NTT Technical Review

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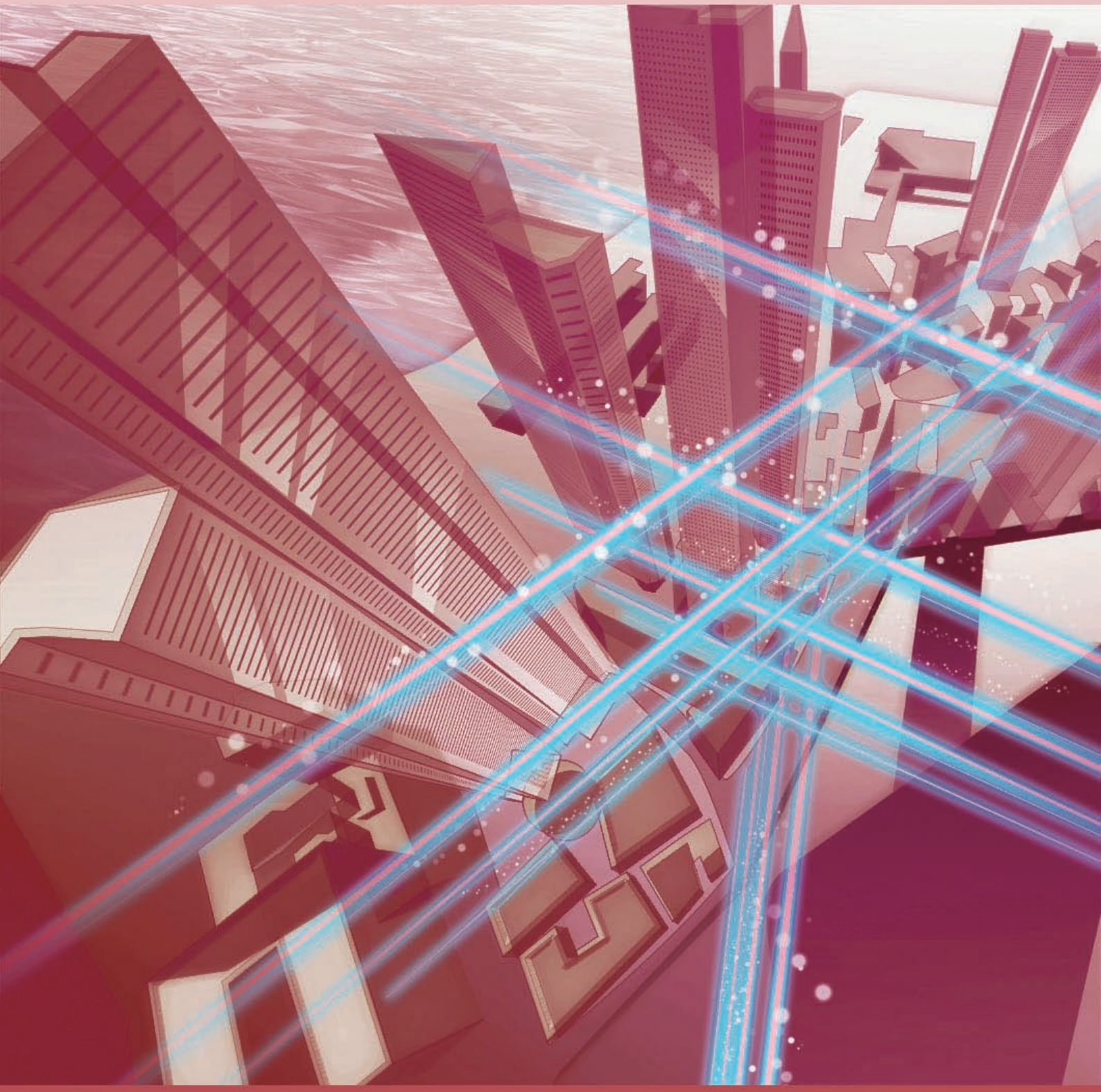

January 2015 Vol. 13 No. 1

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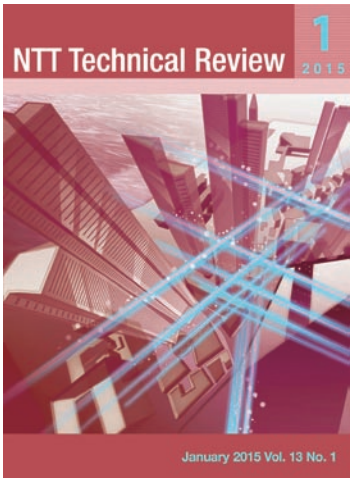


Strengthening the Individual to Reinforce the Entire Group —Towards the Next Stage 2.0

Hiromichi Shinohara
Senior Executive Vice President and Head of R&D Strategy Department, NTT

Overview

Information and communication technology (ICT) has become an indispensable part of our lives supporting finance, education, medical care, and public administration. What kind of viewpoint or behavioral pattern must experts and specialists have in order to develop innovative technologies for achieving a safe and secure society? We sat down with Representative Director and Senior Executive Vice President Hiromichi Shinohara to find out how NTT deals with this question as a leading company.

Keywords: R&D, efficiency, competiveness

Making R&D more competitive and efficient

—Mr. Shinohara, it's been about half a year since you took up your post as Senior Executive Vice President. Please tell us about the conditions that surround technology development today and its future direction.

Well, I see no difference in direction between my position as Head of R&D Strategy Department and as Senior Executive Vice President, but I do feel that my view of research and development (R&D) from a management perspective has intensified. Of course, the importance I place on R&D to grow the NTT Group has not changed, but I must now consider how to make R&D more efficient and competitive across the entire NTT Group.

At present, each of the Group companies is pursuing R&D based on its own policies, which means that work can sometimes be duplicated. To prevent this from happening, I bring together the heads of technology development at each Group company so that they can talk about how to pursue joint development and how best to eliminate overlap in order to optimize work in hot-topic areas such as big data, software-defined networking, and network functions virtualization.

It may be thought that this approach is taken on behalf of the NTT laboratories by NTT as the holding company, but it's essential to enhance the competitiveness of the entire NTT Group. As one who is promoting more efficient and competitive R&D, I consider that one of my new duties is to make it absolutely clear that this approach that I advocate always has the profits of the entire NTT Group in mind.

Changing gears! The 'whole' cannot be reinforced without strengthening the individual.

—It seems that attempting to make R&D more efficient while trying to make it more competitive at the same time is somewhat of a contradiction. How

should researchers take on this challenge?

I consider both to be important and both to be a matter of priority! For example, it goes without saying that R&D is absolutely necessary for an enterprise like the NTT Group that seeks to grow its business by developing and commercializing new technologies and services. On the other hand, making R&D more efficient is a necessity from the viewpoint of corporate management. In addition, these two goals of raising the efficiency and competiveness of R&D are not contradictory; both can be achieved together.

The NTT Group boasts about 2500 researchers within the holding company alone as well as many and diverse research fields appropriate to such a large number of researchers.

Efficiency and innovation are necessary in all research fields, but the specific means of achieving them vary depending on the research theme and development phase. For example, even in the case of "open innovation" that we have recently been emphasizing, researchers need to be aware of what approach should be taken in each research field within the entire NTT Group.

This is especially true when researchers are considering their respective roles in open innovation and collaboration. It is not simply a matter of giving work that one cannot do to others; one must be knowledgeable of one's own strengths and those of other team members and combine those strengths. This assessment can be different depending on whether or not the R&D in question is pursued with a strong sense of purpose. It means the difference between having a desire to develop technology that people find attractive or having a desire to provide society with something really useful. If the latter, the most optimal technology would naturally be selected, as opposed to holding on tenaciously to one's own technology.

I would also like to have our researchers "change gears" according to the present stage of their work. At the research stage, I would like the focus to be on achieving results that individuals are recognized for, such as published papers, but in the commercialization stage, I would like the focus to be on social contributions and product and service penetration.

This way of thinking should prevent individuals from taking matters concerning open innovation at their own pace and minimize lost opportunities to make proposals to the market. It should also help transform the cooperative system within the NTT Group.

—I see: testing the waters and changing gears in research work based on many aspects such as the individual's attitude and market conditions are important. The direction to take can be clarified in this way.

To begin with, I would ask a researcher to reassess the project that he or she is working on. In the case of basic research, one cannot cut corners and do shoddy work. At the same time, commercializing the results of research for practical use is important. I would like the researcher to consider the state of progress of the research and current market trends and give serious thought as to how that project is currently positioned in the steps involved in moving from basic research to commercialization. To the researcher, I would say: "Try changing your point of view by putting yourself in the mind of a person one or two levels higher than you."

R&D is an aggregate of "individuals" having different values. If all employees exhibited the same behavioral pattern, we could not hope for any improvement in values. I believe that it's important that each researcher be aware of the type of behavioral pattern that he or she should adopt. It's not a question of simply receiving orders from above and doing what one is told. It is more important to ask oneself what role one should play as a researcher and get moving by looking upon that role as "work."

By the way, it's not my intention here to impose a certain way of doing things on anyone. I would like all of our researchers as specialists to find on their own the best techniques to achieve their R&D goals. That is, I would like them to find the best way to reach the summit of the mountain they are climbing. What's

important here is that the mountain that each of us must climb is something common to all of us. For this reason, I ask researchers to not get caught up in the words uttered by their superiors and colleagues but to continuously refine their ability to grasp the real meaning or intention behind those words. The whole cannot be reinforced without strengthening the individual!

Towards the Next Stage 2.0: Updating NTT's Medium-Term Management Strategy

—What, then, is the mountain to climb in 2015?

NTT announced an update to its Medium-Term Management Strategy as part of its first-half financial results for the fiscal year ending March 31, 2015 released last November. This update, called "Towards the Next Stage 2.0," states that management will place more importance this year on increasing profits. This includes cost efficiency made possible by our innovative technologies. For corporate management, cost efficiency is extremely important along with increased profits.

However, employees say that they don't feel a boost in morale when hearing that their work is contributing to "cost efficiency." Perhaps this is because of the feelings evoked upon interpreting the words "increase" and "efficiency." At the risk of repeating myself, though, there is value in cost efficiency.

Let me tell you about our undertakings this year in the form of three main projects.

1. Strengthen the competitiveness (enhance the profitability) of network services

Strengthening the competitiveness of our network services can only be achieved through technology development. In just these last few years, we have been introducing integrated-layer transport equipment (100G Policy Traffic Switch) to simplify the network originally configured with multistage connections and a Packet Transport Multiplexer link system to achieve low-cost transmission by integrating the fixed telephone network and the Internet on the packet network. These measures have been achieving cost efficiency and contributing greatly to meeting management objectives. So this year too, I ask our researchers to work with conviction in strengthening the competitiveness of our network services.

As for enhancing the profitability of our network services, I will promote R&D on finding ways of using the network to increase revenues in addition to efforts at streamlining network operations and making them cost efficient. However, I would like to see the NTT Group create new value together with our partners in a behind-the-scenes role, not as a main player. Of importance here is that the results of collaboration in R&D have the power of making 1 + 1 equal not 2 but rather, 3 or 4! This is what I expect of R&D. I would like to move forward by taking the viewpoint of our partner and thinking always how best to use the results of our research to increase our partner's value.

2. Strengthen the cyber security field

This year, we will also work to strengthen the field of cyber security. As you know, cyber attacks are increasing dramatically year-by-year and evolving rapidly. In today's society, all industrial fields including power, transport, and distribution are interconnected via the network. It is therefore imperative that we as an ICT enterprise increase our cyber security abilities, but at the same time, society on the whole must deploy and strengthen cyber security systems. With this in mind, we will first undertake the development of cyber security professionals within the NTT Group. In a five-year plan running to 2020, the goal is to train about 10,000 employees within Japan in development, consultation, and other cyber security-related areas.

Additionally, in the new fiscal year, we will contribute to cyber security training for Japan on the whole. For example, we will provide a course titled "Cyber-attack and Cyber-defense Technologies" at Waseda University. This course will be given by NTT engineers active in the field and will cover the ever-changing conditions in cyber security. In the future, we would like to expand such courses to many more universities in collaboration with other companies. We are also endeavoring to provide a course titled "Information Security for Complete Novices" as part of *gacco*, a joint project of NTT DOCOMO and NTT Knowledge Square providing MOOCs (massive open online courses).

3. Make social contributions through globally advanced technologies

We will advance the preparation for the international sports event to be held in Japan in five years. Of course, we can anticipate all kinds of attacks from fame-seeking hackers as is typical of major events, so enhancing cyber security for this event is a must. For this reason, we will mount a full response to these threats by establishing a close link between operations and technology development. We also expect network traffic characteristics that we have not experienced before to occur in certain areas and during certain time periods as spectators congregate or move about during this event. The challenge here is to come up with novel means of dealing flexibly and economically with these traffic characteristics and raising reliability, including the use of Wi-Fi*. We have already begun testing with a focus on detecting the signs of such traffic characteristics. In addition, we aim to leverage advanced technologies to present information with a high sense of presence heretofore not experienced and to provide a user-friendly network environment. Our target audience here will not only be tourists from abroad but also those attending events in various regions of Japan. I believe that the provision of technologies and services that can inspire and surprise society can help foster the development of children—our future leaders—and provide a great opportunity for Japan to display its fundamental strengths to the world.

—Mr. Shinohara, as we enter a new year, can you leave us with a message for all NTT employees?

I would be happy to. First, to our young employees, please keep in mind that a wide variety of viewpoints can be used in assessing whether something is right or wrong, and what is right or wrong can even change with the times. So please try to state your case to the people around you based first on your own logic. Then, if opposing opinions are expressed, use that as an opportunity to reevaluate and refine your ideas instead of getting discouraged. What you should fear is losing out on an opportunity to grow.

Next, to our medium- and long-term employees, the time you have left to experience your work is, in reality, becoming shorter compared to your younger days. So be aggressive in expressing your opinions before it's too late. Both autonomy and heteronomy are important. Make an effort to create an environment in which you can listen to the opinions of those around you and revise your own opinions accordingly.

Interviewee profile

■ Career highlights

Hiromichi Shinohara joined Nippon Telegraph and Telephone Public Corporation (now NTT) in April 1978. In June 2003, he became a Vice President of Access Network Service Systems Laboratories of the Information Sharing Laboratory Group. He became a Senior Vice President of the Information Sharing Laboratory Group in June 2007. In June 2009, he became a Member of the Board of NTT and Head of R&D Strategy Department. In June 2012, he became Executive Vice President and Head of R&D Strategy Department. In June 2014, he took up his present position.

* Wi-Fi is a registered trademark of Wi-Fi Alliance.

Trends in ICT Involving Life-assist Technologies to Address Social Challenges

Hiroki Morimura, Hiroshi Koizumi, and Akihiko Hirata

Abstract

Various social challenges exist, and some have become serious issues in recent years, for example, the rising cost of medical care due to our aging society and the declining population, and also the increasing infrastructure maintenance costs. Many solutions based on information and communication technology (ICT) are being advocated in various fields and domains. In this article, we review technical trends in ICT directed towards such social challenges, and we introduce life-assist technology that has been developed based on device research and development at NTT laboratories as a new innovative approach to meeting these challenges. The potential use of life-assist technology in gathering and analyzing data on the conditions of people or infrastructure to predict abnormalities could play a major role in preventing illnesses or accidents.

Keywords: healthcare device, low-power wireless sensor nodes, terahertz technology

1. Introduction

Wearable devices equipped with a sensing function and wireless communication capability have become a focus of attention in recent years. Although wireless sensor networks (WSNs) have been advocated as a way to advance the ubiquitous network society by transmitting various sensing data to the Internet, there is a lack of key applications for these networks due to restrictions on the size and battery life of the sensor nodes. WSNs have therefore not become as widespread as ICT (information and communication technology), which has spread dramatically.

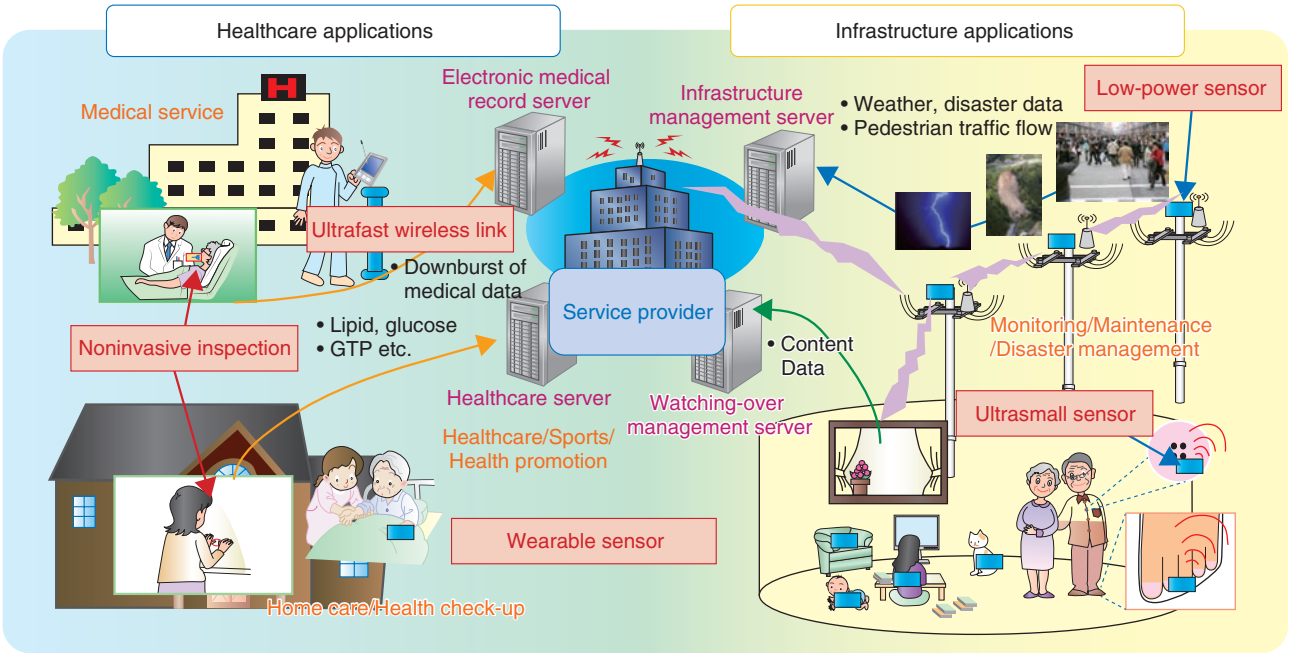
1.1 Advances in technology

However, this situation is rapidly changing with the explosive popularity of smartphones. Smartphones come pre-installed with the GPS (global positioning system) function, Wi-Fi[*1], Bluetooth[*2], and accelerometers, which provide a basic platform for sensor nodes. Moreover, they also function as a hub station that connects to various kinds of electrical equipment. For these reasons, smartphones are starting to be utilized as a platform for connecting wearable devices.

Before the widespread use of smartphones, all components of wearable devices such as the display, processor, wireless communication, and sensing unit, had to be unified in one package. This situation has abruptly changed, though. Now, they only have to have a sensing function and short-range wireless communication capability. Furthermore, there are growing expectations for the development of small sensor nodes that can be embedded in any object without the need for node maintenance. These small sensor nodes will be able to provide more efficient services for infrastructure maintenance, building maintenance, and logistics management. Concretely speaking, these are self-powered wireless sensor nodes that harvest minute amounts of energy from the environment.

Thus, we are seeing the start of huge data processing using cloud technology, which enables the

*1 Wi-Fi is a registered trademark of Wi-Fi Alliance.
*2 Bluetooth is a registered trademark of Bluetooth SIG Inc.



GTP: Guanosine triphosphate

Fig. 1. Innovative approaches to social challenges through life-assist technology.

extraction of useful information and returns it to society or users. This information is commonly known as *big data*. Another advance is that an infrastructure connecting all devices and sensors to the Internet—referred to as the Internet of things (IoT), M2M (machine to machine), or ambient intelligence—is becoming a reality.

1.2 Industrial revolutions

This technological progress has led to many approaches being explored in attempts to build a safe, secure, and healthy society by connecting the real world and cyberspace in a network. In recent history, there have been three industrial revolutions due to technological innovations. The primary industrial revolution in the second half of the 18th century occurred with the invention of the steam engine. The second one was a result of the remarkable improvement in productivity in the second half of the 19th century. The IT (information technology) revolution in the second half of the 20th century is also called the tertiary industrial revolution. A fourth industrial revolution is expected to occur in around 2030, when cyberspace unites with the real world to create something called a *cyber-physical system*. It is said that IoT will play an important role in the fourth industrial revolution. Therefore, data gathering is one of the initial tasks for approaches aimed at meeting social challenges.

A very important issue in business strategy is determining how to obtain information about people and things in the real world from the cyberspace of the Internet. Many technologies have been developed in attempts to meet this challenge. A device that contributes to resolving this issue is called a *social device*. If such social devices become widely used by people in homes, offices, and infrastructure, it is expected that these devices will help to solve social challenges and contribute to people living happy and fulfilling lives.

2. Life-assist technology based on social devices

NTT Device Technology Laboratories has been developing social-device technology that includes sensing and short-range communications to monitor the conditions of people or infrastructure and to support data analyses and diagnoses, as shown in **Fig. 1**. We believe that these social devices connected to the network will lead to new business opportunities, and that a safe, secure, and healthy society will become a reality. Moreover, they will also contribute to efficiently reducing infrastructure maintenance costs

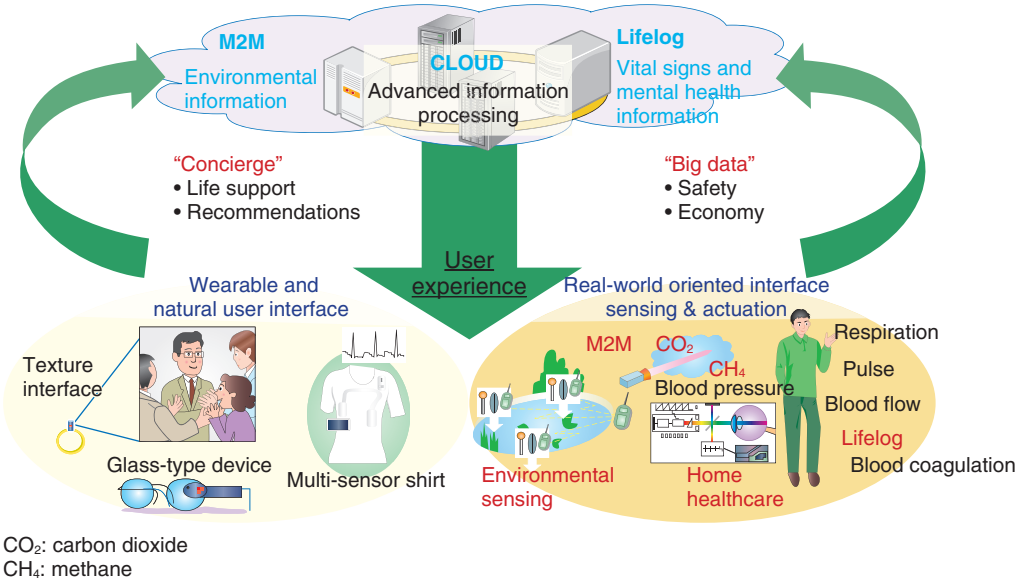


Fig. 2. User experience boosted by wearable devices.

(e.g., due to their labor-saving capabilities and the use of full automation). It is thought that wearable devices with sensing and transmitting functions and ultrasmall, batteryless sensor nodes with an energy harvester as a front-end for big data will pave the way to such a propitious world.

Life-assist technology is based on social devices, but it also includes ultrafast wireless links and ultra-high-resolution sensing to create new possibilities in medicine. Life-assist technology involves more than just devices, however; it also concerns technology for assisting us in our life directly or indirectly. Research and development (R&D) is currently underway in three areas of life-assist technology, as follows.

2.1 Healthcare devices

An image of the new user experience with healthcare devices consisting of wearable technologies is illustrated in **Fig. 2**. Wearable devices can be worn in various forms such as a watch, glasses, a necklace, or a shirt. The place where such healthcare devices are worn on the body and the implemented function are important. Everyday biomedical signals are simply individual big data (on one's physical and/or mental condition, and current activity) that change continuously with the environment. Our technical aim is to extract and provide this valuable information without disrupting a person's activities. Therefore, we are developing wearable devices that connect to mobile devices. Mobile computing devices such as smartphones are very convenient as platforms for carrying out data transfer to the cloud because they are equipped with a high-performance processor, a high-definition display, and large storage capacity. High-added-value information processed in the cloud using machine learning is fed back to the user. We are promoting the research of wearable healthcare devices in order to provide an epoch-making user experience that supports a healthy and comfortable life.

2.2 Low-power wireless sensor nodes

Services using low-power wireless sensor nodes are illustrated in **Fig. 3**. We want to reduce the power consumption of our wireless sensor nodes to the point where one coin-type battery lasts for ten years, or there is no need of a battery at all owing to energy harvesting technology, such as with indoor light power generation. This will eliminate the need for node maintenance and make it possible to install large numbers of sensor nodes almost anywhere. With such technology, monitoring and telecontrol of appliances in homes will become possible by using sensing information. Furthermore, the ability to analyze the gathered data will lead to the creation of new businesses in areas such as childcare support, watching-over the elderly services, home medical care, infrastructure maintenance, and environmental monitoring.

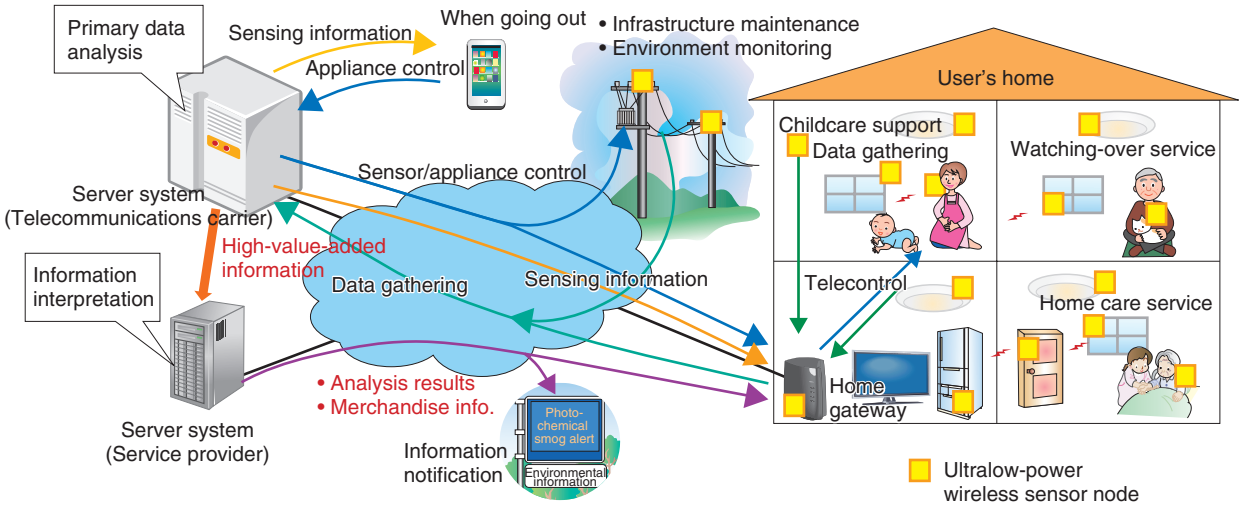


Fig. 3. Various services based on ultralow-power wireless sensor nodes.

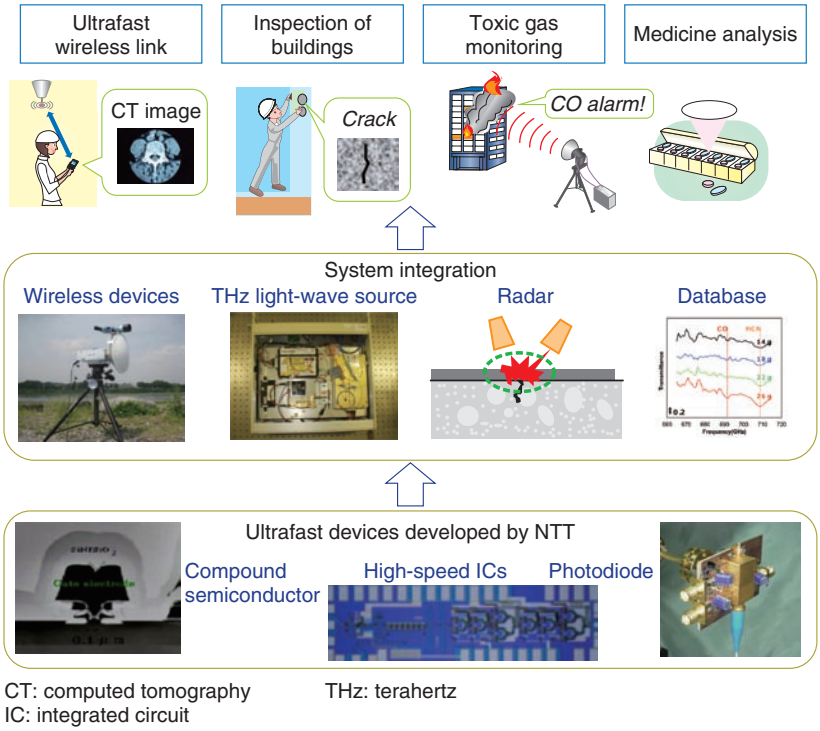


Fig. 4. Millimeter-wave and terahertz-band ultrahigh-speed wireless communication and sensing systems.

2.3 Terahertz-band ultrahigh-speed wireless communication and sensing system

Our ultrahigh-speed wireless communication and sensing technologies use millimeter waves and terahertz waves (**Fig. 4**). These waves are broadband waves that strongly interact with molecules; however, these frequency bands have not been investigated for industrial use because it is difficult for the state-of-the art devices to generate and detect terahertz waves. NTT has made it possible to construct millimeter-wave-band

or terahertz-band wireless communications and sensing systems by developing ultrafast transistors and photodiodes. These systems are expected to be used for instantaneous download of large-capacity data at medical sites, nondestructive inspection of buildings, and remote monitoring of toxic gases at the scene of fires.

3. Topics and structure of Feature Articles

The Feature Articles in this issue introduce six areas we are working on at NTT laboratories.

The first three cover our healthcare devices. The article entitled "Development of Applications for a Wearable Electrode Embedded in Inner Shirt" presents application examples for a wearable heart-rate and electrocardiogram (ECG) monitoring system that includes our wearable device for detecting and transmitting ECG signals. This system obtains a user's vital information when the user simply wears the shirt, without getting in the way of normal daily life activities, and it extracts useful information such as changes in both mental and physical condition. Examples of applications for entertainment and life-log recording are explained [1].

The article entitled "Blood Flow Observed with Smartphone—Ultracompact Wearable Blood Flow Sensor" explains the concept of a blood flow sensor and discusses the design, performance, and application of a system developed at NTT. The unique system design concept was devised for functional use with a smartphone and achieves drastic weight and power savings [2].

A new blood test technology using integration of surface plasmon resonance (SPR) and microfluidics is introduced in "MicroTAS for Biosensors." This biosensor is expected to be applied in medical examinations in which the blood coagulation of patients is observed in order to check for abnormal heart rhythm (atrial fibrillation), cerebral infarction, DVT (deep vein thrombosis, or so-called *economy class syndrome*), and other conditions. We demonstrate how our new design combining SPR and microfluidics solves issues in blood coagulation examinations [3].

The two subsequent articles describe sensing and mobile devices that use ultralow power and ultrahigh-speed wireless technologies.

"Ultralow-power Sensor Node with Nanowatt Wireless Circuit Technology" presents nanowatt-level wireless circuit techniques and an evaluation kit that enables us to evaluate experiments by connecting various sensors. These techniques make it possible to create small wireless sensor nodes without the need to replace batteries. The article describes the effectiveness of the sensor node in logistics management and infrastructure maintenance and as a simple means of transmitting vital data [4].

"Terahertz Device Technologies for Ultrafast Data Downburst Applications" presents the recent progress in modulator IC (integrated circuit) and antenna technologies for terahertz wireless communications, which is expected to achieve 100-Gbit/s data transmission. These technologies enable us to download large-capacity data instantaneously. Therefore, one promising application of these technologies is instantaneous transfer of large capacity data such as image data between medical devices at medical sites [5].

The final article, "Continuous Wave Terahertz Spectroscopy System Designed for Medical Field," presents advanced approaches that contribute to predicting a medicine's efficacy. This technology features the use of terahertz-band homodyne spectroscopy using continuous waves. We have shown that our spectroscopy system enables quantitative analyses that can distinguish the pharmaceutical cocrystals that affect the efficacy of medicine [6].

As demonstrated by these six Feature Articles, the continued R&D of life-assist technology based on social devices as a new innovative approach to social challenges will contribute to our ability to live happier, healthier, and more fulfilling lives.

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He received the B.E. in physical electronics, the M.E. in applied electronics, and the Dr.Eng. in advanced applied electronics from the Tokyo Institute of Technology in 1991, 1993, and 2004, respectively. He joined NTT in 1993. He has been engaged in R&D of low-voltage, low-power SRAM (static random access memory) and complementary metal oxide semiconductor (CMOS) fingerprint sensors. His research interests include noise tolerant circuit design for short-range wireless communications, ultralow power circuit techniques for batteryless sensor nodes, and integrated CMOS-MEMS (microelectromechanical system) technology.

Dr. Morimura served on the program committee of the Symposium on VLSI technology (2011–2014), and the program subcommittee on Advanced Circuits and Systems of SSDM (2011–2013). He also served as a special section editorial committee member of the IEICE Transactions on Electronics in 2011–2012. He received the 2004 CSS Best Paper Award, the 2006 IEICE Best Paper Award, the Best Paper Award of the Symposium on Integrated MEMS Technology at the 26th Sensor Symposium, and the Best Paper Award of IEEE CPMT Symposium Japan 2012. He is a member of the Institute of Electrical and Electronics Engineers (IEEE), the Institute of Electronics, Information and Communication Engineers (IEICE), and the Japan Society of Applied Physics (JSAP).

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He received the B.S. and M.S. in materials engineering from Waseda University, Tokyo, in 1990 and 1992, respectively. Since joining NTT LSI Laboratories in 1992, he has been engaged in R&D of high-speed LSIs for optical communications. His current research interests include optical-biosensing devices. He is a member of IEEE, JSAP, and IEICE.

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He received the B.S. and M.S. in chemistry and the Dr. Eng. in electrical and electronics engineering from the University of Tokyo in 1992, 1994, and 2007, respectively. He received the 2011 Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology.

Development of Applications for a Wearable Electrode Embedded in Inner Shirt

Takayuki Ogasawara, Kazuyoshi Ono, Nobuaki Matsuura, Masumi Yamaguchi, Junji Watanabe, and Shingo Tsukada

Abstract

NTT has developed a conductive fabric called *hitoe* that enables continuous measurement of the biological signals of the person wearing it. Heartbeat variations and electrocardiogram signals detected through hitoe are transmitted wirelessly by a compact dedicated device to a smartphone or tablet, where they can be readily checked using an application. Such technology is expected to lead to the creation of new services in fields such as sports training, health enhancement, security and safety, medical care support, and entertainment. In this article, we introduce some examples of approaches to application development.

Keywords: wearable, electrocardiogram, smartphone

1. Introduction

NTT has collaborated with the textile manufacturer Toray Industries, Inc., to develop a conductive fabric called *hitoe* that enables continuous measurement of the biological signals of the person wearing it [1]. Hitoe is a woven fabric that was created by coating fiber surfaces with an electrically conductive polymer material (PEDOT-PSS: poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate)) [2]. Integrating this fabric with an inner shirt makes it possible to easily record heartbeat variations and electrocardiogram signals over the long term in a variety of daily life scenarios (**Fig. 1**). These physiological signals are measured and then transmitted wirelessly by a compact dedicated device to a smartphone or tablet, where they can be readily checked by using the appropriate application.

Heartbeat variations are naturally of interest in the field of healthcare, but they can also be used as health indicators in sports or dietary activities [3]. It has previously been reported that hitoe can stably measure vital data during sports activities, for example, in sports with intense movements such as badminton [4]. In addition, variations in heartbeat are thought to be related to the sympathetic nervous system and are known to act as indicators of emotional stress [5]. By focusing on the development of both physical and emotional aspects, we can expect to see new services created in the fields of sports training, health enhancement, sleep management, medical care support, security/safety, and entertainment. To cover such a variety of services, it is essential to implement highly applicable systems in which smartphones and tablets are linked to a cloud service. In this article, we introduce three initiatives from the entertainment field and the security/safety field as applications of hitoe.

2. Applications in the entertainment field

Hitoe was exhibited at the Niconico Super Conference 3, an event attracting 100,000 fans of the

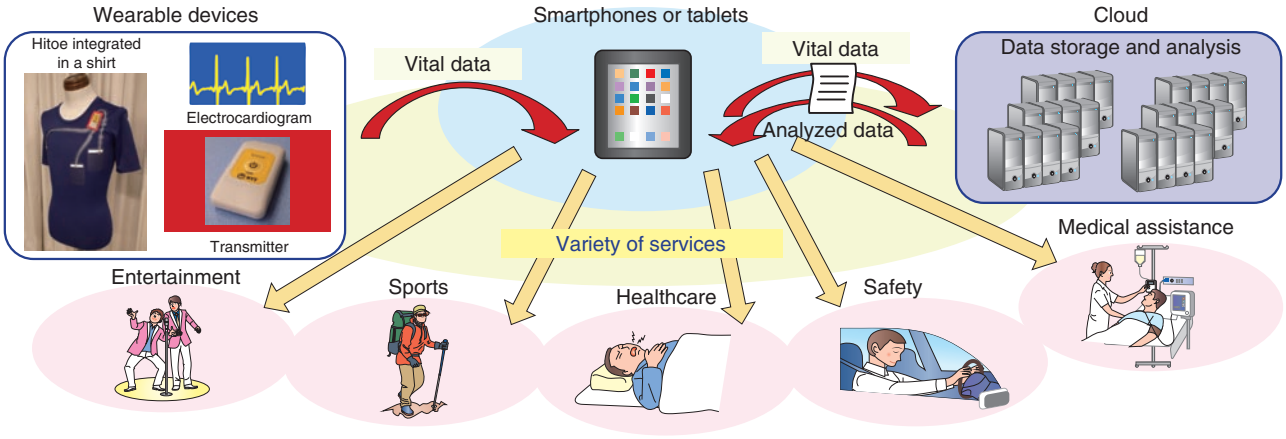
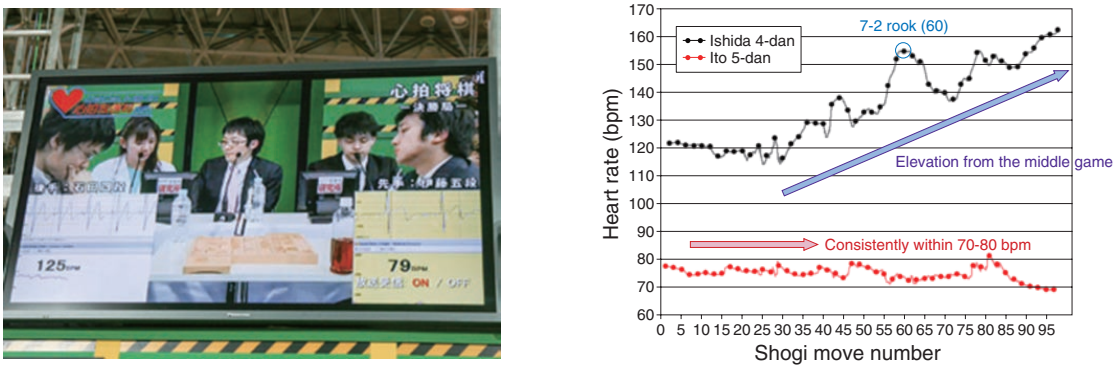


Fig. 1. Future applications of wearable system using hitoe fabric.



(a) Appearance on screen

(b) Heart rates during final game

Fig. 2. Heartbeat Shogi.

Niconico website, on April 26–27, 2014, at Makuhari Messe, Chiba, Japan [6]. We asked various guests to wear hitoe shirts during the conference, and we held five events including talk shows and games. We describe two events here: the First hitoe Cup Heartbeat Shogi Tournament and the Analog Game Workshop at Heartbeat University.

2.1 First hitoe Cup Heartbeat Shogi Tournament

Heartbeat Shogi is a name we coined for this event. It is a shogi (Japanese chess) TV program in which the heart rates of the players wearing hitoe shirts were measured and displayed to visitors on monitors and to an online audience over the Internet. We were looking for a new form of entertainment in which viewers could not only enjoy the battles taking place on the game boards and the body language of the players but could also understand the physiological changes the players were experiencing that we usually have no means of knowing about from their outside appearance. We set up a tournament and invited three professional players to take part in it (**Fig. 2**). The players wore hitoe inner-shirts during the matches.

The heart rates of the players during the final game are shown in Fig. 2(b). The heart rate is plotted along the vertical axis and the shogi move number along the horizontal axis. The heart rate of Shingo Ito, 5-*dan* (on the right in Fig. 2(a)), was within the 70- to 80-bpm level throughout the entire game. The heart rate of Naohiro Ishida, 4-*dan* (on the left in Fig. 2(a)), on the other hand, tended to rise from the middle game and even reached the 160-bpm level in the endgame. Such information was delivered to the audience in real time by integrating the wearable technology with

an Internet image relay.

If we focus on more subtle heartbeat variations, we see that the heart rate of Ishida peaked at 7-2 rook in the middle game (Fig. 2(b)). This occurred at a game position where he took Ito's bishop. Ishida's heart rate continued to rise even in the endgame until Ito resigned. We think that this gives a glimpse into the correspondence between heartbeat variations and game position and can become a method of conveying a further sense of excitement to the audience.

Naohiro Ishida won the tournament and was given the title of First hitoe Heartbeat Shogi Meijin by Hiroo Unoura, President & CEO (Chief Executive Officer) of NTT. A better understanding of the relationship between heartbeat variations and emotional state was gained from the post-game discussion. Ishida, 4-dan, thought back and said that "The endgame was so tense, I could feel my own heartbeat. Even though I was playing aggressively and was in the lead, one false move and I would have lost the game." We can infer from this that the anticipation of making the most of his chances in the game caused him inner tension. Ito, 5-dan, said that "By the endgame, I thought I had already lost, so I was completely relaxed." This perspective might be one reason why his heartbeat variations were stable through the game. With shogi, decisive moments and relative superiority according to the game position can be seen on the board. However, the players' own evaluations of the board positions and their level of tension can usually only be determined by their expressions or actions. We expect that the display of heart rates as an element that mirrors changes in the tension and emotional state of the players during games such as shogi will add new interest for viewers.

2.2 Analog game workshop at Heartbeat University

Heartbeat University is an educational program led by instructors with interests in particular areas. The first instructor we invited to be part of this program was Jun Kusaba, the originator of *Game Market*, Japan's largest analog game experience and sales event and also the executive of the Gaming History Society. He gave a lecture and led workshops in an analog game. During the workshops, participants who were acting as students played an analog game under the coaching of Mr. Kusaba. The students wore hitoe shirts, and their heart rates were measured (**Fig. 3(a)**). We used the card game called *Divinare* in the workshop sessions (**Fig. 3(b)**). There are cards in four colors (red, blue, yellow, and green), and the game involves correctly predicting how many cards of each color were dealt. In this game, the luck and hunches of the players feature highly, in contrast to shogi, and even a beginner has a chance of winning. It was therefore expected that the heartbeat variations would be different from those of the shogi players. Each student was given three points if the predicted number of cards matched the correct number of cards, one point if the number differed by one, and minus one point otherwise.

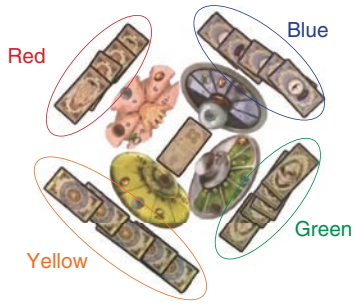
They played four rounds and competed for the total number of points. An example of a student's heartbeat variations is shown in **Fig. 3(c)**. A rise in heart rate can be seen near the end of each round. This was assumed to be related to the way that the difference in his predicted number of cards and the correct number of cards was revealed at the end of each round; the previously unknown correct number of cards is gradually revealed as the game progresses. One student replied in a questionnaire given after the game was finished, that after the second round, "I was in fine form so I thought I might win if I carried on" and after the fourth round, "I thought that I would definitely hold on to my lead and receive a prize." This shows that it is possible for such anticipation and agitation to be reflected in the heart rate.

However, variations in heart rate such as those of this student were not the only interesting example. There was another student whose heart rate remained about 30 bpm higher than usual from beginning to end, irrespective of developments during the game. To integrate biosignal measurements effectively into entertainment, it is important that repeatability between large numbers of people is confirmed and also that variations in the biosignals are presented in correspondence with the event in a way that the audience can understand. It is essential to explore the concept of creating events based on an understanding of the mechanisms of the body, then to search for methods of applying biological information from various viewpoints.

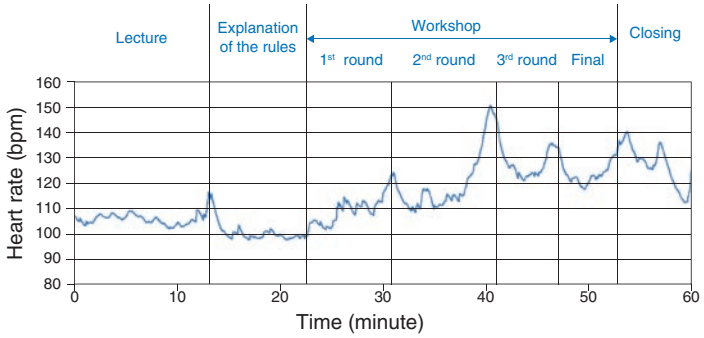
3. Application to security/safety

It is now possible to buy and sell an enormous variety of goods over the Internet, and the demand for distribution and delivery of goods is therefore very high. This has increased the importance of understanding the physical condition and stresses of vehicle drivers. Focusing on heartbeat variations and perspiration as stress markers during driving is thought to be effective for this [7]. We had people wear hitoe

(a) Appearance on screen



(b) Image of Divinare game



(c) Heart rate of one player during Divinare lecture and workshop

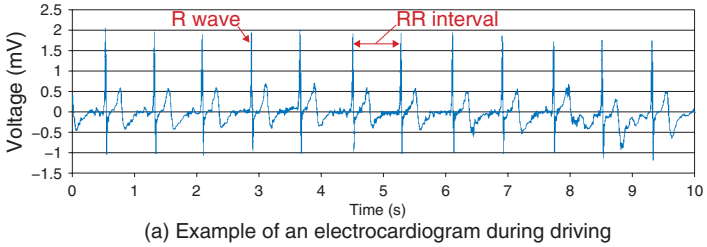
Fig. 3. Heartbeat University.

shirts and then measured their heartbeat variations while they participated in driving tests under real-life conditions. An example of an electrocardiogram waveform taken while a subject was driving is shown in **Fig. 4(a)**. The subject's R waves, which are features of the electrocardiogram waveform, can clearly be seen. Photos taken when the driver was traveling along a road through a pass in a mountain region and along a suburban road with good visibility are shown in **Figs. 4(b)** and **4(c)**. The road through the mountain pass was a narrow one-lane road with a sequence of curves such as that shown in the photo. In contrast, the road with good visibility was a two-lane road that was fairly straight.

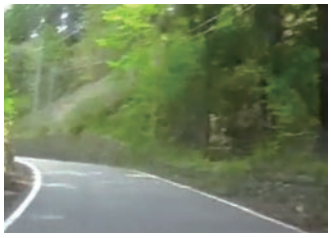
We can visualize heartbeat variations from an electrocardiogram waveform by representing them in Poincaré plots, as shown in **Figs. 4(d)** and **4(e)**. A Poincaré plot is a graph in which the n-th RR interval (the interval between two consecutive R waves; see Fig. 4(a)) from the start of measurement is plotted on the horizontal axis, and the next (n+1)-th RR interval is plotted on the vertical axis. When the driver is in a stressful situation, the fluctuations in heartbeat variations are small, and the plotted points clump together [8]. Conversely, when the driver is relaxed, the plots scatter. A comparison of the plots of Figs. 4(d) and 4(e) shows that the plot for the mountain pass road is clumped closer together than that for the good-visibility road, suggesting the driver was under more stress on the mountain road. A questionnaire was later given to the driver, who said that on the mountain pass road, "I was driving cautiously since I didn't know when an oncoming car would appear from a blind corner," which verified that the driver had a certain sense of tension. This was a fundamental evaluation, but in the future, we plan to estimate driver fatigue, impaired physical condition, or drowsiness, which will contribute to improved security and safety while driving and also effective employee management support.

4. Future developments

In this article, we introduced three applications of hitoe. The ways in which these applications are implemented and combined with other technology will differ with the intended use, but it is important that each application has a high level of usability. We should provide a system that is easy to use, even for people who are not experienced with smartphones,

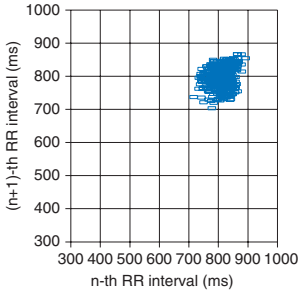


(a) Example of an electrocardiogram during driving

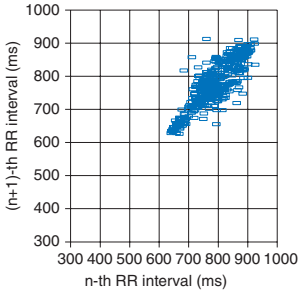


(b) Mountain pass

(c) Road with good visibility



(d) Poincaré plot for mountain pass



(e) Poincaré plot for road with good visibility

Fig. 4. Heart rate of driver while driving.

and a full range of functions corresponding to individual needs. Apart from the methods described here, we are also promoting links with the GPS (global positioning system) functions of smartphones, various sensors, SNSs (social networking services), and digital games with business partners.

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Blood Flow Observed with Smartphone— Ultracompact Wearable Blood Flow Sensor

Kei Kuwabara, Yuichi Higuchi, Hiroshi Koizumi, and Ryoichi Kasahara

Abstract

The flow of blood that circulates through the entire human body and supports life changes dynamically with our emotional and physical state and reveals a huge amount of information. If the flow of blood could be easily visualized in our daily lives, we could expect to see a range of useful applications in areas such as health, beauty, and sports. In this article, we introduce an ultracompact, wearable blood flow sensor that is linked to a smartphone, making it possible to view the flow of blood anywhere and at any time.

Keywords: blood, smartphone, wearable

1. Introduction

The adult human body is estimated to consist of several dozen trillion cells [1]. The oxygen and nutrients necessary for the life of these cells are supplied via the blood that circulates through the entire body. In addition, carbon dioxide and other waste products excreted from the cells are collected in the blood flow. The red blood cells, the major component of blood, account for a large proportion of the total cells in the human body, so we can say that our lives are supported by the flow of blood.

Various health problems can occur if this vital flow is impeded. Heart disease and cerebrovascular disease, the second and third most common causes of death among Japanese people, are prime examples of this. Other bodily disorders that routinely worry many people, for example, chills, numbness, and body stiffness, are also thought to be caused mainly by obstructions in the flow of blood [2]. The importance of blood flow is also recognized in areas such as the beauty industry and sports medicine.

Thus, the flow of blood is vital to human life, and if we could better comprehend it, it might lead to people rethinking their lifestyles and undertaking activities to improve blood circulation. However, it has not been possible for people to measure their blood flow routinely. This is because commercially available blood flow meters are large, impossible to carry around, and expensive, so they can only be used in hospitals and other such facilities. Consequently, we are applying technology acquired through NTT's past communications-related research and development (R&D) to develop a portable, compact blood flow sensor [3]. We have extended this technology even further and linked this blood flow sensor to a smartphone, which will enable users to visualize the flow of blood in daily life over extended periods.

2. System configuration and operating principle

The configuration of our prototype blood flow sensor system is shown in **Fig. 1**. This system consists of a sensor device and a dedicated application for a smartphone. The sensor device consists of a sensor head and a main unit. A laser diode (LD) and a photo diode (PD)—a light-sensitive element—are installed in the sensor head. Infrared light from the laser shines

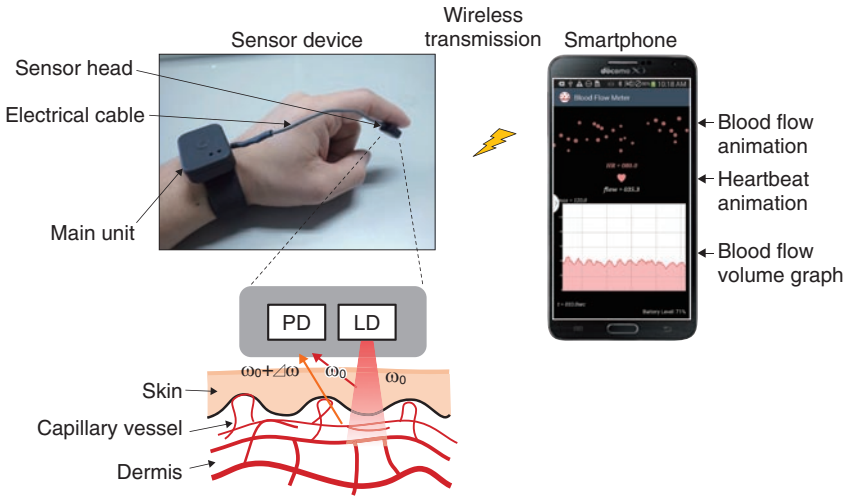

Fig. 1. System configuration of blood flow sensor.

on the skin, and light that is scattered back is detected by the PD. Light that strikes and is scattered by the red blood cells moving within the blood vessels generates a frequency shift that is proportional to the velocity of the moving red blood cells due to the Doppler effect of light, so it is possible to acquire information relating to the flow of blood by analyzing the frequency spectrum of the detected signal [4]. With this information, the smartphone provides visualizations such as a graph of the blood flow volume*1 or animations of the flow of blood and the beating heart.

The weight and power consumption of this blood flow sensor are compared with those of a previous NTT prototype model and a commercially available blood flow meter in **Fig. 2**. The weight and power consumption of the previous NTT prototype model were far lower than those of the commercial blood flow meter. The weight was approximately one-thirtieth lower, and the power consumption was approximately one-fortieth lower. Our current prototype model reduces these values even further; the respective weight and power consumption are approximately one-quarter and one one-hundredth that of the previous NTT prototype. This enables a new form of use in that it can continuously monitor changes in the blood-flow during the day, while being easily carried around in daily life. There are two reasons we were able to achieve such huge reductions in weight and power consumption. The first reason is that some of the functions installed in the previous sensor device are now provided by the smartphone because the

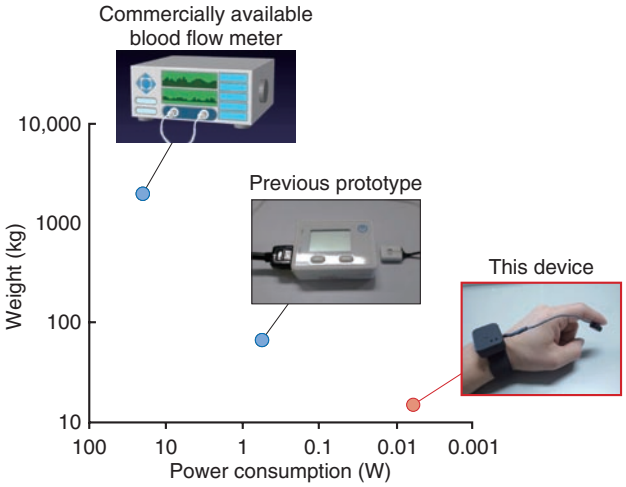

Fig. 2. Comparison of blood flow sensors.

overall system design is based on a link with a smartphone. The second reason is that we modified the circuitry and signal processing so that the blood flow sensor would operate intermittently at high speed in order to achieve efficient operation. We explain these technologies in more detail in the following sections.

*1 Blood flow volume: A quantity equivalent to the sum of the products of the velocity of the blood cells and the number of blood cells.

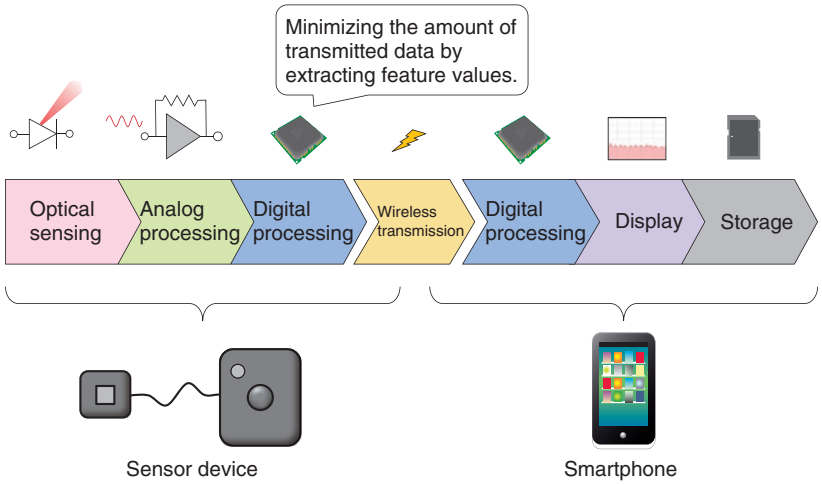

Fig. 3. Sharing of functions between sensor device and smartphone.

3. System design technology linked to smartphone

A blood flow sensor must have certain functions, for example, optical sensing, analog signal processing, digital signal processing, the capability to display the analysis results, and storage. In the past, sensor devices had to be equipped with all of these functions. However, this situation has changed greatly with the recent spread of smartphones. Smartphones come equipped with features such as a sophisticated processor, a high-definition display, a large-capacity memory, and communications functions, and therefore, we were able to install only the minimum necessary functions in the sensor device by actively applying other functions on the smartphone. A sensor that functions in integration with a smartphone in this way is called an *appcessory* (a portmanteau word combining *application* and *accessory*), and it has recently become a new trend in sensor development.

To make the sensor device smaller and reduce its power consumption, it is important to optimize the sharing of functions between the sensor device and the smartphone. An image of the function-sharing of our prototype blood flow sensor is shown in **Fig. 3**. The sensor device implements the processing of raw data acquired by optical sensing—from amplification, filtering, and sampling, to the extraction of feature values by digital signal processing. It relies on a smartphone for other functions such as advanced digital signal processing and the display and storage of analysis results. Having the sensor device transmit the measured raw data (without processing it) to the smartphone would reduce the amount of data processing, but there is a trade-off in that the amount of data being transmitted would increase. Thus, we reduce the amount of communications data to less than one one-hundredth that of the case when the sensor device transmits the measured raw data to the smartphone, by transmitting feature values after extracting them from the raw data on the sensor device side, as described previously. This minimizes the power consumption of the sensor device.

4. Reduced power consumption by intermittent operation

The operation and power consumption of the previous blood flow sensor and the blood flow sensor we have newly prototyped are shown in **Figs. 4(a)** and **4(b)**. In the previous blood flow sensor, the laser fires continuously during the measurement, the analog and digital circuitry also operates continuously, and the measurement results are transmitted frequently. In contrast, our new blood flow sensor implements efficient measurement operations, which substantially reduces power consumption. More specifically, the amplification and filtering of signals is done within a short time period by having the laser fire for only short periods intermittently and having the analog circuitry operate intermittently in tune with the laser. The digital circuitry also goes into sleep mode as soon as it has sampled the signal and extracted feature values in order to reduce power consumption.

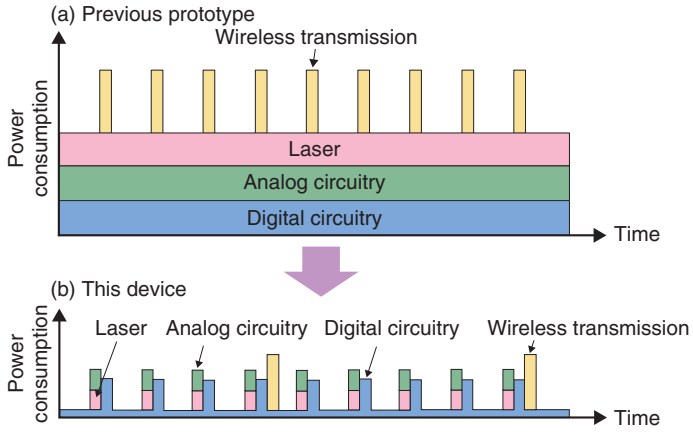

Fig. 4. Operation and power consumption of blood flow sensors.

For wireless communications, we adopted the Bluetooth[*2] low energy (BLE) method, which can operate with low power consumption by using intermittent communications. BLE is a new communication method that is installed in Android[*3] operating systems from version 4.3. This enables even lower power consumption than in previous versions of Bluetooth by transmitting small amounts of data, at a maximum of approximately 20 bytes per packet, only when necessary. With our newly prototyped blood flow sensor, we make the most of BLE communication capabilities and implement efficient communications by collecting the measured data in a buffer without transmitting it immediately, and then transmitting the data in a batch once a packet is full. In this way, we greatly reduce power consumption by running all the optical sensing, analog signal processing, digital signal processing, and wireless communication processing intermittently, making it possible to monitor the flow of blood over long periods of time with a small battery.

5. Examples of measuring blood flow volume

Here, we introduce examples of measuring blood flow volume using this blood flow sensor. The results of measuring blood flow volume when the blood flow sensor was attached to a fingertip and the arm was raised and then lowered are plotted in **Fig. 5(a)**. It is clear that the blood flow volume at the fingertip drops when the arm is raised, due to the effect of gravity, but it returns when the arm is lowered. Thus, the flow of blood in a person changes dynamically with routine actions.

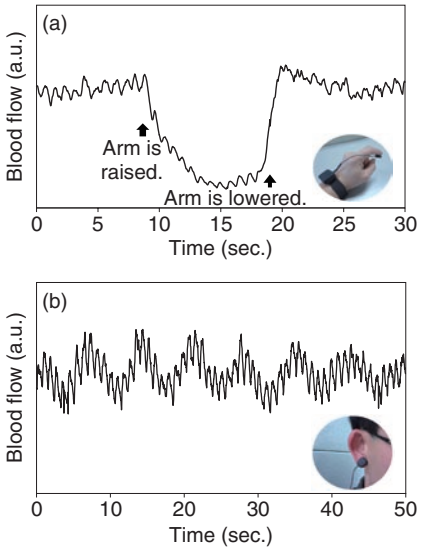

Fig. 5. Results of measuring blood flow at (a) fingertip, and (b) earlobe.

The results of measuring blood flow volume at an earlobe are shown in **Fig. 5(b)**. The blood flow volume at the earlobe has periodic fluctuations at approximately 1-s and 10-s intervals. The fluctuations at approximately 1-s intervals correspond to the heartbeat, and those in the approximately 10-s cycle represent the contraction motion of blood vessels, which is referred to as vasomotion. These fluctuations vary with certain conditions such as the physical

*2 Bluetooth is a registered trademark of Bluetooth SIG Inc.
*3 Android is a registered trademark of Google Inc.

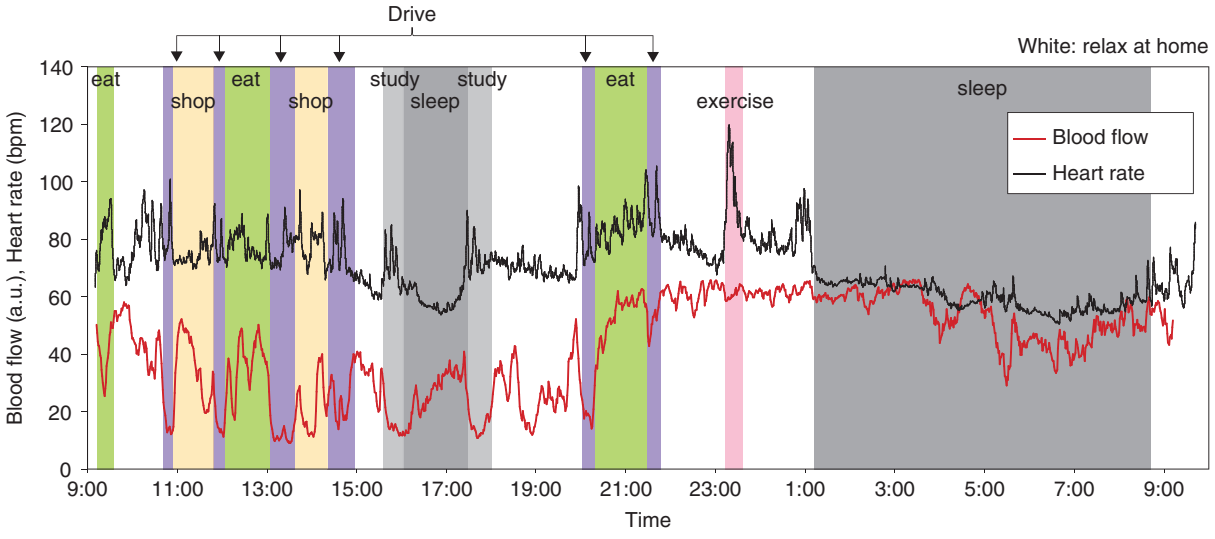

Fig. 6. Results of measuring blood flow continuously for 24 hours.

or emotional state, and therefore, various applications of this phenomenon are being investigated [5].

The results of measuring blood flow volume for 24 hours continuously during daily life are shown in **Fig. 6**. The figure also shows the simultaneously measured heart rate when the subject was wearing a *hitoe* wearable electrode inner shirt [6]. The effects on blood flow of daily actions such as driving, eating meals, and sleeping can be perceived. By taking such measurements, people who are concerned about bodily disorders caused by bad circulation can obtain information on improving their circulation in daily life. It used to be impossible to use a blood flow sensor to measure blood flow over long periods while going about our daily lives, but the features of the blood flow sensor we have newly prototyped, namely its small size and low power consumption, have made it possible to achieve this for the first time.

6. Future development

The flow of blood changes dynamically in response to our emotional and physical states, and it contains a vast amount of information. The fields of application of a wearable blood flow sensor that can measure the flow of blood anywhere and at any time cover a wide range including routine circulation monitoring, at-home medical care, beauty, and sports. We are actively promoting collaboration with businesses and universities that have strengths in these fields, and we are working on creating services that support people in living healthy and active lives.

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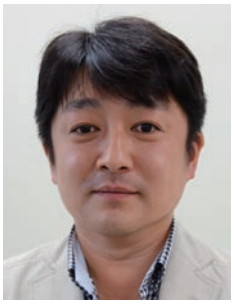

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MicroTAS for Biosensors

Yuzuru Iwasaki and Michiko Seyama

Abstract

Micro-total analysis systems (microTAS) are expected to be useful in daily healthcare applications in the near future because of their ability to measure biological information from molecules in the human body. This information is now assessed using sophisticated analytical systems at specialized institutes. MicroTAS is based on microfluidics, a multidisciplinary field that involves precise control of fluids at the sub-millimeter scale. A microfluidic device handles liquid just as an electronic device handles electricity. In this article, we introduce microTAS technology currently under development that makes measurement protocols as simple as possible through the use of microfluidics and enables end users to measure their health condition by themselves.

Keywords: microfluidics, microTAS, biosensor

1. Introduction

1.1 Overview of microTAS

Analytical chemistry is the scientific field concerning measurement of chemical substances. Blood analysis carried out as part of a medical health checkup is based on analytical chemistry techniques. The primary discipline in analytical chemistry is carrying out chemical experimental protocols in a predefined way. These protocols include the handling of cuvettes, flasks, and pipettes. The basic idea of micro-total analysis systems (microTAS) is to replace those laboratory liquid management tasks with a liquid handling circuit device (microfluidics) and reduce an entire laboratory room down to one chip (**Fig. 1**) [1]. This is why microTAS is also frequently referred to as *lab on a chip*.

The typical liquid handling tasks in analytical chemistry include: dispensing, mixing, initiating a reaction, filtration, transfer, and measurement. Each task requires time and labor if the experiment is carried out using discrete tools and measurement instruments. The task will become more difficult as the sample volume is reduced. The use of microfluidic devices makes it possible to replace such liquid handling tasks with small channels, valves, and junctions. These liquid handling components are formed on a thin flat substrate, and the size is drastically reduced, so we can handle the sample liquid more easily and deal with small volumes automatically.

1.2 Microfluidic devices

Microfluidic devices are fabricated using photolithography and microelectromechanical systems (MEMS) technology, the same technology as that used to integrate electronic circuit elements (registers, transistors, wiring) on a silicon wafer. Therefore, the microfluidic device and the internal volume can be fabricated with a small size. The microfluidic devices have a micrometer-scale trench structure in which liquid flows. Therefore, a very small volume of liquid can be handled and used for chemical reactions in these devices. These characteristics of microfluidic devices make them best suited for analyzing biological and medical samples that are difficult to collect in a large volume for sample analysis.

Microfluidics technology has advanced to the level where elementary liquid handling functionality is achieved with a certain pattern or circuit of liquid flow. For example, mixing is achieved with a Y pattern, dispensing with a cross pattern, and filtration with a pillar array. These patterns are also constructed in a trench structure. These functional units are pieces of patterns in a plane structure, so we can combine and integrate the pieces as in a jigsaw puzzle to construct a chemical reaction device that carries out a specific and total chemical reaction, synthesis, and analysis instead of having to manually carry out these

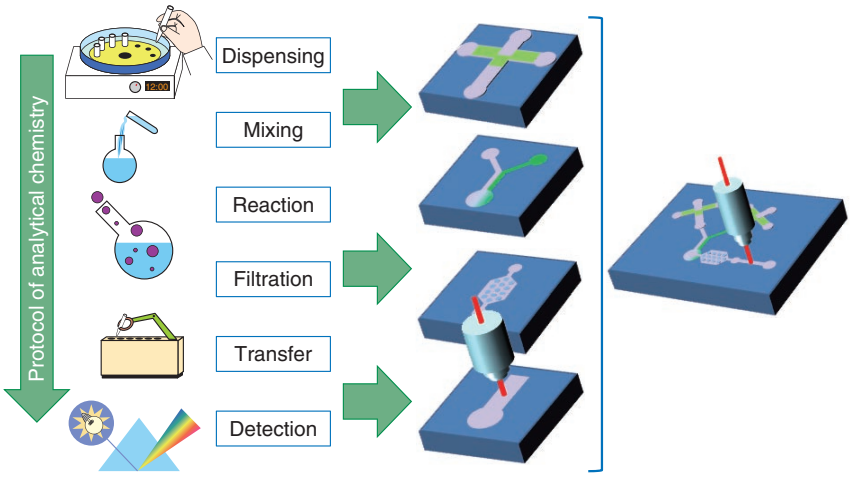
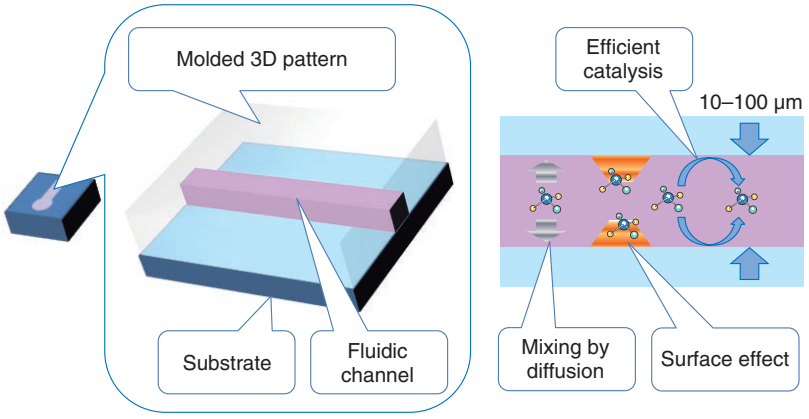


Fig. 1. Device integration of analytical chemistry by microTAS.



3D: three-dimensional

Fig. 2. Microfluidics.

tasks with separate tools. For example, polymerase chain reaction (PCR) is a common process in genetic biochemistry that amplifies the specific sequence of deoxyribonucleic acid (DNA) concentration, and it is necessary in DNA analysis. A PCR protocol consisting of multiple complex chemical reactions was carried out automatically using microfluidic devices [2].

Because microfluidic devices are fabricated using MEMS mass production techniques, they can be made in arbitrary patterns and in large quantities with high dimensional precision. A transparent material is used for the liquid circuit structure (**Fig. 2**) to enable the liquid inside the microfluidic device to be observed in order to measure and check the liquid flow. Mold casting is a common method to make these structures, as it enables repeated fabrication of the devices.

Typically, the trench in a microfluidic device has a cross-sectional length of 10–1000 μm. The shorter the length is, the smaller the internal volume is. This is advantageous for small volume reactions. In general, the area is proportional to the square of the length, but the volume is proportional to the cubic square of the length. Therefore, the ratio of volume to surface area of the internal microfluidics increases as the length gets shorter. This makes the effect of the internal wall of microfluidic devices very strong

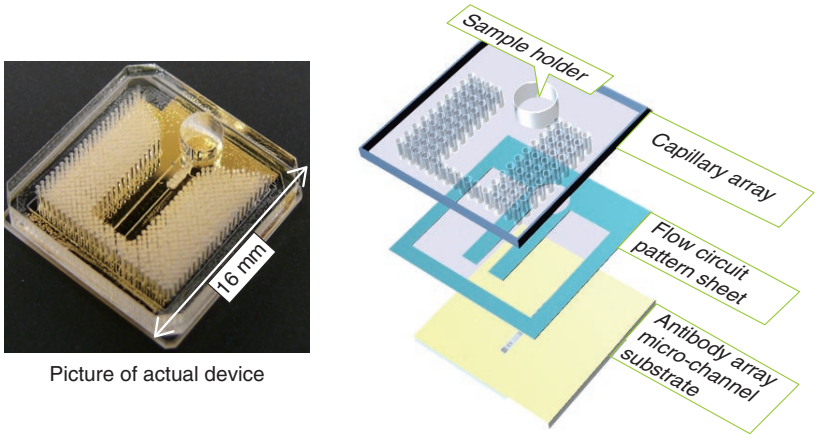


Fig. 3. On-chip sample liquid flow system.

compared to macro-scale liquid handling tools. This is the same phenomenon as that of a straw placed in a glass of liquid; the narrower the straw is, the higher it can draw up the meniscus (the curve in the surface) of the liquid due to capillary force. With microfluidic devices, the smaller they are, the greater the capillary force governing the liquid behavior.

Chemical reactions are usually facilitated by mixing, and mixing is a fundamental procedure in chemical analysis. In a microfluidic device, mixing is controlled by flow and diffusion. The flow in most microfluidic devices is very stable because liquid is held between walls that are spaced closely together, and the mixing is controlled by the fluidic pattern. When the internal wall is modified with a catalyst, the reaction efficiency is enhanced because the reactant has only a short distance to travel to access the catalyst [1].

2. Biomolecule sensing

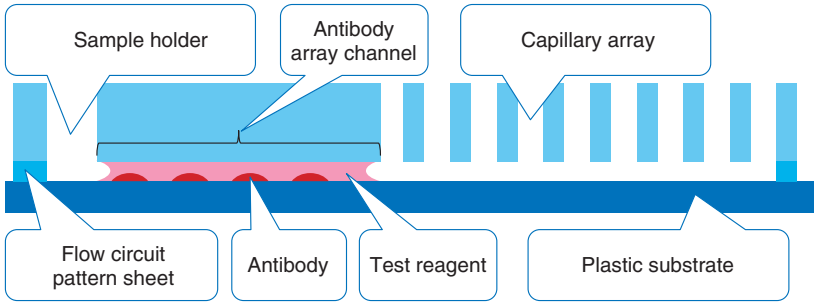
Current healthcare diagnosis involves collecting biological samples (e.g., blood, urine) and analyzing the components to determine the patient's state of health. In most local hospitals, the collected samples are analyzed using specialized massive-scale measurement instruments installed in a specialized medical test center that is usually located away from the hospitals. These instruments measure a large number of samples with high throughput; therefore the test cost becomes low enough to be covered by medical insurance. However, the patient or examinee cannot find out the results on the day of sampling and also cannot be tested more frequently than once a day to assess sudden changes.

However, frequent measurement of concentrations of specific blood components is considered to be effective for controlling or reducing the risk of lifestyle related adult illnesses such as diabetes and stroke. For these purposes, a way for examinees to test themselves at home instead of going to a hospital is desired. This would also enable examinees to monitor changes to their state of health that may occur within a few days. This type of self-test should be easy to do and low in cost, and microTAS has the potential to help achieve this.

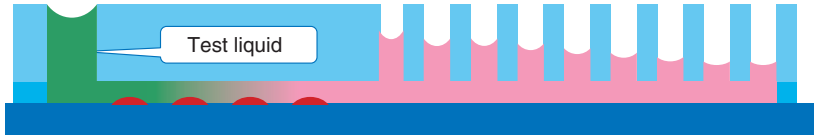
Conventional microTAS chips [1] have been successfully used in liquid handling tasks. However, the pumps that enable the liquid to flow through the circuits and the detectors used for the reaction monitoring are still too large to realize personal measurement capabilities. To overcome this problem, we developed a low cost microfluidic device that is integrated with an autonomous liquid flow mechanism and a small-sized reaction detector; we describe it in the next section.

3. On-chip sample liquid flow system

We developed an on-chip sample liquid flow system using capillary force and surface tension [3]. This device comprises a plastic substrate with antibody array, a capillary array formed in a plastic plate, and a plastic sheet with a flow circuit pattern (**Fig. 3**). These three parts are simply bonded by an adhesive agent on both sides of the sheet. The liquid circuits



(a) Application of test reagent



(b) Application of test liquid

Fig. 4. Self-flow microfluidic device.

connect a sample holder, an antibody array microchannel substrate, and a capillary array to each other. The internal surface of the fluidic device is hydrophilic. The device works as follows. An aqueous test reagent is introduced in the sample holder. Capillary force causes the test reagent to flow into the antibody array channel as in the principle of the narrow straw. The flow stops when the channel is filled if the volume of the reagent is set equal to the internal volume of the channel. In this stage, the capillary force of the head and tail of the liquid plug (i.e., a volume of liquid in air) is balanced (**Fig. 4(a)**). In this way, this device can control the liquid flow in the channel by itself.

When the test liquid is added to the sample holder, the capillary force of the tail of the liquid becomes lower compared to the head. Then the head moves to the capillary array. The test reagent and the test liquid that follows it flow under the many capillaries. The liquid is pumped up by the capillaries, and the test liquid flows continuously through the antibody array channel (**Fig. 4(b)**). This continuous flow enables the antibodies and molecules in the test liquid to react efficiently. The test sample, which may be a biologically hazardous substance, flows into the capillaries and stays in the device.

This device can be used with a small multi-point SPR (surface plasmon resonance) instrument* [4] that was developed by NTT. This instrument can detect subtle refractive index changes of the entire length of the channel at the same time. The refractive index changes are generally caused by the reaction of a molecularly thin film of immobilized antibodies to antigens in the channel. The instrument is sensitive enough to detect changes at the monomolecular-layer level. Therefore, antibody reactions in the antibody array channel can be easily detected.

The developed device had nine antibodies of different specificities in the channel. After the test reagent was introduced, the refractive index recorded by SPR showed a flat response because no reaction occurred in the channel, as shown in **Fig. 5**. Then, after the addition of the test liquid, the refractive index increased because of the refractive index difference between the test reagent and the test liquid. This is an indication of the arrival of a sample. At this stage, the antigens in the test liquid started to react with antibodies in the channel. The reacted antibodies (yellow and black curves) showed a further increase in the refractive index. This is because the complex formation by a specific binding of antigen and antibody causes a high density region (high refractive index) in the channel. In contrast, the other seven curves showed a constant response, which is a result of no binding occurring between antibodies and molecules in the sample. In this way we can measure the pattern

* SPR instrument: A chemical reaction measurement system that can detect monomolecular-layer level refractive index changes. Refractive index changes of antigens captured by antibodies can be directly detected.

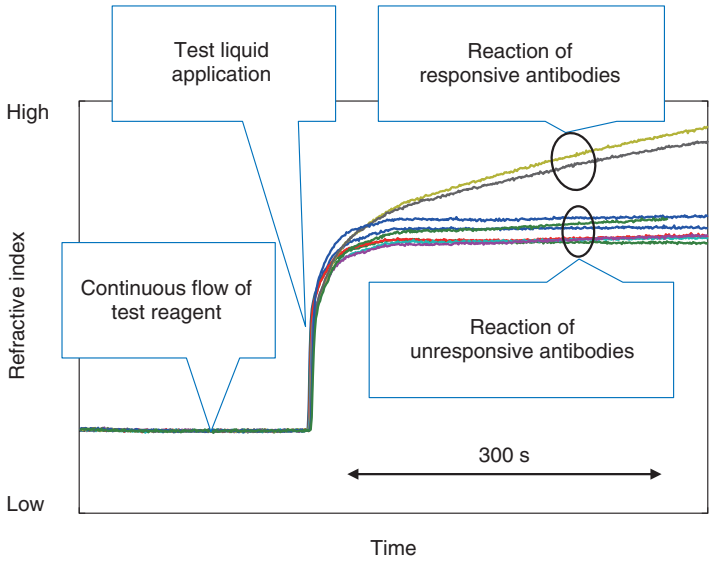


Fig. 5. Response of antibody array measured by SPR.

of response from nine antibodies in a simple operation. Because each antibody detects its specific biologically relevant molecule, we can evaluate the molecular components of the sample from the response pattern of antibodies. By changing the combination of antibodies, we can use this device for specific applications.

Moreover, because the raw data of the SPR instrument consist of a sequence of image data, the device can also detect sample introduction and flow conditions (e.g., whether the liquid is stuck, is leaking, or there has been a liquid introduction error) automatically through the use of sophisticated image processing technology. This automatic recognition helps end users to carry out correct measurements. We developed these technical elements using a simple sensor system.

4. Future perspectives

We developed our on-chip sample liquid flow system with the aim of using it in on-site measurement in the dairy industry as a first step, for example, to identify the pathogens in milk samples on dairy farms. There has long been a demand in this field for a means of instant chemical analysis. In the next step, we are developing technologies enabling personal chemical analysis of biological samples that can be carried out as easily as making a phone call using microTAS. Data analysis of frequent measurements and a large number of examinees will make it possible to detect abnormal health conditions before they require costly treatment. We expect that the developed technology will be useful in providing new services to achieve improved health outcomes at a lower cost, and will expand the choice of treatments for each person.

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Ultralow-power Sensor Node with Nanowatt Wireless Circuit Technology

Shoichi Oshima, Kenichi Matsunaga, Toshihiko Kondo, and Hiroki Morimura

Abstract

Wireless sensor nodes (WSNs) can be mounted on many kinds of objects in order to gather information about them. This enables a range of applications in areas such as healthcare, security, and traceability. This article describes very tiny, ultralow-power WSNs in which nanowatt wireless circuit technology achieves long-term driving without the need for maintenance.

Keywords: sensor node, sensor network, low-power wireless circuit

1. Introduction

The cabability of wireless sensor networks to gather and analyze environmental information such as vibration, temperature, angles, or positions will enable the provision of new services. Such network services, generally referred to as M2M (machine-to-machine) or the Internet of things (IoT), are attracting a great deal of attention. For example, a current sensor attached to electrical appliances in a home can tell us how much electricity is used or saved over time, and it will enable us to control appliances automatically. Sensing vibration patterns caused by wind can indicate cracks in concrete structures of bridges or buildings.

A wireless sensor network consists of wireless sensor nodes (WSNs) that can be mounted on anything and can monitor environmental or physical conditions. An image of how cargo in transport is monitored is shown in **Fig. 1**. WSNs attached to the cargo or to transport vehicles monitor temperature, location, or physical shocks. Then, master receivers connected to a network gather information from the WSNs and send it to servers via public networks such as Wi-Fi[*1] or 3G/4G (third generation/fourth generation). The servers store and analyze the data to produce real-time distribution schedules or to maintain quality assurance.

One proposed requirement for WSNs is that they be much smaller in size and lower in cost than whatever they are attached to. Another is that they have batteries if the objects they are attached to do not. However, this last requirement is difficult to meet. Smaller batteries tend to die rather quickly, so we may need to replace them often, which would raise maintenance costs. To avoid this, WSNs should be able to operate on one battery for as long as the item they are mounted on lasts, say about 10 years, without maintenance. In some situations, it may be possible to use ambient energy sources such as solar energy, temperature, or vibration, to charge batteries.

In this article, we introduce ultralow-power circuit technology for WSNs as a way to achieve long-term WSN operation with a small battery, and we compare the power consumption of our WSNs to that of a conventional wireless system.

2. Ultralow-power wireless technology

Fabricated WSNs with ultralow-power wireless

*1 Wi-Fi is a registered trademark of Wi-Fi Alliance.

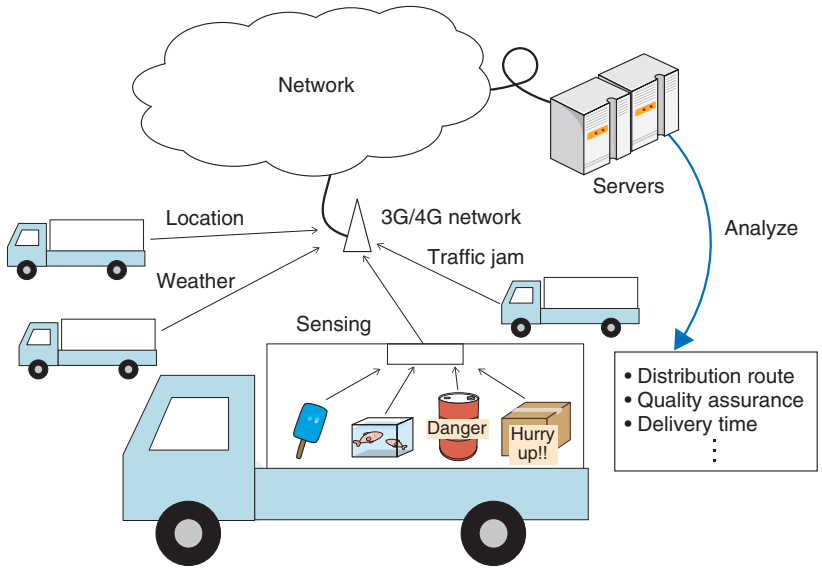
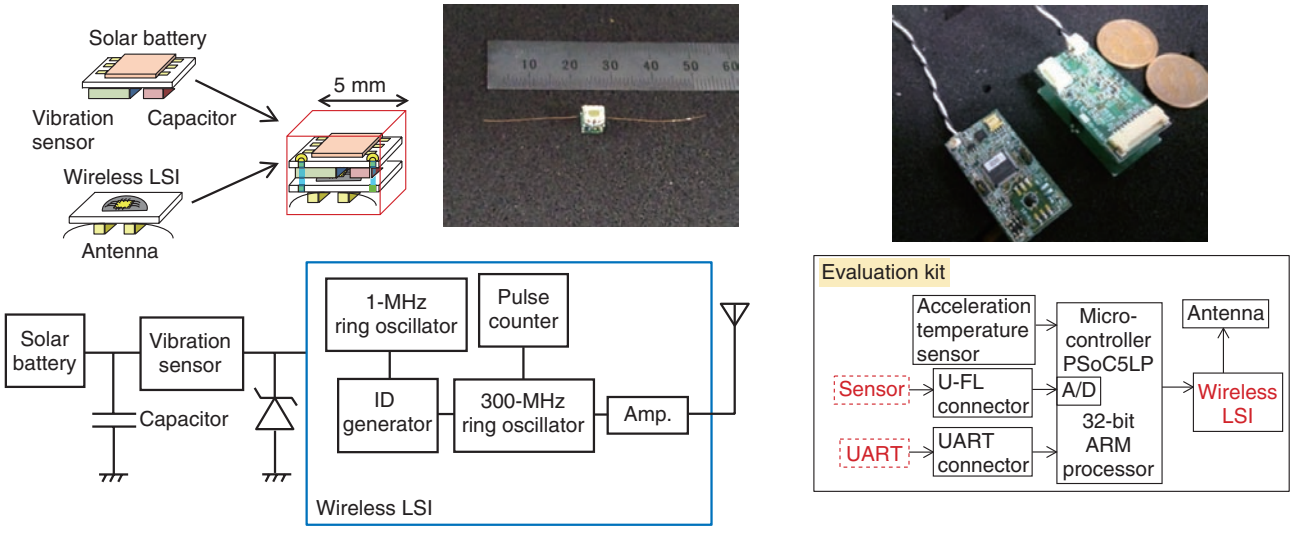


Fig. 1. Wireless sensor network to monitor cargo in transport.



(a) 5 mm × 5 mm × 5 mm WSN

(b) WSN evaluation kit

A/D: analog to digital
ARM: Acorn RISC (reduced instruction set computing) machine
LSI: large scale integrated circuit
UART: universal asynchronous receiver-transmitter
U-FL: user function library

Fig. 2. Compact and ultralow-power WSNs.

technology are shown in **Fig. 2**. A 5 × 5 × 5-mm WSN with a solar battery and vibration sensor is illustrated in Fig. 2(a). It transmits identifications (IDs) when the vibration sensor detects a sufficient physical shock. We confirmed in a marketing demonstration that this type of WSN was effective for monitoring which products in a store were most popular by counting the number of times products were removed

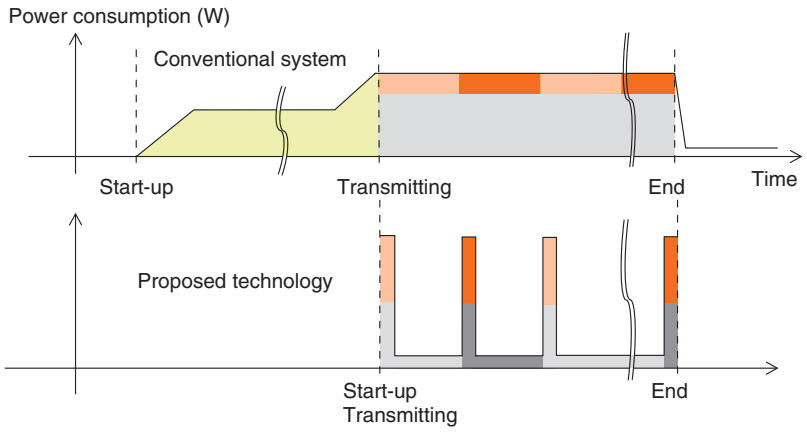


Fig. 3. Low-power technology.

from store shelves (for purchase or closer examination by customers) [1]. An evaluation kit of WSN with vibration and temperature sensors and a connector for connection to other sensors is shown in Fig. 2(b). WSNs of this type can transmit sensing data at the timing of the sensor's trigger and timer. We demonstrated the ability of such sensors to monitor indoor temperatures and human heartbeats [2].

Both types of WSNs feature the large-scale integration of nanowatt wireless circuits. The power consumption of the wireless transmitter from startup to the end of data-block transmission [3] is shown in **Fig. 3**. We use short impulse signals instead of a continuous sinosidal wave—the conventional method—to transmit "1" and "0" binary data. The pulses are generated by a ring oscillator, and when they stop coming, the wireless circuits also stop. This intermittent-driving technology enables us to reduce the total wireless circuit activation time and achieve ultralow power.

In what follows, we explain the driving energy of WSNs and compare our technology with that of EnOcean[*2], a widely known low-power wireless product [4]. EnOcean uses a mechanical energy generator; when the button is pushed, energy is generated and IDs are sent wirelessly into the air. It is popular in Europe, where it is used in buildings to control light switches without electrical wiring.

3. Power consumption of WSNs

A block diagram of our WSN is shown in **Fig. 4**. The WSN comprises a wireless transmitter, digital-signal-processing (DSP) controller, sensor, and battery. Here we consider the use of a small lithium battery. The lifetime, L, of the battery is expressed as follows:

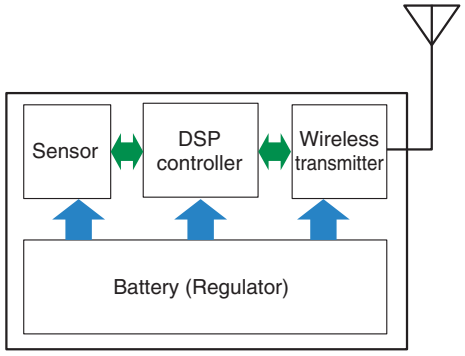


Fig. 4. Block diagram of WSN.

$$L\ [h] = C\ [mAh] \div I\ [mA] \times SF,$$

where C is the energy capacity of the battery, I is the average current consumption, and SF is its safety factor, which corresponds to drops in battery quality due to aging or contamination. For example, if we use a coin-type battery such as a CR2032 with an average current of 1 mA, the battery lifetime is about six days; with an average current of 10 μA, the lifetime is 1.7 years.

Next we look at the WSN's power consumption. The power consumption changes with the driving

*2 EnOcean is a registered trademark of EnOcean GmbH.

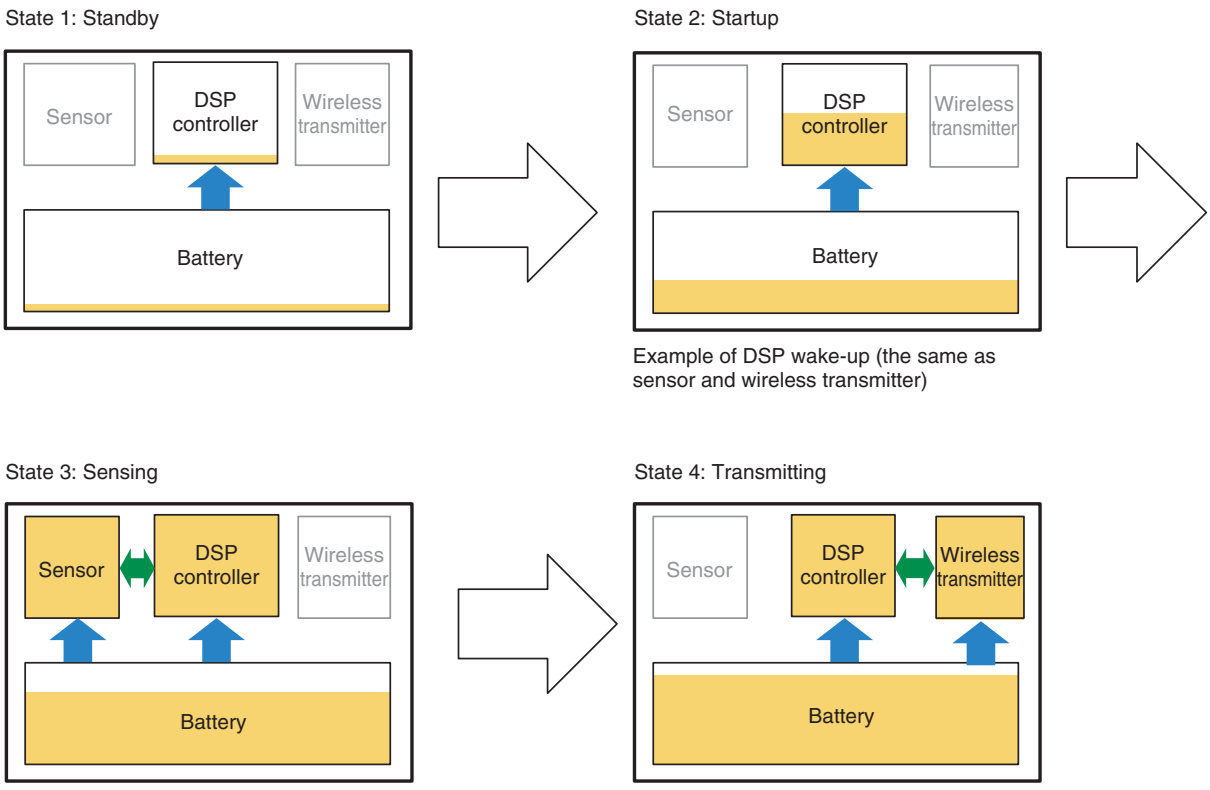


Fig. 5. Power consumption of each state.

condtions. The driving conditions can be said to comprise the following four states:

1. Standby state: activation of minimum necessary elements of circuits in each block, almost the same as sleeping
2. Startup state: transition to activation of each block
3. Sensing state: environmental sensing and data analysis, including communication between DSP and sensor
4. Transmitting state: wireless transmission

Now let us consider the periodic transmission of sensing data. In state 1, most of the components of each block are inactive, and only the minimum necessary elements are activated, for example, the RTC (real-time clock), which counts the periods, and regulators that supply voltage. Some current leakage occurs in this state. The WSN must wake up the DSP controller in order to carry out sensing and transmitting. At this time, the WSN enters state 2 for a while to stabilize the oscillator and to read data stored in memory. Next, the DSP controller instructs the sensor to start sensing to acquire data. This requires state 2 in order to wake-up the sensor block. Then, the state will change to state 3. After data have been acquired, the system enters state 2 again to wake up wireless circuits, and the wireless transmission sequence starts. After state 4, the driving condition returns to state 1. The power consumption of each state is shown in **Fig. 5**.

We plot the average power consumption, taking all states into consideration, for transmitting data versus the transmission interval for EnOcean and our ultralow-power technology [5] in **Fig. 6**. In the EnOcean system, 12-byte data are transmitted three times per cycle. The plot for EnOcean includes the power of the standard sensor and the voltage. When the interval is long, the static energy, corresponding to state 1, is dominant in the total power consumption, and the power becomes constant. In contrast, when the interval becomes shorter, the power consumption increases in proportion to the driving energy of each circuit. EnOcean products are specialized for a button-type power generator, i.e., triggered driving. When they are used periodically, they are useful in long intervals of over 100 seconds.

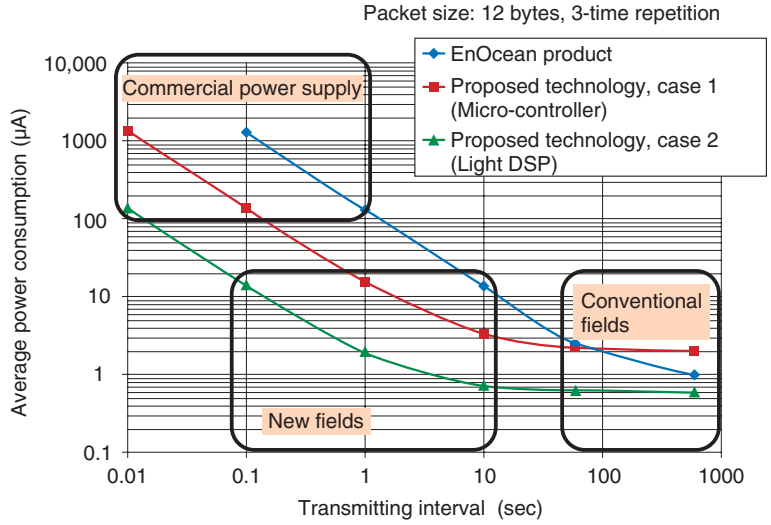


Fig. 6. Average power consumption versus transmitting interval.

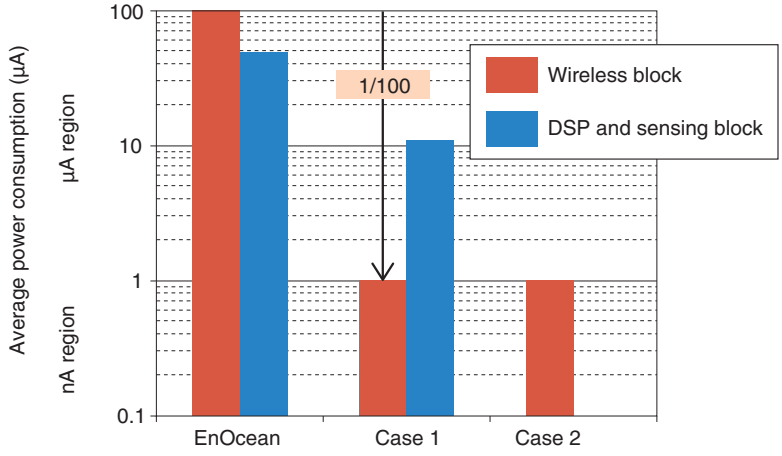


Fig. 7. Average power consumption of one-second transmitting interval.

The power consumption for our ultralow-power technology is plotted for the same condition as that for EnOcean—12-byte data with three transmissions per cycle. We consider two cases: using a commercially available micro-controller to transmit sensor data (case 1) and using simple DSP to transmit only IDs (case 2). The power consumption for a one-second interval is shown in **Fig. 7**. When the interval is short, the differences between EnOcean and our technology become large because the power consumption of our wireless circuits is 1/100 that of the EnOcean product. In EnOcean, the wireless block accounts for most of the power consumption. In contrast, with our technology, the dominant factor in the power consumption for transmitting sensing data is the power used for sensing. Thus, our technology can reduce the total power of WSNs. Moreover, if the system needs only ID information, we can take advantage of the much smaller power consumption of DSP for futher power saving. For shorter intervals, we have to further reduce the power consumption of every block.

When the average power consumption becomes higher than 100 μA, we must use a large energy source such as a commercial power supply instead of a battery (Fig. 6). When the transmitting interval is longer than 100 seconds, the conventional approach,

such as that of EnOcean, becomes useful. When the interval is 0.1 to 10 seconds, our technology has substantial advantages over the conventional technology. In such short intervals, data related to human activities, the distribution of things, and production processes are sampled continuously. This will pave the way to new applications.

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Terahertz Device Technologies for Ultrafast Data Downburst Applications

Ho-Jin Song, Takuro Tajima, and Makoto Yaita

Abstract

Advances in medical imaging technology such as computed tomography and magnetic resonance imaging have made it possible to capture minute defects inside the human body. Correspondingly, the volume of such imaging data has been dramatically increasing. There is also a demand to access such medical data using mobile terminal devices. To accommodate this demand, a wireless system with extremely high throughput of 100 Gbit/s or more is essential to enable instant data downloading. In this article, we give an overview of recent progress in terahertz communications, particularly in front-end technologies, which hold high promise for realizing future ultrafast wireless link applications.

Keywords: ultrafast wireless communications, terahertz wave, terahertz communications

1. Introduction

Steady progress is continuously being made in ICT (information and communication technology), and this has led to substantial changes in hospitals and in the healthcare field in general. Medical records including computed tomography (CT) and magnetic resonance imaging (MRI) data, which were initially in the form of paper documents, are now translated into electrical signals and recorded digitally in electronic medical records (EMRs). Doctors can look through the medical data via a mobile terminal such as a tablet computer or smartphone anywhere and diagnose and treat their patients remotely. The use of the EMR and telemedicine system will not only improve medical services in quality but also lead to new ones.

The quality of medical services is also being improved with the advances in medical instruments and equipment. For instance, state-of-the-art medical imaging systems can detect tiny defects and abnormalities in the human body, which used to be difficult to detect. These advances, especially in the resolution of medical imaging instruments, have led to an explosive increase in the volume of medical data, which has consequently created problems in managing, maintaining, and storing the EMRs. When a CT image is taken of the area from the chest to the abdomen with 0.5 mm resolution, approximately 2000 fragments of CT images are produced that require about 1 GB of storage per patient. In view of the fact that CT is now widely and frequently used in hospitals, one can easily estimate that several hundreds of gigabytes of medical data are generated by a CT machine in a single day. The volume of a person's EMRs if he/she had a regular medical check in the last ten years would be at least 10 GB, and probably much more. Unfortunately, however, the existing wireless data transmission systems are not fast enough to deal with the medical data commonly used these days and may even cause degradation of service quality.

We review in this article the recent progress achieved in an ultrafast wireless system we are developing called *data downburst*, which can transmit a huge amount of medical data instantaneously by utilizing the huge bandwidth of terahertz waves.

2. Terahertz wireless

To achieve ultrafast throughput of 100 Gbit/s or more, we focused on the terahertz frequency band, which is located between the microwave and far-infrared light-wave bands in the electromagnetic spectrum [1]. In terms of frequency, it is defined as 100 GHz to 10 THz in general and is frequently referred to as the *terahertz gap* or the *forbidden region* because of the huge technical barriers in generating and detecting signals at these high frequencies. The conductivity of metals usually used for signal wires or waveguides gradually degrades as the frequency increases, resulting in large signal loss at terahertz frequencies. Because of this, many terahertz signal generators produce very weak signals or are usually operated at impractically low temperatures at around −196°C or even below. Though high power of 1 W or more can be technically generated at terahertz frequencies, it requires a generator so large it would fill a room. Despite these technical difficulties, the inherently large bandwidth of terahertz waves is believed to be the only means to achieve the 100-Gbit/s wireless system. The frequency is approximately 100 times higher than that of microwaves, which the current wireless system operates at, and the available bandwidth is also that much larger.

In 2009, we first proved the effectiveness of the terahertz wave for a large data rate wireless system by experimentally demonstrating 8-Gbit/s data transmission at terahertz frequencies even with a weak power signal emitter, poor sensitivity receiver, and no signal processing. By improving the bandwidth of the devices used in the feasibility test, we were able to increase the maximum data rate up to 24 Gbit/s, which is approximately five times higher than the newest USB (universal serial bus) wire connection technology. These demonstrations clearly showed how the large bandwidth is important to obtain a high data rate in wireless communications systems. Since then, we have continued to investigate and develop functional radio frequency (RF) front-end component integrated circuits (ICs) based on semiconductor devices that are necessary for practical systems in terms of cost, size, and power consumption. The results we have achieved have greatly influenced the global movement toward standardization in the Institute of Electrical and Electronics Engineers (IEEE) for 100-Gbit/s wireless communications systems.

3. Terahertz ICs in 300-GHz band

The composition of the RF front end for terahertz communications systems is basically similar to that of conventional radio systems that consist of amplifiers, modulator/demodulators, local oscillators, and other components. However, the design considerations for the RF front end and component ICs operating at terahertz frequencies are quite different from those for the microwave frequency band because of the large loss and large bandwidth. For example, forward microstrip lines exhibit lower conductive loss but require an inductive inter-layer via between the transistors and signal lines, which leads to inductive signal loss. In contrast, the inverted microstrip lines, in which the signal line is located in the bottom layer, do not require the interlayer via, although the overall conductive loss is quite high due to the thin signal line.

On the basis of these design considerations, we have designed important front-end components such as an amplifier, oscillator, and quadrature phase shift keying (QPSK) modulator and demodulator at 300 GHz, where the first atmospheric window is located. These were fabricated using state-of-the-art compound semiconductor transistor technologies of which the cut-off frequency (f_{max}) is approximately 650 GHz.

A photo of a fabricated 300-GHz three-stage amplifier in cascode configuration is shown in **Fig. 1** along with a schematic diagram for a single stage and the measured gain and noise figure characteristics. The measured small-signal gain and bandwidth are approximately 28 dB at the center frequency and a 10% bandwidth at a single power supply of 3.3 V and total current of around 80 mA. The measured noise figure in the operating bandwidth at around 300 GHz is approximately 10–12 dB, which is the lowest ever reported at these high frequencies. It is most likely also due to the minimized signal loss in the circuit achieved by proper selection of the transmission lines.

A voltage controlled oscillator (VCO) is another important RF block used to generate the terahertz signals on which data will be carried. A photo of a fabricated VCO is shown in **Fig. 2**, as well as the measured spectrum and time-domain traces of outputs. For the design of the oscillator, we selected the common-collector Colpitts topology because of its simple configuration, which helps to avoid signal loss from the circuit complexity. In addition, for the QPSK modulation scheme, the VCO was designed to

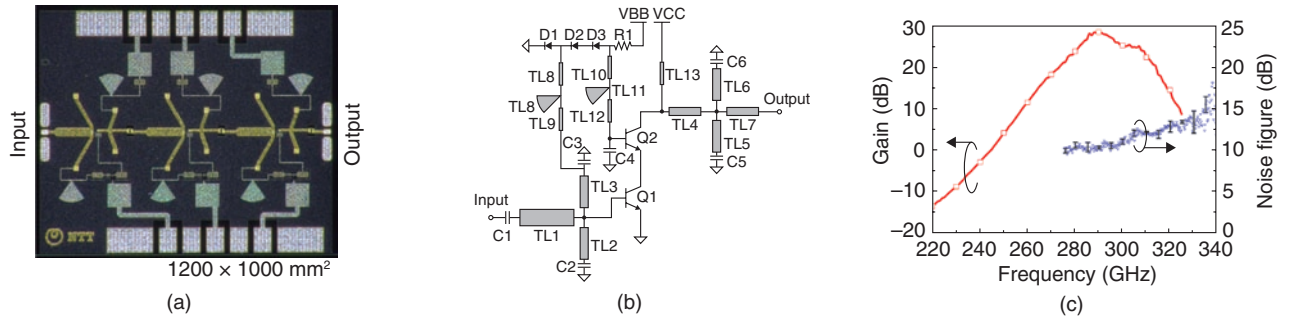


Fig. 1. Fabricated 300-GHz amplifier; (a) top-view photo, (b) schematic for single stage, and (c) measured gain and noise figure.

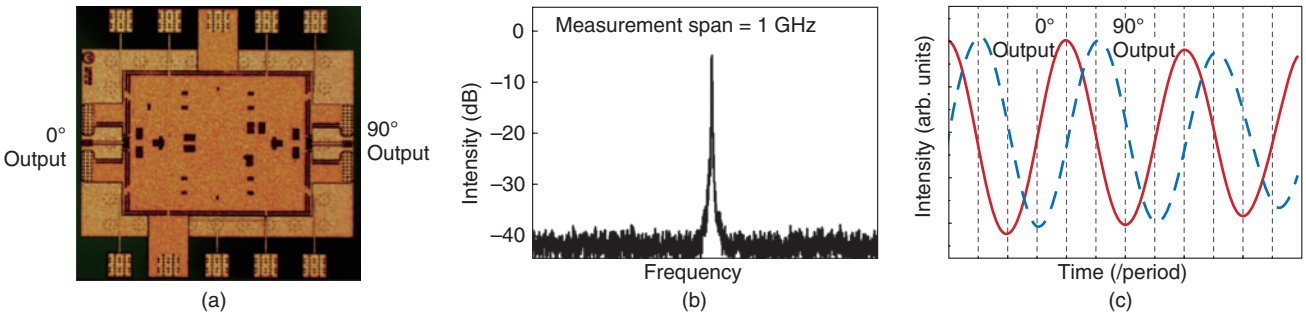


Fig. 2. Fabricated VCO; (a) top-view photo, (b) measured spectrum of output, and (c) measured time domain trace of 0° and 90° outputs.

have four outputs of which the phase states are at 0°, 90°, 180°, and 270°, which is generally called a quadrature VCO. We achieved this by cross-locking two identical oscillators by forcing a node on the symmetry line in the circuit in the in-phase at the second harmonic frequency. The two unit oscillators should be as close as possible, so we employed the inverted microstrip lines, which are advantageous in loss for short distances. As a result, the single-mode oscillation and quadrature signal generation is clearly shown in Fig. 2. To the best of our knowledge, this is the first successful demonstration of a quadrature VCO in the 300-GHz frequency band in the world. The phase noise, which is the figure of merit that implies frequency stability of an oscillator, was measured to be approximately –90.4 dBc/Hz at a 10-MHz offset frequency, which is sufficient for QPSK modulation.

To generate and detect QPSK signals, we selected a direct conversion scheme rather than the heterodyne configuration commonly used in many radio systems. Terahertz communications utilize large bandwidth, so a direct conversion scheme is advantageous for handling a large bandwidth signal with no signal distortion. Photos of the fabricated QPSK modulator and demodulator are shown in **Fig. 3**. As can be seen, two different transmission lines—forward and inverted microstrip lines—were simultaneously adopted in the design. Passive components for balanced signaling are implemented with the forward microstrip lines and can thus be seen clearly, while core parts implemented with the inverted microstrip lines are not seen due to the topmost metal used as a ground plane.

To examine the maximum data rate which the modulator and demodulator can operate at, we prepared a test IC in which the modulator and demodulator were directly connected by the short forward microstrip line and performed back-to-back tests at up to 60 Gbit/s. The measured eye diagrams of the demodulated signals at several data rates are shown in **Fig. 4**. As can be seen, at up to 50 Gbit/s, the eye diagrams are clear and open, and the bit error rate is on the order of 10^{-8} or lower. Although it is half the goal we are aiming for, the 50 Gbit/s is more than ten

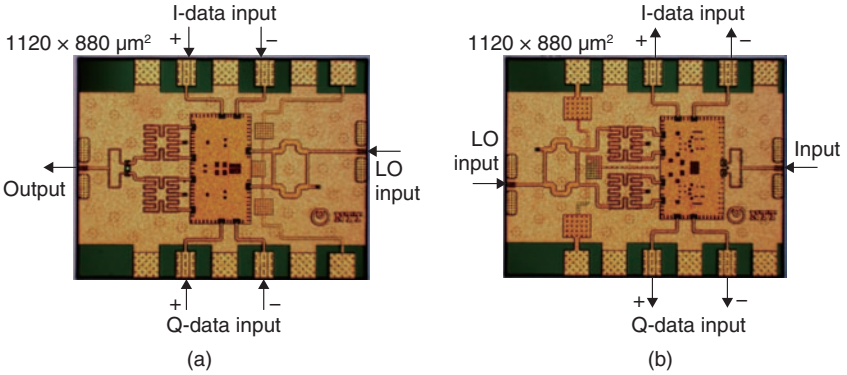


Fig. 3. Fabricated QPSK; (a) modulator and (b) demodulator.

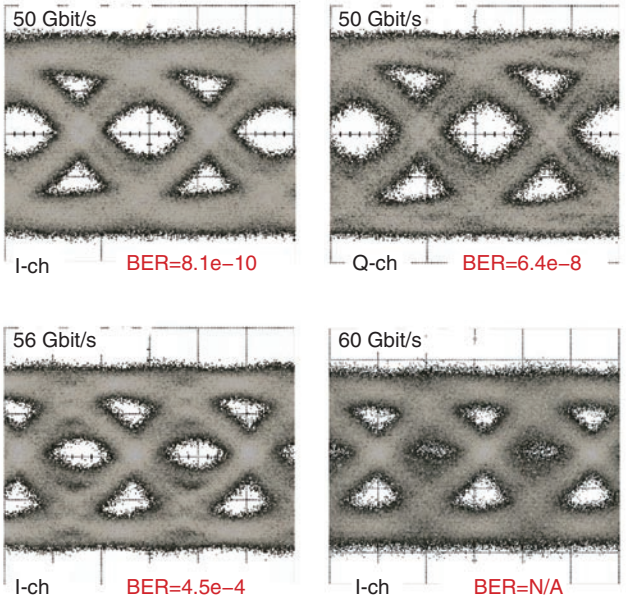


Fig. 4. Measured eye-diagrams and bit error rates (BER) at up to 60 Gbit/s.

times faster than the fastest existing wireless system and is as fast as it takes to completely download a single DVD (digital versatile disc) movie in a second.

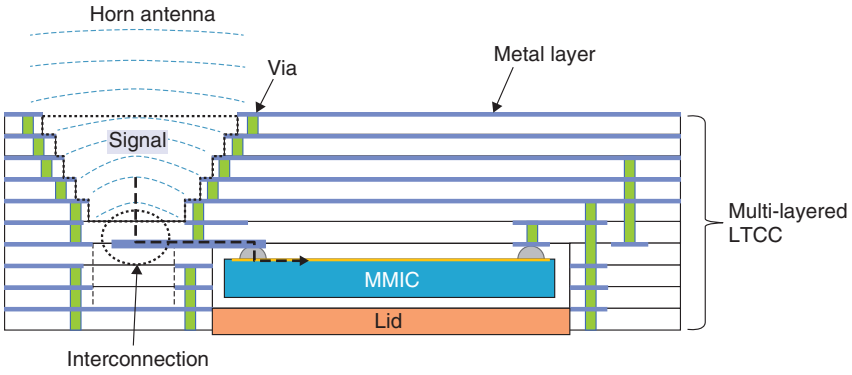
4. 300-GHz horn antenna integrated in LTCC package

The terahertz package in a terahertz wireless front-end module must have an antenna to radiate or capture wireless signals and an interconnection to connect the antenna and RF frond-end ICs to be installed in the package. In the terahertz band, as the wavelength gets shorter, it becomes possible to miniaturize the antenna and package. A compact and low cost terahertz package enables the development of a front-end module that can be embedded into tablet computers and smartphones.

However, conventional terahertz modules are metal packages with a silicon lens antenna on which the IC is directly attached with precise alignment. These packages are expensive, and it is difficult to implement interconnection to the IC with them.

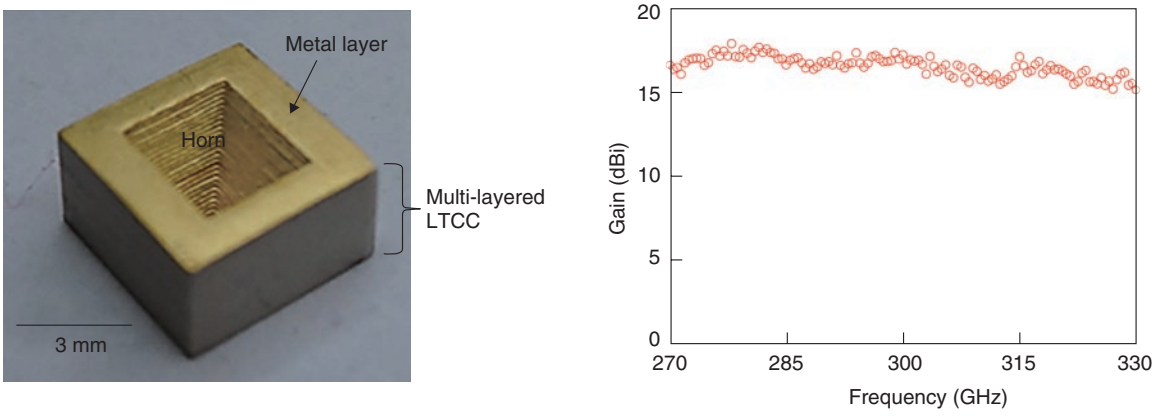
Therefore, we developed a 300-GHz package integrated with a horn antenna by utilizing the ceramic material known as low temperature co-fired ceramics (LTCC), which is used in microwave and millimeter-wave packages [2]. A cross-sectional view of the proposed terahertz package is illustrated in **Fig. 5**. Integrating the antenna into the package not only makes it possible to integrate the terahertz IC, power source, and high-density signal line but also to miniaturize the antenna and the interconnection. Furthermore, it resolves the issue of interconnection and low cost for high-volume production.

A prototype of the antenna using LTCC multi-layered substrates is shown in **Fig. 6**. The horn antenna is shaped by gradually widening the cavity surrounding the vias and metal layers. The antenna is around 5 × 5 × 3 mm in size. Despite the antenna's compactness, its gain is 15 dBi or more, and the bandwidth is more than 60 GHz. An interconnection between the antenna and IC was also developed using LTCC multi-layered substrates [3]. A probe was placed in the waveguide formed in the LTCC to effectively couple the electromagnetic wave propagating in the waveguide and convert the propagation mode of the waveguide into the propagation mode of the microstrip



MMIC: monolithic microwave integrated circuit

Fig. 5. LTCC package integrated with 300-GHz antenna.



(a) (b)

Fig. 6. LTCC horn antenna; (a) photo and (b) measured antenna gain.

line that connects to the IC. A prototype of the interconnection using LTCC multi-layered substrates is shown in **Fig. 7**. The size of the interconnection is around 1 × 1 × 0.3 mm. The insertion loss is less than 3 dB, and the bandwidth is around 40 GHz. We aim to develop a compact and low-cost terahertz front-end module by integrating these components into a single package with a terahertz IC.

5. Conclusion and future perspective

In the history of progress achieved in wireless communications technologies, the advances in terms of data rate in the last few years have been much greater than those during the first 100 years, but the speed of progress is not fast enough to accommodate the demand from users, which is explosively increasing. This is because the operating frequencies of wireless systems are still in the microwave frequencies, where bandwidth is inherently limited. At this time, one may think the use of terahertz waves, of which the frequency is 100 times higher than that of the microwave band, for wireless communications is technically nonsense. However, when we consider that the amount of digital information generated is exponentially increasing day by day, and recent new industries related to big data and cloud computing will accelerate the increase further, it is not difficult to estimate that the large bandwidth in the terahertz wave band will be necessary in the next ten years.

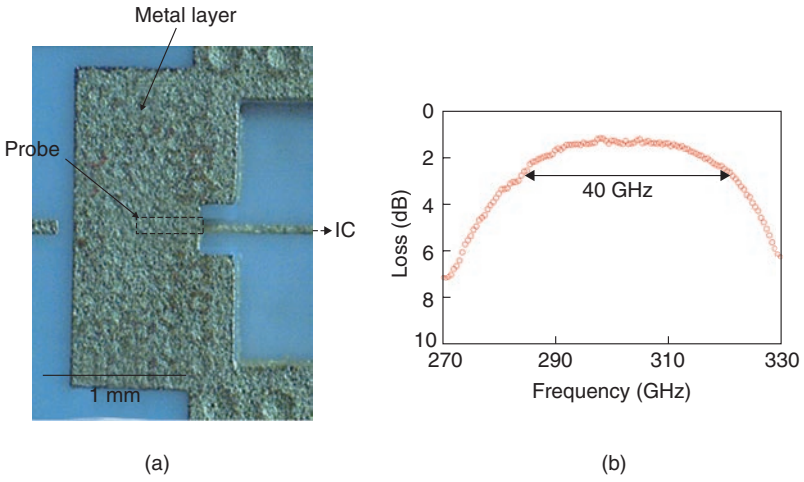


Fig. 7. Interconnection integrated in LTCC; (a) photo of mode transition probe and (b) measured loss.

We have taken a future perspective and have developed several RF front-end components including an amplifier, oscillator, and modulator/demodulator for future terahertz communications at 300 GHz. We have also demonstrated the successful operation of 300-GHz QPSK ICs at data rates up to 50 Gbit/s, which is ten times faster than current state-of-the-art wireless systems. In addition, we investigated compact packaging technology for practical use. These results indicate the great potential of terahertz waves for use in future ultrafast data downburst systems providing data rates of 100 Gbit/s or more.

Acknowledgement

This work was supported in part by the research and development program on 'Multi-tens gigabit wireless communication technology at sub-terahertz frequencies' of the Ministry of Internal Affairs and Communications, Japan.

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Continuous Wave Terahertz Spectroscopy System Designed for Medical Field

Katsuhiro Ajito, Jae-Young Kim, and Ho-Jin Song

Abstract

We have constructed a continuous wave (CW) terahertz spectroscopy system using photonic integration-compatible technology. This system is intended for use in the medical field as a miniaturized terahertz spectroscopy system, in contrast to the conventional pulsed wave method. This system can simultaneously measure the absorption and phase (dielectric constant) responses of a sample, and it exhibits a dynamic range of at least 75 dB at under 1 THz. In addition, we used the CW spectroscopy system to identify a new type of complex molecule crystal (cocrystal) formed from a molecule of a pharmaceutical drug and various coformers. Cocrystals have been developed for use in the pharmaceutical manufacturing field to improve the solubility and absorbability of medicines. By fixing the measurement frequency at the absorption peak of intermolecular interactions of those crystals, we obtained a two-dimensional distribution of cocrystals within a test tablet.

Keywords: homodyne, pharmaceutical products, cocrystal

1. Introduction

Terahertz (THz) spectroscopy has been used in the field of astronomy for the past few decades as a form of passive spectroscopy for observing the rotational modes of gaseous molecules. However, as the use of active spectroscopy for analyzing molecules, crystals, and even biological samples has become more common, it has attracted a lot of attention as a new spectroscopic analysis technique. THz spectroscopy involves the penetration of THz waves within a solid, which makes it possible to discriminate the intermolecular interactions between molecules or crystals inside the solid. It is anticipated that it will be applied in areas where it is difficult to apply X-ray diffraction methods such as with materials or ultrafine particles having multiple components that are mixed together.

THz waves lie between light waves and microwaves in the range from 0.1 to 10 THz (10^{11} to 10^{13} Hz), and therefore, they easily penetrate materials that are not readily transparent to visible light such as paper, wood, and plastic, enabling nondestructive analysis. In the region above 1 THz, there are many vibration modes of molecules or crystals that occur due to the intermolecular interactions. Consequently, the spectral fingerprint, in which the vibration modes absorb THz waves, allows us to identify the materials. The molecular interaction is stronger as the frequency increases. However, the penetration of THz waves within solids tends to decrease because the shorter wavelengths at higher frequencies are easily scattered by particles. Therefore, there is a limited region inside the frequency range from 0.3 to 5 THz where the two advantages of deep penetration and spectral fingerprint are both obtained. Even within the THz spectrum in the low frequency region of 0.1–0.3 THz, it is difficult to identify molecules or crystals even though penetration is easy, whereas in the higher frequency region of 5–10 THz, extremely high loss limits the available sample thickness within thin films or surfaces.

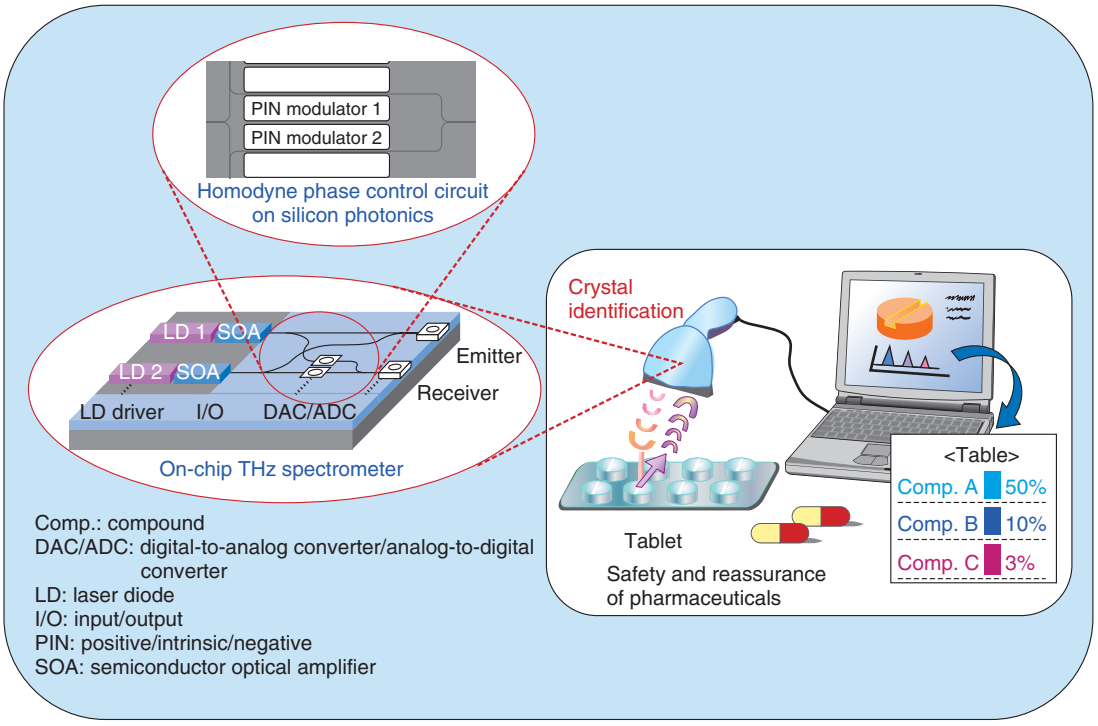

Fig. 1. Application of miniaturized CW THz spectroscopy system in medical field.

2. Miniaturization of devices and application to medical field

Process analytical technology (PAT) is a system for designing, analyzing, and managing the manufacturing process, and for ultimately guaranteeing product quality. The United States Food and Drug Administration (FDA) has published guidelines for introducing PAT into pharmaceutical production. Consequently, there is an increasing need for the analysis of medicines to reassure consumers and increase safety. Accordingly, the application of THz spectroscopy in the medical field requires not only high system performance in areas such as sensitivity, stability, and speed, but also a miniaturized THz spectroscopy system such as an on-chip analyzer for convenient nondestructive inspection of pharmaceutical products. A conceptual diagram of the miniaturized continuous-wave (CW) THz spectroscopy system and its use in the medical field is shown in **Fig. 1**. Current THz spectroscopy systems generally employ a pulsed wave method based on a femtosecond pulse laser, although it is very difficult to miniaturize certain components such as delay controllers. In contrast, the CW method is less challenging to reduce the size of components because all components from the laser diodes to the THz emitter, receiver, and optical waveguides can be fabricated on chip by using common photonic integration technologies. As a first demonstration, we previously used silicon photonics technology to fabricate a THz phase control circuit only a few square millimeters in size, and we verified the operation of the circuit in the CW THz spectroscopy system [1].

The phase-controlled CW THz homodyne spectroscopy system uses photomixing of light waves from two laser sources, as shown in **Fig. 2**. The frequency of the THz waves is the same as the frequency difference between the two laser sources. When the THz waves generated from the photomixer arrive at the receiver, a photoconductive antenna (PCA) mixes the THz waves using a phase-controlled replica signal transmitted via an optical waveguide. The principle of homodyne detection enables the use of two general-purpose free-running laser sources such as a 1.55-μm-band semiconductor diode laser, and therefore, THz waves can be simply generated and tuned over a wide bandwidth by changing the wavelength of the lasers. Also, the homodyne detection method still supports the two important advantages of

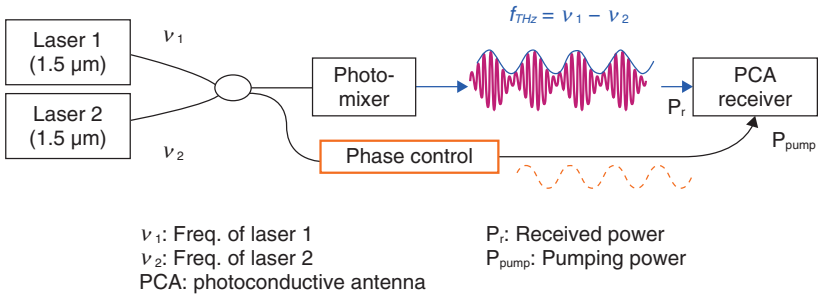

Fig. 2. Operating principle of CW THz homodyne spectroscopy system.

coherent detection methods—detection of both intensity and phase responses, and a high dynamic range. A comparison of the dynamic ranges of the coherent and envelope detection methods is shown in **Fig. 3**. When P_r is receiving power and P_{pump} is higher pumped power as noted in Fig. 2, the output from envelope detection (P_r^2) is always lower than the output from coherent detection ($P_r \times P_{pump}$).

A schematic diagram of a THz spectroscopy and imaging system using the CW homodyne method is shown in **Fig. 4** [2]. LD 1 and LD 2 are variable-frequency and fixed-frequency laser diodes, respectively. The outputs of these two laser diodes are amplified by an erbium-doped fiber amplifier (EDFA); then the THz wave is generated by photomixing in a uni-traveling carrier photodiode (UTC-PD). The THz waves from the UTC-PD transmitter passing through the sample on a two-dimensional (2D) scanning stage are then injected into the PCA receiver. Two phase modulators, PM 1 and PM 2, positioned between the LDs and the UTC-PD provide phase control operations for the homodyne detection. The relationship between the controlled phase of the CW THz wave and the received signal waveform is illustrated in **Fig. 5**. When symmetrical sawtooth waveforms are applied to PM 1 and PM 2, they linearly change the phase shift between -2π and 2π. The received signal then forms a sine wave at a fixed frequency even without a sample. Thus, when a sample is inserted, the THz amplitude (A_s) and phase ($\angle\Phi_S$) responses of the sample directly change the received sine wave, enabling the measurement of the THz absorption and dielectric constant of the sample. In this method, the two phase modulators are used to mitigate the limited dynamic range caused by the nonlinearity of both phase modulators. A high dynamic range of 100 dB at 0.3 THz and 75 dB at 1 THz were obtained from the homodyne system, as shown in **Fig. 6**. Several sharp

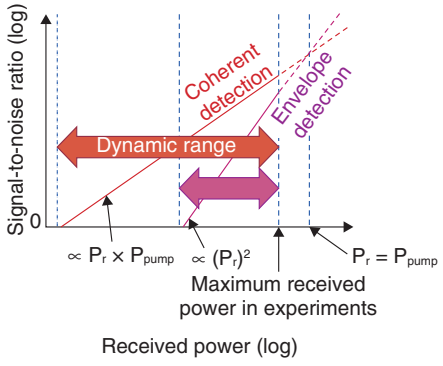

Fig. 3. Comparison of dynamic ranges of coherent and envelope detection methods.

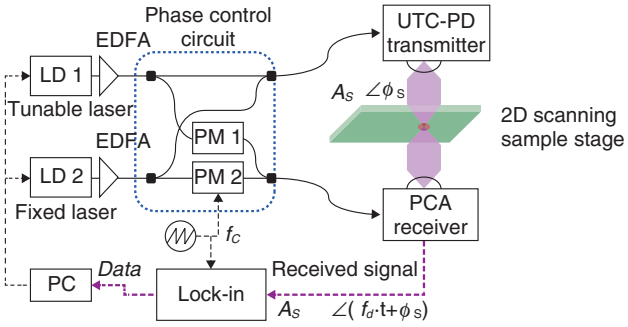

Fig. 4. Schematic of CW THz homodyne spectroscopy and imaging system.

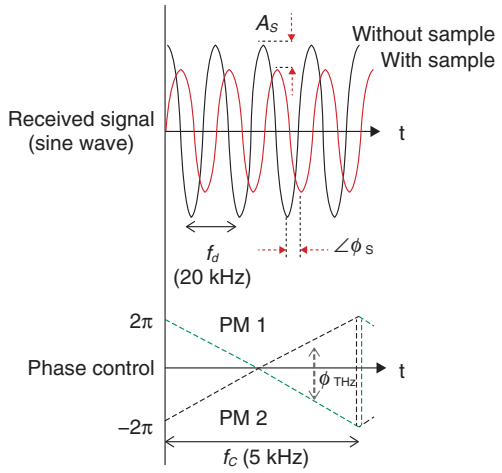

Fig. 5. Relationship of phase control and received signals.

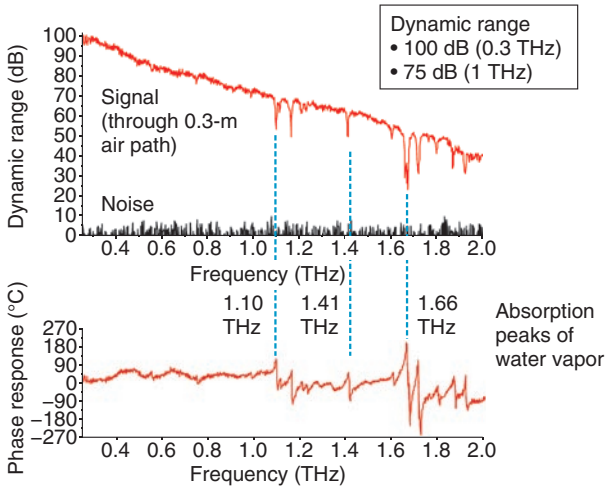

Fig. 6. Dynamic range and vapor absorption.

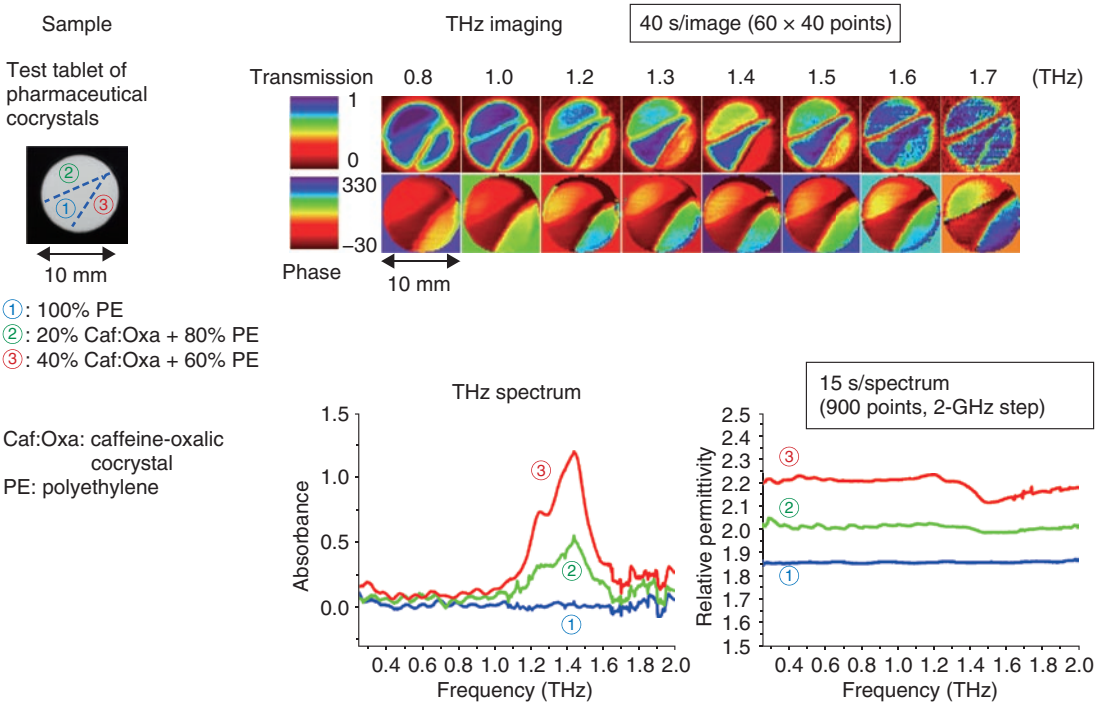

Fig. 7. Identification of cocrystal components of pharmaceutical tablet.

peaks in the spectra caused by atmospheric moisture were clearly detected with corresponding phase changes.

3. Identification experiment

An example of the identification of cocrystal components of a pharmaceutical tablet is shown in **Fig. 7** [3]. A test sample containing cocrystals of caffeine and oxalic acid, which has high absorption of THz

waves, was used in the experiment. The test tablet was 10 mm in diameter and approximately 1 mm in thickness and contained cocrystals mixed with polyethylene powder. The density of the cocrystals was 20% at the top left and 40% at the bottom right, as shown in the figure. The THz spectrum shown at the bottom of Fig. 7 was measured in 2-GHz steps, and it took approximately 15 s to capture 900 points. We can see that the broad cocrystal absorption peaks are located in the vicinity of 1.4 THz, and the intensity is proportional to density. The dielectric constant also changes at the peak absorption frequency weighted by the cocrystal density. As shown at the top of the figure, the THz images were also measured with the same experimental setup by using the 2D scan at a fixed frequency. Each image consists of 60 × 40 points, and the measurement time was approximately 40 s. This is very fast in comparison with the THz spectroscopy device using pulse waves and a mechanical type of delay stage, where the imaging usually takes several hours. The images at 1.4 THz clearly show the cocrystal distribution because that frequency corresponds to the cocrystal absorption peak. Although the current measurement speed is limited by the movement of the 2D scanning stage, we expect that a faster stage and an advanced scanning method can further improve the speed.

4. Future plans

We introduced the CW THz homodyne spectroscopy and imaging system and demonstrated its usage for a medical application. The CW method has huge potential advantages because of its compactness and fast imaging speed. However, currently, the frequency range possible with the CW spectroscopy system is only in the range of 0.3–2 THz, and the pulse method is superior in measurement sensitivity and bandwidth. Therefore, we are first focusing on developing a higher-power THz CW generator that operates at a wider bandwidth and has higher sensitivity. In addition, it is necessary to improve the method of THz spectrum analysis in order to overcome the difficulty of identifying multiple components in commercially available pharmaceutical products [4].

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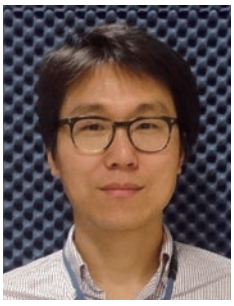

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Color-temperature Correspondence: Its Nature and Its Impact on Object Temperature Perception

Hsin-Ni Ho

Abstract

Color cues are often used to represent information concerning temperature, with red typically being associated with warm/hot, and blue with cold. Recent research from NTT Communication Science Laboratories demonstrated that such correspondences between color and temperature are not merely a design practice derived from a common sense belief. Instead, they have an actual impact on our information processing efficiency and object temperature perception. These findings are useful for the development of multimodal interfaces whose purpose is to provide a holistic experience in telecommunication and virtual environments.

Keywords: multisensory information processing, multimodal interface, temperature perception

1. Introduction

In developing multimodal interfaces aimed at providing a holistic experience in telecommunication and virtual reality environments, it is important to understand how our brains process and integrate multisensory information in order to achieve optimal performance. Color cues have been widely used to indicate information concerning temperature in the fields of industrial and interior design [1–4], and therefore, our current research on multisensory information processing focuses on such correspondences between color and temperature.

Correspondences between color and temperature have been studied by asking people to rate colored stimuli as being either warm or cold [2, 3, 5–7] or by instructing people to report which color they were reminded of when a thermal stimulus was presented to them [6]. As expected, people reported the color red being more often associated with warm, and blue with cold. This kind of association has been shown to affect people's feelings of warmth and coldness, with reddish colors inducing warm feelings and bluish colors inducing cold feelings [3, 7–12]. The effects of color shown in those studies are presumably knowledge-based. That is, the effect may result from direct employment of the knowledge of red-warm/blue-cold association *per se*, since in those previous studies, only subjective measures were used, and in most of the experiments the warmth and coldness were only *thought of*, rather than being physically presented.

In our research on color-temperature correspondences, we investigated whether such correspondences could have an actual impact on people's information processing efficiency and object temperature perception. The findings are expected to be useful in designing multimodal interfaces that aim to represent thermal information in virtual environments.

2. Impact of color-temperature correspondences on efficiency of information processing

We utilized two objective behavioral measures: the Implicit Association Test (IAT) and a priming task in order to examine what impact color-temperature correspondences have on information processing [13]. Both paradigms use reaction time (RT) as an objective task performance measure.

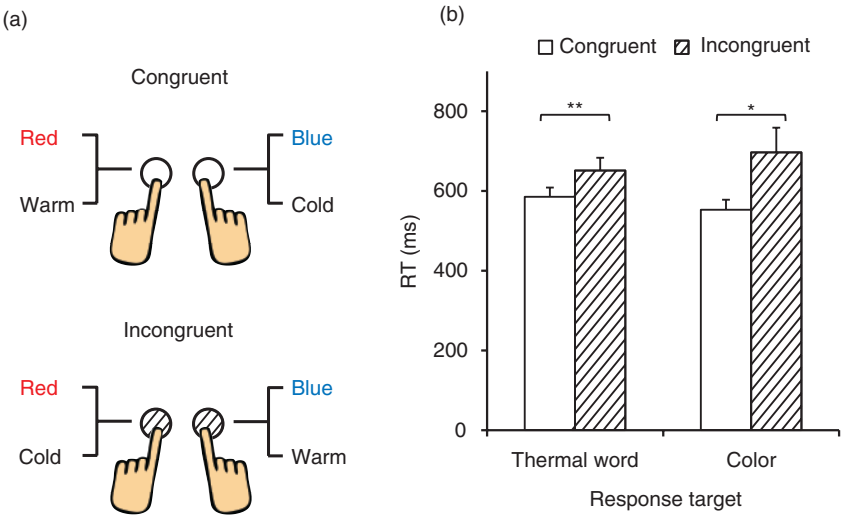

Fig. 1. (a) Stimulus-response key assignment. (b) Results of the IAT. Congruent key assignments are represented by white bars and incongruent assignments by striped bars. The error bars show the standard errors of the means; the symbols * and ** respectively indicate the statistical significance of $p<0.05$ and $p<0.01$.

2.1 Simplified IAT

IAT is widely used in social psychology to assess the strength of an individual's automatic associations between different concepts [14]. Here, we adapted a simplified version of IAT introduced by Parise and Spence [15] to examine the correspondences between color and temperature. In the experiment, a series of color patches and thermal words were presented on a display, one at a time. The participants' task was to categorize thermal words (warm versus cold) or color patches (red versus blue) with two response keys. We manipulated the assignment of the color and temperature to each response key, as shown in **Fig. 1(a)**. The foundation of the IAT is that it is easier to map two concepts into the same response key when they are internally associated (congruent) than when they are internally unrelated (incongruent). The participants consisted of 11 people (6 women), between the ages of 19 and 37; all had normal color vision.

We found that people's responses were faster with congruent key assignments (red-warm, blue-cold) than with the incongruent key assignments (red-cold, blue-warm), regardless of whether the response target was a thermal word or a color patch (see **Fig. 1(b)**). Our results indicated that correspondences between color and temperature affect the speed of response to a color or thermal stimulus. Incongruent combinations may lead to a prolonging processing time.

2.2 Priming task

We also used a priming task to investigate the interaction between color and temperature during information processing. In the experiment, color and thermal stimuli were presented sequentially in each trial, with the first stimulus acting as the task-irrelevant prime and the second stimulus as the target. When the prime consisted of a color stimulus, the target was a thermal stimulus, and vice versa. We manipulated the congruency of prime and target presented in each trial, so that half of the trials were congruent (e.g., red and warm) while the others were incongruent (e.g., red and cold). The color stimuli used were color patches, and the thermal stimuli used were words such as *warm* or *cold* that indicate thermal conditions, or physical warmth or coldness applied to the skin of the participant's index finger. The participants consisted of 31 people (23 women), between the ages of 19 and 61; all had normal color vision. They were instructed to discriminate the color target (i.e., red or blue) or the thermal target (i.e., warm or cold) as rapidly as possible. Our purpose was to assess the influence of a prime stimulus on the perception of the target stimulus under different color-temperature combinations.

We found that exposure to a thermal stimulus had no effect on the RTs to discriminate the color of a stimulus (**Figs. 2(b)** and **2(d)**), regardless of whether the thermal stimulus was semantic or physical, but exposure to a color stimulus did affect the RTs required

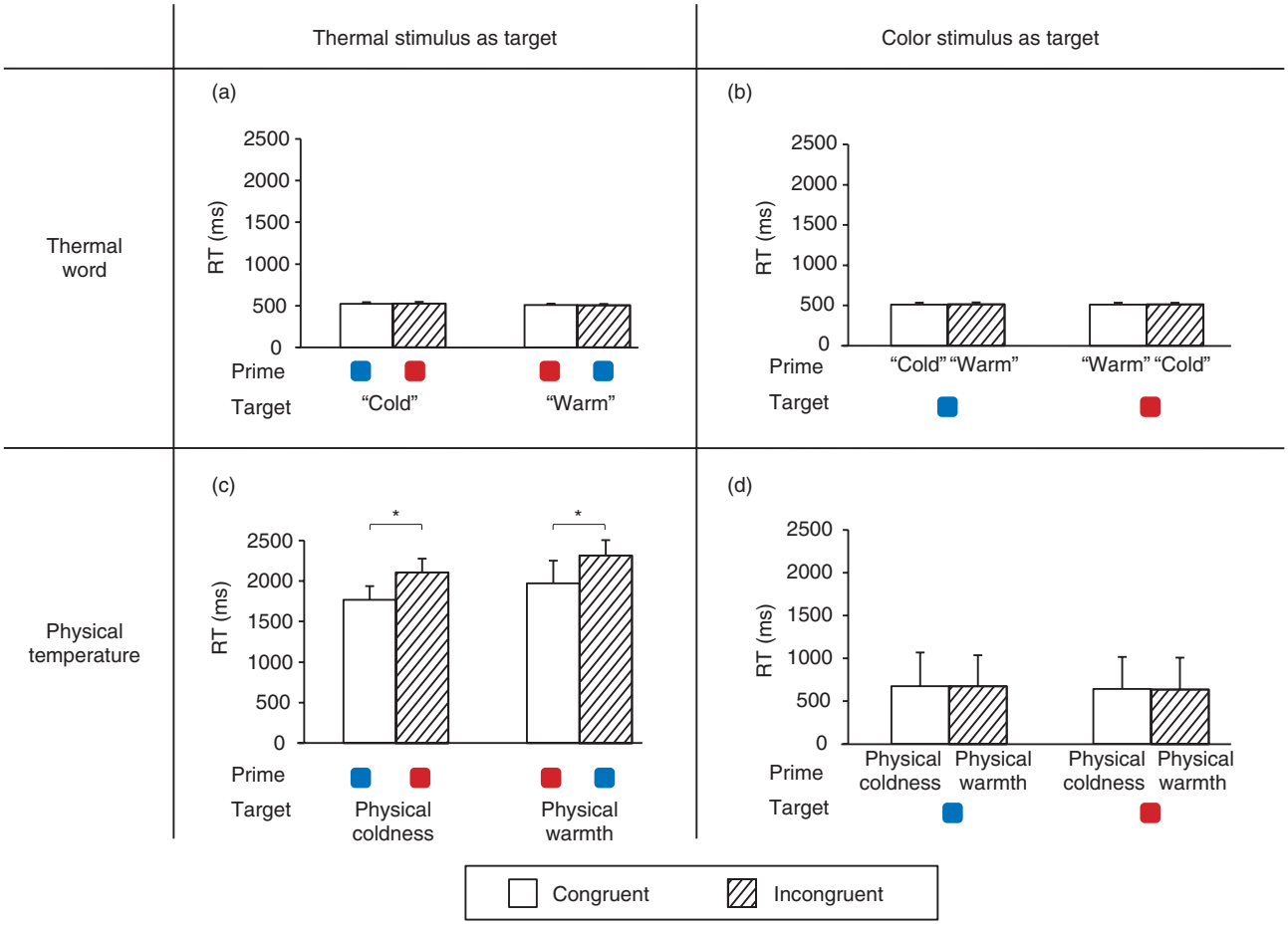

Fig. 2. RTs for participants discriminating (a) thermal words and (b) color stimuli when the prime is a thermal word, and (c) physical temperature and (d) color stimuli when the prime is a physical temperature. Congruent and incongruent combinations are shown in white and striped bars, respectively. Error bars indicate the standard errors of the means, and * indicates statistical significance of $p<0.05$.

to discriminate a physical temperature (**Fig. 2(c)**). This asymmetrical effect suggested that the color-temperature association might be stronger in the direction of color to temperature than temperature to color. This is not unexpected given that colors are often used to indicate temperature, but temperature is seldom used to indicate color. It was also found that when the target was a thermal word, there was no effect (**Fig. 2(a)**). However, when the target was a physical temperature, the RTs were significantly faster with a congruent prime (Fig. 2(c)).

While IAT indicated that the correspondences between color and temperature have similar effects on the speed of response to a color or a thermal stimulus, a priming task showed that the correspondences are more effective in reducing the RTs for physical thermal stimuli than for color stimuli. This difference in the results presumably comes from the difference between these two paradigms. In IAT, a single stimulus is presented in each trial, and this design ensures that the effects result from the difference in the color-temperature congruency between the two stimulus-response key assignments (See Fig. 1(a)), rather than the stimulus *per se*. Therefore, similar effects were obtained for a color and a thermal stimulus as long as the color and temperature were associated. In contrast, in the priming task, two stimuli are presented in a single trial, and this design allows for the possible interaction between the color and thermal stimuli during information processing. Thus, the effect of color-temperature correspondences would be more effective for a target stimulus that requires a relatively long processing time such as a physical temperature (RT of ~2000 ms, see Fig. 2(c)).

This is because a congruent color prime may facilitate people's classifying/labeling a physical temperature to the response categories *warm* and *cold* and therefore reduce the RTs. In the case of a color target, the facilitation would be limited because its RTs are already short in the first place (500–600 ms; see Figs. 2(b) and 2(d)).

In summary, our findings from both tasks demonstrated that the correspondences between color and temperature have an effect on information processing efficiency. These findings are useful for the design of multimodal interfaces that intend to convey information with both visual (color) and thermal feedback.

3. Impact of color-temperature correspondences on object temperature perception

While our research introduced in section 2 confirmed that correspondences between color and temperature have an actual impact on information processing efficiency, it remains unclear whether such correspondences can influence temperature perception. Although previous studies have shown that color-temperature correspondences can affect people's feelings of warmth and coldness, in most of these studies the temperature information was presented to the participants in an indirect, non-contact fashion [3, 7–12]. Because the most intuitive and natural way for people to obtain temperature information is to directly touch the object of interest, our purpose was to understand whether colors can still exert an influence under this circumstance. Although an old study reported some effects of color on object temperature judgments (e.g., green objects were more likely to be judged as warm than purple objects) [16], it remains unclear whether and how the effect is associated with the prevailing color-temperature correspondences.

When a hand touches an object, the feelings of warmth or coldness depend on not only the object temperature but also the hand temperature [17]. Accordingly, we studied the effect of color on object temperature perception by manipulating either the object color or the hand color while participants touched an object (**Fig. 3(a)**). We developed a novel multimodal system that utilizes a thermal display and advanced projection technology (**Fig. 3(b)**). This system can project colors onto the hand region selectively when the hand touches the object surface, and it can also control the temperature of the object surface. We varied the temperature of the object surface and asked the participants to judge whether or not the

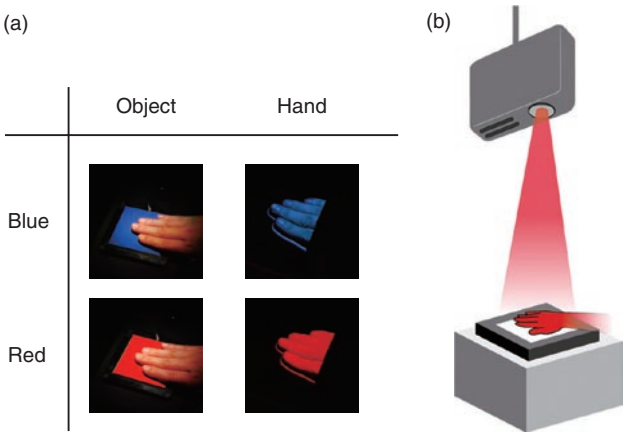

Fig. 3. (a) We manipulated object colors by attaching blue or red paper to the thermal display and hand colors by projecting blue or red light onto the hand. (b) The novel multimodal system developed for this study can perform feedback control to the surface temperature of the thermal display and selectively project colors onto the hand that was in contact with the thermal display.

object felt warm [18]. Our purpose was to see whether object and hand colors have an influence on the lowest temperature required for the object to feel warm.

What we found is that colors can affect our perception of object temperature, but not in the way that people would expect. Our data indicated that a red object, relative to a blue object, raises the lowest temperature required for an object to feel warm by 0.5°C (see **Fig. 4(a)**). In other words, our results indicated that a blue object is more likely to be judged as warm than a red object of the same physical temperature, which goes against the general expectation from the red-warm/blue-cold association. When the hand was colored red or blue, a reverse effect was found. This time, the lowest warm temperature for a red hand was lower than that for a blue hand by about 0.5°C (see **Fig. 4(b)**), indicating that red hands made objects feel warmer. Although the effect of colors here might seem small at first glance, our hands are able to detect temperature changes as small as 0.2°C and to distinguish temperatures that differ by as little as 0.03–0.09°C [19, 20]; thus, a change of 0.5°C is in fact relatively large and clearly perceptible.

It is known that the brain integrates visual and tactile information when estimating the properties of an object explored by the hand [21]. For properties such as size or surface roughness, direct sensory inputs and

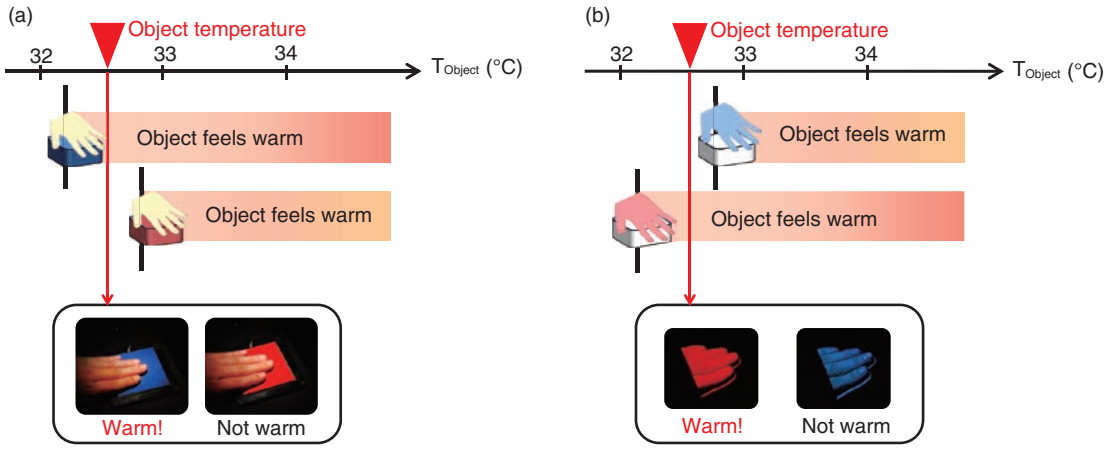

Fig. 4. (a) A red object, relative to a blue object, raises the lowest temperature required for an object to feel warm, so that a blue object is more likely to be judged as warm than a red object of the same physical temperature. (b) The lowest warm temperature for a red hand was lower than that for a blue hand, so that with a red hand, participants tended to judge the touched object as being warmer than they did with a blue hand.

expectations based on the visual information are averaged, so that the final perception is biased toward the expectations [21, 22]. In the case of estimating the temperature of an object, our data suggest that instead of taking the average of the expected and direct temperature inputs, our brain focuses on the difference between the two. As a result, the final perception is opposite to the expectation. Other object properties that have the same integration rule include weight, in which a larger object is tended to be judged as lighter than a smaller object of the same mass [23–27], and force, in which the perceived force from an impact on the palm is tended to be judged as weaker when the collision speed is fast compared to when the collision speed is slow [28].

In summary, our findings demonstrate that both object and hand colors can directly modulate temperature perception of an object touched by the hand and that the effect is opposite to the common red-warm/blue-cold expectation.

4. Applications to multimodal interface design

While current applications of color-temperature correspondences mainly focus on modulating people's thermal experiences in different environmental conditions and providing information concerning temperature with color cues, our new findings that color-temperature correspondences have an impact on not only the efficiency of information processing but also object temperature perception provide new guidelines for multimodal interface design.

For applications involving visual and thermal feedback, as indicated in section 2, it is important to avoid presenting incongruent visual and temperature information, such as presenting the color red and a low temperature together, especially in situations where users need to respond to physical temperature information. This is because with incongruent combinations of color and temperature, the time required for users to process the information could be prolonged, and the performance of the interface would degrade. When the purpose of the interface is to create a holistic experience of interacting with an object in virtual environments or at a remote site, manipulating the object and hand colors with visual feedback can in fact modulate the perceived warmness or coldness during hand-object interactions, as indicated in section 3. For example, coloring a user's hand red would make an object held in the hand feel warmer, and coloring a user's hand blue would make the object feel cooler. It is important to note, however, that when manipulating the color of the object itself, the opposite effect is obtained. That is, when coloring an object red, it would give a cooler feeling instead of a warmer feeling. Because thermal feedback control is relatively complicated and requires special hardware, the effect of object and hand colors on temperature perception would allow a more energy-saving and lower cost multimodal interface.

5. Conclusion

Our findings on color-temperature correspondences not only provide fresh insights on how our brains process multisensory information, but they are also expected to contribute to the development of interfaces for providing multimodal information and holistic experiences in telecommunication and virtual environments.

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DataBridge: Technology to Transfer Data Securely and Efficiently Between Terminals Connected to Different Networks

Hiroyuki Adachi, Nagatoshi Nawa, Fumihiro Yokose, Kimio Tsuchikawa, and Akira Inoue

Abstract

NTT Access Network Service Systems Laboratories is working on enhancing operational efficiency and reducing operational errors. In this article, we introduce our product called DataBridge, which enables data to be transferred securely and efficiently between terminals connected to different networks.

Keywords: data transfer, security, operational efficiency

1. Introduction

Companies use various operation systems (OpSs) to improve operational efficiency and ultimately reduce costs. For the most part, OpSs are applied to typical operations in which the volume of business is large rather than to atypical operations in which the business volume is comparatively small. Atypical operations occur less frequently, but their total business volume is not insignificant because there are many types of such operations. To further improve operational efficiency, we need more than ever to address the issue of improving the efficiency of operations that are difficult for OpSs to handle.

NTT Access Network Service Systems Laboratories is proposing *client side cooperation* as a solution to this issue. This solution enables OpSs to cooperate with each other through terminals rather than through system servers or networks. It has a minimal impact on OpSs and can be applied flexibly according to operations because it is applied on the client side. We have developed DataBridge as one of the elemental technologies of client side cooperation.

2. DataBridge outline

It is often the case that networks used within a corporation cannot be interconnected mainly because of security constraints. Networks for OpSs are designed to transfer only necessary data, and mission-critical tasks will not be affected even if OpSs are not connected to the Internet. However, in some atypical operations such as sending e-mail with attached files that are stored only in OpSs, there is a need to exchange data between different networks.

In such cases, data are currently transferred by manual operations such as using universal serial bus (USB) flash drives, or by printing the information on paper and manually inputting it. DataBridge allows transfer of data between terminals that are not interconnected via a network, based on the concept of client side cooperation. It ensures that data will be transferred securely and efficiently, which is not the case with the conventional approach of using USB flash drives or manually inputting data printed on paper, as shown in **Fig. 1**.

In general there is a trade-off relationship between

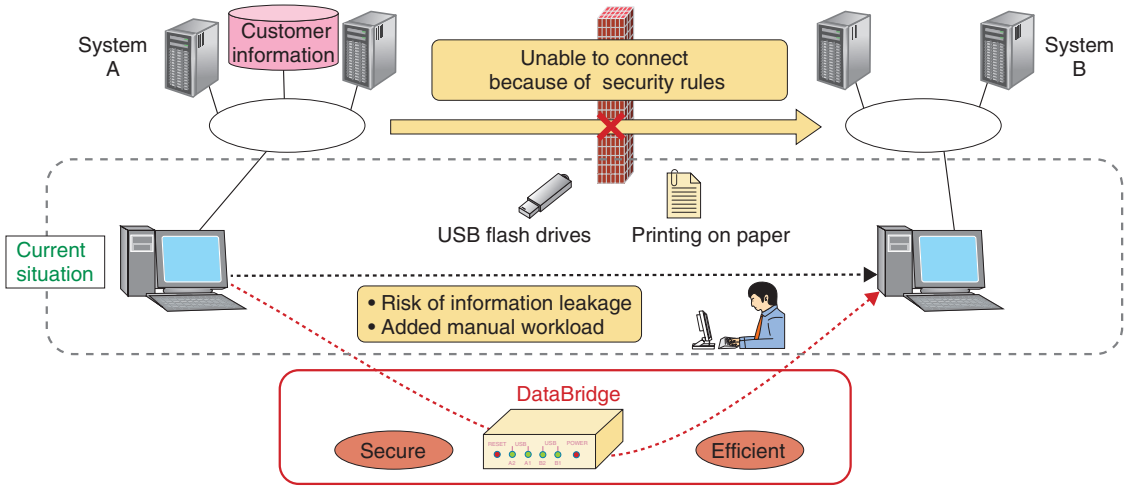
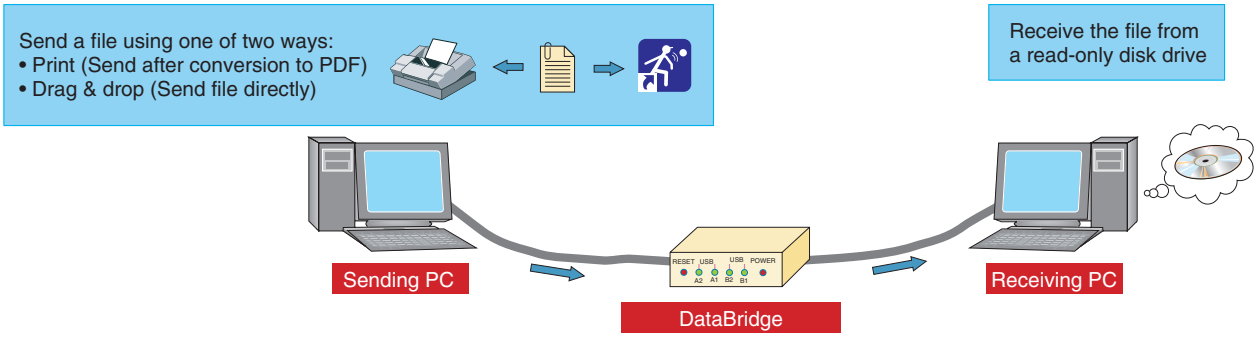


Fig. 1. Schematic of DataBridge.



PDF: Portable Document Format

Fig. 2. Utilization of DataBridge.

security and convenience. However, using the various functions of DataBridge enables users to obtain the most suitable balance with respect to security criteria and business content.

3. DataBridge mechanism

DataBridge is software for general purpose personal computers (PCs). It enables PCs to be used as a data bridge after the software has been installed in them. (Hereinafter, a PC installed with DataBridge software is referred to as "DataBridge"). DataBridge has two USB client ports, one for sending and one for receiving. It also has a function that filters the data input to the sending port so that the user gets only appropriate data from the receiving port (**Fig. 2**).

A user only needs to connect two USB cables in order to utilize DataBridge—one from DataBridge to the sending PC and one from DataBridge to the receiving PC. DataBridge ensures the two networks are never connected to each other because it transfers data without an IP (Internet protocol) connection. The sending PC recognizes DataBridge as a virtual printer, and the receiving PC recognizes it as a read-only removable drive. Users who specify DataBridge as a printer when printing applications (e.g., Excel or OpS) can then get portable document format (PDF) files on the receiving PC.

With this feature, DataBridge provides the following advantages to users.

(i) It transfers only data that are permissible to extract from the system on paper.

Table 1. Examples of setting items.

Setting item		Explanation
Data transfer restrictions		Per-day data volume and number of transfers can be limited to prevent unduly large data transfers. Unrestricted volume and number of transfers can also be set.
Availability period		Available time and days can be set to prevent off-hours usage.
Automatic deletion time frame		Time frame for automatic deletion of DataBridge-stored data can be set.
Policy expiration date		Policy expiration date can be set to enable periodic policy reviews. Data cannot be transferred after policy expires. Unlimited-duration policy can also be set.
Available terminals		Available sending PCs and receiving PCs can be registered.
Authorized users		Authorized users can be registered.
Unit recognition information		Identification names can be set for identifying which DataBridge unit was used when using multiple units in parallel.
File filters	File name filters	Keywords can be set as file name filters. File names containing keywords enable DataBridge to allow or disallow data transfers.
	Application filters	Applications available for transfer can be set.

(ii) It can remove viruses from files.
(iii) It can transfer data in a single direction.

These advantages enable users to transfer data securely. When users convert files to the PDF format, it becomes difficult to reuse the data. Therefore, DataBridge has a function that allows users to transfer files directly without converting them to PDF, as long as the abovementioned items (i) and (ii) are unnecessary. (The administrator can freely configure enable/disable settings.)

4. DataBridge features

4.1 Security features to ensure safe and appropriate data transfer

DataBridge provides functions for transferring *appropriate* data; the meaning of appropriate is determined based on the conditions listed in **Table 1**.

DataBridge can filter files by checking file names and types; thus, it functions as a file type filter by checking whether file extensions coincide with the file contents. DataBridge can even extract and check archived files in formats such as zip and lha.

It also has functions to ensure that usage is limited to authorized users and connected PCs. The administrator registers the MAC (media access control) address of PCs so that only registered PCs can use the system. Its user recognition function displays a dialog box in which the user name and password are entered. It can also recognize users by using Windows login information.

By combining these functions, the administrator can set different rules for different people, depending on the positions they hold within their company or organization.

Some examples of usage and restrictions are:

- Managers can use DataBridge at any time via all connected PCs.
- Rank-and-file users can use it only from 9 a.m. to 5 p.m. and only via their own PCs.
- Dispatched employees can transfer only Excel files for which the file name includes the word *application*.

Because data stored in DataBridge may not be taken from the office, DataBridge encrypts the stored data and automatically erases the data if it detects a disconnection or power-off of the USB cable being used. The erased data can never be restored.

4.2 Automatic usage history record for audits

It is important to ensure that the administrator is able to check whether data have been transferred appropriately. If this check is done using a manual operation, it imposes a heavy burden on both the person recording the usage history and the person checking it. To prevent this, DataBridge automatically records the usage history showing who used the system and when, as well as what files were used and from which PC and to which PC data were transferred. This usage history is basically stored inside DataBridge but can be transferred outside of it, which is useful when multiple DataBridge units are used in parallel.

4.3 Comparison with USB flash drives

USB flash drives are used for transferring data between terminals that are not interconnected over a network, and they present risks of unauthorized use

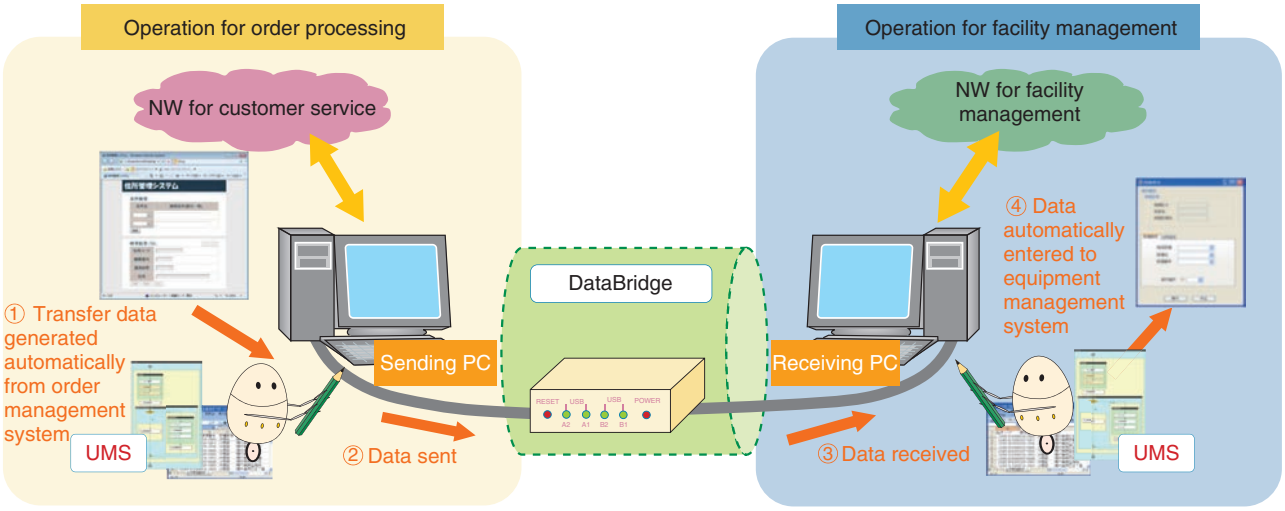


Fig. 3. Automated operation by combining DataBridge and UMS.

and information leakage. DataBridge prevents these risks by limiting the ways data are transferred and by recording the usage history.

4.4 Cooperation with UMS

The Unified Management Support System (UMS) is a software program that automates a variety of operations being executed on a single terminal. Like DataBridge, it is an example of client side cooperation technology [1, 2]. Combining DataBridge and the UMS makes it possible to automate operations that span across terminals that are not interconnected via a network, as shown in **Fig. 3**.

5. Summary and future plans

We have developed DataBridge, which enables users to transfer data easily and securely between terminals connected to different networks without any need to modify existing networks or systems. DataBridge is currently being used in the NTT Group. The DataBridge technology was transferred to NTT Software Corporation, where the plan is to further develop and commercialize it.

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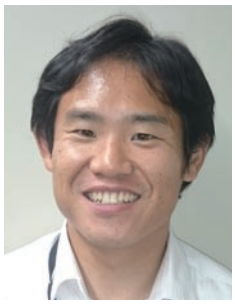

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Report of ITU-T TSAG Meeting and Activities of NTT R&D European Representative Office

Masakatsu Fujiwara

Abstract

The ITU-T TSAG (International Telecommunication Union, Telecommunication Standardization Sector, Telecommunication Standardization Advisory Group) and Review Committee conducted meetings June 16–20, 2014. This document reports the results of deliberations on major issues in this TSAG meeting: revision of patent policy and the creation of two new Focus Groups. It also covers the activities of NTT's R&D (Research and Development) European Representative Office based in Frankfurt, Germany with respect to major standards conferences in Europe.

Keywords: ITU-T TSAG, patent policy, R&D

1. Summary of TSAG and Review Committee meeting

The International Telecommunication Union, Telecommunication Standardization Sector (ITU-T)'s Telecommunication Standardization Advisory Group (TSAG) meeting differs from that of standard Study Groups (SGs), the objective of which is to create recommendations. Instead, it is intended as an event to debate ITU-T's standardization activities, work plans, and methodologies. Topics covered include approaches to the way future standardization will be deliberated, how standardization is to be maintained across multiple SGs, the creation of Focus Groups (FGs) for the intensive investigation of new issues, and other themes.

The Review Committee is a group created for the purposes of debating the organizational structure of ITU-T beyond 2016 with an eye to efficient deliberation on standards issues, and for considering partnerships with other standards organizations. Mr. Yoichi Maeda, formerly with NTT and now the chief executive officer and senior vice president of TTC (Telecommunication Technology Committee), serves as its chair.

Focusing on trends in TSAG and the Review Committee enables members to gain an early understanding of the major thrust of ITU-T's activities as a whole. The following section describes the core issues discussed at the June 2014 TSAG and Review Committee meetings.

2. Core issues discussed at June 2014 meeting

The meetings in June were held at ITU headquarters in Geneva, Switzerland, and they focused on two core issues—the revisions to patent policy and the creation of two new FGs.

2.1 Revision of patent policy

For a year and a half prior to the meeting, ITU's patent policy had been debated by the ITU-T Telecommunication Standardization Bureau (TSB) Director's Ad Hoc Group on IPR (intellectual property rights). Reaching a consensus was difficult, with one side in favor of licensers and the other in favor of licensees. An emergency proposal to revise patent policy on injunctive relief was presented at the meeting by representatives from the US government.

The Ad-Hoc Group had been deliberating on 1) assignment and transfer of patent rights, 2) the definition of *reasonable* and *non-discriminatory*, and 3) the

limits on the right to demand an injunction. While a consensus was reached at this TSAG meeting concerning point 1, there was no sign of reaching a resolution or compromise on points 2 and 3.

The US has been looking for ways to alleviate the major outlays of costs and manpower borne from lawsuits over standard-essential patents, and the US contingent expressed a desire to communicate a government-level policy that promotes their swift resolution.

However, the proposal came amidst a lack of sufficient advance coordination between the teams from the US and other countries, and there was little in the way of indication that an inquiry of said nature is underway. As a result, the majority of non-US countries attended without IPR specialists (whereas the US had close to 20). Participants came to the meeting with the assumption that progress on the above front would be difficult and that deliberations would have to be ongoing, so the US did not garner support for its proposal. At NTT, the NTT Intellectual Property Center has been dealing with this case, and we were in accordance with other countries in postponing deliberations on this matter until the next ITU-T IPR Ad Hoc Group meeting.

As a result, a resolution on the issue was deferred, and the Ad Hoc Group decided to reexamine the subject, with TSAG requesting the Ad Hoc Group to release an agreement at the TSAG meeting to be held in June 2015.

2.2 Creation of new FGs

2.2.1 FG Aviation

In response to the March 2014 incident of Malaysia Airlines Flight 370 going missing, the Malaysian government proposed the creation of an FG to explore the use of cloud computing technologies as a means of collecting real-time aircraft flight data. Attendees, Japan included, agreed to this proposal, which will establish the Aviation Application of Cloud Computing for Flight Data Monitoring FG.

The International Civil Aviation Organization (ICAO) also plans to cooperate on issues of real-time aircraft flight data collection. The organization is aware that this project will require coordination not just with ITU, but with ICAO, ISO/IEC JTC 1 (Joint Technical Committee 1 of the International Organization for Standardization and the International Electrotechnical Commission), ISO Technical Committee (TC) 20, and other units. The standardization issue at ITU-T is expected to focus on the use of big data and cloud technologies, as well as data searching and security. Plans are for Malaysia to present a candidate for FG Chair and for China and ICAO to present a candidate for Vice Chair. NTT plans to explore ways to contribute to this FG from the vector of cloud services, big data, and security.

2.2.2 Digital Finance Services

The US-based Bill and Melinda Gates Foundation (B&MGF) proposed the creation of a Digital Financial Services FG at ITU-T. B&MGF was founded by Bill Gates, the former chairman of Microsoft, and his wife Melinda, and is the world's largest charitable foundation.

Digital Financial Services refers to digital methods for the safe remittance and receipt of money for people primarily in developing countries who lack physical bank accounts. A study on these systems as a whole, including telecommunications, will proceed from ITU-T. It was made clear that the funds for this study would come from the aforementioned foundation, with the FG Director coming from the same. ITU-T SG2, SG3, SG13, SG16, and SG17 expressed their readiness to collaborate with the FG. Collaboration with ITU-T and other organizations, such as ISO TC 68, ISO/IEC JTC 1, GSMA (Groupe Spéciale Mobile Association), and SWIFT (Society for Worldwide Interbank Financial Telecommunication), was also highlighted. NTT must carefully follow where the investigation leads in order to ensure the outcome does not conflict in a technical manner with our existing mobile payment services.

3. Future ITU-T trends

The new FG issues agreed upon at this year's TSAG meeting involve proactively utilizing information and communication technology (ICT) and standardization to address social needs. A key point to this attempt is that it will be consistent with e-health, smart grid, and ITS (intelligent transport system) approaches and will not involve the orthodox horizontal approach to classifying issues by layer, but instead will employ a vertical, integrated approach to these layers and consider how standardization must be deployed in the aid of existing social concerns. Japan must actively contribute to these efforts, and through our activities at ITU-T, aid the development of global business by understanding vertical (industry-wide) needs.

4. Activities of Frankfurt R&D European Representative Office

The R&D (Research and Development) European Representative Office was established in 2010 as an overseas branch of the NTT Research and Development Planning Department for the promotion of our network operator partnerships, joint research, and standardization activities in Europe.

Based in Frankfurt, Germany, the organization is the sole representative office in Europe under the NTT holding company. The staff currently consists of this author alone.

The goal in establishing this office is to further expand NTT's R&D activities in Europe. Thus, efforts are underway to communicate with each country's carrier and vendor research organizations to build trust and create wide-ranging partnerships.

In terms of standardization, in addition to participating in discussions on standardization strategy such as the TSAG described herein, and also taking part in a timely fashion in new technical endeavors, this office is simultaneously supporting the globalization of R&D as a whole and launching investigation into the use and joint research of ICT in Europe. The European office is also working to build partnerships with carriers and has contributed to the smooth collaboration in research activities with major European carriers such as BT and Orange; in addition, the business side of the firm has promoted communication and collaboration with carriers.

Europe has begun taking steps to deliberate on a framework for the future, with Horizon 2020, the successor to FP7 (7th Framework Programme), itself a program designed to foster R&D, being launched as a new seven-year plan. The European Commission (EC) is also supporting a multitude of research programs. In particular, deliberation on 5G, the fifth generation mobile telecommunications system, is rapidly moving into motion through industry-government-academia partnerships in Europe. In December 2013, 5GPPP (5G Public-Private Partnership Association), an agreement on public-private research, was officially inaugurated as part of the EU's move towards establishment of 5G services. Horizon 2020 is moving forward with cutting-edge approaches in healthcare systems, smart cities and communities, and transportation, areas of core importance to NTT, so the progress of the program merits careful attention.

NTT's R&D European Representative Office plans to focus closely on R&D trends in the above areas and how they concern telecommunications networks, as well as movements within vertically oriented industries.

Going forward, we plan to further strengthen our R&D partnerships with overseas Group companies and to enhance the communication of information on these topics to contribute to the global activities of the NTT Group.

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General Manager, NTT R&D European Representative Office, NTT Research and Development Planning Department.
He received the B.E. in electrical engineering and the M.E. in applied systems science from Kyoto University in 1994 and 1996, respectively, and the M.B.A. from Cornell University, USA, in 2005. After joining NTT Network Service Systems Laboratories in 1996, he was engaged in R&D of key technologies for network management systems during 1996–2007 and 2010–2013. He was engaged in R&D strategy planning at NTT Research and Development Planning Department during 2007–2010. He has been with NTT R&D European Representative Office in Frankfurt, Germany, since 2013.

New NTT Colleagues
—We welcome our newcomers to the NTT Group

This is a corner of the NTT Technical Review where we introduce our new affiliate companies.

InfoTrust AG
IT security service provider; established in 2002, headquartered in Switzerland

Founded in 2002 and based in Zurich, InfoTrust AG is one of the most successful information technology (IT) security companies in Switzerland. Their team of experienced IT security specialists with proven industry know-how advises companies on all IT security issues and has successfully positioned itself over the years in the Swiss market. In November 2014, InfoTrust AG was fully acquired by NTT Com Security AG, a global information security and risk management organization and a member of the NTT Communications Group. For further information about InfoTrust AG, please visit http://www.infotrust.ch/

Contacts:
NTT Com Security AG
http://www.nttcomsecurity.com/en/news-and-events/press-releases/nid-00365/ntt-com-security-ag-acquires-infotrust-ag-in-switzerland-and-extends-market-leadership-in-europe/

Oakton
Technology and consulting service provider; established in 1988, headquartered in Australia

Founded in 1988, Oakton is a consulting and technology firm based in Melbourne, Australia. For over 25 years, Oakton has worked with corporate and government clients across a range of industries. The company brings together a deep experience-based understanding of the issues and trends of key industry sectors, with an intimate knowledge of business processes, operational processes, and management systems. In November 2014, Oakton was acquired by Dimension Data Holdings plc, an ICT (information and communication technology) services and solutions provider and a member of the NTT Group. For further information about Oakton, please visit http://www.oakton.com.au/

Contacts:
Dimension Data Holdings plc
http://www.dimensiondata.com/Global/Downloadable%20Documents/Dimension%20Data%20Australia%20Announces%20Successful%20Acquisition%20of%20Oakton.pdf

Electronic Environments Corporation

Mission-critical lifecycle services provider; established in 1986, headquartered in USA

For nearly three decades, Electronic Environments Corporation (EEC) has successfully helped thousands of telecom and datacenter clients maximize the productivity of their mission-critical infrastructure. EEC provides design, construction, maintenance and 24/7 support services throughout all phases of the mission-critical life-cycle. EEC's proven practices enable IT and facilities managers to optimize the reliability, performance, and value of their datacenter and telecom sites. In December 2014, NTT FACILITIES, INC., the leader in designing and constructing state-of-the-art information facilities that support communications and Internet infrastructure and a member of the NTT Group, acquired a majority stake in EEC. For further information about Electronic Environments Corporation, please visit http://www.eecnet.com/Home/

Contacts:
Public Relations Office, General Affairs and Personnel Division,
NTT FACILITIES, INC.
http://www.ntt-f.co.jp/english/news/heisei26/h26-1117.html

External Awards

Outstanding Paper Award

Winner: Ryo Ishii, Kazuhiro Otsuka, Shiro Kumano, and Junji Yamato, NTT Communication Science Research Laboratories
Date: November 14, 2014
Organization: 16th ACM International Conference on Multimodal Interaction

For "Analysis of Respiration for Prediction of "Who Will Be Next Speaker and When" in Multi-Party Meetings."

To build a model for predicting the next speaker and the start time of the next utterance in multi-party meetings, we performed a fundamental study of how respiration could be effective for the prediction model. The results of the analysis reveal that a speaker inhales more rapidly and quickly right after the end of a unit of utterance in turn-keeping. The next speaker takes a bigger breath toward speaking in turn-changing than listeners who will not become the next speaker. The results of the evaluation of our prediction model suggest that the speaker's inhalation right after a unit of utterance is effective for predicting whether turn-keeping or turn-changing will occur about 350 ms before the start time of the next utterance, and that the listener's inhalation before the next utterance is effective for predicting the next speaker in turn-changing about 900 ms before the start time of the next utterance.
Published as: R. Ishii, K. Otsuka, S. Kumano, and J. Yamato, "Analysis of Respiration for Prediction of "Who Will Be Next Speaker and When" in Multi-Party Meetings," Proc. of the 16th ACM International Conference on Multimodal Interaction, pp. 18–25, Istanbul, Turkey, November 2014.

APMC 2014 Prize

Winner: Kazuki Maruta, NTT Access Network Service Systems Laboratories; Jun Mashino, Takatoshi Sugiyama, NTT Network Innovation Laboratories
Date: November 6, 2014
Organization: Institute of Electronics, Information and Communication Engineers (IEICE)

For "Blind Adaptive Arrays with Subcarrier Transmission Power Assignment for Spectrum Superposing."
Published as: K. Maruta, J. Mashino, and T. Sugiyama, "Blind Adaptive Arrays with Subcarrier Transmission Power Assignment for Spectrum Superposing," Proc. of the 2014 Asia-Pacific Microwave Conference (APMC 2014), Sendai, Japan, November 2014.

Hornarable Mention Poster Award

Winner: Takahiro Matsumoto, Shunichi Seko, Ryosuke Aoki, Akihiro Miyata, Tomoki Watanabe, and Tomohiro Yamada, NTT Service Evolution Laboratories
Date: October 30, 2014
Organization: The Second International Conference on Human-Agent Interaction (HAI 2014) organizing committee

For "Affective Agents for Enhancing Emotional Experience."

We propose shared emotional experience agents that enhance the user's emotional experience through emotional contagion. Our experiment had 12 participants, who watched videos together with a robot that expressed an emotional state using its body and voice. The results suggest that the affective robot makes the user more excited and relaxed, and less depressed and afraid than if they viewed it alone.
Published as: T. Matsumoto, S. Seko, R. Aoki, A. Miyata, T. Watanabe, and T. Yamada, "Affective Agents for Enhancing Emotional Experience," Proc. of HAI 2014, pp. 169–172, Ibaraki, Japan, October 2014.

Best Technical Exhibition Award

Winner: Takayuki Yamada, Doohwan Lee, Hiroyuki Shiba, Yo Yamaguchi, Takana Kaho, Tadao Nakagawa, and Kazuhiro Uehara, NTT Network Innovation Laboratories
Date: October 31, 2014
Organization: SmartCom2014 (Singapore - Japan International Workshop on Smart Wireless Communications) organizing committee

For "Broadband Spectrum Sensing Platform based on Received Waveform Cross-correlation Using Distributed Sensors."

ETSI NFV Excellence Award

Winner: Tetsuya Nakamura, Research Laboratories, NTT DOCOMO
Date: November 21, 2014
Organization: European Telecommunications Standards Institute (ETSI)

For outstanding leadership and support for network functions virtualization (NFV) in Phase 1.

Papers Published in Technical Journals and Conference Proceedings

Evaluation of Window Interface in Remote Cooperative Work Involving Pointing Gestures

R. Ishii, S. Ozawa, H. Kawamura, A. Kojima, Y. Nakano, and K. Otsuka

Proc. of the Seventh International Conference on Advances in Computer-Human Interactions (ACHI 2014), pp. 242–251, Barcelona, Spain, March 2014.

We previously proposed a "MoPaCo" window interface system that can reproduce a communication partner's space within a display as if the display were a glass window to achieve geometrical consistency between remote spaces. Experiment results demonstrated it enables users to feel that the distance between themselves and their conversational partners on video is about the same as in a face-to-face situation and the partner is actually present. We consider MoPaCo can generate video images that smoothly transmit gazes and pointing gestures; this paper describes experimental tests of the system's effectiveness in doing so. Results suggest MoPaCo allows users to accurately identify target objects as they would under face-to-face conditions through an actual glass window. Results of experiments on conversation quality show MoPaCo facilitates smooth conversation and communication among users and strengthens their memories of the conversations, suggesting the users actively engage in conversation, and the system makes a strong impression on them.

Nine Years of Memory of Personal Things: Accuracy and Distortions

N. Shingaki, M. Kitabata, H. Matsuoka, T. Takada, A. Orino, Y. Kato, Y. Tsuzuki, and T. Owada

Cognitive Studies, Vol. 21, No. 1, pp. 15–28, March 2014.

How should we save our memories? Many people keep diaries and take pictures for that purpose. In this study, we kept things of personal significance in a time capsule for nine years and examined whether personal memories could be saved in a time capsule and how they might possibly change over time. We held a workshop in 2003 when participants put something that they had possessed which had personal significance at that time of their life. They were interviewed to explain what kinds of significance these possessions had for them, and these interview sessions were recorded. Nine years after the initial workshop, the participants came together again. Before the time capsule was opened, they were asked to recall what they had put in the time capsule and to describe in what ways their item in the time capsule had been significant to them. By comparing the contents of the participants' responses between 2003 and 2012, we found that a great deal of the contents had changed.

Analysis and Modeling of Next Speaking Start Timing in Multi-party Meetings

R. Ishii, K. Otsuka, S. Kumano, and J. Yamato

Proc. of IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2014), pp. 694–698, Florence, Italy, May 2014.

To realize a conversational interface where an agent system can smoothly communicate with multiple persons, it is imperative to know how the start timing of speaking is decided. We demonstrate a relationship between gaze transition patterns and the start timing of the next spoken utterance against the end of the last spoken utterance in multi-party meetings. Then, we construct a prediction model for the start timing using gaze transition patterns near the end of an utterance. An analysis of data collected from natural multi-party meetings reveals a strong relationship between gaze transition patterns of the current speaker, next speaker, and listener and the start timing of the next speaker. On the basis of the results, we used gaze transition patterns of the speaker, next speaker, and listener, and mutual gaze as variables, and devised several prediction models. A model using all features performed the best and was able to predict the start timing well.

Quantum Algorithms for Finding Constant-sized Sub-hypergraphs over 3-uniform Hypergraphs

F. Le Gall, H. Nishimura, and S. Tani

Proc. of the 20th International Computing and Combinatorics Conference (COCOON 2014), pp. 429–440, Atlanta, GA, USA, August 2014.

We develop a general framework to construct quantum algorithms that detect whether a 3-uniform hypergraph given as input contains a sub-hypergraph isomorphic to a pre-specified constant-sized hypergraph. This framework is based on the concept of nested quantum walks recently proposed by Jeffery, Kothari, and Magniez [SODA'13], and extends the methodology designed by Lee, Magniez, and Santha [SODA'13] for similar problems over graphs. As applications, we obtain a quantum algorithm for finding a 4-clique in a 3-uniform hypergraph on n vertices with query complexity $O(n^{1.883})$, and a quantum algorithm for determining if a ternary operator over a set of size n is associative with query complexity $O(n^{2.113})$.

An In-Operation IP-over-Optical Network Planning Method that Supports Unpredictable IP Traffic Transitions

T. Tanaka and A. Hirano

Proc. of the 40th European Conference on Optical Communications (ECOC 2014), Cannes, France, September 2014.

We propose a first-time in-operation IP (Internet protocol)-over-optical network planning method that offers optical path provisioning criteria under temporal and geographical IP traffic changes. Simulations show the proposed method can support traffic transitions with less additional optical path provisioning.

Proposal and Evaluation of Web Framework for Ubiquitous Sensor Network

T. Nakamura, K. Mori, Y. Higashijima, M. Nakamura, H. Matsumura, and M. Matsuo

IEICE Transactions on Communications (Japanese Edition), Vol. J97-B, No. 9, pp. 793–807, September 2014.

This paper proposes a web framework for a ubiquitous sensor network (u-framework), which supports development of server-side applications used for M2M services on wireless sensor networks, and

evaluates the proposed method by applying it to development of actual systems. We first analyzed some examples of vertical-domain services using wireless sensor networks, and found that server-side functions in each of the services share some degree of similarity. The proposed u-framework is built on a web framework and extends it on supporting sensor networks. Our method can save a great deal of effort in the development of such common functions. This paper also proposes the real-world development studio, which supports development and debugging of sensor network services including server-side applications and sensor terminals. Evaluations of the proposed methods applied to practical system developments for two independent field trials are also explained in this paper.

Distinct Pseudo-attraction Force Sensation by a Thumb-sized Vibrator that Oscillates Asymmetrically

T. Amemiya and H. Gomi

Proc. of Eurohaptics 2014, pp. 88–95, Versailles, France, June 2014.

This paper describes the development of a thumb-sized force display for experiencing a kinesthetic illusory sensation of being continuously pushed or pulled. We previously succeeded in creating a sensation of being pulled with a prototype based on a crank-slider mechanism, but recently we did so with a thumb-sized actuator that oscillates asymmetrically.

With this tiny and light force display, the directed force sensation is perceived just as strongly as with the previous larger prototypes. We conducted a user study using the method of paired comparisons. The results show that a specific vibrator with a 7-ms pulse at 40 Hz induces the sensation most clearly and effectively.

Influence of Dolly Shape on Adhesive Property and Correlation Between Adhesion and Cross-cut Test Results

T. Miwa, Y. Takeshita, S. Sakata, and T. Sawada

Rust Prevention and Control Japan, Vol. 58, No. 10, pp. 368–372, October 2014.

Coated steel structures need to be checked regularly for deterioration in the coatings and subsequently repainted at an appropriate time. An adhesion test is the standard method for evaluating coating adhesion, and a cross-cut test is usually used to evaluate peel resistance. In this study, adhesion was measured on the same sample using two kinds of dollies with different shapes. One dolly had a hand-hold with a spherical shape. In the adhesion test with this dolly, it was found that the relative standard deviation in multiple adhesion measurements on the same sample was reduced to one fourth of that using a standard dolly. Additionally, a new method of classifying cross-cut test results for a coating on hot dip galvanized steel was developed, and it was confirmed that there was consistency between the classification and the adhesion of the coatings.

Violation of Equipartition of Energy in Thermal Noise of a Small DRAM

K. Nishiguchi and A. Fujiwara

Proc. of the 27th International Microprocesses and Nanotechnology Conference (MNC 2014), 6B-4-3, Fukuoka, Japan, November 2014.

We introduce a transition between the valid and invalid law of equipartition of energy in thermal noise in a small DRAM (dynamic random access memory). We analyzed Brownian motion, i.e., thermal noise, of single electrons entering and exiting a small capacitor whose Ec is comparable to kBT. When Ec>kBT, the electron motion is suppressed due to the violation of the law of equipartition of energy.

Zero Dimensional Ion-sensitive Field-effect Transistors

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Proc. of MNC 2014, 6P-7-61, Fukuoka, Japan, November 2014.

We propose to fabricate and characterize a tiny pH electrode so small that the number of charged sites can be statistically null. We also show a rupture in the universal pH response of such sensors and propose a dedicated model.

Tunnel Diode Composed of $MoS_2/SiO_2/Si$ Heterojunction

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Proc. of MNC 2014, 5D-3-2, Fukuoka, Japan, November 2014.

We introduce a tunnel diode based on a combination of MoS_2 with a Si MOSFET. An n-type-MoS_2/SiO_2/p-type-Si heterostructure provides current characteristics with negative differential resistance (NDR) reflecting the number of the MoS_2 layers.

Analysis of Timing Structure of Eye Contact in Turn-changing

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Proc. of the 16th ACM International Conference on Multimodal Interaction (ICMI 2014), the 7th Workshop on Eye Gaze in Intelligent Human Machine Interaction, pp. 15–20, Istanbul, Turkey, November 2014.

With the aim of constructing a model for predicting the next speaker and the start of the next utterance in multi-party meetings, we focus on the timing structure of the eye contact between the speaker, the listener, and the next speaker. The results of analysis show that the listeners in turn-keeping tend to look at the speaker first more often, before the speaker looks at the listeners than the next speaker in turn-changing looks at the speaker first before the speaker looks at the next speaker when the eye contact with the speaker happens. The listeners in turn-keeping also tend to look away from the speaker later more often, after the speaker looks away from the listener than the listeners and the next speaker in turn-changing look away from the speaker later when the eye contact with the speaker happens.

OpenStack Upgrade Without Down Time

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Proc. of OpenStack Summit November 2014 Paris, Paris, France, November 2014.

Many public cloud service providers utilize OpenStack software to build IaaS (Infrastructure as a Service) systems. OpenStack is open source software that is developed by a community that many organizations and individuals participate in. New versions of OpenStack are released at intervals of six months, and only the two latest versions are maintained. Therefore, system update methods without service interruption are necessary for public cloud service providers who want to keep the systems up to date. This document proposes system update methods without service interruption in public cloud services

and explains an evaluation of the proposed update methods. Furthermore, we describe some problematic issues which were found in the evaluation. On the basis of these issues, items to be improved are suggested to the OpenStack community.

Impact of Pulse Poling on Static and Dynamic Ferroelastic-domain Contributions in Tetragonal Pb(Ti, Zr)O_3 Films Determined by In-situ x–ray Diffraction Analysis

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Journal of Applied Physics, Vol. 116, No. 19, pp. 194102–194102-7, November 2014.

The effects of bipolar pulse poling on the ferroelastic domain structure and their contribution to the electrical and piezoelectric properties of $Pb(Ti_{0.7}Zr_{0.3})O_3$ films are investigated. Micro x-ray diffraction measurements clearly show that the volume fraction of the c-domain increases irreversibly as the poling field is increased, leading to changes in the remanent polarization, dielectric constant, and piezoelectric coefficient. Theoretical estimations well explain the changes of remanent polarization and dielectric constant, but the increase in piezoelectric coefficient is much larger than the theoretical estimation. *In-situ* x-ray diffraction analysis under an electric field reveals that this disagreement is due to the unexpected activation of the ferroelastic domain wall motion. Our results provide new insight into the poling effect on the electric and piezoelectric properties of ferroelectric films.

Electric Tuning of Direct-indirect Optical Transitions in Silicon

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Scientific Reports, Vol. 4, No. 6950, pp. 1–6, November 2014.

Electronic band structures in semiconductors are uniquely determined by the constituent elements of the lattice. For example, bulk silicon has an indirect bandgap, and it prohibits efficient light emission. Here, we report the electrical tuning of the direct/indirect band optical transition in an ultrathin silicon-on-insulator (SOI) gated metal-oxide-semiconductor (MOS) light-emitting diode. A special Si/SiO_2 interface formed by high-temperature annealing that shows stronger valley coupling enables us to observe phononless direct optical transition. Furthermore, by controlling the gate field, its strength can be electrically tuned to 16 times that of the indirect transition, which is nearly 800 times larger than the weak direct transition in bulk silicon. These results will therefore assist the development of both complementary MOS (CMOS)-compatible silicon photonics and the emerging "valleytronics" based on the control of the valley degree of freedom.

Auto Bias Control and Bias Hold Circuit for IQ-modulator in Flexible Optical QAM Transmitter with Nyquist Filtering

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Optical Express, Vol. 22, No. 23, pp. 28163–28168, November 2014.

An auto bias control (ABC) technique for the IQ (in-phase and quadrature)-modulator of a flexible optical QAM (quadrature amplitude modulation) transmitter is described. This technique can support various optical QAM signal formats with Nyquist filtering and electronic dispersion pre-compensation. 16-, 32-, and 64-QAM signals (21 Gbaud) are successfully generated, and all bias voltages are held to their optimum value even when signal format is changed.

Improving Method of Disaster Response Manual Based on the Guidelines of the Cabinet Office by ICT

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Journal of Institute of Social Safety Science, No. 24, pp. 201–210, November 2014.

The guidelines for earthquakes occurring in a local city were exhibited in August 2013 by the Cabinet Office. These guidelines are a checklist of response actions to implement in the event of an earthquake. It is expected that a municipality can prepare a very effective emergency response manual if the municipality bases the manual on these guidelines and clarifies the Emergency Support Functions in the manual. In this paper, we describe the efficient method used in Kashihara-shi. We have improved the Disaster Response Manual and clarified the Emergency Support Functions in Kashihara-shi based on the guidelines and by utilizing information and communications technology.