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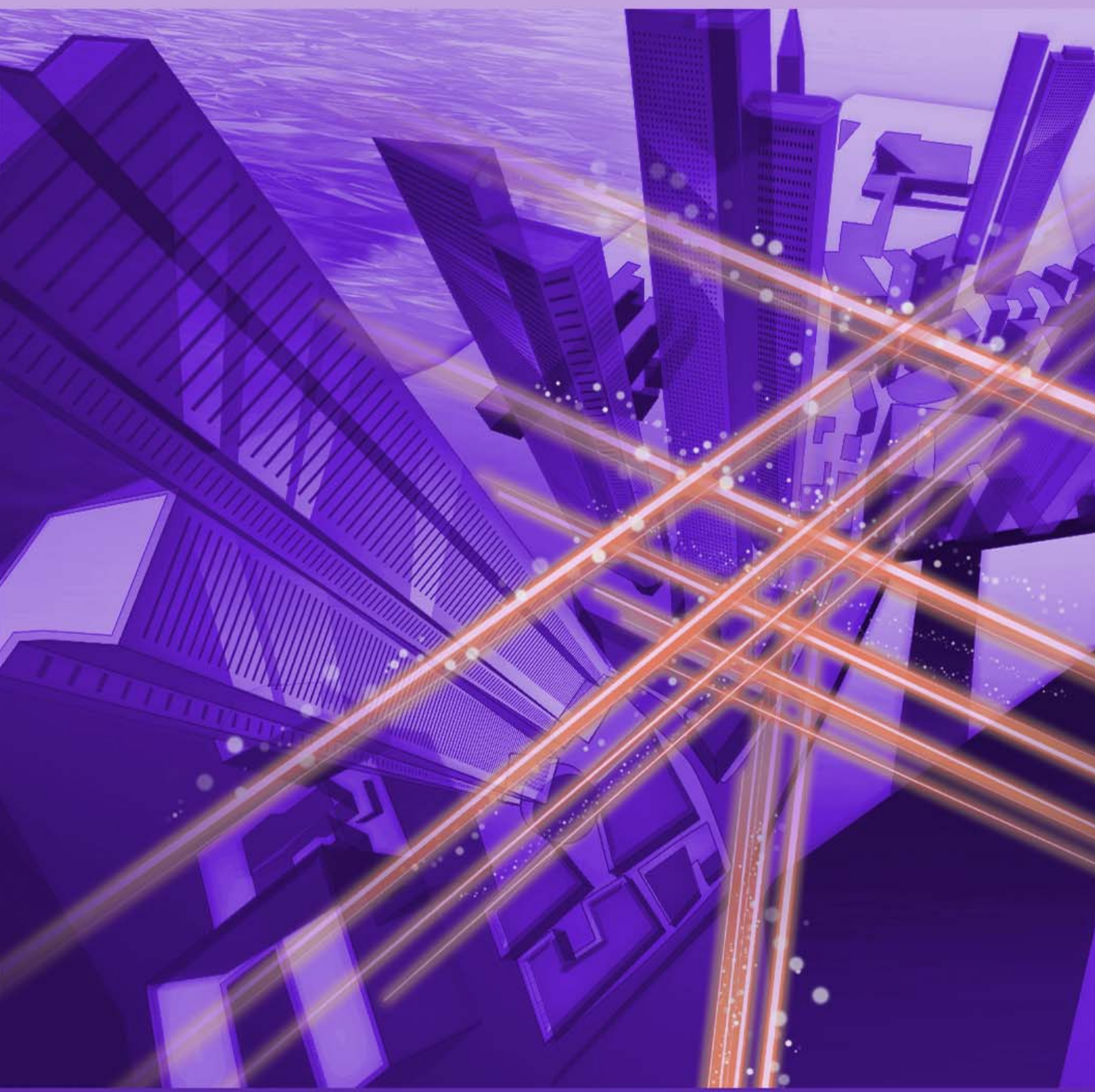

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Invigorating Regional Economies and Solving Social Problems with "Local Revitalization Clouds"—Building the Present with a View to the Future through "Moonshot" Thinking

Mitsuyoshi Kobayashi
President and Chief Executive Officer,
NTT WEST

Overview

Aiming to be a company that contributes to solving social problems, NTT WEST is transforming itself into a pioneer in the era of Internet of Things and artificial intelligence by leveraging the technologies, know-how, and services it has cultivated to date. We asked Mitsuyoshi Kobayashi, NTT WEST President and Chief Executive Officer, to tell us about his plans and specific initiatives in support of the new NTT WEST Medium-term Management Plan that is aimed at creating new value to realize a prosperous, vibrant, and safe and secure society.

Keywords: regional revitalization, ICT, cloud

Daring to create a synergistic effect among 800 local governments and 2 million companies

—Mr. Kobayashi, please tell us about the current business environment surrounding NTT WEST.

July 2019 will mark the 20-year anniversary of the founding of NTT WEST. At the time of founding, operating conditions were such that we were operating at a loss of about 200 billion yen. However, in fiscal year (FY) 2016, operating profits reached 95.1 billion yen, a record high in the history of NTT WEST, and after making incremental improvements such as further rationalization of operations, they climbed to 167.4 billion yen in FY2017, making two consecutive years of record profits. I attribute these positive results to nothing other than the tireless efforts of our employees.

On the other hand, if we look only at revenues, we can see a 20-year drop, and this is continuing for various reasons, for example, the severely competitive environment and a growing shift toward mobile communications. Specifically, operating revenues were 2700 billion yen 20 years ago but not much more than 1400 billion yen in recent years, an overall drop of about one-half. No matter how much our operating profits rise, a company whose revenues continue to drop can produce some anxiety about the future in its employees. My mission is to resolve this situation, which I think is the earnest desire of all

NTT WEST employees. I would like to get on a sound path toward revenue growth as soon as possible.

—What kind of strategies do you have in mind?

To begin with, what kind of image has NTT WEST as a company been projecting to society? It would probably be a network company or circuit provider that provides fixed-telephone (landline) and optical-broadband services. From here on, however, I would like to be known as an ICT/IoT (information and communication technology/Internet of Things) company that provides its customers with a wide array of services that add value to our existing infrastructure. However, there are already many enterprises working on ICT and IoT and providing services, so we must think carefully about what kind of vision we should have toward the future.

To give an example, Japan has been called a developed country facing many challenges such as the declining birth rate and aging society as well as regional disparities. We would like to be a company that can solve such social problems or provide support by using ICT. NTT WEST, in particular, is in charge of the telecommunication networks of a total of 30 prefectures spanning the Kinki, Chugoku, Shikoku, Kyushu, Tokai, and Hokuriku regions, excluding Niigata. The markets that we cover have many remote islands and are dispersed over a large area. In short, there are many small markets under our umbrella, some of which are a microcosm of Japanese society. Problems that are left unattended can provoke crises, so I would like to be a company that sees such situations as opportunities for rolling out new services that will endear us to the people of those regions.

The NTT WEST coverage area includes about 800 local governments of diverse sizes and about 2 million companies, most of which are small or medium in size. Each of these entities provides services to the public or to other customers while facing a variety of problems. I would like to take on these local governments and companies as our customers and help them solve their problems or expand their businesses. In this way, I want to meet the expectations of their end users. This is none other than the B2B2X (business-to-business-to-X) model that we have been promoting. With this model, we would like to contribute to the wellbeing of regional communities.

To this end, it is important, first and foremost, that we keep in mind our own strengths and features.

Fortunately for us, we have communication channels with our customers from past business activities and trusting relationships that we have been building through the years. With these as a foundation to work from, and using technologies not only for communication but also for artificial intelligence (AI) and IoT plus our physical assets (about 4000 central offices and related equipment, about 40 datacenters, 26 call centers, etc.), I would like to promote business process outsourcing services, where companies outsource their work to us, to provide added value to our customers.

For example, many local governments have expressed a desire to convert their systems to cloud-based operations, but they are also somewhat anxious about placing their systems and data outside their regions. I think we can eliminate this anxiety by providing comprehensive cloud services that enable local governments to entrust us with their systems at our 40 or so datacenters and to even outsource some of their operations.

In addition, there are many small- and medium-sized companies within the NTT WEST coverage area where regional characteristics make for unique types of businesses. Collaborating with such companies provides another opportunity for contributing to these regional communities. It should also be possible to collect large amounts of data by establishing links between local governments and companies and to extract problems and needs by analyzing those data. We can then match up companies and other enterprises with those problems and needs to work out solutions. I have named this process of regional revitalization through community-based collaboration "local revitalization clouds."

Supporting communities through local revitalization clouds and promoting regional features with tourist-oriented services

—That's a unique and easy-to-understand name. How will you apply local revitalization clouds to the NTT WEST Medium-term Management Plan?

I believe that these local revitalization clouds will provide a means of combining people, technologies, and assets to solve social problems and invigorate regions and that we can be of assistance in achieving mutually beneficial collaboration and development. By forming new partnerships and widening our circle with each and every achievement, I would eventually like to create a synergistic effect among 800 local governments and 2 million companies.

Under the new Medium-term Management Plan, we plan to substantiate this initiative to build a foundation for achieving revenue growth and stable profits. One specific tactic here is edge computing. In this regard, I would like to make the primary processing and analysis of video and other types of data and their application to diverse measures as the centerpiece of the local revitalization clouds. This approach could be used to tackle the energy problem, which is one key social issue. For example, lead storage batteries are usually installed in our central offices and datacenters as insurance against power outages caused by disasters or other events, and they are of the type that deteriorates through repeated charging and discharging. Since such backup batteries are not used very often, and periodic inspection and replacement are conducted, battery deterioration would not be a major problem. However, such repeated charging and discharging makes lead storage batteries unsuitable for everyday use. However, if lithium-ion batteries could be used instead, no such deterioration would occur, which means that they could be used on a day-to-day basis. If this were to happen, I would like to explore the use of central offices and datacenters as core energy-supply facilities by utilizing AI or ICT to monitor battery conditions and perform optimal power transmission and distribution. At the present stage, cost and safety problems are a concern, so we are studying solutions to these issues together with the NTT laboratories.

In a way, this is related to the local production and consumption of energy. A central office typically covers customers dispersed over an area with a radius of about 8–10 km, and it would be located in the city center from the viewpoint of efficiency. The electric power generated by solar panels located in this area could be used to charge the lithium-ion batteries in the central office, and customers in the same area could then be supplied with power. Although a variety of means already exist for transmitting energy from a power plant to remote locations, they result in much power loss that could be reduced by local production and local consumption. I would like to achieve continuous growth as a company that creates a virtuous cycle and endears us to a region through such community-based services and businesses that invigorate local economies.

—2020 is near at hand. How does NTT WEST plan to deal with this historic year?

The international sports event of 2020 will be held in and around Tokyo, but this does not mean that all inbound visitors to the events will remain in the Tokyo area. At present, visitors to Japan using Kansai International Airport make up about 30% of all visitors. Together with visitors to Japan who use Chubu Centrair International Airport in Nagoya, Fukuoka Airport, and other airports in western Japan, we can say that about 50% of all visitors to Japan get off an airplane somewhere in this area. To provide these guests with even better services, we are currently deploying augmented reality systems at airports to provide information services that can be accessed by simply holding up a smartphone, and we are providing digital signage to attract customers. I believe that going forward, we can use ICT to make more contributions like these in an indirect way.

We are also preparing services for all major international events to be held before and after 2020 including

the Rugby World Cup and G20 Summit in 2019. These services will naturally include navigation services in the manner of airport information services, but our main mission here is to support communications. In addition, other events that are expected to draw large numbers of guests are being planned or envisioned based on the concepts of integrated resorts and MICE (meetings, incentives, conventions/conferences, and exhibitions). Our main role here will be to provide support through ICT and AI technologies including cybersecurity measures.

I feel that taking advantage of these opportunities to support inbound visitors may also be effective in revitalizing Japan on the whole. Also, responding to and supporting people with diverse customs and values can give us a new perspective on the world. It could lead to activities for solving social problems such as the declining birth rate/aging society and regional disparities.

I think that such initiatives and activities are somehow helping western Japan to come alive compared with conditions a few years ago. As I alluded to earlier, it could be said that the 800 local governments and 2 million large and small companies in western Japan are collaborating with each other, and that this diversity in values and viewpoints is helping to support the economy of western Japan.

Let's create excitement, inspiration, and brilliance through "moonshot" thinking

—In such an environment, how do you carry out your beliefs as a top executive?

NTT WEST employees may be tired of hearing it, but I often use the word "moonshot." This word is used by engineers in the United States and goes back to the space development policy and Apollo program put forth by President John F. Kennedy upon taking office in 1961. The Cold War between the United States and Russia (formerly called the Soviet Union) was an era of fierce competition in space development as a matter of honor. At that time, Russia was ahead, but President Kennedy declared, "This nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to Earth." These words were not simply a call to compete through a steady improvement of technology. Rather, they expressed the importance of setting a goal and looking at what should be done to achieve the original objective of sending human beings into space. The Apollo 11

lunar module touched down on the lunar surface in 1969 and fulfilled the mission of landing people on the moon and returning them to Earth.

This word "moonshot" originates from this historic mission. It expresses the idea of setting a primary objective or establishing the goal of understanding the true essence of something and thinking how to approach the problem. We tend to make an effort to solve problems that are close at hand, but it is more important to consider primary objectives and issues. By the way, there are three principles behind a good moonshot. First, is it original? Second, does it have a certain technical foundation and can its success be envisioned? And third, does its proposal and plan fascinate many people and create a desire for cooperation? I can proudly say that the new NTT WEST Medium-term Management Plan is a "moonshot."

—Do you have a message for researchers?

I would like to see more research related to regional revitalization, and I would like to work together with researchers to return the results of that research to our customers. Some products such as WinActor, ForeSight Voice Mining, and @InfoCanal have already been introduced, and I expect more to follow.

WinActor is a robotics process automation tool that improves business efficiency by using a bot to automate repetitious input tasks, thereby shortening work time and reducing input errors. Many customers in western Japan are using it, and it's a product that I heartily recommend to other customers.

ForeSight Voice Mining, meanwhile, is a voice-oriented big data solution. It can be used, for example, at call centers to automatically extract customer complaints from phone calls. It is not limited to

extracting emotional complaints in which a voice is raised in anger, for example. It can also infer and extract emotionally contained, matter-of-fact complaints based on intonation or pauses, which have been difficult for existing systems to automatically extract. This solution can improve business operations and enable the provision of services that better fit customer needs.

Finally, @InfoCanal is an information delivery service targeting a wide range of terminals that use an IP (Internet protocol) communications network including the cloud and mobile phone network. It has already proven to be extremely useful in recent disasters as a means for local governments to deliver disaster information. To give some background, broadcasts made over a community wireless system may be drowned out by the sound of heavy wind, and it may not be possible to confirm whether that information has actually reached the residents. The @InfoCanal product makes it possible to deliver disaster information all at once by text and voice to smartphones and tablets, dedicated home receivers for the elderly, and disaster-prevention radio terminals. It also has bidirectional capabilities that can be used for safety confirmation purposes and for sending individual messages to non-responding terminals for double-checking. This feature enables a local government to visualize the ratio of residents who have received the information.

These products all use technologies developed by the NTT laboratories. NTT Advanced Technology and NTT TechnoCross transformed these technologies into practical and commercial products, and we have the role of delivering these products to our customers. There are many examples of such relationships within the NTT Group, too many to mention. I would like to expand and strengthen these relationships. In addition, I would like to ask researchers to work together with us in making regional contributions by fostering new technologies in edge computing and energy too.

When our engineers make contact with customers, the customers are relieved to hear comments such as, "We have research laboratories within the Group and many technologies like this one." This results in a favorable response from our customers, which underscores just how important a role the NTT laboratories play. This is why we are committed to delivering the output from the laboratories to our customers.

—Mr. Kobayashi, can you leave us with a message for all NTT WEST employees?

I would be happy to. In the end, you cannot excel in your work if you don't enjoy it. I believe that having one's existence as a company or individual recognized as being useful to society is what makes work pleasurable. There is truly nothing more enjoyable than having yourself or your company and the value of your work appreciated as expressed by the words "Glad you're here!" or "Glad you could do this for me!" To this end, you must take pleasure in your work. I believe that having joyful and exciting times is very important. The role of managers is to create an exciting company and implement stimulating work procedures, and we are working hard to create such an environment, so I would like to ask everyone to be excited about your work even when times are difficult. If you are excited, you will be inspired, and then you will be brilliant! If you do your work with a sense of joy, good ideas will come to you. And if good ideas come your way, you can excel in your work and shine, which then fosters a virtuous cycle of having the world around you appreciate the work that you do.

Interviewee profile

■ Career highlights

Mitsuyoshi Kobayashi joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1982. He served as General Manager of the Okayama Branch of NTT WEST beginning in 2006, General Manager of the Service Management Department of NTT WEST beginning in 2008, Senior Vice President and General Manager of the Service Management Department of NTT WEST beginning in 2010, Senior Vice President and Director of the Technology Planning Department of NTT beginning in 2012, and Executive Vice President and Director of the Technology Planning Department of NTT beginning in 2014. He took up his present position in June 2018.

Kirari! Ultra-realistic Communication Technology: Beyond 2020

Akihito Akutsu, Kenichi Minami, and Kota Hidaka

Abstract

The NTT Group is creating new value to overcome the limitations of space through research and development of Kirari! ultra-realistic communication technology. Kirari! goes beyond simply improving sound and image quality; it is aimed at achieving a sense of realism, as though the objects or people being viewed were actually there in front of the viewer. This article gives an overview of Kirari! technology, introduces some application examples, including live public viewings and other unprecedented productions, and reviews trends for beyond 2020.

Keywords: ultra-realism, media, telepresence

1. Introduction

The 5th Science and Technology Basic Plan [1] was established in a cabinet decision on January 22, 2016 and defines the new concept of Society 5.0 [2]. The fifth society, or age, in human history, Society 5.0 follows the hunting and gathering society (1.0), the agrarian society (2.0), the industrial society (3.0), and the information society (4.0) (**Fig. 1**). It is defined as follows in the integrated science and technology innovation strategy set in the cabinet decision of May 24, 2016 [3].

"A human-centered society able to deliver high-quality lifestyles, rich in energy and comfort, through advanced integration of cyberspace and physical space, achieving both economic development and solutions to social issues by providing goods and services to meet the detailed, various and latent needs of all, without disparity by region, age, gender, language, or other factors."

With advances in information and communication technology (ICT), voice and video communication with people in distant locations has been achieved and advanced, increasing in sound and image quality. It has also become possible to sense the physical space we are in, with advances in various types of

Fig. 1. Image of Society 5.0.

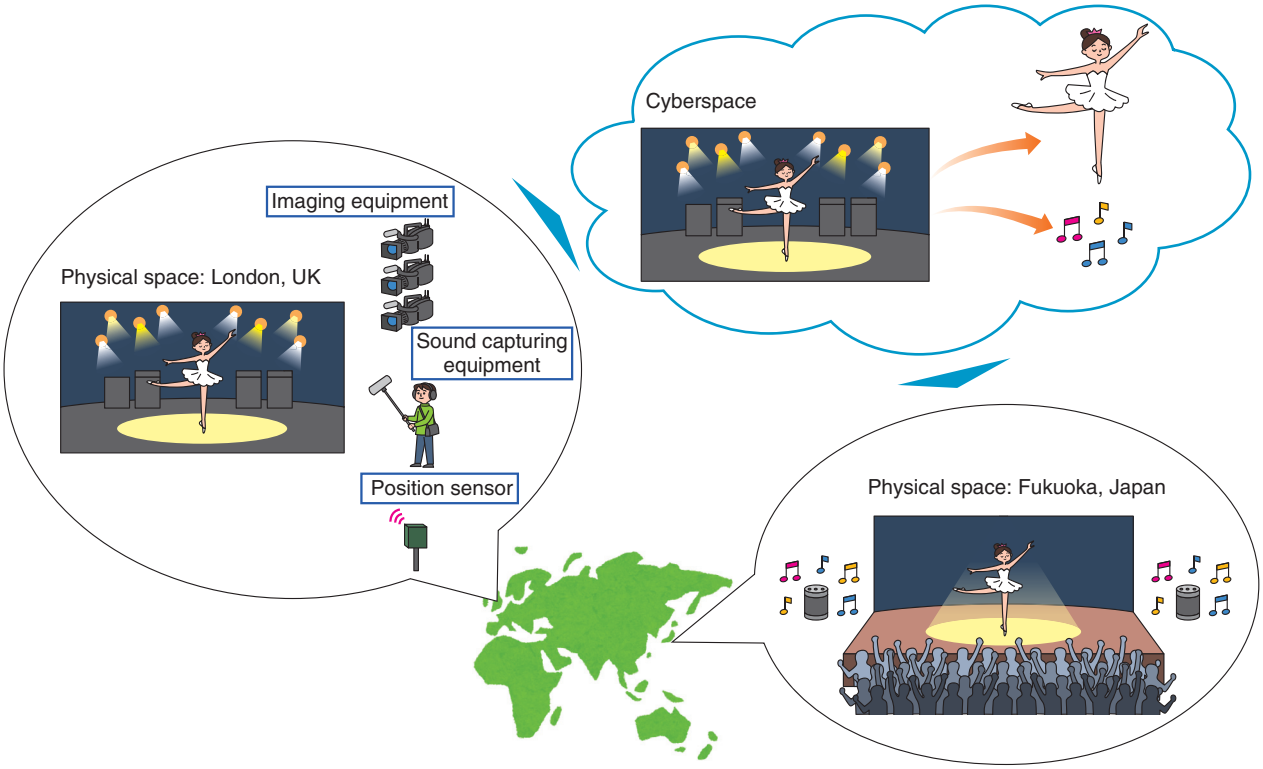

Fig. 2. Kirari! overcomes boundaries of physical space and cyberspace.

sensing technologies. Media processing of such sensor data in cyberspace and the subsequent transmission and reproduction in another physical space—creating a sense that the person is right before your eyes—may well become common in Society 5.0 (**Fig. 2**). Such reproduction can be called *high realism*. The Kirari! system being developed by the NTT Group is the future of media transmission, going beyond improvements in sound and image quality, to implement ultra-realistic communication.

With Kirari!, distance can be overcome, and information and images of people and spaces can be transmitted from distant locations in real time. With Kirari!, people can experience a sporting event without having to travel to the venue, or a speaker can participate in an event from a location far from the venue. We believe Kirari! will contribute to overcoming the limitations of space in the coming Society 5.0.

Examples using Kirari! are shown in **Fig. 3**. In the examples of local live viewing of overseas sports competitions, which would not be easy to see otherwise, illusion effects have been used to create near three-dimensional (3D) viewing experiences or to provide a wider field of view than ever before possible. Astonishing performances not previously possible can also be produced. For example, by sensing the actual performer and applying media processing, another performer can be recreated and overlaid using illusion effects. By controlling the timing of the overlay, a *joint* performance featuring a performer in real time and an image of that same performer from a few minutes earlier can be implemented, which would not otherwise be possible. Through this sort of initiative, we hope to provide ultra-realistic experiences that overcome the limitations of space for various types of content.

2. Overview of Kirari! technology

An overview of Kirari! technology is shown in **Fig. 4**. It is divided into the three aspects of the sports or performance venue, communication, and the viewing venue. Kirari! ultra-realistic communication technology is in the communication area. Information extracted using cameras, microphones, and sensors is handled by media control, media processing, and synchronization and transmitted to the viewing venue.

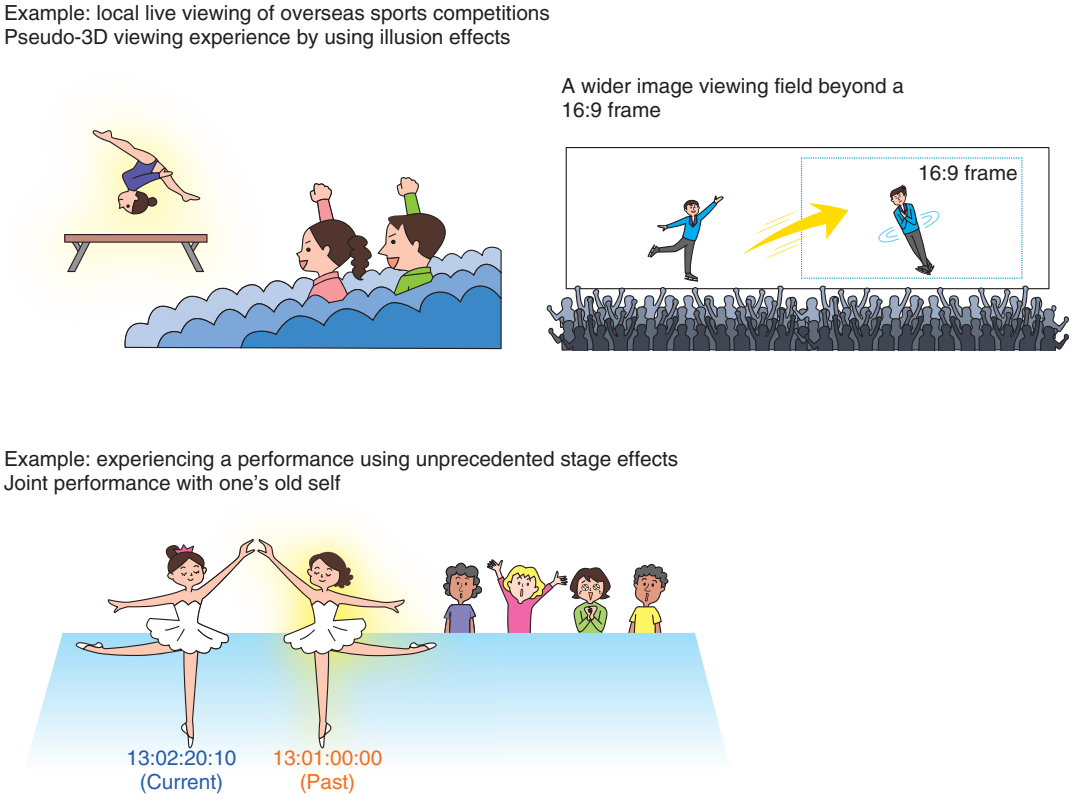

Fig. 3. Application examples of Kirari!.

Media control consists of spatial information, which includes position data obtained from sensors, people in camera imagery, and associated lighting information, and time control, which is used for controlling the distribution of people in absolute time.

Media processing includes object extraction, in which people in the captured video can be extracted from the background, and audio wave-field synthesis technology [4] for highly realistic sound. For sports coverage and other performances as shown in Fig. 3, these features use illusion effects to display people in 3D and perform the processing needed to reproduce audio that seems to come from the image to the viewer's position. In the other wide-angle viewing experience in Fig. 3, images from multiple cameras are synthesized to produce an ultrawide image [5]. Then encoding is done to transmit the content efficiently.

We have created our own extension to the MPEG* Media Transport (MMT) standard, called Advanced MMT, which we use for synchronized transmission [6]. It is capable of synchronization with absolute time, so synchronized transmission to any location in the world with the same timing is possible. Advanced MMT has the role of providing a design plan for achieving ultra-realism based on video, audio, lighting, and other information. At the viewing venue, projection, speakers, lighting, and other elements are set up according to the Advanced MMT design plan.

Some of the technologies used in Kirari! are explained in the Feature Articles in this issue [7–10].

3. Future prospects

To allow as many users as possible to experience the ultra-realism achieved by Kirari!, we have conducted proof-of-concept and live viewing trials, including sports events that seem to be happening before the viewer's eyes, unprecedented performing arts using ICT, dance performances featuring both current and past performers, and coverage of lectures

* MPEG: Moving Picture Experts Group, a working group of ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) in charge of developing international standards for compression of audio and video data.

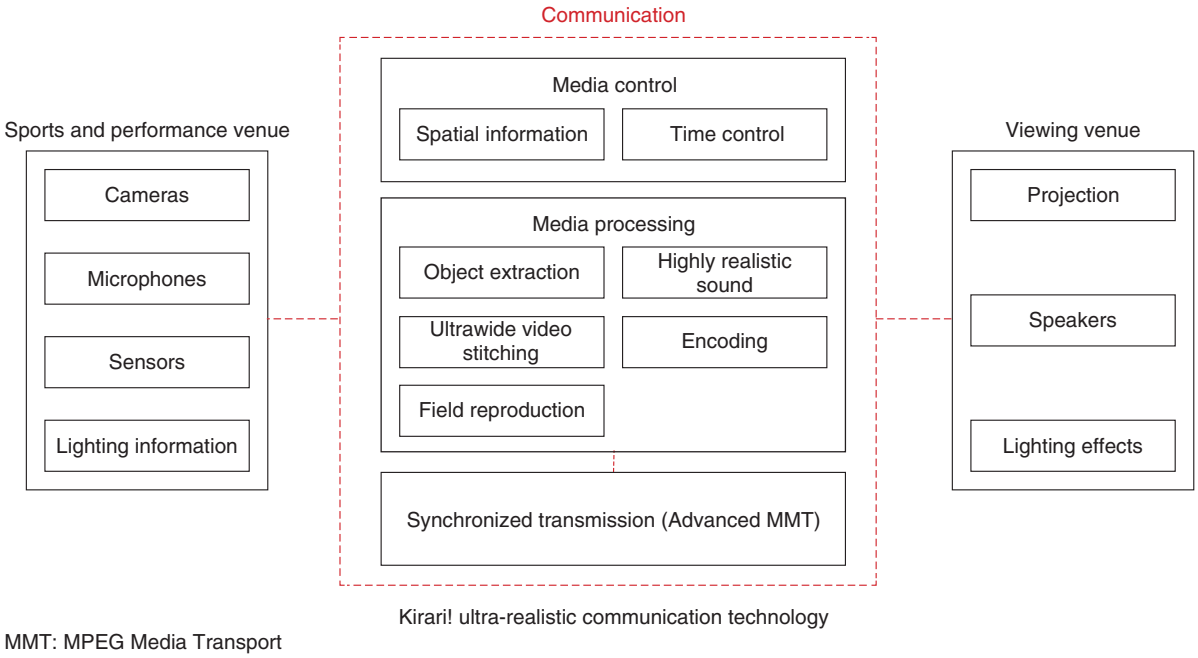

Fig. 4. Overview of Kirari! technology.

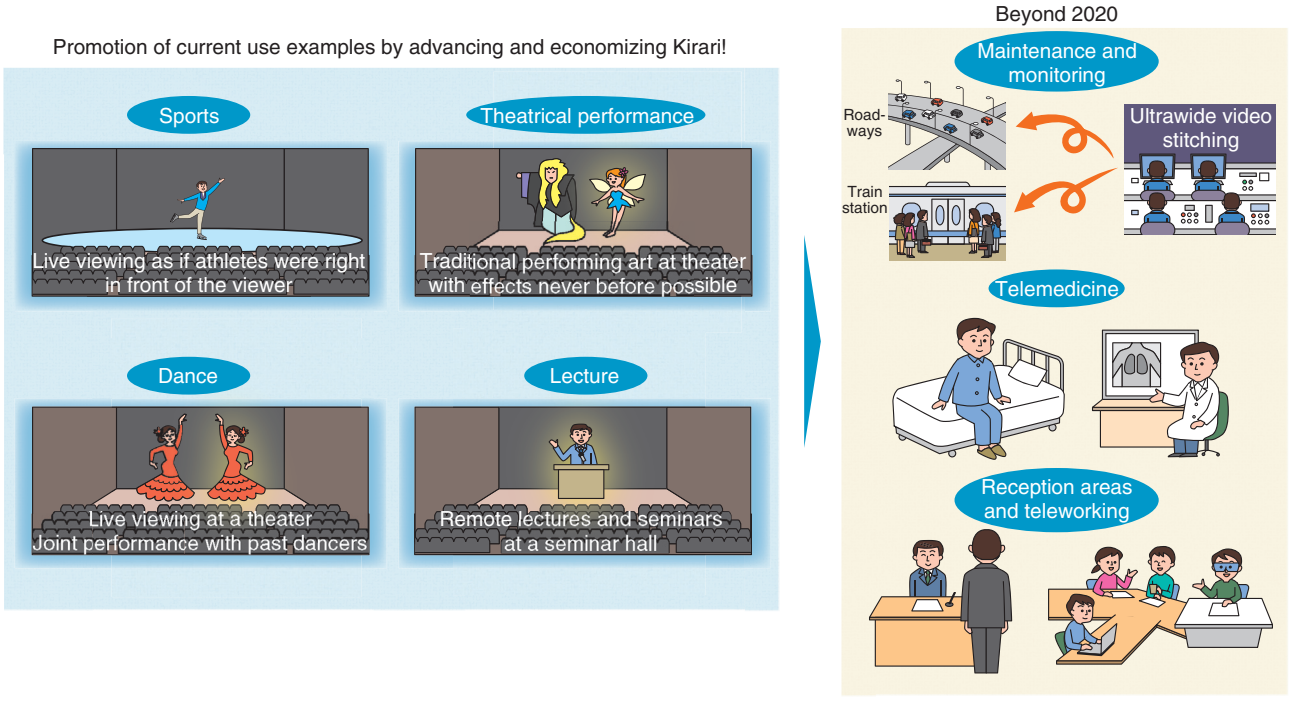

Fig. 5. Further development of Kirari!.

from remote locations (**Fig. 5**). One advancement to Kirari! that is needed to promote these measures is more accurate extraction of the object being viewed, even in environments with people coming and going.

Another issue is to create ultrawide compositions of high-definition video.

Measures to reduce costs are also an important issue for implementation in society. For example, we are studying ways to further compress high-definition video, and to reduce the number of media processing servers required. Also, with more advanced media control, it will become possible to automatically and accurately overlay video of performers from the past next to real performers. This could contribute to reducing the personnel costs for productions.

In addition to promoting Kirari! in society with sports and other performances, we are looking at possibilities beyond 2020. For example, in fields such as maintenance and surveillance, roadways and train stations could be monitored using ultrawide composed video, giving an experience in which items being monitored seem to be right before the viewer's eyes. Increasingly, applications are being studied in medicine for remote examinations, in business situations to replace receptionists, and to promote telecommuting. With these initiatives, we will continue to create value by overcoming the limitations of space in Society 5.0.

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Akihito Akutsu
Vice President, NTT Service Evolution Laboratories.

He received an M.E. in engineering from Chiba University in 1990 and a Ph.D. in natural science and technology from Kanazawa University in 2001. Since joining NTT in 1990, he has been engaged in research and development (R&D) of video indexing technology based on image/video processing, and man-machine interface architecture design. From 2003 to 2006, he was with NTT EAST, where he was involved in managing a joint venture between NTT EAST and Japanese broadcasters. In 2008, he was appointed Director of NTT Cyber Solutions Laboratories (now NTT Service Evolution Laboratories), where he worked on an R&D project focused on broadband and broadcast services. In October 2013, he was appointed Executive Producer of 4K/8K HEVC (High Efficiency Video Coding) at NTT Media Intelligence Laboratories. He received the Young Engineer Award and Best Paper Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in 1993 and 2000, respectively. He is a member of IEICE.

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Executive Research Engineer, Natural Communication Project, NTT Service Evolution Laboratories.

He received a B.E. in electronic engineering and an M.S. in biomedical engineering from Keio University, Kanagawa in 1991 and 1993. He received an MBA from Thunderbird, Global School of Management, Arizona, USA, in 2002. He has been engaged in R&D management in the development of "Kirari!" immersive telepresence technology since 2016. During 2012–2014, he was responsible for the development of mobile application services at NTT DOCOMO. His research interests include image and audio processing, user interfaces, and telepresence technologies. He is a member of IEICE.

Kota Hidaka
Senior Research Engineer, Supervisor, Group Leader, NTT Service Evolution Laboratories.

He received an M.E. in applied physics from Kyushu University, Fukuoka, in 1998, and a Ph.D. in media and governance from Keio University, Tokyo, in 2009. He joined NTT in 1998. His research interests include speech signal processing, image processing, and immersive telepresence. He was a Senior Researcher at the Council for Science, Technology and Innovation, Cabinet Office, Government of Japan, from 2015 to 2017.

Real-time Extraction of Objects from Any Background Using Machine Learning

Hirokazu Kakinuma, Jiro Nagao, Hiromu Miyashita, Yoshihide Tonomura, Hidenobu Nagata, and Kota Hidaka

Abstract

NTT Service Evolution Laboratories is conducting research and development on the Kirari! ultra-realistic communication system, which can make an athlete or performer in a remote location seem to be right before the viewer's eyes. This article describes a system that can extract objects from an arbitrary background in real time, which is essential for realistic remote presentation of athletes and performers using pseudo-three-dimensional video and other techniques.

Keywords: image segmentation, machine learning, ultra-realism

1. Introduction

The ability to accurately identify the region of a person or object within an image is an essential technology for performing high-quality image editing and composition, and it is therefore a major research theme in computer vision. Selecting the object region is also essential for achieving realism in the Kirari! ultra-realistic communication system when performing pseudo-three-dimensional video display. In the article "Real-time Extraction of Objects with Arbitrary Backgrounds" [1], NTT Service Evolution Laboratories proposed a system able to extract only the object region in real time from video of a sports venue or performance stage, without using studio equipment such as a green screen. This article introduces a system that can extract object regions with greater accuracy. It was developed by introducing machine learning to distinguish more subtle differences in feature values that have been indistinguishable earlier and generating feature values of the object being extracted using infrared light.

2. Framework for real-time object extraction using machine learning

Background subtraction is a common method for extracting objects in real time. Background subtraction involves finding the differences between the input image and a background image and applying a threshold to identify changes as the object area. This method is fast and requires little preparation, so it is widely used. However, there are challenges with this method, including the difficulty in deciding an appropriate threshold value and the inability to support backgrounds that change.

We have developed an object extraction method that uses a neural network (NN) to convert input feature vectors to a different feature space and perform the discrimination. With the NN, we hope to derive a feature space for making discriminations within the NN using training data provided beforehand and to automatically convert to this more suitable feature space. Inputs other than the image being detected, for example, reference images with features of the object, images from different times, region information, and infrared images, can also be included and will also be converted to suitable feature spaces in the

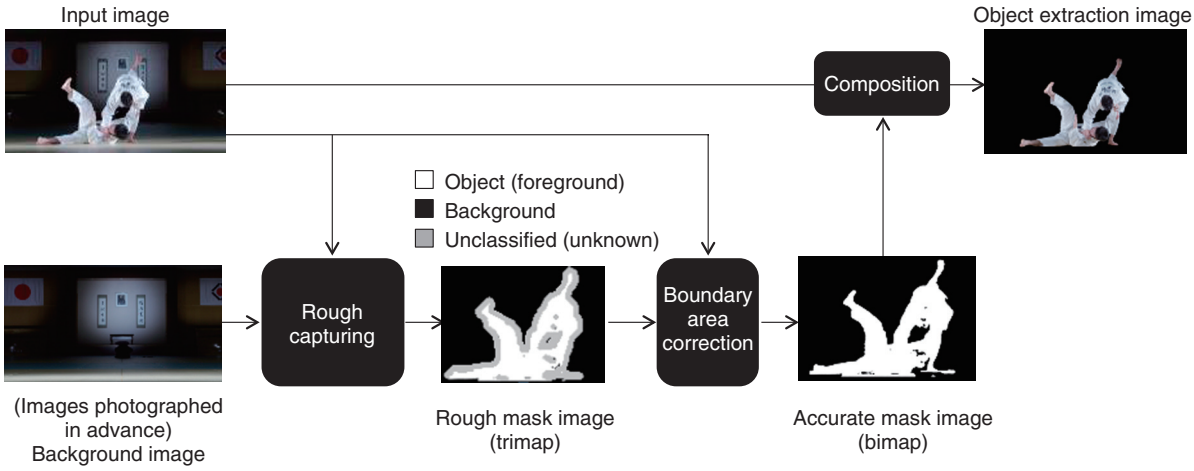
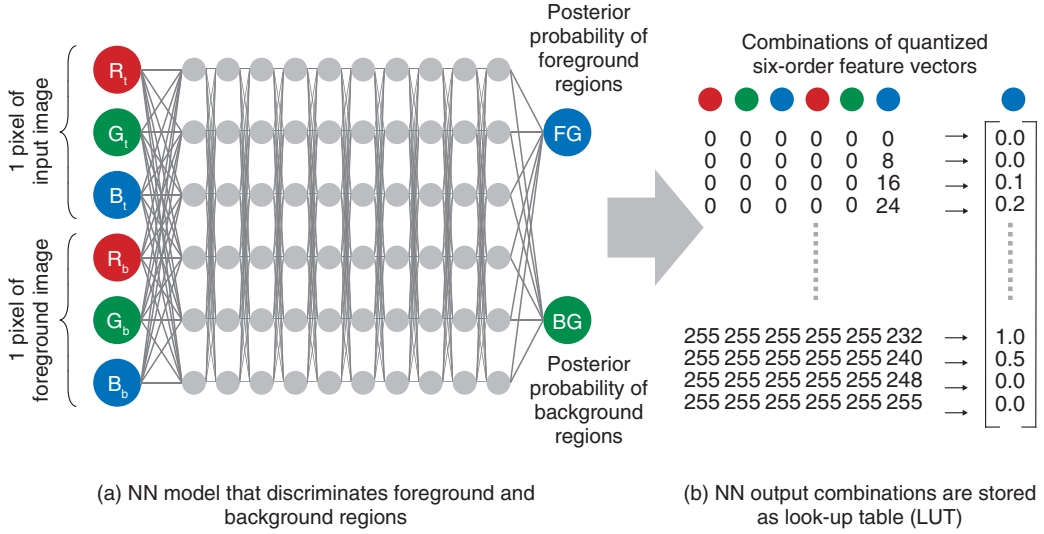


Fig. 1. Framework for real-time object extraction using machine learning.



(a) NN model that discriminates foreground and background regions

(b) NN output combinations are stored as look-up table (LUT)

Fig. 2. Training process.

NN in order to perform object extraction using higher-order feature values of the background and object. This should make operations such as changing the background more robust.

The workflow for the system we developed is shown in **Fig. 1**. Object extraction is done in two steps. In the first step, the object region is selected using a rough mask image (a trimap[*1]), and in the second step, a matting process[*2] dependent on this trimap creates a more accurate object region. Machine learning is used to capture trimap in the first step.

Machine learning is divided broadly into training and application processes. In the training process, parameters in the NN model are learned from training data. This process is shown in **Fig. 2**. Training data are first prepared. Background images that do not contain the object, and sample images that do contain

*1 Trimap: A region map indicating known and unknown regions of an image. Known foreground regions are set to white, known background regions to black, and unknown regions to grey.

*2 Matting process: A process that derives an alpha mask for extracting the object. The alpha mask has values ranging from 0 to 1, and the extracted image is obtained by multiplying the input image by the mask.

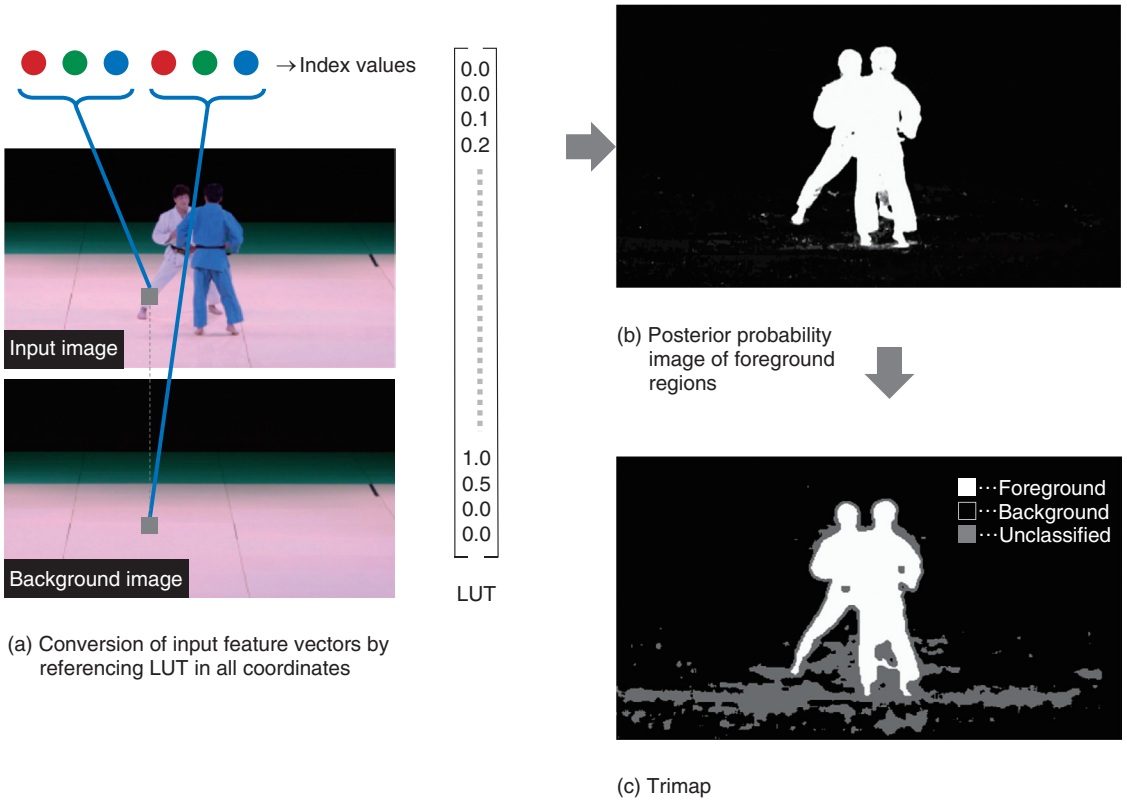


Fig. 3. Application process.

the object are obtained, and correct mask images are created. Then, input feature vectors are created. These feature vectors combine target pixels from the sample image corresponding to the foreground area in the mask, with the corresponding pixels from the background image. These combinations are used to train for the foreground region. Similarly, input feature vectors combining the background pixels from the sample image and corresponding pixels from the background image are created, and these combinations are used to train for the background region.

In this way, we obtained an NN model able to discriminate the foreground from the background regions for combinations of input target pixels and background image pixels (Fig. 2(a)). Generally, NN processing requires large computing resources, so we increased speed by implementing processing using a look-up table (LUT). We reduced the number of gradations in the input feature vectors by quantizing them and stored all combinations of quantized input feature vectors and NN outputs as an LUT (Fig. 2(b)). Note that in Fig. 2, we describe this process in terms of RGB (red, green, and blue color model) pixels for simplicity, but the input vectors can include more than color information, for example, image position.

The process for applying the LUT to generate the trimap is shown in **Fig. 3**. A quantized input feature vector is derived in a process similar to that for the machine learning process, and this derived feature vector is used to reference the LUT, rapidly determining a posterior probability that the pixel in question is in the foreground (Fig. 3(b)). The trimap is generated from the derived foreground-posterior-probability image by setting regions that are not clearly foreground or background to the unclassified region (Fig. 3(c)). The unclassified region in the trimap is discriminated by using a nearest-neighbor search with information about whether pixels neighboring the pixel in question and having similar feature vectors were classified as foreground or background.

The details of this nearest-neighbor search are shown in **Fig. 4**. For each pixel in the unclassified region, a spiral search in the local neighborhood is done to determine whether the pixel is more similar to a foreground pixel or a background pixel, and this is used to derive an alpha value for the pixel. The

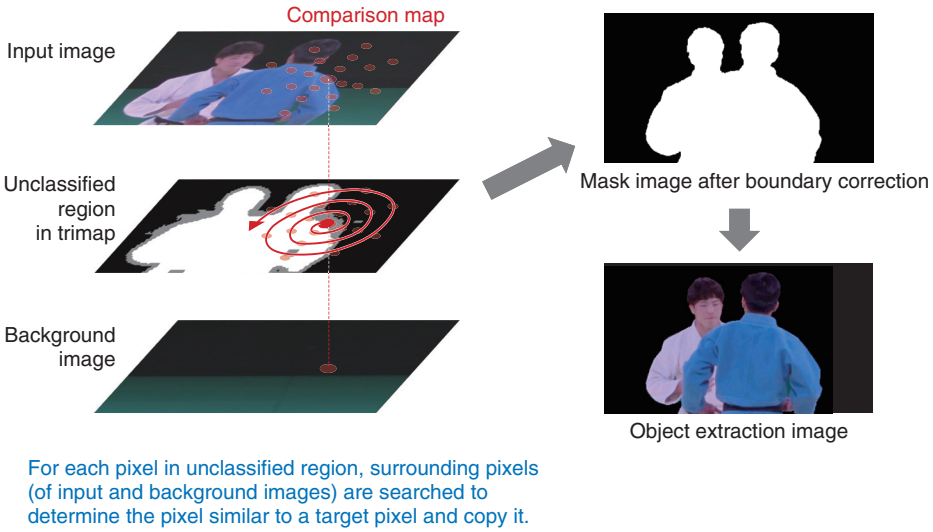


Fig. 4. Boundary correction by nearest-neighbor search, and masking process.

object is then extracted using the derived alpha values. By introducing this boundary correction process, we can extract objects based on information from the pixel itself and also from surrounding pixels. We also provide a framework for optimizing this process such as by processing the rough mask on a low-resolution image, or by performing only the magnification process on all pixels.

3. Real-time extraction of objects from backgrounds of similar color using infrared

Even though machine learning is used to automatically convert input feature vectors to a high-order feature space within the NN, we are still extracting objects based on color and shape information, so it is theoretically impossible to separate cases when the input feature vectors are the same. For this reason, we developed an object extraction system using RGB and infrared (IR) cameras, utilizing IR light that is invisible to the naked eye in an attempt to add new features.

The object extraction photography environment using the RGB and IR cameras is shown in **Fig. 5**. An RGB camera and an IR camera were placed side by side, respectively capturing visible light and IR images. The background was illuminated with IR, while deliberately preventing IR light from reflecting from the object. In this way, the background appeared brighter in the IR image, while the object was relatively dark.

In the RGB camera image in Fig. 5, the background and the person are of the same color, so it is difficult to distinguish them based on color, but the person's silhouette can be obtained from the IR camera image. Then, to extract the object accurately from the IR camera image, we correct for the parallax between the IR camera and the RGB camera. To perform the correction, photos of a calibration board were taken beforehand, a projection transform from the IR image was derived so that the same feature points from the IR camera and the RGB camera aligned, and this transform was applied. By adding the IR image obtained in this way to the input of machine learning, we were able to extract objects using new features other than color and shape.

4. Evaluation experiments

We developed a real-time object extraction system using machine learning and used it in the Cho-Kabuki play called "Tsumoru Omoi Hana no Kaomise," at the Niconico Chokaigi event held in April 2018 at Makuhari Messe, Chiba, Japan. The system developed is capable of 3840 × 2160 resolution video at a frame rate of 60 fps, but for this trial, a resolution of 1920 × 1080 and a frame rate of 59.94 fps were used for compatibility with other systems. In the climax scene of the Cho-Kabuki main production, Koretaka-shinno, played by Shido Nakamura II, emerges from the screen in real time as the stage video background changes, while the confrontation with Princess

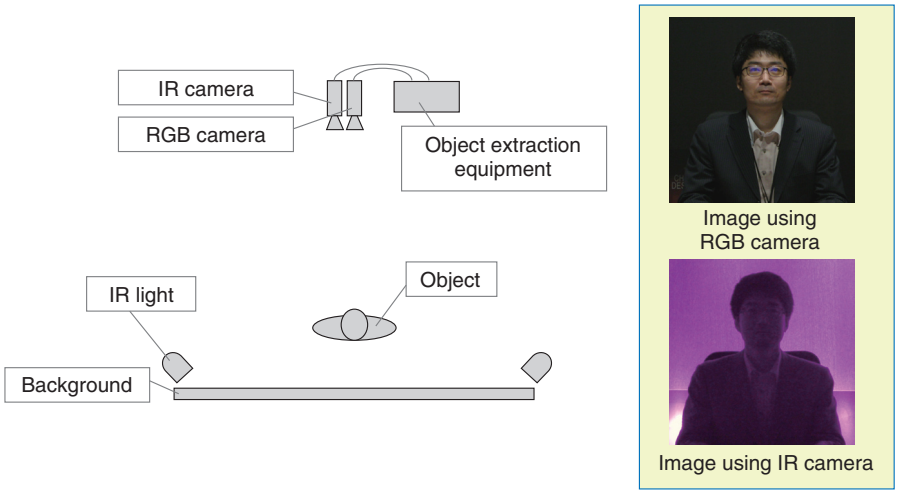
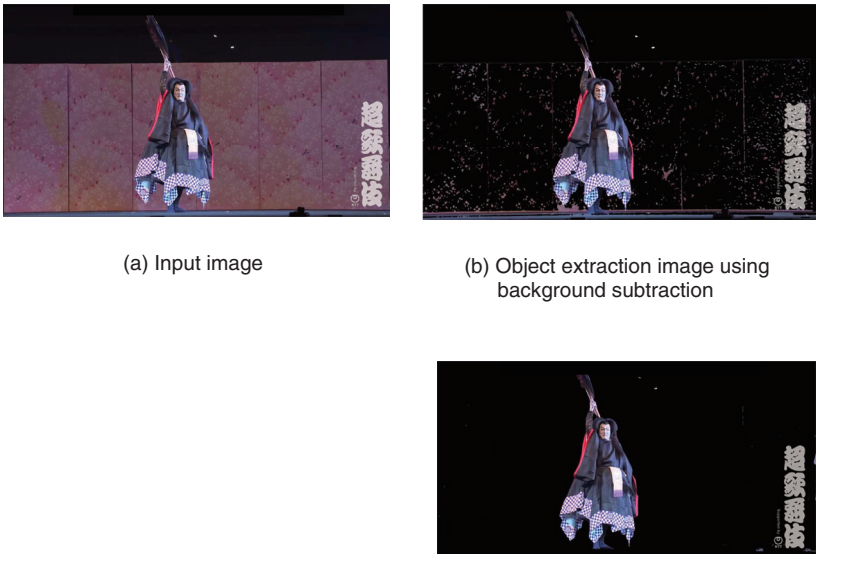


Fig. 5. Object extraction photography environment using RGB and IR cameras.



(a) Input image

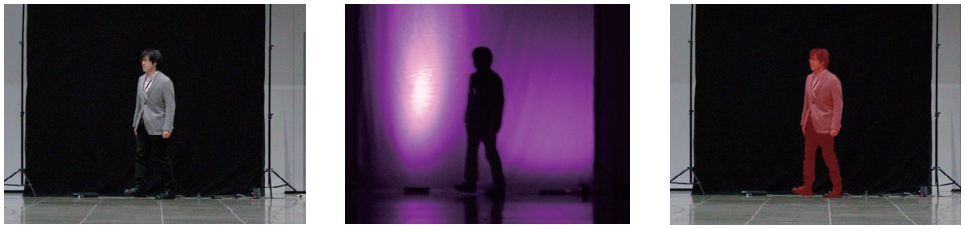
(b) Object extraction image using background subtraction

(c) Object extraction image using machine learning

Fig. 6. Real-time object extraction using machine learning on *kabuki* stage.

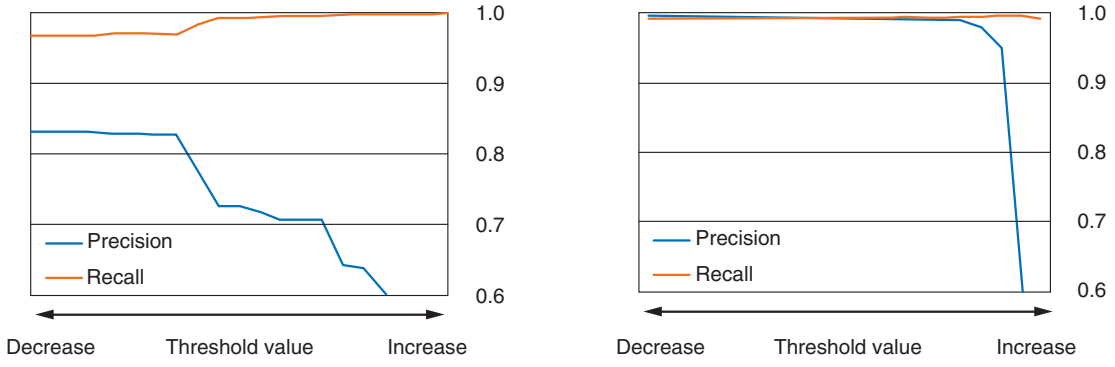
Hatsune Ono, played by virtual personality, Miku Hatsune, comes to its peak. Samples of the video at that point are shown in **Fig. 6**. The board behind Koretaka-shinno is being held by stage-hands, so it is not steady, and the image cannot be extracted well using background subtraction (Fig. 6(b)). We showed that it can be extracted more accurately using our system using machine learning (Fig. 6(c)).

We also checked the effect of using the IR camera (**Fig. 7**). We were able to confirm that objects can be extracted accurately, even in cases where it was difficult using an RGB camera. In this case, we did not do the automatic conversion of input feature vectors to a high order feature space or the threshold processing in the NN training, but we evaluated how robust the method using the IR camera would be by applying background subtraction and changing the threshold values (**Fig. 8**). We confirmed that using the IR camera



(a) Image using RGB camera (b) Image using IR camera (c) Result of object extraction

Fig. 7. Object extraction with machine learning using RGB and IR cameras.



(a) When using RGB camera only (b) When using both RGB and IR cameras

Fig. 8. Precision and recall using background subtraction.

enabled us to achieve very reproducible results as well as stable operation, even when the threshold values changed considerably.

We have introduced cases using an IR camera, but other characteristics suitable for extracting objects, depending on the conditions, can be input to the system, for example, depth maps generated using stereo cameras or LiDAR (light detection and ranging).

5. Future prospects

This article introduced a highly accurate object extraction method based on high-order feature values of objects, using machine learning to convert input feature vectors to a new feature space and performing the discrimination within an NN. We also introduced the use of features based on IR light, which is not visible to the naked eye, to handle use cases where this extraction is difficult using only an RGB camera.

In the future, to consider semantics when performing object extraction, we will work to perform object extraction using deep learning in real time and also study methods for extracting objects accurately when there are occlusions.

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"Kirari! for Arena"—Highly Realistic Public Viewing from Multiple Directions

Takeru Isaka, Motohiro Makiguchi, and Hideaki Takada

Abstract

NTT Service Evolution Laboratories has developed a display system that achieves highly realistic public viewing surrounding the venues of sporting events. We utilize human visual perception to make viewers perceive the subject in space, including a motion in the depth direction, in order to achieve a presentation that appears as though the subject was actually in front of the viewer. This article gives an overview of an approach to present motion in the depth direction by using visual perception, and a display system that can be implemented with a simple configuration and enables viewing from anywhere surrounding the display.

Keywords: high realistic, depth perception, floating image

1. Highly realistic public viewing

From television (TV) screens placed where passers-by on the street can watch them, to public viewing of various events, media that enable viewers to meet in one place and enjoy sports events have made it possible for viewers to share in the excitement of the event by emphasizing the connection between them. We expect that with the spread of 4K and 8K broadcasts in 2020, many more sporting events from around the world will be covered on TV, and such excitement will be shared much more widely, regardless of the location or time, through various viewing styles such as live distribution on the Internet and informal public events in the street.

NTT Service Evolution Laboratories is taking this diversification in viewing styles around the world into account while conducting research and development on the "Kirari!" immersive telepresence technology, which implements highly realistic public viewing in real time from any location, giving viewers the sense of actually being at an event taking place elsewhere.

Research is in progress on various imaging methods for "Kirari!"; one method uses two-dimensional (2D) floating images and can display life-sized images as though they were actually on the stage in front of the viewer. The method uses virtual images and involves a simple configuration combining an ordinary 2D display with an optical element such as a half-mirror, which transmits and reflects part of the incident light (**Fig. 1**). The method presents the image in a position separated from the display, so it appears that the image is floating in the same space as the viewer, and subjects in the image are perceived as real objects [1]. This method can be used for public viewing of sports events, giving a sense of reality as though the event was actually happening in front of the viewer.

2. Greater reality using floating images

For most cases of public viewing, many viewers usually gather at the same location to watch the content at the same time, so the content must be presented accurately in space for a wide range of viewpoints. However, until now, images from the same viewpoint have been presented on TV or on screens to all viewers, so it has not been possible to correctly reproduce different positions and distances in the

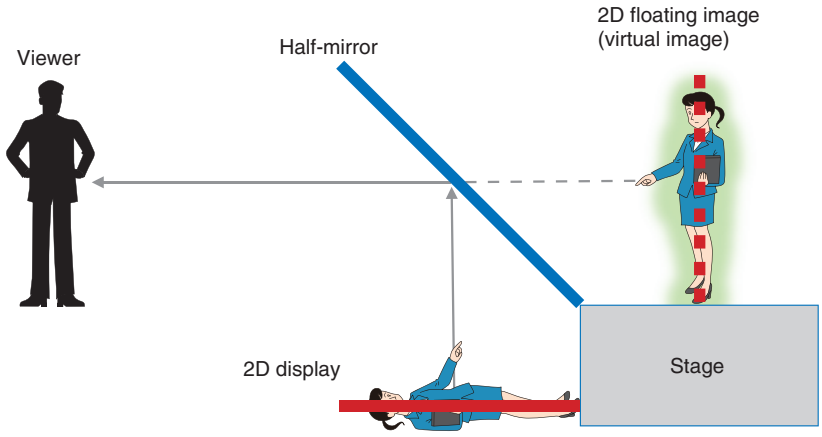

Fig. 1. Setup of 2D floating image.

content. This issue also occurs when using 2D floating images.

Many methods have been developed to present spatial positions of subjects for a wide range of viewpoints [2, 3]. However, most of these methods have required many projectors or special optical systems, with large and complex equipment that makes it difficult to present the content as life-sized. Therefore, these methods have been difficult to apply for public viewing.

We have instead focused on a method with a simple configuration that uses 2D floating images. It can expand the size of the content and can be easily applied to smartphones and tablets [4].

With 2D floating images, the virtual image plane is at a fixed position in space, so it is not possible to reproduce motion in the depth direction. Prior research has been done on adding motion in the depth direction to 2D floating images [5], but it was limited to a single viewer and required the use of special glasses. To date, there have been no attempts to reproduce the motion of subjects in the depth direction for multiple viewers over a wide range of viewpoints.

In this article, we propose a method with a simple configuration to present motion in the depth direction to multiple viewers by implementing psychological depth-perception effects, and we introduce an application of this method to a display system that enables viewing from all around.

3. Perspective and depth perception

The concept of perspective has long been known to be a way to express depth based on psychological factors. When the positions and sizes of subjects are drawn as they would appear to the eye, the viewer is able to recognize significant distances, even when drawn in a picture or other 2D fixed surface. It is also possible to present motion in the depth direction by applying perspective to 2D floating images.

The position and size of the subject drawn using perspective converge to a point as the distance to the subject increases. Such a point is called a vanishing point. As an example, if the left and right edges of a floor are extended infinitely in the depth direction, they will cross at the vanishing point in an image. If a subject moves straight in the depth direction, its motion will also be toward this vanishing point. If there are multiple viewpoints, the vanishing points will be different for each viewpoint, so subjects must also move in a direction determined for each viewpoint. When 2D floating images are displayed, there are correct vanishing points for each viewpoint, depending on the stage and other real objects, but only one vanishing point for one viewpoint can be set for subjects displayed as floating images. When such images are viewed from different viewpoints, motion in the correct depth direction cannot be represented.

4. Method to present motion in the depth direction

As shown in **Fig. 2**, even when there is error, and the direction of the subject motion (shown with the square and the dotted line connected to it) does not match the vanishing point of the floor plane (shown with the circle), people can empirically perceive motion in the depth direction. We have experimentally

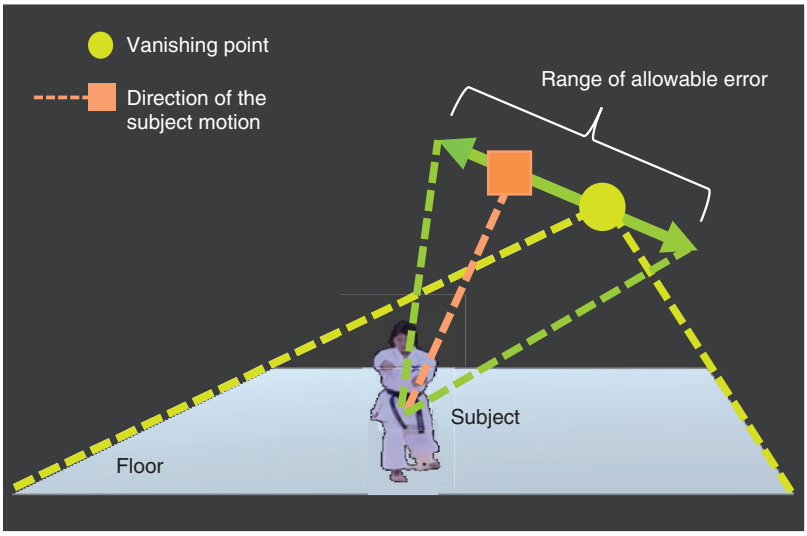

Fig. 2. Range of allowable error in which motion in the depth direction is recognized.

verified and defined a range of allowable error within which this motion in the depth direction is recognized [6]. We have also proposed a method for representing motion in the depth direction for multiple viewpoints by setting this permissible range for each viewpoint and restricting the motion of subjects to within a range common to all viewpoints.

The permissible range of error within which motion in the depth direction is recognized depends strongly on the positional relationship between the subject and the floor plane. If the motion of the subject is within the triangular region formed by the feet of the subject and the left and right endpoints at the back of the floor plane, any perceived strangeness in motion in the depth direction will be reduced. With this in mind, we derived a method for representing motion in the depth direction with 2D floating images as an algorithm that determines the subject position in each frame using information on the subject position and the viewing range. We can also adjust the representation of subjects in the virtual image so that they have contact with the real-space floor surfaces.

With this method, we can represent the motion of subjects in the depth direction without any apparent inconsistencies and ensure that they remain connected to the floor. The paths of motion for subjects before and after applying this depth assignment method are shown in **Fig. 3**. The movement of the subject is shown with the solid line, while the permitted range of motion is the region bounded by the dotted line and the floor surface. In this figure, before the proposed method was applied, the path of motion goes out of the permitted region, but after the method was applied, it stayed within the region. This shows that for life-sized subjects moving within a floor range of 10 m × 10 m, motion in the depth direction with a range of 7.5 to 9.0 m can be represented.

5. Prototype of "Kirari! for Arena"

We built a prototype "Kirari! for Arena" system that enables viewing from all around by combining four optical systems consisting of a 2D display and a half-mirror, all sharing a single floor surface. Images of the subjects captured from four directions are displayed on the virtual image planes (**Fig. 4**). The system takes images of just the subjects, extracted from their respective backgrounds, as well as subject distance information measured using LiDAR (light detection and ranging). The method described here is used to process and display the images in real time. Compared to existing display systems requiring many projectors and special optical devices, this system is capable of enabling viewing from all around using a simple configuration of ordinary displays and half-mirrors. Because it is so practical, we hope to apply it for public viewing of sports and other events, where many people surround the venue while watching.

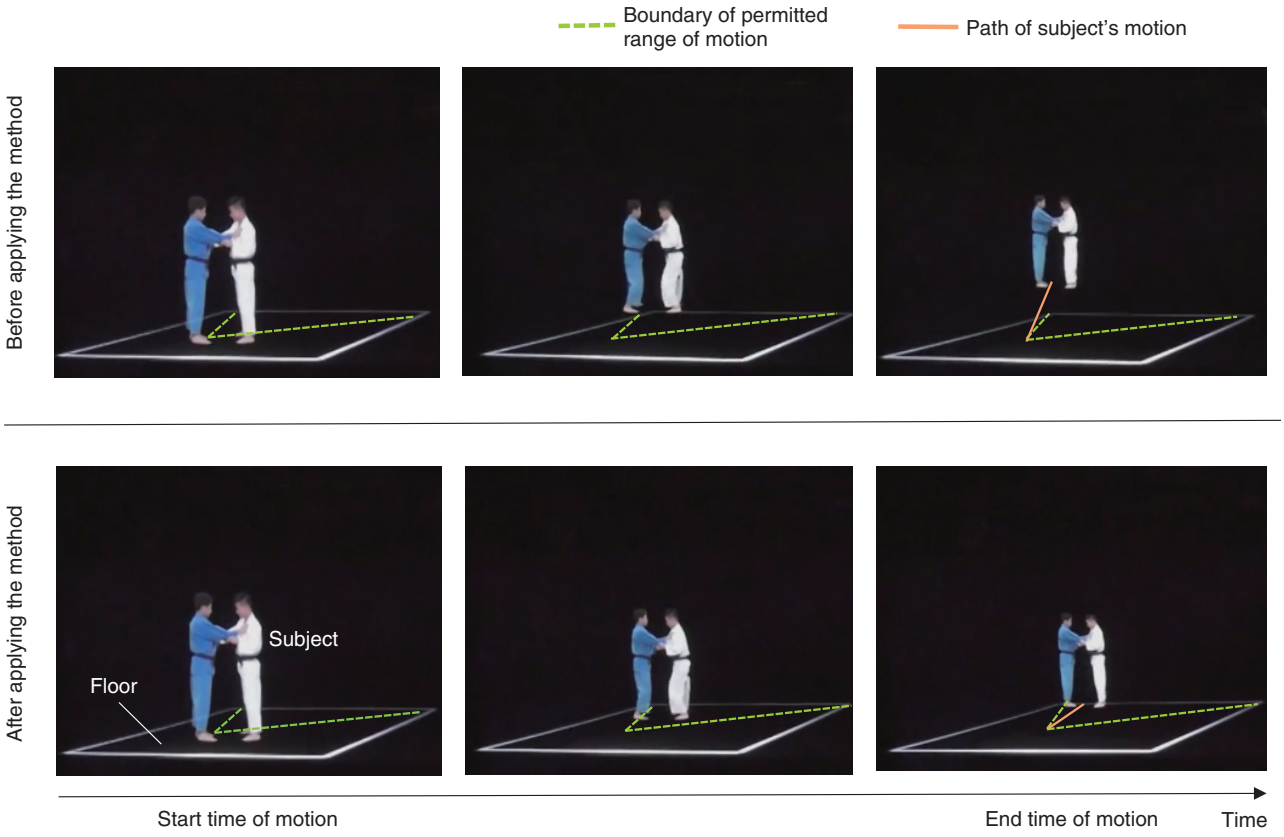

Fig. 3. Path of subject's motion before and after applying proposed method.

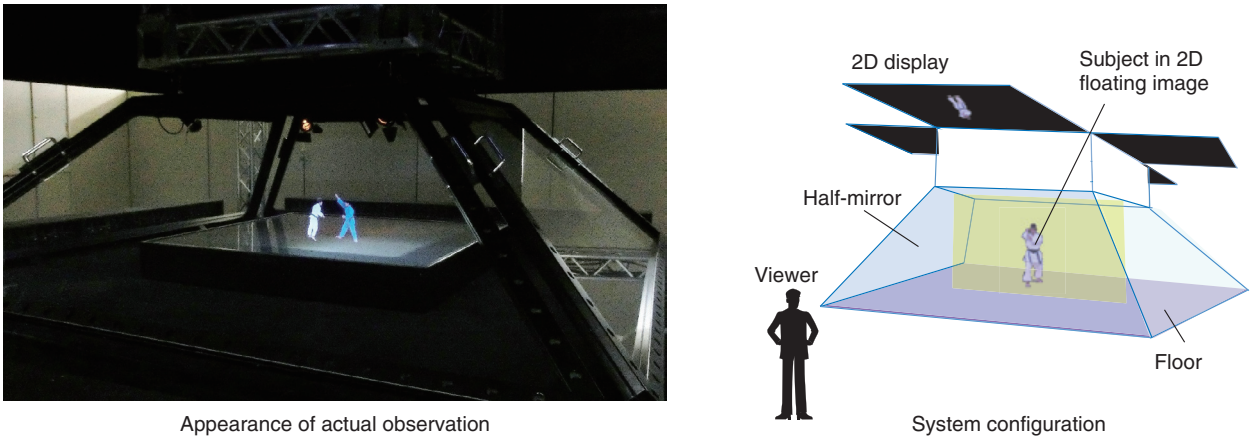

Fig. 4. Prototype of "Kirari! for Arena".

6. Future work

In this study, we focused on 2D floating images implemented using a simple configuration combining a display and half-mirror. We also proposed a method for representing depth to multiple viewers when subjects being viewed move in the depth direction, by using psychological depth-perception effects. We

applied this method in prototyping "Kirari! for Arena," which provides viewing of content from all around, including its position in space.

In the future, we plan to represent the position of subjects more precisely and expand the viewing area by applying shadows or other depth cues.

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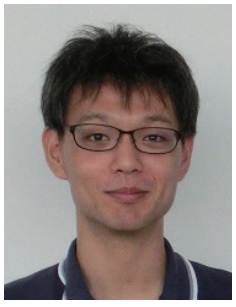

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360-degree Tabletop Glassless 3D Screen System

Motohiro Makiguchi and Hideaki Takada

Abstract

NTT Service Evolution Laboratories has developed 360-degree tabletop glassless three-dimensional (3D) screen technology, which produces 3D images that appear on a table and provides experiences of viewing from the full perimeter of sports venues and other scenes. This article deals mainly with the basic visual mechanism of depth perception and the optical configuration for projector placement used for this technology.

Keywords: autostereoscopic 3D, linear blending, smooth motion parallax

1. Introduction

Expectations are rising for autostereoscopic three-dimensional (3D) screens that can achieve smooth motion parallax and natural 3D viewing without requiring 3D glasses or other such mechanisms as the ultimate display system of the future. In particular, tabletop 3D screen technologies, which can display items as though they were actually on the table, are anticipated for a wide range of applications such as viewing live sporting events with an overhead view of the entire field, or for modeling manufactured products. With this system, several viewers can stand around the table and watch the sports event from whatever direction they want. This could dramatically improve the communication environment among viewers. Autostereoscopic 3D screen technology is necessary to create this sort of experience, as it supports 360-degree motion parallax and does not require the use of 3D glasses or other special mechanisms that become an obstacle to eye contact or seeing the facial expressions of other viewers.

Autostereoscopic 3D screen technologies with 360-degree motion parallax have been proposed before, including a system that uses several hundred projectors placed at very small intervals that project images onto a special cone-shaped screen [1]. The use of multiple projectors to project viewpoint images in this way is advantageous in that multiple people can view the 3D content without glasses at the same time. However, to switch smoothly between video sources as the viewpoint moves, many projectors at very close intervals are needed, which increases equipment costs and the scale and complexity of the facility.

We previously proposed the basic technology for an autostereoscopic 3D screen system that supports horizontal motion parallax using a 50-inch diagonal screen and 13 projectors [2]. This system achieves smooth viewpoint motion requiring just one-fourth to one-tenth the number of projectors of earlier systems by using a perceptual mechanism of the visual system called *linear blending*, in which the luminance of the image from neighboring viewpoints is composed based on the viewing position, so that the intermediate viewpoint is perceived as visually interpolated.

Linear blending is achieved optically using a spatially imaged iris plane optical screen. We are continuing to study the implementation of a tabletop screen by applying this screen in the horizontal direction and have implemented a prototype that is effective in reducing the number of projectors using linear blending [3]. However, in our investigation so far, a screen and projection system developed for wall mounting were simply extended to a tabletop form, so optical design constraints limited the field of view to approximately ±65 degrees of center, which did not achieve 360-degree viewing.

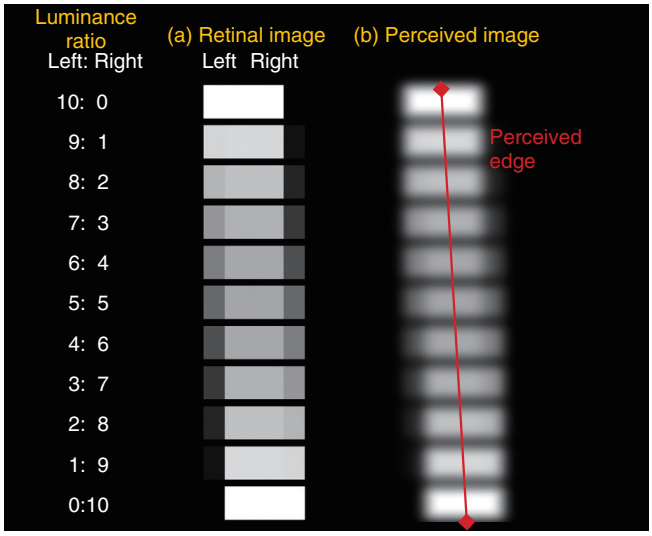

Fig. 1. Image edge perception mechanism with linear blending.

In this article, we describe a new optical configuration to expand the tabletop linear-blending autostereoscopic 3D screen system for 360-degree viewing, and a new tabletop type prototype using 60 projectors.

2. Utilization of perception mechanisms of the visual system

For two images that overlap with only a small offset to the left or right, if the relative brightness of each image is varied, an image with double edges to the left and right is projected onto the human retina, as shown in **Fig. 1(a)**. However, in the human visual system, if the distance between these two edges in the image is sufficiently small, it is perceived as one edge instead of two, with the position of the edge smoothly changing according to the relative brightness, as shown in **Fig. 1(b)** [3]. This principle, based on using this image edge perception mechanism to blend viewpoint images from adjacent projectors according to the relative luminance, is called linear blending in this article.

Earlier autostereoscopic 3D screens using multiple projectors had projectors positioned at intervals narrower than the distance between viewers' eyes, so that binocular and motion parallax would be displayed smoothly. This required large numbers of projectors as the viewing range was increased, as shown in **Fig. 2(a)**. In contrast, with linear blending, parallax is presented by blending images from two viewpoints that have a disparity less than the fusion limit angle, using relative luminance depending on the viewing position. Intermediate viewpoints are perceived as interpolated, so projectors are not needed for those viewpoints (**Fig. 2(b)**). This enables 3D images to be displayed with smooth binocular and motion parallax, even when using projector intervals that are wider than the spacing between viewers' eyes.

3. Optimization of the tabletop optical configuration

The spatially imaged iris plane screen [2] that uses linear blending is composed of a reflective layer, a fresnel lens layer, and a diffusion layer. Light from the projectors is reflected on the screen, and it focuses in the opposing space on the side of the screen. In this way, the projector iris plane (the part equivalent to the iris in the projector optical system) forms in the space, and the viewer can only perceive the projected image within that range. In tabletop configurations studied earlier [4], a straight-line projector array was used, with projectors in a straight horizontal line facing the spatially imaged iris plane. However, with this straight-line projector array, the farther the viewpoint was horizontally from the center of the array, the more the projected viewpoint images were distorted, so simply extending this by combining linear projector arrays in four directions to create a full perimeter system would not enable presentation of 3D images to all viewpoints.

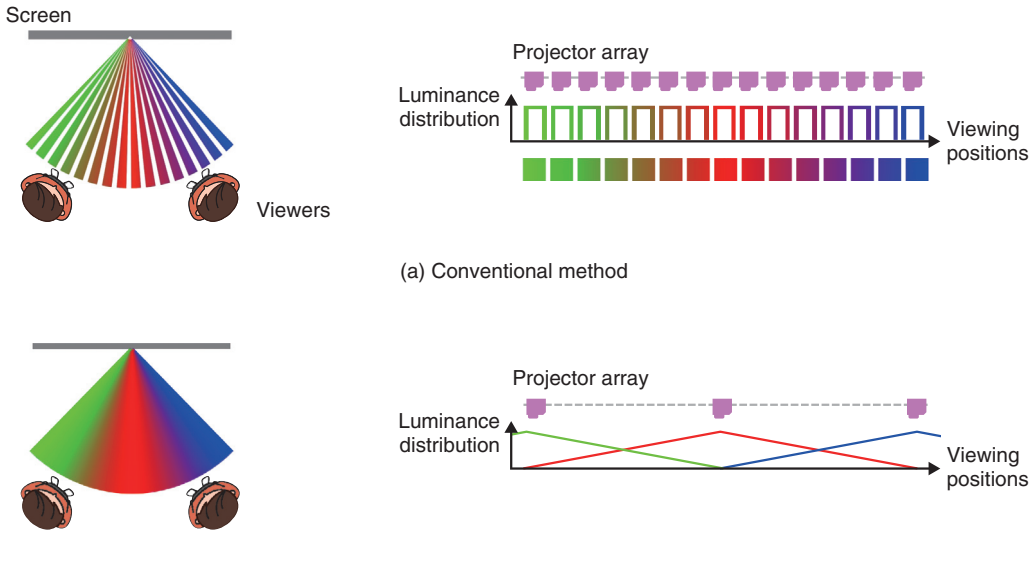

Fig. 2. Comparison of conventional and proposed methods.

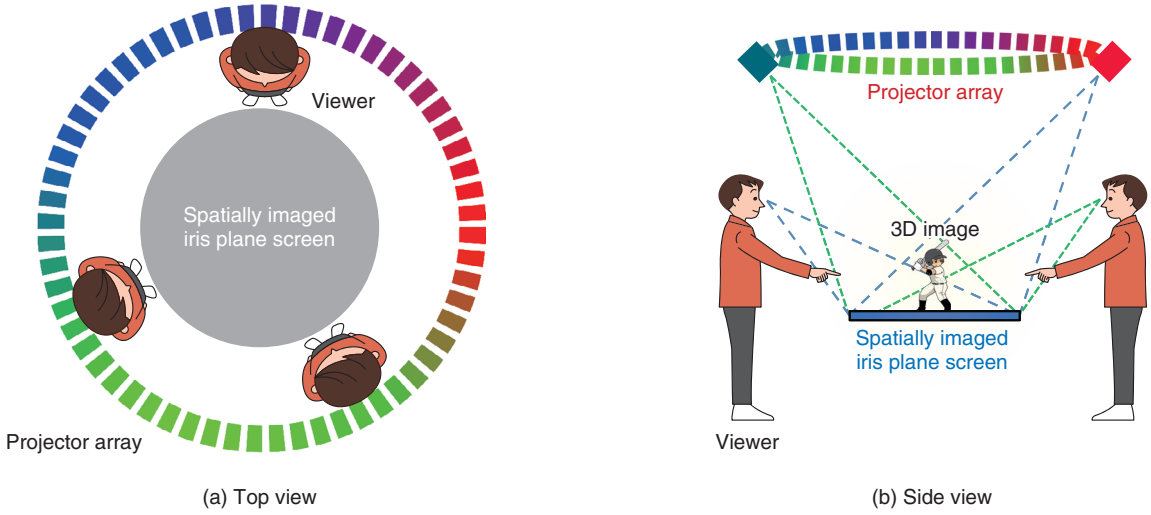

Fig. 3. Optical system with a circular projector array for 360-degree viewing.

To expand the viewing range to the entire perimeter, we designed an optical system with a circular projector array as shown in **Fig. 3**; a side view of the positional relationship between the viewer and the iris plane is shown in **Fig. 4**. The properties of the diffusion layer cause the luminance distribution of the iris plane to peak in the center and also result in attenuation with distance from the center. The intermediate viewpoint images can be interpolated with the linear blending effect by optimizing the design of the diffusion angle θ_2 of the diffusion layer and the horizontal interval of projector placement, so that adjacent viewpoint images are composed with luminance corresponding to the viewpoint position.

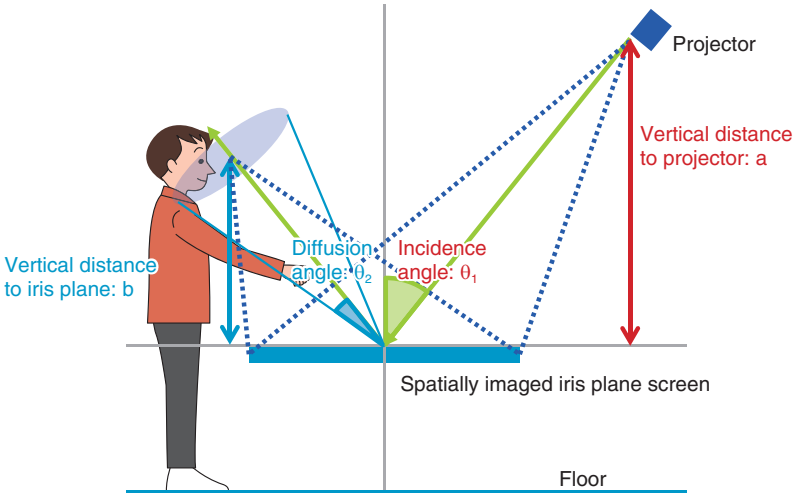

Fig. 4. Positional relationship between viewer and iris plane.

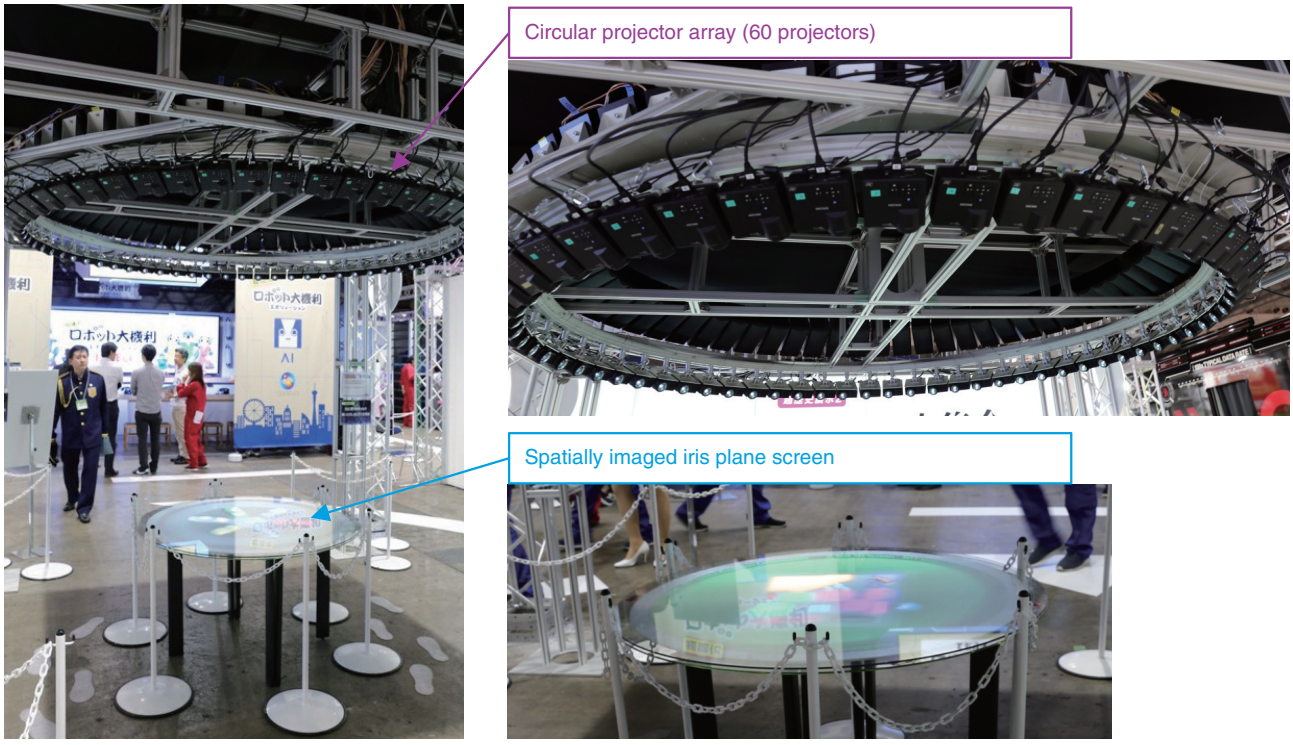

Fig. 5. Prototype of 360-degree tabletop autostereoscopic 3D screen system.

4. Full-range 360-degree tabletop autostereoscopic 3D screen system prototype

We implemented a prototype full 360-degree, autostereoscopic 3D screen using the circular projector array optical system described above (**Fig. 5**). The spatially imaged iris plane screen had a diameter of 110 cm and was placed 70 cm from the floor. Additionally, 60 projectors with a resolution of 1280 x 800 pixels and brightness of 600 lm were placed at

Fig. 6. 3D screen photographed from five viewpoints.

6-degree intervals. The viewpoint images projected from each projector were rendered with real-time synchronization on 60 client personal computers (PCs), one for each projector. Each client PC shared the same computer graphics space and rendered the image from a virtual camera in the position of the corresponding projector. Time synchronization of the viewpoint images was done by sending UDP (user datagram protocol) packets from a server PC with information for the 3D model position and the start of animation.

Photographs from five viewpoints around the prototype are shown in **Fig. 6**. The photographs show how changes in motion parallax with changes in viewpoint are reproduced.

5. Future prospects

We have demonstrated the feasibility of a natural autostereoscopic 3D screen technology with smooth, full-perimeter-viewpoint motion parallax using a prototype system. However, with the current prototype, there is some degradation in image quality caused by multi-edges from neighboring projectors and some other projectors. We are studying how to reduce the adverse effect of multi-edges using visual effects [5]; We plan to improve image quality in the future by optimizing the optical characteristics of the screen. We will also work toward future implementation of highly realistic viewing of sports competitions and other events around a table for venues such as sports bars.

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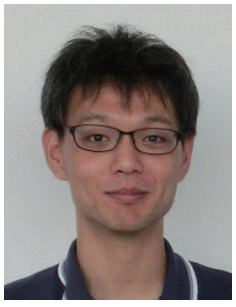

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Video Processing/Display Technology for Reconstructing the Playing Field in Sports Viewing Service Using VR/AR

Megumi Isogai, Kazuki Okami, Masaaki Matsumura, Munekazu Date, Akio Kameda, Hajime Noto, and Hideaki Kimata

Abstract

Sports viewing services using virtual reality (VR) and augmented reality (AR) technology have been introduced recently due to the development of sensor devices and video production/delivery technology. NTT Media Intelligence Laboratories aims to provide a sports viewing service using VR/AR to display reconstructed playing field videos without user operation. In this article, we present a video processing technology to reconstruct the playing field for VR/AR displays and a three-dimensional display technology for representing a playing field three-dimensionally on a table.

Keywords: virtual reality/augmented reality, video processing technology, 3D display technology

1. Introduction

Advances in sensor devices and video production and delivery technology have led to the introduction of sports viewing services using virtual reality (VR) and augmented reality (AR) technologies. NTT DOCOMO demonstrated an AR sports viewing service for rugby games that displays player information and video in a high visibility area through a user's smart glass [1]. KDDI has already launched a VR sports watching service that provides VR views while switching among viewpoints from five cameras in a baseball stadium [2].

However, neither AR nor VR can cover all of the game scenes in a stadium because suitable scenes for VR/AR change in response to the constantly varying game state. To enable viewers to have a good game watching experience, it should be possible to change VR/AR viewing modes without any need for user operation. NTT Media Intelligence Laboratories thus aims to give the crowd in the sports stadium an additional element of excitement by using VR/AR to display reconstructed playing field videos without user operation. To achieve this, we have been studying video processing technology to generate common content for VR and AR, as well as video display technology to create a feeling of physical presence, as if real objects were actually there.

In this article, we first give an overview of a sports viewing system we developed that uses VR/AR. We then present a three-dimensional (3D) reconstruction technology we developed as a means for processing videos to reconstruct the playing field for VR/AR displays. It generates arbitrary viewpoint images from places where cameras cannot be placed on the playing field. We also describe our diminished reality technology that focuses on particular players by removing everything except the players from the video. Finally, we introduce a novel visually equivalent light field 3D display technology that we propose

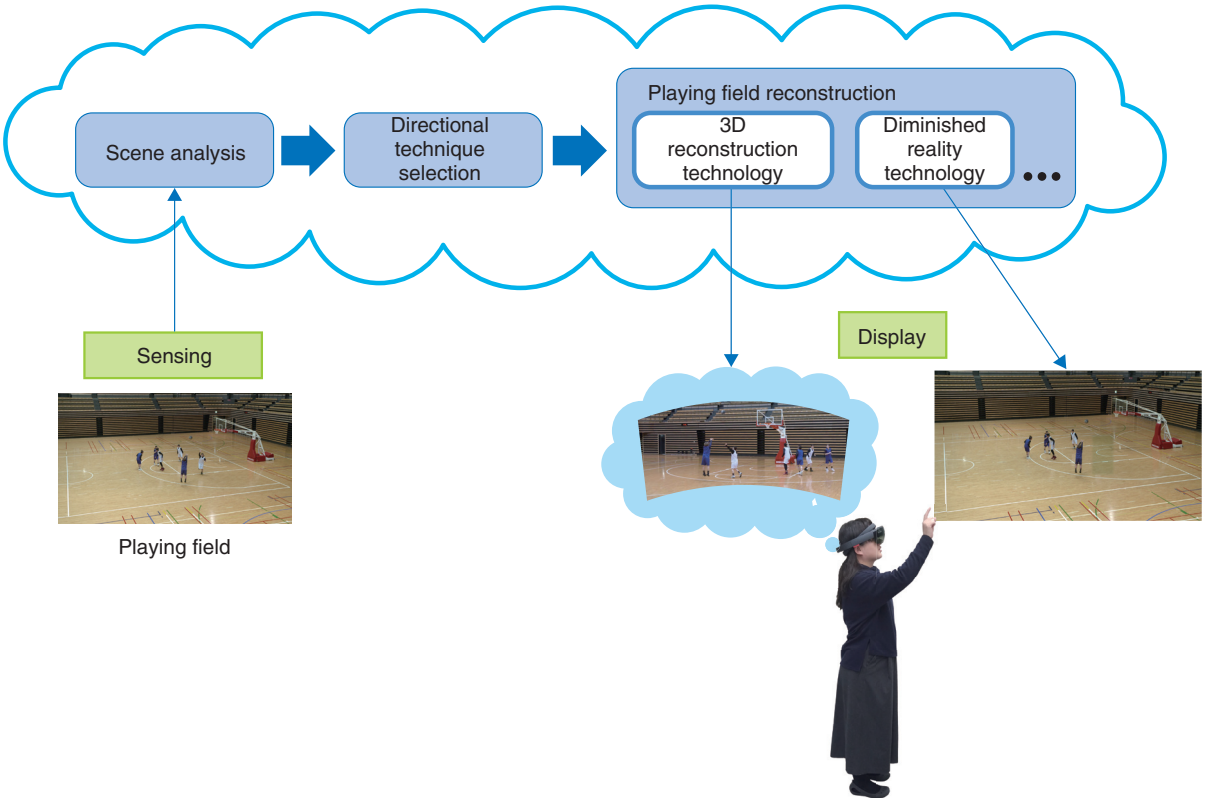

Fig. 1. Overview of sports viewing system using VR/AR technologies.

as a future AR method for representing a playing field three-dimensionally on a table.

2. Overview of sports viewing system

Our system for watching sports in a stadium using VR/AR technologies is shown in **Fig. 1**. It features multiple cameras that surround the stadium and capture videos of the playing field. The videos are delivered to a server on a cloud. The server uses the videos to analyze the event that occurred on the playing field and selects the videos to provide to the users from the analysis results. The playing field is then reconstructed from the videos based on preprocessing results and distributed to the user viewing devices.

3. 3D reconstruction technology for the playing field

One of the video processing technologies used to reconstruct the playing field is 3D reconstruction technology. It enables viewpoint images to be generated from places inside the playing field where cameras cannot be installed. Since the spectators' seats are fixed in stadiums and arenas, the spectators can only watch the event going on from a limited direction. They cannot see players if their seats are far away from the playing field, and often cannot watch the event from the viewpoint they would like in order to get the best view of how the event is developing.

A method has been developed to generate arbitrary viewpoint images from multiple cameras that surround the playing field. However, it requires the installation of a very large number of cameras, which is difficult to do in a stadium. Also, the method cannot generate high quality viewpoint images of what is happening in front of the camera because of insufficient video resolution and because 3D information cannot do estimations in occluded areas.

To address these problems, we propose a new form of 3D reconstruction technology based on computer graphic (CG) characters. It estimates a player's motions from videos and applies the estimation results to a preprepared high quality CG model of the player. With the notably improved CG quality for movies and games achieved in recent years, our

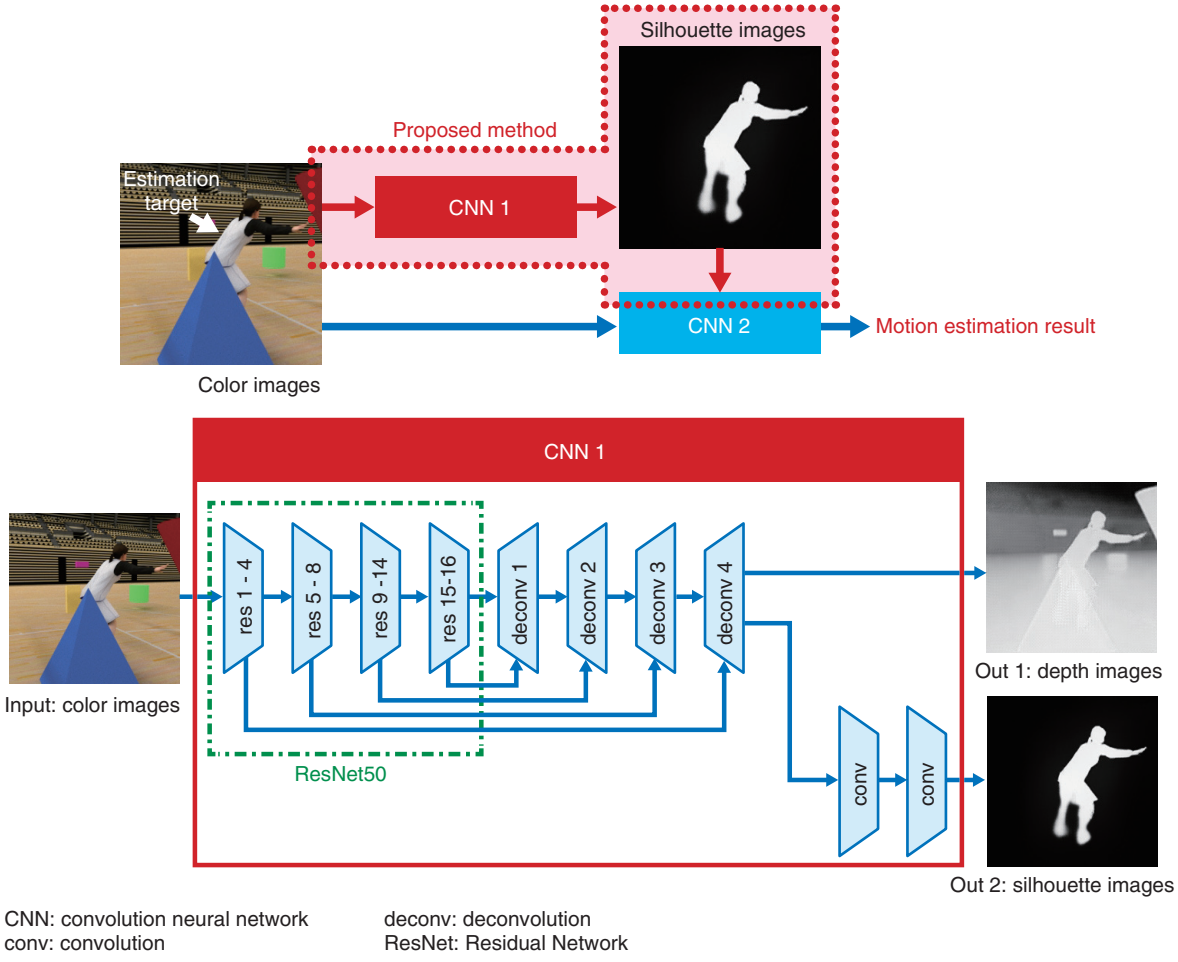

Fig. 2. Overview of proposed method.

method generates high quality viewpoint images that make users feel as if they were watching scenes in the real world.

To achieve this, it is necessary to estimate player motions from videos. While conventional methods have been proposed to estimate human motions from videos using deep learning [3], the pose estimation accuracy they provide is substantially reduced when the people being videoed are partly occluded by objects. An important task is to improve robustness in occluded areas, because in sports scenes many athletes are frequently intertwined in one scene and can easily shield each other.

Thus, we propose the idea of estimating athletes' motions not from color images directly but from color images and silhouette images of people, including those in occluded areas (**Fig. 2**). By using silhouette images to limit the area for searching human motions, our method achieves higher human motion estimation accuracy than conventional ones can provide.

4. Diminished reality technology for the playing field

Here, we describe the diminished reality technology we developed that removes unnecessary players and objects from videos in order to focus on target players.

In movie and cartoon scenes, only the persons to be focused on remain in the scene, and effects such as a spotlight are added. We anticipate that applying this to sports events held in stadiums and arenas will ensure that increased attention is directed towards players involved in decisive moments of the game, which will make watching the game more exciting.

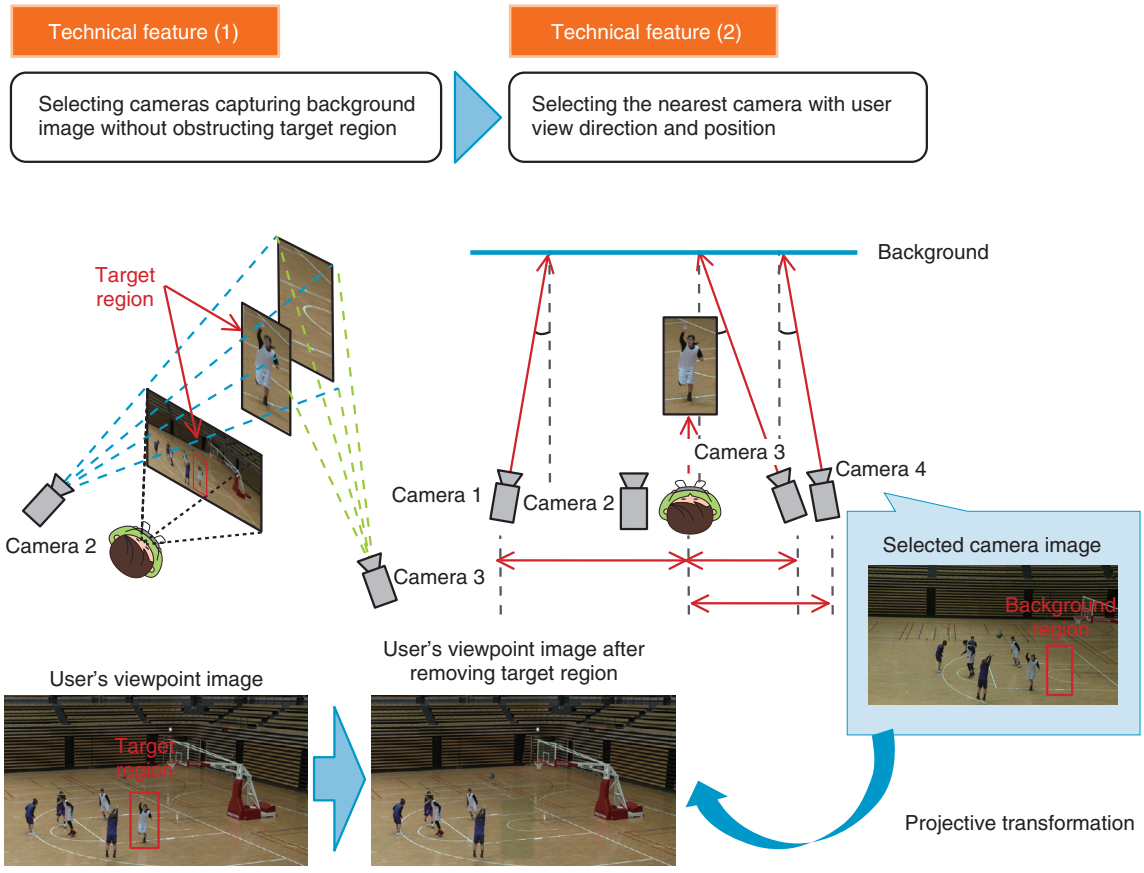

Fig. 3. Technical features of proposed method.

Diminished reality (DR) technology removes unnecessary target regions from video images and reconstructs the missing regions with background images. To apply this to sports events, DR technology must reconstruct only target regions while considering the relationship between players in 3D space. Furthermore, since spectators watch sports events in various positions and postures, it needs to present images in which the target region does not stand out above all others for each spectator's viewpoint.

To address these points, we propose a DR method that selects the optimal camera capturing the background of the target region from multiple cameras installed in a stadium and overlays the transformed image so that it matches that seen from the user viewpoint. This prevents the target region from becoming overly conspicuous [4].

The technical features of our proposed method are shown in **Fig. 3**. The first feature is that the playing field is treated as a multilayered plane, and 3D information is estimated on that basis, since a wide range of depth is unnecessary to reconstruct the playing field. This enables it to select the group of cameras capturing the background of the target region with less calculation than that needed in methods estimating 3D information of the entire playing field.

The second feature is that the method automatically determines the optimum camera—one that is near the user's location and thus catches the action from a direction and position similar to that of the user. This makes it possible to provide images that are natural from a user's viewpoint by simply applying projective transformation to selected camera images.

5. Visually equivalent light field display technology

Finally, we introduce a novel visually equivalent light field 3D display technology, which we propose as a future AR method that three-dimensionally represents a playing field on a table. We believe that showing game highlights at the box office, lobby, or

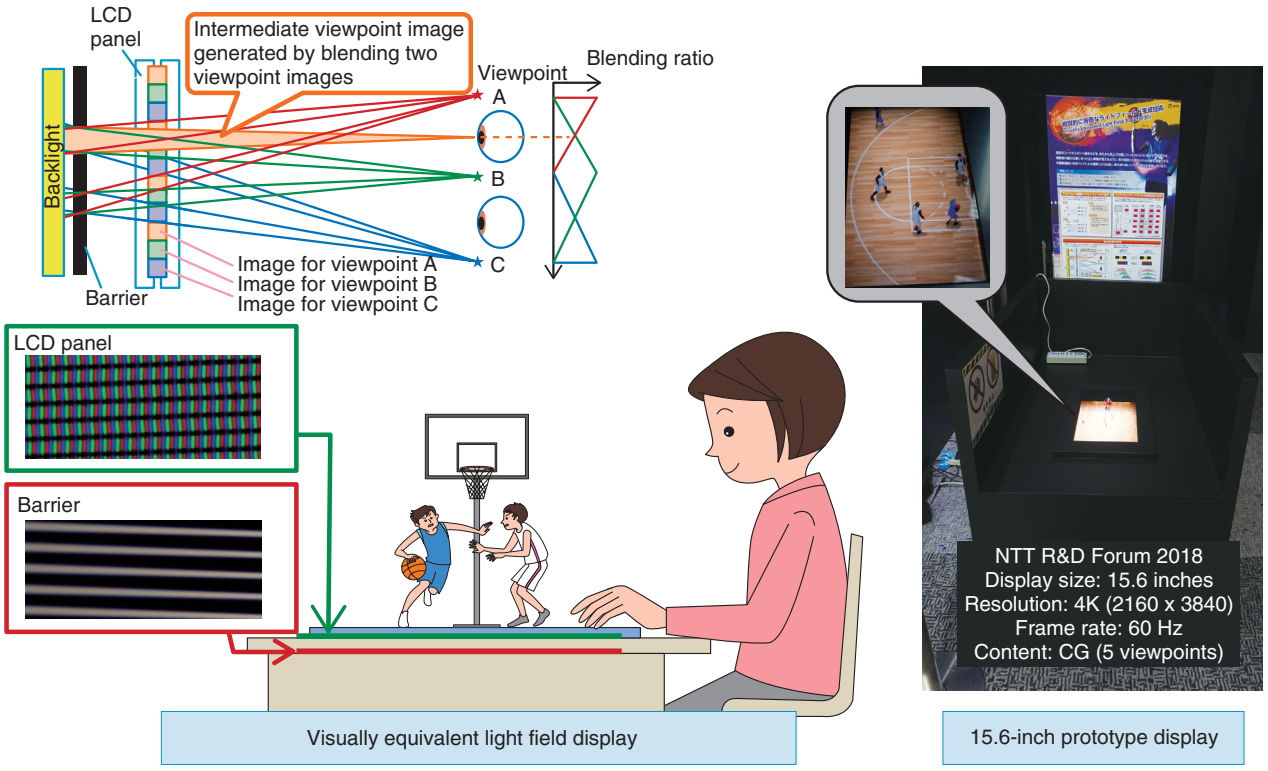

Fig. 4. Overview of visually equivalent light field display.

some other place outside the playing venue will increase people's interest in certain players and teams so they will come to see them again and again. To provide spectators with a more attractive viewing experience, it is important to show them the players in a way that makes them feel as if the players were actually there in front of them.

Objects such as players, fields, and balls emit rays with different colors and brightness in each direction by reflecting light or by emitting light themselves. Fields generated with these rays, called light fields, can be made to seem highly realistic by accurate ray reproduction. However, to display different rays depending on the direction, we allocate pixels in accordance with the number of directions. For example, generating rays in 100 directions requires 100 times more pixels than needed for a 2D display with the same resolution.

Human vision perceives objects from incident rays entering the pupils of the eyes. This perception involves not only acquiring simple images like pictures taken by a camera, but also using differences in rays between the left and right eyes and small temporal variations of rays due to viewing position changes induced by fluctuations of posture or eye movement. This perception seems to be high at first glance but is insensitive to elements that are not necessary. Therefore, a visually equivalent light field should exist. Though it is different from the light field of an actual object, human vision perceives it as the same as that of an actual object.

This is the concept of a visually equivalent light field display. With this technology, light rays to an intermediate viewpoint are interpolated with visual equivalence. The interpolation is a weighted average of rays to discrete viewpoints that is optically created in the display [5].

An overview of a visually equivalent light field display is given in **Fig. 4**. As shown in the top left corner, the display consists of an LCD (liquid crystal display) panel, a stripe-pattern barrier, and a backlight, in order from the rear. When an observer's pupils are at viewpoint A, rays from the barrier spacing illuminate the pixels of the viewpoint A image only, and that image can be seen. When an observer's pupils are at viewpoint B, the image for viewpoint B can be seen. When an observer's pupils are midway between viewpoints A and B, the pixels for both

images A and B are partially illuminated, and a weighted average is achieved. Since the weights depend on the distance between pupil position and viewpoints A and B, an intermediate viewpoint image is perceived as expected. Because the image quality is high when a displayed object is close to the display panel, we placed the panel horizontally as shown at the bottom left in the figure. This made it possible to display and maintain high resolution, high quality images in every corner of the court.

Reproducing the light field in this way enables the correct depth to be perceived even if the distance between the left and right eyes is different (e.g., for an adult and a child). We believe the efficacy of interpolation can not only improve pixel usage efficiency but also improve feelings of object existence or reality.

6. Future work

We have improved VR/AR technologies and expect that sports viewing services using them will increase as interest in sports increases with the approach of the major international sports event in 2020. The research on scene analysis technology NTT Media Intelligence Laboratories is conducting will facilitate the selection of video effects and VR/AR displays that will accord with game situations. The development of video processing technology will facilitate the reconstruction of playing fields and visually equivalent light field 3D displays. This will enable us to contribute to the development of innovative ways to provide people with a new and enhanced sports watching experience.

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Forum Survey Activities by TTC (The Telecommunication Technology Committee) Technology Research Advisory Group

Hideyuki Iwata

Abstract

The Technology Research Advisory Group of The Telecommunication Technology Committee (TTC) of Japan surveys and analyzes trends in the standardization activities of Japanese and world forums in the field of information and communications on a yearly basis. These efforts help to establish direction in TTC standardization activities. The results of this survey and analysis can be accessed on the TTC website. These results provide valuable information for individual companies that wish to grasp the latest trends in standardization and evaluate the need to join a particular forum. This article reports in particular on the activities of forums recently added to the survey and on forums focusing on current technology topics.

Keywords: forum, consortium, standardization

1. Overview of Technology Research Advisory Group

Forum surveys [1] at the Technology Research Advisory Group of The Telecommunication Technology Committee (TTC) commenced in 1994, making the survey scheduled for fiscal year (FY) 2018 the 25th version. The forums targeted by these surveys consist of organizations, voluntary bodies, and groups aiming to promote or promulgate standardization, but exclude de jure standardization bodies such as the International Telecommunication Union (ITU), International Electrotechnical Commission (IEC), International Organization for Standardization (ISO), and the ISO/IEC Joint Technical Committee 1 (JTC1). The names of these bodies commonly include the words *forum*, *consortium*, *alliance*, or *project*. The survey team consists of eight TTC-member operator/vendor companies. Their activities involve (1) determining the latest trends in the information and communications field and narrowing down the forums to be surveyed, (2) collecting information on the selected forums such as membership fees, target fields, and member makeup from publicly released information on the web, and (3) examining the temporal change in member makeup, the types of activities carried out, and other details from survey data.

2. FY2017 surveyed forums

After the review was completed of the 58 forums targeted in FY2016 version 23 of the forum survey, it was decided to add 13 bodies and to terminate the surveying of 4 bodies whose activities had ended or that had merged with other bodies, or for which information could no longer be obtained.

The following provides a brief introduction to the 13 forums added for FY2017 version 24 of the forum survey.

2.1 5G Automotive Association (5GAA)

The 5GAA was founded in September 2016 to promote the cooperative development of connected car services using fifth-generation mobile communications systems (5G). Although the founding members of 5GAA consist mainly of European companies, today a total of 48 companies from the United States, Japan, China, Korea, and other countries around the world are participating in 5GAA activities. These companies include telecommunications equipment vendors, telecommunications operators, automotive manufacturers, and parts suppliers. The mission of 5GAA is to jointly develop, test, and promote communications solutions, support the standardization of those solutions, and encourage their commercialization and global penetration.

2.2 OpenStack Foundation

The OpenStack Foundation is a non-profit organization established in September 2012. It aims to provide an open and vendor-agnostic cloud-computing environment deployed as an infrastructure as a service (IaaS) and to develop and disseminate open source software (OSS). The foundation consists of individual members and corporate members, the latter of which consist primarily of telecommunications equipment vendors and telecommunications operators.

2.3 OpenAPI Initiative (OAI)

The OAI is a Linux Foundation Project established on November 5, 2015 under the leadership of SmartBear Software as a consortium focused on promoting a standard format for describing RESTful APIs (representational state transfer application programming interfaces). As of August 2017, a total of 28 companies had become OAI members. The Swagger open source API development tool developed by SmartBear and adopted by OAI for describing APIs is already finding widespread use. The initial version of the OpenAPI Version 3.0 Implementer's Draft based on the Swagger Specification was released on March 1, 2017. The OAI has adopted OpenStack as an IaaS platform.

2.4 FIWARE Foundation

Based in Germany, the FIWARE Foundation is a non-profit organization established as a private initiative to promote the FIWARE smart application platform developed by FI-PPP (Future Internet Public-Private Partnership), a project of the European Union's 7th Framework Programme. FIWARE is attracting attention as a set of APIs that facilitate data usage thanks to its key feature of treating data as context information and its handling of cross-industry data in common. It is taking hold in Europe as a common platform for smart cities. As of September 2017, The FIWARE Foundation had 28 member companies located mainly in Europe, with one Japanese company participating.

2.5 Hypercat Alliance

The Hypercat Alliance is an organization established in September 2014 by 42 British companies and municipalities using funds from the IoT Demonstrator Phase I Clusters of Innovate UK, an organization under the Department for Business, Innovation and Skills. Hypercat is a technology that is released in the form of an online catalog that tags the specifications needed to design Internet of Things (IoT) devices with metadata and that enables automatic interconnectivity between devices. Its purpose is to achieve high functionality, high-speed operation, and interoperability in IoT devices by combining necessary objects and functions in the catalog to generate and share IoT devices. The Hypercat Alliance had 70 members as of September 2017, including one Japanese company.

2.6 OpenID Foundation (OIDF)

OIDF is a non-profit organization established in June 2007 in Oregon, USA. In addition to formulating digital identifier (ID) standards, OIDF promotes inter-site ID linking, access to web services via smartphone applications and API linking by using OpenID Connect and other ID-authentication technologies and is engaged in the dissemination, protection, and training of OpenID technologies. As of September 2017, 40 companies were OIDF members, with some of the major members including OTT (over-the-top) telecommunications operators.

2.7 Spring Framework Project

The Spring Framework is an open-source application framework targeting Java platforms. It addresses various problems common to conventional web application frameworks such as weakness with respect to specifications changes, difficulty of performing tests in program units, and difficulty of maintenance and reuse. The Spring Framework can interact with existing protocols and products such as HTTP (Hypertext Transfer Protocol), SOAP (Simple Object Access Protocol), and Enterprise JavaBeans. While there are only six main developers, the

development is open, and anyone can participate. The Japan Spring Framework User Group is a Spring Framework community with a presence on social networking services.

2.8 Trusted Computing Group (TCG)

TCG is an industry organization established in April 2003 with headquarters in Oregon, USA, with the aim of formulating standard technologies to improve reliability and safety in the use of personal computers. It formulated the specifications for the Trusted Platform Module (TPM) security chip equipped with a hardware-based encryption function. The most recent version of this specification is version 2.0 released in 2014. Almost all personal computers manufactured today are equipped with a TPM chip to safely store and manage personal authentication information and encryption keys. The application of this technology to IoT devices has come into view with the aim of enhancing terminal security.

2.9 Zero Outage Industry Standard Association

The Zero Outage Industry Standard Association was established in November 2016 with the aim of maximizing customer satisfaction and value by offering best practices and a standard framework to provide secure, high-reliability, and high-availability information technology services and solutions. It had 12 member companies as of September 2017.

2.10 Wi-Fi Alliance

The Wi-Fi Alliance is an industry organization founded in 2000 with the aim of promoting the spread of wireless local area network products. It formulates interconnectivity test methods, certifies products, and engages in promotional activities toward the widespread use of the Wi-Fi brand. It had a total of 790 member companies as of August 2017. Although the main Wi-Fi standard is 802.11ac at present, the Wi-Fi Alliance plans to provide products based on new standards such as 802.11ad, 802.11ax, and 802.11ah and on the Wi-Fi Agile Multiband that enables instantaneous access to the most optimal wireless environment.

2.11 Z-Wave Alliance

The Z-Wave Alliance was established to ensure interoperability between devices and equipment equipped with the Z-Wave wireless communications protocol for smart homes. It had a total of 365 member companies as of August 2017. Z-Wave is a low-power technology for smart homes centered on the technology developed by the Danish company Zensys (acquired by the US company Sigma Designs in 2009). It operates in the sub-gigahertz band. Devices equipped with Z-Wave have found widespread use in Europe and other regions around the world.

2.12 EnOcean Alliance

EnOcean and other corporate groups established the EnOcean Alliance in April 2008 to promote the spread of EnOcean technology and ensure interoperability between EnOcean products. EnOcean is an energy harvesting technology developed by EnOcean GmbH in Germany. It converts weak forms of energy such as light, heat, and vibration into electric power to perform low-power wireless communications. EnOcean switches and sensor modules are being used in offices, factories, and industrial equipment throughout the world. It adopts the lower three layers specified in ISO/IEC 14543-3-10 as wireless specifications and prescribes an application protocol called EEP (EnOcean Equipment Profiles). As of August 2017, 430 companies had joined the EnOcean Alliance, and more than 1200 products had been certified.

2.13 Digital Stationery Consortium (DSC)

DSC was established in October 2016 in Delaware, USA, to promote the use of digital ink and achieve mutual compatibility between digital ink products. It already provides SDKs (software development kits) to partner companies for the WILL (Wacom Ink Layer Language), which is a technology that can share digital writing tools such as pen tablets in a cloud environment and ensure mutual compatibility. DSC seeks to achieve even closer collaborations going forward. It has nine participating members from Japan, Korea, China, and Europe including Montblanc, a manufacturer of stationery goods, plus equipment vendors and telecommunications operators.

3. Forums related to current technology topics

The following highlights forums classified by technology topics that have been attracting interest in recent years, namely, software-defined networking (SDN)/network functions virtualization (NFV), big data/IoT/machine to machine (M2M), smart cities, 5G, and intelligent transportation system (ITS)/connected cars. Note that a few of these forums were introduced in section 2.

3.1 SDN/NFV

- Open Networking Foundation (ONF) (established 2011): ONF released the second version of Atrium, an SDN software distribution, in February 2016. ONF has made improvements to version 1 of the Open Network Operating System (ONOS) and developed extensions to OpenDaylight platform. ONF merged with Open Networking Lab (ONOS/CORD (Central Office Re-architected as a Datacenter)) in October 2017 and added a use-case discussion forum.
- Broadband Forum (BBF) (established 1994): As of December 2017, BBF had taken up a variety of virtualization themes such as SDN access node architecture, a Yet Another Next Generation (YANG) model for passive optical networks, and a YANG model for access nodes.
- OpenDaylight Project (established 2013): This group develops SDN controller software to achieve SDN/NFV, providing it as OSS. It released Carbon as the sixth version of its SDN platform in June 2017 and is developing extensions for IoT applications.
- Open Platform for NFV (OPNFV) (established 2014): OPNFV released Danube 1.0 as its fourth OSS release in April 2017 and released Danube 2.0 and Danube 3.0 in May and July, respectively, of the same year. OPNFV Summit 2017 was held in June 2017.
- TM Forum (established 1988): The ZOOM (Zero-touch Orchestration, Operations and Management) project team is collaborating with the NFV Industry Specification Group of the European Telecommunications Standards Institute (ETSI) to develop an NFV management and implementation model.

3.2 Big data/IoT/M2M

- Object Management Group (OMG) (established 1989): OMG announced a supplementary provision to the Industrial Internet Connectivity Framework standard of IIoT (Industrial Internet of Things) for application to the energy field at the Work in Oil and Gas event in September 2017. OMG has held two webinars (web-based seminars).
- Industrial Internet Consortium (IIC) (established 2014): IIC has been quite active in testbed development with 25 testbeds in total as of September 2017. It holds many events and issues many types of documents including white papers.
- Open Connectivity Foundation (OCF) (established 2016): The parent organization of OCF is the Open Interconnect Consortium, which previously merged with the Universal Plug and Play Forum. In October 2016, OCF and the AllSeen Alliance merged under the OCF name, and it was decided to make IoTivity and Alljoyn frameworks compatible. In June 2017, OCF announced that six of its IoT specifications were put to a vote at ISO/IEC JTC1.
- THREAD Group (established 2014): Since the release of the Thread Wireless Networking Protocol version 1.1 in the summer of 2016, The THREAD Group has been active in equipment certification and interconnectivity testing. Seamless connectivity was exhibited by 17 companies at CES (Consumer Electronics Show) 2017, and the group completed its first certification of version 1.1 products.
- OpenFog Consortium (established 2015): The OpenFog Consortium collaborates with the IoT Acceleration Consortium in Japan to develop technologies and testbeds and promote standardization. On September 25, 2017, it announced that it had concluded a memorandum of understanding with ETSI to cooperate in the development of fog and edge applications.
- Hypercat Alliance (established 2014): The Hypercat Alliance has presented use cases in 14 fields including smart buildings and smart energy. It released "PAS 212:2016 Automatic resource discovery for the Internet of Things - Specification" as a British standard in August 2016.

3.3 Smart cities

- Japan Smart Community Alliance (JSCA) (established 2010): JSCA held the Smart Community Summit in June 2017 and conducted active discussions on issues surrounding the dissemination of solar power generation and entry into emerging energy markets.
- Smart Grid Interoperability Panel (SGIP) (established 2009): SGIP is an organization that supports the National Institute of Standards and Technology in the development of smart grid standards. SGIP merged with SEPA (Smart Electric Power Alliance) in April 2017, becoming part of its organization.
- ECHONET Consortium (established 1997): As of January 2018, the ECHONET Consortium had certified 530 devices under the ECHONET Lite specification, 296 devices under the AIF

(application communication interface) specification, and 19 devices under the ECHONET specification. It held the 1st Plugfest event in July 2018.
- OpenADR Alliance (established 2010): This organization released the OpenADR 2.0 Program Guide for the OpenADR smart grid standard in February 2016. As of May 2017, it had certified 120 devices.
- FIWARE Foundation (established 2011): The FIWARE Foundation has released OSS and APIs as a common platform for smart cities. It has also released DSEs (Domain-Specific Enablers) as field-specific sets of resources.

3.4 5G
- NGMN (Next Generation Mobile Networks) Alliance (established 2006): This group began by conducting studies of Super 3G and Long-Term Evolution (LTE) in 2006 but is presently focused on 5G. It published the NGMN 5G White Paper in March 2015. The NGMN Alliance has published 12 technical documents to date.
- 5G Automotive Association (5GAA) (established 2016): 5GAA has published a variety of white papers including "Edge computing for advanced automotive communications" and "An assessment of LTE-V2X (PC5) and 802.11p direct communications technologies for improved road safety in the EU" in December 2017.

3.5 ITS/connected cars
- ITS Forum (established 1991): ITS Forum has published many technical guidelines such as "700 MHz Band Intelligent Transport Systems - Experimental Guideline for Roadside-to-roadside Communications Ver. 1.1," "700 MHz Band Intelligent Transport Systems - Experimental Guideline for Inter-vehicle Communication Messages Ver. 1.1," and "700 MHz Band Intelligent Transport Systems - Test Items and Conditions For Mobile Station Interoperability Verification Guideline Ver. 1.2" in October 2017.
- ITS America (established 1991): ITS America published a white paper titled "The Impact of a Vehicle-to-Vehicle Communications Rulemaking on Growth in the DSRC Automotive Aftermarket" in October 2016.

4. Trends in number of members

Twelve forums showed an increase in members from FY2016 to FY2017. A case in point is the LoRa Alliance, which has already expanded its membership to more than 400 member companies despite being established less than three years ago. Its membership increased in FY2017 by more than 70% over the previous year, reflecting a growth trend. In addition, Hyperleger, which promotes standardization in blockchain technology, also experienced a jump in membership of more than 70% over the previous year. In terms of medium-term trends, 10 forums showed an increase in members for two consecutive years from 2015, and 6 forums—OPEN Alliance SIG, Wi-SUN Alliance, The Open Group, IIC, OpenADR Alliance, and ECHONET Consortium—showed an increase in members for three or more consecutive years. These forums tend to be in fields such as smart cities, IoT, cloud computing, and connected cars, reflecting heightened interest in those technologies.

5. Future plans

The release of version 25 of the forum survey report is planned for the end of FY2018.

Reference

[1] Forum Survey Report (Japanese version only), http://www.ttc.or.jp/e/inv/

Hideyuki Iwata
Senior Research Engineer, Supervisor, Research and Development Planning Department, NTT.

He received a Ph.D. in electrical engineering from Yamagata University in 2011. From 1993 to 2000, he conducted research on high-density and aerial optical fiber cables at NTT Access Network Service Systems Laboratories. Since 2000, he has been responsible for standardization strategy planning for NTT research and development. He has been a delegate of IEC Subcommittee 86A (optical fiber and cable) since 1998 and of the ITU-T (Telecommunication Standardization Sector) Telecommunication Standardization Advisory Group since 2003. He is a vice-chair of the Expert Group on Bridging the Standardization Gap in the Asia-Pacific Telecommunity Standardization Program Forum. In 2004, he received an award from the IEC Activities Promotion Committee of Japan for his contributions to standardization work in IEC.

Initiatives Targeting Snow Damage to Communication Facilities

Technical Assistance and Support Center, NTT EAST

Abstract

Many communication facilities installed outdoors are continuously exposed to harsh weather including snowfall. This article presents a countermeasure to prevent the bands that secure signboards to utility poles from breaking and a countermeasure to prevent snow from accumulating on overhead equipment. This is the forty-ninth article in a series on telecommunication technologies.

Keywords: snow damage, utility pole, closure

1. Introduction

Many communication facilities installed outdoors are continuously exposed to harsh weather including wind, rain, and snowfall. Consequently, many countermeasures to prevent damage caused by such conditions have been implemented. Moreover, in the winter of 2017/18, snowfall in Japan was heavier than that in normal years, and damage due to the heavy snowfall was reported, particularly in northern Japan. Accordingly, concerns about snow damage have increased.

In regions with heavy snowfall, NTT facilities are also affected by snow damage, which leads to failures and accidents. The Technical Assistance and Support Center is working on countermeasures to prevent the bands that secure signboards to utility poles from breaking and countermeasures to prevent snow from accumulating on overhead equipment. Both of these phenomena contribute to increases in repair operations and accidents in snowy areas.

1.1 Breakage of bands

Utility pole signboards are installed on utility poles along roads across the country for the purpose of preventing accidents such as vehicles accidentally hitting the utility poles (**Fig. 1**). The signboards are affixed to the poles with vinyl bands. A common phenomenon that occurs is that one or more of the vinyl bands breaks due to the load of accumulated snow, and the band(s) and/or signboard falls off as a result. This band breakage occurs over a wide region and thus requires a large operation to replace the broken bands. Moreover, if the bands and/or signboards fall off, they might affect passing pedestrians or vehicles, possibly leading to accidents.

1.2 Snow accumulation

In snowy areas, snow accumulates on overhead equipment such as cable closures and cable intersections (**Fig. 2**). If the snow continues to fall for several days, repeated melting and resolidification will generate lumps of ice, and the risk of those ice lumps falling is a very dangerous one that may lead to traffic accidents resulting in injury or property damage (**Fig. 3**). Accordingly, maintenance to remove accumulated snow is carried out periodically to prevent such accidents. When workers clear snow in this kind of operation, they must use an aerial platform, the use of which is a major operation.

Details about certain countermeasures against snow damage to utility poles devised by the Technical Assistance and Support Center have previously been introduced [1]. In this issue, two of our initiatives—

Fig. 1. Breakage of vinyl bands securing utility pole signboards.

Fig. 2. Snow accretion on overhead equipment.

Fig. 3. Property damage accident caused by snow falling from overhead equipment.

namely, a countermeasure to prevent breakage of the vinyl bands securing utility pole signboards and a countermeasure to prevent snow from accumulating on overhead equipment—are introduced.

2. Measures to prevent breakage of vinyl bands securing utility pole signboards

In this section, we describe the problem in detail and explain the proposed countermeasures and the results of field trials.

2.1 Mechanism by which bands break

We conducted a field trial to confirm the mechanism by which the bands break. In this trial, two patterns of load application by snow accumulation were assumed: (i) the case in which the bands break due to application of a load to the utility pole signboard and (ii) the case in which a load is applied only to the band itself, causing it to break. The aim of the trial was to verify by which pattern (or both) the bands break. During the trial, lasting from December 2015 to April 2016, a countermeasure was applied that involved closing the gap between the utility pole and the utility pole signboard (**Fig. 4**). This was done to verify the case in which the band broke due to snow

Fig. 4. Verification of state of band breakage.

Fig. 5. Layers of accumulated snow in trial site.

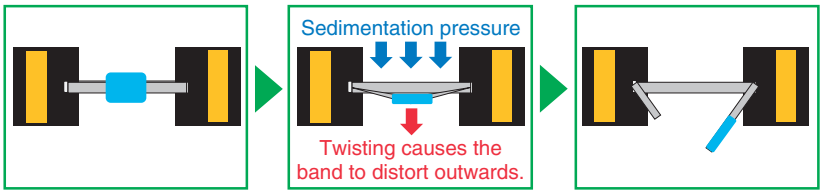

Fig. 6. Mechanism by which the band breaks.

loading on the band itself. A countermeasure involving protecting the band with sealants was also applied to verify the case in which the band broke due to snow loading on the utility pole signboard. The trial site used a utility pole placed in a residential area located at the foot of a mountain in a region that receives heavy snowfall. The amount of snowfall in the year of the trial (2016) was about 2.5 m, and the trial site was a location where snowfall and ploughed snow regularly pile up significantly (**Fig. 5**).

We checked the state of the signboard and band during snowfall and after snow thawing. In the case where the gap between the utility pole and the utility pole signboard was closed by attaching tape, icing and twisting of the band's fastener and the left/right ends of the band still occurred. These phenomena caused the band to break. Since breaking, sagging, and twisting of the band was confirmed even if the gap between the utility pole and the signboard was closed, it was assumed that sedimentation pressure (pressure caused when snow accumulates and settles in one place) acts directly on the band. The mechanism leading to the band breaking was considered to have three stages: (1) ice building up on the band, (2) generation of sedimentation pressure causing twisting of the band so it distorts outward, and (3) breakage of the band (**Fig. 6**).

In contrast, in the case where the band was protected with sealants, snow only accumulated on the signboard and the band did not break.

2.2 Proposed countermeasures and field trials

It became clear that the load is directly applied to the band by sedimentation pressure, so three proposed countermeasures against band breakage (**Table 1**) were tested in trials from December 2016 to April 2017 (**Fig. 7**).

When proposed countermeasure (1) was applied, certain effects of reducing sedimentation pressure were confirmed, and no band breakage was observed in any of the five samples. However, loosening and twisting of the band as well as peeling of part of the standard sealant were observed. This result is thought to be due to the fact that working with standard sealant is somewhat difficult, and thus it is not easy to apply it evenly. It is therefore conceivable that in the future, the standard sealant will peel off, and the band will subsequently break.

In the case of proposed countermeasure (2), although no twisting or breaking of the band was seen, the band did loosen. It is therefore also conceivable that the band might break in the future.

Table 1. Proposed countermeasures against loading of the band due to snowfall.

Proposed countermeasure	Name	Principle
(1)	Standard sealant	Reduce the effect of sedimentation pressure by protecting the entire band.
(2)	Power band	Improve durability and resistance to sedimentation pressure by using a band resistant to twisting.
(3)	Signboard with adhesive backng*	Remove the need for a band by bonding signboard directly to the utility pole with adhesive sheet.

*A product satisfying JIS Z 9117 (Japanese Industrial Standard for Reflectivity) for visibility was used for the signboard with adhesive backing.

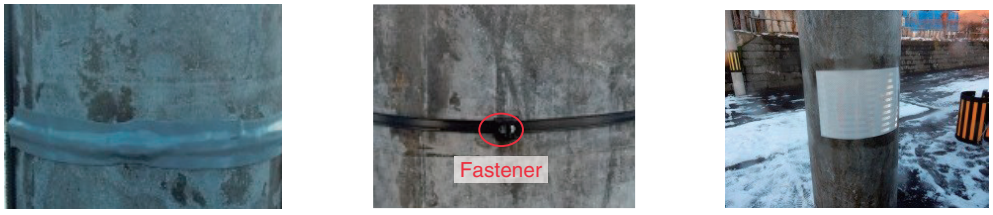

Fig. 7. Countermeasures: (1) standard sealant; (2) power band; and (3) reflective sheets (signboard with adhesive backing).

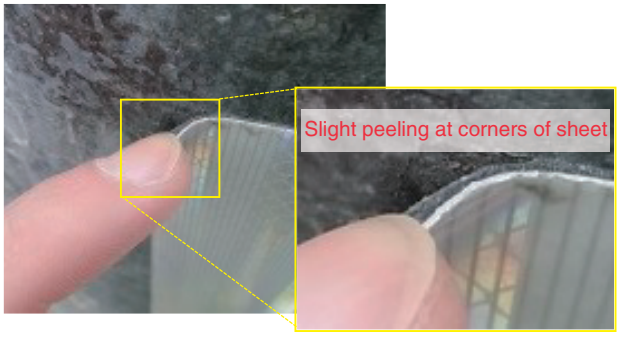

Fig. 8. Result of applying proposed countermeasure (3).

Fig. 9. Additional trial of signboard with adhesive backing.

With proposed countermeasure (3), some of the trial samples showed slight peeling at the four corners of the sheet (**Fig. 8**), but the adhesiveness of the sheet was found to be basically satisfactory, and it was easy to apply the sheet evenly, with the correct alignment and without puckering or air bubbles.

Since no problem concerning adhesiveness was found, and the sheet was easy to apply, an additional verification of countermeasure (3) was conducted. We are currently evaluating whether cutting off the four corners of the sheet before applying it will prevent the peeling at the corners. In addition, to achieve stable sheet visibility and improve adhesion quality, an on-site trial of an improved version of this countermeasure (3), namely, a signboard with adhesive backing is continuing. In this trial, in addition to the adhesiveness and visibility of the signboard, the size and color suitable for installation are being evaluated (**Fig. 9**). Similar trials were also carried out on steel-pipe columns.

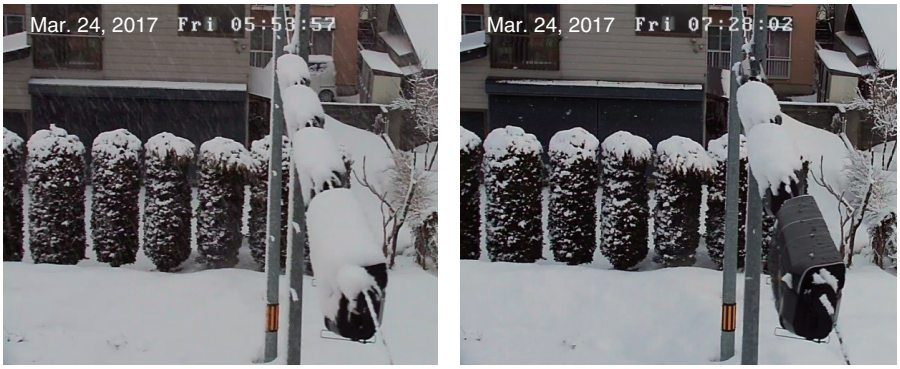

Fig. 10. Test to prevent snow accumulation on closures.

3. Countermeasure to prevent snow accumulation on overhead equipment

It is difficult to avoid snow accumulation on overhead equipment in snowy areas, but it is thought that if the snow falls off harmlessly before it turns into a lump of ice, accidental damage can be prevented. Therefore, an initial test was carried out to evaluate a method of prompting snow to fall from overhead equipment after it accumulates during snowfall. A water-repellent sheet was attached to the top of a cable closure, and the closure was observed to determine if the sheet caused the snow to fall off rather than to accumulate (**Fig. 10**). The test result revealed that by attaching the water-repellent sheet to the top of the closure, the snow that accumulates on that closure was eliminated in a short time (seen in the photo on the right), so that snow was prevented from becoming a lump of ice. Investigations will continue to monitor aging deterioration of the sheet and other factors in order to verify the effectiveness of this countermeasure.

4. Concluding remarks

These trials were conducted with the assistance of the NTT EAST-Tohoku, Aomori Branch, Facilities Division, Aomori Service Center; NTT EAST-Tohoku, Yamagata Branch, Facilities Division, Yamagata Service Center; and NTT EAST-Kanshin-etsu, Nagano Branch, Facilities Division. More information will be reported as it becomes available.

Reference

[1] Technical Assistance and Support Center, NTT EAST, “Snow-stopper Pole as a Countermeasure for Preventing Snow Damage to Utility Poles,” NTT Technical Review, Vol. 16, No. 10, pp. 83–86, 2018.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201810pf1.html

External Awards

Eco-ICT Award 2017
Winner: Hideki Maeda, Daisaku Shimazaki, Masaaki Inami, Takeshi Seki, Takafumi Fukatani, Masatoshi Namiki, and Yuji Minato, NTT Network Service Systems Laboratories
Date: February 21, 2018
Organization: Telecommunications Carriers Association

For the development of optical packet multifunctional system "100G-PTS."

Excellent Technology Award
Winner: Motohiro Makiguchi and Hideaki Takada, NTT Service Evolution Laboratories; Tohru Kawakami and Mutsumi Sasai, Tohoku University
Date: June 22, 2018
Organization: The Institute of Image Electronics Engineers of Japan (IIEEJ)

For the development of "glassless motion parallax 3D screen system using visual perception."

1906 Award
Winner: Yohei Sakamaki, NTT Device Technology Laboratories
Date: July 31, 2018
Organization: The International Electrotechnical Commission (IEC)

For his achievement and contribution as a key project leader in IEC Subcommittee 86C/Working Group 5, with very good results in developing IEC 62343-3-4, a performance specification template for the multi-cast optical switch—an important component in reconfigurable optical add-drop multiplexer (ROADM) systems.

Communications Society: Distinguished Contributions Award
Winner: Hideki Maeda, NTT Network Service Systems Laboratories
Date: September 12, 2018
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

For his contributions as secretary of the Technical Committee on Network Systems.

Young Scientist Presentation Award
Winner: Motoki Asano, NTT Basic Research Laboratories
Date: September 18, 2018
Organization: The Japan Society of Applied Physics (JSAP)

For "Evanescent Coupling between an Optical Microbottle and an Electromechanical Resonator."
Published as: M. Asano, R. Ohta, T. Yamamoto, H. Okamoto, and H. Yamaguchi, "Evanescent Coupling between an Optical Microbottle and an Electromechanical Resonator," Proc. of the 65th JSAP Spring Meeting, 18p-C301-5, Tokyo, Japan, Mar. 2018.

Young Scientist Presentation Award
Winner: Masaaki Ono, NTT Basic Research Laboratories
Date: September 18, 2018
Organization: JSAP

For "Enhancement of Graphene Absorption in Plasmonic Waveguides with 30 x 20 nm^2 Core."
Published as: M. Ono, M. Hata, K. Nozaki, H. Sumikura, and M. Notomi, "Enhancement of Graphene Absorption in Plasmonic Waveguides with 30 x 20 nm^2 Core," Proc. of the 65th JSAP Spring Meeting, 20p-C301-13, Tokyo, Japan, Mar. 2018.

JSAP Poster Award
Winner: Makoto Takamura, Norio Kumada, Shengnan Wang, Kazuhide Kumakura, and Yoshitaka Taniyasu, NTT Basic Research Laboratories
Date: September 18, 2018
Organization: JSAP

For "Tuning of Plasmonic Reflection in Graphene by Carrier Density Modulation."
Published as: M. Takamura, N. Kumada, S. Wang, K. Kumakura, and Y. Taniyasu, "Tuning of Plasmonic Reflection in Graphene by Carrier Density Modulation," Proc. of the 79th JSAP Autumn Meeting, 18p-PB3-58, Nagoya, Aichi, Japan, Sept. 2018.

Best Paper Award
Winner: Hiroshi Ishikawa, Salah Ibrahim, Tatsushi Nakahara, Hiroki Sugiyama, and Toshikazu Hashimoto, NTT Device Technology Laboratories
Date: September 20, 2018
Organization: International Conference on Photonics in Switching and Computing 2018 (PSC 2018)

For "A Novel Optoelectronic Parallel-to-Serial Converter for 100-Gbps Optical Packets."
Published as: H. Ishikawa, S. Ibrahim, T. Nakahara, H. Sugiyama, and T. Hashimoto, "A Novel Optoelectronic Parallel-to-Serial Converter for 100-Gbps Optical Packets," PSC 2018, Th3B.3, Limassol, Cyprus, Sept. 2018.

Papers Published in Technical Journals and Conference Proceedings

Wideband Slow Short-pulse Propagation in One-thousand Slantingly Coupled L3 Photonic Crystal Nanocavities

E. Kuramochi, N. Matsuda, K. Nozaki, A. H. K. Park, H. Takesue, and M. Notomi

Optics Express, Vol. 26, No. 8, pp. 9552–9564, April 2018.

Coupled cavities have been used previously to realize on-chip low-dispersion slow-light waveguides, but the bandwidth was usually narrower than 10 nm and the total length was much shorter than 1 mm. Here we report long (0.05–2.5 mm) slow-light coupled cavity waveguides formed by using 50, 200, and 1000 L3 photonic crystal nanocavities with an optical volume smaller than $(\lambda/n)^3$, slanted from Γ-K orientation. We demonstrate experimentally the formation of a single-mode wideband coupled cavity mode with a bandwidth of up to 32 nm (4 THz) in telecom C-band, generated from the ultra-narrow-band (~300 MHz) fundamental mode of each L3 nanocavity, by controlling the cavity array orientation. Thanks to the ultrahigh-Q nanocavity design, coupled cavity waveguides longer than 1 mm exhibited low loss and allowed time-of-flight dispersion measurement over a bandwidth up to 22 nm by propagating a short pulse over 1000 coupled L3 nanocavities. The highly dense slanted array of L3 nanocavity demonstrated unprecedentedly high cavity coupling among the nanocavities. The scheme we describe provides controllable planar dispersion-managed waveguides as an alternative to W1-based waveguides on a photonic crystal chip.

Experimental Investigation of Laser Linewidth Tolerance of 32-GBaud DP-256QAM Optical Coherent System

T. Sasai, F. Hamaoka, A. Matsushita, M. Nakamura, H. Kawakami, and Y. Kisaka

Proc. of the 23rd OptoElectronics and Communications Conference (OECC 2018), 6D2-1, Jeju, Korea, July 2018.

We experimentally investigate the laser linewidth tolerance of 32-GBaud DP-256QAM system for back-to-back and 50-km transmission. Results show that laser linewidth (0.1–550 kHz) has only a slight effect on the signal quality even for higher-order QAM.

Room Temperature Continuous-wave Nanolaser Diode Utilized by Ultrahigh-Q Few-cell Photonic Crystal Nanocavities

E. Kuramochi, H. Duprez, J. Kim, M. Takiguchi, K. Takeda, T. Fujii, K. Nozaki, A. Shinya, H. Sumikura, H. Taniyama, S. Matsuo, and M. Notomi

Optics Express, Vol. 26, No. 20, pp. 26598–26617, September 2018.

Few-cell point-defect photonic crystal (PhC) nanocavities (such as L_X and H1 type cavities), have several unique characteristics including an ultrasmall mode volume (V_m), a small device footprint advantageous for dense integration, and a large mode spacing advantageous for high spontaneous-emission coupling coefficient (β), which are promising for energy-efficient densely integratable on-chip laser light sources enhanced by the cavity quantum electrodynamics (QED) effect. To achieve this goal, a high quality factor (Q) is essential, but conventional few-cell point-defect cavities do not have a sufficiently high Q. Here we adopt a series of modified designs of L_X cavities with a buried heterostructure (BH) multi-quantum-well (MQW) active region that can achieve a high Q while maintaining their original advantages and fabricate current-injection laser devices. We have successfully observed continuous-wave (CW) lasing in InP-based L1, L2, L3 and L5 PhC nanocavities at 23°C with a DC current injection lower than 10 μA and a bias voltage lower than 0.9 V. The active volume is ultrasmall while maintaining a sufficiently high confinement factor, which is as low as ~10^{-15} cm^3 for a single-cell (L1) nanocavity. This is the first room-temperature current-injection CW lasing from any type of few-cell point-defect PhC nanocavities (L_X or H1 types). Our report marks an important step towards realizing a nanolaser diode with a high cavity-QED effect, which is promising for use with on-chip densely integrated laser sources in photonic networks-on-chip combined with CMOS (complementary metal-oxide semiconductor) processors.

Adaptive Compensation for SOA-induced Nonlinear Distortion with Training-based Estimation of SOA Device Parameters

F. Hamaoka, S. Okamoto, M. Nakamura, A. Matsushita, and Y. Kisaka

Proc. of the 44th European Conference on Optical Communication (ECOC 2018), We2.31, Rome, Italy, September 2018.

The semiconductor optical amplifier (SOA)-induced nonlinear distortion is compensated solving a time-evolving equation for the gain exponent using SOA device parameters estimated by our proposed training-based technique. In experiments for 32-GBaud PDM-16QAM (polarization division multiplexed 16 quadrature amplitude modulation), a maximum 2.52-dB Q-factor improvement was obtained by adaptive nonlinear compensation.

150.3-Tb/s Ultra-wideband (S, C, and L bands) Single-mode Fibre Transmission over 40-km Using >519Gb/s/λ PDM-128QAM Signals

F. Hamaoka, K. Minoguchi, T. Sasai, A. Matsushita, M. Nakamura, S. Okamoto, E. Yamazaki, and Y. Kisaka

Proc. of ECOC 2018, Mo4G. 1, Rome, Italy, September 2018.

A record capacity of 150.3-Tb/s SMF (single-mode fibre) transmission over 40 km is achieved with 13.6-THz ultra-wideband WDM (wavelength division multiplexed) 45-GBaud PDM-128QAM signals with 11.05-b/s/Hz spectral efficiency by using our proposed optimization scheme of fibre input powers considering the nonlinear interaction by stimulated Raman scattering.

Novel ODU4 Path Protection without Bit Disruption for Low Latency and Resilient Core/Metro Network

K. Kitamura, F. Inuzuka, T. Tanaka, and A. Hirano

Proc. of ECOC 2018, Mo4D. 4, Rome, Italy, September 2018.

We demonstrate novel 100Gbit/s ODU4 path switching without bit disruption at a relative delay difference up to 400 km experimentally. We confirmed ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) standard-compliant

jitter characteristics and applicability for core and metro networks by evaluating the accommodation rate in a European network.

Underground Infrastructure Management System Using Internet of Things Wireless Transmission Technology

Y. Yamaguchi, Y. Fujino, H. Katsuda, M. Nakano, H. Fukumoto, S. Teruhi, K. Akabane, and S. Yoshino

IEICE Transactions on Electronics, Vol. E101-C, No. 10, pp. 727–733, October 2018.

This paper presents a water leakage monitoring system that gathers acoustic data of water pipes using wireless communication technology and identifies the sound of water leakage using machine leaning technology. To collect acoustic data effectively, this system combines three types of data-collection methods: drive-by, walk-by, and static. To design this system, it is important to ascertain the wireless communication distance that can be achieved with sensors installed in a basement. This paper also reports on radio propagation from underground manholes made from reinforced concrete and resin concrete in residential and commercial areas using the 920 MHz band. We reveal that it is possible to design a practical system that uses radio communication from underground sensors.

Incremental Environmental Monitoring for Revealing the Ecology of Endangered Fish

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This paper proposes a novel environmental monitoring strategy, incremental environmental monitoring, that enables scientists to reveal the ecology of wild animals in the field. We applied this strategy to the habitat of endangered freshwater fish. Specifically, we designed and implemented a network-based system using distributed sensors to continuously monitor and record the habitat of endangered fish. Moreover, we developed a set of analytical tools to exploit a variety of sensor data, including environmental time-series data such as the amount of dissolved oxygen, as well as underwater video capturing the interaction of fish and their environment. We also describe the current state of monitoring the behavior and habitat of endangered fish and discuss solutions for making such environmental monitoring more efficient in the field.