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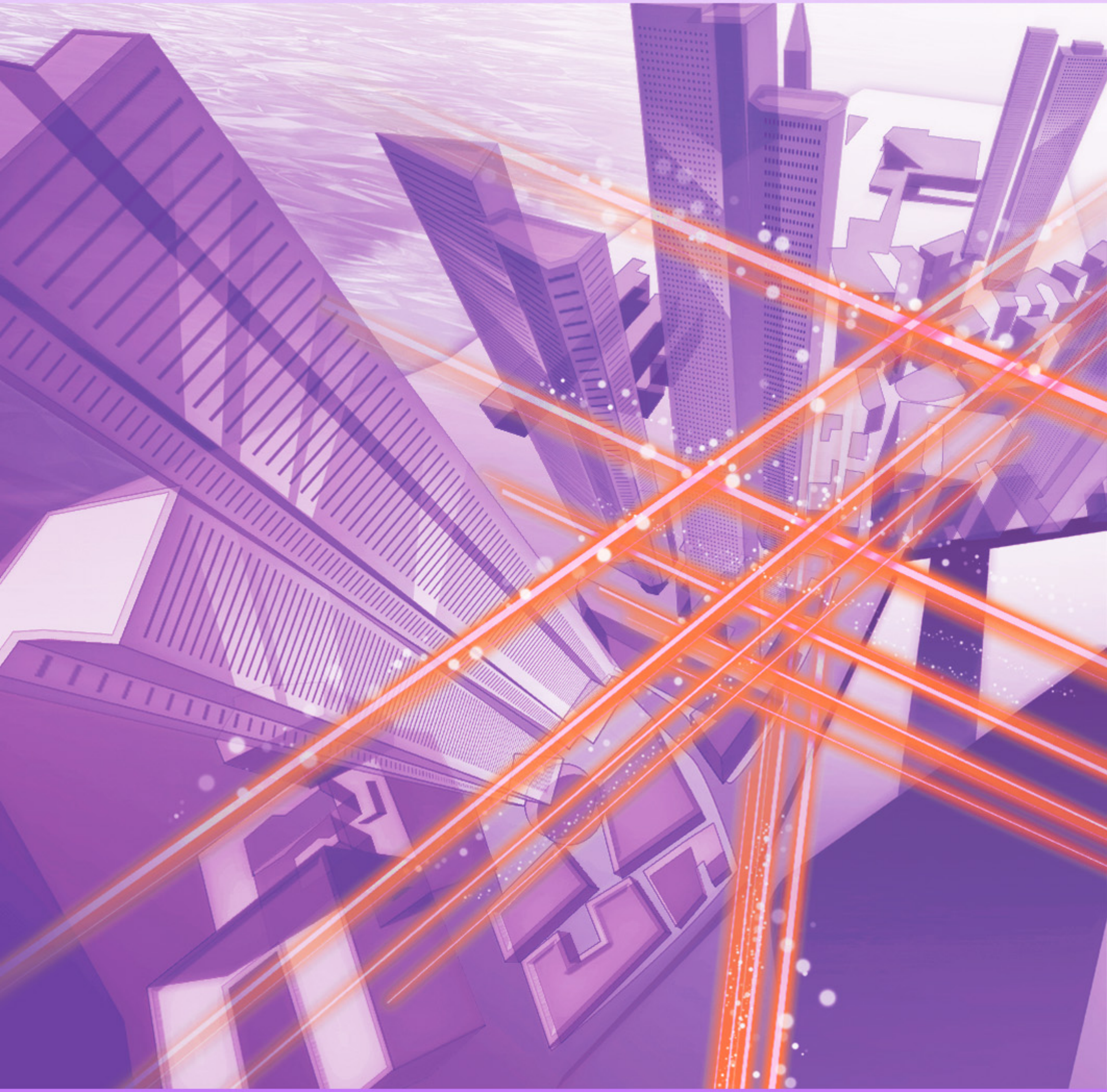

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By Utilizing the "Swing-by Model," We Can Convert the Environment around Us to a Source of Power

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Overview

Japan is a so-called *super-aging society*, with people aged 65 and older accounting for over 25% of its population. The needs for early detection of diseases and care for elderly people living alone at home are increasing, and it is urgently needed to establish high-precision measurement of biological signals and a platform for processing biological information. In the meantime, society is rapidly globalizing. We asked NTT Fellow Shingo Tsukada of NTT Basic Research Laboratories what kind of stance researchers should take as they tackle research in such an era.

Keywords: hitoe, bioelectrode, interdisciplinary research

Taking up the challenges of medical diagnosis, health promotion, and the sports field from the viewpoint and insight of a former clinician

—Tell us about your current research.

My current research involves the application of a sensing fabric called hitoe™ in three areas: medical diagnosis and treatment, sports and health promotion, and safety management and monitoring. On the basis of my experience as a clinician, I have been keenly aware of the need for technologies that help treat diseases that are difficult to cure and technologies for finding diseases faster, so I have been involved in basic research on those themes. As my research progressed, I focused on the bioelectrodes used to connect weak signals in the body to an electronic circuit, and I thought that PEDOT-PSS,* a conductive polymer being studied at NTT Basic Research Laboratories at that time, would be suitable for bioelectrodes. PEDOT-PSS is very fragile when it gets wet on contact with water, and that fragility is a major barrier regarding bioelectrodes used in wet environments. However, we overcame this problem by coating PEDOT-PSS onto surgical silk sutures, so it can now be used for bioelectrodes. After that, in collaboration with Toray Industries, Inc., we replaced the silk fibers with polyester nanofibers (700 nm in diameter), which we developed and commercialized as the sensing fabric hitoe.

Although hitoe has been practically applied, it continues to be researched. Its usefulness will only be realized when it becomes popular. To ensure that

* PEDOT-PSS: poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate)

happens, it is also necessary to deal with it as a business. Since hitoe was developed, wearable products with similar functions—such as smart watches that can measure heart rate—have hit the market one after another, and they have rapidly gained popularity as simple heart-rate measurement devices. However, measurements taken in a person's daily life or when a person is exercising tend to increase distortion, loss, and noise in the measurement data, but using such measurements in medical examinations such as electrocardiograms requires very high precision. Fields that require high-precision measurements that are difficult to handle with such common wearable products are areas in which hitoe is being actively applied.

In collaboration with medical institutions and other partners, we are currently focusing on promoting the spread of hitoe in the medical, sports, health-promotion, safety-management, and elderly-care fields. In the sports field in particular, with an eye on the major event to be held in Tokyo in 2020, efforts to strengthen athletes are underway, and we expect hitoe to be utilized in such programs.

—I heard that you took up the challenge of measuring a race car driver's vital signs during an IndyCar Series race, the highest peak of formula racing in North America.

When it first came out that we wanted to measure vital data of racing drivers, it was half a year before the IndyCar Series racing season started. We had no idea that an IndyCar race takes place in such a harsh environment, and we did not have the necessary information concerning the car, so we were groping in the dark. I made some time between my other tasks and handcrafted a wearable sensor based on a research prototype. However, it looked as if I wouldn't make it in time. I did everything I could by myself from processing the surface of a fireproofing garment to wiring and attaching transmitters. Eventually, I had to go to the site and check it, so I went to Indianapolis. On the international flight there, I sewed the wearable sensor into the garment to be worn by the driver.

We were able to get the cooperation of the famous IndyCar driver Tony Kanaan and some excellent engineers. In addition, we obtained valuable information that could not be understood unless on site. We then went through a series of trial and error experiments, at the end of which, we managed to make it in time for the actual IndyCar race.

A major factor in our success was that the special areas of responsibility of each party were combined skillfully—like the pieces of a jigsaw puzzle—to make the project a success. To be honest, the project would not have been a success if those members were not involved (**Fig. 1**). Although both the level of skills required and the schedule were tough, it was a great collaborative effort. We leveraged this experience to carry out measurements at other motor races, and it seemed that everyone was surprised at the quality of our technology.

What I have reaffirmed through such experiences is the importance of going to the site and working directly on manufacturing. If the manufacturing work is left entirely to others, it will soon become a virtual world with a poor sense of reality. Some people at the factory, including people at our partner companies, are doing hard physical work, while others are coding and solving bugs in programs. If you get involved in the actual work as much as possible, you will understand their hard work, and you will feel the sense of reality of the research itself. Probably because I'm clumsy, I tend to make a lot of mistakes when I try to do things in an easier way, so I inevitably go by trial and error. By going through trial and error, you get to know what processes are time-consuming, and if you fail you can see why.

Interdisciplinary research has become common. Constantly check your competence in a global society.

—You recognize that the world has largely shifted from the conventional style of research.

As for the environment surrounding research, the framework of research has changed dramatically between the 20th and the 21st centuries. Those who can respond to this change are likely to increase their chances of success in the future. If we look back at the state of scientific research from the early 20th century to the middle of the 20th century, it seems that many of the initial important tasks in each field were tackled by a handful of experts. Then, in the second half of the 20th century, applied research and development (R&D) became the main force, and the number of people involved in it increased as the amount of information grew exponentially. Since the time when there were only a few specialists in a particular area who led in that field of specialization, we have entered an era in which the overwhelming amount of information obtained through the collaboration of many researchers does the leading; in other

ECG: electrocardiogram
HR: heart rate

Fig. 1. Initial members and a driver of the IndyCar Series race project with hitoe™ and the results of biosignal measurement.

words, the information itself has power.

In response to this explosion in the amount of information, signal processing that handles a large amount of data—as represented by machine learning—has made remarkable progress, and various fields are facing upheavals. At the same time, interdisciplinary research is advancing internationally at a speed beyond imagination. It is fine for researchers to focus on a single area of expertise in the conventional manner. However, the environment surrounding research has also changed with the times, and it may seem as if it has become difficult to continue research in one area or specific subject for a long period of time. Since we have entered such an era, I think it is important to study themes beyond one's specialized field from time to time and to learn the external situation through cross-disciplinary exchanges. It may become more common to expand one's research area and work across multiple areas.

—It seems that researchers must change their own way of thinking.

I feel that creating something original in today's highly globalized environment is tough for researchers. Immediately after the introduction of hitoe, wearable sensors appeared one after another around the world, and many products similar to hitoe were marketed. However, the boom in wearable sensors has ended, and we have now entered the age of culling of some of them. In this globalized world, as soon as a breakthrough or research result is noticed, rivals—sometimes even challengers from all over the world—emerge.

Future innovations may need to have the impact of changing existing values. Society does not notice the improvement level in which something a little more convenient is made. And even if we struggle to bring a new technology to the world, we don't always taste success. Multiple hurdles must be overcome before we can spread it in society and earn a stable income. With the emergence of rivals and rapid commoditization of technology, we are conducting R&D that focuses on what can only be done with hitoe.

For example, we are promoting a project to apply hitoe in the area of rehabilitation at Fujita Health University Hospital (**Fig. 2**). In this case, hitoe is being used to monitor the status of exercise and recovery from the amount of activity and the heart rate of patients in the hospital. Compared with the monitoring of healthy young people, monitoring of elderly hospitalized patients—who have small pulse signals—is problematic because those signals are difficult to measure with a normal optical-pulse-wave

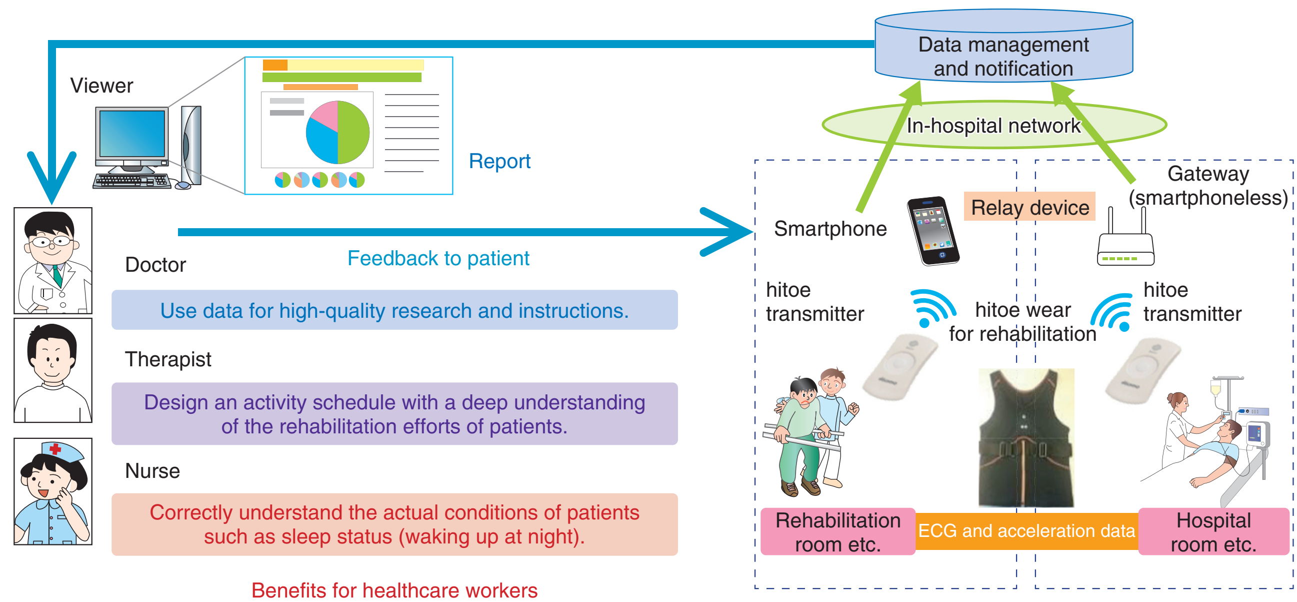

Fig. 2. Activity estimation and data-relay technology for rehabilitation support.

meter. That being said, accurate values must be used as an evaluation index for rehabilitation. Under that severe condition, the strength of hitoe, which measures heart rate from cardiac potential, is utilized. It can meet the expectations of experts, and it is configured so that people who wear it will not feel inconvenienced. For that reason, hitoe is currently in the phase of being optimized for specialized areas that can make use of its features.

The speed and fierceness of competition due to globalization is enough to make researchers cry. When I studied abroad, I felt that research was truly a "global professional society" in a world where research professionals were competing on the world stage just as the world's athletes will compete in Tokyo in 2020. It is thus necessary to train oneself, create an environment, and prepare the necessary conditions to win. However, the style of Japanese researchers sometimes seems to be far from the speedy research style of their Western counterparts. It is likely that some researchers only focus on the topics of the research areas to which they are related and do not pay attention to changes in the environment and society surrounding their research. It is better to evaluate where you are in relation to the global environment by applying objective measures from time to time.

I am trying to recognize the need for that evaluation and to do it myself. That evaluation involves not only evaluating one's output of published papers and amount of knowledge but also focusing on a comprehensive evaluation that includes skills, research styles, and one's philosophy of research. In particular, Japanese workers should maintain an awareness of time and deadlines and also pay attention to work efficiency. Compared with other nationalities, Japanese people, including those involved in research activities, tend to set vague deadlines, so it may be unsurprising that they often work endlessly without setting time limits. Since we lack a sense of completing tasks before key deadlines, we may feel like we are passing time vaguely and will somehow manage because we still have tomorrow.

Only a "handyman" has the chance to grasp real intentions, so go out and meet people!

—What kind of consciousness do you have when confronting such a great change?

I'm aware of my own sense of time, so I try to be as quick as possible. Even if one has such awareness, others do not necessarily have the same awareness. As with athletes at sporting events, it is important for researchers to set a time goal when achieving results, because no matter how good the results are before or after the tournament, they won't be evaluated positively. This is because people (the evaluators) tend to focus on the main event such as a race, rather than all of the practice sessions before and after it. I am always trying to be aware of issues related to time and to finish tasks as quickly as possible.

Because I'm clumsy, I'm often taking detours. Although I sometimes waste time, I try to be aware of how I can work efficiently in a focused manner. And I think above all else, the most important thing is to take action. Whether it is called agile development or not, we do not completely set specifications from the beginning; instead, we plan our R&D activities to better meet the needs of our customers, including those needs concerning technologies and specifications.

In the area of medical care, that situation might be close to the treatment given to an emergency patient on their initial medical examination. In the case of non-emergency medical care, treatment progresses as test results are reviewed, so diagnostic treatment can be performed systematically. In contrast, in emergency care with a patient transported by ambulance, it is necessary to judge the patient's condition immediately from a limited amount of information and test values. Sometimes emergency surgery is required, so it is necessary to be responsive. In regard to R&D as well, I think we should get out into the field as much as possible, meet face-to-face with customers and people in charge, find out their true needs, gather necessary technologies, and start R&D promptly.

Moreover, instead of just listening to requests in the field, we are constantly striving to increase the amount of technology, knowledge, and tools that we can apply so that we can respond promptly to various requests. I must admit though, if I do too much, things get out of hand, and I forget what my specialty is.

Customers may think of me as a "handyman." I think that people feel free to talk to such a "jack of all trades" so they speak their mind. As a result, we can gather more down-to-earth information and get new ideas from the motivation obtained on the spot. And in parallel with the work of gathering the needs of the market, we will work on development while sharing efforts in collaboration with experts knowledgeable in matching seeds. If you work in collaboration with experts in each area, you will be involved with people in more fields, and that involvement will make that work more significant. I always try to put all my effort into solving problems that our customers talked to us about. Sometimes I do too much as a handyman and exceed my workload limit. As a researcher, I try to ensure that I take rests and spare as much time as possible to scientifically explore the subject.

The swing-by model can correct the trajectory of R&D and accelerate it in the direction in which it can proceed.

—How will you conduct research activities going forward?

I have two dreams. One is the development of advanced medical devices. I have a desire to create products that are evaluated positively by experts. For example, I'd like to make a new electrode for cardiac pacemakers with Japanese technology. It is one of the most difficult medical devices to fabricate, and presently it is mostly made outside Japan. The other is to try to detect signs of the onset of sickness and serious symptoms. The first stage of sensing technology has almost reached its goal; however, the second stage, which is signal processing, is very difficult. Although we are struggling at this stage, we are resolutely developing new methods while enjoying the challenge.

—What would you like to say to young researchers?

First, you should build up your basic strength. I think it is important to steadily build up your own specialized area from the basics. For example, in the case of informatics, I think that it is possible to properly evaluate the validity of the currently popular machine learning only by learning the basics of mathematics, statistics, and neuroscience behind the technology and by utilizing that knowledge in practice. I hope that you gain a solid foundational strength that enables you to grasp, analyze, apply, and build things correctly, and gain on-site experience. Second, you must grasp your position on a global scale. Although it is also my personal commandment, receiving objective and international assessments on a regular basis is a very tough but necessary one. To that end, I'd like you to write a research paper, make a presentation at a conference, and interact with researchers. This is an age when it is easy to develop such activities across borders, so I hope that you can go out from NTT and deepen exchanges with other researchers, regardless of your skill in English.

If I may digress, I'm interested in the asteroid explorer Hayabusa. Many planet probes such as Japan's Hayabusa and those of NASA use the "swing-by" principle to reach target planets. Swing-by is a means of navigation to reach a planet; that is, as a spacecraft traverses the solar system and approaches a certain planet, it is accelerated by the gravity and motion of the planet, so its trajectory is altered. Then, by repeating the fly-by with other planets, the spacecraft can travel to its destination planet by expending less energy.

Actually, I thought that our R&D was progressing in the same swing-by manner, so I named it the "swing-by model." When the seed (i.e., a research theme = a small satellite) approaches the area of attraction (i.e., the need = a planet), its trajectory is directed toward the planet (the need), the development is then accelerated by the attraction of the planet, and its trajectory can be corrected (i.e., the directionality of the development is determined). By repeating the swing-by, you can further increase your speed and boost your amount of experience. If you have a distant destination that is slow to reach at first and you cannot reach it by yourself, take advantage of the chance to approach nearby planets, and if you courageously take one step toward your needs (planets), you will be able to accelerate, gain valuable experience (kinetic energy), and get a chance to fly far.

If you are worried that you are not the type of person who'd make the first move, the first step is to try it and start small by yourself. Or if you don't have the courage, you can do it as a hobby. Try your favorite things in your own time. I'm presently searching for a method of biosignal processing. Although I think my pace is rather slow from the viewpoint of a specialized teacher, I'm enjoying increasing my knowledge outside my field as I read textbooks for high school and university students. It's also fun to buy electronic parts and handicraft materials and make things on your own. Being a little adventurous will lead to the first step.

■ Interviewee profile
Shingo Tsukada

NTT Fellow, NTT Basic Research Laboratories.

He received an M.D. from Toyama Medical and Pharmaceutical University and a medical license in 1990. He received a Ph.D. in medicine from the University of Tsukuba, Ibaraki, in 2003. He was a visiting researcher at the University of California at San Diego from 2003 to 2005. He joined NTT Basic Research Laboratories in 2010 as a Research Specialist. He has been studying the mechanism and activity control of signal transduction of brain cells. His current interests include the detection of biomedical signals using novel wearable-type and implant-type bioelectrodes based on the composites of conductive polymers with various fibers and textiles. He is a member of the Physiological Society of Japan, the Japan Society of Applied Physics, the Japanese Circulation Society, and the Japanese Orthopaedic Association.

Technology Report for Smart World

Yasushi Matsuno

Abstract

NTT Research and Development Planning Department has selected 11 key technologies for realizing a smart world based on social trends for the next 7 to 10 years and published "NTT Technology Report for Smart World." This article introduces a summary of these 11 technologies and the social changes that will be brought about by such technologies.

Keywords: smart world, technology trend, social trend

The Smart World is Inevitable

The Smart World is not just some imaginary ideal. It is a future that will inevitably arrive. The more that technology advances, the more data, work, people, and industries that were once separate will become intertwined and "smart." Collaborative connections will enable new co-creation that could not have occurred before, accelerating the Smart World even more.

The term Smart World refers to many different things, as smart technology is introduced in fields including smart cities, smart mobility, smart manufacturing, smart entertainment and smart healthcare. For example in the manufacturing sector, work is underway on an industry-wide platform to tap into the knowledge of skilled workers and construct a connected value chain, and investments are being made in a variety of AI and speech recognition, sensing, and networking technologies.

Building the Smart World is a vital step for solving many of the social challenges confronting society today. Contemporary social issues such as food waste and environmental destruction span a wide range of fields, and cannot be solved simply by reforming one company. In order to solve social issues and create a richer society, we should strive for a smart world that enables co-creation across corporate and industry boundaries.

We have been working for some time on a "B2B2X" business model that will accelerate the creation of the Smart World. This model aims to create new value by having major industry players take advantage of new technologies that we have developed together with our partner companies. We want to accelerate the necessary transition to the Smart World in order to achieve a more sustainable world and richer lives.

Technology Must Be Natural

In the Smart World, it is essential that people of all ages, genders, occupations and ethnicities benefit from technology. This is why technology must be natural. Using current cutting-edge technologies such as virtual reality (VR) requires clear awareness, and sometimes specialized knowledge. This leads to disparities between those who can benefit from technology and those who cannot. Accordingly, technology must become so natural that people are unaware of its presence.

The advent of natural technology also promises less stressful lives. AI that can converse naturally like human beings would make it possible to communicate beyond simple questions and answers, while more natural everyday devices could eliminate the need to worry about various settings and operations. Natural technology is a crucial concept for eliminating stress in all fields and for people to live comfortably.

In the past, we have understood technology as something in conflict with humanistic things and nature. Accordingly it has sometimes been seen as lacking humanity or warmth. However, as technology grows more natural in the future, it will overcome this opposition and become integrated into what we have thought of as human values and emotions, contributing to a good environment for both the Earth and human beings.

As technology becomes more natural, it should grow better at supporting human activities on a deeper level. Technology must be natural in order for human beings to display their creativity and increase their own value—to truly expand human potential and unleash groundbreaking innovation.

11 Technologies for the Smart World

We are focusing our energy on 11 technologies that will contribute to natural technology and the Smart World—from maturing technologies beginning to be being implemented in a wide range of fields to emerging technologies that should flourish in the future.

Learn how these 11 technologies will bring about the Smart World.

1. Artificial Intelligence
Technology that is tolerant and sincere

The basic abilities of artificial intelligence (AI) to see, listen, and speak are reaching practical levels. However, this only means that separate functions can derive standardized outputs, and are still unsuited to dealing with complex problems. AI is being developed that can handle more complex problems by streamlining learning and creating "white box" algorithms. In addition, we believe that AI needs to be able to process human values. AI that can present a number of options tailored to diverse values will deepen human thought by offering multiple solutions, even for more complex problems. AI that can "think" in accordance with people's values is technology with the tolerance to accept diversity, and the sincerity to respond to different ways of thinking.

2. Virtual Reality / Augmented Reality
Creating moving experiences across time and space

Virtual reality and augmented reality (VR/AR) have already been released as part of various services, products, and content, but we want to naturally introduce this technology into an even wider range of fields in the future. For that purpose, we are focusing our VR/AR research not only on enriching qualitative expression but also speeding up processing. Our research includes technology that stimulates senses beyond vision such as hearing, touch, force, and temperature, in addition to technologies such as "Kirari!" that can transmit entire spaces over distance via real-time high-speed data processing. By reducing latency, Kirari! 2.0 will even overcome time. People's experiences in the Smart World may evolve into something completely different from today.

3. Human-Machine Interface
Deeply understanding humans to naturally integrate with robotics

The Smart World will not only bring updates to products, systems and services. In the future, human-machine interfaces (HMI) will also extend the human body. Brain wave analysis and other methods have unraveled mysteries of brain function, which coupled with much-improved understanding of the mechanisms of the human body, should lead to the creation of more sophisticated and complex interfaces. Through our HMI research such as Point of Atmosphere (PoA), we aim to naturally integrate humans with their environment and robotic devices. With the new technology we envision, people will be able to substitute lost bodily functions and make use of information that natural senses cannot detect. Just as virtual and augmented reality expand the human senses, human-machine interface (HMI) expands the body's potential—indeed, the very body itself.

4. Cyber Security
Shifting to active defense

As the spread of networks and IoT increases the risk of cyber terrorism, existing passive cyber security technology tends to result in a back-and-forth battle against constantly evolving attackers. In order overcome this situation, a shift towards active security centered on the use of AI is underway around the world. Stronger security is essential to our vision of the Smart World where everything is networked. In addition to developing security technologies adapted to a wide range of applications including mobility, plant systems, and healthcare, we are focusing on active defense that actively deals with cyber attacks. The Smart World will show its true value only with the establishment of new security technologies that can head off cyber attacks.

5. Information Processing Infrastructure
Making strides in real-time, scalable processing infrastructure

Next-generation information processing technology could be called the infrastructure of the Smart World. Thus, effective utilization of rapidly evolving technology requires building out information processing infrastructure. Attention in this field is focused on technology that can overcome the trade-offs between performance and flexibility or power consumption. We are also hard at work developing new information processing platforms that surpass conventional limitations. Projects currently underway include scalable data processing technology to process large amounts of information in real time, and highly efficient data management technology to promote use of data across industries. Of course, we are also making efforts to improve hardware itself and develop new technology that can overcome Moore's Law. The fruits of this research are leading to the emergence of new infrastructure.

6. Networks
Creating a breakthrough all-photonic network

New networks are key to realizing the Smart World, where rich flows of data will connect numerous actors and products across industries. We are embarking on the creation of new networks that surpass the 5G technology entering use in the near future. These networks must be higher capacity, lower latency, stronger and more flexible, as well as energy efficient in order to address the explosive increase in energy consumption. That is why we are working hard to convert to an all-optical network and pursuing creation of new networks. We will lead the way to a new world as these new networks spur innovative collaboration.

7. Energy
Realizing an intelligent energy network

As various advanced technologies enter practical use and the world's population increases in the future, the energy needed to power systems in every industry is a key part of the social infrastructure of the Smart World. In order to meet growing energy demand while also managing environmental issues, research institutions around the world are trying to improve high-capacity storage batteries. To create this new social infrastructure, we are also hard at work developing energy that is not only environmentally friendly and high capacity, but able to be freely distributed as if it has intelligence. Accordingly, we are conducting efficient energy distribution through virtual power plants that virtually manage dispersed energy, while also embarking on research into new hybrid energy networks. In the Smart World that we are building, energy will evolve into something smart that can circulate almost as if intelligent.

8. Quantum Computing
Innovation with post-Moore's Law technology

Quantum computing technology, which is expected to vastly outperform conventional computers, is likely to be used in nearly every industry. Quantum computing is often discussed in relation to solving optimization problems that require the testing of endless numbers of choices, but in the future it may also result in breakthroughs in the energy and drug discovery fields. Our quantum computing research has made remarkable progress in recent years, with technologies such as LASOLV introducing new concepts distinct from conventional quantum computing including gate type and annealing type. At the same time, we are also pursuing research on quantum computer hardware utilizing quantum gates, and significant advances in both software and hardware are expected in the future. Quantum computing does not merely provide extremely fast computing technology, but has the potential to transform information processing itself. In the Smart World, quantum technology will change the way information is handled.

9. Biotechnology / Medical Care
Evolution of biosensing leads to precision medicine

Hand-in-hand with advances in biology and chemistry, biotechnology is also steadily evolving. Biotechnology is mainly being introduced in medicine, as well as agriculture, forestry and fisheries, but amid the changing nature of information today, biotechnology actually reveals new possibilities for communication. We are also approaching biotechnology from a number of directions spanning the fields of chemistry, biology and physics. In particular, research is ramping up in recent years in the field of biomedical care. In addition to our development of functional materials such as "hitoe," in 2019 we entered into research partnerships with Australian institutions including Deakin University and Western Sydney University. We will accelerate our activities going forward as part of our vision of "a society where elderly people can live independently and safely."

10. Advanced Materials
Innovative production expands the concept of materials

In the future, instead of conventional fixed materials, multifunctional materials that change flexibly in response to the environment will become commonplace. In fact, research into new materials such as nanomaterials is making steady progress, and numerous materials are beginning to enter practical use. In order to further advance research and development of new materials, we are using AI and other methods to speed up the development process. In order to build the Smart World, rapid development of materials is essential to meet demand for development of personal functions tailored to people's diverse needs. We plan to pursue development of these new materials, and are already making progress with some technologies such as advanced thin films that will be used to create more flexible and functional materials.

11. Additive Manufacturing
Personalized production in every field

Additive manufacturing, frequently symbolized by 3D printing, will become an indispensable technology in the Smart World by enabling greater personalization. Additive manufacturing makes possible more than just items such as industrial products and building materials. In the future, even parts of the human body including bones and organs are expected to be manufactured at will. Currently, interest is growing in the field of bioprinting. We are also working on research and development of artificial cells in a layered structure. Another technology to watch is 4D printing, which could incorporate information on changes in time and condition to enable self-healing. As this technology evolves, it will be possible to manufacture more personal products.

A booklet entitled "NTT Technology Report for Smart World" that describes these 11 technology trends and NTT R&D initiatives was published [1]. We hope that this report will be useful in communicating with customers.

Reference

[1] NTT Technology Report for Smart World, http://www.ntt.co.jp/RD/e/techtrend/index.html

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Electron Spin Resonance Spectroscopy Using a Superconducting Flux Qubit

Hiraku Toida, Kosuke Kakuyanagi, William J. Munro, Hiroshi Yamaguchi, and Shiro Saito

Abstract

We use a superconducting flux qubit for the sensing application of electron spin resonance (ESR) spectroscopy. The superconducting flux qubit is a highly sensitive magnetometer with micrometer-scale spatial resolution. The sensitivity of our spectrometer is 400 spins/√Hz, and the sensing volume is 0.05 pL. This high sensitivity and high spatial resolution enable us to investigate a small number of electron spins in a microscale area. The spectrometer also obtains a wider ESR spectrum range with two-parameter (frequency and magnetic field) scanning. This enables us to refine the material parameters.

Keywords: superconducting flux qubit, electron spin resonance, sensing

1. Electron spin resonance

The spin resonance phenomenon occurs in various actions undertaken in ordinary life, for example, when visualizing the properties of a human body using magnetic resonance imaging (MRI). The target of MRI is nuclear spins in atoms (nuclear magnetic resonance: NMR), but electron spins are also good targets for the spin resonance technique. Historically, the proof-of-principle experiment of electron spin resonance (ESR) occurred earlier than NMR.

ESR is a commonly used tool to investigate the electron properties in materials. An electron spin can be considered as a small magnet. When an external magnetic field is applied, the electron spin has different energy depending on its orientation to the external magnetic field. The parallel spin is more stable (lower energy) than the antiparallel one (**Fig. 1**). To detect this energy splitting as an X-band microwave response, a magnetic field of around 300 mT is usually applied to the spin. The energy splitting can then be investigated by measuring the microwave transmittance because if the spins resonate with the microwave, the spin resonance will appear as microwave absorption. This microwave response of the spin contains information on the target material, and the spectrum is considered to be a *fingerprint* of the material, which can be used to identify the material.

In standard ESR spectrometers, microwave cavities (metal boxes) are utilized as a sensor to detect the electron spins. The target sample is enclosed in the cavity, and the microwave transmittance of the cavity is measured as a function of an external magnetic field. However, we use a magnetometer to sense the state of the spins because if the spins resonate with the microwave, the spin resonance can also be detected as a change in the magnetic field generated by the spins. In this work, we have developed an ESR spectrometer with a superconducting flux qubit that works as a magnetometer with a micrometer-scale spatial resolution.

2. ESR spectrometer with a superconducting flux qubit

We investigated a magnetometer based ESR spectrometer using a superconducting quantum interference device (SQUID) [1, 2]. The sensitivity was

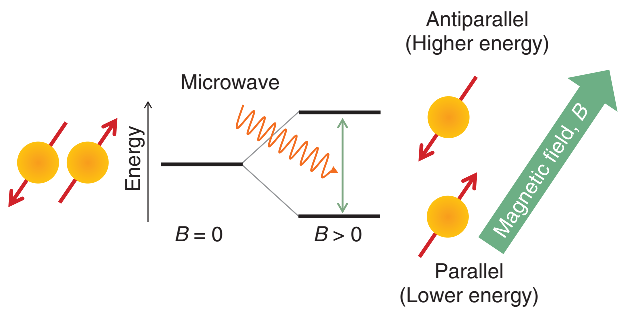

Fig. 1. Energy diagram of an electron spin under a magnetic field *B*. Energy degeneracy is lifted by applying an external magnetic field to the spin. This energy splitting can be investigated by applying a resonant microwave signal.

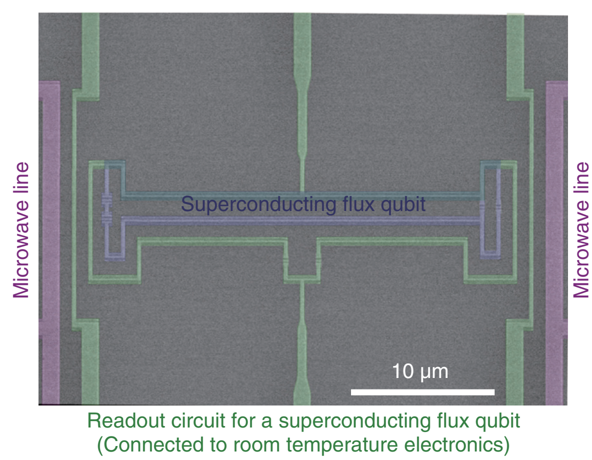

Fig. 2. Scanning microscope image of the superconducting flux qubit. The blue loop is the superconducting flux qubit. Purple patterns are microwave lines to excite the superconducting flux qubit and spins. Green patterns are an on-chip readout circuit for the flux qubit connected to room temperature electronics.

improved from 10^6 spins/√Hz to 15,000 spins/√Hz by improving the magnetic sensitivity of the SQUID magnetometers using a faster readout method of the SQUID.

Here, we use a superconducting flux qubit as a sensitive magnetometer to sense the magnetic field generated by electron spins to further improve the sensitivity [3]. A scanning electron microscope image of the device is shown in **Fig. 2**. The superconducting flux qubit (blue false-colored area) senses a magnetic field through the loop structure.

The experimental setup of our ESR spectrometer is shown in **Fig. 3**. We prepare the superconducting flux qubit on a silicon substrate. The target sample is directly attached on top of the substrate. Magnetic fields are applied in two directions. An out-of-plane magnetic field is applied to control the flux qubit, while an in-plane magnetic field is applied to polarize the spins in the target sample. A microwave line near the flux qubit is used for two purposes: for the spectroscopy of the flux qubit and for exciting the spins in the sample. In the experiment, only one line of the purple false-colored area in Fig. 2 is used. The state of the flux qubit is read by the readout circuit fabricated on the same chip (green false-colored area in Fig. 2) which is connected to room temperature electronics. The experiment is performed below 20 mK using a dry dilution refrigerator.

The principle to detect a magnetic field using a superconducting flux qubit is depicted in **Fig. 4**. The flux qubit is the artificial atom whose energy structure (Fig. 4) is controllable by an external magnetic field. If an external magnetic field is applied to the flux qubit, the energy level curve shifts from the blue

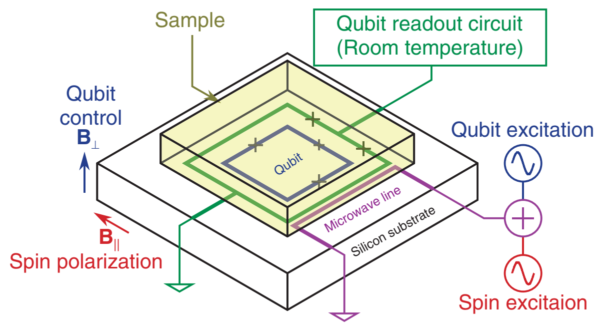

Fig. 3. Experimental setup. A target spin ensemble (yellow) is directly attached to the flux qubit substrate. Two magnetic fields—in-plane (red) and out-of-plane (blue)—are applied to the sample to control the spins and the flux qubit, respectively. Microwave tones to excite the flux qubit and the spins are mixed in the room temperature electronics and sent to the same on-chip microwave line.

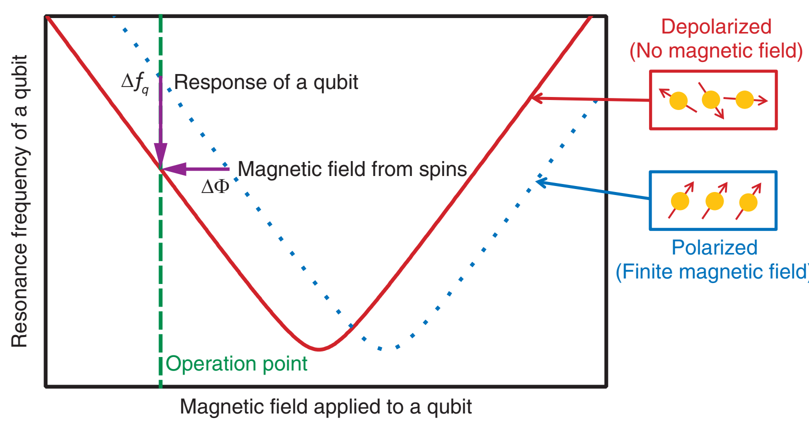

Fig. 4. The principle to detect a magnetic field using a superconducting flux qubit. The blue (red) curve corresponds to the spectrum of the superconducting flux qubit with (without) a magnetic field from the spins. When the operation point of the flux qubit is fixed at a specific point (green), the magnetic field signal is converted to the change in the resonance frequency of the flux qubit.

one to the red one. This change in the magnetic field can be converted to the change in the qubit resonance frequency by fixing the operation point of the qubit at a specific point (green dashed line). Thus, we can measure the magnetic field shift by monitoring the qubit resonance frequency. In our experiment, the detected magnetic field shift is caused by the change in the electron spin alignment, namely, the polarization ratio (Fig. 4).

To excite the spin ensemble, we use a microwave line near the flux qubit. When a microwave signal is applied to the line, electron spin near the line is excited, and this changes the magnetic field when the energy splitting of the spin resonates with the microwave energy. We detect this change in the magnetic field generated by the spin system using the flux qubit. In the experiment, we sweep the microwave frequency of the spin excitation to obtain the ESR spectrum of the target material.

3. ESR spectroscopy of nitrogen-vacancy centers

We use nitrogen-vacancy (NV) centers in diamond [4] as a target sample of ESR spectroscopy. A measured ESR spectrum under the fixed in-plane magnetic field of 5.8 mT is shown in **Fig. 5(a)**. The two sharp dips at around 2.8 GHz and 3.0 GHz appear to reflect the electron spin properties of the NV centers because NV centers have a three-level structure

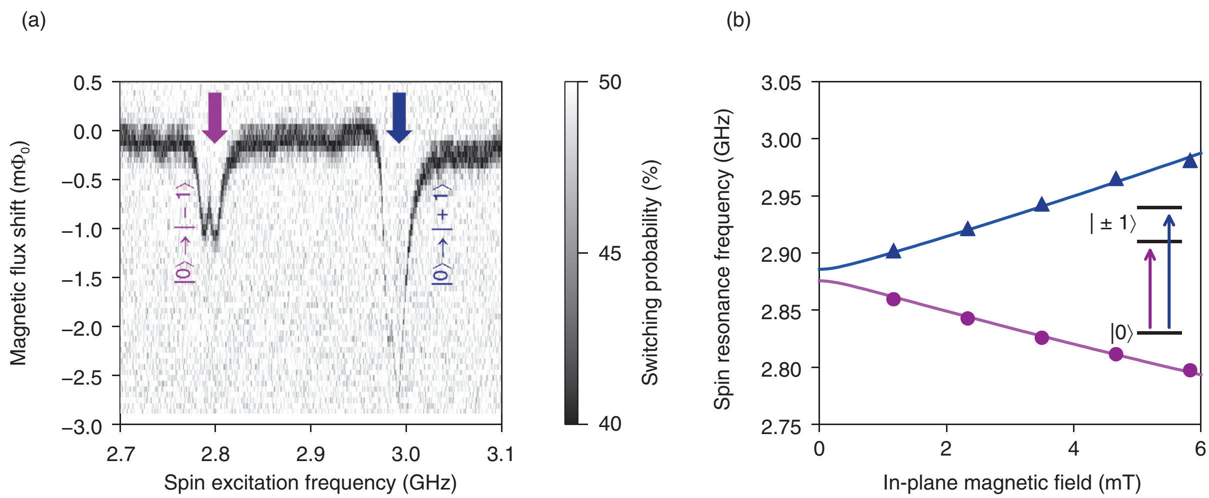

Fig. 5. ESR spectrum of NV centers in diamond. (a) ESR spectrum measured under a fixed magnetic field of 5.8 mT. The magnetic field is applied along the [100] direction of the diamond crystal. The arrows indicate the position of the resonances. A measured magnetic field shift is converted to a magnetic flux shift through the qubit loop. (b) ESR spectrum as a function of an in-plane magnetic field. The symbols are experimental data, and the lines are fitted curve. ((b) inset) Energy level structure of NV centers in diamond.

(**Fig. 5(b)** inset). After repeating this measurement for various magnetic fields, we plot the peak position of the spectrum as a function of the in-plane magnetic field (Fig. 5(b)). The positions of the peaks split into two branches starting from the position of the zero field splitting of 2.88 GHz. The material parameters of the NV center can be extracted by fitting the experimental data. The resulting g-factor and zero field splitting were respectively determined to be 1.996 ± 0.013 and 2.88071 ± 0.00087 GHz. These results agree well with the values from the literature [4] within the range of the error bars. It is worth mentioning that our spectrometer can sweep two parameters—magnetic field and spin excitation frequency—while standard ESR spectrometers can only sweep the magnetic field. This wider range of parameter sweep enables us to refine the material parameters. It is especially powerful in investigating low frequency spin transitions where the features of hyperfine and quadrupole interactions appear.

4. Sensitivity and sensing volume

We estimate figures of merit of our ESR spectrometer: sensitivity and sensing volume. The sensing volume is calculated by multiplying the sensing area and the effective sensing height. The sensing area of our magnetometer is limited to the loop structure of 47.2 μm^2, and only the spins within a height of ~1 μm can be detected [5]. Thus, the sensing volume is calculated to be ~0.05 pL. The sensitivity is estimated by analyzing the noise of the magnetometer signal output. By measuring the noise for an integration time of one second and converting the noise to the number of spins using experimentally determined parameters, we estimate the sensitivity to 400 spins/√Hz. This value is comparable to state-of-the-art ESR spectrometers using superconducting technologies [6, 7].

5. Future work

We plan to improve the sensitivity and the spatial resolution of the spectrometer by refining the design of the superconducting flux qubit and the measurement system. We will also fabricate a flux qubit array to obtain spatial distribution of the materials. In this article, we have only focused on solid-state spins. However, the application area of our ESR spectrometer is not limited to such spins, and we are planning to measure soft materials such as bio-related materials.

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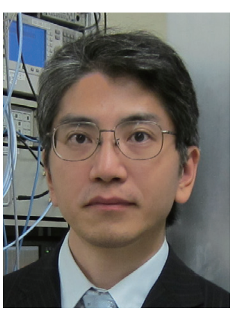

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Activities of ITU-T Study Group 5 (Environment, Climate Change and Circular Economy) and Discussion Results

Naomichi Nakamura, Xiaoxi Zhang, and Yuichiro Okugawa

Abstract

The NTT Group participates in the development of international standards by the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) with a view to protecting telecommunication equipment from electromagnetic interference and lightning surges, assessing the impact of information and communication technology on climate change, promoting a circular economy conducive to sustainable development, enhancing the reliability of telecommunication services, and reducing the environmental load of the Group's business activities. This article reports on the main discussion results of the ITU-T Study Group 5 meeting held in September 2018.

Keywords: ITU-T SG5, climate change, circular economy

1. Introduction

The International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 5 (SG5) is responsible for studying issues related to the environment, climate change, and the circular economy and consists of two working parties (WPs) as shown in **Fig. 1** [1]. WP1 studies five Questions relating to protection of information and communication technology (ICT) infrastructure against electromagnetic surges, electromagnetic compatibility (EMC), and human exposure to electromagnetic fields (EMFs). WP2 tackles three Questions relating to energy efficiency, the circular economy, and assessment of the environmental impact of ICT. In this article, we report on the main results of discussions in the SG5 meeting held in Geneva, Switzerland, September 11–21, 2018. An executive summary of this meeting is posted on the ITU-T website [2].

2. WP1 discussion results

WP1 addresses Questions 1 through 5. The contents of each question are explained in this section.

2.1 Question 1

Question 1 concerns lightning strikes, earthing (grounding), and protection of communication systems against electromagnetic surges caused by power systems. A proposal was made at this meeting to expand the scope of a new Recommendation on protection of small-size telecommunication installations with poor earthing conditions to include systems without earthing ports or high-voltage direct current systems. The meeting discussion included the idea of applying an isolation transformer (with limitations on the length of the cable in the secondary winding and a requirement to indicate the danger of electric shock) to a system without earthing ports. Consent was reached on a draft as Recommendation (K.134).

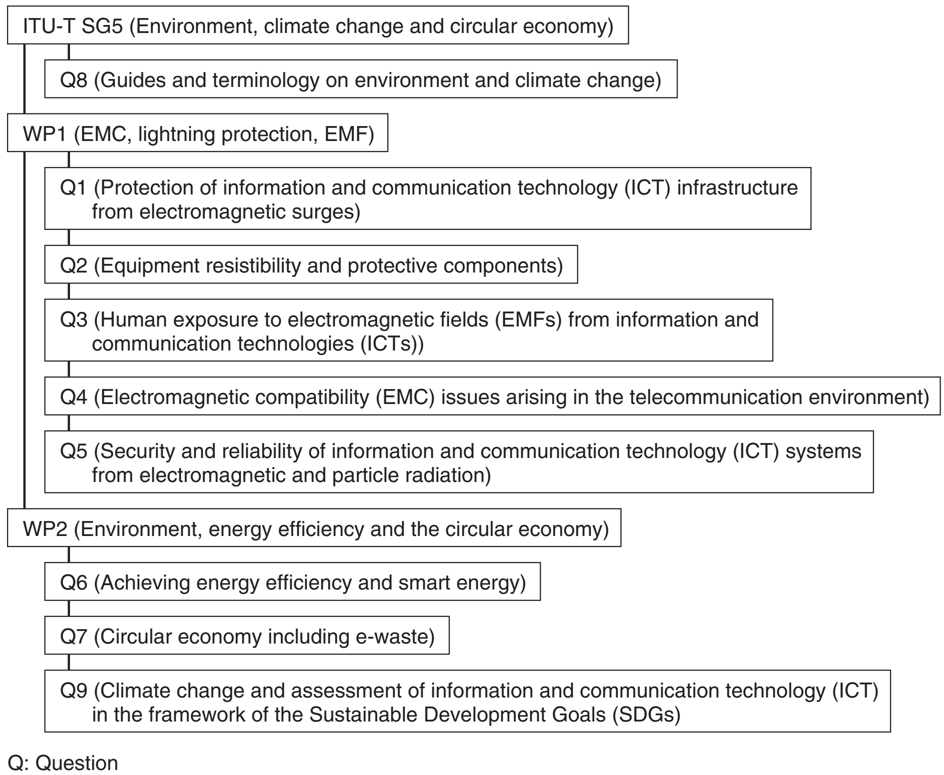

Fig. 1. Questions and organization of ITU-T SG5.

2.2 Question 2

Question 2 concerns test methods and requirements for overvoltage protection devices such as varistors and lightning arrestors. A comment on grounding of direct current (DC) power lines was submitted. This comment was related to existing Recommendation revisions that had been discussed and given consent at the previous meeting. They include K.20 and K.21, which respectively specify overvoltage-related requirements for systems installed in telecommunication buildings and those for systems installed in customer premises, and K.44, which specifies basic requirements regarding overvoltages and overcurrents in telecommunication equipment. The meeting participants agreed to issue a document on internal DC powering interface surge testing factors as a supplement to K.20, K.21, and K.44.

NTT has been leading the development of K.spd-safe, which serves as guidance on safety relating to the use of surge protective devices and surge protective components in customer buildings and access networks. The meeting participants agreed to add to this draft Recommendation information about safety for cases where high voltage occurs suddenly on telecommunication lines when the power system malfunctions, and for cases where an overvoltage occurs on internal line ports. This draft Recommendation will be consented to when International Electrotechnical Commission (IEC) Technical Committee 108 arrives at a basic understanding of it.

The participants also discussed K.135, a new Recommendation on technical parameters for residual-current-operated protective devices with an automatic reclosing feature for telecom applications, and they reached consent on it with some editorial changes.

2.3 Question 3

Question 3 concerns management, measurement, and guidelines regarding human exposure to EMFs from telecommunication equipment such as wireless access systems. NTT DOCOMO and the National Institute of Information and Communications Technology, both based in Japan, submitted evaluation data on human exposure to EMFs in the vicinity of a maintenance hole (manhole)-installed base station. It was found at the meeting that such data had not previously existed and that the data were very useful for member countries. The data were added to K.91 (Guidance for assessment and monitoring of human exposure to radio frequency EMFs), an existing Recommendation, as Appendix VIII. Four version-one draft Recommendations were also discussed and agreed to, including K.workers, which concerns the assessment and management of restrictions regarding exposure of wireless equipment workers to EMFs.

2.4 Question 4

Question 4 pertains to EMC-related requirements for new telecommunication equipment, telecommunication services, and wireless systems. The meeting members discussed two new Recommendations (K.136 and K.137) related to EMC-related requirements for wireless and wireline equipment, specified their scopes of application, reviewed the compatibility of these Recommendations with existing standards, and consented to their final drafts. NTT proposed adding specifications on acceptable values for conducted interference waves below 150 kHz to K.123, an existing Recommendation on EMC-related requirements for electrical equipment within a telecommunication building. This proposal was based on NTT technical requirements [3], which NTT revised in fiscal year 2018. Consensus was reached on that proposal. The final draft was discussed and consented at the next meeting, which was held in May 2019.

2.5 Question 5

Question 5 concerns soft errors in telecommunication equipment caused by particle radiation, and electromagnetic security. Japan proposed the fourth version of a new draft Recommendation on methods for estimating quality from soft error test results, and guidelines for application of these methods. The meeting members discussed definitions of terms and specification grounds and consented to the final draft for K.138. Similarly, consent was reached on the final draft for a new Recommendation (K.139) on reliability requirements for telecommunication equipment to counter soft errors, which Japan was proposing to study, after minor revisions.

In the coming years, WP1 will develop new Recommendations on requirements for measures against soft errors in semiconductor devices used in telecommunication equipment, and will revise K.78, an existing Recommendation on protection of telecommunication equipment from high-altitude electromagnetic pulses, which has recently been the subject of considerable discussion, by incorporating the latest IEC standards and study results.

3. WP2 discussion results

WP2 deals with Questions 6, 7, and 9, the topics of which are explained here.

3.1 Question 6

Question 6 pertains to the energy efficiency of telecommunication equipment and datacenters. It was proposed to include main battery technologies and characteristics, a selection of battery technologies suitable for individual applications, and battery evaluation and test methods in L.1220, an existing Recommendation on energy storage technology, as Part 2. Part 2 will be based on Part 1 of L.1220, which describes general methods for selecting and evaluating storage system technology. The meeting members consented to the final draft (L.1221). They also discussed the criteria and methods for measuring energy efficiency of functional components such as virtual network functions and network functions virtualization (NFV) infrastructure in an NFV environment in connection with L.mmNFV, a new Recommendation on the measurement method for measuring the energy efficiency of NFV. The members consented to the final draft (L.1361).

3.2 Question 7

Question 7 concerns the circular economy including e-waste (electrical and electronic devices that have been disposed of). The Connect 2020 Agenda* is aimed at achieving a 50% reduction in e-waste by 2020. It was proposed to create a guidance document that specifies three steps: (1) creation of a comprehensive e-waste inventory; (2) development of a sustainable e-waste management system; and (3) introduction of support measures to promote the use of said management system. The meeting members consented to the final draft (L.1031). They also studied L.CEM, a new Recommendation on criteria for evaluating the environmental impact of mobile phones. Criteria for this assessment, which takes into consideration the entire life cycle of a product, from design through production and use to end of life, and is based on the contents of L.Suppl.32 (supplementary document) and UL Standards (electric product safety standards in the US), such as UL110. The meeting members consented to the final draft (L.1015).

* Connect 2020 Agenda defines ITU's policies on ICT-related activities up to 2020.

3.3 Question 9

Question 9 pertains to methods for assessing the sustainability impacts of ICT in order to promote the United Nations Sustainable Development Goals. Both the assessment procedure part and the future forecast part of L.MAE, a new Recommendation on methodology for assessing the environmental impact of the ICT sector, were revised at the meeting in order to incorporate received comments, and agreement was reached on the final draft (L.1450).

A proposal was made and accepted to create, as a supplementary document to this Recommendation, greenhouse gas (GHG) emissions trajectories for the ICT sector compatible with the United Nations Framework Convention on Climate Change Paris Agreement. This supplementary document will be developed in collaboration with the Global e-Sustainability Initiative. The collaboration will be extended to include the Science Based Targets Initiative.

Discussions on L.MAAP, a new Recommendation on methods for assessing the positive impact of ICT on sector level, have been ongoing since 2017. The currently proposed method is a bottom-up method. It aggregates GHG emissions from each component to be assessed. At this meeting, NTT proposed a top-down method to assess the impact of ICT use on the environment and economy based on an Input-output Table, which represents nation-level inter-industry trade. The meeting members agreed to include NTT's proposal in the draft Recommendation.

4. Conclusion

We have introduced the latest standardization activities of ITU-T SG5. Communication technology is advancing on a daily basis, as is manifested by the emergence of 5G (fifth-generation mobile communications), the Internet of Things, and virtualization. We will promote timely standardization in order to enable rapid response to changes in the environment surrounding telecommunication facilities and to contribute to enhancing the quality and reliability of telecommunication services while reducing their environmental load.

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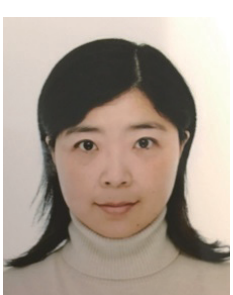

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Countermeasures against Insect Damage to User Equipment—Repellent Sheet and Repellent Spiral

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Abstract

Telecommunication equipment can malfunction if it is damaged by insects. It is therefore necessary to develop measures to prevent such damage. This article presents examples of the damage that can occur when cockroaches nest inside equipment and introduces two products designed to stop them from accessing the equipment. This is the fifty-third article in a series on telecommunication technologies.

Keywords: insect damage, repellent, cockroach

1. Introduction

Telecommunication equipment is installed in various environments, and it therefore must coexist with any creatures living there. Equipment installed outdoors or at a customer's premises is usually exposed to living things, and that exposure often leads to damage to the equipment. This report introduces the characteristic damage that occurs to telephones and communication equipment such as home gateways caused by insects such as cockroaches—about which the Technical Assistance and Support Center has received many inquiries from all over the country—and describes our countermeasures against such damage.

2. Characteristics of damage due to cockroaches

If cockroaches invade and nest inside communication equipment such as a telephone and home gateway at a customer's premises, they may chew the substrate and wiring, or their habitation may cause a malfunction such as substrate shorting due to their excrement (**Photo 1**). In the field, although the equipment can be repaired or replaced, if the surrounding environment does not change, it is likely that the cockroaches will crawl into and nest in repaired or new equipment again and again, and the malfunctions will keep reoccurring.

The results of investigations into the cause of malfunctions that occurred due to cockroaches revealed that the intruding cockroaches are 3 to 12 mm in length. Their brown body and pale back led to the conclusion that they are the species called German cockroaches (*Blattella germanica*) [1]. The German cockroach inhabits all regions of Japan and prefers warm and dark places; accordingly, it is often found in air-conditioned environments such as restaurants. Since the interior of communication equipment is always warm and dark, it is considered a convenient environment for the cockroaches to nest in.

Previous measures against cockroach damage involved asking customers to remove the cockroaches and block places that serve as cockroach entrances to communication devices. However, such countermeasures were difficult to implement since radical extermination was difficult, and not all entry points to the equipment could be closed off.

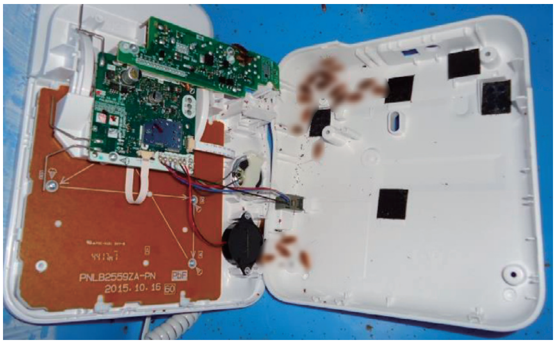


Photo 1. Cockroaches nesting inside a telephone (images of cockroaches are blurred).

Photo 3. Inside a core-wire housing containing broken fibers (images of ants are blurred).

Photo 2. Repellent tape.

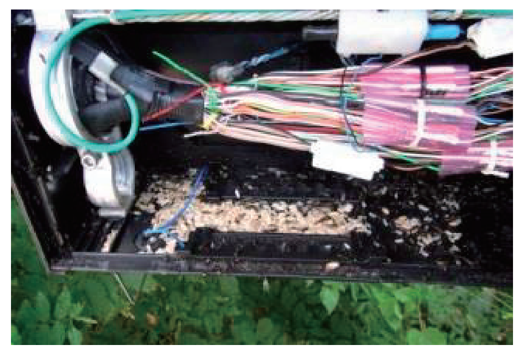


Photo 4. Interior of metal terminal box in which core-wire insulation is broken.

3. New countermeasures based on insect repellent

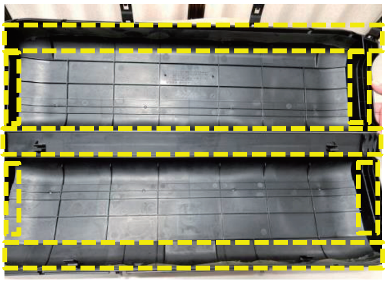
In the meantime, the Technical Assistance and Support Center has been examining damage to access equipment caused by insects such as ants. We have also been collaborating with pharmaceutical companies to promote measures to prevent such damage. These measures include producing a type of tape that contains a repellent composed primarily of a pyrethroid*1, which has a repellent effect against insects (**Photo 2**).

Damage by ants to access equipment was mainly caused by ants nesting in the optical closures of overhead equipment. The ants often chewed through optical-fiber core wires inside core-wire housings, disconnecting them (**Photo 3**). Moreover, inside metal terminal boxes, the ants chewed the outer sheaths of the core wires. The effect of formic acid*2 caused the core wires to come into contact with each other, and that contact caused insulation failure (**Photo 4**). Implementing measures using repellent tape makes it possible to prevent ants nesting in optical closures and metal terminal boxes (**Photo 5**).

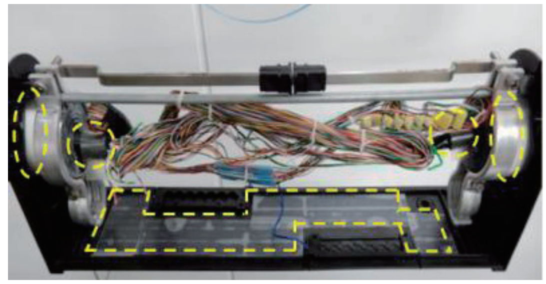
As a result of the examinations described above, we devised a repellent sheet and a repellent spiral—both of which use the same repellent agent—as a new countermeasure against cockroach damage (**Photo 6**).

*1 Pyrethroid: A generic term for substances related to pyrethrins, which are the active ingredient of the flower pyrethrum chrysanthemum. Insects are repelled from surfaces treated with a pyrethroid because when it penetrates their skin and mouth, it acts on their nerves in a manner that numbs them. Pyrethroid-containing substances have no effect if they enter the body of warm-blooded animals such as mammals and birds because they are quickly broken down and excreted. Moreover, pyrethroids are not affected by moisture or water droplets, so their efficacy does not decrease if they get wet.

*2 Formic acid: Strongly acidic component secreted by ants when they lay markings to attract companions or when they attack enemies.

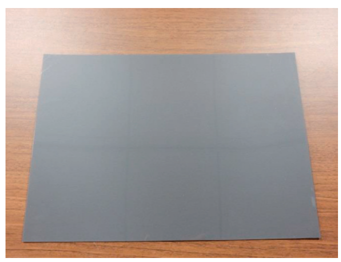


Optical closure



Metal terminal box

Photo 5. Installation of repellent tape.



Repellent sheet

Repellent spiral

Photo 6. Cockroach prevention measures.

The repellent sheet is an A4-size sheet that has a repellent coated on its surface. The sheet is placed under communication equipment to stop cockroaches entering from the bottom of the equipment. The repellent sheet has a three-layer structure consisting of repellent, polyester sheet (semi-transparent), and non-slip coating. As well as having a repellent effect, the non-slip coating prevents movement of the sheet while the equipment is in use.

The repellent spiral is made of a polyester material, with repellent agent applied to the inner and outer surfaces of the spiral. This prevents insects from invading communication equipment via electrical cables. The spiral has an inner diameter of 12 mm and a length of about 30 cm. It is simply wrapped around power supply cords, local area network cables, and the like.

The repellent sheet can simply be placed under the main units of communication equipment, and the repellent spiral can simply be wrapped around power supply cords and cables by workers in a quick and easy manner (**Photo 7**). Moreover, the period during which the repellent effect of these countermeasure products lasts is about 10 years (for equipment installed in dark places). Although it is necessary to avoid exposure of these products to direct sunlight since ultraviolet (UV) rays reduce the repellent effect, we know that about 80% of the insect-repellent effect is maintained after two years if the usage environment is under UV light at the level produced by indoor fluorescent light.

4. Verification of effectiveness of countermeasures

We conducted the following experiment in collaboration with a pharmaceutical company in order to evaluate the repellent effect of the repellent sheet and the repellent spiral in relation to cockroaches. A phone fitted with both the sheet and the spiral and a phone without either of them were set up in a large case used for the experiment. About 50 cockroaches were left in the test case for six days, after which we checked whether any cockroaches were nesting in either of the phones. The result of this experiment was that after six days, cockroaches had invaded and nested in the phone without the repellent products; in contrast, no cockroaches had nested inside the phone

Telephone　　Home gateway

Photo 7. Installation image of countermeasure products.

fitted with the products.

We also implemented the countermeasures in the following example of an on-site application. In this example, cockroaches had intruded into a telephone installed in a restaurant, and the phone had repeatedly malfunctioned due to cockroach damage.

At the restaurant, there were regular incidents of the phone malfunctioning (about once every three months) and not being able to be used. The phone was replaced after each incident. The malfunctions were later found to be due to cockroach damage. Consequently, the Technical Assistance and Support Center received a request to conduct research on biological damage to equipment and countermeasures against such damage. We then decided to implement countermeasures at the restaurant using the repellent sheet and repellent spiral. First, to prevent cockroaches getting into the phone, we installed the repellent sheet under the phone and attached the repellent spiral to the cables connected to the phone. At this writing, it has been about six months since the countermeasures were implemented, and the phone has not malfunctioned since then. We thus believe that it will be possible to prevent cockroaches nesting inside phones by applying these countermeasures in the future. We are currently working on the commercialization of these countermeasures as products that can also be purchased by companies outside the NTT Group that construct telecommunication facilities.

5. Concluding remarks

This report focused on biological damage to user equipment and specifically introduced measures to prevent damage caused by cockroaches. These countermeasures are easy to implement and are expected to help our customers reduce such damage in the field. The Technical Assistance and Support Center, including our predecessor the Technical Cooperation Department, has provided on-site assistance through technical cooperation activities for over 50 years. We will continue to apply the knowledge and experience we have accumulated so far as well as to develop new technologies in our efforts to reduce the number of malfunctions that occur and improve the reliability of communication equipment.

Reference

[1] "Encyclopedia of Insects I," Sekai Bunka Publishing Inc., 2004 (in Japanese).

External Awards

International Standard Development Award
Winner: Noboru Harada, NTT Media Intelligence Laboratories
Date: April 25, 2019
Organization: Information Technology Standards Commission of Japan (ITSCJ), Information Processing Society of Japan (IPSJ)

For his contribution to the development of international standards on lossless audio coding by the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC).

Contribution Award for Standardization
Winner: Shinya Shimizu, NTT Media Intelligence Laboratories
Date: May 21, 2019
Organization: ITSCJ, IPSJ

For his contribution to standardization activities in ISO/IEC Joint Technical Committee 1/Subcommittee 29/Working Group 11.

Papers Published in Technical Journals and Conference Proceedings

One-way Transfer of Quantum States via Decoherence

Y. Matsuzaki, V. M. Bastidas, Y. Takeuchi, W. J. Munro, and S. Saito

Proc. of the 20th Anniversary of Superconductiong Qubits, P-61, Tsukuba, Ibaraki, Japan, May 2019.

Quantum state transfer is an important technique in quantum information processing. The standard way to transfer the quantum state is to use a unitary evolution and/or a measurement feedforward operation. A sequential implementation of SWAP gates can transfer the quantum states from the initial site to the target site. Implementations of control-phase gate and subsequent measurement feed-forwards can perform quantum teleportation. Unitary evolution due to the flip-flop interaction induces oscillations of quantum states between sites, and an appropriate turn on/off of the interaction can implement a quantum state transfer. However, such approaches need to switch on/off the interaction between quantum systems with accurate timing, which could induce time jittering error. Here, we propose an alternative way to implement a directional transfer of the quantum state via decoherence from the tailored environment.

Kirari! for Arena: Real-time Remote Reproduction of 4-directional Views with Depth Perception

J. Nagao, H. Miyashita, T. Sano, K. Hasegawa, and T. Isaka

Journal of the Imaging Society of Japan, Vol. 58, No. 3, pp. 306–315, June 2019.

This paper describes the “Kirari! for Arena” system, which is an integral combination of NTT’s immersive telepresence technology “Kirari!”. This system transports events such as sports and entertainment to remote locations in real time and reproduces the scene in four directions with depth perception. At the capture site, it shoots videos from four directions, scans the positions of objects, performs image extraction and tracking of objects, and transmits the information to the remote locations in real time. At the reproduction site, it transforms the videos to add depth perception and projects them to a special four-sided display device.

Word-based Japanese Typed Dependency Parsing with Grammatical Function Analysis

T. Tanaka and M. Nagata

Journal of Natural Language Processing, Vol. 26, No. 2, pp. 441–481, June 2019.

We present a novel scheme for word-based Japanese typed dependency parsing which integrates syntactic structure analysis and grammatical function analysis such as predicate-argument structure analysis. Compared to bunsetsu-based dependency parsing, which is predominantly used in Japanese NLP, it provides a natural way of extracting syntactic constituents. This makes it possible to jointly decide dependency and predicate-argument structure, which is usually implemented as two separate steps. By using grammatical functions as dependency types, we can obtain the detailed syntactic information from parsing results, while keeping the converted bunsetsu-based dependency accuracy as high as CaboCha, one of the state-of-the-art dependency parsers.

Sound Event Localization and Detection Using FOA Domain Spatial Augmentation

L. Mazzon, M. Yasuda, Y. Koizumi, and N. Harada

The Fifth Edition of the IEEE AASP Challenge on Detection and Classification of Acoustic Scenes and Events (DCASE 2019 Challenge), New York, USA, Mar.–June 2019.

This technical report describes the system used in the DCASE 2019 Task 3: Sound Event Localization and Detection challenge. The system consists of a convolutional recurrent neural network (CRNN) reinforced by a ResNet structure. A two-stage training strategy with label masking is adopted. The main advancement of the proposed method is a data augmentation method based on rotation in the first order Ambisonics (FOA) domain. The proposed spatial augmentation enables us to augment direction of arrival (DOA) labels without losing physical relationships between steering vectors and observations. Evaluation results of the development dataset show that even though the proposed method did not use any ensemble method in this experiment, (i) the proposed method outperformed a state-of-the-art system published before the submission deadline and (ii) the DOA error has significantly decreased: 2:73° better than the state-of-the-art system.

An Experimental Demonstration of Secure Quantum Sensing

P. Yin, Y. Takeuchi, W. Zhang, Y. Matsuzaki, and G. Chen

Gordon Research Conference, Hong Kong, China, June 2019.

In a previous work, we theoretically proposed a secure delegated quantum sensing protocol. In this presentation, we give results of a proof-of-principle experiment of our delegated quantum sensing protocol. From the experiment, we have confirmed that our protocol is secure.

Quantum Computational Universality of Hypergraph States with Pauli-X and Z Basis Measurements

Y. Takeuchi, T. Morimae, and M. Hayashi

Quantum Information and String Theory 2019, Kyoto, Japan, May/June 2019.

Measurement-based quantum computing is one of the most promising quantum computing models. Although various universal resource states have been proposed so far, it was open whether only two Pauli bases are enough for both universal measurement-based quantum computing and its verification. In this talk, we construct a universal hypergraph state that only requires adaptive Pauli X and Z-basis measurements for universal measurement-based quantum computing. We also show that universal measurement-based quantum computing on our hypergraph state can be verified in polynomial time using only non-adaptive X and Z-basis measurements.

A Pilot Study on Consumer IoT Device Vulnerability Disclosure and Patch Release in Japan and the United States

A. Nakajima, T. Watanabe, E. Shioji, M. Akiyama, and M. Woo

The 14th ACM ASIA Conference on Information, Computer and Communications Security (ACM ASIACCS 2019), Auckland, New Zealand, July 2019.

With our ever-increasing dependence on computers, many governments around the world have started to investigate strengthening the regulations on vulnerabilities and their lifecycle management. Although many previous works have studied this problem space for mainstream software packages and web applications, relatively few have studied this for consumer IoT devices. As a first step towards filling this void, this paper presents a pilot study on the vulnerability disclosures and patch release behaviors related to three prominent consumer IoT vendors in Japan and three in the United States. The goals of this study include (i) characterizing trends and risks using accurate data that spans a long period, and (ii) identifying problems, challenges, and potential approaches for future studies of this problem space. To this end, we collected all published vulnerabilities and their patches for the consumer IoT products by these vendors between 2006 and 2017; then, we analyzed them from multiple perspectives such as the timing of patch releases with respect to disclosures and exploits as well as the severity of the vulnerabilities. Our work has uncovered several important findings that may inform future studies. These findings include (i) a stark contrast in the vulnerability disclosures in the two included countries, (ii) multiple alarming practices by the included vendors that may pose significant risks of 1-day exploits, and (iii) challenges in data collection including crawling automation and long-term data availability. For each of these findings, we also provide discussions on its consequences and/or potential migrations or solutions.
