congestion. The proposed method suppresses the flow of massive amounts of data onto the DCN by performing failure detection and failure cause inference at the TRPD and forwarding only the inference results to the network control server.

In Step 2, we use a network control server that we are studying in collaboration with NTT Communications. With the results of Step 1, the network topology information, and route information of optical paths, the network control server localizes the failure coverage area in terms of NTT central office unit. Given the failure cause inferred in Step 1 and conventional technology, the network control server determines which package needs replacing. Facility restoration is then carried out.

3. Failure detection and failure cause inference at TRPD

The process in Step 1, up to failure cause inference, is shown in detail in **Fig. 2**. The TRPD is a transmission package that converts an optical signal into a client signal. First, an optical device within the TRPD performs photoelectric conversion while saving optical parameter information. Then, after performing optical parameter compensation by a digital signal processor (DSP), the symbol detection process converts the signal into a bit sequence, and optical parameter information is dropped. Finally, an optical transport network (OTN) framer performs bit error correction and deframing to produce a client signal. Signal quality is conventionally monitored using a parameter such as bit error rate (BER), the acquisition of which results in the loss of the optical parameter information. While this method can be used to



BER: bit error rate
DSP: digital signal processor
OTN: optical transport network

Fig. 2. Failure detection and failure cause inference at TRPD.

detect failures, it is incapable of identifying the optical parameters contributing to the signal quality degradation.

With the extraction of multiple optical parameters by the DSP, the proposed method can monitor the state of transmission links and infer the cause of the failure. Since commercial systems are unable to monitor the state of transmission links, we introduce here a method that offers high-resolution time-series data of both the BER output by the OTN framer as is presently done and the optical parameters obtained from the DSP. The method detects failures from the temporal degradation in signal quality. With this method, a correlation analysis based on time-series data of all optical parameters and signal quality is done, and the correlation is evaluated using a criterion, for instance a correlation coefficient close to '1.' In this way, the proposed method can identify the optical parameters contributing to signal degradation (infer the cause of failure).

4. Future plan

Because the locations issuing alarms and the actual failure locations can differ, this method localizes failures in which the impacts have taken time to determine and the causes have normally taken time to troubleshoot. The proposed method obtains optical parameters as high-resolution time-series data, so it therefore looks promising for the early detection and

prediction of failures. Desktop studies and the development of prototype equipment are currently in progress, and verification experiments began in the spring of 2019.

Development of a failure localization method is necessary for core networks that are expected to offer increased capacity in the future. We hope to advance this study and contribute to reducing the maintenance and operation overheads of the NTT Group.

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Business Navigation Technology

Makoto Komiyama, Hidetaka Koya, Hajime Nakajima, Akira Kataoka, and Takeshi Masuda

Abstract

With the aim of achieving advanced and smart network operations supporting the digital transformation of the NTT Group, researchers at NTT Access Network Service Systems Laboratories are researching and developing business navigation technology to make business tasks more efficient. This article introduces two key results of this effort: annotation technology supporting human decision-making when performing business tasks and user interface augmentation technology for automating and simplifying operations by adding graphical user interface elements with diverse functions on the operation screen.

Keywords: improved business efficiency, next-generation RPA, reduced operating costs

1. Introduction

As part of the work-style reform movement in Japan, business automation is making rapid progress through the use of robotic process automation (RPA)* products. At present, however, it is still difficult to completely automate all business tasks that include human decision-making (non-routine work).

At NTT Access Network Service Systems Laboratories, research and development (R&D) is underway on business navigation technology to make business tasks more efficient with the aim of further upgrading network operations and bringing about a digital transformation of the NTT Group [1]. Here, we have made non-routine work more efficient through the application of annotation technology instead of upgrading the system. This technology supports user operations and decision-making by directly displaying on the operation screen helpful information (annotations) related to operation procedures, know-how, and other details.

Furthermore, to meet the need for even more efficient business operations, we have developed evolved annotation (advanced annotation technology) and user interface (UI) augmentation technology. The former reduces the processing load by specializing in web systems and displays information in a flexible manner according to the type of operation or task and the user's skill level. The latter, meanwhile, automates and simplifies user operations by adding graphical user interface (GUI) elements with diverse functions (automatic entry button, comma-separated values (CSV) file import/export button, etc.) on the operation screen.

2. Advanced annotation technology

Like conventional annotation techniques [2], this technology displays annotations (icons and messages) on the operation screen based on previously established rules (**Fig. 1**).

A key feature of this technology is the function to specify an annotation display position by the object-matching method using HTML (hypertext markup language). This reduces the processing load of displaying annotations. In addition, this technology can obtain a value input by the user or a value displayed on the screen and switch the annotation to be displayed based on that value. It can also select and display an annotation appropriate to the user's current task or skill level.

This technology has been commercialized as BizFront/Annotation Pro by NTT TechnoCross Corporation [3].

* RPA: Software that performs operations on a personal computer on behalf of the user and automatically executes business tasks.

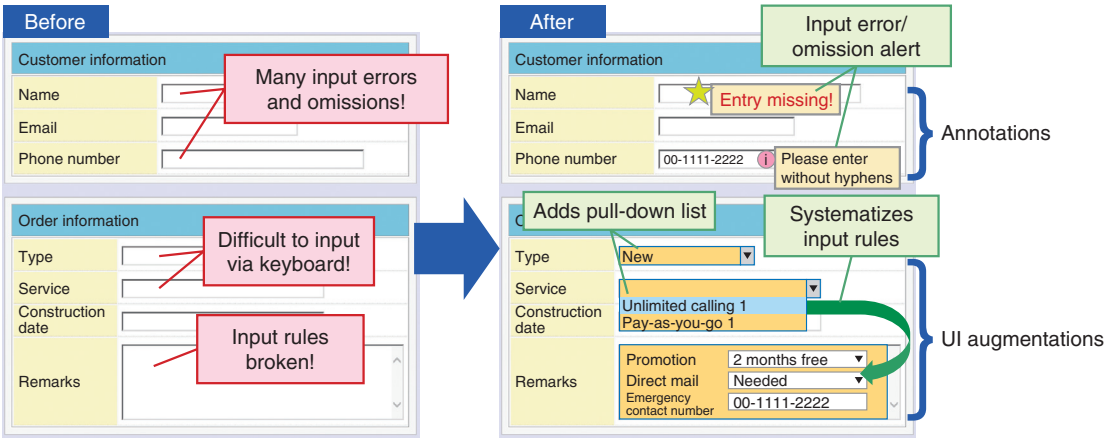

Fig. 1. Typical application of annotation and UI augmentation technology.

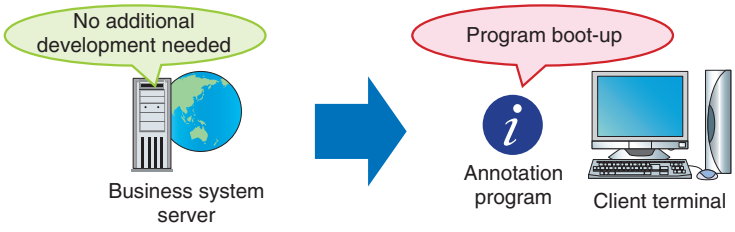

Fig. 2. Overview of client system.

3. UI augmentation technology

This technology achieves a user-friendly operation screen by adding GUI elements (buttons, pull-down lists, text boxes, etc.) to optimize user operations on the operation screen. This is accomplished by using the object-matching method just as with the above advanced annotation technology without having to upgrade the target system (Fig. 1).

These added GUI elements can take on a variety of functions. For example, adding a GUI element having an automatic entry function or a function for incorporating input data in CSV format can automate and simplify user operations.

With this technology, a dedicated editor can be used to set the arrangement and visual design of added GUI elements as well as the operational settings of functions provided by GUI elements, without requiring knowledge of programming languages or other specialized skills.

4. Application systems

This technology has been applied in two systems. The first was a client system in which the program was applied in individual terminals (**Fig. 2**), and the second was a server system that uses a proxy server (**Fig. 3**).

The client system is advantageous for a small-start deployment due to its ease of installation, whereas the server system is geared to deployment of a large-scale system since it makes client-side management unnecessary. In this way, an application system can be selected depending on the actual operation format.

5. Future outlook

Our plan going forward is to continue our R&D to achieve integrated improvement in business efficiency by linking up with other business navigation technologies and commercially available technologies.

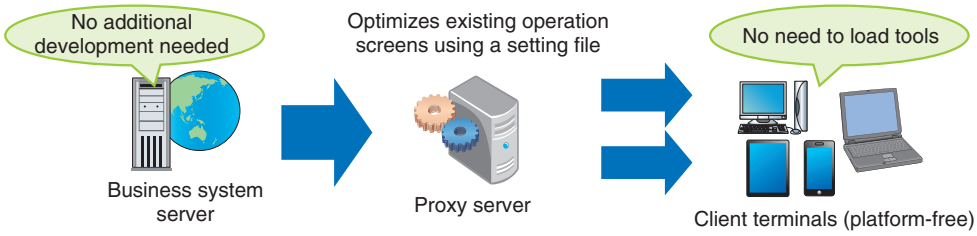

Fig. 3. Overview of server system.

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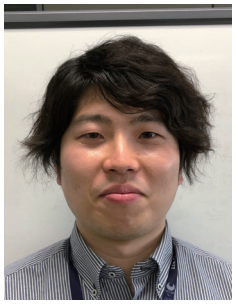

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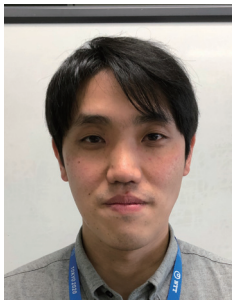

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Toward the Realization of Eco-friendly Telecom Centers

Tomonori Iino, Tomomi Nagao, Farhan Mahmood, Naruto Arai, Tomohiro Kawano, and Tatsuya Fujimoto

Abstract

The NTT Group is working to protect the global environment in line with the NTT Group Environmental Statement and its Eco Strategy 2030. Various initiatives toward global environmental protection in telecom centers are included in the strategy. This article introduces two such initiatives—under-floor wiring technology that improves the energy efficiency of telecom centers by optimizing the cooling method, and noise suppression technology that reduces maintenance personnel operations by improving work efficiency.

Keywords: cooling efficiency, wiring, noise suppression

1. Introduction

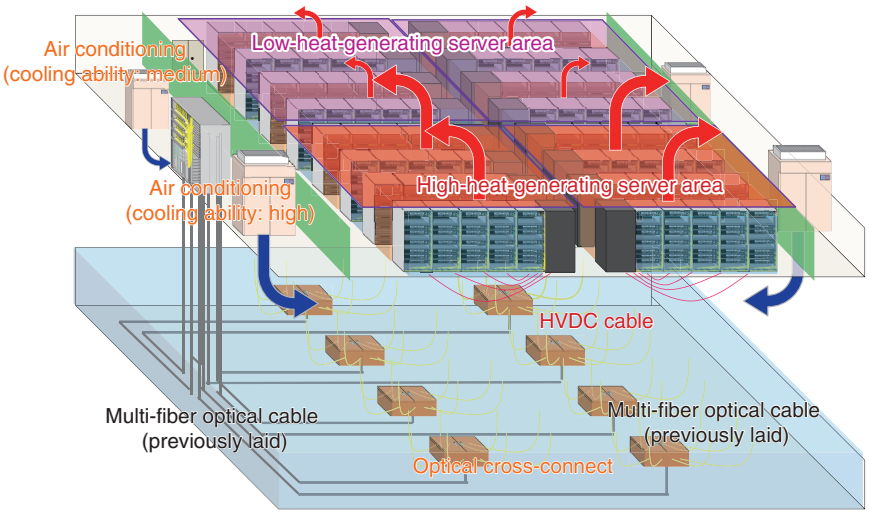
The Eco Strategy 2030 [1] declares the NTT Group's commitment toward research and development that can help make communication facilities more efficient and consume less energy with the aim of achieving more efficient use of power, the main factor driving CO_2 (carbon dioxide) emissions in telecommunications. To achieve these targets, we are working to improve cooling efficiency in telecom centers and to improve work efficiency in the construction and operation of facilities.

One problem surrounding cooling efficiency in telecom centers is that repeated replacement of information and communication technology (ICT) equipment tends to result in heavy congestion of under-floor wiring and consequently, narrow airflow space. This obstructs the flow of cold air and reduces cooling efficiency. In addition, a problem surrounding work efficiency is that specialized skills and complex work procedures are required in restoration work after a communications failure caused by electromagnetic noise. This makes failure troubleshooting extremely time consuming. We have been working to solve these problems and achieve optimized telecom centers by investigating methods to reduce the volume of under-floor wiring and to suppress noise.

2. Under-floor wiring technology

When laying cables to accommodate equipment replacement or service changes, laying the cables freely or laying new cables and keeping unnecessary old cables without carefully considering under-floor airflow space for cold air can result in the accumulation of a lot of unneeded cabling under the raised floor. This, in turn, can obstruct cold air flowing from air conditioners and prevent it from diffusing evenly throughout the floor. To improve cooling efficiency, the volume of cables occupying the space under the raised floor must be reduced to secure adequate space for the flow of cold air (**Fig. 1**).

With regard to communication cables, laying multi-fiber cables beforehand reduces the volume of cables to at least one-fourth the conventional value. In addition, converting the optical mode within the rack when replacing ICT equipment enables continued use of previously laid multi-fiber cables, eliminating the need to replace them. Furthermore, the use of optical cross-connect devices enables remote and automatic switching of connections between ICT equipment, thereby reducing the amount of onsite work. Moreover, as a method of downsizing power cables, the application of a high-voltage direct current (HVDC: 380-VDC) power supply system can reduce the



HVDC: high-voltage direct current

Fig. 1. Integrated optimization for telecom center (under-floor wiring technology).

volume of cables to at least one-sixth that of a 48-VDC power supply system from the viewpoint of allowable current and voltage drop. The application of these technologies can secure much more under-floor airflow space and improve cooling efficiency.

3. Noise suppression technology

Conductive electromagnetic noise into ICT equipment causes problems such as erroneous device operation and Ethernet frame loss. In general troubleshooting, noise suppression filters are installed on cables that connect to equipment on which problems have occurred, but the filters have a narrow range of applicable frequencies, so maintenance personnel must be skilled in measuring noise and selecting filters suitable for those frequencies. In addition, it is necessary to shut down the ICT system and disconnect the cables in order to install a filter that can sufficiently attenuate electromagnetic noise.

To therefore eliminate the need for measuring electromagnetic noise in the field and for selecting and installing filters, we are developing a non-contact (clamp-on) filter that can achieve sufficient attenuation against broadband noise. We have examined a filter structure that can detect electromagnetic noise and inject the amplified noise with an opposite phase to the cable, thereby achieving a level of attenuation of 10 dB or greater for a frequency band of 150 kHz–8 MHz (**Fig. 2**).

4. Future outlook

Going forward, we will expand our research from improving the under-floor airflow space to achieving integrated optimization of telecom centers by investigating airflow control around ICT equipment and communication rack arrangements based on heat-generation density. Additionally, with the aim of improving work efficiency in dealing with electromagnetic noise, we plan to conduct field trials of prototype equipment in collaboration with an NTT operating company to extract problems that occur in actual deployment and make further improvements to functions. We are committed to rolling out these technologies to support an increasingly sophisticated communication network while achieving telecom centers that can contribute to the preservation of the global environment.

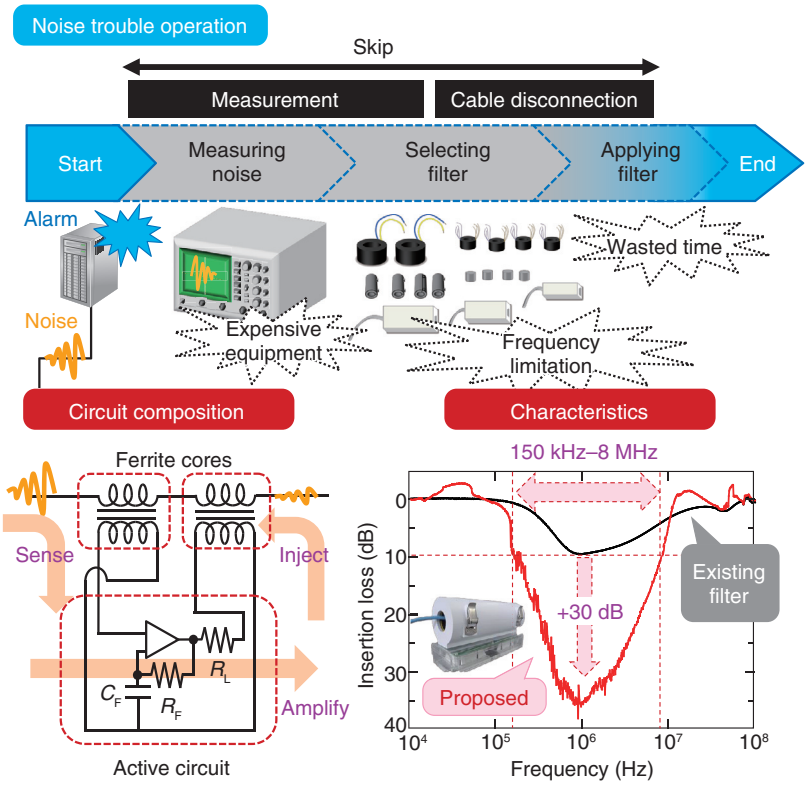


Fig. 2. Noise suppression technology.

Reference

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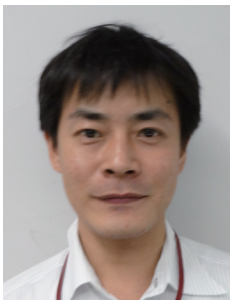

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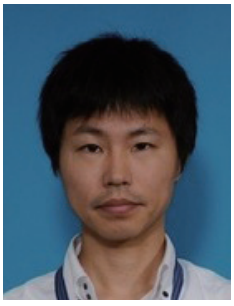

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Technical Trends in ISO/IEC Joint Technical Committee 1

Hideaki Yamamoto

Abstract

The International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) Joint Technical Committee (JTC) 1 is an organization established by the ISO and IEC that is responsible for international standardization in the field of information technology. This article introduces the emerging technologies being addressed by the Advisory Group, which were identified in resolutions from two recent ISO/IEC JTC 1 Plenaries.

Keywords: ISO/IEC JTC 1, Plenary, Advisory Group

1. Introduction

The International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) Joint Technical Committee (JTC) 1 [1] was established by the ISO [2] and IEC [3] and is responsible for the international standardization of information technology. Formerly, ISO/Technical Committee (TC) 97 (established in 1960) and IEC/TC 53 (established in 1961) independently promoted standardization activities in the information technology field, resulting in the duplication of some technical fields between these organizations [4]. JTC 1 was established in 1987 to solve this problem. The secretariat of JTC 1 is the American National Standards Institute (ANSI). As of June 2019, JTC 1 comprised 34 P-members (active participants) and 65 O-members (observers).

The Plenary is JTC 1's highest decision-making meeting, and the main agenda is as follows:

- Establishment and/or abolition of Subcommittees (SCs) and Advisory Groups (AGs) under JTC 1
- Appointment of SC Convenors
- Revision of Directives
- Reports on SC activities

2. Organization of ISO/IEC JTC 1

The organization of JTC 1 is shown in **Fig. 1**. The development of standards is carried out by 22 SCs and 2 Working Groups (WGs) directly under JTC 1. Discussions on management issues such as the review of Directives and on technology issues such as examination of issues with a view to development of future standards, are carried out by AGs under JTC 1. JTC 1 has established liaisons with organizations other than JTC 1, including IEC/TC 65 (industrial-process measurement control and automation), IEC/TC 100 (audio, video, multimedia systems, and equipment), ISO/TC 215 (health informatics), ISO/TC 307 (blockchain and distributed ledger technologies), ITU-T (International Telecommunication Union - Telecommunication Standardization Sector), and Ecma International.

Until the JTC 1 Stockholm Plenary held in November 2018, the JTC 1 Advisory Group (JAG), which was established directly under JTC 1, handled both management and technology issues. Because the JAG meeting was not scheduled to be held after the JTC 1 Stockholm Plenary, a management-related meeting body and a meeting body for conducting research on emerging technologies were established and reorganized directly under JTC 1.

Japan has contributed to the operation of JTC 1 as follows:

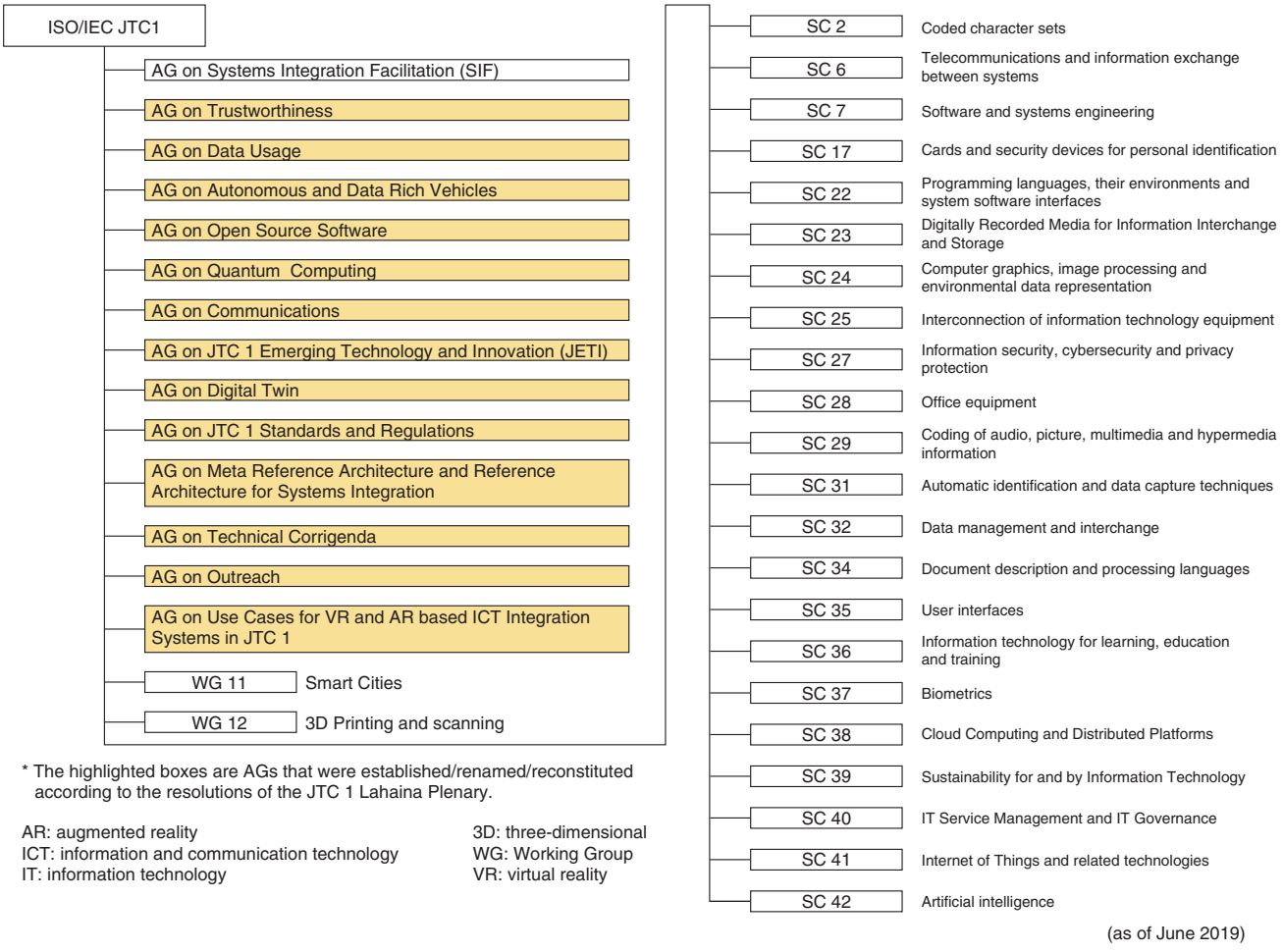

Fig. 1. Organization of ISO/IEC JTC 1.

- P-members in all 22 SCs and 2 WGs directly under JTC 1
- Convenors and Secretaries of SC 2 (character code), SC 23 (digital storage media), SC 28 (office equipment), and SC 29 (media coding)
- Approximately 80 Project Editors (total in FY 2018)
- Hosts of JTC 1 Plenaries (four times, including the Okayama Plenary to be held in November 2020)

3. Establishment of AG for emerging technologies and activities in Japan National Body

The two most recent JTC 1 Plenaries are the aforementioned one held in Stockholm and the one held in Lahaina, Hawaii, US, in May 2019.

During these Plenaries, the Japanese National Body (NB)* contributed in various ways to the management of JTC 1 activities, including by submitting contribution papers, discussing work items for newly established Study Groups (SG) (now renamed AGs), and through member participation in drafting committees.

The following sections introduce several AGs on emerging technologies. The establishment of these AGs was decided at the two recent JTC 1 Plenaries. Post-Plenary activities in the Japan NB are also introduced.

* NB: ISO uses the term MB (Member Body), and IEC uses NC (National Committee). As ISO/IEC JTC 1 is common to both organizations, it is called NB.

3.1 Major AGs on emerging technologies

(1) Quantum Computing

A technological survey of quantum computing in JTC 1 was conducted by the Joint Advisory Group on Emerging Technology and Innovation (JETI) [5]. JETI is an SG established within JAG in August 2016 for the purpose of identifying potential new standardization items to be addressed by JTC 1. After the JTC 1 Lahaina Plenary, JETI was reorganized as an AG just under JTC 1. JETI has defined 15 areas of top priority technology, and most recently identified 4 of those technology areas (digital twin technology, autonomous vehicles, quantum computing, and brain computer interfaces) as important emerging technologies.

In October 2018, JETI summarized a report called the Technology Trend Report (TTR), which included the results of a survey on quantum computing technology, the status of standardization activities on quantum computing in several standardization organizations, and a proposal to JTC 1. In response to this TTR, NBs including China and the US submitted contributions indicating that an SG for quantum computing should be created. The creation of the SG was decided at the JTC 1 Stockholm Plenary and renamed AG at the JTC 1 Lahaina Plenary.

This AG is chaired by Hong Yang (China), and its Terms of Reference (ToR) are listed in **Table 1**. The duration of this AG is through the May 2020 JTC 1 Plenary.

(2) Data Usage

The establishment of this AG (formerly SG) was proposed by an Australian contribution (Data Sharing Framework) submitted for the JTC 1 Stockholm Plenary. This contribution proposed to JTC 1 to consider data sharing and smart services.

Regarding this contribution, several opinions were put forward at the JTC 1 Stockholm Plenary that many SCs including SC 27 (security) and SC 38 (cloud computing) are concerned with data utilization, and this topic should be studied within JTC 1. It was raised by many countries, and the establishment of an SG (currently AG) was resolved.

This AG is chaired by Donald Deutsch (US), and its ToR is in Table 1. The duration of this AG is through the May 2020 JTC 1 Plenary.

(3) Trustworthiness

Although there is no established definition for trustworthiness, it often means "reliability in a wide sense" including safety, security, privacy, reliability (in a narrow sense), and resilience. As indicated in **Table 2**, there are different definitions of trustworthiness (trustworthy) among standards developing organizations.

In June 2018, ISO/IEC JTC 1 SC 41 (Internet of Things) raised an issue to JAG that the definition of trustworthiness should be considered at the JTC 1 level. A JAG Group on Trustworthiness was subsequently established at the JAG Toronto Meeting in August 2018. This group was reorganized as an SG directly under JTC 1 following the termination of the JAG Meeting and renamed an AG according to the resolution of the JTC 1 Lahaina Plenary.

This AG is chaired by Walter Fumy (Germany), and its ToR is indicated in Table 1. The duration of this AG is through the May 2020 JTC 1 Plenary.

(4) Digital Twin

In March 2019, JETI summarized a TTR on digital twin technology, which included the status of standardization activities on digital twin technology in several standardization organizations, and a proposal to JTC 1. This proposal requests that JTC 1 begin Digital Twin standardization, with the scope to include principles, overall framework, reference model, and reference architecture of Digital Twin, interoperability of Digital Twin, and application specific standardization in the work scope of JTC 1. In response to this TTR, the creation of the AG was decided at the JTC 1 Lahaina Plenary.

This AG is chaired by Sha Wei (China), and its ToR is also indicated in Table 1. The duration of this AG is through the November 2020 JTC 1 Plenary.

3.2 Post-Plenary activities in Japan NB

This section introduces Japan's activities after the JTC 1 Stockholm Plenary. In December 2018, the Information Technology Standards Commission of Japan (ITSCJ), corresponding to a Japanese mirror committee of ISO/IEC JTC 1 [6], established the JTC 1 Subgroup Subcommittee. This subcommittee comprehensively addresses the issues that the AGs are required to participate in as the NB. This subcommittee shares deliberations of each AG and discusses how to deal with AGs. If necessary, this subcommittee is ready to appoint experts to address the specific AGs and establish ad-hoc organizations for them. Japanese companies and organizations other than the members of this subcommittee are also interested in the emerging technology issues of data usage and trustworthiness. ITSCJ therefore established an ad-hoc organization for data usage and trustworthiness.

Table 1. Examples of AGs for emerging technologies.

Technical field	Quantum Computing	Data Usage	Trustworthiness	Digital Twin
Terms of Reference	1. Provide a description of key concepts related to Quantum Computing, and describe relevant terminology; 2. Study and document the technological, market and related societal requirements for the future ICT standardization on Quantum Computing; 3. Study and document current technologies that are being deployed in Quantum Computing; 4. Promote the awareness of JTC 1 activities on Quantum Computing outside JTC 1; 5. Assess the current state of standardization activities relevant to Quantum Computing within JTC 1, in other relevant ISO and IEC Committees, in other SDOs and in consortia; 6. Identify and propose how JTC 1 should address the ICT standardization needs of Quantum Computing; 7. Engage with standards setting organizations that are involved in Quantum Computing standardization as approved by the AG on Quantum Computing.	1. Conduct a study of potential standards for Data Sharing Frameworks that would describe factors to consider when sharing data. a. Determine what is covered by data sharing frameworks. b. Identify the JTC 1 subgroups that are relevant to data sharing frameworks and existing work in JTC 1, and other ISO and IEC groups. c. Identify the concerns relating to data sharing frameworks, existing standards that address these concerns, and any gaps, such as: i. lack of guidance and best practices for data sharing; ii. why many data custodians remain hesitant to share data (cultural, economic or other reasons); iii. privacy, security and safety as concerns that are raised by advocates as the capability of data analytics increases; 2. Cooperate with SC 27, SC 32, SC 36, SC 38 and SC 42 on definitions and relationships between Personal Information and Personally Identifiable Information. 3. Conduct a study of potential standards for defining and determining Personal Information Factor (PIF) levels along with a levels-of-assurance framework. The study should consider ISO/IEC 29115, Entity Authentication Assurance to inform the levels-of-assurance framework and consider ISO/IEC 38505-1, Governance of data. 4. Engage with standards setting organizations that are involved in data sharing framework standardization as approved by the AG on Data Usage.	1. Assess the current state of standardization activities relevant to Trustworthiness in JTC 1 SCs, JTC 1/WGs, other ISO and IEC Committees and other SDOs; 2. Collect information about standardization gaps relevant to Trustworthiness; 3. Develop a common JTC 1 definition of Trustworthiness; 4. Describe a superset of components or considerations of Trustworthiness; 5. Identify and propose how JTC 1 should address the standardization needs of Trustworthiness; 6. Engage with standards setting organizations that are involved in Trustworthiness standardization as approved by the AG on Trustworthiness; 7. Provide reports and recommendations to JTC 1 including whether a guidance document or a JTC 1 Standing Document on Trustworthiness should be developed.	1. Provide a description of key concepts and relevant terminology related to Digital Twin; 2. Identify current technologies and reference models that are being deployed in Digital Twin; 3. Promote the awareness of JTC 1 activities on Digital Twin outside JTC 1; 4. Assess the current state of standardization activities relevant to Digital Twin within JTC 1, in other relevant ISO and IEC Committees, in other SDOs and in consortia; 5. Identify and propose the relevant standardization issues of Digital Twin that need to be addressed by JTC 1, covering at least foundational areas, ICT standardization needs, etc. 6. Engage with standards setting organizations that are involved in Digital Twin standardization as approved by the AG on Digital Twin. 7. Prepare a report and recommendations to JTC 1, which may include proposed New Work Items.

Source: Resolutions adopted at the meeting of ISO/IEC JTC 1, 6–10 May 2019 in Lahaina, Maui, Hawaii (ISO/IEC JTC 1 N 14262)
SDO: standards developing organization

4. Future Plenaries

The JTC 1 Plenary will be held twice a year starting in 2019. The upcoming Plenaries will be held in New Delhi (India) in November 2019, Limerick (Ireland) in May 2020, and Okayama (Japan) in November 2020.

Table 2. Different definitions of *trustworthiness*.

Organization	Term	Definition
ISO/IEC JTC 1 SC 41	Trustworthiness	"Property of deserving trust or confidence" (Source: ISO/IEC 20924)
ISO/IEC JTC 1 SC 7	Trustworthy data	"Data and related information that is accurate, complete, relevant, readily understood by and available to those authorised users who need it to complete a task" (Source: ISO/IEC 19970-1)
IEC SC 45a	Trustworthiness	"Likelihood that an entity will behave as expected. In the context of industrial automation, attributes of trustworthiness include reliability, security, and resiliency" (Source: IEC 62918, ed. 1.0 (2014-07))

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[2] ISO, https://www.iso.org/home.html
[3] IEC, https://www.iec.ch/
[4] Information Processing Society of Japan, "50-year History," 2010 (in Japanese), http://www.ipsj.or.jp/50anv/50nenshi/data/pdf/000050.pdf
[5] JETI, https://jtc1info.org/technology/jeti/
[6] ITSCJ, https://www.itscj.ipsj.or.jp/itscj_english/index.html

Hideaki Yamamoto

Manager, Information Security Management Section, NTT Information Network Laboratory Group.

He received a B.E. and M.E. in electronic engineering from Osaka University in 1994 and 1996. He joined NTT in 1996, where he has been engaged in research and development (R&D) of smart card systems, in security design of information and communication systems, and in standardization activities, mainly in ISO/IEC JTC 1/SC 17 (smart cards). He is currently in charge of risk management for NTT R&D's information and communication systems.

He received FY 2011 Industrial Standardization Awards from the Ministry of Economy, Trade and Industry for his outstanding contributions to activities regarding ISO/IEC SC 17/WG 8 (contactless cards). He is a member of the board of directors of ITSCJ and Vice Chairperson of Standard Assembly T60 (Task force for wireless card systems) in the Association of Radio Industries and Business of Japan.

He has been registered as a Professional Engineer, Japan (P.E.Jp) in electrical and electronics engineering since 2011 and in engineering management since 2015. He has been registered as an APEC Engineer (Electrical) and International Professional Engineer (IntPE) since 2015. He is a member of the Institute of Electronics, Information and Communication Engineers, the Japan Society of Applied Physics, the Information Processing Society of Japan, and the Institution of Professional Engineers, Japan.

Orange and NTT Sign Strategic R&D Framework Agreement to Accelerate Digital and Network Transformation in 5G, AI, IoT Cybersecurity and Beyond

1. Introduction

Orange and NTT signed a strategic research and development (R&D) framework agreement up to 2022 to mutualize research findings in several key domains including fifth-generation mobile communications (5G), network transformation, artificial intelligence (AI), Internet of Things (IoT), cybersecurity, cloud services, smart cities, sports, tourism, and culture.

Both organizations believe that greater alignment and cooperation in R&D topics will accelerate digital and network transformation and lead to more innovation and the development of new products and services that can be leveraged across the Asia Pacific region covered by NTT, and Orange's unique geographical reach across Europe and Africa.

Stéphane Richard, Chairman & Chief Executive Officer (CEO), Orange Group, commented: "As Europe embarks on its own 5G journey, our collaboration with NTT will be very precious. Both parties share a commitment to continuous learning and cultural exchange, which I fundamentally believe is essential in today's global environment. The mutualization of our respective research learnings will enable us to identify and develop better services for customers in our respective regions and support the development of our multinational business customers internationally."

Jun Sawada, CEO, NTT Group, commented: "As 'Your Value Partner,' NTT Group will aim to resolve social issues by means of advancing digital transformation through its business activities by utilizing its various management resources and capabilities such as R&D, ICT (information and communication technology) infrastructure, and personnel, while also collaborating with its partners. Orange is one of the most innovative and important players to cooperate closely with in various ways to advance AI, IoT, and 5G. With this agreement, we will be able to enhance our capabilities and accelerate digital transformation in various industries, cities, sports, and international events worldwide."

2. Cooperation areas

The agreement, which may be extended to other areas in the future, covers cooperation in several areas:

- 5G and network technology and transformation: 5G, LoRa,* SDN (software-defined networking), NFV (network functions virtualization) organization, software asset management, identity and access management, and open ecosystems by using open and white box technologies
- IoT: connected value chain with massive devices including connected vehicles, cellular drones, machine to machine, and smart city automation
- AI: use cases for telecom AI, Orange Djingo
- Cybersecurity for telecom, cloud, disaster prevention, and integration services
- Global and cultural events by using immersive communication technology, tourism, and corporate social responsibility
- Digital lifestyle innovation: healthcare, education,

* LoRa: A long-range digital wireless communication technology for low power wide area networks.

connected devices, augmented reality/virtual reality, payment/finance, carrier billing, and consumer experience

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Achievements of Government Sponsored Contract Research on Autonomous Mobility Systems Aimed at Developing an Autonomous Mobility Society in the Future

1. Introduction

In fiscal year 2017, NTT, NTT DOCOMO, and Hitachi Ltd. were entrusted along with other research institutions with contract research sponsored by the Ministry of Internal Affairs and Communications. The research project was called "Research and development (R&D) of frequency effective utilization technology corresponding to various situations supporting a vast number of autonomous mobility systems." The companies involved have been proceeding with R&D in this project for the last two years. In this project, NTT was entrusted with researching both technologies for fast moving object edge computing (technologies to be challenged (i)) and technologies for detection and response-judgment of large amounts of abnormal traffic (technologies to be challenged (iii)), as indicated below. The results that NTT has achieved have helped to improve the target frequency utilization efficiency.

The research results of the said contract research were integrated, and a demonstration event was staged at the Yokosuka × Smart Mobility Challenge 2019, which was held at the Yokohama Research Park January 24–26, 2019. The event featured panel discussions as well as an autonomous mobility system consisting mainly of cars on public roads.

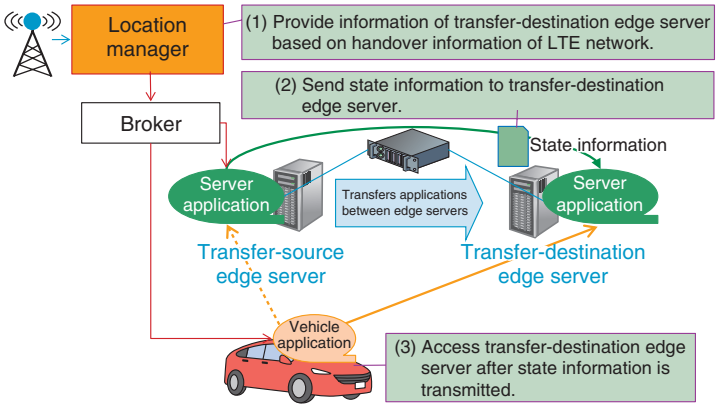
- Technologies to be challenged (i): Highly effective communications processing technologies using distributed data processing (entrusted to NTT)
- Technologies to be challenged (iii): Technologies of detection and suppression of large amounts of abnormal traffic for improving reliability (entrusted to NTT)

2. Results of research

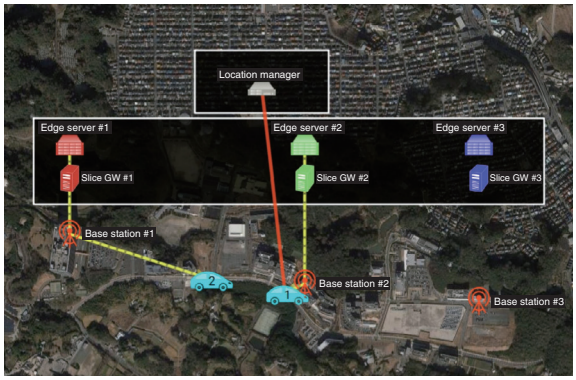
One of the technologies in category (i) that NTT is developing is edge computing technology,* a kind of distributed computing technology, that is applicable to fast moving objects, mainly cars. Specifically, these technologies enable fast transfer of application data between edge servers by utilizing mobile network control information when sending and receiving large amounts of data to and from fast moving objects such as cars (**Fig. 1**). This makes it possible to effectively distribute large amounts of information to fast moving cars by means of distributed processing.

The technologies that NTT is developing in category (iii) include anomaly detection technology applicable to the autonomous mobility system, which enables efficient analysis of large amounts of traffic. This technology includes techniques for distributed cooperative detection of abnormal traffic, enabling the minimum information required for continuous monitoring of target mobility to be transferred from a transfer-source edge server to a transfer-destination edge server by capturing the timing of movement of autonomous mobility between edges. This enables continuous and effective monitoring of communications traffic that follows the movement of autonomous mobility between edges.

* Edge computing technologies: Faster processing of big data and provision of real-time services are made possible by decentralizing the data computing process by means of edge servers that execute intermediate processing of data, as they are installed between datacenters and devices.



Mechanism of application data transfer using location manager of edge servers



Demonstration environment was built at the Yokohama Research Park, and the connection status of edge servers was visualized in real time.

GW: gateway
LTE: Long Term Evolution

Fig. 1. Fast transfer of application data between edge servers.

3. Future development

The developed technologies will be considered in light of their utilization in business activities as well as their international application and standardization by standardizing bodies. The social needs associated with the realization of autonomous driving will also be taken into account. In the future, NTT will strive to contribute to the realization of autonomous mobility systems through these efforts.

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First Proof-of-principle Experiment of Quantum Repeaters with All Photonics—Major Step towards a Quantum Internet as the Holy Grail of Information-processing Networks

1. Summary

A research team consisting of Prof. Takashi Yamamoto and Assistant Prof. Rikizo Ikuta at Osaka University and a research team consisting of Dr. Koji Azuma at NTT, collaborating with Emeritus Prof. Nobuyuki Imoto at Osaka University, Prof. Kiyoshi Tamaki at the University of Toyama and Prof. Hoi-Kwong Lo at the University of Toronto, have succeeded in demonstrating a first proof-of-principle experiment of quantum repeaters by adopting an all-photonic quantum repeater protocol. This protocol enables a global quantum network using only optical devices (**Fig. 1**).

2. Background

The current Internet is based on a global optical fiber network, where long-distance communication is enabled by repeaters. An all-optical-network approach involves using only communication devices made with optical components. This approach holds promise for an energy-efficient high-speed Internet.

The quantum version of this all-optical approach is called an all-optical quantum network and can be realized by replacing the conventional repeaters with all-photonic quantum repeaters. This would lead to a future *quantum internet*[*1] that would have applications far beyond the current Internet.

The all-photonic quantum repeater protocol was proposed in 2015 [1, 2] as a promising quantum repeater protocol that is implementable only with optical devices, in contrast to conventional schemes necessitating matter quantum memories.[*2] However, since the all-photonic protocol is based on a new principle called time-reversal that is enabled only with quantum entanglement,[*3] demonstrating this principle experimentally is regarded as the first major step towards realizing not only all-photonic quantum repeaters but also the quantum internet.

3. Research results

Prof. Yamamoto's group at Osaka University, in collaboration with NTT, the University of Toyama, and the University of Toronto, has successfully demonstrated experimentally a key component of all-photonic quantum repeaters—the time reversal. This corresponds to a first proof-of-principle experiment of all-photonic quantum repeaters.

*1 Quantum internet: In the field of quantum information, a quantum internet describes a global quantum-communication network that enables the exchange of quantum information—which is represented by quantum superposition states—between arbitrary information-processing devices all over the world.

*2 Matter quantum memory: Quantum memory is the function to store the quantum superposition states for a certain period of time. For instance, in contrast to the memory in conventional computers that can store both bit values 0 and 1, quantum memory can store not only 0 and 1 but also their quantum superposition states. A matter quantum memory is the realization of quantum memories based on matter such as an atomic ensemble, a single atom, an ion trap, a quantum dot, a superconducting qubit, and a nitrogen-vacancy center in a diamond.

*3 Quantum entanglement: A quantum superposition state of composite systems that can never be expressed by any collection of the descriptions of the subsystems. This is an essential resource for quantum communication and quantum computation. The existence has already been experimentally demonstrated by using photons and atoms.

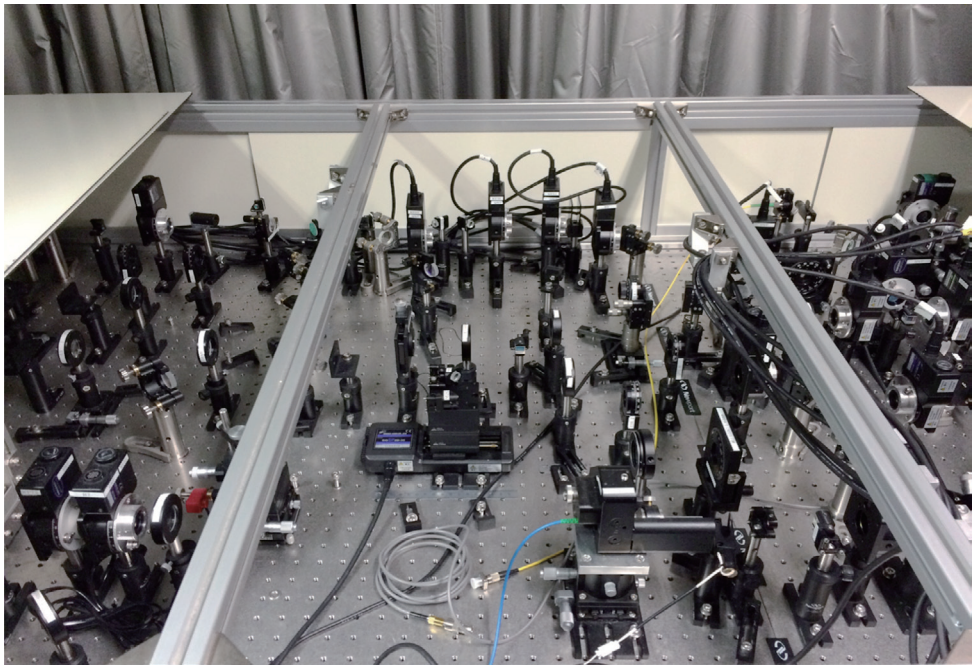

Fig. 1. Experimental setup for all-photonic quantum repeaters.

This demonstration indicates that not only all-photonic quantum repeaters but also a global all-photonic quantum internet is possible once ultralow-loss integrated optics and efficient entanglement light sources are available. At the same time, the current demonstration also corresponds to a first proof-of-principle experiment of an adaptive Bell measurement,[*4] which is required for arbitrary quantum repeater schemes (including the conventional approach with matter quantum memories). This suggests that the all-optical approach is one-step closer to achieving quantum repeaters than conventional approaches.

4. Future prospects

This experiment showed that the all-photonic repeater approach has a promising advantage compared to the other approaches with matter quantum memories for building a worldwide quantum internet. The next steps towards achieving the quantum internet with the all-photonic repeaters are developing large-scale graph-state photon generators and ultralow-loss photonic circuits so as to be able to perform a larger-scale adaptive Bell measurement. This experiment is merely a first step. However, it is essential for achieving a future energy-efficient high-speed quantum internet, where we are able to enjoy absolutely secure communication, uncopiable money, secure e-commerce, longer-baseline telescope arrays, a single international clock with high stability and accuracy, cloud quantum computing, large-scale quantum computer networks, and other benefits.

This work was published in the journal Nature Communications on January 28, 2019 [3]. This research is in part executed under a project of the Japan Science and Technology Agency CREST called ‘Creation of an innovative quantum technology platform based on the advanced control of quantum states,’ ‘Global quantum network’ (Research director: Nobuyuki Imoto). It is also supported by the Ministry of Education, Culture, Sports, Science and Technology/Japan Society for the Promotion of Science KAKENHI, and the Center for Promotion of Advanced Interdisciplinary Research of the Graduate School of Engineering Science, Osaka University.

*4 Adaptive Bell measurement: The Bell measurement is a measurement on a pair of particles to reveal which state of possibly maximally entangled states has been taken by the pair of particles. Each quantum repeater needs to perform the Bell measurement on a pair of particles, on confirming that each particle shares quantum entanglement with other repeater nodes. This Bell measurement performed in an adaptive manner is called adaptive Bell measurement.

References

[1] K. Azuma, K. Tamaki, and H. Lo, "All-photonic Quantum Repeaters," Nat. Commun., Vol. 6, Article no. 6787, 2015.
[2] Press release issued by NTT, "Against a Dogma, Quantum Repeaters for Long-distance Quantum Communication Are Made All Photonic.—Rendering the Quantum Internet an Ultimate Challenge for the Future Photonic Network," Apr. 15, 2015. http://www.ntt.co.jp/news2015/1504e/150415a.html
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Development of Novel Material Sr_3OsO_6 with the Highest Ferromagnetic Transition Temperature for Insulators—Breaking the World Record for the First Time in 88 years

1. Summary

Researchers at NTT Basic Research Laboratories (NTT-BRL) have synthesized Sr_3OsO_6 (Sr: strontium, Os: osmium, O: oxygen), a novel material that exhibits ferromagnetism above 780ºC, which is the highest temperature among insulators. In collaboration with the Tsuneyuki Research Group at the University of Tokyo, we have also revealed the electronic state of this material, which is the key to comprehending the origin of the emergent ferromagnetism.

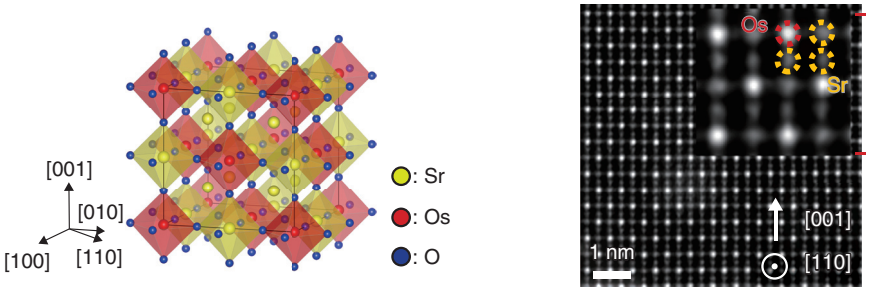
This discovery surpasses the long-standing Curie temperature (T_c) record for insulators for the first time in 88 years and is thus epoch-making for the development of magnetic materials. It also provides fundamental knowledge about the mechanism of the emergent ferromagnetism at high temperatures. Unlike most conventional magnetic materials, our new material is free from Fe (iron) and Co (cobalt) and hence paves a new way to the exploration and development of other novel magnetic materials. Furthermore, the Sr_3OsO_6 was synthesized in the form of single-crystalline thin films. This suggests that the Sr_3OsO_6 films can be readily implemented in device fabrication and are thus promising for high-performance magnetic devices that can be stably operated at high temperatures (room temperature to 250ºC). Examples of such devices include magnetic random access memory (MRAM) and magnetic sensors.

This research was reported in Nature Communications on February 12, 2019 [1].

2. Background

Ferromagnetic insulators include maghemite, the first magnet that humans discovered and used as a compass. Today, ferromagnetic insulators are widely used as permanent magnets and in microwave devices incorporated into, for instance, smartphones, cars, and computers, and such technology could not have been developed without ferromagnetic insulators. Recently, spintronic devices, in which both the electrical and magnetic properties of electrons are utilized simultaneously, are being extensively investigated to achieve high-speed devices with low power consumption. Ferromagnetic insulators are also thought to be essential constituents that will make such spintronic devices viable.

In conjunction with trends in computerization, there has been a steadily growing demand for practical devices with higher performance. In terms of temperature, stable operation even above 200ºC is required. However, the record T_c, which is the crucial factor determining the temperature range in which any ferri/ferromagnetic system remains stable, has stood in insulators ever since ferrite magnets were first developed over eight decades ago in the 1930s. Therefore, researchers have sought to develop the next generation of ferromagnetic insulators with high T_c as well as to establish guiding principles to search for such materials.



(a) (b)

Fig. 1. (a) Schematic diagram of Sr_3OsO_6 (double perovskite). The yellow, red, and blue spheres respectively indicate Sr, Os, and O atoms. (b) Atomic scale microscopy (scanning transmission electron microscopy) image of a Sr_3OsO_6 film viewed along the [110] direction. We can clearly see the atomic ordering depicted in Fig. 1(a).

3. Achievements

Researchers at NTT-BRL have synthesized the novel material Sr_3OsO_6 (**Fig. 1**), using a unique oxide thin-film growth technique developed over many years. The T_c value of this material, estimated from the magnetic measurements, is above 780ºC, which surpasses the T_c record for insulators for the first time in 88 years by more than 100ºC.

Density functional theory calculations carried out by the University of Tokyo team revealed that the ferromagnetic insulating state of Sr_3OsO_6 originates from the large spin-orbit coupling of the 5*d* element Os. This insight into the mechanism of the emergent high-temperature ferromagnetism will open a new avenue for developing functional materials in which elements having large spin-orbit coupling play a role.

Sr_3OsO_6 was synthesized in the form of single-crystalline thin films, which have high compatibility with device fabrication processes. This is in marked contrast to typical new oxides often synthesized in a powder or sintered polycrystalline form. Thus, Sr_3OsO_6 is expected to be readily implemented in high-performance magnetic device applications, such as MRAM and magnetic sensors that work above room temperature.

4. Technical features: preparation of high-quality Sr_3OsO_6 thin films

We used the molecular beam epitaxy method to synthesize the Sr_3OsO_6 thin films, which have a crystal structure called double perovskite (Fig. 1(a)). Precise control of the flux rate of each constituent cation (Os, Sr) is mandatory in order to grow high-quality Sr_3OsO_6 thin films. Generally, controlling the flux of Os is a challenge because of its high melting point (3033ºC). Nevertheless, we have succeeded in precisely controlling both the Sr and Os flux rates. We accomplished this by monitoring the flux rates with an atomic emission spectrometer and feeding them back to the evaporation source power supplies in real time, which enabled the synthesis of Sr_3OsO_6 thin films with the Sr and Os atoms arranged in a highly ordered structure (Fig. 1(b)).

5. Future plans

In our quest to better understand the fundamentals of ferromagnetism, we will further investigate the electronic structures of Sr_3OsO_6 using advanced spectroscopy techniques provided by synchrotron radiation facilities. We are working to fabricate some test devices comprising Sr_3OsO_6 to examine the tunnel magnetoresistance effect toward the development of high-performance magnetic devices that can be operated at high temperatures.

Reference

[1] Y. K. Wakabayashi, Y. Krockenberger, N. Tsujimoto, T. Boykin, S. Tsuneyuki, Y. Taniyasu, and H. Yamamoto, "Ferromagnetism above 1000 K in a Highly Cation-ordered Double-perovskite Insulator Sr_3OsO_6," Nat. Commun., Vol. 10, Article no. 535, 2019.

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NTT and Dimension Data Sign Memorandum of Understanding with Deakin University and Western Sydney University to Accelerate Innovation

1. Summary

NTT and its Group company Dimension Data have entered into a memorandum of understanding (MOU) with Deakin University in Victoria, Australia, and Western Sydney University (WSU) in New South Wales, Australia, to collaborate on research and development (R&D) projects with a focus on solving social challenges that are common between Australia and Japan. This joint-vision partnership is the first time NTT has entered into an agreement of this nature with research institutions outside of Japan. Under this agreement, all parties will start working together to develop and implement innovative solutions with the joint vision of improving the lives, health, and well-being of citizens.

2. Background and purpose of innovation

In 2018, delegates from Deakin University and WSU participated in the NTT R&D Forum held in Tokyo. The R&D Forum serves as the annual proving ground for NTT's breakthrough technologies and is an opportunity to introduce next-generation innovations to NTT's customers, partners, and employees. Here, delegates were first exposed to innovations such as NTT's wearable vital-sensing fabric called hitoe™, which has been integrated with Deakin University's virtual reality firefighting simulator known as FLAIM Trainer™. Delegates also encountered San-shi™, the secure computation system that underpins the data value management ecosystem Mass Data Observations, which has been co-developed by Dimension Data and WSU. Both technologies were showcased at the launch of Dimension Data's first Client Innovation Centre in August 2018 [1].

The emphasis on healthcare, disability, and ageing is influenced by the ageing populations in both countries and the challenges this poses for society as a whole. Japan's societal transformation plan Society 5.0 was the inspiration behind the MOU and explores how the development and access to disruptive technologies such as connected healthcare can transform and improve society. This partnership provides a framework for Australia and Japan to drive the creation and commercialization of technologies and solutions to address real-world issues such as the needs of the disabled and those of an ageing population.

To realize this vision, several joint research projects will be established and will commence in fiscal year 2019. These projects include R&D of communication between dementia patients, their family, and other caregivers; as well as R&D of smart homes to ensure a safe and secure life for the elderly and the disabled.

Under the terms of the agreement, research projects will be tested through a proof-of-concept model in Australia. Viable projects will draw upon Dimension Data's commercial experience and leverage this co-innovation partnership to take these ideas to a global market.

3. Roles of the organizations

NTT brings a rich heritage of R&D and innovation with significant R&D capability, a portfolio of assets, their B2B2X (business-to-business-to-X) framework, and the Society 5.0 ethos. Dimension Data's role is to

provide technical integration capability, relationship coordination, and expertise in collaboration, co-innovation, and commercialization. Both universities bring applied research expertise, specific domain expertise, and commercialization expertise. Together, Dimension Data and the universities bring a network of partnerships and innovation ecosystems.

Reference

[1] D. Bordignon, "Co-innovating to Accelerate Transformation and Create New Value," NTT Technical Review, Vol. 17, No. 3, pp. 27–34, 2019.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201903fa5.html

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External Awards

Maejima Hisoka Award
Winner: Makoto Yaita, NTT Device Technology Laboratories; Yasuhiro Nakasha, Fujitsu Laboratories; Akifumi Kasamatsu, National Institute of Information and Communications Technology
Date: April 10, 2019
Organization: Tsushinbunka Association

For research on terahertz wireless communications.

PKC Test-of-Time Award
Winner: Eiichiro Fujisaki, Japan Advanced Institute of Science and Technology; and Tatsuaki Okamoto, NTT Secure Platform Laboratories
Date: April 12, 2019
Organization: International Association for Cryptologic Research (IACR)

For "How to Enhance the Security of Public-key Encryption at Minimum Cost."
Published as: E. Fujisaki and T. Okamoto, "How to Enhance the Security of Public-key Encryption at Minimum Cost," Proc. of the 2nd International Workshop on Practice and Theory in Public Key Cryptography (PKC 1999), pp. 53–68, Kamakura, Japan, Mar. 1999.

PKC Test-of-Time Award
Winner: Tatsuaki Okamoto, NTT Secure Platform Laboratories; and David Pointcheval, The French National Centre for Scientific Research
Date: April 12, 2019
Organization: IACR

For "The Gap-problems: A New Class of Problems for the Security of Cryptographic Schemes."
Published as: T. Okamoto and D. Pointcheval, "The Gap-problems: A New Class of Problems for the Security of Cryptographic Schemes," Proc. of the 4th International Workshop on Practice and Theory in Public Key Cryptography (PKC 2001), pp. 104–118, Cheju Island, Korea, Feb. 2001.

The Young Scientists' Prize, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology
Winner: Kengo Nozaki, NTT Basic Research Laboratories
Date: April 17, 2019
Organization: Ministry of Education, Culture, Sports, Science and Technology

For his research on extremely power-saving optical devices based on semiconductor photonic crystal.

Featured Poster Award
Winner: Shuhei Yoshida, Yuta Ukon, NTT Device Innovation Center; Koji Yamazaki, NTT Device Innovation Center (currently, NTT Advanced Technology Corporation); Koyo Nitta, NTT Device Innovation Center
Date: April 19, 2019
Organization: The 22nd IEEE Symposium on Low-Power and High-Speed Chips and Systems (COOL Chips 22)

For "Design Optimization Methodology for FPGA-based Accelerator with Multiple Users."
Published as: S. Yoshida, Y. Ukon, K. Yamazaki, and K. Nitta, "Design Optimization Methodology for FPGA-based Accelerator with Multiple Users," Proc. of COOL Chips 22, Yokohama, Japan, Apr. 2019.

Best Presentation Award
Winner: Toshimori Honjo, NTT Basic Research Laboratories
Date: May 9, 2019
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE) Technical Committee on Reconfigurable Systems

For "Design and Implementation of FPGA Measurement Feedback System in Coherent Ising Machine."
Published as: T. Honjo, T. Inagaki, K. Inaba, T. Ikuta, and H. Takesue, "Design and Implementation of FPGA Measurement Feedback System in Coherent Ising Machine," IEICE Tech. Rep., Vol. 118, No. 432, RECONF2018-52, pp. 37–42, 2019.

Distinguished Service Award
Winner: Kei Harada, NTT Network Innovation Laboratories
Date: June 18, 2019 (awards ceremony)
Organization: Telecommunication Technology Committee (TTC)

For her contribution to standardization efforts concerning oneM2M specifications.

Distinguished Service Award
Winner: Hidenori Iwashita, NTT Network Technology Laboratories
Date: June 18, 2019 (awards ceremony)
Organization: TTC

For his contribution to standardization efforts concerning soft errors that affect telecommunication equipment.

Papers Published in Technical Journals and Conference Proceedings

Flat Panel Visually-equivalent Light Field 3D Display

M. Date, D. Ochi, and H. Kimata

The Journal of the Institute of Image Electronics Engineers of Japan, Vol. 48, No. 2, pp. 264–272, April 2019.

A novel autostereoscopic flat-panel three-dimensional (3D) display that can display viewpoint images directly and reproduce smooth horizontal motion parallax using a small number of directional images is introduced. Using the human perception characteristics of doubled images, we interpolate directional images and generate visually equivalent rays using optical linear blending in the display. Our previous proposal required a huge apparatus and had low image quality. Since this new display only requires a barrier, whose spacing is almost the same as the pixel width, to be added to a regular horizontal RGB (red-green-blue) stripe type 2D LCD (liquid crystal display), it yields thin flat panel displays. The lens-less optical configuration enables high image quality because it is intrinsically free from distortion and blur. Moreover we sorted out phenomena from the standpoint of spatial frequency and showed that perception can be explained optically only by assuming the cutoff frequency of the visual system.

Table Top Visually Equivalent Light Field 3D Display Using 15.6-inch 4K LCD Panel

M. Date, Y. Tanaka, M. Isogai, S. Shimizu, and H. Kimata

Proc. of SID Display Week 2019, pp. 791–794, San Jose, CA, USA, May 2019.

A highly realistic table-top type light field three-dimensional (3D) display that offers horizontal parallax is proposed. With a 4K LCD (liquid crystal display) and parallax barrier, rays are interpolated directionally, and high resolution and smooth motion parallax are achieved. Since this interpolation works as anti-aliasing itself, small characters can be displayed stably in 3D space.
