NTT Technical Review

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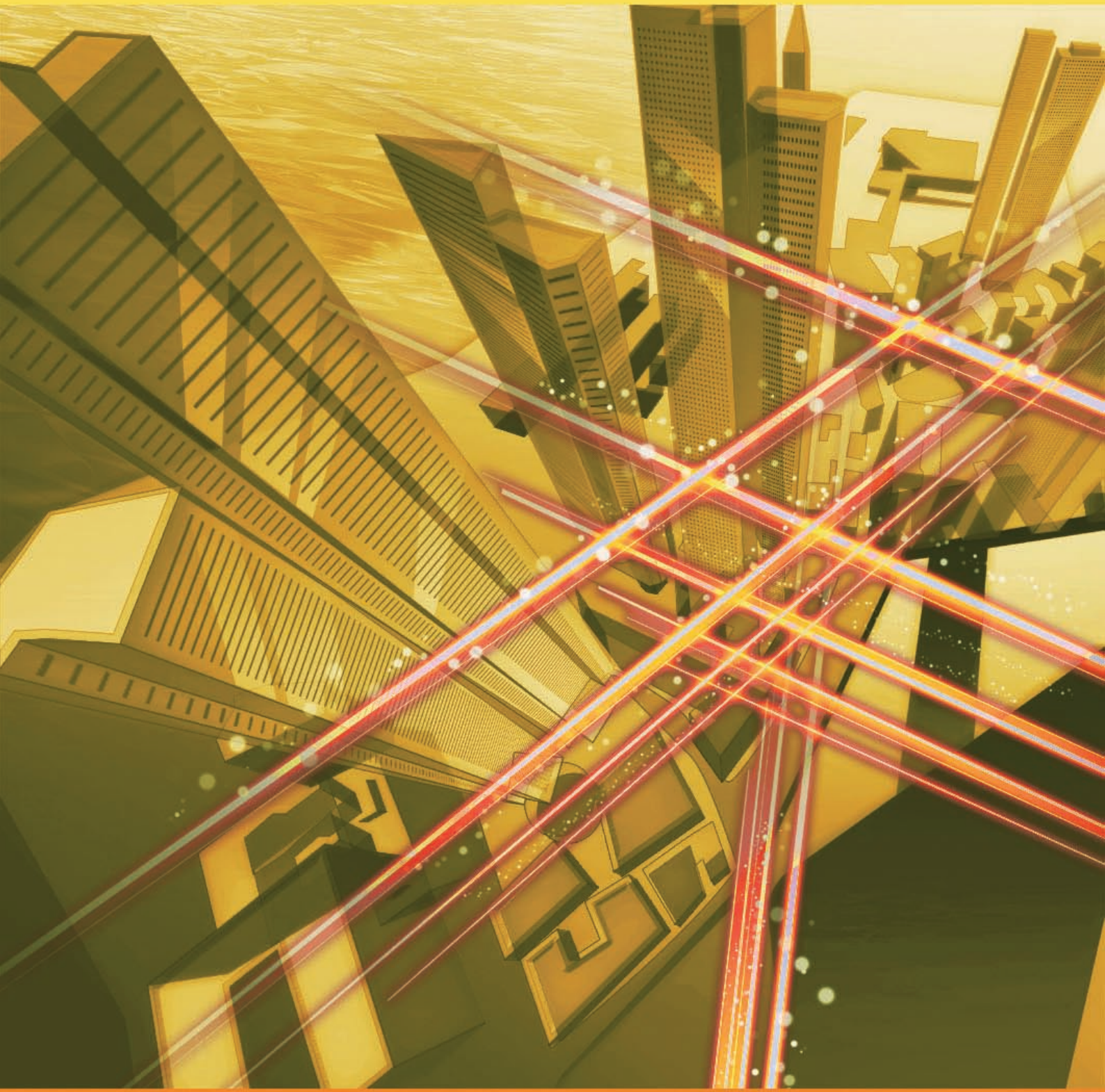

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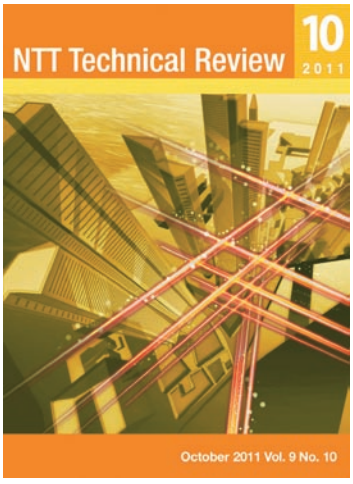

Practical Field Information about Telecommunication Technologies

Case Studies of Failures of Business Phones Connected to VoIP Gateway

External Awards/Papers Published in Technical Journals and Conference Proceedings

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Ask Not What Can Be Done but What Should Be Done—True Achievement Is Not Just Creating New Business but Clarifying One's Role in R&D

Hiromichi Shinohara
NTT Senior Vice President, Director of Research and Development Planning Department

Overview

In the wake of the Great Eastern Japan Earthquake of 2011, the importance of the network has been reaffirmed. What, then, does society expect of the NTT Group as a carrier that includes research laboratories? We asked Hiromichi Shinohara, NTT Senior Vice President and Director of the Research and Development Planning Department, to tell us about the stance that researchers should take against the backdrop of a rapidly advancing mergers-and-acquisitions business environment extending across national borders.

Following an unprecedented earthquake, Japan takes on the urgent task of developing network services that are more robust to disaster

—Mr. Shinohara, please tell us about the environment that currently surrounds R&D at NTT.

The Great Eastern Japan Earthquake has certainly forced us to rethink many things. It had always been our intention to construct a highly reliable, robust network, but upon objectively evaluating the damage caused by this earthquake, we could see that there are areas where our efforts have come up short. In particular, the effects of this disaster have made us keenly aware of how much our network depends on electricity. Our primary goal, therefore, should be to construct a network that is less dependent on commercial power supplies.

At the same time, we should look at the changes that occurred in the makeup of NTT revenues in the 2000 fiscal year. Up until that point, revenues and expenditures for optical services had never been able to move into the black. Moreover, we needed to make up for declining revenues from conventional telephone services by increasing revenues from Internet protocol (IP) services, but that goal has not yet been reached.

However, at NTT EAST, further expansion of optical facilities and aggressive provision of services by NTT business companies have helped to move optical services into the black on a single-year basis, and increases in IP service revenues have finally made up for the decreases in telephone service revenues. This is a result of an increase in the average revenue per user (ARPU), and I believe that we should undertake more research and development (R&D) with an eye

toward further increasing the ARPU.

In addition, there are many customers who are still using metallic circuits. It is therefore important that we create an environment that enables these customers to make a smooth transition to optical services and that we propose attractive ways of using these services. There are also groups of people such as the elderly who appear to have difficulty entering the world of the Internet. I believe that we can contribute to improved revenues across the entire NTT Group by providing optical services that can be used easily by such groups, thereby expanding the customer base.

—NTT has been energetically promoting Green ICT for these last two years. This initiative, which includes power consumption reductions as well as environmental conservation, would appear to be relevant even at the time of a disaster such as the recent earthquake.

Yes, we have been working diligently to lower overall power consumption to reduce CO_2 emissions. Now, however, after the earthquake, we also need to reduce the peak power consumption in addition to the overall power consumption. At the same time, we need to create new mechanisms that can prevent communications from being disrupted even if commercial power supplies are no longer available.

To put this into perspective, let's think back to the era of the analog telephone for a moment. The simple act of picking up the receiver would immediately connect a circuit, meaning that current would begin to flow and that the system would start using electricity. By contrast, optical services are always connected, so current is always flowing. With this being the case, studies have begun on control schemes in which the amount of power consumed is commensurate with the amount of communications performed.

While the recent disruption of communications can, of course, be attributed in part to immediate failures caused by the earthquake and subsequent tsunami, the biggest factor here was the eventual depletion of backup power supplies in radio base stations and NTT office buildings due to the relatively long cessation of commercial power. This is why I would also like to improve current technologies for storing energy as well as to develop and deploy new technologies of this kind so that we can provide customers with stable services over longer periods of time.

—We have heard that NTT's laboratories played a major role in recovery efforts after this earthquake.

NTT faces a variety of problems every day in the process of operating a network, and in order to come up with solutions and reflect them in the field, its business personnel and researchers interface with each other to exchange ideas and opinions. In other words, the ability of business personnel and researchers to collaborate to determine R&D priorities reflects the strength of a carrier that has its own research laboratories. In terms of making contributions to society, I think we should make the most of our strengths, whatever they may be.

Meeting diverse needs by accepting outside technologies in order to enhance service development

—The environment surrounding R&D has really changed since the earthquake. What issues do you think will be important in the future?

Of particular importance is improving our service development capabilities. For example, media processing technologies such as speech processing, image processing, and Japanese-language processing are essential to providing new services. In this regard, the NTT R&D Laboratory Group (NTT R&D) is fortunate in being highly competent in such technologies. But that is not to say that simply developing new technologies will enable us to create attractive and commercially viable services. For new services to be successful, convenience and market timing are also important. That is, new services must also provide the customer with convenient functions and they must be released to the market at just the right time. Up to now, however, NTT R&D, in addition to developing

key technologies for the creation of new services, has also been involved in the development of services themselves and the making of proposals to NTT's business companies. As a result, researchers, who do not necessarily specialize in such areas as customer convenience and market timing, have taken it upon themselves to do so. What researchers do best is technology development, and in this field, they tend to be perfectionists, which can cause them to take more time than perhaps necessary to release new technology.

Looking forward, I would like to promote the development of basic technologies, which is a strong point of NTT R&D, while also rapidly bringing those technologies to the attention of NTT business companies. In this way, we can receive feedback from them on aspects in which they specialize, such as how to make functions even more convenient, and quickly incorporate that feedback into the development process. In short, I would like to pursue unified development of new services together with the business companies so that NTT can release highly competitive services to the market in a timely manner.

As services become increasingly diversified, technologies behind those services are likewise becoming quite varied. Since we cannot develop all of those technologies, we must closely consider what technologies we should tackle on our own from among those needed to configure services. I believe that, instead of adhering to just our own technologies, we should be ready to accept technologies based on ideas from the outside and the expertise of others. In other words, I think that we should face the challenge of creating new services with a spirit of open innovation. This same kind of attitude is also needed in the expansion of NTT's global business. In addition to proposing and providing our products overseas as we have been doing up to now, it is becoming increasingly important that we pursue open innovation with NTT overseas consolidated subsidiaries and overseas companies.

True achievement is not just creating new business: It's clarifying one's role in R&D

—It appears that the effects of the earthquake and the acceleration of globalization are forcing researchers to change their way of thinking radically.

Looking back at the way I was trained, I can say that my mindset has been to aim for perfection and deliver results. I think that many researchers have naturally adopted a similar attitude. However, the world is changing quickly and the services that people desire are becoming increasingly diverse. For these reasons, I am asking researchers to rethink what it means to make a contribution to NTT's business. In particular, I am telling them that making a contribution does not simply mean introducing researched and developed technology to the business companies so as to turn a profit and reduce expenses. Making a genuine contribution comes in a variety of forms. In fact, I have defined six ways of making business contributions.

(1) Short-term R&D to introduce R&D projects to business companies, turn a profit, and reduce expenses
(2) Development of a competitive R&D engine while promoting open innovation
(3) Medium-term R&D with the aim of making drastic improvements in business operations
(4) Cutting-edge R&D that can have a major impact on society
(5) Support for business companies through optimal use of technology and contributions to business operations through advice based on accumulated knowledge
(6) Promotion and support of efficient R&D operations

It is also important that we assign targets to each of these research roles. I tell our researchers to think not

only about what can be done but also about what should be done while pursuing their work. This is because if we compare the accumulated results of *what can be done each year* after ten years with the results of *setting targets that should be achieved in ten years time*, we will see a big difference in the level of achievement and the results obtained, even for the same area of research. Researchers need to set high goals and devote their efforts toward achieving them.

In this way, by clarifying the role that each and every researcher needs to take on and by pursuing R&D with high goals set for each role, I believe that we as researchers can make more extensive and meaningful business contributions.

I believe that by working to create new services by setting high goals, demonstrating our strong points without being ashamed of our weak points, and accepting the expertise of others through open innovation, we can achieve great breakthroughs.

Interviewee profile

■ Career highlights

Hiromichi Shinohara received the master's degree from the Graduate School of Waseda University in 1978 and entered Nippon Telegraph and Telephone Public Corporation (now NTT) in the same year. He became a project manager in the NTT Access Network Systems Laboratories in 1998. In 2003, he became an executive research engineer and subsequently the general manager of the Access Network Service Systems Laboratories of the Information Sharing Laboratory Group. In 2007, he became the Director of the Information Sharing Laboratory Group. In 2009, he was elected Senior Vice President and Director of the Research and Development Planning Department of NTT. Since June 2011, he has doubled as the Director of the Information Sharing Laboratory Group.

Take a Global View of Your Research and Put Your Ideas to Work

Hiroshi Yamaguchi
Senior Distinguished Researcher
NTT Basic Research Laboratories

We asked Dr. Hiroshi Yamaguchi, Senior Distinguished Researcher, to tell us about his research on nanomachine technology, which is attracting increasing attention in the world, from how he first conceived of pursuing nanomachines to the current state of his progress. We also asked him how his ten years of research in this field have influenced his outlook as a researcher, how he expresses his individuality as a researcher, and what advice he would give to young researchers.

Globally acclaimed nanomachine technology

—Dr. Yamaguchi, could you tell us about your research in terms that a person with no knowledge of semiconductors can understand?

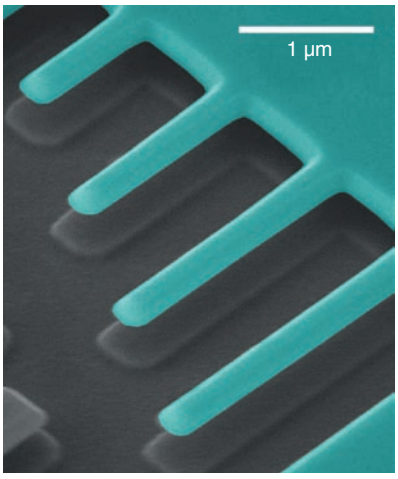
Sure. Let me give you a straightforward explanation using things we are all familiar with. To begin with, what do you think of upon hearing the word *machine*? No doubt many people think of a complicated piece of equipment made up of all kinds of components like gears and springs. This might be Astro Boy, the famous android character, or a locomotive that moves with a huge grinding sound generated by its internal gears and springs. The preconception that a machine uses a large amount of energy is also very common.

Nowadays, however, *making things small* is becoming a dominant way of thinking in various research fields, and the same holds for machines. This field of technology is called *micromachines* or *micro electromechanical systems*. A projector for a personal computer, for example, can be equipped with an array of mirrors each smaller than an insect's foot. If such a micromirror is irradiated with light, the direction of reflection can be adjusted by fine mirror movement. When this is applied across the entire array, it enables the three primary colors (red, green, and blue, or RGB) to be synthesized on a screen and an image or video to be displayed. In short, micromachines are working away continuously like clockwork inside the projector, which represents one example of how micromachine technology can be applied in practice. Another example in common use can be found in car automobile airbags. The deployment mechanism includes a microscopic device less than 1 mm in size that vibrates at the time of a collision and a means for detecting that vibration electrically.

Research and development on applying micromachine technology to such switch and sensor functions is progressing. We are taking up the challenge of developing new techniques for making micromachines as small as possible. Our ultimate goal is to achieve micromachines on the nanotechnology level, or in other words, *nanomachines* (**Fig. 1**).

—What kind of research activities are you coordinating to create such small machines?

Well, this is all fundamental research, so we are at



1–2 µm long, 200 nm thick, and 300 nm wide; each of these structures vibrates at a certain frequency like a diving board.

Fig. 1. Electron microscope image of typical nanomechanical structures.

the stage of searching out what can be done and proposing what might be possible. There are two main research flows here.

In the first one, our aim is to achieve a nanomachine computer that extends the function of the switch to information processing. Right now, we are just looking for the right way to go about this, but if we can come up with a completely novel idea to make calculations by a nanotechnology-based machine, it just might be possible to create a very-low-power computer. Such a nanomachine need not be limited to computers—it might also be possible to apply it to memory devices and components used for processing digital information. The key words here are *low power*.

In the second research flow, we are pursuing the role of the micromachine as a sensor. We are researching ways of improving the sensitivity of existing accelerometers by several orders of magnitude, and our ultimate goal is to be able to detect contact with even one atom! Our theme here is "How small a force or object can we detect?" In this role, there is much anticipation from many fields for applying micromachines to biotechnology, DNA (deoxyribonucleic acid) detection, and medical laboratory equipment, as well as to the pursuit of limits in physics and the search for minimum units in physical movement and forces.

—So your research is exploring unknown worlds. How far will these research efforts progress?

There are various viewpoints on how far our research can go, so I can't really say in just a few words, but I can tell you about some results that we recently announced as examples of the progress we've been making.

In April 2008, we proposed a *nanomachine computer* using a new principle for performing digital operations by using the minute vibration of a beam spring (**Fig. 2**). The heart of this device is the beam spring, which is thinner than the diameter of a human hair. In this device, a *period offset* occurs when the beam spring vibrates with an extremely small amplitude equivalent to only a few tens of atomic diameters (about 10 nm). By making such offsets correspond to '0' and '1' bits of information, we successfully performed 1-bit basic operations using a nanomachine. Achieving computation in this way using the extremely small vibrations of a beam spring suggests the possibility of a very-low-power device.

Moreover, in September of the same year, as joint research with Delft University of Technology in the Netherlands, we fabricated part of a superconducting quantum interference device (SQUID) as a nanomachine structure (beam spring) and successfully detected minute vibrations on the order of one ten-thousandth the size of an atom, which is about ten femtometers (10 fm) (**Fig. 3**). Observing quantum phenomena in a macroscopic object is a difficult challenge, but this new technique might make it possible in future. Although it has frequently been confirmed experimentally that the behavior of atoms—the constituent elements of all matter—is governed by quantum mechanics, which describes the basic laws of the microworld, experimentally investigating how *macroscopic* objects in the real world behave in quantum terms is expected to become a major research theme in the years to come. In short, we fabricated a vibration sensor with extremely high sensitivity for use in research of this type and successfully detected vibration on the order of one ten-thousandth the size of an atom.

More recently, we announced platform technology that shows promise for increasing the degree of integration in nanomachine computers. This technology is the first in the world to offer the possibility of configuring a logic circuit with only one basic device through the development of a digital operation technique that can execute multiple logic operations simultaneously. Up to now, multiple transistors have

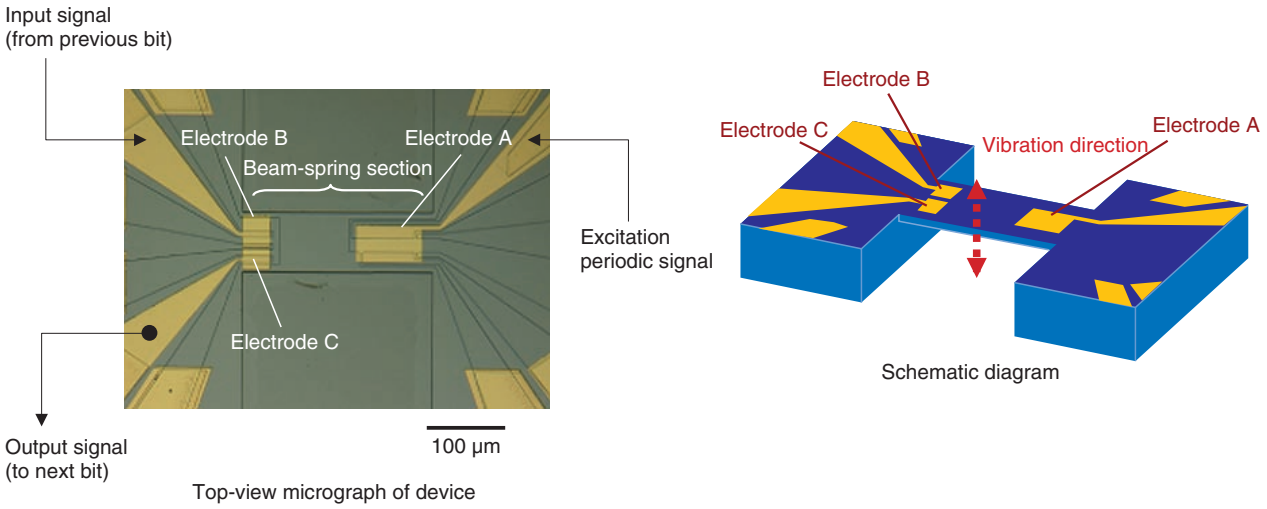


Fig. 2. Micrograph and schematic diagram of nanomachine device.

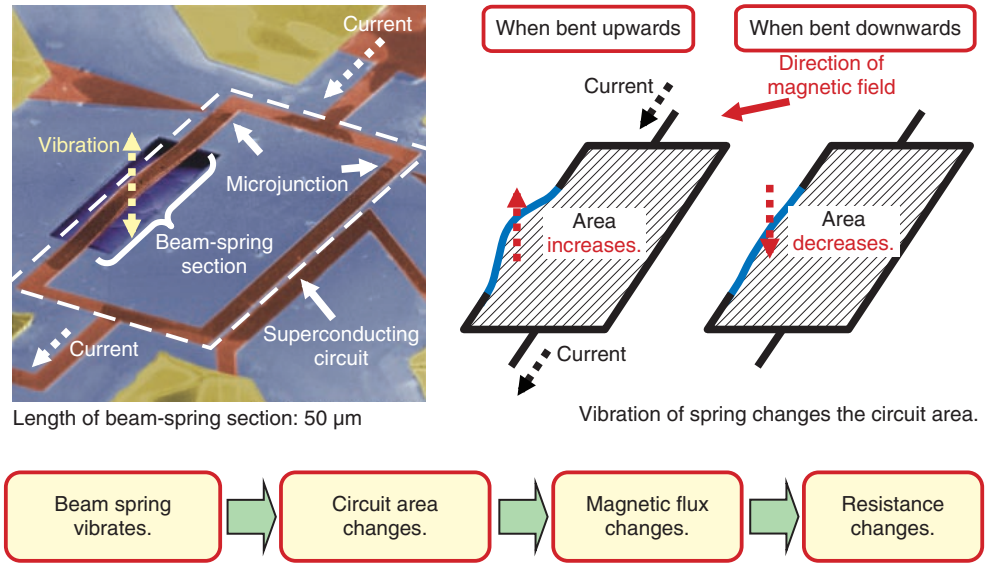


Fig. 3. Principle of ultrasensitive vibration sensor.

been necessary for even the most basic of logic operations, but with this new technique, we have successfully executed multiple logic operations with just one device.

These technologies are not ready to be used in the development of actual equipment, but we will be testing the feasibility of applying them to practical devices in future research.

—When did you begin this research?

I began this research on nanomachines in 2000. Actually, I had been studying fundamental semiconductor properties up until 1998, but in this year I was transferred to the Planning Department of NTT Laboratories for a two-year stint. As a result, my work shifted from research to management. Upon completing this assignment, I found that I would be far behind other researchers if I were to continue with the same

line of research after a two-year hiatus, so I thought, "Why not try something new, something that no one has worked on yet?"

As a researcher, this two-year period of management duties prevented me from performing any experiments, but that did not mean that I took a break from research activities. Looking back, it was a great opportunity for making a big change in the way I looked at research. I learned of new research trends and was able to exercise originality and express my own ideas without imitating anyone.

During my student days, I enjoyed the work of Shinichiro Tomonaga, the renowned theoretical physicist, and I read many books by him and about him and his work. Many wise quotes have been attributed to him, and among these, I cannot forget this one: "If there is a principle that I ascribe to, it's to not do what other people do." Being a follower may be comfortable, but doing things differently from others has shaped my stance on research in no small way.

I also felt that, as one gains experience, the overall direction of the research that you are engaged in comes into view. I thought that by obtaining a firm understanding of the principle roles of your research —by taking a global overview instead of focusing on the fine details—and then applying your own original ideas, you could give birth to incredibly novel technology.

There were just two or three groups around the world that had begun research on nanomachines at that time, and I kept a close eye on their progress. And it occurred to me that combining the semiconductor technology that I had researched for many years with nanomachine technology could very well help me create some very interesting devices. Now, after ten years of researching nanomachines, I feel that things are finally taking shape.

A ten-year journey of experiencing growing pains but delivering world-first technologies

—Was it smooth going during these last ten years?

It was very hard at the beginning! I think that my research style is based more on the new ideas that come into my mind than on continuous and steady effort. I like new things, and I'm not satisfied unless I can move quickly on a new idea. But upon moving to the Planning Department in 1998, it suddenly dawned on me that the work of management would keep me busy and that I would not be able to research my ideas any day soon. So, while keeping abreast of nanomachine trends, I used to do some thinking on my days off or before going to bed. In this way, I gradually accumulated ideas. Then, when I returned to research in 2000, I found that those two or three groups elsewhere in the world researching nanomachines had already been announcing amazing results one after another. Of course, I had just started, and because of this late start, I wanted to do something different instead of just following the pack. But it's not that simple to get immediate results from something new and different. I was trying to produce results in an environment in which the people around me really couldn't help me, so perhaps it's natural that the early days of my research here were difficult. In fact, I began this research on my own, and I could not achieve even vibration measurement, which other researchers were doing on a routine basis. Being able to detect vibration would be the first step toward creating a device like a sensor, but I still could not do anything that would constitute this first step. So I got a real taste of growing pains here.

—How can vibrations be detected?

The resistance of a vibrating semiconductor changes as a result of bending, and the task is to read that change from the outside. However, this change in resistance appears as an extremely small change in current on the order of one millionth of the applied current. In retrospect, reading such a small change in current is not so difficult, but at the time, the know-how to do so was simply non-existent, so I had no choice but to fabricate structures and devise characterization methods on my own from scratch.

It was around this time that an intern from France was assigned to me to work as my assistant. One of his duties was to carry out experiments under my supervision. When an experiment was going well, my task of supervising him went well too, but when no progress was being made, he would have no material to report on, so I found myself worrying not only about myself but also about my assistant. This was a difficult environment to be in.

To be honest, this period at the beginning of these ten years of research was the most trying. But then, on Christmas night in 2000, we were working late, and we detected minute vibrations for the very first time, which means that we had successfully completed the first stage of our research. What a wonderful Christmas present that was! And I remember well how happy this made my French assistant.

Somehow, our research continued to progress. In

2004, a paper that my colleagues and I wrote was accepted by the prestigious journal Physical Review Letters of the American Physical Society and it received enthusiastic praise from readers. Then, in 2007, my colleagues and I developed an original device called a parametric resonator. I was honored that this technology received much praise from outside NTT, and it made me feel that our research was finally taking off.

—In such a difficult environment, you might have given up. How were you able to persevere?

Perhaps it was because I had already left one research area before. When starting a completely new line of research, it feels as if the ladder has been pulled away from underneath you leaving you stranded. I think that making up my mind to go forward at any cost had a big impact on how I dealt with this situation. Furthermore, while my experiments did not go as planned in the beginning, doing them over and over again eventually produced not only results that I had hoped to find but also very interesting ones that I had not expected at all. A feeling of "I can do this!" suddenly came upon me.

It is essential to continue with research even if results are not immediately forthcoming. And when I say *continue*, I also mean exploring new possibilities. In other words, I think that a researcher should strive for a good balance between a stubborn attitude that continues with one approach and an adventurous attitude of not being afraid to try new things.

Experiencing the true pleasure of *monozukuri*

—Other than research, do you have other interests that take up your time?

Yes, I do. Since childhood, I have enjoyed making things, which in Japanese we call *monozukuri*. I began assembling radios as a kid, and since then, I've assembled or made a variety of things, like stereo amplifiers, speakers, racks, desks, and small balcony ponds. My current work leaves me with little time for this pursuit, but I have recently built some bookshelves for my daughter's desk and a stand for my large-screen television (**Photo 1**). The true pleasure of making things yourself comes from possessing a unique item that exists nowhere else in the world and creating something that completely matches your personal needs. I love the feeling of looking for the best way to make something and finally completing

Photo 1. Homemade items: amplifier, rack, television stand, corkboard, speakers, etc.

it, which tells me something about the research process. For example, techniques for producing good sound from speakers and methods for amplifying small electrical signals in a stereo amplifier with low noise are very similar in concept to what I use in generating vibration in the nanomechanical devices that I'm currently working on and amplifying those signals. In this sense, the ability to work at something related to things that I first learned about through childhood hobbies gives me great satisfaction.

In addition, since I'm not so young anymore, I'm concerned about maintaining my health, and though I'm not a sports enthusiast, I jog several kilometers on the weekends and sometimes walk to work from the train station, instead of catching the bus, which takes me about fifty minutes. This exercise helps improve my blood circulation and make me feel better all around.

—Dr. Yamaguchi, would you leave us with some words of encouragement for young researchers?

I would love to. First, it's vitally important for a researcher to express his or her originality, and this, of course, applies to me too. I think that young researchers, especially talented and ambitious ones, want to experience great results early on and to perform work that they have devised themselves. But I would ask them to develop their originality in research carefully without rushing things along. Instead of going all out for an early home run, I believe that focusing diligently on the work that has been assigned to you and then expressing your originality as an extension of that work will be more effective in putting you on the path to success. At first, this

might take some time, but in years to come, there will be more than enough opportunities for you to demonstrate the knowledge and know-how that you have accumulated. I think that many young researchers are ill at ease with the work that has been assigned to them since it differs from the main field of their university studies and is not what they feel they are good at. I can empathize with this, as I was very impatient when I entered NTT Laboratories. But in truth, I think that a good approach is to figure out how to make the best of work that has been assigned to you regardless of your past studies and to supplement that work with your original ideas and methods. You may experience great difficulties in the beginning, but once your hard work begins to bear fruit, you should be able to look back at the road you have taken with a whole new perspective. So, to all young researchers, I wish you great success in your endeavors.

Hiroshi Yamaguchi

Senior Distinguished Researcher, Executive Manager of the Physical Science Laboratory and Group Leader of the Nanostructure Technology Research Group, NTT Basic Research Laboratories.

He received the B.E. and M.S. degrees in physics and the Ph.D. degree in engineering from Osaka University in 1984, 1986, and 1993, respectively. He joined NTT Basic Research Laboratories in 1986. His current interests are micro/nanomechanical devices using semiconductor heterostructures. He has been a guest professor at Tohoku University since 2006. He is an IOP Fellow and a member of the Japan Society of Applied Physics, the Physical Society of Japan, and IEEE.

Efforts Toward Organizational University Collaborations

Terufumi Shinomiya†, *Takashi Ikegawa, Katsumi Iwatsuki, Akihiko Hashimoto, Yasuyoshi Okada, and Eriko Sano*

Abstract

NTT Service Integration Laboratories is striving to create organizational collaborations with universities across a wide range of academic disciplines in order to carry out joint research projects and human resources exchanges more efficiently and effectively. In this article, we introduce the framework for university collaboration and the content of activities. We also introduce specific examples of such collaborations.

1. Introduction

Societies today cannot help but be drawn into a maelstrom of rapid globalization, drastic changes in the business landscape, and fierce competition on a global scale. To respond to the rapid changes in social needs and diversification, it is necessary to partner organizations capable of thinking in different ways and perform research and development (R&D) that incorporates such thinking. In Japan, academic-industrial collaboration—linking companies and universities—in R&D and exchanges of human resources took a great leap forward as a result of the establishment of national university corporations in 2004, which drew the government's attention [1]. NTT is also working to create organizational R&D collaborations with universities [2].

To research and develop basic technologies in order to create new forms of communication and their supporting networks and to actively engage in advanced basic research with a ten-year outlook, NTT is engaged in R&D collaborations with universities across a wide range of disciplines. We have great expectations for diverse results by achieving open innovations. The fruits of these innovations will be profitable not only from a technological standpoint but also from a social standpoint and will make possible R&D that integrates disparate fields. For universities, such collaborations present a win-win situation for improving research and educational activities.

In this article, we introduce our framework for university collaboration and the content of our activities. We also introduce specific examples of such collaborations.

2. Levels of collaboration

NTT has a long history of collaborating closely with universities to conduct joint research. However, such collaborations have been based on individual-to-individual relationships among fellow researchers. Thus, it has been hard to grasp the overall state of organization-to-organization activities. Moreover, because the points of contact were unclear, problems emerged, including a lack of continuity in the collaborations, difficulties with collaborations across multiple fields, and researchers having to shoulder the burden of contract negotiations related to joint research.

To solve such problems, we began efforts toward collaborations with universities on the organizational level, and these have resulted in various joint research projects and human resources exchange. Our efforts center on signing comprehensive organization-to-organization contracts and creating collaboration committees consisting of executives from both NTT and universities to serve as the core of the

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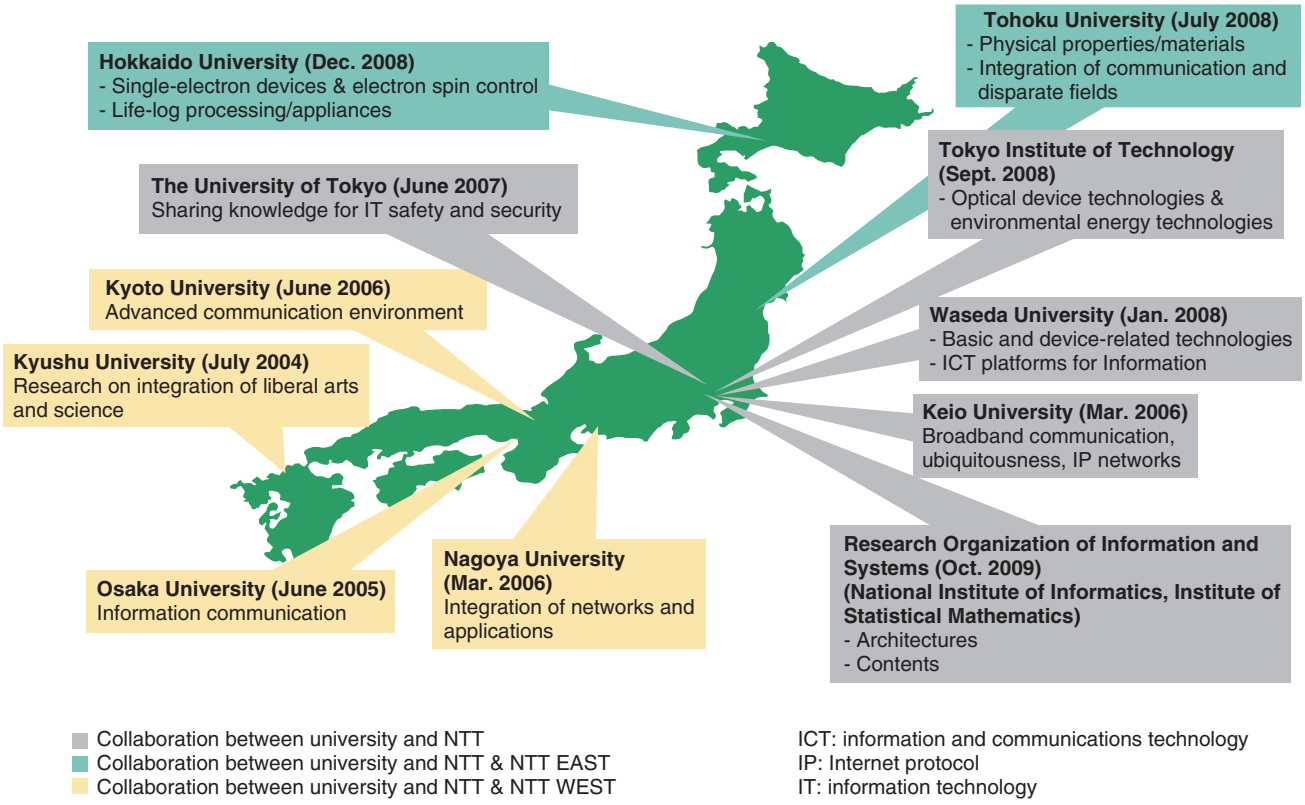

Fig. 1. Universities and research institutes in organizational collaborations with NTT. Fields of joint research are listed under the partner's name. Dates in parentheses are contract-signing dates.

collaborations. In July 2004, we signed the first organizational collaboration with Kyushu University. Since then, NTT has signed agreements with ten universities and one research institute, as shown in **Fig. 1**. Moreover, NTT EAST and NTT WEST, which are intimately connected with regions outside Tokyo, have forged close relationships with three institutions.

The planning and operation of an organizational collaboration is the responsibility of the collaboration committee, which is composed of collaboration managers and research representatives from both parties. The committee has a shared awareness of the R&D being tackled and the human resources available for exchange and creates collaborative relationships that span a wide range of disciplines.

To strengthen and further expand joint research projects that have past connections, we are working on creating new collaborations between departments that have not collaborated before; we are also creating integrative collaborations that span multiple laboratories. We are doing this through matching conducted from a wide perspective on the basis of the needs and seeds of each party. In the area of human resources exchange, we are working on accepting student interns and establishing new occasions for technological exchanges through the participation of a wide range of departments, while being aware of sustained development.

The issues associated with conventional collaborations, their drawbacks, and the goals and methods of organizational collaborations are shown in **Fig. 2**. The forms of collaboration and the contact department on the university side may differ depending on the university. However, for NTT R&D, the unified point of contact for all organizational collaborations is NTT Service Integration Laboratories.

3. Achievements

By utilizing the special features of each university and complementing each other's strengths, we have conducted joint research and human resources exchanges in various areas centered on the field of

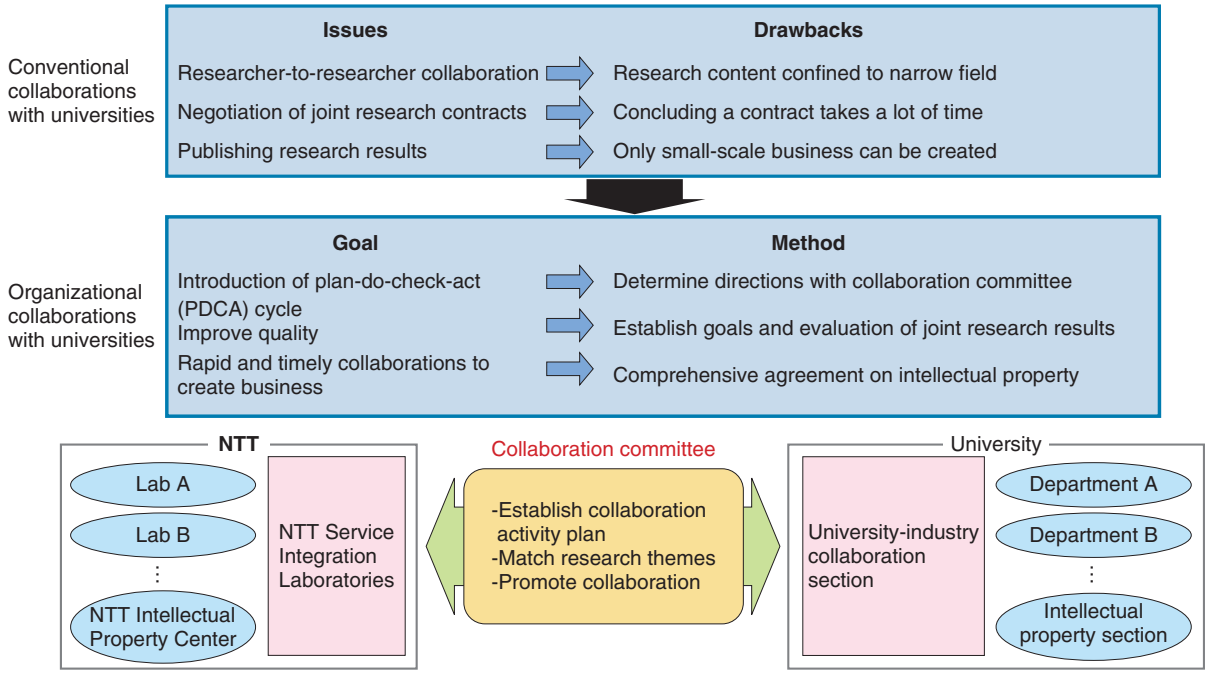

Fig. 2. Advancing organizational collaborations with universities.

communications, including physical properties and materials science, leading-edge devices, IP (Internet protocol) networks and ubiquitousness, information and communications technology (ICT) (including information security), as well as higher-level themes such as audio/video and communications. We are also working on social concerns, including energy and the environment, disaster prevention, medical science, and agricultural science.

In FY 2010, more than 150 joint research projects were carried out through organizational university collaborations, resulting in more than 100 patent applications being filed and more than 200 papers being submitted to academic journals and presented at international conferences [3].

We are also committing ourselves to transmitting the achievements of our joint research projects to the public through press releases from NTT and our university partners (see **Table 1**) and by publishing books. As an example of the latter, we published the results [4], [5] of our research collaboration with Kyoto University's Disaster Prevention Research Institute in a book aimed at the general public [6]. Studies in disaster prevention have until now focused on protecting society against natural disasters, for example through anti-disaster technologies such as construction methods to improve the ability to resist disasters. However, this book is premised upon the occurrence of disasters and focuses on effective implementation of relief and recovery and on technologies for minimizing the harmful effects of natural disasters. It calls for the creation of a *resilient society* by exploiting ICT. Such a society would have resistance to natural disasters and greater recovery strength.

Next, we introduce two examples of human resources exchanges.

3.1 Kyushu University COE Program

First, we were involved in two programs: (1) MEXT's 21st Century COE Program "Development of Dynamic Mathematics with High Functionality" (MEXT: Ministry of Education, Culture, Sports, Science and Technology in Japan; COE: Center of Excellence) conducted by Kyushu University's Faculty of Mathematics (2003–2007) and the graduate school reform support program "Training Program for Ph.D. and New Master's in Mathematics for Industry" (2007–2009) and (2) the Global COE Program "Education-and-Research Hub for Mathematics-for-Industry" (2009–2013) [7]. The curricula of these programs require an internship of three or more months by doctoral students. Since 2006, NTT has been accepting students every year as interns for such

Table 1. Press releases of joint research achievements.

Year	Date	Source(s)	Theme
FY2010	Mar. 15, 2011	Hokkaido University	Elucidation of physical constants in the control of electron spin: Accelerating R&D of next-generation electronic devices
	Nov. 2, 2010	NTT and Kyoto University	Development of error resilience technology that brings quantum computing a big step closer to reality: Enabling quantum computing by using electron gates with large errors
	Sept. 3, 2010	Kyushu University, Takarazuka, Kadokawa, and NTT WEST	Joint R&D for highly realistic sensations during live transmission with communication networks: Live transmission of Takarazuka Review with highly realistic sensations
	Sept. 2010	The University of Tokyo, Toyo University, NTT	Verification of divergence and security using "The International Comparative Survey on Concerns when Using the Internet": Clarifying characteristics of anxiety felt by Japanese users even when safe
	July 27, 2010	Nagoya University	Test release of MAGIC, an automatic English fill-in-the-blank test generation system: Promise of creative learning support
	June 29, 2010	Tokyo Institute of Technology	Direct generation of frequencies over 1 THz at room temperature: Developing the world's first electron device
FY2009	July 27, 2009	NTT and Tokyo Institute of Technology	Success in developing multifunctional 2-qubit (quantum bit) logic element: Realizing inversion of control logic and exchange operation with one electron
	July 17, 2009	Tohoku University, NTT EAST, and NTT	Testing for collaborative business of "Invented by Miyagi"'s new image resolution: Implementing a renewal opening ceremony for "HIKARI PARK"
	April 30, 2009	NTT and Kyushu University	Successful observation of temporal change in the shape of a receptor: Elucidating the structural change mechanism of ATP receptor
FY2008	Dec. 25, 2008	Keio University and NTT	Success in demonstrating multi-location teleconference with 4K ultrahigh-definition resolution: Creating a network cooperative industry using ultrahigh-definition video
	May 26, 2008	NTT and Osaka University	Test of the world's first teleportation-based quantum calculation: A breakthrough in making photon quantum computers

programs. We have also been continuing to accept summer interns for the new master student development program and dispatching lecturers. Through its COE program activities, Kyushu University has established an internationally unprecedented Institute of Mathematics for Industry. This laboratory is Japan's third mathematics research institute, following the Research Institute for Mathematical Sciences (Kyoto University) and the Institute of Statistical Mathematics [8].

3.2 Keio University Symposium

In February 2011, the collaboration committee of Keio University and NTT held the symposium "Seeking to Realize Ubiquitous Innovations through ICT: From Creating Leading-edge Basic Technologies to Application" at Keio University's Mita campus [9]. Atsuhiro Goto, the director of NTT Cyber Communications Laboratory Group (now at Institute of Information Security) gave the keynote address entitled "The Promise of Academic-Industrial Collaborations: Creating New Services for the Optical Era" (see **Photo 1**). Next, researchers from Keio University and NTT gave six presentations in three areas—electronics and physical properties/materials science, networking, and human communication technologies, announcing the results of their cutting-edge research. There were over 170 participants from companies, research institutes, and government agencies as well as universities. A rich variety of presentations on a wide range of topics was given, from basic research to applications in the field of ICT, making the symposium an overwhelming success.

4. Collaborations with overseas universities

NTT is also exploring organizational collaborations with overseas universities. Recognizing that collaborations in Asia are growing in strength, we are proceeding with collaborations with universities in China, Vietnam, and India. Because there are issues such as differences in customs and laws, we are still at the stage of carrying out trials of offshore software development related to research rather than conducting R&D collaborations like those with domestic universities. The universities have favorably evaluated the acquisition of new research themes and the training of students. For NTT, the advantages are

promoting exchanges of human resources and reducing costs.

5. Conclusion

For efforts toward organizational university collaborations, it is critical to regularly commit energy to the creation of new research themes as part of the metabolism of an organization and to develop strong research themes that take account of business and social developments. It is also essential to widely and continually foster mutual understanding through exchanges of human resources. With NTT's organizational university collaborations, we are not only creating win-win relationships with universities, but also working to improve Japan's growth strategy and increase its international competitiveness and contribute to solutions to society's problems.

Photo 1. Keynote address.

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Room-temperature Resonant-tunneling-diode Terahertz Oscillator Based on Precisely Controlled Semiconductor Epitaxial Growth Technology

Hiroki Sugiyama†, *Safumi Suzuki, and Masahiro Asada*

Abstract

This article presents the recent achievement of fundamental oscillations in resonant tunneling diodes (RTDs) above 1 THz at room temperature. One of the key technologies for this achievement is precisely controlled epitaxial growth of ultrathin semiconductor heterostructures. The structural design of oscillators and microfabrication technology are also crucial. To increase the oscillation frequency toward the terahertz range, we devised a novel RTD structure with a graded emitter, which effectively reduces both the operating bias voltage and electron transit time in the collector depletion region. An InP-based InGaAs/AlAs RTD oscillator with a graded emitter and 1.2-nm-thick barriers exhibited fundamental oscillations with frequencies of up to 1.04 THz at room temperature, which is the highest oscillation frequency ever reported in single solid-state electron devices. This project is part of collaborative research and development between NTT and Tokyo Institute of Technology.

1. Introduction

The resonant tunneling diode (RTD) is a quantum-effect semiconductor device using quantum mechanical tunneling. Its operating principle is based on the resonant tunneling effect proposed by Tsu and Esaki in 1973 [1]. The conduction-band profiles of a conventional RTD and their relation to current-voltage characteristics are schematically shown in **Fig. 1**. The case under zero bias is shown in Fig. 1(a). The RTD's active layers consist of a double barrier (DB) structure where an undoped quantum well layer is sandwiched between two undoped barrier layers. Owing to the use of the quantum mechanical behavior of carriers, each layer of the DB structure is usually on the order of 1 nm thick. The DB layers are connected with heavily doped emitter and collector contact regions filled with electrons. Discrete quasi-bound or resonant levels are formed in the well layer. In Fig. 1(a), the lowest resonant level is indicated. As the bias voltage increases, electrons flow from the emitter to the collector through the resonant level. The current increases almost linearly until the emitter's conduction band edge exceeds the resonant level, as shown in Fig. 1(b). A further increase in the bias voltage causes a sharp drop in the current because the resonant level falls below the emitter's conduction band edge, as shown in Fig. 1(c). The current-voltage characteristics in Fig. 1(d) exhibit negative differential conductance (NDC), which is one of the distinctive features of RTDs. The ratio of peak current to valley current (I_P/I_V) in Fig. 1(d) is called the peak-to-valley ratio (PVR) and is one of the figures of merit of RTDs.

One practical application of such NDC devices is a

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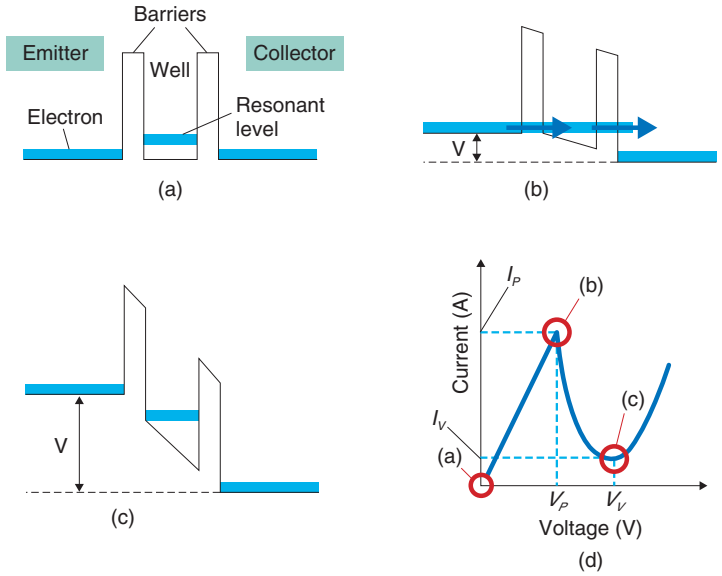

Fig. 1. Conduction band profiles of a DB RTD at three different bias voltages (V): (a) zero bias (V=0), (b) resonance (V= V_P), and (c) off-resonance (V= V_V). (d) Schematic current-voltage characteristics of a DB RTD.

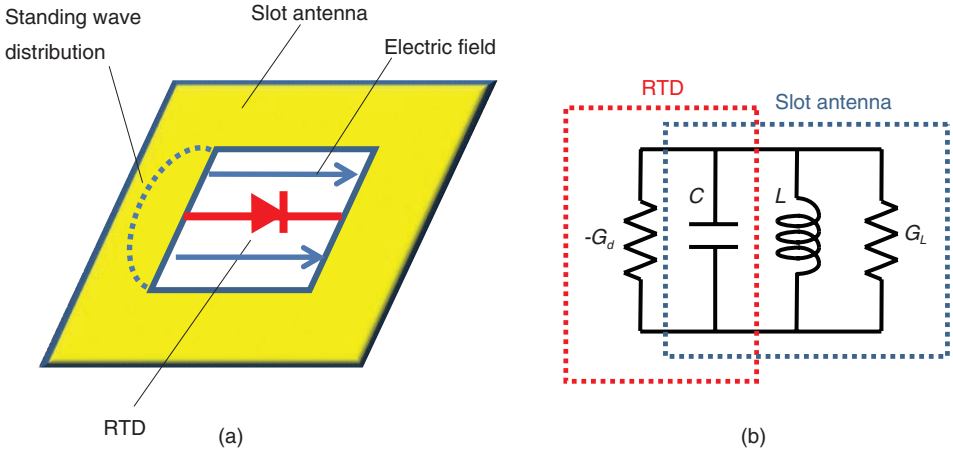

Fig. 2. (a) Fundamental structure of the RTD oscillator integrated with slot antenna. (b) Equivalent circuit of (a).

high-frequency oscillator, which can be constructed by connecting NDC devices and external resonators. The fundamental oscillator structure used in this work, which has an RTD integrated with a slot antenna [2], is shown in **Fig. 2**. The RTD's NDC provides the gain necessary for the oscillation. The slot forms a standing wave of the electromagnetic field as a resonator and also acts as an antenna by radiating output power at the same time. The equivalent circuit for the structure in Fig. 2(a) is shown in Fig. 2(b). Here, some of the parasitic elements such as contact resistance have been omitted. Oscillation takes place if $G_d > G_L$, i.e., the NDC's absolute value exceeds the slot antenna's radiation loss. The oscillation frequency is determined by the parallel resonance of L and C in Fig. 2(b) corresponding to the standing wave in Fig. 2(a), where inductance L is dominantly produced by the antenna, and capacitance C is produced by the

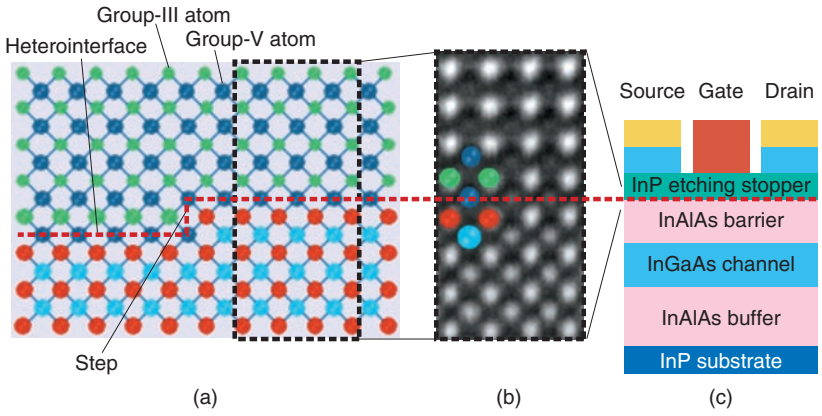

Fig. 3. (a) Schematic illustration of heterointerface of III-V semiconductors. (b) HAADF STEM image of InP/InAlAs heterointerface in an InP-based HEMT. (c) Schematic layer structure of InP-based HEMT.

RTD and antenna.

The RTD's high-speed operation is based on some of the RTD's distinctive features. One is the short resonant tunneling time, which corresponds to the quantum-mechanical tunneling time of an electron passing through the DB structure; this is estimated to be on the order of 1 ps or less. Another is the short charging time of its own capacitance. The RTD's high current density of over 1×10^5 A/cm^2 and comparatively small capacitance effectively reduce the charging time. These are quite a contrast to other NDC devices such as Esaki diodes where high current density is associated with high doping in the active region, which significantly increases their capacitance and charging time. In the early stage of research, such excellent features of the RTD indicated that RTD oscillators could operate at frequencies never reached by other semiconductor devices. The first demonstration of an RTD oscillator was reported by Sollner in 1984 for GaAs/AlGaAs RTDs; the oscillation frequency was 18 GHz at 200 K [3]. The oscillation frequency reached 712 GHz at room temperature in 1991 with InAs/AlSb RTDs [4].

Recently, the sub-terahertz (sub-THz) and terahertz (THz) ranges have been attracting a lot of interest since there are various potential practical applications such as broadband wireless communications, safety, and security. Although the demands for room-temperature devices operating in the sub-THz to THz range increased, no further increases in RTD oscillation frequency were reported until 2009. Room-temperature operation in the THz range has not yet been achieved in any other single devices. NTT Photonics Laboratories and Tokyo Institute of Technology (Tokyo Tech) have been collaborating on RTD THz oscillator development since 2007. NTT has developed a precisely controlled epitaxial growth technique to obtain high-quality ultrathin semiconductor heterostructures [5]. Tokyo Tech has developed design and microfabrication technology for RTD oscillators operating in the sub-THz to THz range [6]. In 2009, we reported a record-breaking fundamental oscillation at 831 GHz [7]. Last year, we successfully extended the fundamental oscillation frequency to above 1 THz at room temperature [8].

In this article, we present essential technologies for the achievement. Precisely controlled semiconductor epitaxial growth technology developed in NTT and its application to ultrahigh-speed electron devices are described. The design and microfabrication technology for RTD oscillators developed by Tokyo Tech is also presented. Finally, our approach to THz oscillation and its experimental demonstration are shown.

2. Precise control of semiconductor epitaxial growth for ultrathin heterostructures in ultrahigh-speed electron devices

The atomic configuration of an ideal III-V semiconductor heterointerface is schematically shown in **Fig. 3(a)**. The RTD's DB structure consists of such heterointerfaces between barrier and well. Good crystal quality for such a heterostructure is essential for modern semiconductor devices, such as high-speed transistors, lasers, and photodiodes, to produce high performance. For example, excellent abruptness of

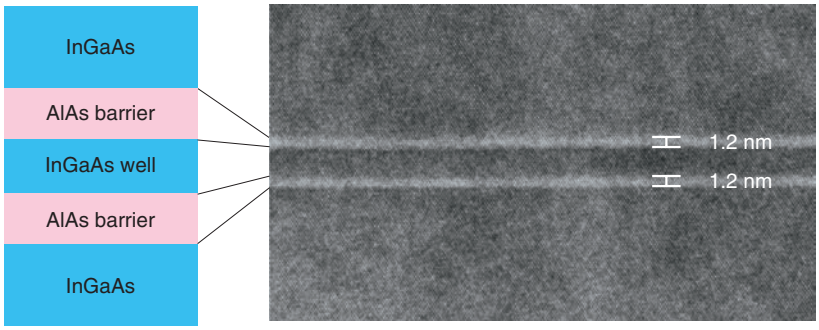

Fig. 4. (a) Schematic of InGaAs/AlAs DB structure and (b) cross-sectional TEM image of DB structure.

the layer composition is required in actual devices to form an ideal band profile. In Fig. 3(a), the atomic composition changes abruptly at the interface, and there is no mixing layer around the interface. Control of the layer thickness on the order of 1 nm or less is also required. In addition, heterointerface flatness is also important for device performance since actual heterointerfaces often include a high density of monolayer steps, which often affect carrier transport.

These III-V semiconductor heterostructures are usually fabricated by an epitaxial growth technique such as molecular beam epitaxy (MBE) or metalorganic vapor-phase epitaxy (MOVPE), in which semiconductor epitaxial layers are grown by depositing source materials on substrates. In NTT Photonics Labs, MOVPE is mainly developed for advanced semiconductor devices for broadband communication systems. In MOVPE, organic metals and hydrides are used as precursors and supplied to the substrate during epitaxial growth. For the fabrication of high-quality heterostructures, control of precursor-supply switching is one of the key procedures. NTT has developed such key techniques and fabricated high-quality heterostructures for practical devices. A high-angle annular dark-field (HAADF) scanning transmission electron microscope (STEM) image of the InP/InAlAs heterointerface in an InP-based high-electron mobility transistor (HEMT) developed in NTT is shown in **Fig. 3(b)**. The HEMT's layer structure is shown in **Fig. 3(c)**. In Fig. 3(b), each bright dot corresponds to a group-III or group-V atom. It should be noted that the brightness of dots corresponding to group-V atoms changes abruptly at the interface, which means that the distribution of group-V atoms changes abruptly from arsenic to phosphorus. This HAADF-STEM image demonstrates our excellent control of compositional abruptness at the heterointerface. The abruptness provides high wet-etching selectivity in the device fabrication process and contributes to excellent device characteristics. InP-based HEMT integrated circuits based on our MOVPE technology have been used in a 120-GHz advanced broadband wireless communication system [9].

NTT has applied such epitaxial growth techniques to the fabrication of high-performance RTDs. We used InP-based InGaAs/AlAs DB structures because the large conduction-band offset between InGaAs and AlAs is beneficial to obtain a large PVR. Oscillation in the THz region requires peak current density (J_P) of around 1×10^6 A/cm^2 or more with a large PVR. We have demonstrated precise control of a barrier thickness of around 1 nm and the formation of high-quality heterointerfaces with excellent compositional abruptness and flatness [10]. An example of a cross-sectional TEM image of our RTD is shown in **Fig. 4**. The image shows the uniformity of 1.2-nm-thick barriers and the smoothness of the heterointerfaces. We have also confirmed excellent on-wafer uniformity on a 3-inch wafer where the barrier-thickness fluctuation was estimated to be around ±0.1 monolayers.

3. Fundamental oscillation above 1 THz at room temperature

Schematic drawings and microscope images of an actual RTD oscillator integrated with a slot antenna are shown in **Fig. 5(a)**. The structures are based on Tokyo Tech's advanced semiconductor microfabrica-

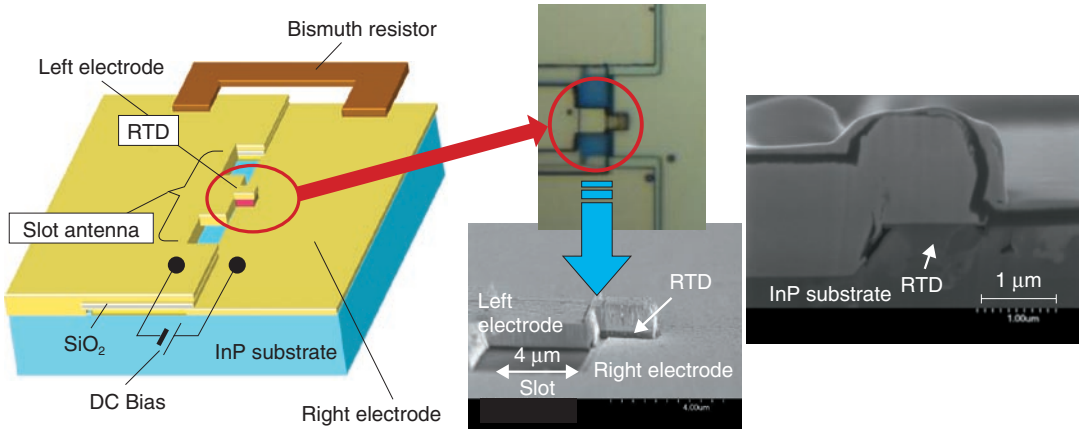

Fig. 5. (a) Schematic and microscope images of the RTD oscillator integrated with slot antenna. (b) Cross-sectional SEM image of the RTD oscillator.

tion technology. The RTD's electrodes are connected to the antenna's left and right electrodes. At both edges of the antenna, the electrodes are overlapped with a SiO_2 layer between them. This structure forms reflectors of high-frequency electromagnetic waves, and DC bias separation is achieved at the same time. A resistor made of bismuth film is connected in parallel outside the antenna electrodes to suppress parasitic oscillation caused by the resonance formed by external circuits including the bias supplying lines. A cross-sectional image of the RTD oscillator is shown in **Fig. 5(b)**. The RTD's emitter mesa area is around 1 μm^2 or less. The emitter mesa area and slot antenna length are key structural parameters that determine the oscillation frequency and they were carefully designed to increase the oscillation frequency.

We have improved the RTD's layer structure to extend the oscillation frequency toward the THz range. The structural-parameter dependences of RTD characteristics, such as the effect of barrier thickness reduction, have been investigated to obtain high J_P and reduce the resonant tunneling time. In addition, our previous research revealed that lowering the operating bias voltage of the oscillator is important in order to reduce the electron transit time in the collector depletion region because a low operating bias voltage should suppress electronic transition from Γ to the L valley, which leads to a decrease in electron velocity [11].

To reduce the operating bias voltage, we have proposed a novel RTD structure with an undoped graded

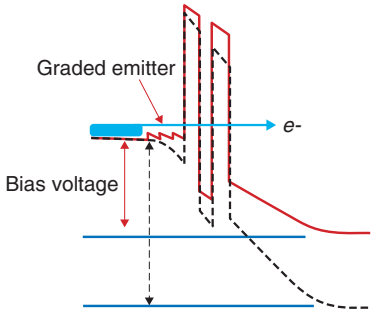

Fig. 6. Conduction band profile of double barrier region in the RTD oscillators with (red solid line) and without (dashed line) graded emitter at operation bias voltage.

emitter. The conduction band profiles of the DB regions in RTD oscillators with and without a graded emitter at around the operating bias voltage are shown in **Fig. 6**. Inserting a graded emitter, which consists of Ga-rich InGaAs and forms potential steps at the DB structure's emitter side, effectively reduced the operating bias voltage. We examined the effectiveness of barrier thickness reduction and graded emitter insertion. An example of the current-voltage characteristics of this novel RTD with 1.2-nm-thick barriers and a graded emitter is shown in **Fig. 7**. We have successfully obtained an extremely high J_P of 2.4×10^6 A/cm^2 with a PVR of 2 under a comparatively low bias voltage of 0.8 V. To our knowledge, this is the highest

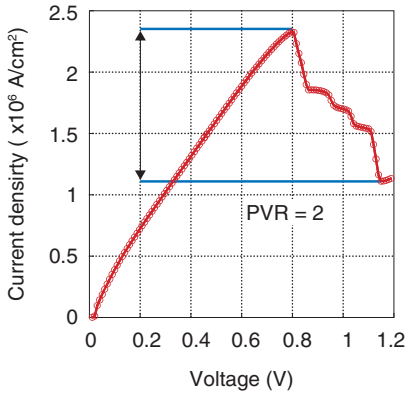

Fig. 7. Current-voltage characteristics of the RTD.

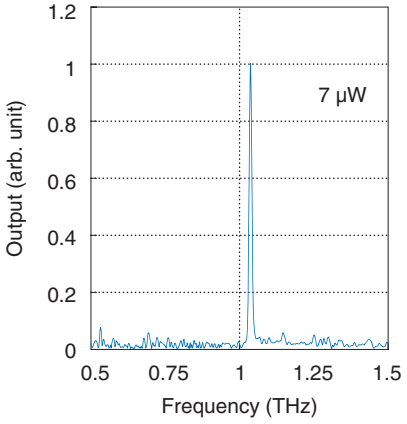

Fig. 8. Measured oscillation spectra.

J_P ever reported. The current-voltage characteristics indicate the formation of high-quality ultrathin barriers and heterointerfaces. The RTD oscillator's measured spectrum for fundamental oscillation at 1.04 THz, which is the highest oscillation frequency ever reported in a single solid-state device operating at room temperature, is shown in **Fig. 8**. The output power was 7 μW. Further optimization of the structural parameters should enable increases in the oscillation frequency and output power to meet the demand for practical compact THz devices.

4. Conclusions

NTT and Tokyo Tech have had great success in their collaborative development of RTD THz oscillators. Using precisely controlled semiconductor epitaxial growth and microfabrication technologies, we have achieved fundamental oscillations above 1 THz at room temperature through optimization of the RTD layer structure. Further increases in oscillation frequency and output power are expected through further improvement of the oscillator structures, which should lead to a practical room-temperature compact THz light source.

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Automatic Generation of English Cloze Questions Based on Machine Learning

Tomoharu Iwata[†], *Takuya Goto, Tomoko Kojiri, Toyohide Watanabe, and Takeshi Yamada*

Abstract

We are developing a system that automatically generates multiple-choice cloze questions in English, which we call MAGIC. By using machine learning techniques, MAGIC extracts the characteristics of manually generated questions and selects appropriate sentences for questions, determines words to be blanked, and generates multiple choices. This project is part of collaborative research and development between NTT and Nagoya University.

1. Introduction

With the development of information and communications technology (ICT), e-learning has become popular. One of its main benefits is that each user can learn in accordance with his or her own achievement level, interests, and pace. However, we need to prepare a huge quantity of learning materials in order to suit the levels and interests of a wide variety of users.

To resolve this problem, we are researching and developing systems that generate learning materials automatically. By fusing e-learning technology studied in Nagoya University and machine learning technology studied in NTT, we have developed a system that automatically generates multiple-choice cloze questions for English, which we call MAGIC (multiple-choice automatic generation system for cloze questions) [1]. Some examples of multiple-choice cloze questions are shown in **Fig. 1**. There were several reasons for focusing on this type of English questions. First, a lot of Japanese learn English, and English learning is in demand not only in Japan but all over the world. Second, this question type is common and used in TOEIC (test of English for international communication) and university entrance examinations.

MAGIC takes English sentences as input. Users may input just one sentence or multiple sentences from newspaper articles and novels. MAGIC sorts the sentences in order of appropriateness for English questions and outputs sentences containing blanks and four options for each blank. Figure 1 shows an example of MAGIC's input and output.

MAGIC can be used for a variety of ways. First, by entering English sentences that match their own interests, users can learn while having fun. For example, users who like football can learn English using football articles, and users can learn using novels by authors that they like. Second, users can learn a type of English that suits their study purpose. For example, users can learn business English by using business news articles, scientific English by using scientific papers, and travel English by using travel guidebooks. Third, users can overcome their weak points by generating and learning questions that test them.

The interests and goals for learning depend on users, and they may change over time. Therefore, it is difficult to prepare learning materials that meet the diverse interests and goals of all users.

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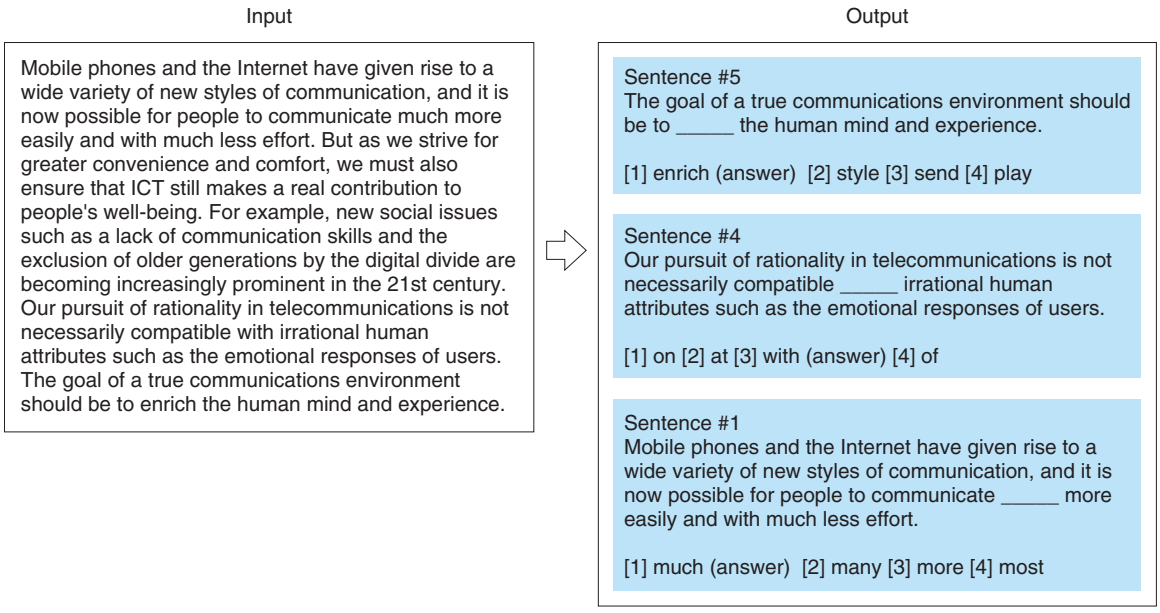

Fig. 1. Input and output of MAGIC.

2. Rule extraction using machine learning

MAGIC has three components, which 1) sort sentences in order of appropriateness for English questions, 2) determine words to be blanked, and 3) generate multiple choices. The procedures of MAGIC are shown in **Fig. 2**. For these three components, we need rules for evaluating the appropriateness of English questions, selecting words to be blanked, and generating choices, respectively. However, such rules are not available, and humans do not generate questions by following explicit rules.

MAGIC can automatically extract these rules by using machine learning techniques, which find statistical rules from given training data by using computers. The training data for MAGIC are manually generated English questions. By analyzing hand-made questions, we can extract rules for sorting sentences and generating blanked sentences with their multiple choices.

By changing the training data, we can change the question generating characteristics. For example, by using TOEIC questions for the training data, we can generate questions that are similar to TOEIC questions. We can also increase the level of difficulty by using high-level questions for the training.

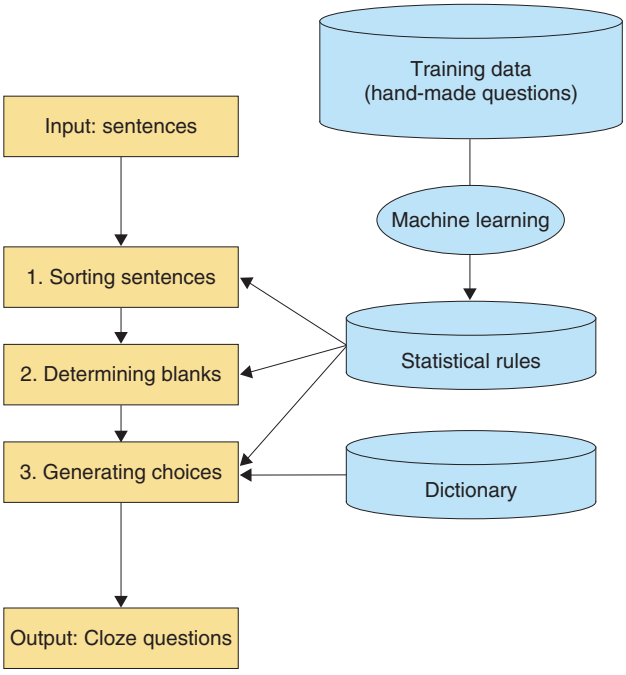

Fig. 2. Procedures of MAGIC.

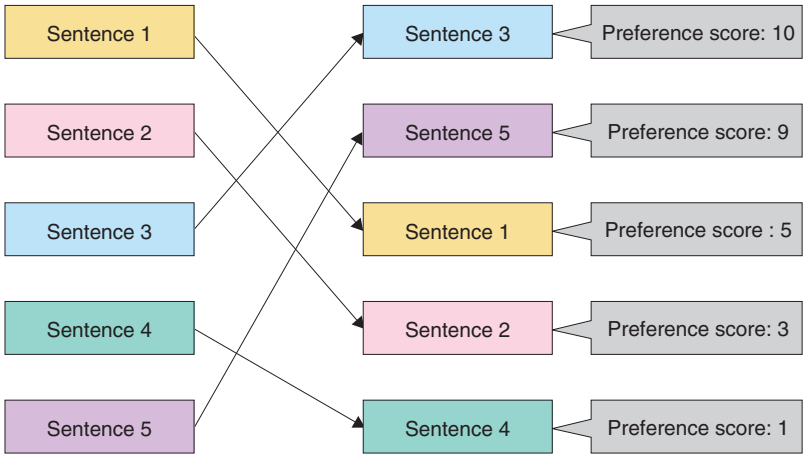

Fig. 3. Sorting sentences on the basis of preferences.

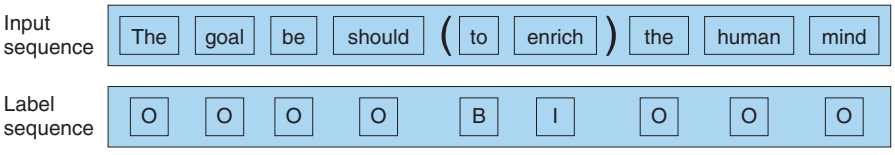

Fig. 4. Determining blanks by using sequence labeling.

3. Question generation procedures

In this section, we explain each component in detail.

3.1 Sorting sentences

Some of the input sentences might be appropriate and some of them might be inappropriate for English questions. For example, sentences that contain important idioms and have important grammar structures are more appropriate for questions. MAGIC sorts English sentences by comparing hand-made questions (training data) and standard English sentences by using preference learning [2]. An example is shown in **Fig. 3**. Preference learning enables us to assign high preference scores to sentences that are similar to the training data. The similarities can be calculated by using word appearance frequencies and parts of speech (POSs) in the sentences. By sorting input sentences in preference score order, users can learn English with appropriate sentences for questions.

3.2 Determining blanks

Determining words to be blanked can be regarded as a sequence labeling problem in machine learning. The sequence labeling problem is to estimate an optimal label sequence for a given input sequence. In our case, the input sequence is a sentence (word sequence), and the output label sequence is a sequence that represents the blank's position. The label sequence can be represented as shown in **Fig. 4**, where B, I, and O are standard IOB2 tags indicating the blank's beginning and words inside and outside the blank, respectively. With MAGIC, we use Conditional Random Field (CRF) [3], which has achieved high performance in sequence labeling problems. As features for CRF, we used words around the blank and their POSs. We confirmed that by using these features, we could select the words to be blanked more accurately than by using conventional methods.

3.3 Generating choices

MAGIC generates multiple choices on the basis of statistical information and patterns obtained from the training data. We classify a set of choices into two

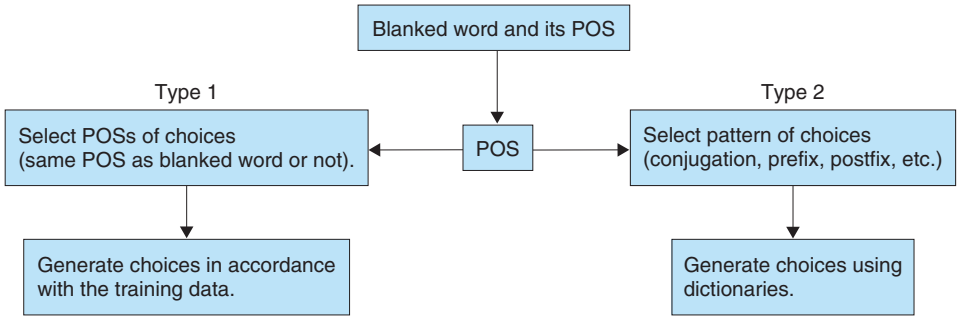

Fig. 5. Flow of choice generation.

types by the blank's POS. The first type is a POS that restricts words that can be chosen. For example, when the preposition *of* is blanked, the alternative choices are likely to be other prepositions such as *to*, *in*, and *at*. The words of an interrogative and auxiliary verb are also included in this type as well as prepositions. With this type, we can generate choices by considering the POS and word probabilities. The second type is a part of speech that has patterns in conjugation, orthography, or meaning. This type includes verbs, adjectives, and nouns. For example, patterns include various conjugations of the same base word (ask, asked, asking, asks), the same prefix or postfix (defective, elective, emotive, active), and similar meanings (told, said, spoke, talked). This type lets us select a pattern in accordance with the POS and generate choices using dictionaries. The flow of choice generation is shown in **Fig. 5**.

4. Conclusion

We are developing a system for automatically generating English cloze questions. We would like to sort sentences in order of user interests or difficulties [4], and this leads to personalized learning. We would also like to extend the system so that it can generate questions for learning other languages besides English and to generate learning materials in other subjects such as history and mathematics.

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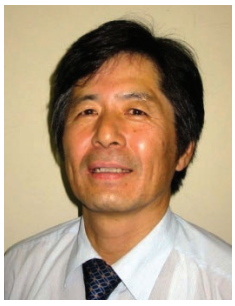

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High-presence Audio Live Distribution Trial

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Abstract

This article reports on a trial of live distribution of video featuring high-presence audio over optical networks conducted in September 2010 and presents an evaluation of the results. With the spread of such distribution, demand for high-presence replay is on the rise, and NTT WEST has been involved with Kyushu University in joint research on high-presence video and audio.

1. Introduction

NTT WEST believes that one way of using optical networks in the future will be live distribution, so it has been involved in various undertakings to this end.

On September 8, 2007, NTT WEST conducted a live broadcast of the "TCA Special 2007" from the Takarazuka Grand Theater in Hyogo Prefecture to two theaters: one in Tokyo and one in Osaka (TCA: Takarazuka Creative Arts). And on December 24 in the same year, NTT WEST conducted live broadcasts of the "Closing day of the Takarazuka Review Hanagumi Performance" from the Tokyo Takarazuka Theater to seven cinemas: four in Tokyo, two in Osaka, and one in Nagoya. Unlike normal movie content, this advanced live broadcast featured high-quality content distributed via the network to a number of commercial cinemas [1].

Conducted jointly by TCA, NTT, and content holders, these trials aimed to provide an overall assessment of the potential of the future business of live broadcasting over networks; address audio-visual quality issues, management structures, technical issues, business models, and profitability; and gather feedback from the content viewers themselves.

The configuration used for the trial (**Fig. 1**) involved connections between NTT Communications' optical network (leased circuit services etc.) and NTT WEST's optical networks (local area network communications services), across which the multicasting took place. The distribution equipment included an IP (Internet protocol) interface (NA5000), an encoder (HE5000), and a decoder (HD5000) (all products of NTT Electronics Corporation); the distributed content was MPEG-2 (46 Mbit/s) video with stereo-quality audio. The equipment was continually monitored from a web console to enable monitoring of the entire distribution network and to enable communications for troubleshooting between sites. An IRC (Internet relay chat) server was set up as part of the platform to allow two-way chat-style communications from client personal computers at different sites, as well as an Internet telephony system.

2. Technical issues with live distribution services

The 2007 trial showed that the MPEG-2 resolution (46 Mbit/s) enabled clear viewing of details such as individual spangles on the Takarazuka Review costumes, indicating that there are no issues with resolution. However, when the camera panned sideways during line dancing scenes and similar scenes, the image on the screen became very difficult to watch—it induced seasick-like feelings in those viewing in the cinema's front rows—so we concluded that conventionally shot TV content is not always suitable for the big screen. Furthermore, although these cinemas had 5.1 surround sound systems, distortion in the

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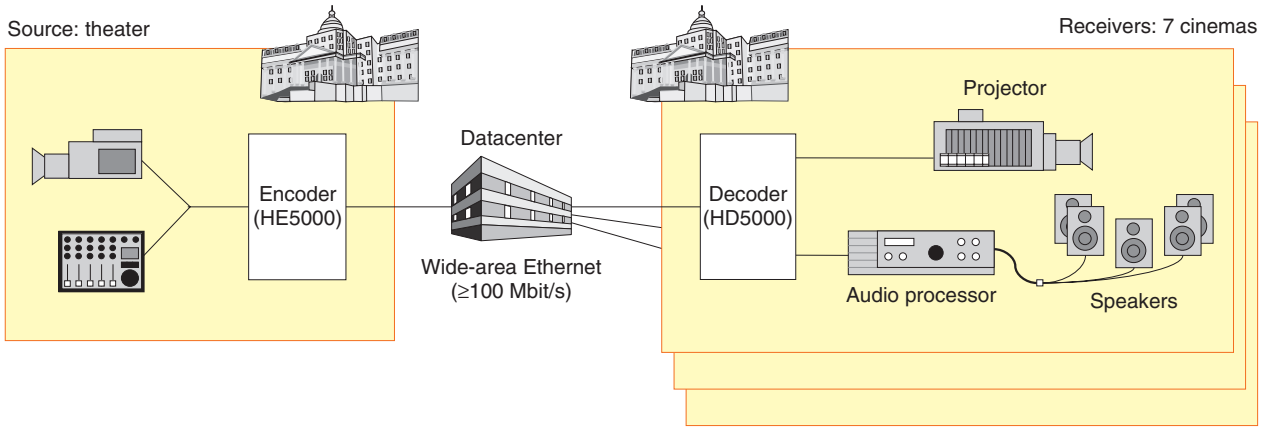


Fig. 1. 2007 live distribution trial.

stereo audio signals that had been encoded, compressed, and transmitted led to viewers complaining that the sound was thin or no good.

Regarding video quality, resolutions higher than MPEG-2 (46 Mbit/s) are possible, but they generally lead to higher network costs, which prompts content holders to ask whether it is possible, in terms of actual business, to keep costs down without affecting video quality.

To resolve the issue of nauseous feelings induced by camera panning, we have introduced shooting methods that take into account the constraints of large-screen projection by switching shots among multiple cameras while eliminating panning as much as possible. To address the issue of network costs, we have been able to halve the video bandwidth while maintaining the same video quality as MPEG-2 (46 Mbit/s) by using MPEG-4 AVC/H.264 instead.

However, the audio quality problems still needed to be addressed. There were four issues that needed to be resolved: (1) audio quality at the time of recording, (2) audio quality during mixdown, (3) transmission quality suitable for 5.1 surround sound, and (4) an audio environment that can be replayed on 5.1 surround sound systems.

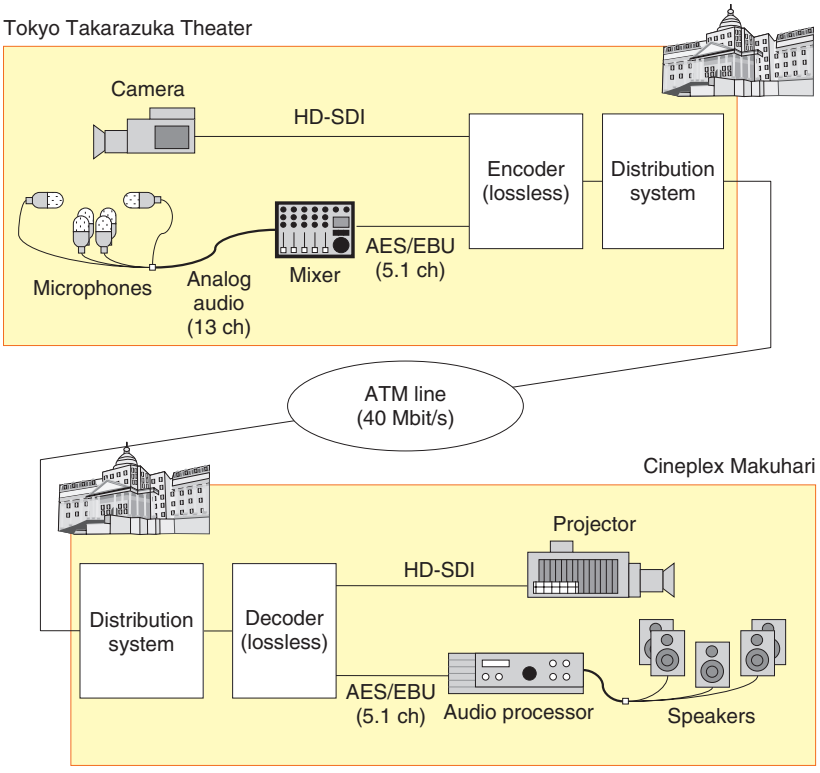
3. Joint research with Kyushu University

With a knowledge base in audio-visual engineering and staging technologies, Kyushu University runs a "Culture Hall Management Engineer Training Program" training unit. The aims are to (1) teach personnel the skills to make and implement plans as part of community measures to promote local arts and culture, while making efforts to promote effective use of local citizen halls and public centers using optical networks; (2) promote regional development; and (3) bridge the information gap by distributing arts and cultural events that are held predominantly in the big cities of Osaka and Tokyo, and thus expand opportunities to use content in local settings.

Since measures to distribute arts and cultural events to local public halls via optical networks match NTT WEST's approaches and ideas for live distribution, and since both NTT WEST and Kyushu University are working to spread live distribution via optical networks, we have embarked upon joint research.

As part of this joint research, NTT WEST and Kyushu University have considered ways to combine knowledge and technologies to address the audio quality problems identified in the 2007 trial and demonstrate solutions and have also considered ways to promote live distribution to public halls by using optical networks.

Specifically, research supervised by Associate Professor Akira Omoto of Kyushu University into the visualization of reflected sound in an enclosed space by means of sound intensity measurement [2] has been conducted for both the sender and receiver of the audio signals. Through an understanding of the characteristics of the acoustic fields at both ends, this research has provided us with new and optimized recording and mixing techniques. By using Kyushu University's knowledge in combination with NTT WEST's optical networks and encoding technology created through NTT's R&D, and with the cooperation of NTT Learning Systems, we were able to achieve mixing optimized for the replay venue. For



AES/EBU: advanced encryption system, European Broadcasting Union
ch: channels
HD-SDI: high-definition serial digital interface

Fig. 2. 2010 high-presence audio live distribution.

the system demonstration, we were provided with content from TCA in the same way as in the 2007 trial, and we were also assisted by Kadokawa Cineplex as the receiver of the high-presence live audio (replay venue). We conducted joint research with the participation of TCA and Kadokawa Cineplex [3].

4. High-presence audio live distribution trial

On September 12, 2010, we transmitted the Takarazuka Review—Snow Group performance of the final performance of the "Natsuki Mizu Goodbye Show" from the Tokyo Takarazuka Theater to test the high-presence audio distribution system (**Fig. 2**). Because our aim was to find out if we could reproduce the original audio from Tokyo Takarazuka Theater at the replay venue, we used only one receiving site: the Cineplex at Makuhari. The two sites were linked by a 40-Mbit/s network connection in asynchronous transfer mode (ATM). We used the NA5000 as the IP interface. We also used the new audio rate oriented adaptive bit-rate video encoder/decoder developed by NTT Network Innovation Laboratories; this codec can control the bitrate between video and audio in real time, and higher video quality is achieved by making use of extra bits saved by using lossless audio compression. Since any audio quality degradation should be avoided, we used MPEG-4 Audio Lossless Coding (ALS) [4], to which NTT Communication Science Laboratories is one of contributors in standardization activities.

Moreover, we used a highly efficient live distribution system developed by NTT Network Innovation Laboratories, which served to ensure end-to-end reliability with error correction and IP packet encryption. For picture quality, we chose to use the MPEG-4 AVC/H.264 (average 20 Mbit/s) format after evaluating the 2007 trial results. Furthermore, to compare high audio presence with conventional systems, we used TCA's commercial service to connect the Tokyo Takarazuka Theater with another cinema (a conventional stereo-sound cinema) via the Business

1. Responses to the questionnaire

Cineplex Makuhari

Number of responses	Response rate
157	57.1%

* Screen 7 (275 viewers)

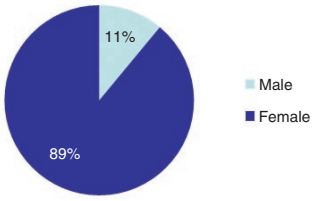
Stereo-sound cinema

Number of responses	Response rate
103	33.4%

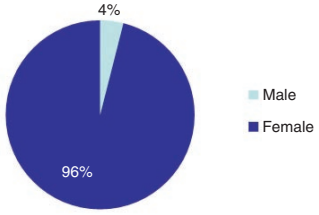
* Screen 2 (308 viewers)

2. What is your gender?

Cineplex Makuhari: 154 valid responses

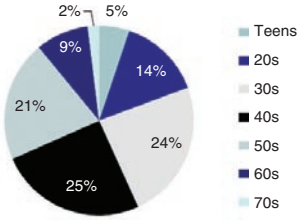


Stereo-sound cinema: 101 valid responses

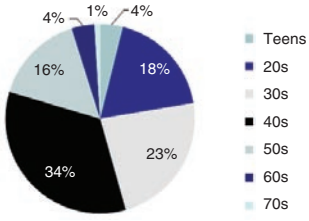


3. What is your age group?

Cineplex Makuhari: 154 valid responses



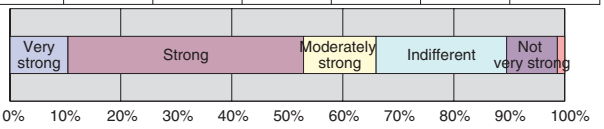
Stereo-sound cinema: 103 valid responses



4. What was your impression of the impact of the sound?

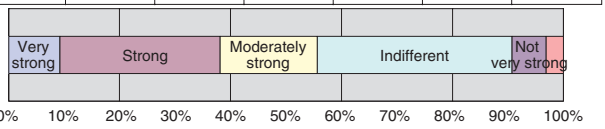
Cineplex Makuhari: 153 valid responses

Very strong	Strong	Moderately strong	Indifferent	Not very strong	Weak	Very weak
16	65	20	36	14	2	0
10.5%	42.5%	13.1%	23.5%	9.2%	1.3%	0.0%



Stereo-sound cinema: 97 valid responses

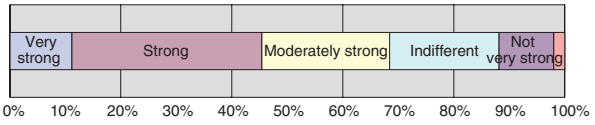
Very strong	Strong	Moderately strong	Indifferent	Not very strong	Weak	Very weak
9	28	17	34	6	3	0
9.3%	28.9%	17.5%	35.1%	6.2%	3.1%	0.0%



5. To what degree did you feel that the sound was surrounding you?

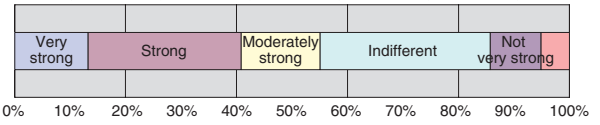
Cineplex Makuhari: 152 valid responses

Very strong	Strong	Moderately strong	Indifferent	Not very strong	Weak	Very weak
17	52	35	30	15	3	0
11.2%	34.2%	23.0%	19.7%	9.9%	2.0%	0.0%



Stereo-sound cinema: 98 valid responses

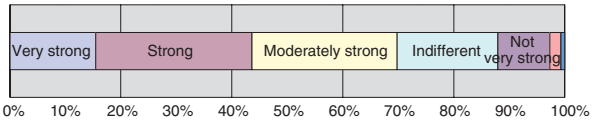
Very strong	Strong	Moderately strong	Indifferent	Not very strong	Weak	Very weak
13	27	14	30	9	5	0
13.3%	27.6%	14.3%	30.6%	9.2%	5.1%	0.0%



6. How strongly did you feel as if you were actually in the Tokyo Takarazuka Theatre? (Please answer only if you have actually been there.)

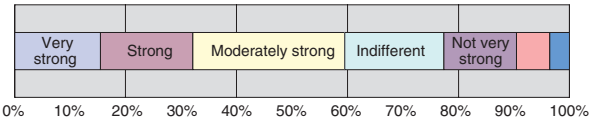
Cineplex Makuhari: 149 valid responses

Very strong	Strong	Moderately strong	Indifferent	Not very strong	Weak	Very weak
23	42	39	27	14	3	1
15.4%	28.2%	26.2%	18.1%	9.4%	2.0%	0.7%



Stereo-sound cinema: 84 valid responses

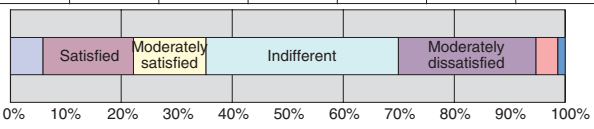
Very strong	Strong	Moderately strong	Indifferent	Not very strong	Weak	Very weak
13	24	23	15	11	5	3
15.5%	16.7%	27.4%	17.9%	13.1%	6.0%	3.6%



7. What do you think of the entrance fee?

Cineplex Makuhari: 153 valid responses

Very satisfied	Satisfied	Moderately satisfied	Indifferent	Moderately dissatisfied	Dissatisfied	Very dissatisfied
9	25	20	53	38	6	2
5.9%	16.3%	13.1%	34.6%	24.8%	3.9%	1.3%



Stereo-sound cinema: 100 valid responses

Very satisfied	Satisfied	Moderately satisfied	Indifferent	Moderately dissatisfied	Dissatisfied	Very dissatisfied
4	7	3	39	34	9	4
4.0%	7.0%	3.0%	39.0%	34.0%	9.0%	4.0%

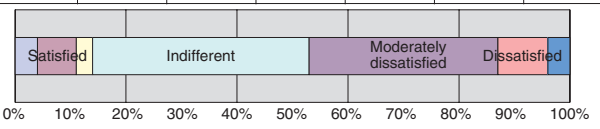


Fig. 3. Questionnaire results.

Ether-Wide service and feed high-definition video with stereo audio to it. Furthermore, with the cooperation of NTT Cyber Space Laboratories, we created a questionnaire for viewers and statistically analyzed the results to assess audio quality.

Regarding source audio recording, we sent a total of 13 channels to the mixer, which included 9 channels from the Takarazuka Review venue audio and 4 channels of independently added ambient audio, which were mixed for the 5.1 surround sound system at Cineplex Makuhari with the output fed to the lossless audio encoding equipment.

This setup enabled us to faithfully reproduce the mixed audio signal at the Cineplex Makuhari venue. A supervisor in the seating at Cineplex Makuhari was able to relay information about the replayed audio back to the mixer at the Tokyo Takarazuka Theater in real time to enable mixing adjustments as required.

As a result, viewers in the movie theater were able to experience a similar atmosphere to the source venue. They were naturally compelled to cheer and clap just as if they were really at the Takarazuka Theater—a reaction that was not observed during the 2007 trial. In this way, we were able to successfully overcome the limitations of conventional live network distribution and create a unified feeling between the two venues.

5. Trial evaluation

We surveyed viewers about the high-presence audio replay at Cineplex Makuhari and compared the results with survey results collected from viewers at the conventional stereo-sound cinema.

We received 157 responses from the 275 viewers at Cineplex Makuhari (about 57.1%) and 103 responses from the 308 viewers at the conventional cinema (33.4%). When we compared these results, we found several noteworthy differences between the two groups (**Fig. 3**).

In response to the question about the impact of the sound on a scale of 1–7, 66.1% of respondents at Cineplex Makuhari rated the sound in the top 3, i.e., as very strong, strong, or moderately strong compared with only 55.7% for the stereo-sound cinema. In response to the question, "How strongly did you feel as if you were actually in the Tokyo Takarazuka Theater?" 69.8% of respondents at Cineplex Makuhari selected very strongly, strongly, or moderately strongly compared with 59.6% for the stereo-sound cinema.

The biggest difference between the two groups was for the question regarding entrance fees. 35.3% of Cineplex Makuhari respondents said that they were very satisfied, satisfied, or moderately satisfied and, including ones who answered indifferently, 69.6% of them were agreeable to the entrance fee. By contrast, the corresponding figures for the stereo-sound cinema were 14% and 53%. These results indicate that the general level of satisfaction was significantly higher at Cineplex Makuhari.

6. Future plans

At NTT WEST, we plan to further analyze these results and establish business models for commercializing audio-visual lossless encoding and transmission and live distribution technologies with the aim of involving even more content holders to popularize live distribution services. Furthermore, we aim to increase business efficiency by using optical networks and increase content security by providing a safe and reliable network while promoting research into optical live distribution services.

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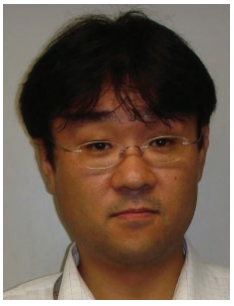

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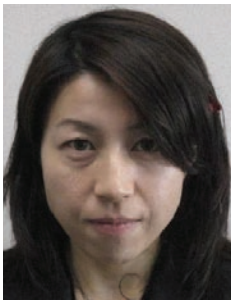

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CMOS LSI for Brain-machine Interface Used in Bidirectional Communication

Akiyoshi Shimada† *and Nobuhiko Nakano*

Abstract

We introduce our approach to making an LSI (large-scale integration) chip for a brain-machine interface by integrating neuroscience technology developed in NTT Basic Research Laboratories (NTT BRL) with LSI chip design and simulation techniques of Keio University. This LSI contains everything required for bidirectional communication, which enables the brain-machine interface to communicate with the brain on the molecular level when it is combined with a nano-bio device developed in BRL.

1. Introduction

A brain-machine interface (BMI) links the external world and the neural circuits in the brain, as shown in **Fig. 1**. The feasibility of communication between the brain and the external world was demonstrated by Wilder Penfield, a Canadian brain surgeon, in the 1930s and 1940s [1]. He stated that "in the course of operations on the brain, electrical stimulation of the human brain, while patients are conscious, has sometimes activated the neuronal record of past experience." [2]. These findings suggest not only that there may be a correlation between the brain and memory but also that the brain may be accessible from the external world. With today's technology, neural activity is commonly evoked by electrical, magnetic, and chemical stimulation.

Studies related to controlling a robot or computer by using information in the brain made progress at around the end of the twentieth century. Chapin et al. showed that a robot arm can be controlled by neural activity in the cortices of a rat [3] and monkey [4]. Recently, BMI technology has been used for communication and device control for people with severe motor disabilities [5].

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2. Collaboration with Keio University

NTT Basic Research Laboratories (NTT BRL) has studied information transmission of neurons, especially in the central nervous system. We have revealed that neural activity in neurons cultured on a planar multielectrode array (MEA) is influenced by electrical stimulation with an MEA-based multisite stimulation and recording system [6]. Although this system was optimized for in vivo experiments, it is applicable to the BMI if the system is miniaturized. On the other hand, the Nakano Lab. in Keio University has studied the design and simulation of an LSI chip that consolidates analog and digital circuits. Since 2008, we have been collaborating to achieve a BMI by combining these technologies through the intermediation and constant encouragement of the Liaison Council of NTT Corporation and Keio University.

3. LSI chip and MEA

3.1 Design and function

The human brain is thought to have more than one hundred billion neurons. Each neuron receives synaptic inputs from several thousand other neurons. A single neuron alone cannot evoke the electrical signals that are called action potentials. Furthermore, electroencephalography shows that local activity in the cerebral cortex is high when the brain processes

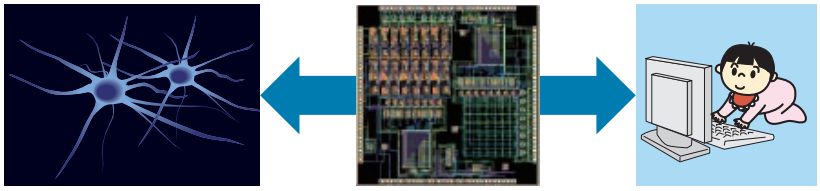

Fig. 1. Brain-machine interface.

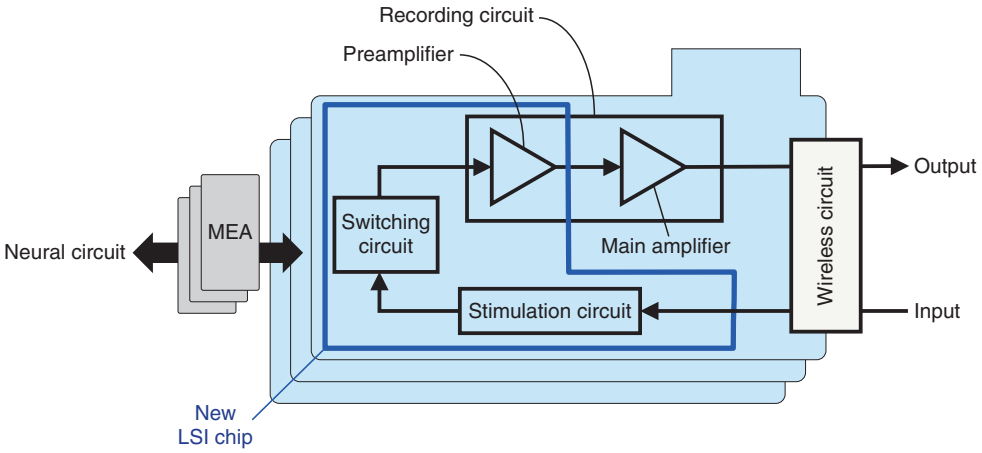

Fig. 2. Block diagram of LSI chip for BMI.

information. This information processing in the brain is produced through the cooperation of many neurons. So the MEA is suitable for use with a BMI that requires parallel information processing.

We have developed a complementary metal-oxide-semiconductor (CMOS) LSI chip with 8-channel preamplifiers for data recording and a stimulus generating circuit [6] based on a multisite stimulation and recording system [7].

The selection of the stimulation sites, their timing, and the applied stimulus waveforms are programmable, which results in vibration-free selection of any combination of the eight electrodes (the MEA) for stimulation. A block diagram of the final form of this LSI chip together with the MEA is shown in **Fig. 2**. The LSI chip consists of four parts: 1) a recording circuit for measuring neural activity, 2) a stimulation circuit for generating and applying a stimulus signal, 3) a switching circuit and 4) a wireless circuit. The first three circuits are on a 2.5 mm × 1.4 mm chip fabricated by the CMOS process. We are now developing packaging for the main amplifier in the recording circuit and the wireless circuit.

3.2 Stimulation

Information from the external world is input to this LSI chip by time-division multiplexing of eight channels by using a 4-bit digital parallel-to-serial converter. This makes it possible to stimulate multisite channels independently. The maximum voltage output is ±700 mV with a biphasic waveform and the minimum pulse width is 20 μs.

3.3 Neural activity measurement

The neural activity of dissociated rat cortical neurons (embryonic day 18) cultured on a planar MEA (40 days in vitro) is shown in **Fig. 3**. The neural activity, which was measured as voltage signals with the LSI chip via the MEA, was relatively small compared with the noise level. The noise comes from lines between a preamplifier and an electrode because it is difficult to seal them. So the noise level depends on

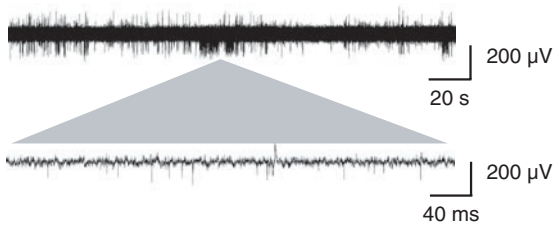

Fig. 3. Neural activity measured with LSI chip.

the lengths of these lines. An LSI chip with a preamplifier allows a shorter line length when it is mounted near the MEA. Moreover, it can evoke neural activity and measure it through the same electrode by switching the stimulation and recording circuits. These characteristics make it a suitable device for enabling a BMI to be attached to a body and exchange information via an MEA with low noise.

4. Interface for nano-bio device

Neural information is transmitted by means of the action potential in one neuron and chemical signals between two neurons across a synapse. When the action potential arrives at a synapse called a presynaptic terminal, a chemical substance called a neurotransmitter is released. Neurotransmitters bind receptor channels on a neighboring neuron called a postsynaptic neuron. Then, receptor channels open and the current flow carried by ions enters and exits through the receptor channels. When depolarization of the postsynaptic neuron as a result of the current flow reaches a certain threshold, an action potential is generated in the postsynaptic neuron.

Recently, nanotechnology has attracted attention in industrial, medical, and scientific fields. In the field of neuroscience, this technology enables access from one neuron to one protein molecule such as a receptor channel, which is an essential component for neural information transmission.

NTT BRL has studied an artificial synapse for accessing neural information by means of a silicon substrate by integrating nanotechnology and biotechnology [8]. The silicon substrate has microwells covered with a lipid bilayer containing reconstituted membrane proteins. This device emulates the functions of a postsynaptic membrane and lets us measure chemical signals as electric signals when electrodes are installed on the two sides of the lipid bilayer.

5. Conclusions

An LSI chip integrated with an artificial synapse enables communication with neurons at the biomolecular level. This feature could provide an alternative function for patients with nervous diseases or a new tool for discovering drugs that act directly on receptors.

Acknowledgments

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High-quality Software Development Through Collaborations with Major Universities in China

Xiaojun Wu†

Abstract

To achieve high-reality visual telecommunications, NTT Cyber Space Laboratories is conducting research to obtain high-fidelity three-dimensional vision information. This article introduces collaborations in this field with several major universities in China and reviews software developed through these collaborations.

1. Introduction

In communications, images and videos have great advantages over other media, such as audio and text because they can be perceived and understood directly by people, so they can transfer a much greater amount of detailed information. To achieve high-reality telecommunications, my colleagues and I at NTT Cyber Space Laboratories are conducting research on visual media in a wide range of fields, covering image processing, image compression, and three-dimensional (3D) computer graphics (CG) [1], [2]. In recent years, along with increases in the computing power of central processing units, both high-resolution and high-quality digital cameras have become popular. These days, ordinary people can send photographs attached to messages from their mobile phones by using a multimedia messaging service. Such services have resulted from advances in both image processing techniques and the image sensors installed in mobile phones. Meanwhile, it is widely recognized that high-reality visual telecommunication cannot be achieved by just sending such visual images or videos. Techniques for understanding images are needed. Specifically, it is necessary to understand the object in the scene, what the object is doing, and even the object's purpose by processing and analyzing the captured images. In this article, I focus on human motion analysis and introduce several collaborative projects in this field with major universities in China.

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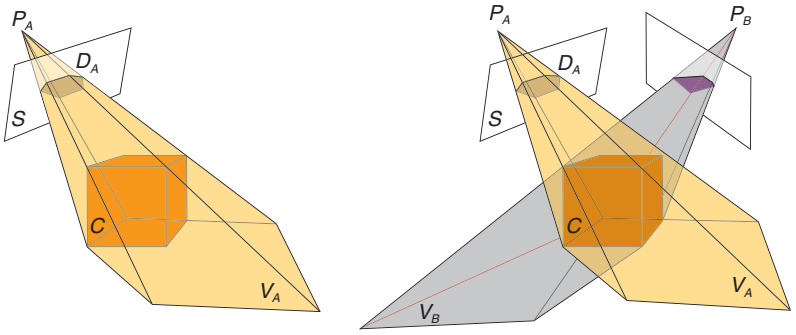
2. Research themes on computer vision

2.1 Overview

Research in the field of computer vision (CV) has become very popular in recent years. The aim is to understand the real world from photographs or videos. One of the ultimate goals of CV is to reconstruct a complete 3D visual model of the visual experience in common activities. That is, not only the shape but also the textures and lighting environment are all reconstructed as high-fidelity models, which are just like CG models. The difference between CG and CV is that CV models represent portions of the real world but CG models are artificial creations. In fact, it is still very hard to reconstruct such 3D models from 2D photos. We have had some limited success in reconstructing the 3D shape of a moving person under certain conditions. We have also constructed a multi-camera video capture studio as a platform for our 3D modeling research.

2.2 General approach

The basic method of reconstructing 3D shapes from photographs is explained below. It is called the shape from silhouette method or volume intersection



(a) Visual cone (b) Intersection of multiple visual cones

Fig. 1. Shape from silhouette. Here, C denotes a cube, which is an example of a 3D object, S denotes a 2D screen, P_A denotes a viewpoint in 3D space, D_A denotes a 2D polygon on the screen, which is the silhouette of the cube, and V_A denotes the visual cone back-projected from the viewpoint P_A. P_B, D_B, and V_B denote the corresponding meanings to P_A, D_A, and V_A.

method.

(1) Set up multiple cameras with multiple different viewpoints. All the cameras should be synchronized to capture the object at exactly the same time.

(2) For each frame, capture multiple pictures from different viewpoints and calculate the object's silhouette in each picture. In this way, multiple 2D silhouettes can be obtained.

(3) Back-project one 2D silhouette from a certain viewpoint; this produces a 3D cone, which is called a visual cone. The object is inside this visual cone. (**Fig. 1(a)**).

(4) Calculate all the visual cones from the multiple 2D silhouettes (**Fig. 1(b)**). Since the object is inside all of the visual cones, the 3D shape of the object can be calculated as the region where the visual cones intersect. Such a 3D shape is just an approximate model of the real object, but its accuracy can be improved by increasing the number of cameras.

While the idea of shape from silhouettes is simple, this method is powerful for 3D shape reconstruction of moving objects. In practice, the space is divided into a large number of cubes, which are called voxels (volume elements), and the shape is represented by a certain number of voxels. Below, we consider a 3D shape as such a group of voxels.

2.3 Trends of 3D shape reconstruction

Once we have obtained approximate 3D shapes, we can then get much more advanced or enhanced visual information. Three examples of 3D shape research are introduced below.

(1) Refinement of the 3D shape

Research is being conducted on refining the approximate representation of the true shape obtained by the shape from silhouette method.

(2) High-fidelity texture reconstruction

In a real lighting environment, when an object is captured from different viewpoints simultaneously, the color value for the same part may differ among pictures taken from the different viewpoints. Such differences occur for various reasons, such as differences in camera sensing responses and surface reflections. While the differences among cameras can be reduced by calibration and tuning, a lot of research is focused on detecting the characteristics of surface reflections and computing the lighting environments.

(3) 3D motion analysis

By introducing a 3D human skeleton model, we can calculate both static and motion parameters of a 3D body, which is represented by voxels, because the length of each part of the skeleton and the rotation angle of each joint can be estimated by just fitting the 3D shape, i.e., group of voxels, to the 3D skeleton model. That is, such an estimation results in the capture of motion information just like a motion capture system. Such 3D-skeleton-model-based estimation is usually referred to as a markerless form of motion capture; not requiring the use of markers is an advantage. Markerless motion capture systems can capture much more detailed motions of natural actions than

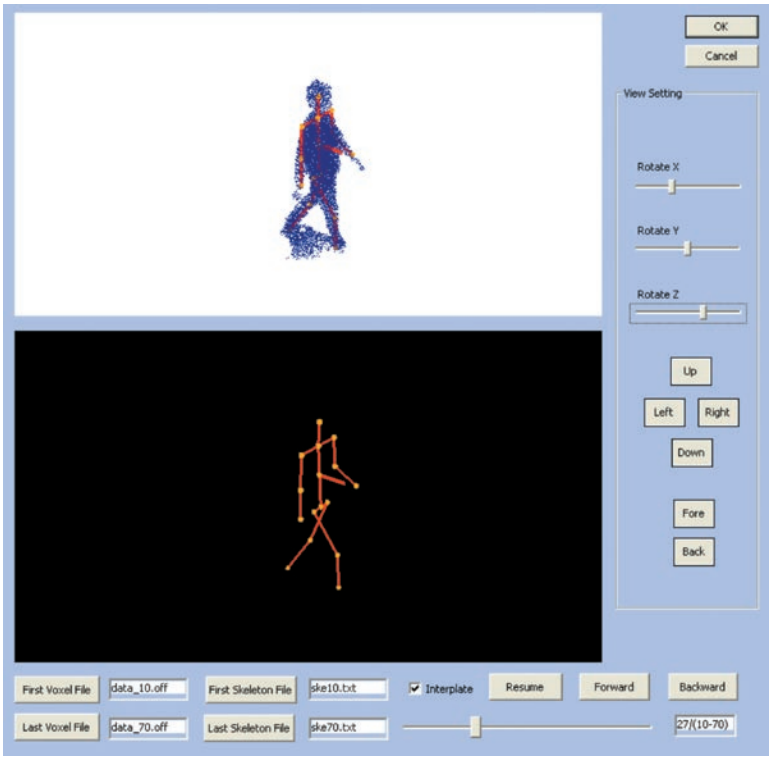


Fig. 2. Basic motion estimation tool.

the traditional system because neither markers nor special costumes (e.g., tights) are needed. However, their accuracy is still poor for practical usage and needs to be greatly improved to reach a comparable level.

As mentioned above, a lot of research focusing on human-body 3D reconstruction in the CV field is being conducted to achieve the ultimate goal. In our laboratories, we are fortunate to have the advantage of doing voxel-based 3D human body reconstruction in our studio with multiple well-calibrated synchronized cameras. Such voxel-based 3D data is very useful for all of the types of research mentioned above.

3. Collaboration with universities

The abovementioned CV research trends are interesting hot topics. To speed up the progress of such studies, we are conducting international collaborations with major players in this field.

3.1 Shanghai Jiaotong University: markerless motion capture

3.1.1 Proposal

We approached Prof. Yuncai Liu of Shanghai Jiaotong University in China, and as a result his team became our first partner. Professor Liu has worked successfully in the USA and Japan as well as China, where he currently leads a top-class CV team. He has studied human motion analysis and published papers in several famous international conferences. He was interested in our themes and agreed to our proposal for collaboration. As the first step, we decided to start a project to create a markerless motion capture system based on our voxel-based 3D shape reconstruction platform.

3.1.2 Development of basic tool

To get best performance out of both sides as quickly as possible, we decided to develop a basic tool first. This tool is a software program that takes the voxel-based 3D shape as input and outputs 3D motion data obtained by fitting to a 3D human skeleton model designed by Liu's team. The program's input and output are shown in **Fig. 2**. For the 3D model-fitting algorithm, we used one given in a published paper [3].

The program's flow is described below.

The motion estimation is divided into two phases: the initialization phase and the pose tracking phase. In the initialization phase, the length of each part of the 3D skeleton model is determined and the skeleton's pose is matched to the initial shape. In the pose tracking phase, the previous pose is taken as input and this input pose is adjusted to match the current shape; the optimal result gives the current pose. Since it is technically difficult to initialize the phase automatically, we decided to develop the pose tracking phase first while leaving the initialization phase to be done manually. Thus, the problem could be defined as estimating all joint angles of the current shape by giving the lengths of all parts and the previous angles of all joints. The algorithm is described below, where $t - 1$ is the previous time and t is the current time.

(1) Since all joint angles at $t - 1$ and all part lengths are given, calculate the positions of all joints and parts at $t - 1$.
(2) Consider a cylindrical area around each part. Determine the radius of each cylinder so that the voxels are included within as many cylinders as possible by applying the 3D shape at $t - 1$ to the skeleton calculated in step (1).
(3) For each joint, choose N values as rotation angle candidates. As a result, we get a mixture of all candidates, and each element of the mixture represents a candidate pose. For each candidate pose, by applying the 3D shape at t, calculate the error in that candidate pose as the number of voxels outside the cylinders corresponding to the candidate pose.
(4) Choose the candidate pose with the lowest error as the estimation result.

By implementing the above algorithm, we developed the first version of the 3D motion estimation tool.

3.1.3 Automation of initialization phase

Since initialization phase was not implemented in the basic tool, the next target was to automate it. In fact, doing the initialization phase manually is a really hard and complicated task because the number of parameter dimensions increases with the number of joints. Manual initialization is obviously a bottleneck for a practical 3D motion estimation system. Therefore, the project focused on automating the initialization phase. Both sides thought that it would be impossible to achieve perfect automation for any arbitrary pose, so we took a more practical approach and aimed to simplify the initialization task. The goal was to develop an interactive initialization tool. That is, the initialization phase was divided into several steps. The processing for each step was automated and manual interactive tuning was applied between steps. The graphical user interface for this step-by-step initialization is shown in **Fig. 3**. The steps are described in detail below.

(1) Head detection

Detect the head part by using a sphere model and fitting the sphere to the upper part of the 3D body shape.

(2) Torso detection

Detect the torso part by fitting a cylinder model to the part underneath the 3D body shape's head detected in the previous step.

(3) Limb detection

Detect the positions of limbs by iterating the torso detection algorithm.

While the idea of step-by-step detection is simple, it is useful in practice as a means of developing tools for further research. By avoiding direct parameter tuning, we achieved much easier interactive tuning.

3.2 Zhejian University: application of estimated 3D motion to CG animation

While much work remained to be done on the markerless motion capture developed through collaboration with Shanghai Jiaotong University to improve the system performance, we next considered the application of CG animation. To identify the possibilities of such applications, we conducted a collaborative project with the team of Prof. Xiaogan Jin at Zhejiang University in China. Professor Jin has studied in Japan and is a leader in the CG field in China. We proposed that his team should develop high-reality human CG models. While applying the motion data to the CG model, the joints of the CG model must be deformed properly to achieved natural and visually smooth motion. Jin's team was perfect for achieving such deformation. Tools to link the estimated 3D motion and the CG model were developed. While the resulting synthesized motion was not smooth enough, the project revealed issues related to 3D motion estimation. Both sides gained CG and CV technical skills from each other.

3.3 Tsinghua University: face reconstruction

While pursuing our overall aim of high-quality 3D reconstruction for the whole human body, we also focused specifically on modeling the face in detail. After surveying research on modeling emotions from facial expressions, we decided to contact Tsinghua University, the top academy of science and engineering

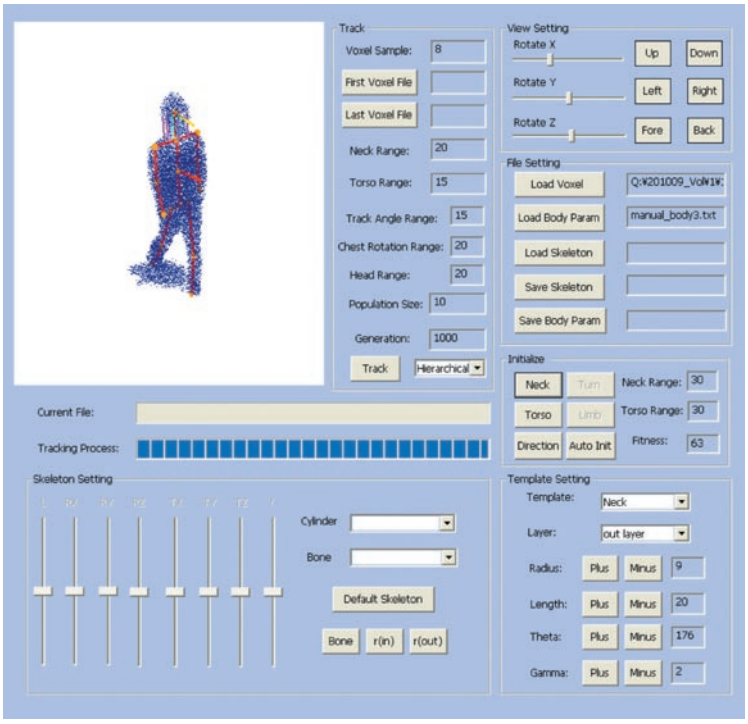


Fig. 3. Initialization by interactive tuning.

in China. Professor Guangyou Xu at Tsinghua University has been tackling emotion tracking for several years and has developed high-quality libraries for feature tracking. As the first step of emotion modeling, a tool for tracking the features of face images was developed through collaboration with Tsinghua University. This tool is being utilized to refine the face model.

4. Concluding remarks

China has several major universities conducting top-class research and development. Our collaborations with Chinese universities have rapidly yielded highly useful tools. The successful development of the markerless motion capture system enabled us to work on motion analysis of long sequences of movement. Furthermore, these collaborative projects have led to the creation of a wide network of research colleagues. Collaboration enhances not only the quality of actual developments but also the relationships among researchers.

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Secure Method of Managing Digital Content in Ubiquitous Computing Environment

Akihiro Tsutsui† *and Tomoko Sawabe*

Abstract

A research project for building a remote collaboration environment based on technologies for handling large-scale digital content is being undertaken by NTT Network Innovation Laboratories. This article briefly reviews collaborative research with Keio University on a secure method of managing digital content in a ubiquitous computing environment.

1. Introduction

NTT Network Innovation Laboratories has developed a digital cinema system and related technologies based on ultrahigh-definition video coding and content delivery technologies. We are currently using these technologies in research and development (R&D) of a networked remote collaboration environment and in its application for the creation of content such as movies [1]–[3].

Keio University has developed several technologies for digital content delivery through basic research on digital media creation, editing, and usage. It is also engaged in R&D of permanent archiving and digital media handling.

In a collaboration program between NTT Network Innovation Laboratories and Keio University, my colleagues and I are designing a platform that enables secure remote access to large-scale digital media. We are also planning demonstration experiments using this platform. These goals can be achieved by applying the previous research outcomes and know-how associated with digital content handling of both parties. Another aim of the collaboration program is to clarify the technical problems of building a network supported cooperative work (NSCW) environment. So far, in the program's first year, we have investigated an authentication mechanism that enables secure and flexible access to digital content via a network. In this article, we discuss security issues related to large-scale digital content.

2. NSCW

NSCW is an advanced concept based on computer supported cooperative work (CSCW). Compared with CSCW, the aim with NSCW is to build a distributed cooperative working environment that makes maximum use of networks. NTT Network Innovation Laboratories has developed several key technologies for processing and transmitting ultrahigh-definition images and videos stably and securely. We are now striving to achieve an NSCW environment that consists of high-quality audio/video communication with high reality, effective data sharing, and interactive work spaces among distributed workers. Some examples of the application of NSCW are shown in **Fig. 1**. One example is collaborative film making, such as digital cinema. Currently, digital cinema creation and editing processes are done all over the world as a result of ongoing globalization, so they are conducted in a networked distributed environment. To promote research on NSCW, it is essential to build practical experimental environments. By studying an actual use case such as film making, we can consult with experts in this area and clarify their requirements. More comprehensive technologies are required for

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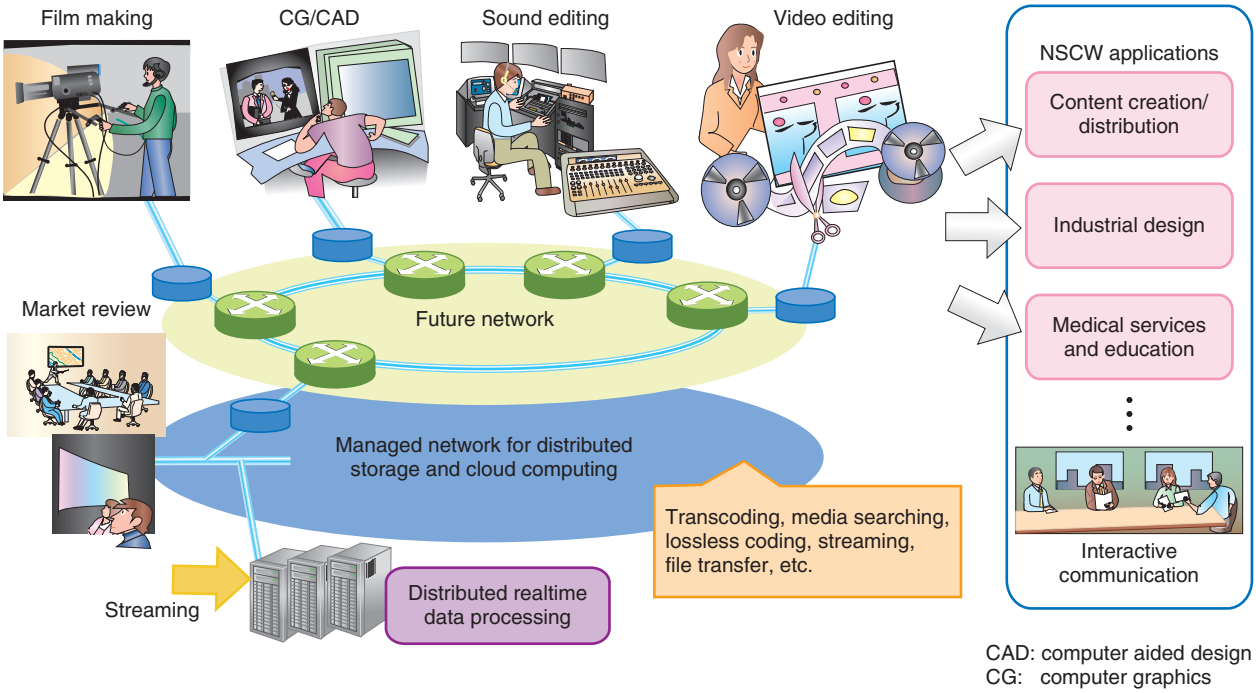

Fig. 1. Application examples of NSCW.

building such an experimental environment, e.g., content archiving and distribution. In addition, technical studies from the ubiquitous computing viewpoint are requiring in order to consider remote collaboration in various distributed networks.

3. Content and security management in ubiquitous environment

The Internet is utilized in various business fields. Therefore, information security must be ensured during content distribution. A major theme of this collaboration program is the security of digital content. Currently, some security-sensitive remote collaborations that handle digital assets operate a safe working space and use a dedicated leased line, which ensures network security. However, excluding open networks, such as the Internet, sacrifices the convenience and expandability of the remote collaboration itself. Many kinds of wired and wireless network access services are available nowadays. Though there may be variations in the communication quality, we can get online anywhere anytime. In Japan, because of the spread of broadband services using optical fiber, high-speed network access is available in almost all offices and homes at low cost. WiMAX and Long Term Evolution (LTE) wireless network access services are provided in public in downtown areas, which enables large-scale content distribution to mobile devices.

In this context, two keys to investigating a flexible remote collaboration environment are ubiquitous computing and cloud computing using open networks. If we assume remote collaboration over the Internet, it is important to create a platform that enables collaborative work via the network anywhere. Of course, communication quality and working circumstances are not uniform because there are various types of access networks. However, content creation can be divided up into many kinds of work. Each kind has its own networking requirements. Enhancing the ubiquitous features of remote collaboration can lead to improved efficiency of all the work.

Ensuring information security in the ubiquitous environment of the Internet is a difficult task. In particular, unauthorized access must be prevented and copyright protection technologies are indispensable for valuable content (e.g., commercial audio and video).

With today's rapid development of cloud computing and business globalization, it is necessary to use the Internet for remote collaboration. Therefore,

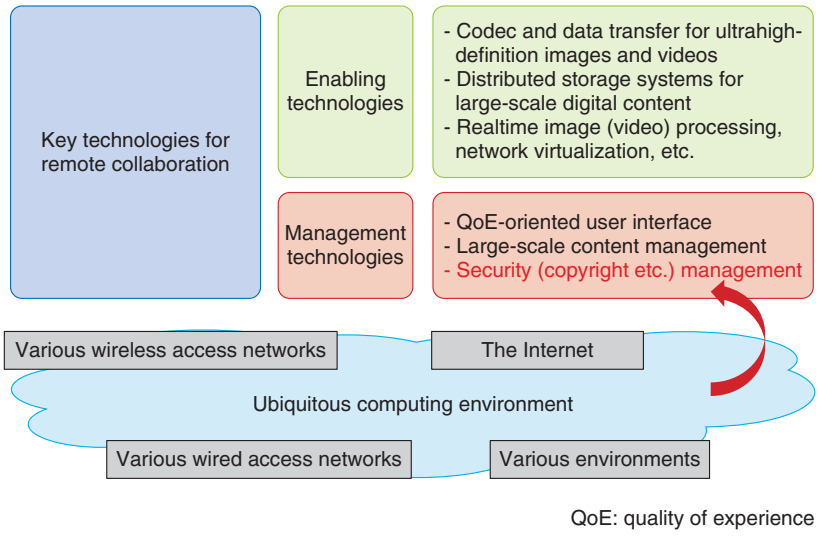

Fig. 2. Key technologies for remote collaboration environment in ubiquitous networks.

security will become more important in this research area in the future (**Fig. 2**).

4. Importance of authentication technology

Security is the key to handling valuable digital content in a ubiquitous computing environment. In particular, an access control method for digital content is especially important. From the network security viewpoint, there are several technologies for protecting digital content from illegal tapping, unauthorized access, and tampering. These include encryption, authentication, and digital watermarking [4]. The main focus of this article is authentication technology.

Robustness against unauthorized access and resistance to tampering are important features of authentication for digital content distribution. They enable distribution of appropriate content to identified people. In terms of security, ideal content distribution would be the delivery of specific content (containing an embedded identifier) by hand from the copyright holder to a user in a closed room. This would require face-to-face confirmation and a physically closed space for absolute authentication. Meeting both conditions in content distribution over a network is impossible. They may be almost met by using high-definition videoconferencing systems and network security technologies. However, this approach is impractical because it is costly. Thus, the general use of password authentication is currently a reasonable solution. In addition, the trade-off between authentication strength and user-friendliness of the authentication process must be considered. The implementation and operational cost of an authentication mechanism should be balanced against the value of the content.

If the authentication process is complicated and difficult for users to understand, they may try to access target content through illegal or unexpected methods. In that case, authentication strength degrades drastically. We focus on this security hazard and describe an easy implementation example of multifactor authentication.

5. Multifactor authentication

Authentication via a network can be broken down into identification, judgment, and authorization processes. In each process, the authentication strength can be enhanced by using multiple methods and information. This is the concept of multifactor authentication. For example, the combination of a specific device and secret knowledge possessed by users can act as a highly secure key for authentication. Using multiple communication methods can also enhance authentication strength. For example, some online banking transactions these days require confirmation by phone.

In particular, mobile phones are useful for multifactor authentication because they are widely used, are used predominantly by one individual, and have a

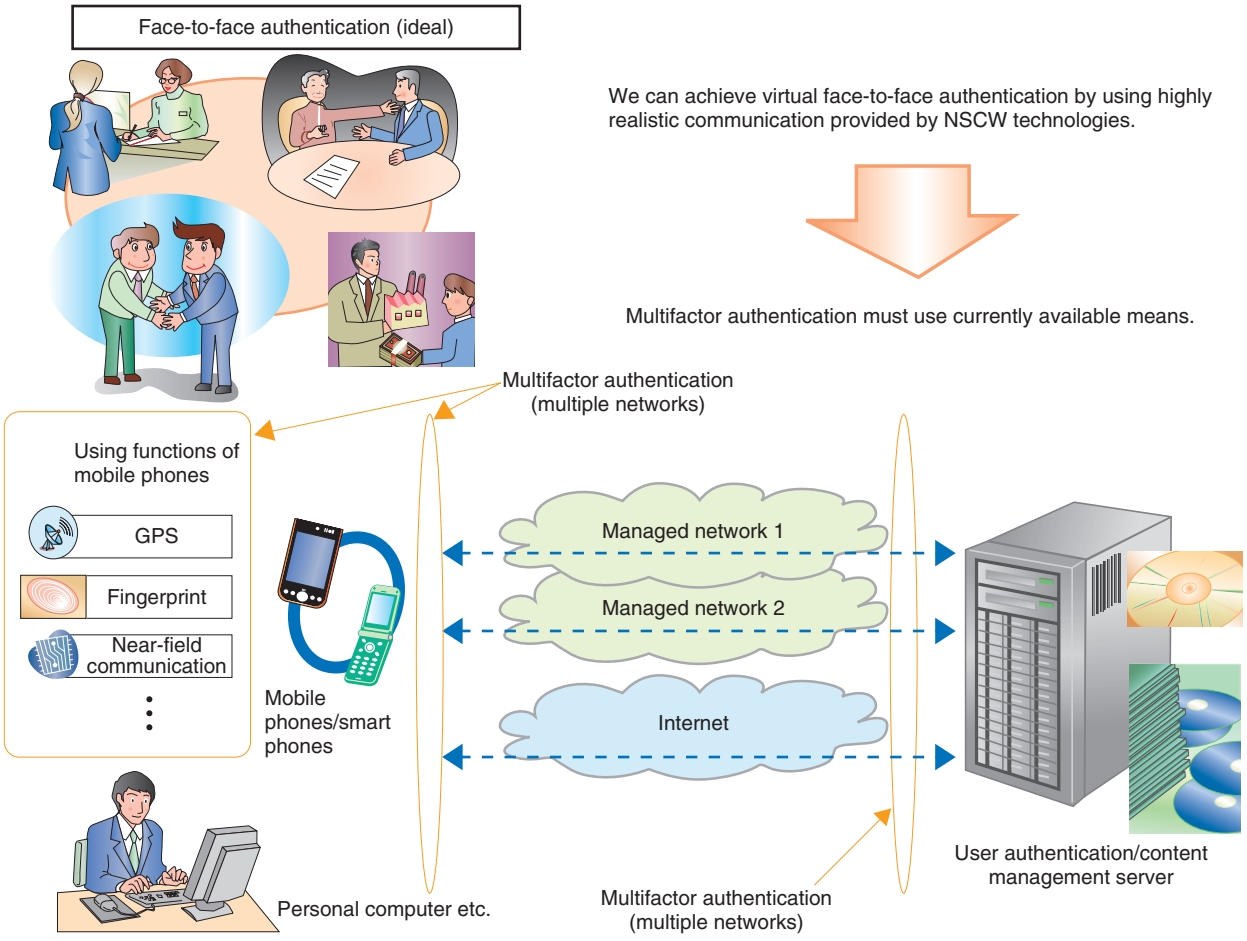

Fig. 3. User authentication and multifactor authentication technologies.

specific identifier (e.g., phone number). Moreover, the physical hardware cannot be copied and the carrier (operator) can detect illegal usage and tampering and some mobiles contain biometric sensors and GPS (global positioning system) functions. In addition, mobile phones use closed carrier network services (telephone and social networking system (SNS) services), which are independent of other open networks such as the Internet.

One existing example of multifactor authentication for large-scale digital content management is the Arianna System [5]. It is a practical implementation using the Internet (web service) and mobile phone services. However, it cannot support smartphones, which are becoming increasingly popular. We are investigating and developing a new multifactor authentication method using a smartphone as an authentication device (**Fig. 3**). Our method combines multiple authentication keys (users' secret knowledge), biometrics, and geographical information to enhance authentication strength.

6. Future work

NTT Network Innovation Laboratories is promoting research activities for creating an advanced remote collaboration environment through NSCW. The next step is to build an experimental testbed for demonstration experiments on handling large-scale digital content in networks. This will let us examine key technologies such as content storage & archiving and content transmission (**Fig. 4**). We are planning to test multifactor authentication technologies and demonstrate an actual remote collaborative application, such as film making.

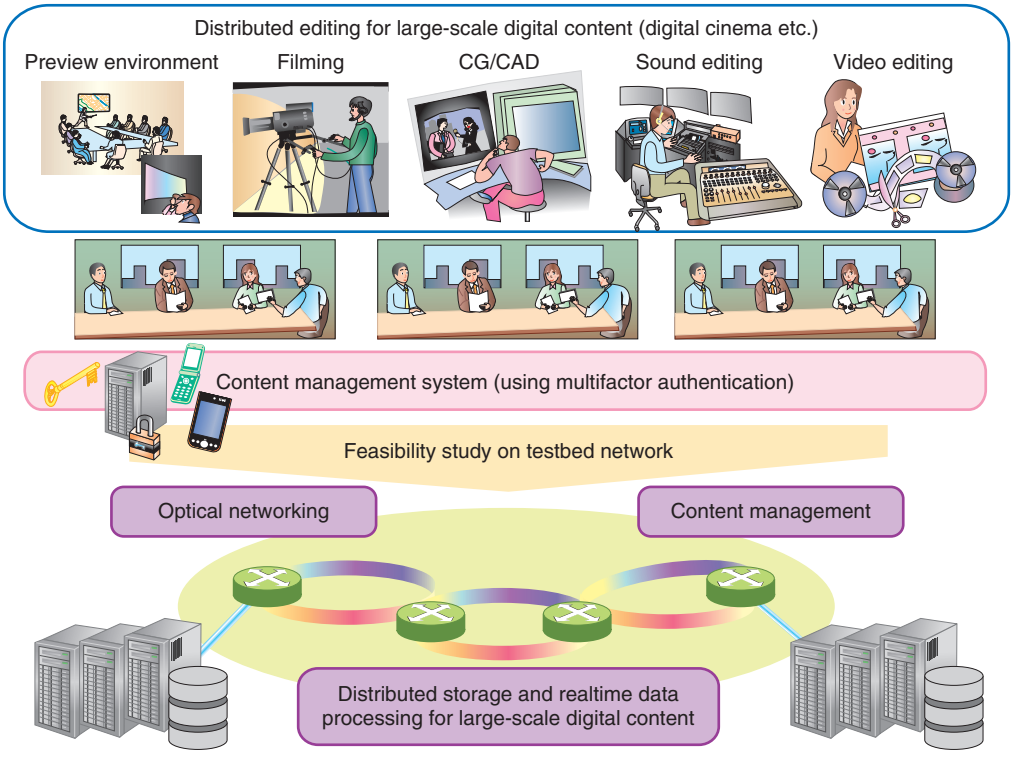

Fig. 4. Feasibility study of remote collaboration environment for content creation.

7. Conclusion

We think that multifactor authentication is suitable for handling large-scale digital content in a ubiquitous computing environment on open networks. In general, component technologies, such as authentication, encryption, and digital watermarking, are required for the security management of large-scale digital content. Applying these technologies to an actual remote collaboration system handling digital content is a future challenge.

Standardization activities for encryption and digital watermarking are under way and de-facto standards already exist. However, the standardization of authentication technologies is not yet mature. In particular, discussion of the user interface is an open issue.

In this collaboration program between NTT Network Innovation Laboratories and Keio University, we have so far focused on security for remote collaboration and investigated a multifactor authentication mechanism using a mobile phone (a typical ubiquitous device). In the future, we intend to build a testbed and further investigate this topic.

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Joint Research on *Anshin* in Internet Usage

Taro Yamamoto†, *Naoko Chiba, Fumihiko Magata, Katsumi Takahashi, Hiroki Ueda, Naoya Sekiya, Isao Nakamura, Morihiro Ogasahara, and Yoshiaki Hashimoto*

Abstract

NTT Information Sharing Platform Laboratories is conducting joint research with specialists in socio-psychology at the University of Tokyo and Toyo University to study *anshin* (安心) in Internet usage. Anshin, which is often translated as peace of mind, security, or reassurance, is a vague concept with a wide range of meaning. Therefore, we decided to focus first not on anshin itself but on *fuan* (不安), which has roughly the opposite meaning (anxiety) because anxieties are easier to recognize. We constructed a model of the anxiety generation process and conducted two investigations—a home-visit investigation in Tokyo and an international investigation by telephone—and we put out a press release describing proof of an unbridgeable gulf between anshin and safety. In this article, we outline our current studies.

1. Introduction

Anshin (安心) is a kind of emotion or feeling in Japanese. It often translated as peace of mind, security, or reassurance, but it is a vague concept in Japanese with a wide range of meaning. This word is frequently used by the government, mass media, and many companies in Japan. Many Japanese people think that it is an important concept. However, methods of achieving anshin and also the concept of anshin itself are not shared universally. One reason is that anshin is basically a subjective feeling and the trigger for it and amount of it felt vary from person to person. Even the same person may feel differently in similar situations [1].

Because we believe that it is possible to share, at least partially, the objective and universal concept of anshin, we began studying anshin, especially with regard to Internet usage. The Internet has become a social infrastructure and demand for its availability by both end users and suppliers is very high.

We think that trying to study anshin using only an approach based on information technology (IT) is inadequate, so we also applied a social-science approach. NTT began a collaborative study with the University of Tokyo, which was later joined by Toyo University. The NTT team members are IT engineers and the University members are social scientists. Since the start of the project, the number of people in the research team has grown, enabling us to conduct social research from a wider range of viewpoints.

In this article, we describe our studies and present the results. On the basis of the results of group interviews with 23 people in Tokyo on anshin and anxiety, we conducted a home-visit investigation with 500 people in Tokyo and an international telephone investigation of 3300 people in ten countries (330 in each country). In this article, we do not define anshin precisely or use an English translation because it is so vague. On the other hand, *fuan* (不安) is a clearer concept and its translation as anxiety is more accurate, so in this article we do use the English word anxiety.

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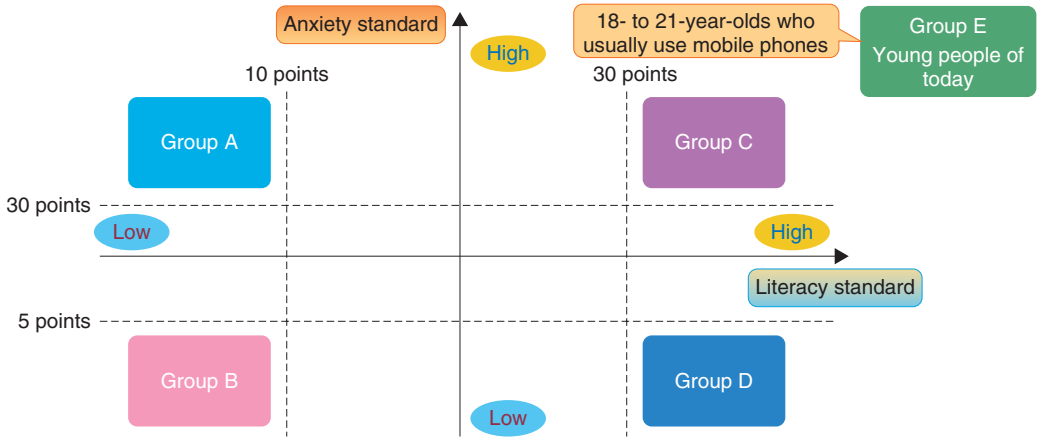


Fig. 1. Characteristics of groups.

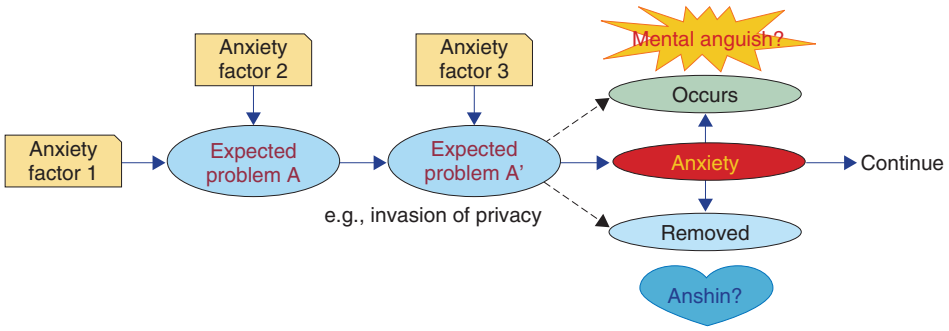


Fig. 2. Model of anxiety generation process.

2. Group interviews

Before investigating negative factors of anshin and the correlation among them, we conducted group interviews about anshin and anxiety to help us design appropriate questionnaires for use in the following investigations. The interviews took place on September 17–19, 2008 (Wednesday–Friday) in Tokyo, Japan. There were 23 people in five groups (A–E). The characteristics of these groups in terms of anxiety and literacy are shown in **Fig. 1**. Each session lasted two hours. The questions asked about cases in which the participants felt anshin or anxiety in their daily lives and while using the Internet.

From these group interviews, we found that it is not easy to obtain clear, adequate, and quick answers to questions about cases of anshin. By contrast, relatively clear and quick answers tended to be obtained to questions about cases of anxiety. Moreover, anshin varied from person to person. So, as our first step, we decided not to study anshin directly but to study anxieties. We believe that anxiety is a close antonym of anshin and that anxiety is easier to handle.

3. Anxiety generation process

3.1 Model

To study anxiety, we used the results of the group interviews to construct a model of the anxiety generation process in order to clarify how anxiety is generated (**Fig. 2**). This model includes the following definitions: 1) Anxiety is generated by expectations of problems (e.g., invasion of privacy). 2) There are factors that are the reasons for expecting problems and there are also factors that strengthen the expectations and anxieties. 3) There are also factors that weaken or eliminate the expectations and anxieties. We called these factors *anxiety factors*. In future, we intend to

refine and verify this model and also evaluate the anxiety factor candidates.

3.2 Control of Internet anxiety

We think that controlling (reducing) anxiety can weaken the feeling of expecting trouble and leads to a kind of anshin. We also think that the anxiety factors are determined by each type of expected trouble for each Internet service. We selected anxiety factor candidates mainly on the basis of the group interview results. They are listed in **Table 1**. We hope that establishing a method of controlling anxiety will lead to anshin.

4. Home-visit investigation in Tokyo

Next, partially to verify the anxiety generation process model and to obtain facts about anxiety from various viewpoints, we conducted a home-visit investigation of Internet anxiety [2]. The investigation took place in February 2009 in Tokyo. It involved 500 people (aged from 15 to 69). The visited homes were chosen by random area quota sampling. The questions concerned anxiety when using the Internet.

4.1 Internet users and anxiety

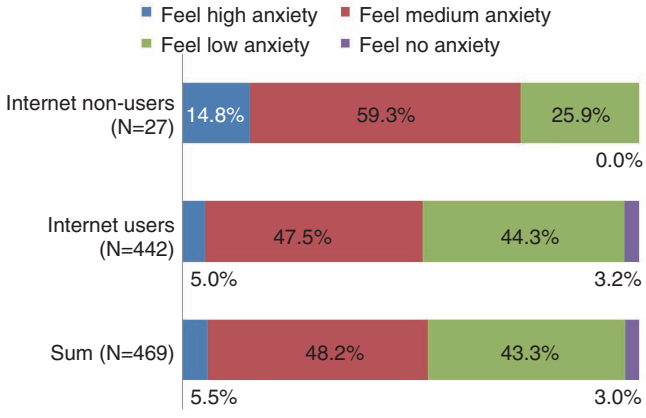
We found that Internet users felt less anxiety about Internet usage than non-users did (**Fig. 3**). The more time they spent using the Internet, the less anxiety they felt concerning security and Internet communication. People who wrote things and posted them on the Internet (consumer generated media (CGM*) users) felt less anxiety in their general Internet usage than people who only read content on the Internet. The more frequently people commented on SNSs, the less anxiety they felt about Internet communication. These findings may indicate that anxiety decreases with experience.

4.2 Usability and content of anxiety

Many people use online shopping despite having strong feelings of anxiety (**Fig. 4**). This may indicate that there is a trade-off between anxiety and usability. The most common specific anxiety for general Internet use was the leakage of personal information (**Fig. 5**).

Table 1. Anxiety factor candidates.

1	Character & feeling
2	Confidence
3	Sense of intimacy
4	Likes & dislikes
5	Mob psychology
6	Controllability
7	Ability to estimate
8	Difference from ideal
9	Difference from daily life
10	Context
11	Importance
12	Probability of occurrence
13	Sympathy
14	Superiority & inferiority
15	Usability
16	Experience
17	Knowledge
18	Information source
19	Insurance
20	Support
21	Alternatives
22	Ability to troubleshoot



* No-choice rate for people who do not know because they do not want to use the Internet.

Fig. 3. Internet anxiety for Internet users and non-users (in Tokyo).

* CGM: The CGM studied in our two investigations differed. In the Tokyo investigation, the targets were weblogs (blogs), social networking services (SNSs), bulletin board services (BBSs), and video hosting sites. In the international investigation, the targets were blogs, SNSs, and BBSs.

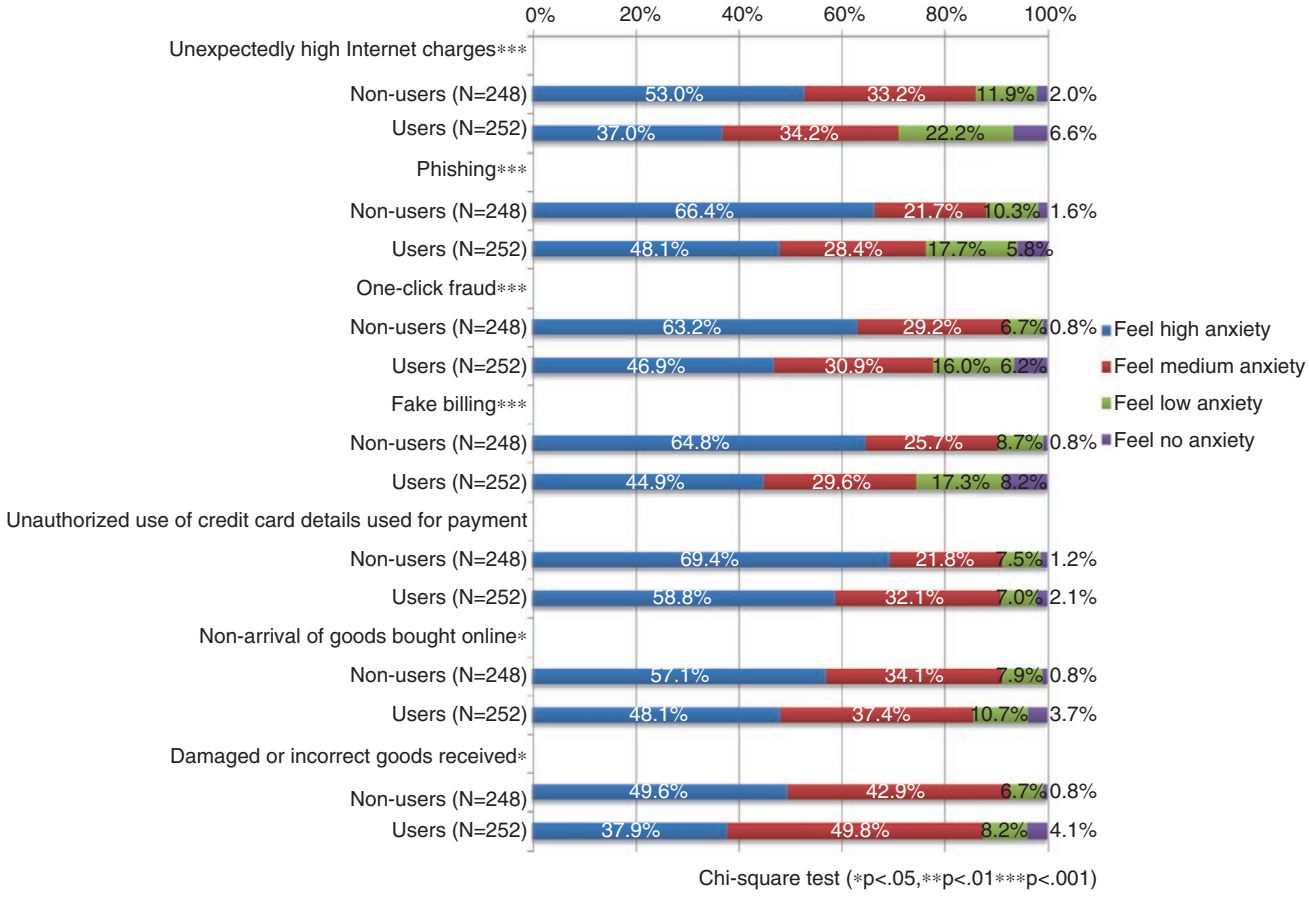


Fig. 4. Online shopping users and anxiety (in Tokyo).

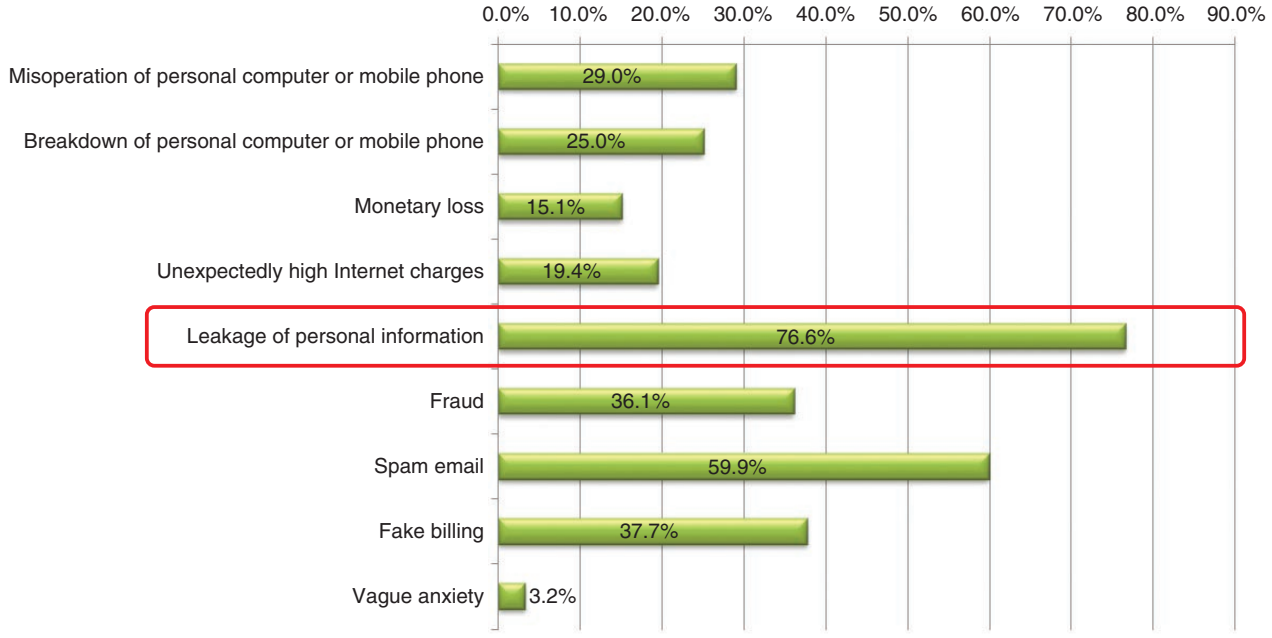


Fig. 5. General Internet anxieties (in Tokyo).

4.3 Damage experience and news experience

The amount of damage actually experienced by people is generally small. Even for spam emails and spam in blogs (also called blog spam or comment spam), which account for the highest percentage of anxieties in Fig. 5, only 12.0% of the subjects we questioned reported experiencing actual damage from them. Although the values are really too small to let us evaluate the correlation with anxiety, we nevertheless tried to evaluate the correlation, but we were unable to find any significant correlation (the only exception was unexpectedly high Internet charges). By contrast, damage is extensively reported by the news media. Our analysis of the results of the influence of news reports indicates that the more time people spend consuming mass media news, especially newspapers, the more anxiety they feel about security and Internet communication.

5. International investigation by telephone

Despite obtaining the abovementioned findings about Internet anxiety, we did not know whether they represent universal characteristics or local peculiarities. Unlike anshin, which is an obscure concept and hard to translate, fuan can be translated from Japanese into English, so anxiety is a universal concept. Therefore, we thought that an international comparison of Internet anxieties would be possible. To study anxiety in Japan and also to study anshin indirectly, we conducted an international investigation of ten countries by telephone [3]. The interviews took place in January and February 2010. We interviewed 3300 people (aged from 15 to 69) in the largest cities in Japan, China, South Korea, Singapore, the UK, Germany, France, Finland, America, and Chile (330 in each). They were contacted by random digit dialing. The questions concerned Internet anxiety.

5.1 Unbridgeable gulf between anshin and safety

We publicly disclosed our findings in an NTT press release in September 2010 [4]. It stated that Japanese people feel high anxiety about using the Internet although they have less direct experience of trouble than people in other countries. We showed, by using real data, that there is an *unbridgeable gulf between anshin and safety*. These results (**Table 2**) show that there are a lot of Japanese who cannot use the Internet with anshin only owing to safety concerns. Specifically, in terms of the percentage of people having experience of *exposure of own home address or telephone number on the Internet without permission*, Japan ranked low (9th out of 10 countries; 1.2%). However, Japanese feel high anxiety despite having little actual experience of damage (Japan: 2nd out of 10; 82.7%). In particular, Japanese women feel high anxiety (1st out of 10; 75.2%). Japan ranked 1st (65.2%) for people with anxiety about computer viruses without having any experience of damage. Moreover, it ranked 2nd for anxiety about phishing, unauthorized use of credit card details used for online payment, and harmful content being seen by children when browsing, again without any experience of damage (76.4%, 83.6%, and 77.9%, respectively).

5.2 Internet anxieties of specific countries

We analyzed the results by country to see if people in different countries had specific anxieties. For gen-

Table 2. Experience for exposure of personal information and anxiety (international investigation).

	Rate for each country			Rank among the 10 countries		
	No damage experience but anxiety	No damage experience	Anxiety	No damage experience but anxiety	No damage experience	Anxiety
Japan	82.7%	98.8%	83.6%	2nd	2nd	3rd
USA	60.3%	94.5%	64.5%	6th	4th	7th
Chile	25.2%	99.1%	26.1%	10th	1st	10th
China	77.9%	86.1%	90.0%	3rd	10th	2nd
South Korea	83.6%	91.5%	91.5%	1st	8th	1st
Singapore	73.0%	91.5%	78.5%	4th	8th	4th
UK	62.4%	94.8%	67.0%	5th	3rd	5th
Finland	42.2%	93.6%	46.2%	9th	5th	9th
Germany	48.6%	92.4%	55.2%	8th	6th	8th
France	59.7%	91.8%	66.7%	7th	7th	6th

Table 3. Anxiety level, damage experience, and news experience for CGM trouble (international investigation).

	Anxiety	High			Low		
	Damage experience	Much	Little		Much	Little	
	News experience	—	Much	Little	—	Much	Little
Abuse/violent language and teasing		South Korea, China	Japan	USA	Finland	Germany	
Exposure of personal information		South Korea, China	Japan		Finland, Germany		
Damage by self-exposure of own personal information * CGM users only		China, South Korea, Singapore		Japan		Germany	Finland

eral use of the Internet, South Korea, the USA, and China ranked high in that order while Japan was not placed so high (5th out of 10 countries). We compared the ten countries in terms of the proportion of people in the country having damage experience, news experience, and anxiety, for eleven specific types of Internet trouble such as fake billing. People in China and Singapore had a lot of damage experience and high anxiety. Those in Germany had much news experience but low anxiety. People in Finland had much damage and news experience but low anxiety. People in Chile do not use the Internet much, but like people in the USA they had little damage and news experience and low anxiety. People in South Korea did not have so much damage and news experience but had high anxiety. People in Japan had little damage experience but much news experience and high anxiety about trouble.

5.3 Anxiety concerning CGM, information leakage, and children browsing harmful content

This section describes our findings concerning CGM, information leakage, and children browsing harmful content (**Tables 3** and **4**).

Higher anxiety about CGM was felt in South Korea, China, Japan, the USA, and Singapore. By contrast, lower anxiety about CGM was felt in Finland and Germany. Among the people of countries in the high anxiety column, South Koreans and Chinese had experienced actual damage while Japanese had experienced little damage. Japanese generally had much news experience and Japan ranked 1st out of the 10 countries for the proportion of people having news experience of three cases of CGM trouble.

For personal information leakage, people of Japan, South Korea, and China had high anxiety, much mental anguish caused by incidents, and a high likelihood of occurrence. By contrast, people of Finland, the UK, and Chile had low anxiety, mental anguish, and occurrence likelihood.

For browsing of harmful content such as information about drugs and violent and pornographic images by children, people in the ten countries selected "Many suppliers of harmful content are not adequately arrested" and "Many website managers do not delete harmful content adequately" as being big problems. People in the UK and Japan thought that those two problems were bigger than other problems. Japanese also thought that "many parents do not teach appropriate website browsing" was a big problem (Table 4).

6. Concluding remarks

We are studying anshin during Internet usage. Initially, we focused not on anshin itself but on anxieties because they are easier to recognize. After conducting preliminary group interviews with 23 people in Tokyo, we conducted a home-visit investigation of 500 people in Tokyo and an international telephone investigation of 3300 people in ten countries (330 in each). We made a model of the anxiety generation process, obtained some knowledge from our investigations, and put out a press release describing the unbridgeable gulf between anshin and safety. We think that this research was persuasive because it was joint research with the specialists in socio-psychology.

To confirm and strengthen the results of the international investigation, we conducted a second set of group interviews with foreigners from nine countries living in Japan (December 2010 to February 2011). We are also conducting an Internet investigation about anxieties for particular Internet services such as Twitter. To obtain real opinions, this investigation includes many free-answer questions. Some of the

Table 4. Problems in browsing of harmful content by children (international investigation).

Problem	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
High accessibility	Finland 75.8%	UK 73.6%	South Korea 72.4%	Japan 68.2%	USA 67.3%	Singapore 61.8%	Germany, China 56.7%		France 42.1%	Chile 9.4%
Parents	Finland 80.6%	Japan 79.7%	UK 68.5%	Germany 63.6%	France 63.3%	South Korea, Singapore 59.7%		USA 58.8%	China 48.8%	Chile 22.1%
School	UK 70.6%	USA 62.1%	South Korea 53.0%	Singapore 51.8%	Finland 50.6%	China 47.6%	Japan 45.5%	Germany 33.9%	France 29.4%	Chile 20.6%
Low arrest rates	UK 83.9%	Japan 82.4%	USA 74.2%	South Korea 71.5%	Finland 68.2%	Germany 58.2%	Singapore 55.5%	China 52.1%	France 45.2%	Chile 34.2%
Website management	UK 84.8%	Japan 81.8%	Finland 78.8%	USA 76.1%	South Korea 67.9%	China 62.4%	Singapore 59.7%	Germany 47.3%	France 45.8%	Chile 20.3%
Average	UK 76.3%	Japan 71.5%	Finland 70.8%	USA 67.7%	South Korea 64.9%	Singapore 57.7%	China 53.5%	Germany 51.9%	France 45.2%	Chile 21.3%

results are scheduled to be presented at the 2011 JASI-JSIS Joint Conference (Japan Association for Social Informatics, Japan Society for Socio-Information Studies). In the future, we will verify and refine the anxiety generation process model and evaluate the anxiety factor candidates through user experiments and other means. After that, we will consider solutions for controlling anxieties from both the operation and technology viewpoints. We will also conduct further studies on anshin.

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Stripping-free Physical-contact Connector

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Abstract

We introduce a new physical-contact optical connector that uses a stripping-free connection method. The connector's assembly procedure does not require the coated optical fiber to be stripped or cleaved, which facilitates assembly. We designed the connector structure and the shape of the fiber's end to achieve physical-contact connection and developed a method for forming the required fiber endface.

1. Introduction

Optical fiber is being widely introduced as a communication medium to handle the expansion of broadband services, and many ways of connecting optical fiber such as fusion splicing, mechanical splicing, and optical connectors have been developed and are being used in FTTH (fiber-to-the-home) systems. Conventional connection methods achieve good optical performance by aligning bare glass fibers after their coatings have been removed. All of these connection methods require careful handling of the bare glass fiber, which is fragile. This has led to demand for a method of connecting coated fibers that does not require a stripping process. Such a stripping-free fiber connection method would also enable us to simplify the assembly procedure. However, the concentricity error between the core and coating diameter of the coated fiber causes a large misalignment between the mated fiber cores.

In this article, we introduce a new stripping-free optical connector that enables us to achieve a physical-contact (PC) connection and facilitate assembly. We also present experimental results for PC connection with a low connection loss.

2. Principle of stripping-free PC connector

A cross-sectional view of the new connector is shown in **Fig. 1**. This connector has a ferrule and a split sleeve to make it compatible with the existing SC [1] and MU [2] connectors. To achieve a PC connection, axial compression force is required between the mated fiber endfaces. We used the axial compression force generated by a buckled fiber to simplify the connector structure. As shown in Fig. 1(a), the fiber end protrudes from the ferrule end and the fiber is fixed to the clamp part. This structure enables us to buckle the fiber inside the flange when we connect the ferrules, as shown in Fig. 1(b). The buckling force can be controlled by setting the length of the buckled section of fiber (buckling length) [3].

We designed the coated fiber alignment structure to achieve a low connection loss. The conventional ferrule is designed so that the glass fiber is inserted only after its coating has been stripped off. Therefore, we designed a new ferrule for the new stripping-free connector, as shown in **Fig. 2**. It consists of an external part with a microhole to align the glass fiber and a coating-hole part to align the coated fiber, as shown in Fig. 2(a). The external part has the same outer diameter as the conventional ferrule. When the coated fiber is inserted into the ferrule, the fiber end reaches the microhole located at the ferrule end through the coating-hole. When the fiber is pushed into the microhole, the fiber coating is pushed back slightly at the microhole's entrance and only the glass enters the microhole, as shown in Fig. 2(b). The new connector enables us to obtain the same low connection loss as a conventional connector.

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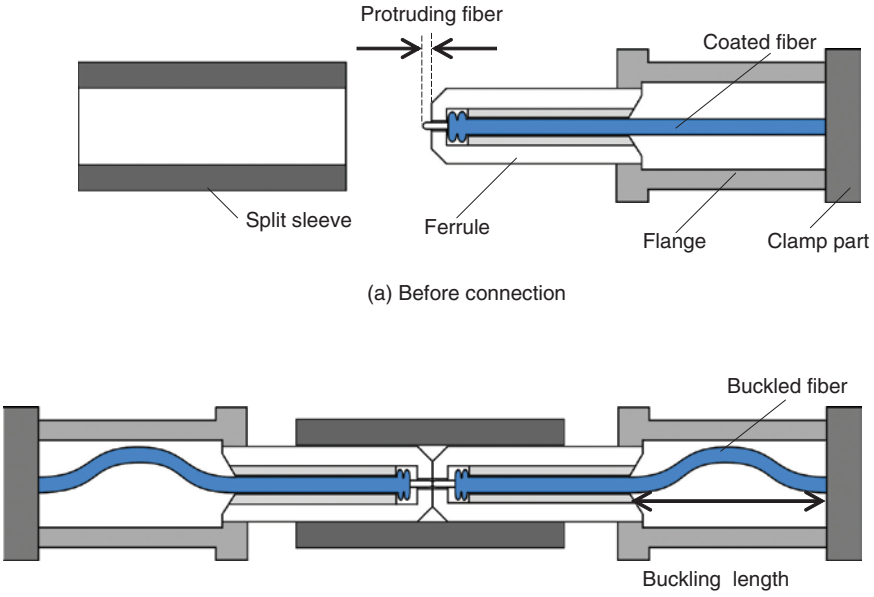

Fig. 1. Cross-sectional view of connector.

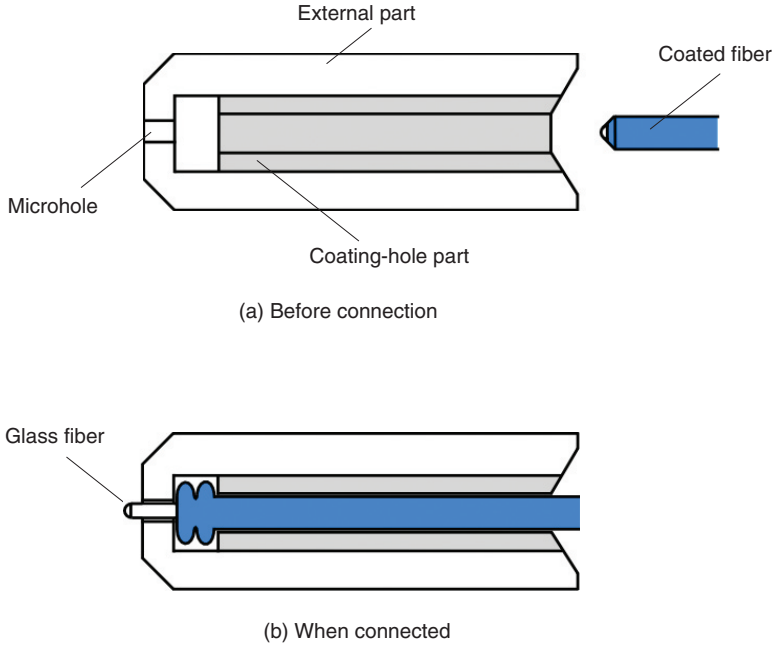

Fig. 2. Cross-sectional view of ferrule.

3. Fiber endface forming technique

We devised a new technique for forming the required fiber endface. This technique does not require the cleaver, which is a special tool, used in the conventional fiber preparation technique. The coated fiber is cut with an ordinary tool such as wire cutters. The new technique forms this cut fiber endface into a

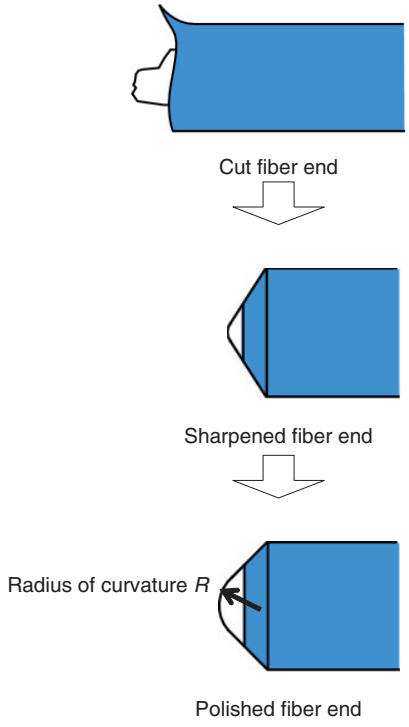

Fig. 3. Fiber end shape.

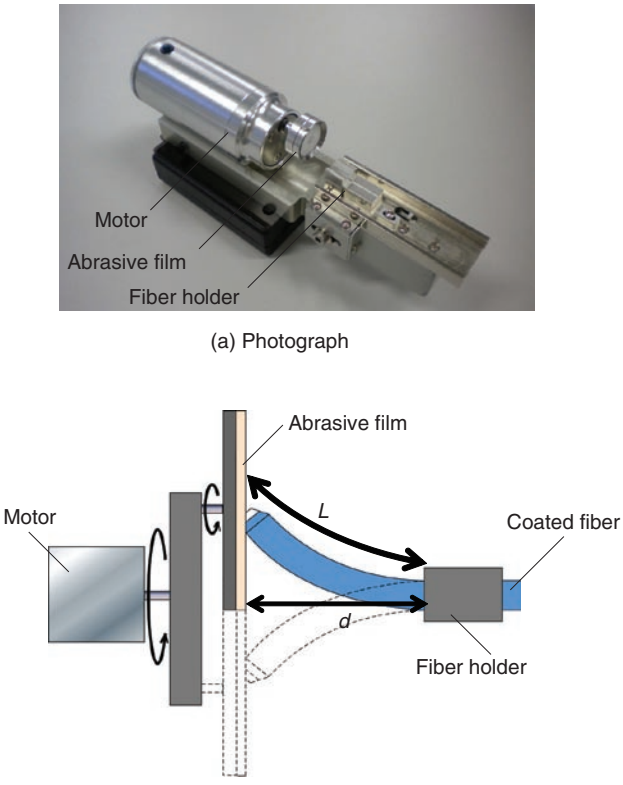

Fig. 4. Fiber endface forming tool.

curved polished endface that enables us to achieve a PC connection, as shown in **Fig. 3**. It comprises a sharpening process and a polishing process. The sharpening process is designed to eliminate the cracked fiber end produced by the blade of the wire cutters when the coated fiber is cut. The polishing process is designed to create a curved fiber endface for PC connection.

A photograph and schematic diagram of the endface forming tool for the sharpening and polishing processes are shown in **Fig. 4**. The tool consists mainly of an abrasive film, motor, and fiber holder. The fiber is held mechanically in the fiber holder. When the fiber is moved toward the abrasive film, the fiber end makes contact with the film and is pressed against it by the buckling force of the bent fiber. The motor rotates the abrasive film, which polishes the fiber endface.

4. Fiber endface design

We designed the fiber endface shape for PC connection in order to determine the process conditions required for fiber endface forming. We calculated the axial compression force F_p needed to achieve PC connection with single-mode fibers (SMFs) with a curved endface. F_p is expressed as a function of the radius of curvature of the fiber endface R [4] by

$$Fp=\frac{4a^3E}{3(1-\nu^2)R}, \quad (1)$$

where a is the core radius, E is the Young's modulus, and ν is the Poisson's ratio of the fiber. The calculated results are shown in **Fig. 5**. The required F_p value increases as R decreases. Applying our previous findings that the estimated maximum axial compression force obtainable with a buckled fiber is 0.9 N [5], we determined from Fig. 5 that an axial compression force of less than 0.9 N requires a fiber endface with a radius of curvature of more than 23 μm.

5. Processing conditions for forming coated fiber endface

First, the end shape of a fiber cut with wire cutters was estimated. When a coated fiber is cut with wire cutters, the fiber end is cracked by the cutter's blades.

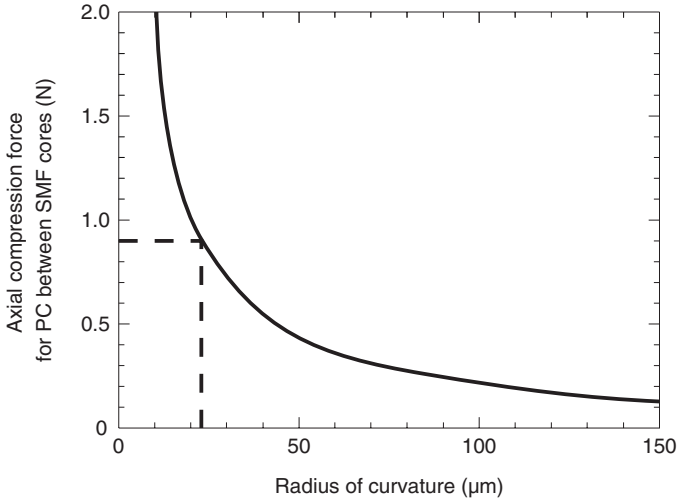

Fig. 5. Dependence of axial compression force on radius of curvature.

A photograph of the fiber end after we cut the coated fiber and removed the coating to measure the cracked length accurately is shown in **Fig. 6**. We measured the cracked lengths of the cut ends of 90 fibers after we cut the coated fibers with wire cutters (**Fig. 7**). The average cracked length was 0.214 mm with a standard deviation σ of 0.094 mm. From this result, we estimated that the maximum cracked length likely to occur in practice is about 0.5 mm (average + 3σ). The sharpening process eliminates the cracked end by reducing the fiber length, as shown in **Fig. 8**. Therefore, we designed the sharpening process to shorten the fiber by more than 0.5 mm in order to ensure that the formed fiber endface is not cracked.

In the sharpening process, the shortened length of the coated fiber is determined by the processing time, the grain size of the abrasive film, and the shape of the bent fiber (bending shape). The bending shape is determined by the length of the fiber protruding from the fiber holder L and the distance between the abrasive film and the fiber holder d, as shown in Fig. 4. We measured the relationship between the shortened length of the coated fiber and the processing conditions when the forming tool was used. Here, the processing time and bending shape were varied. The abrasive film's grain size was 40 μm. The distance between the abrasive film and fiber holder was 10 mm. The experimental results that we obtained for the shortened length of coated fiber are shown in **Fig. 9**. The shortened length increased with increasing processing time and L value. The results indicate that we can achieve a shortened length of more than

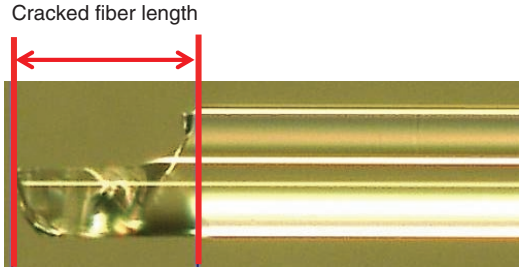

Fig. 6. Photograph of cut fiber end.

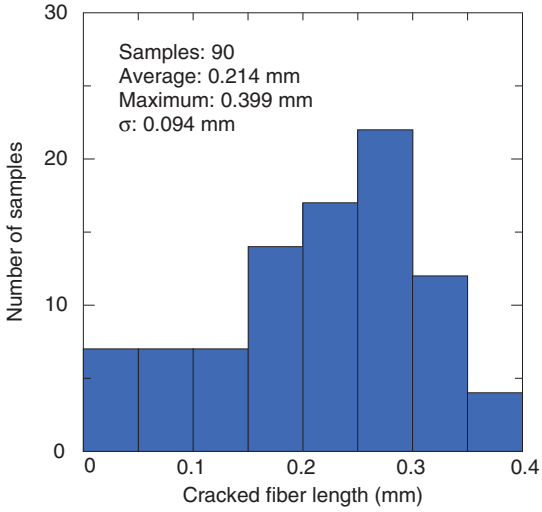

Fig. 7. Cracked fiber lengths.

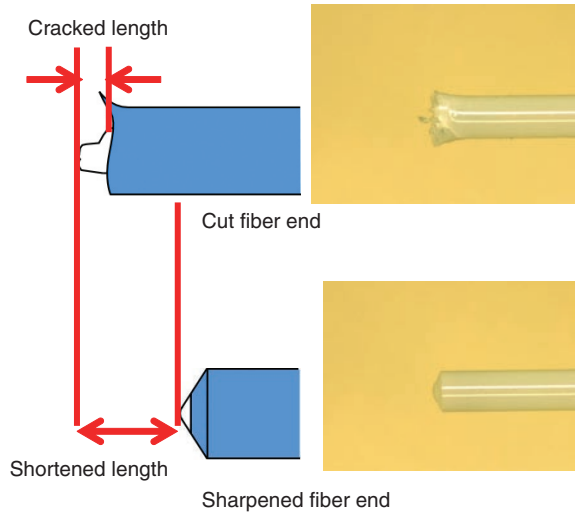

Fig. 8. Sharpening process for forming fiber end.

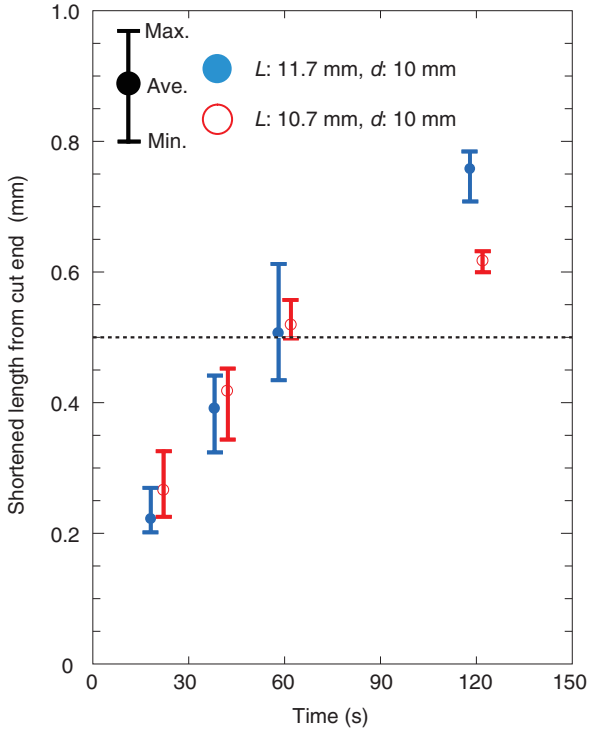

Fig. 9. Dependence of shortened length on processing conditions.

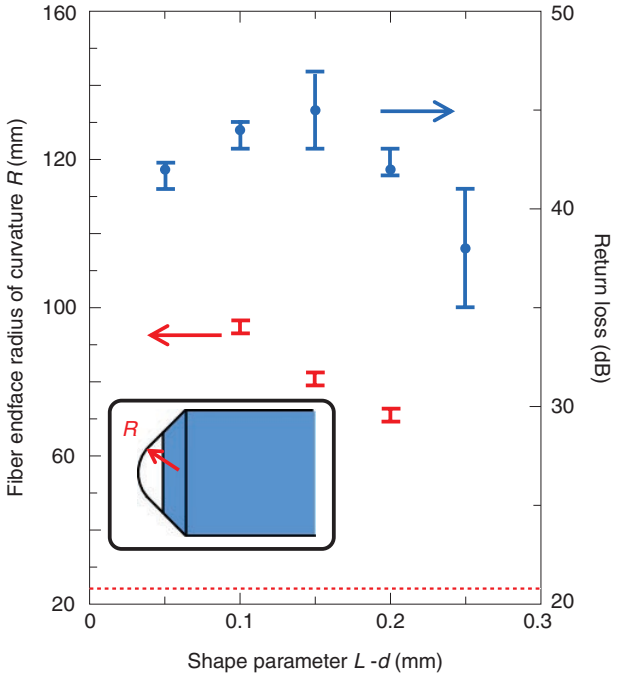

Fig. 10. Dependences of radius of curvature and return loss on fiber shape parameter.

0.5 mm by controlling the bending shape and processing time.

The sharpened endface is polished by using the forming tool, as shown in Fig. 4. The polished endface is formed by using the same configuration as in the sharpening process simply by changing the distance between the abrasive film and fiber holder. In the polishing process, L is smaller than in the sharpening process. A slightly bent fiber enables us to form the sharpened endface into a convex endface. We measured the relationship between the fiber's bending shape and the radius of curvature of the convex endface when we changed the bending shape. An abrasive film with a grain size of less than 1 μm was used. The distance between the abrasive film and fiber holder was 10 mm. Our experimental results for the radius of curvature of the polished endface are shown in **Fig. 10**. They reveal that we can achieve the target radius of curvature of more than 23 μm by controlling the bending shape. We measured the return loss when we connected the polished endface using the axial compression force, as shown in Fig. 10. We found that the polished endface achieved PC connection with a return loss of more than 40 dB when we used a shape parameter $L - d$ of less than 0.2.

6. Optical performance

We prepared a connector having a 100-μm-long microhole and a flange with a buckling length of

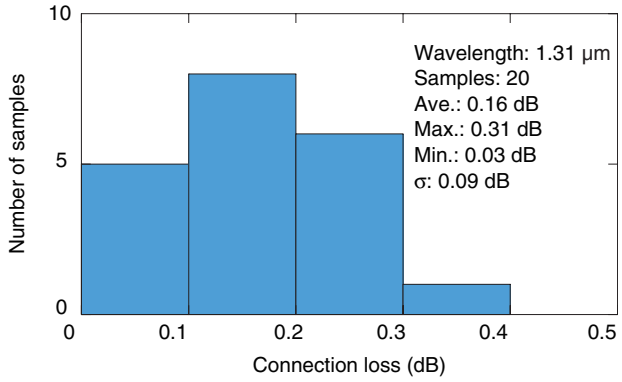

Fig. 11. Connection loss histogram.

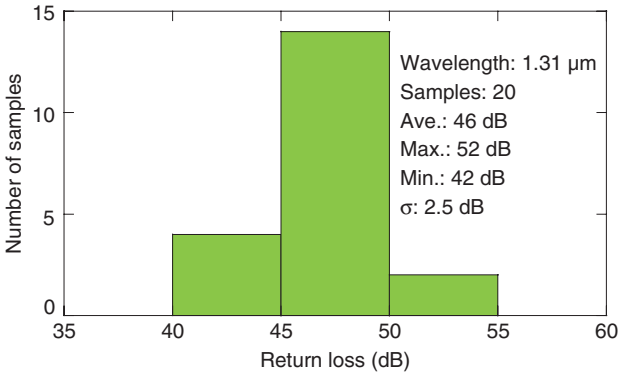

Fig. 12. Return loss histogram.

8 mm according to the PC connection design. We measured the optical performance of SMFs with endfaces formed with the forming tool. We confirmed that when the coated fiber was inserted into the microhole, the coating was pushed back and only the glass entered the microhole in accordance with design shown in Figs. 1 and 2. Histograms of the connection and return losses for 20 pairs of connected fibers are shown in **Figs. 11** and **12**, respectively. The connection losses for SMFs were less than 0.31 dB with an average value of 0.16 dB and standard deviation σ of 0.09 dB. The minimum return loss was 42 dB, which confirms that all the connected fibers achieved PC connections. The results meet the performance requirements stipulated in IEC 61753-2-1, which sets the performance standard for SMF connection for an uncontrolled environment.

7. Conclusions

We introduced a new physical-contact (PC) optical connector that does not require a coated fiber to be stripped and cleaved, so it facilitates connector assembly. A new method of forming the fiber endface enables us to achieve PC connection. In laboratory experiments, the stripping-free connector has achieved PC connection with a return loss of more than 42 dB and average connection loss of 0.16 dB.

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Optical Power Budget Enhancement Technologies for Long-reach GE-PON System

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Abstract

This article describes technologies for enhancing the optical power budget of the Gigabit Ethernet passive optical network (GE-PON) system. The design goal is to significantly extend the fiber-to-the-home (FTTH) service area in a cost-effective manner. Following the development of enhanced optical line terminals in 2009, work to enhance optical network units was completed this year. These technologies enhance the optical power budget of the GE-PON system to 37 dB, which makes this system one of the longest-reach systems in the world. These enhancements enable us to deploy FTTH to rural areas economically.

1. Introduction

Fiber-to-the-home (FTTH) services, such as B FLET'S and FLET'S HIKARI NEXT, have been widely deployed in Japan, and the number of the customers exceeded fifteen million this year. However, it is difficult to provide FTTH services to areas far from the central office because of the limit on the maximum optical power budget between the optical line terminal (OLT) in NTT's central office and optical network units (ONUs) in customers' homes.

In this article, we describe a long-reach Gigabit Ethernet passive optical network (GE-PON) system that offers an enhanced optical power budget between the OLT and ONUs. It enables further economical expansion of FTTH coverage areas.

2. Power budget and optical signal attenuation

The transmitter and receiver of an optical fiber system must be designed taking into consideration the expected attenuation of the optical signals. Because a PON uses optical splitters in the network, the optical attenuation is expected to be high, as shown in **Fig. 1**. Therefore, the PON requires a higher optical power budget than the conventional point-to-point system. E-PON, which was standardized as IEEE 802.3ah, which specifies 1:16 optical splitting, has a power budget of 26 dB for a 20-km span [1]. This value is based on the ideal optical path.

3. Optical power budget of NTT's GE-PON system

Even after the release of IEEE 802.3ah, we continued our access network development and considered using a splitting ratio of 1:32 and treating the non-ideal optical paths of actual optical networks. In 2004, NTT developed a GE-PON system with an optical power budget of 29 dB. Its 7-km span with a 1:32 optical splitting ratio covers more than 90% of the access networks in Japan.

4. Development of long-reach GE-PON system

For further FTTH service area expansion, a cost-effective GE-PON system with a span of greater than

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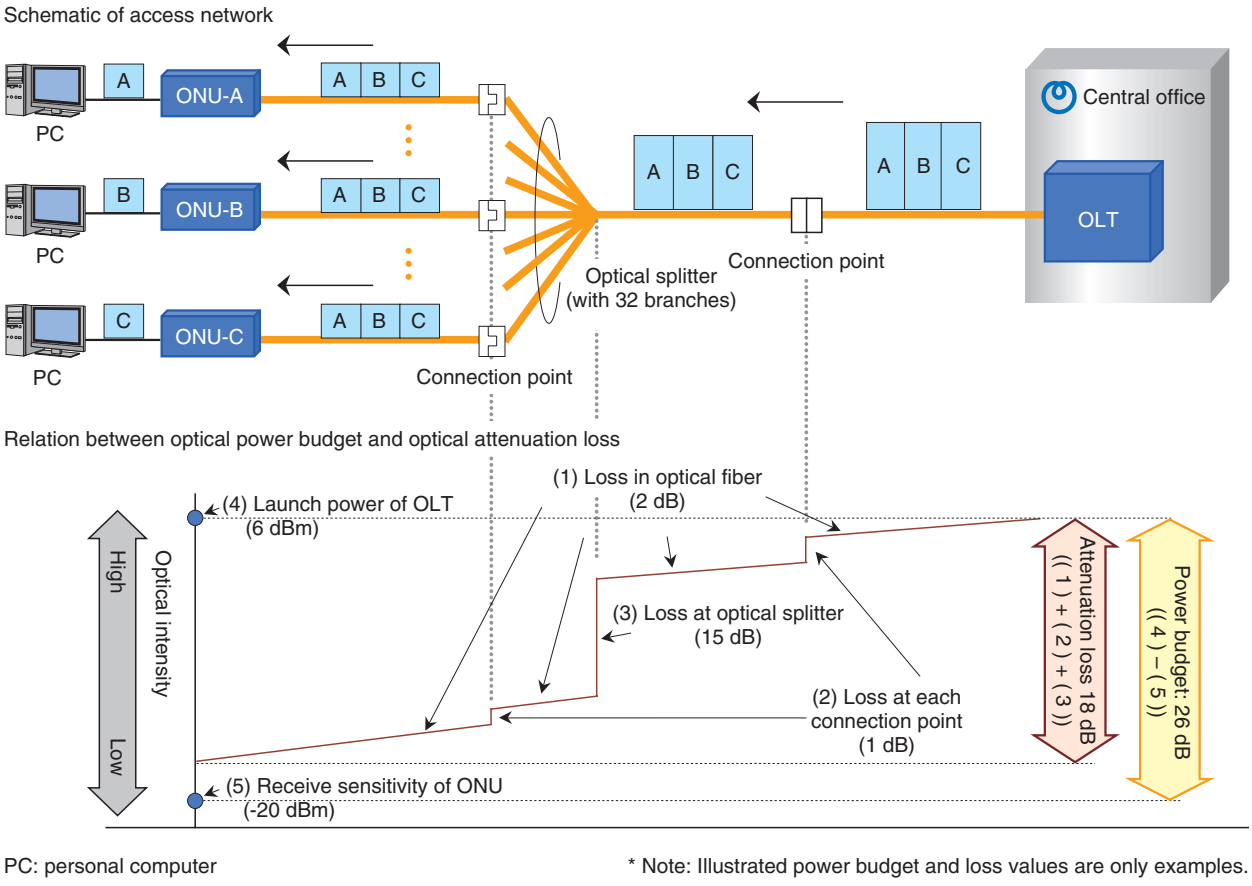


Fig. 1. Optical power budget and optical distribution network attenuation.

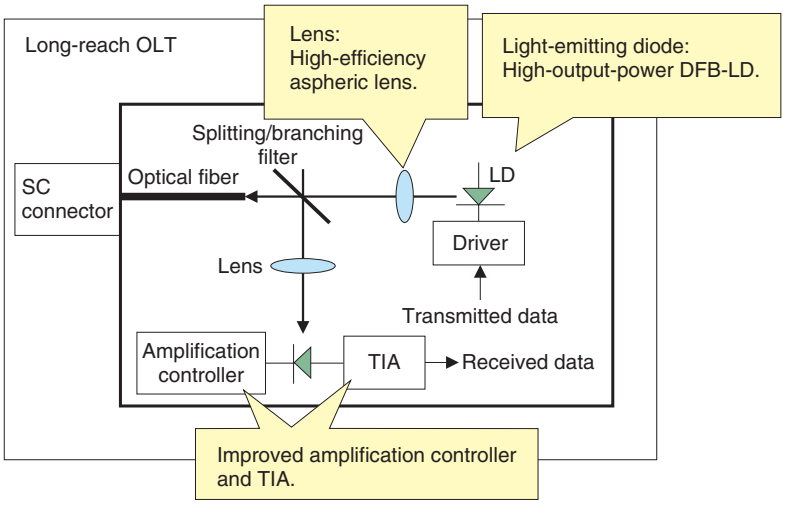
7 km is required to provide rural coverage. There are three possible solutions:

(1) Improve the OLT's transmitter and receiver performances
(2) Improve the ONU's transmitter and receiver performances
(3) Improve the performances of both OLT and ONU

If the customers in the extended FTTH area (>7-km span) are uniformly distant from the OLT, the first option is most efficient because the cost of the OLT enhancement is shared by multiple customers (ONUs). For this reason, we chose to develop a long-reach OLT as the first step. A development summary is shown in **Fig. 2**. We have increased the OLT's power budget by 3 dB by using a high-efficiency aspheric lens and a high-output-power light-emitting diode in the transmitter and an improved amplifier control circuit and transimpedance amplifier in the receiver. As shown in **Fig. 3**, the existing OLT chassis can accommodate the new OLT packages alongside the conventional ones. This minimizes the cost of expanding the FTTH service area. The long-reach OLT yields an economical GE-PON system with a 32-dB optical power budget and allows FTTH services beyond 7 km from the central office. It was first deployed in 2010.

5. Development of even-longer-reach GE-PON system

FTTH service can be provided to the few, but more distant, customers, by developing long-reach ONUs (option 2 above). Our long-reach ONU is summarized in **Fig. 4**. The transmitter uses an aspheric lens in place of the previous spherical lens and a distributed-feedback laser diode. The receiver uses an avalanche photodiode. The ONU complies with IEC (International Electrotechnical Commission) class 1 requirements for eye safety [2], which is mandatory for equipment installed in customer premises. These improvements to the ONU side raise the power



DFB: distributed feedback
LD: laser diode
SC connector: a type of optical connector
TIA: transimpedance amplifier

Fig. 2. Development summary of the long-reach OLT.

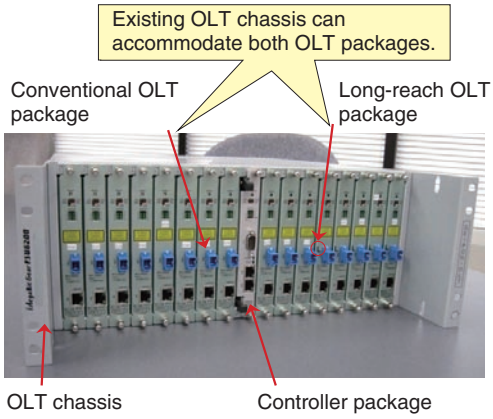


Fig. 3. OLT.

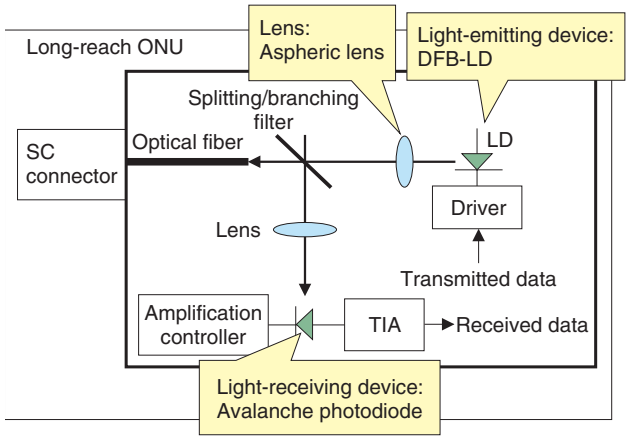


Fig. 4. Development summary of the long-reach ONU.

budget by 5 dB.

The new ONU matches the volume and power consumption of the conventional ONU. Since the OLT can accommodate both long-reach and conventional ONUs simultaneously, no special techniques are needed to install the new ONUs in the same PON network except for regular checks of the optical path attenuation. The combination of the long-reach OLT and the long-reach ONU provide an optical power budget of 37 dB, which is one of the highest budgets of any commercial GE-PON system in the world. NTT has started using this system to deploy FTTH services to customers more than 20 km from the central office (using a splitting ratio of 1:32).

6. Applications of long-reach GE-PON systems

The long-reach GE-PON system has three main application scenarios, as shown in **Fig. 5**: (1) expanding existing FTTH service areas, (2) adding new

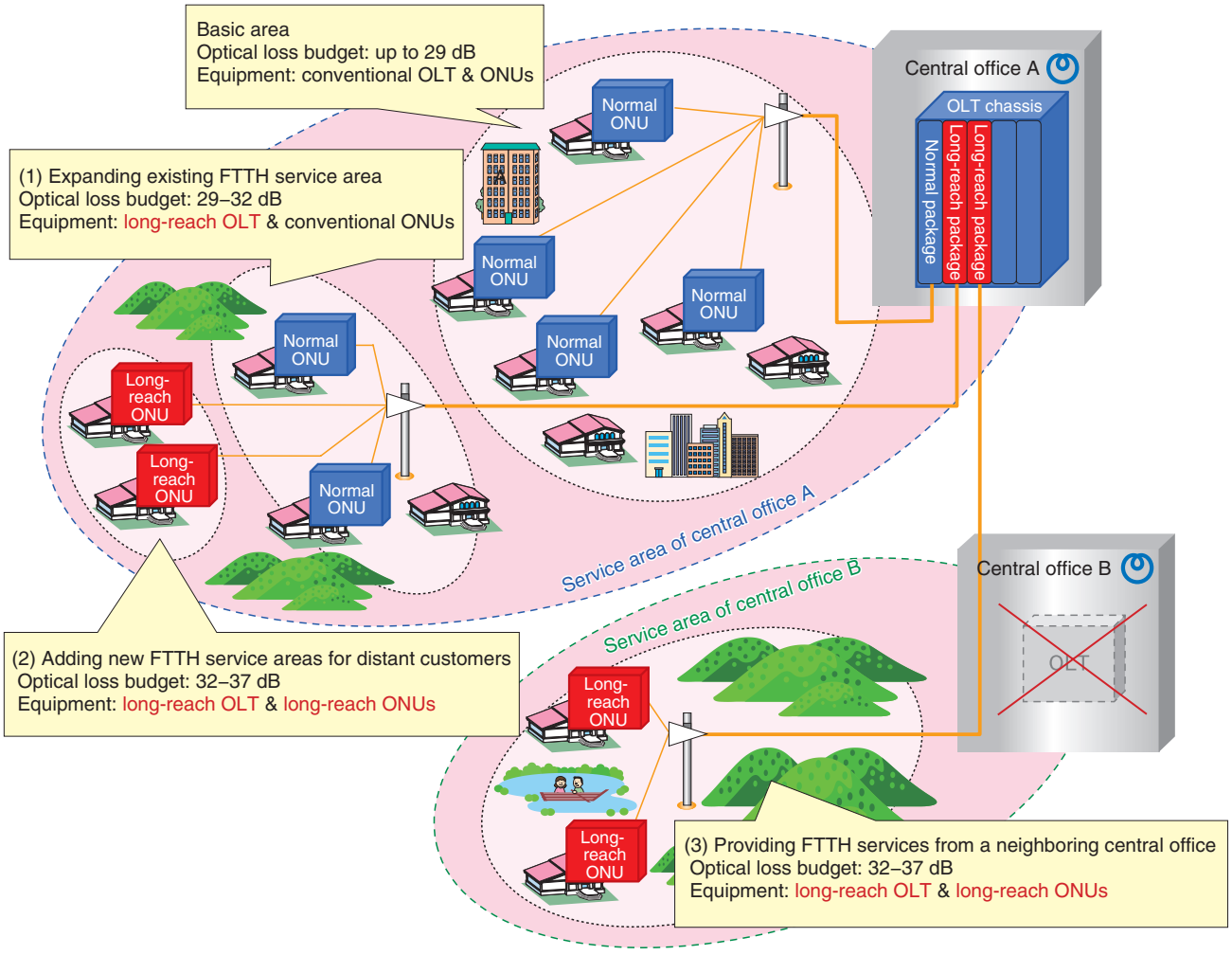


Fig. 5. Application scenarios of long-reach GE-PON.

FTTH service areas for distant customers, and (3) providing FTTH services from a neighboring central office.

By installing a long-reach OLT package in an existing OLT chassis, we can provide FTTH services to locations more than 7 km from the central office at minimum cost. For customers living in even further areas, we can deploy long-reach ONUs, but the higher installation cost imposes a limit because the long-reach ONUs will be deployed only to those customers rather than being shared among multiple customers. Although the basic concept of FTTH deployment is to connect ONUs to the nearest central office, some rural central offices do not have any fiber transmission systems. In such cases, it is possible to connect the ONUs to a more-distant neighboring central office that has OLTs and fiber transmission systems. The 37-dB power budget GE-PON system readily supports this kind of deployment.

7. Conclusion

We have developed a long-reach GE-PON system (with a splitting ratio of 1:32) that significantly expands the optical power budget from 29 dB to either 32 dB or 37 dB. These developments enable us to expand FTTH service areas cost-effectively. We have been supporting the commercial deployment of these systems and are thus contributing to further expansion of FTTH service areas in Japan.

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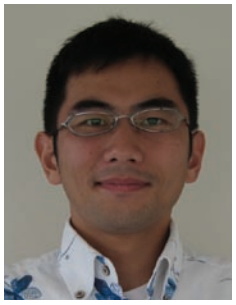
[2] IEC 60825-1 Edition 2.0, 2007.



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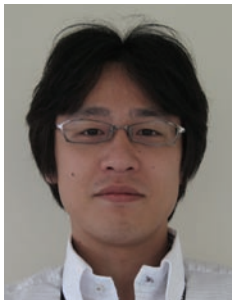

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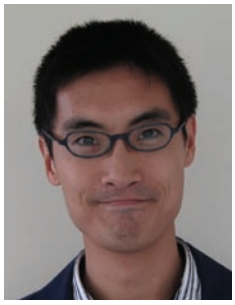

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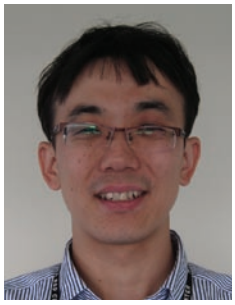

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Trends of International Standardization of Three-dimensional Video Coding

Hideaki Kimata†

Abstract

This article introduces the trends of international standardization of three-dimensional video, which should lead to new services that differ from conventional television.

1. Introduction

Video compression technologies have made possible various exciting new services since their international standardization started. While the main target has been high compression efficiency, a lot of attention has recently been paid to three-dimensional (3D) video. International standardization of 3D video has started and it is expected to lead to novel video services. This article introduces the trends of 3D video format and compression standardization, which have been studied in the Motion Picture Experts Group (MPEG), and mentions the background, applications, and features of the H.264 Annex H (MVC) standard, which has been adopted in the fixed-media Blu-ray 3D format (MVC: Multiview Video Coding).

2. 3D video and multiview video

We live in a 3D space. Therefore, if we could transmit the 3D space itself, that would be a straightforward way to communicate correctly what one sees as the scenery and appearance of objects to other people. However, it is currently impossible to capture the 3D space itself. Instead, a two-dimensional (2D) image projected from the 3D space is captured by a camera and transmitted. Using several camera images captured by multiple cameras enables a large amount of detailed spatial information to be communicated. A collection of multiple videos capturing the same scene from different viewpoints is called multiview video. 3D video is a more general medium for representing 3D space and it may include 3D geometry information of the scene as well as multiview video. By transmitting 3D video, we can communicate a more realistic impression of the scenery and appearance of objects than conventional TV can.

3. 3D video and H.264 standardization

3D video representation and compression formats have been standardized to achieve 3D video services. 3D video standardization activities started about ten years ago. This was the time when TV services began to change from analog broadcasting to digital broadcasting, and also it was when personal video delivery services such as video on demand started. Against this background, high-compression-efficiency video coding H.264/MPEG-4 AVC (advanced video coding) standardization by the joint team of ITU-T and ISO/IEC JTC1 was started in 2001 (ITU-T: International Telecommunication Union, Telecommunication Standardization Sector, ISO: International Organization for Standardization, IEC: International Electrotechnical Commission, JTC1: Joint Technical Committee 1). On the other hand, expansion of services using new video formats was expected at the same time (**Fig. 1**). Since it was predicted that high-definition television (HDTV) displays would be popularized within a few years, such new video formats needed to handle different representations from

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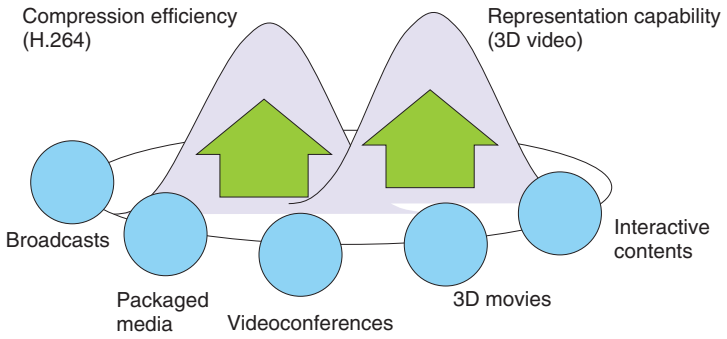


Fig. 1. Expansion of services resulting from video coding standards.

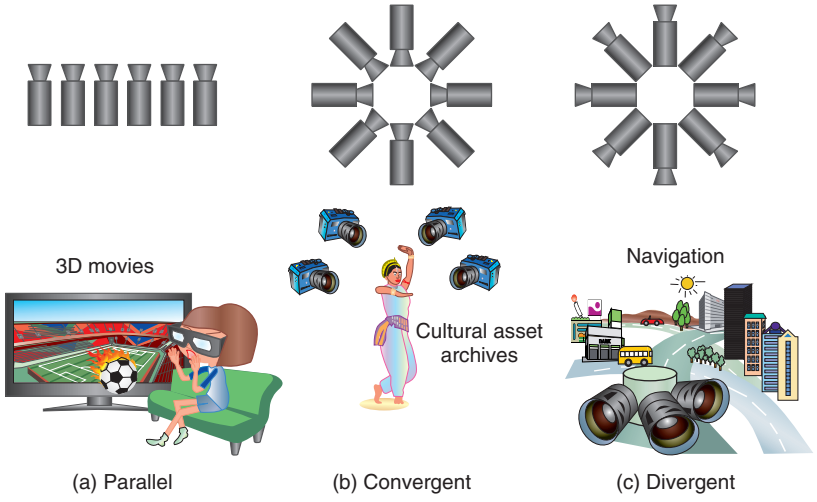


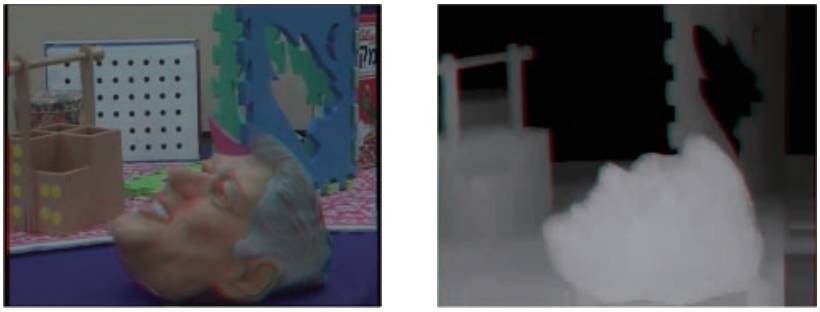
Fig. 2. Camera arrangements and applications.

ordinary TV and Internet video delivery services. Moreover, a new video format that would treat 3D space was expected. The standardization of video representation and compression formats for 3D space was started in 2001 by MPEG, which is a Working Group under ISO/IEC JTC1. The MPEG 3D space activity is called 3D video standardization.

In 3D video standardization, first, video representation formats were classified according to the arrangement of cameras constructing the 3D video. If the relative differences in positions and directions among cameras are simple, camera arrangements are classified into three types: parallel, convergent, and divergent arrangements (**Fig. 2**). Applications of 3D video are also classified according to the camera arrangement.

The parallel arrangement provides enhanced depth impression, as typified by the current boom in 3D movies. The convergent arrangement is suitable for free viewing around a tangible or intangible cultural asset. The divergent arrangement is suitable for free viewing of city scenery from the street, as typified by the current boom in web maps and navigation services.

At about the same time, the depth camera, which captures depth (distance) information in 2D arrays, appeared. A depth camera can be used alongside a normal video camera to simultaneously acquire depth and video (color) information (**Fig. 3**). Alternatively, depth information can be estimated by computer vision technologies from multiple cameras images. And from the depth and video (color) information, a virtual camera image representing the image that would have been taken by a camera having a slightly



Video (color) Depth

Fig. 3. Video (color) and depth information.

Table 1. Characteristics of MVC profiles.

Profile	Multiview High Profile	Stereo High Profile
Maximum views	1024	2
Interlace scan	Not supported	Supported

different position or angle from the original cameras, can be synthesized by computer graphics (CG) technologies. MPEG also discussed a 3D video data format supporting image synthesis from depth information. For instance, depth information can be treated as a gray-scale image because it is obtained in a 2D array. The assumed application was 3D TV.

Because applications were classified according to camera arrangement and camera type, experiments exploring the efficiency of data formats were conducted in case studies with end users for 3D video standardization discussions. From the deep discussion based on the evaluation results, it was concluded that the fundamental data format for 3D video was multiview video, geometry information about the videos, and depth information according to the conditions. Standardization of Multiview Video Coding (MVC) as a compression format of multiview video started in 2005.

When MVC standardization was about to start, the standardization of the state-of-the-art high-efficiency video compression format H.264 had just finished and MVC was expected to be standardized over H.264. Sure enough, MVC standardization started as an extension of H.264 and it was finished in 2009 and specified as H.264 Annex H. In H.264, the operational guidelines are specified as profiles, and MVC specifies two profiles. The main characteristics of MVC profiles are given in **Table 1**. Historically, the Multiview High Profile was specified first and the Stereo High Profile was specified a couple of years later.

4. Characteristics of MVC standard

Here, the main characteristics of the MVC standard are introduced. The main video format is multiview video, and several functional extensions were required to support the assumed 3D video applications. The main features discussed in MVC standardization are listed in **Table 2**. In MVC, virtual camera image synthesis is considered as the final process before display. The series of processes from capture to display assumed in MVC is depicted in **Fig. 4**. On the subject of video streaming, the case of a feedback streaming channel from a user was also discussed. When no feedback streaming channel is available, it is necessary to transmit all video streams; however, when it is available, it is possible to transmit only the requested part of the compressed stream. Accordingly, at the acquisition and encoding side, all information should be compressed and then at the display side, a user will see part of the total. The idea of transmitting only part of the stream is an extension of conventional scalable video coding. In scalable video coding, the stream is composed of multiple layers: the fundamental layer called the base layer should always be transmitted and other layers are optionally transmitted in addition to the base layer. On the other hand, in MVC, because an arbitrary part of stream should be extractable and transmittable, a base layer is not defined as a specific layer. Instead, the novel unit of a *view* is introduced. The function of extracting an arbitrary part of the stream is called view scalability in MVC. Note that the use of view was

Table 2. Main features of MVC standard.

Simultaneous output of multiple views	Application to 3D displays
Predictive coding between views	High compression efficiency
Support for view scalability and extraction of arbitrary view	Support for various types of 3D display and improved transmission efficiency
Inexpensive implementation of extension from video codec	Low cost because only predictive coding is used between views

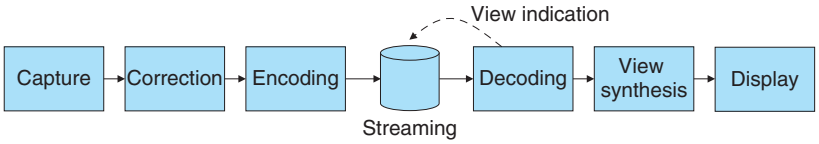


Fig. 4. Flow of processes assumed in the MVC standard.

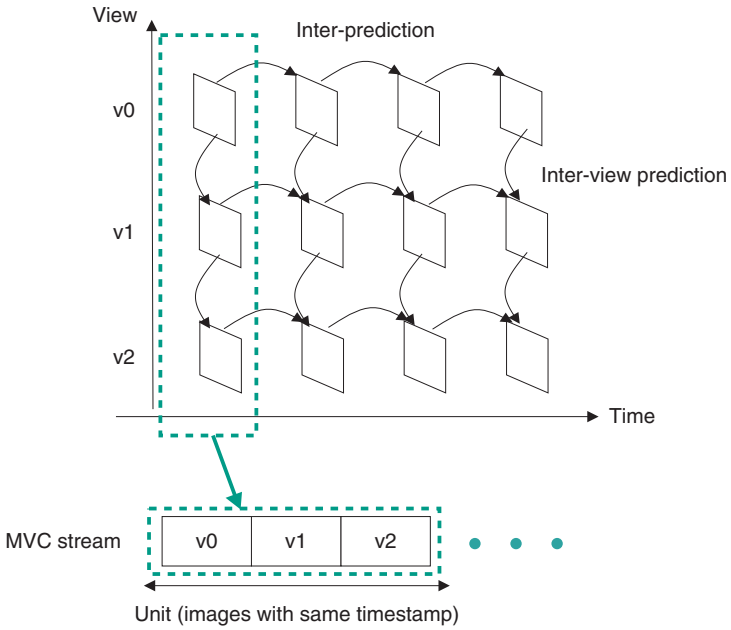


Fig. 5. Structure of MVC stream.

intended to distinguish camera images, but in the MVC standard, it is not limited to camera images. For instance, a view can be assigned to a region of an image and it can be used to extract part of a huge image. MVC supports many data formats besides multiview video as a result of the introduction of this versatile view concept.

In MVC, multiple views are synchronized and compressed together. Images with the same timestamp for views are compressed sequentially according to the predetermined ordering of views. At the decoding side, the decoder just decodes part of the stream and obtains the images with the same timestamp as the target views (**Figs. 5** and **6**). Thus, synchronization is achieved at the codec level and extraction of the target view stream is easily achieved. And

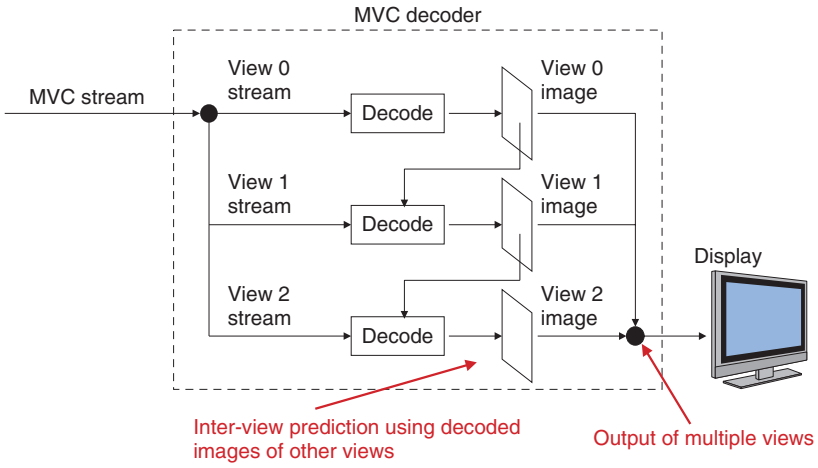


Fig. 6. Example of MVC decoder component blocks.

to improve compression efficiency, predictive coding between views can be applied when images having the same timestamp are compressed. This feature is efficient for compressing 3D video and achieves a significant reduction in the data rate because the similarity among views is high in 3D video.

Moreover, one feature for implementation is that the compression process is not very different from that in a conventional video compression codec. Since the only difference is predictive coding between views, an MVC decoder can easily be constructed from a conventional video decoder when images of views are decoded sequentially.

5. Standardization of related technologies

Several related technologies have been standardized. For the delivery of video contents, the system layer standard MPEG-2 TS (transport stream) has been extended to support MVC. This extension has led to not only the transmission of 3D video but also the adoption of MVC as the fixed-media standard Blu-ray 3D format.

For 3D video viewing without the need for special glasses, the delivery of supplementary information about the view synthesis process should be considered because the positions and directions of displayed views are usually dependent on the capabilities of the display system. Two types of supplementary information have been standardized. One is the camera parameter of views. This is a description of the camera's position and direction. The camera parameter is necessary in order to assume the position of signals of views in the 3D space, which are exploited to synthesize a virtual camera image by the CG method of 3D warping. The camera parameter description is specified in the MVC standard as supplementary information about the compressed stream. The other supplementary information is the relationship between 3D scene depth and disparity. This relationship is applied when the depth information that is compressed in the stream is converted into disparity information for 3D display. The supplementary information about this relationship has been standardized as MPEG-C part 3, which is independent of compression standards.

For stereoscopic video, the conventional compression format is currently used in TV broadcasting instead of the brand-new compression format MVC. In order to transmit two views, stereoscopic video is transformed into a single side-by-side (SBS) formatted video, and mapping information about the SBS transformation is necessary for the display side to perform the inverse transformation. This mapping information has been standardized for H.264, and it is under consideration for MPEG-2 Video.

6. 3D video applications

Let us return to the topic of 3D video applications. First, for the parallel camera arrangement, 3D TV is assumed. Stereoscopic video is becoming popular as a result of the recent boom in 3D movies, and the MVC standard has been adopted as the Blu-ray 3D format to deliver high-quality stereoscopic video to homes. In the Blu-ray 3D format, the view scalability feature of MVC is exploited efficiently. For 3D

display, both views are extracted and displayed; for ordinary display, either one view or the other is extracted and displayed.

On the other hand, the convergent and divergent camera arrangements are expected to lead to more exciting services in the near future. For instance, the convergent arrangement may be used for free viewpoint video covering the whole of a sports stadium, and the divergent arrangement may be used for panoramic video that gives us a strong feeling of actually being at the site of an event. My coworkers and I have studied video processing technologies for a panoramic video service.

7. Conclusions and future activities

This article introduced the trends of 3D video standardization and the novel video services that may result from it. In particular, features and applications of H.264 Annex H (MVC), which has been adopted in the fixed-media Blu-ray 3D format, were explained.

In MPEG, a new activity concerning the next standard after MVC is now under way. To support glasses-free 3D video more efficiently, a new representation and compression format of video and depth are being studied. This activity is called FTV (free viewpoint TV) in MPEG. An efficient standard should be specified in the very near future, in time for the current 3D movie boom.

On the other hand, video compression standardization of High Efficiency Video Coding (HEVC), which should be the successor to H.264, is also under way. Like the relation between 3D video and H.264, another 3D video standardization linked to HEVC can be expected in the future.

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Case Studies of Failures of Business Phones Connected to VoIP Gateway

Abstract

This article introduces case studies of failures of business phones connected to a VoIP (voice over Internet protocol) gateway developed by NTT EAST. It is the seventh in a bimonthly series on the theme of practical field information about telecommunication technologies. This month's contribution is from the Network Interface Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters.

1. Introduction

In parallel with the spread of broadband services, a migration from traditional subscriber telephone services to IP (Internet protocol) telephony is taking place. When a customer who has been using traditional subscriber telephone services changes to IP telephony over existing circuits accommodating business phones, connections to those business phones are made via a VoIP-GW (voice-over-IP gateway). Consequently, the troubleshooting of business phones involves VoIP technologies (e.g., Session Initiation Protocol (SIP) and Real-time Transport protocol (RTP)) used in IP telephony in addition to existing analog and ISDN (integrated services digital network) technologies used in subscriber telephone services. This article presents two case studies of failures that occurred in existing business phones connected to a VoIP-GW.

2. Case studies

2.1 Business phone unable to make outgoing/incoming calls

(1) Equipment configuration

In this example, the customer was using NTT EAST's Hikari Denwa Business Type IP telephony service and had six VoIP-GWs connected to existing business phones. The VoIP-GWs were connected to ISDN basic rate interface (BRI) units in the main business phone unit since the customer had been using NTT EAST's INS-Net 64 service* before the IP telephony service. The equipment configuration is shown in **Fig. 1**.

(2) Failure description

The customer reported that outgoing and incoming calls occasionally could not be made via a certain VoIP-GW. This problem could be resolved by turning the VoIP-GW's power off and then on again or by unplugging and reinserting the cable connected to the BRI units.

(3) Inspection details

A maintenance console (personal computer (PC)) was used to collect and analyze the failure log from the VoIP-GW in question. An ISDN protocol analyzer was used to monitor the protocol transfers between the VoIP-GW and business phone. An oscilloscope was used to monitor signals in the segment between the VoIP-GW and the ISDN BRI unit (signals between wires TA & TB and RA & RB) and to inspect the noise environment at the time of a failure (e.g., the quality of the commercial power supply and telecommunication lines. VoIP analyzers were used to perform packet capture and analyze captured data in the segment between the optical network unit (ONU) and the switching hub and in the segment between the switching hub and the VoIP-GW (Ethernet sections).

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* INS-Net 64: 64-kbit/s ISDN service [1], [2]

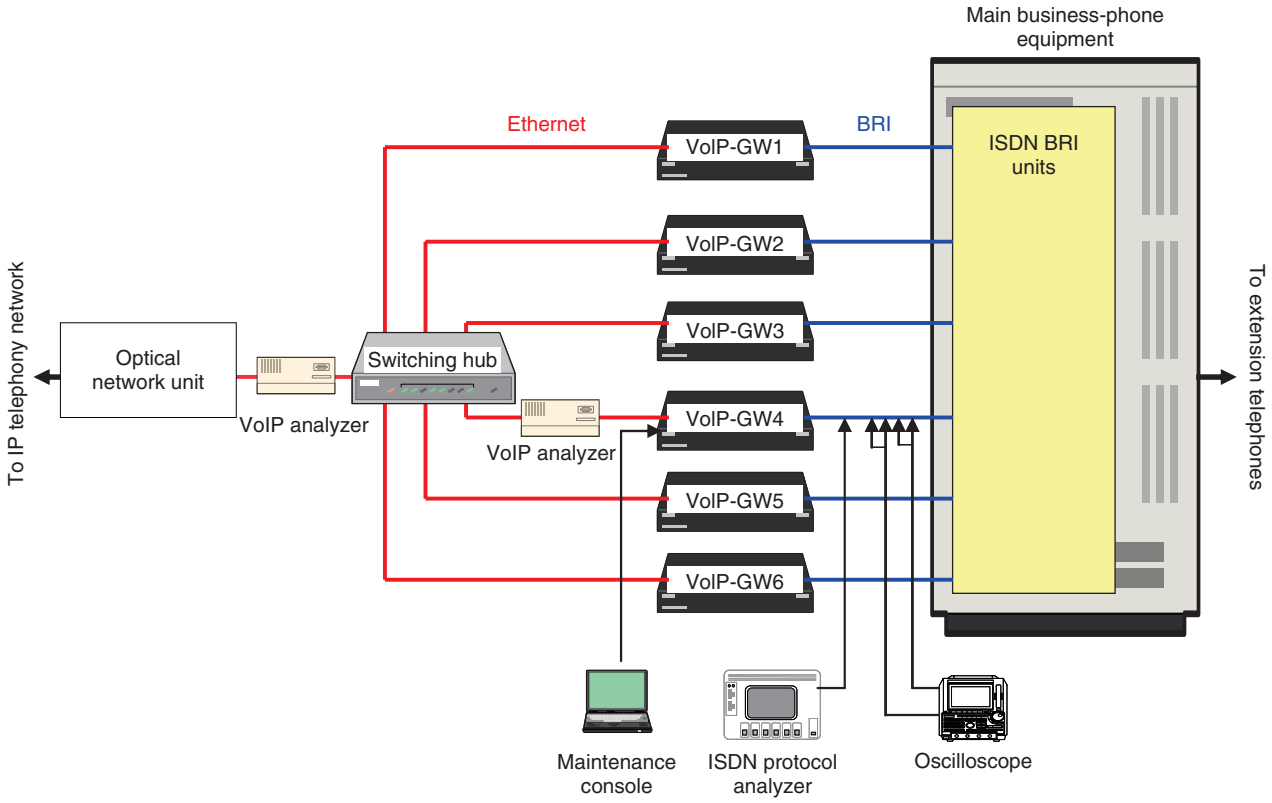

Fig. 1. Equipment configuration.

(4) Inspection results

The VoIP-GW failure log revealed that a "layer 1 down" event occurred many times on the BRI circuit between the VoIP-GW and main business-phone equipment. An excerpt from the log at the time that a failure occurred is shown in **Fig. 2**. Protocol monitoring using the ISDN protocol analyzer revealed "INFO lost" indicating "layer 1 down" in the same time period as the timestamps of the failures recorded in the VoIP-GW failure log. Signal monitoring between the VoIP-GW and main business-phone equipment revealed signal distortion and signal-suspended states in the signal waveform of the TA-TB line for transmissions from the main business-phone equipment to the VoIP-GW (**Fig. 3**). At this time, no changes in conduction noise in the commercial power supply or telecommunication lines were detected. Analysis of captured packed data revealed no packets or sequences that could be considered abnormal.

Date/time	Description	No. of times
12/06 17:47:46	Line (1) Layer 1 down: 170 times	
12/06 17:47:45	Line (1) Layer 1 up: 170 times	
12/06 17:41:42	Update check failure (unable to connect to server)	
12/06 17:41:42	Firmware update check (automatic)	
12/06 05:24:36	Line (1) Layer 1 down: 32 times	
12/06 05:24:35	Line (1) Layer 1 up: 32 times	
12/06 05:24:24	Line (1) Layer 1 down	

Fig. 2. VoIP-GW failure log at time of failure (excerpt).

(5) Cause of failure

This failure was considered to occur for the following reason. Owing to the distortion and suspended state of the signal transmitted from the business phone (TA-TB line signal), the VoIP-GW could not detect a frame-synchronization signal in three time-frames, which it interpreted as a frame-synchronization offset; this prompted the transmission of an INFO2 signal and the disabling of outgoing and incoming calls (**Fig. 4**).

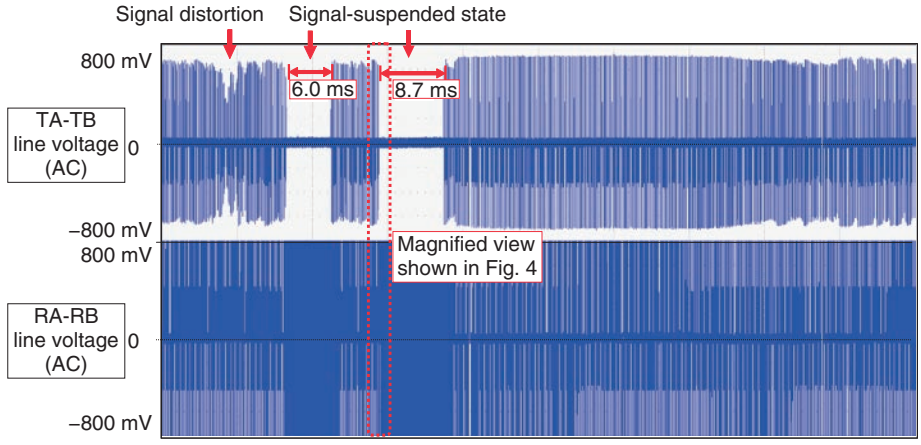

Fig. 3. Waveform at time of failure.

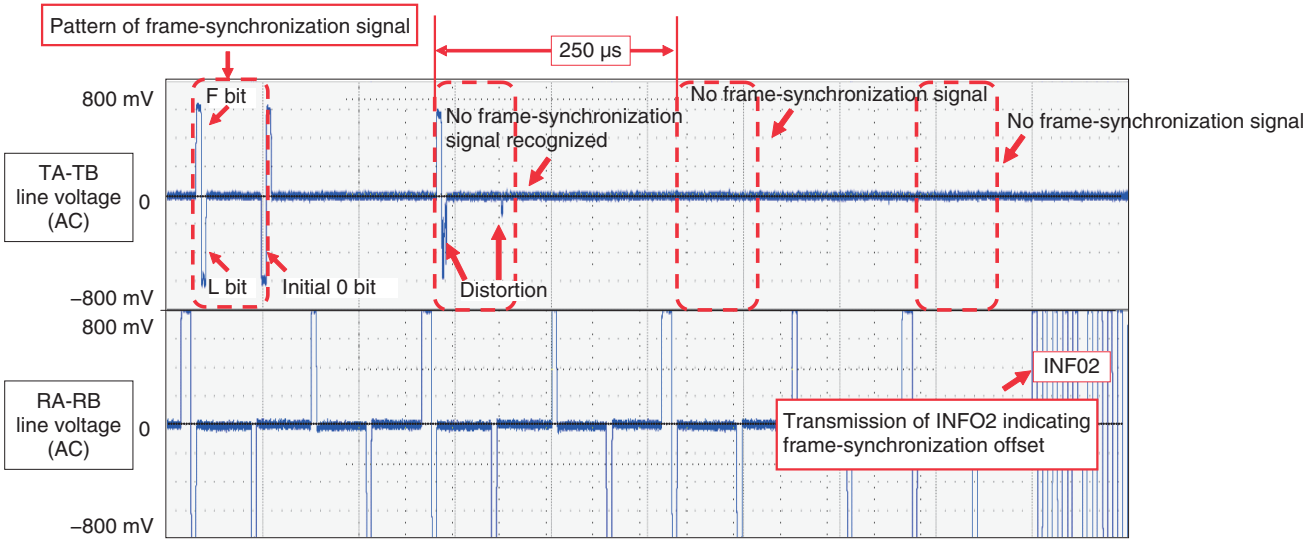

Fig. 4. Magnified waveform at time of failure.

(6) Countermeasures and results

The ISDN BRI unit connected to the business phone was replaced. This restored the line to normal operation.

(7) Summary

An analysis of the VoIP-GW failure log revealed that "layer 1 down" events had occurred between the VoIP-GW and business phone, which enabled the cause of this phenomenon to be inferred. Checking failure logs of installed equipment is a relatively simple and important form of troubleshooting.

2.2 Faulty transmission/reception in a fax machine acting as a business-phone terminal

(1) Equipment configuration

In this example, a customer was using NTT EAST's Hikari Denwa Business Type IP telephony service. The business phones were connected to a single VoIP-GW via the main business phone equipment. They were also connected to INS-Net 64 as a backup circuit. The main business phone equipment contained an ISDN primary rate interface (PRI) unit connected to the VoIP-GW to accommodate the IP telephony service; an ISDN BRI unit to connect to

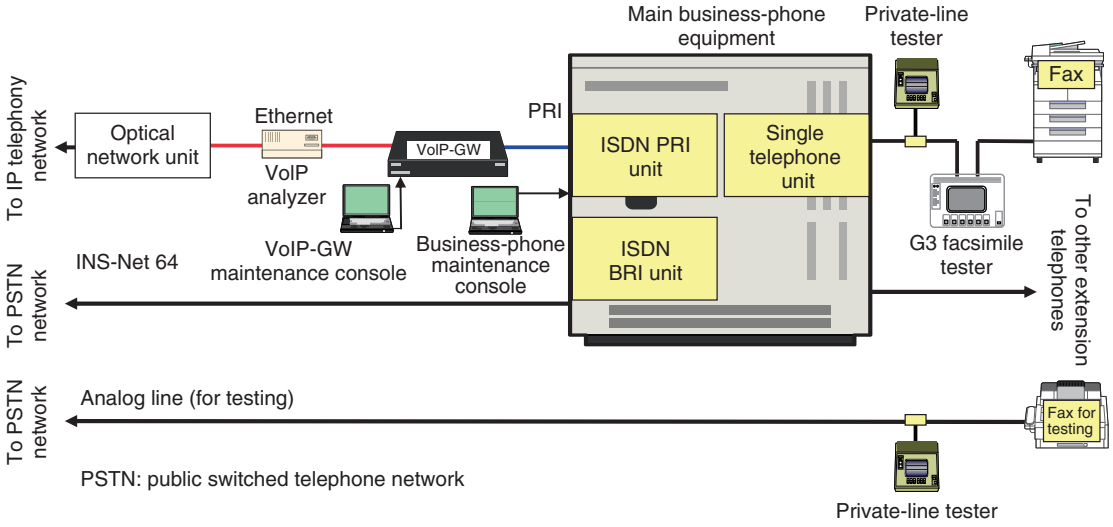

Fig. 5. Equipment configuration.

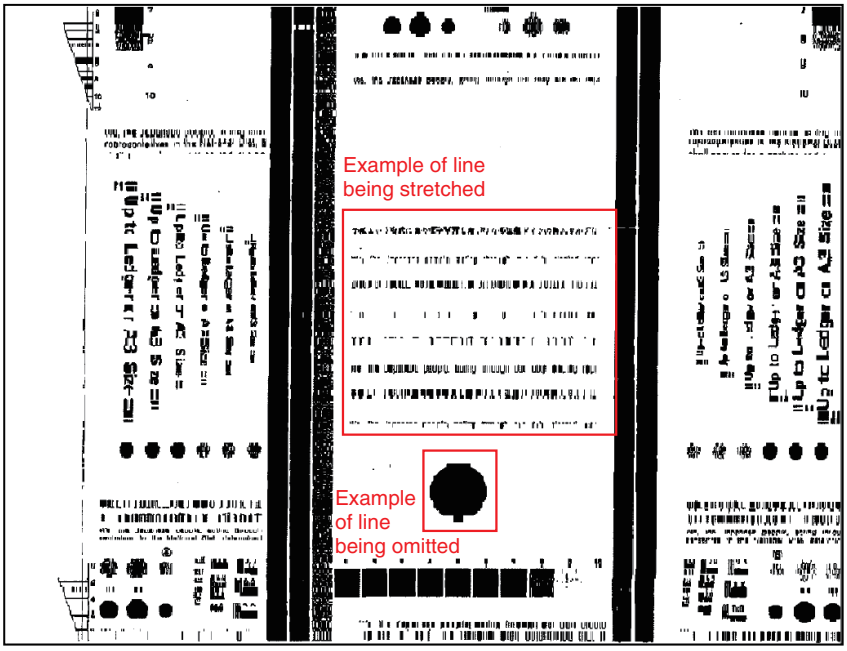

Fig. 6. Fax image received at the time of failure.

INS-Net 64; and a single telephone unit, which connected to a fax machine acting as an extension business-phone terminal. The equipment configuration is shown in **Fig. 5**.

(2) Failure description

Images transmitted or received by this fax machine were occasionally distorted (lines stretched or omitted) and sometimes faxes could not be transmitted or received. An example of a fax image received at the time of failure is shown in **Fig. 6**.

(3) Inspection details

A G3 (third-generation) facsimile tester was used to

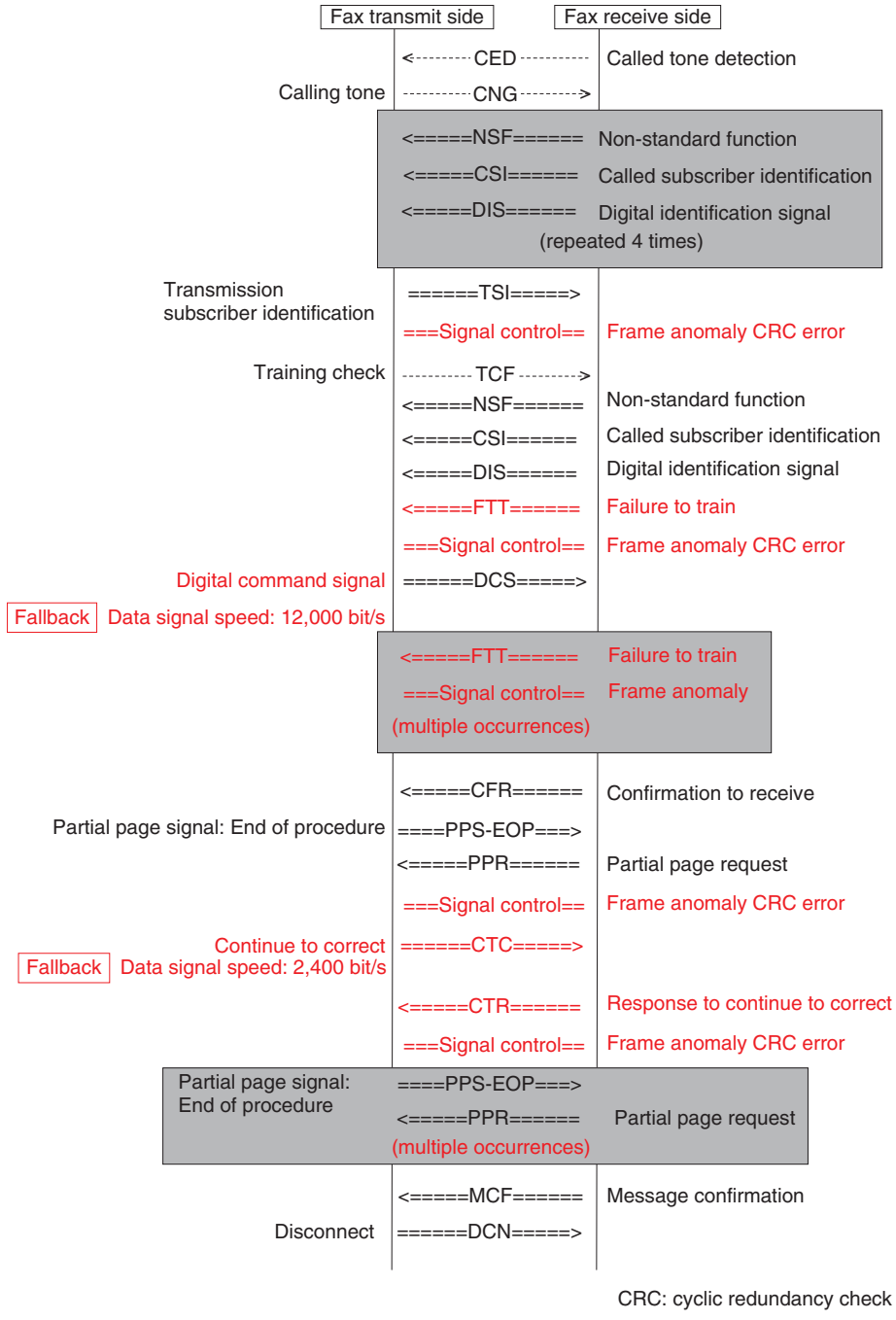

Fig. 7. Fax communication sequence at time of failure.

monitor the fax communication sequence. A private-line tester was used to measure the bit error rate on the transmission path used for fax communications. A VoIP analyzer was used to capture packets and analyze captured data between the ONU and VoIP-GW (Ethernet interval). Maintenance consoles (PCs) were used to check the data settings in the VoIP-GW and business-phone ISDN interfaces.

(4) Inspection results

Monitoring of the fax communication sequence by the G3 facsimile tester revealed “failure to train”

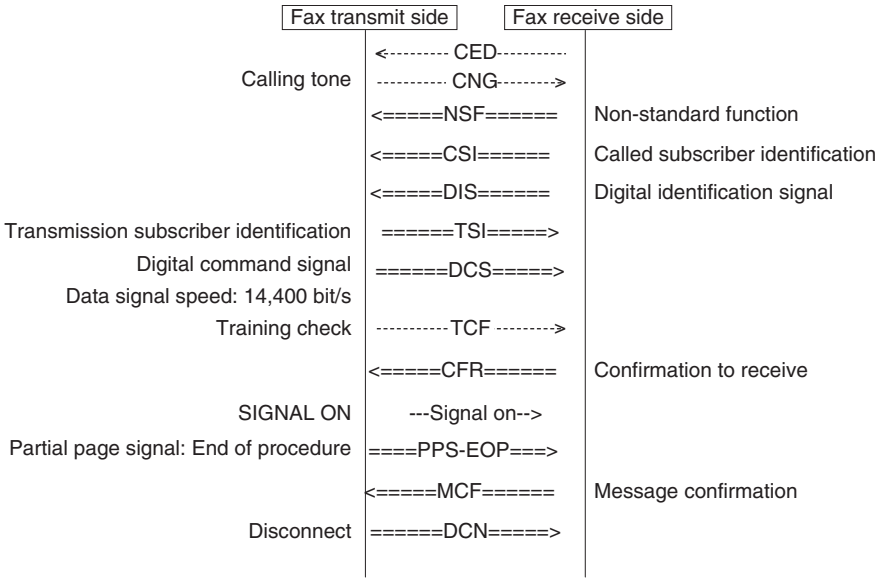

Fig. 8. Fax communication sequence during normal operation.

signals, "frame anomaly" signals, and drop-in-transmission-speed sequences not observed during normal operation. The fax communication sequences at the time of failure and during normal operation are shown in **Figs. 7** and **8**, respectively. Bit-error measurements revealed a bit error rate of about 4–5% (effective number of bits: 10^6 in both the uplink and downlink. An analysis of captured packed data revealed no packets or sequences that could be considered abnormal. Data settings in the VoIP-GW's ISDN interface indicated that the synchronization clock was set to slave, meaning that the clock was extracted from other equipment.

(5) Cause of failure

This failure was considered to occur because of a mismatch in the setting covering the synchronization clock between the VoIP-GW and the main business phone unit, which led to unstable synchronization between them and degraded the transmission quality and generated defects in the fax communications.

(6) Countermeasures and results

The VoIP-GW synchronization setting was changed from slave to master so that the clock would be self-generated. This prevented this failure from reoccurring.

(7) Summary

A bit error rate of about 4–5% on the transmission path used for fax communications affected the quality of fax communications. When the failure occurred, only fax communications, which has strict data-transmission requirements, suffered a drop in quality—no problems such as choppiness could be perceived in voice calls made using other extension (business) phones.

3. Conclusion

This article presented case studies of failures that occurred when the circuits accommodating existing business phones were migrated from traditional subscriber telephone services to IP telephony in a configuration in which business phones were connected to VoIP-GWs. In these case studies, failures that did not occur when using traditional subscriber telephone services occurred when the equipment configuration changed upon migration to IP telephony and upon the addition of new equipment. Both IP technologies and existing analog & ISDN technologies are essential in troubleshooting when VoIP is used with existing business phones.

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External Awards

JSIAM Best Author Award
Winners: Daisuke Satoh[*1] and Masato Uchida[*2]
*1 NTT Information Sharing Laboratory Group
*2 Kyushu Institute of Technology
Date: Sep. 15, 2011
Organization: The Japan Society for Industrial and Applied Mathematics (JSIAM)

For "Worm Propagation Model via E-mail".
Published as: D. Satoh and M. Uchida, "Worm Propagation Model via E-mail," Bulletin of the Japan Society for Industrial and Applied Mathematics, Vol. 20, No. 3, pp. 236–241, 2010 (in Japanese).

Papers Published in Technical Journals and Conference Proceedings

Hierarchical Auto-tagging: Organizing Q&A Knowledge for Everyone

K. Nishida and K. Fujimura

Proc. of CIKM, the 19th ACM International Conference on Information and Knowledge Management, Vol. 2010, No. 10, pp. 1657–1660, Toronto, Canada, 2010.

We propose a hierarchical auto-tagging system, TagHats, to improve users' knowledge sharing. Our system assigns three different levels of tags to Q&A documents: category, theme, and keyword. Multiple category tags can organize a document according to multiple viewpoints, and multiple theme and keyword tags can identify what the document is about clearly. Moreover, these hierarchical tags will be helpful in organizing documents to support everyone because different users have different demands in terms of tag specificity. Our system consists of a hierarchical classification method for assigning category and theme tags, a new keyword extraction method that considers the structure of Q&A documents, and a new method for selecting theme tag candidates from each category. Experiments with documents at Oshiete! goo demonstrate that our system is able to assign hierarchical tags to documents appropriately and is capable of outperforming baseline methods significantly.

Designing Efficient Authenticated Key Exchange Resilient to Leakage of Ephemeral Private Keys

A. Fujioka and K. Suzuki

CT-RSA 2011, Lecture Notes in Computer Science, 2011, Vol. 6558/2011, pp. 121–141, San Francisco, CA, USA, 2011.

We investigate a sufficient condition for constructing authenticated key exchange (AKE) protocols which satisfy security in the extended Canetti-Krawczyk (eCK) model proposed by LaMacchia, Lauter and Mityagin. To the best of our knowledge, this is the first approach for providing secure protocols based on the condition. With this condition, we propose a construction of two-pass AKE protocols, and the resulting two-pass AKE protocols are constructed with a single static key and a single ephemeral. In addition, the security proof does not require the Forking Lemma, which degrades the security of a protocol relative to the security of the underlying problem where it is used in the security proof. Therefore, these imply that the protocols constructed with the condition have an advantage in efficiency such as sizes of storage and communication data. The security of the resulting protocols is proved under the gap Diffie-Hellman assumption in the random oracle model.

Digital Cinema over Optical Network—Status of Super HD Development

T. Fujii, K. Shirakawa, D. Shirai, Y. Tonomura, and M. Kitamura

Proc. of the Optical Fiber Communication Conference and Exposition (OFC/NFOEC 2011) and the National Fiber Optic Engineers Conference, Los Angeles, CA, USA.

Digital Cinema is a promising application that utilizes high-speed optical networks to transfer super-high-definition images. The networks are primarily used for distributing packet data of digital cinema contents and also used to support new services such as the live streaming of musicals and sports games to movie theaters. While current transfer services offer high-definition (HD) quality video, live streaming applications will soon shift to cinema-quality 4K for both business and movie theaters users. The extra-high-quality 4K enables a realistic telepresence and will be combined with special tools such as video editing systems to realize effective remote-collaboration for business workspaces. This paper introduces current research on super-high-definition image transmission and its application, especially in digital cinema and relevant application fields.

An Approximately Universal Set Consisting of Two Observables

Y. Takahashi

Proc. of the 6th Conference on Theory of Quantum Computation, Communication, and Cryptography (TQC 2011), Madrid, Spain.

We show that if we are allowed to use two ancillary qubits, a set consisting of one one-qubit observable and one two-qubit observable is approximately universal for quantum computation. Using the proof, we also show that if we are allowed to use two initialized ancillary qubits, one two-qubit observable is sufficient for graph state preparation. The use of only one two-qubit observable is optimal in terms of the number of observables available and the number of qubits to be measured jointly.

Generation of a Vocal-tract MRI Movie Based on Sparse Sampling

S. Hiroya and T. Kitamura

Proc. of the 9th International Seminar on Speech Production (ISSP'11), pp. 1–8, Montreal, Canada, 2011.

We present a novel technique that can provide a high-quality vocal tract magnetic resonance imaging (MRI) movie during speech production. The method uses MRI vocal-tract images at the central point of each phoneme and interpolation functions between adjacent phonemes obtained from electromagnetic articulographic data. It is based on our finding that articulatory parameters are suitable for a sparse representation. Preliminary results showed that the quality of the obtained vocal-tract MRI movie is high compared with that of the previous technique. The method will be useful for constructing a large database of vocal-tract MRI movies and understanding speech production mechanisms.

Tweet-topic Classification Using Data Compression

K. Nishida, R. Banno, K. Fujimura, and T. Hoshide

Proc. of the 3rd Forum on Data Engineering and Information Management (DEIM Forum 2011), pp. 1–6, Izu, Shizuoka, Japan (in Japanese).

Twitter, a micro-blogging service, has emerged as a new information infrastructure. In this study, we propose a new method that uses data compression for classifying topics of tweets (conversational, short, and real-time messages). Experiments with Japanese tweets assigned hash tags demonstrate that our method using the Deflate data compression method, which gzip uses, achieved higher precision and recall rates than the confidence-weighted linear classification method, which uses the character n-grams or morphemes of a tweet text as input features.

Design and Performance of a Sub-nano-ampere Two-stage Power Management Circuit in 0.35-μm CMOS for Dust-size Sensor Nodes

M. Ugajin, T. Shimamura, S. Muto, and M. Harada

IEICE Trans. on Electronics, Vol. E94.C, No. 7, pp. 1206–1211, 2011.

The design and performance of a sub-nanoampere two-stage power management circuit that uses off-chip capacitors for energy accumulation are presented. Focusing on the leakage current and the transition time of the power switch transistor, we estimated the minimum current for accumulation. On the basis of the results, we devised a two-stage power management architecture for sub-nanoampere operation. The simulation and experimental results for the power management circuit reveal the accumulation operation with a 1-nA current source.

Electrical Characterization of Terphenyl-based Molecular Devices

T. Goto, H. Inokawa, Y. Ono, A. Fujiwara, and K. Torimitsu

Japanese Journal of Applied Physics, Vol. 50, No. 7, pp. 071603–071603-6, 2011.

The electrical characteristics of phenylene-based molecular devices were assessed. A device consisted of nanogap electrodes and phenylene-based conjugated molecules. Two different types of nanogap electrode were tested. One was obtained by electromigration of a Au nanowire modified with a self-assembled monolayer (SAM) of 4,4-*p*-terphenyldithiol and the other was fabricated by the shadow evaporation of metals and subsequent deposition of a SAM. Some of the devices with electrodes of the first type exhibited activation energy for electrical conduction of up to 0.26 eV. This high activation energy coincides with the intramolecular barrier estimated by *ab initio* molecular orbital calculations. On the other hand, all of the devices with electrodes of the second type exhibited a comparatively low activation energy. Neither device type showed a clear gate effect with an electrical field of up to 3 MV/cm. These results indicate that the electrical characteristics of molecular devices are affected by the fabrication process and the resultant molecule-electrode configuration.

Localized Corrosion of Lead in Water Containing High Concentration of Chloride Ions

M. Watanabe, E. Yoneta, S. Yanagi, M. Matsumoto, M. Kama, H. Saito, T. Handa, and T. Sawada

Journal of Material Testing Research Association of Japan, Vol. 56, No. 3, pp. 139–146, 2011.

We investigated the reproduction of crevice corrosion in lead and observed the corroded samples. Electrochemical tests revealed the pitting corrosion mechanism of passive film on lead surface. The crevice corrosion progressed with exposure time. First, a passive film was formed after exposure to the atmosphere. Next, pit corrosion occurred at the film/metal interface. Roughly speaking, the pit corrosion rate was reduced because of the formation of a new passive film. However, the corrosion rate of lead was accelerated when the pH became lower at the crevice.

A System for Creating the Content for a Multi-sensory Theater

K. Hirota, S. Ebisawa, T. Amemiya, and Y. Ikei

Virtual and Mixed Reality—Systems and Applications, Lecture Notes in Computer Science, 2011, Vol. 6774, pp. 151–157, 2011.

This paper reports on the current progress of a project to develop a multi-sensory theater. The project targets not only the development of hardware devices for multi-sensory presentations but also an investigation into the framework and method of expression for creating the content. Olfactory, wind, and pneumatic devices that present the sensation of odor, wind, and gusts, respectively, were developed and integrated into an audio-visual theater environment. All the devices, including the video device, are controlled through a MIDI interface. A framework for creating multi-sensory content by programming the sequence of device operations was also implemented.

Concave-convex Surface Perception by Visuo-vestibular Stimuli for Five-senses Theater

T. Amemiya, K. Hirota, and Y. Ikei

Virtual and Mixed Reality—New Trends, Lecture Notes in Computer Science, Vol. 6773, pp. 225–233, 2011.

The paper describes a pilot study of perceptual interactions among visual, vestibular, and tactile stimulations for enhancing the sense of presence and naturalness for ultra-realistic sensations. In this study, we focused on understanding the temporally and spatially optimized combination of visuo-tactile-vestibular stimuli that create concave-convex surface sensations. We developed an experimental system to present synchronized visuo-vestibular stimulation and evaluated the influence of various combinations of visual and vestibular stimuli on the shape perception by body motion. The experimental results motivate us to add a tactile sensation to facilitate ultra-realistic communication by changing the contact area between the human body and motion chair.

Sparse Source Separation Based on Simultaneous Clustering of Source Locational and Spectral Features

S. Araki, T. Nakatani, and H. Sawada

Acoustical Science and Technology, Vol. 32, No. 4, pp. 161–164, 2011.

This paper proposes blind source separation methods for sparse sources that have an inherent ability to align the permutation of frequency components, and the approach can be applied even if the number of sources is unknown. The proposed method simultaneously classifies both the source locational feature (phase difference between microphones) and the spectral feature (spectral temporal envelope). In this method, source separation in each frequency bin is performed by clustering the source locational features while synchronizing the spectral envelop. Thanks to the common amplitude modulation characteristics, this method inherently aligns the permutation of the frequency components.

Carrier-mediated optomechanical coupling in GaAs cantilevers

Phys. Rev. Vol. B 84, p. 014305, 2011.

H. Okamoto, D. Ito, T. Watanabe, K. Onomitsu, H. Sanada, H. Gotoh, T. Sogawa, and H. Yamaguchi

We have investigated optomechanical coupling in n-GaAs/i-GaAs bilayer cantilevers induced by optical band-gap excitation. The strain-assisted optopiezoelectric effect, which is associated with the separation of electron-hole pairs due to the built-in electric field, causes a time-delayed backaction force and influences the thermal vibration of the cantilevers. Vibration of the [110]-oriented cantilever is amplified by this optopiezoelectric backaction, and self-oscillation is induced for strong excitation. In contrast, for the [$\bar{1}$ 10]-oriented cantilever, the optopiezoelectric backaction dampens the vibration because the direction of the piezoelectric stress is reversed. We have experimentally extracted the response time of this optopiezoelectric backaction, where the delay is on the order of the nonradiative recombination lifetime in GaAs. This optopiezoelectric backaction is maximized when the laser wavelength matches the optical absorption edge. This is because the strain-induced change in the optical absorption is maximized at the absorption edge, so a large force gradient results.
