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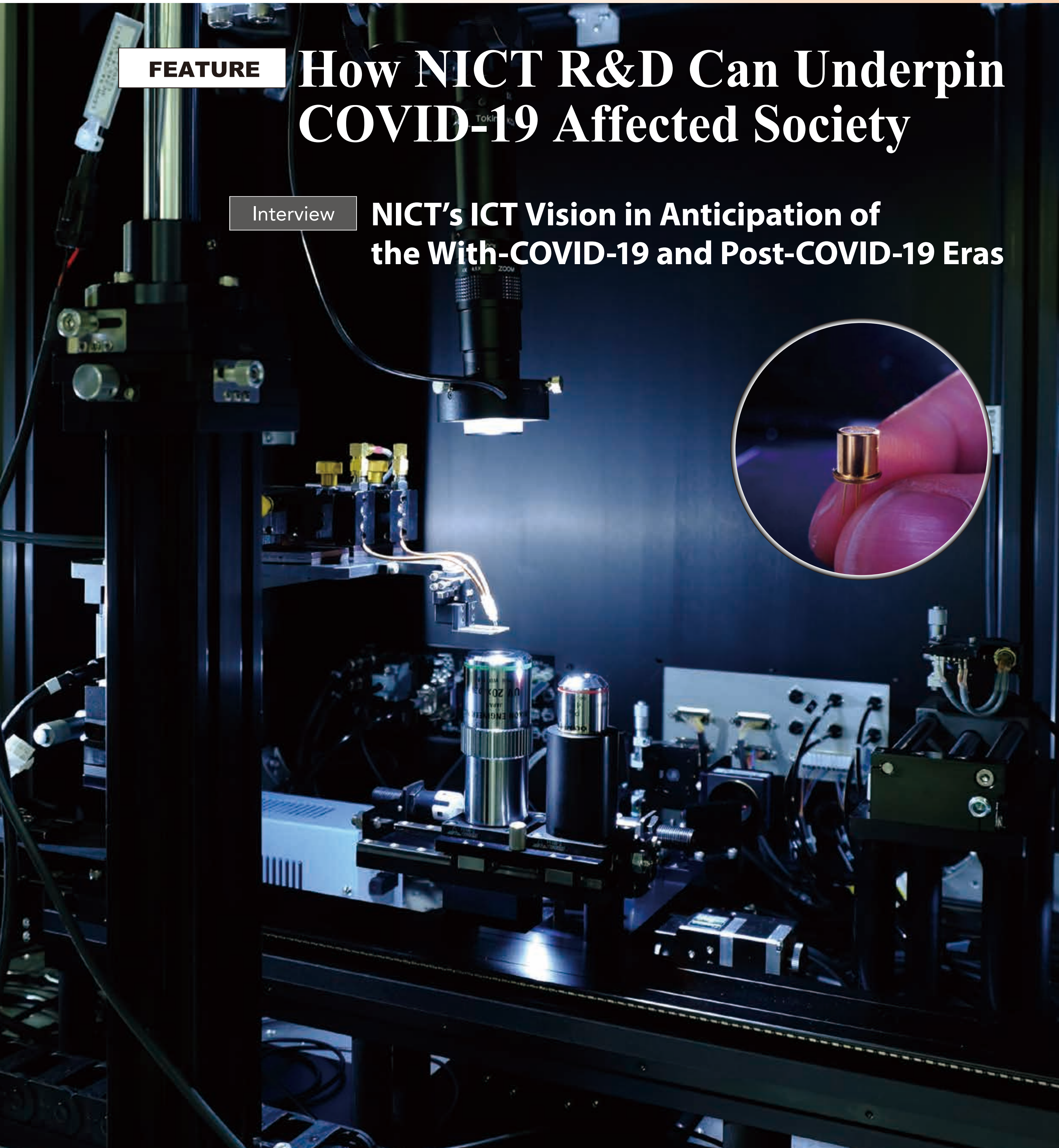
FEATURE

How NICT R&D Can Underpin COVID-19 Affected Society

Interview

NICT's ICT Vision in Anticipation of the With-COVID-19 and Post-COVID-19 Eras



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Cover Photo
System capable of evaluating the electrical and luminescence characteristics of deep-ultraviolet LEDs (DUV-LEDs)
NICT has been researching and developing high performance DUV-LEDs, which are expected to have the ability to deactivate the COVID-19 virus and prevent the spread of infections. The evaluation system confirmed that the world's most powerful light output—over 500 mW at a wavelength of 265 nm—has been achieved.

Upper Left Photo
DUV-LED developed by NICT
DUV-LEDs (chip size: 1 mm^2, mesa area: 0.35 mm^2) with an AlN nanophotonic light-extraction structure were fabricated by nanoimprint lithography and flip-chip-mounted in a TO-Can package. The large-area AlN nanophotonic light-extraction structure covering the entire chip area was formed accurately and shows uniform optical interference.

Interview

NICT's ICT Vision in Anticipation of the With-COVID-19 and Post-COVID-19 Eras

TOKUDA Hideyuki

President of the National Institute of Information and Communications Technology

Dr. TOKUDA Hideyuki completed Ph.D. in 1983. Then, he joined School of Computer Science, Carnegie Mellon University as Research Computer Scientist. He came back to Keio University in 1990 and became Professor, Faculty of Environment and Information Studies in 1996. He has been Executive Vice President of Keio, Dean of Faculty of Environment and Information Studies and Dean of Graduate School of Media and Governance, Keio. His research interests are ubiquitous computing systems, operating systems, distributed systems and cyber-physical systems.
In 2017, he became President of the National Institute of Information and Communications Technology (NICT) . He is also Professor Emeritus, Keio University, a member of Science Council of Japan (SCJ), president of CCDS, IPSJ fellow, JSSST fellow and a chair of IEEE Tokyo Section.

Since early 2020, the COVID-19 pandemic has thrown the world into unprecedented crisis. We have experienced many dramatic changes in our lives, including the adoption of working from home and online schooling, after the Japanese government declared a state of emergency. These lifestyle changes have caused many issues to emerge. Information and communications technologies (ICT) and their services are expected to play a crucial role in resolving these issues. In this issue of NICT NEWS, we asked NICT President TOKUDA Hideyuki about his vision of the post-COVID-19 society and the contribution of NICT's R&D activities in bringing this vision into reality.

—What COVID-19-related ICT issues have you noticed?

TOKUDA Japan has been making steady efforts to develop its digital environment. However, the recent COVID-19 outbreak unexpectedly made us discover many ICT issues. For example, public health centers are still using fax machines to report COVID-19 testing results and a delayed medical data digitalization has been preventing medical institutions from efficiently sharing and searching information on various COVID-19 symptoms and effective treatments.

Many businesses have adopted remote working policies to protect their employees from infection. Some issues were also found in this practice. While major corporations were largely able to shift to remote working as they had already digitalized their operations, some small and medium-sized enterprises (SMEs) are still unable to read internal documents online. In addition, many workers need to come to the office just to stamp a document with their own personal seals due to the old Japanese tradition of hanko seals.

Furthermore, only 5% of public elementary schools, junior high schools and high schools combined adopted online schooling; a large difference from the adoption rate by universities, Japanese colleges of technology and vocational schools combined of an average of approximately 60%. This is a very serious problem, as children's right to education has been compromised.

Some problems have also been seen in public administration. When the Japanese government offered COVID-19 relief benefits to the citizens, some of them applied for the benefits online. However, because of inadequate coordination between the system that manages certificates of residence and another system that manages social security and tax numbers, applications submitted online had to be printed out for paper-based verification.

—What are the causes of these issues?

TOKUDA I believe that delayed digitalization and lack of ICT literacy in Japan are the causes. Elementary school students have just begun receiving basic ICT literacy education, in which they learn information science, including computer programming. It is vital for Japan to more actively promote digital transformation (DX) in many areas.

Expectations for ICT

—NICT has gained considerable ICT skills and experience over the years. What kind of contribution do you expect from ICT?

TOKUDA I envision that all things, namely objects, devices and information, will be

Interview

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integrated at a massive scale in the forms of IoT, AI, and other technologies through the combination of cyberspace (i.e., virtual space) and physical space (i.e., real space). We have to be mindful that these technologies must be operated in a human-centered, sustainable, and socially inclusive manner. In other words, these technologies should benefit people, not machines, contribute to the development of a sustainable society and serve everyone equally. The power of ICT may potentially free people from spatial and temporal constraints and even from their own physical bodies.

The NICT Center for Information and Neural Networks (CiNet) has been researching brain-machine interfaces. If this research effort bears fruit, we may be able to develop a social system in which people can have avatar robots do work by simply thinking about the specific tasks they want to accomplish.

CiNet is developing a SPA (sensing, processing, and actuation) model-based technology capable of performing a sequence of tasks (i.e., sensing, inputting, and analyzing information and taking actions in physical space in response to the information). The current actuator technology—which performs actual work—is still far from practical use. I anticipate that this SPA component will play a particularly important role in the post-COVID-19 society.

NICT's technological contribution in the "with COVID-19" era

—Does NICT have technologies that can be used to effectively cope with COVID-19 issues?

TOKUDA We have several. The deep-ultraviolet (DUV) LED technology that NICT has developed is capable of emitting 265 nm DUV radiation, which can inactivate the COVID-19 virus 3 cm away in one second. NICT is currently developing a 500 mW high-output DUV-LED. This device can be used to inactivate viruses in hospitals by installing it on robots and allowing them to thoroughly inspect hospitals and inactivate viruses.

NICT has also developed an 8K technology that can be used to monitor all activities in patients' rooms. We are currently testing the usability of this technology in collaboration with several university hospitals. The use of this technology may also allow doctors to remotely treat patients in intensive care units (ICUs) by monitoring all ICU activities at high resolution, making it a useful tool for local hospitals where ICU resources are often limited.

In addition, NICT's multi-language translation technology has been used by pharmaceutical companies developing COVID-19 vaccines. AstraZeneca PLC in the UK and NICT conducted an experiment in which this technology was used to translate a large volume of English documents needed for clinical trial application into Japanese. This technology allows them to complete the translation task in two weeks—twice as fast as the existing translation process AstraZeneca had been using, which took 4 weeks to finish the same task. The higher translation speed of this technology may expedite the development of vaccines by pharmaceutical companies.

Other technologies NICT is developing include: a privacy-protected data analysis technology, which enables the direct use of encrypted data in big data analysis and deep learning, thereby protecting personal information; an ultrahigh-speed communications technology, which uses terahertz waves to achieve data rates ranging from 100 Gbps to 1 Tbps—the communication speeds expected in 6G and later generation mobile communications systems; and a three-dimensional holographic technology that can realize "ultra-realistic communication" where people can share the same space with others in remote locations. I believe that these technologies will all be valuable for us coping with the COVID-19 pandemic.

Vision of a society and issues in the post-COVID-19 era

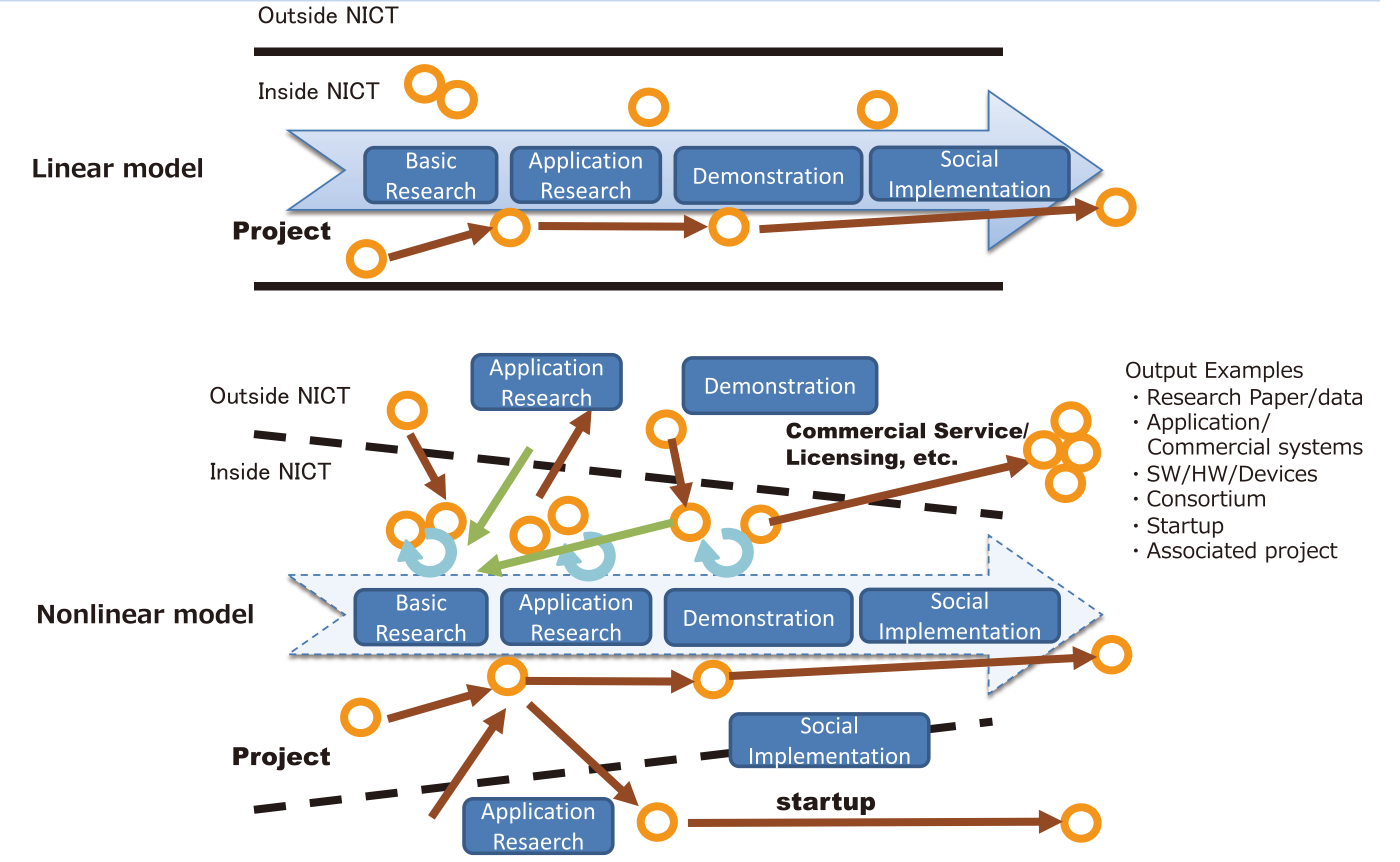
—What do you think our society will look like after the COVID-19 crisis is over?

TOKUDA The US non-profit organization i4j (Innovation for Jobs) expects that adoption of AI by one company will lead to the adoption of AI by its competitors in an effort not to fall behind. Because a company's value is represented by the collective values of its employees, AI should be used with care not to socially exclude anyone, according to i4j. I believe that this concept exemplifies the approach to developing a human-centered, inclusive society.

—What types of technologies are needed to bring positive changes to society?

TOKUDA Technological innovation must be accompanied by technological shaping—a concept that the social acceptance and understanding of new technology should be increased before it is put into practice. Technological researchers have traditionally given 100% of themselves to technological development. However, even the most amazing technology is worthless unless it is socially accepted. The technology shaping concept needs to be integrated into technological development in order to reform society (e.g., changing social rules, traditional pork-barrel politics, and people's mindsets) in ways so that new technology becomes more socially acceptable.

Social Implementation : Linear Model and Nonlinear model



Future efforts and prospects

—In what direction is NICT heading to meet post-COVID-19 demand?

TOKUDA While basic research is NICT's main activity, collaborative efforts with the private and other sectors in transforming basic research to technological development are also important. We then test the usability of a newly developed technology and—if proven to be promising for practical use—hand it over to another firm or a venture company capable of transforming it into a commercial product. Although we are accustomed to traditional R&D processes, in which a series of steps proceed in a linear fashion, I will encourage NICT researchers to attempt nonlinear technological development, in which they collaborate with other organizations from the early R&D stages. I believe this approach will accelerate the development and commercialization of new technologies.

It would be a good idea for basic researchers to envision specific forms in which their research products may put into practice 20 to 30 years ahead.

—What approach are you going to take to bring the technological blueprint into reality?

TOKUDA Ethics and legislation relevant to resolving social issues need to be reviewed. The 6th Science and Technology Basic Plan to be effective from FY2021 contains a new concept that science and technology innovation should take humanities research into account. This concept is relevant, for example, to discussion about the use of AI to simulate the human brain to process information. We now need to determine the boundary between human tasks and machine tasks. This issue needs to be addressed by taking into consideration advice from philosophers and ethicists and their research in addition to discussion among natural scientists.

The US Defense Advanced Research Projects Agency (DARPA) recently proposed the explainable AI (XAI) concept, which is now being researched by many research institutes and companies around the world. I often hear the concern that the solutions generated by AI—particularly deep learning—seem to be correct but it is unclear how they were derived. The XAI concept promotes the creation of AI capable of explaining the process by which a solution is derived. The XAI approach to shaping and perfecting technology is important because machines may generate unreasonable or incomprehensible solutions.

—What else would you like to achieve as an organization?

TOKUDA After all, human resources are the most valuable asset we have. I am interested in adding business and project coordinators to NICT to facilitate interactions between our outstanding researchers and external organizations, such as private companies. In addition to making steady efforts in basic and fundamental research, we have the ambition to develop high-impact technologies in the next medium-to-long-term framework and to put them into practice in a speedy manner.

INOUE Daisuke

Director of Cybersecurity Laboratory, Cybersecurity Research Institute

After completing a doctoral course in 2003, he joined Communications Research Laboratory (currently NICT). He has been engaged in research and development of network security focusing on Network Incident analysis Center for Tactical Emergency Response (NICTER) since 2006. Ph.D. (Engineering).

COVID-19 Brings Out Light and Dark Sides of ICT

In response to the COVID-19 outbreak, the Japanese government declared a state of emergency on April 7, 2020. Since then, many types of conventional activities have been replaced by online activities (e.g., work from home (WFH) and online schooling). These activities have been supported by variousICT, including video conferencing tools and VPNs—secure, high-speed networks. However, many incidents of cyberattacks that use COVID-19-related information as a lure have been reported. Thus, we have seen both the bright and dark sides of the ICT.

The increased use of online services due to widespread COVID-19 infection has been supported by ICT, such as high-speed networks available across Japan, VPNs that are secured with encryption techniques and chat and video conferencing tools that make remote communications easy and convenient.

In addition, ICTs have been playing a vital role in collecting and sharing information on COVID-19. For example, the Tokyo Metropolitan Government's COVID-19 information website[*1] is designed to effectively convey various types of information using infographics. Apple and Google jointly released a COVID-19 contact tracing API on smartphones. In Japan, the messaging application LINE has been used to conduct nationwide surveys[*2] for preventing COVID-19 infection.

While the use of ICT has been helping us cope with COVID-19, many incidents of cyberattacks taking advantage of the COVID-19 pandemic have also been reported. The number of people receiving COVID-19 phishing emails has increased rapidly. These emails typically mention COVID-19 and face masks in their subject and main text sections. The number of COVID-19 phishing emails NICT received in 2020 increased monthly from 30 in March to 71 in April and to 127 in May. Many cyberattacks were attempted during the rapid transition from "work from office" to "work from home" arrangements. These attacks took a variety of forms, e.g., some attacks targeted the vulnerability of VPN products[*3], others were detected as brute-force attacks against the Remote Desktop Protocol[*4] and yet others were identified as unauthorized third parties breaking into online meetings using video conferencing tools[*5].

Moreover, ransomware attacks on healthcare providers have been a serious issue. Ransomware encrypts data on the infected computers, making it inaccessible to the victims. The attackers then demand a ransom payment from the victims in return for decrypting the data. In May 2020, the technology system of Fresenius—the largest private hospital operator in Europe—was found infected with the Snake ransomware, interrupting the company's operations[*6]. Warnings were issued for COVID-19-themed cyberattacks targeting healthcare institutions first by INTERPOLin April 2020 and then jointly by CISA in U.S.A. and the NCSC in UK in May[*7*8].

The WFH practice was rapidly adopted and continues to be widely implemented in Japan. Many organizations traditionally use "boundary protection measures" to secure their internal networks by setting up a defense against malicious and other unauthorized communications at the external boundary of the network. However, this mechanism is becoming inadequate because of the drastic changes in work environments. In response, an increasing number of organizations have adopted a so-called Zero Trust security model: an emerging paradigm. This model focuses on protection of information assets rather than network security[*9].

Well before COVID-19 became a threat, NICT created a secure work-from-home environment for its employees by making VPNs available to them and developed a sophisticated security management system based on earlier research on NIRVANA-Kai[*10] and other technologies. These efforts, including the devoted support from the ICT System Office, facilitated smooth transition to a WFH-based organizational operation in NICT. Lastly, I would like to express my gratitude to all the people around the world working to protect the ICT environment.

(＊1, ＊2, ＊3 , ＊10 are written in Japanese.)

＊1 https://stopcovid19.metro.tokyo.lg.jp

＊2 https://guide.line.me/ja/coronavirus-survey.html

＊3 https://blogs.jpcert.or.jp/ja/2020/03/pulse-connect-secure.html

＊4 https://securelist.com/remote-spring-the-rise-of-rdp-bruteforce-attacks/96820/

＊5 https://www.justice.gov/usao-edmi/pr/federal-state-and-local-law-enforcement-warn-against-teleconferencing-hacking-during

＊6 https://krebsonsecurity.com/2020/05/europes-largest-private-hospital-operator-fresenius-hit-by-ransomware/

＊7 https://www.interpol.int/en/News-and-Events/News/2020/Cybercriminals-targeting-critical-healthcare-institutions-with-ransomware

＊8 https://us-cert.cisa.gov/ncas/alerts/AA20126A

＊9 https://csrc.nist.gov/publications/detail/sp/800-207/final

＊10 https://www.nict.go.jp/press/2016/06/07-1.html

NICT's Natural Language Processing Technology for COVID-19

TORISAWA Kentaro

NICT Fellow, Director General, Data-driven Intelligent System Research Center, Universal Communication Research Institute

After receiving MSc in computer science, he became an assistant professor in Graduate School of Science, the University of Tokyo, in 1995. In 2001 Associate professor in School of Information Science, Japan Advanced Institute of Science and Technology. Joined NICT in 2008. Ph.D. (Science).

NICT is developing AI-based technologies capable of processing natural languages, such as Japanese and English. The use of these technologies—some of them have already been commercialized—is not limited to research purposes: their use may potentially have significant social impacts. In this article, I will describe the ways in which these technologies may be useful for helping people cope with COVID-19-related issues.

NICT has researched and developed speech translation technologies, implemented for example in the VoiceTra application, which is capable of translating speech inputs in one language (e.g., Japanese) into speech outputs in another language when installed on a smartphone or similar devices. NICT has also developed text translation technologies capable of translating patent and other types of documents. The ongoing COVID-19 pandemic has increased the importance for the global healthcare community to share information internationally and examine research papers published on COVID-19 written in various languages. The use of translation technologies may greatly facilitate these activities. For example, Japanese healthcare practitioners with inadequate English skills may wish to have meetings with English-speaking counterparts or peruse research papers written in English in search of more effective COVID-19 treatments and anti-COVID-19 measures. Translation technologies will help them achieve these objectives more efficiently.

Currently available speech translation technologies are incapable of initiating translation until users pause their speech. NICT is developing a revolutionary translation technology capable of translating users' speech as it continues without interruption—a potentially useful tool in cross-lingual communication situations such as international video conferences. We are aiming to put this technology into practice by 2025. NICT has also been engaged in a so-called "translation bank" project. Translation of research papers and simultaneous interpretation in professional meetings require proper translation of terms, phrases and wordings unique to specific fields of expertise. In this project, NICT is collecting past translation data used in various professional fields from private companies and other organizations and using this data to develop highly accurate machine translation systems specialized in specific fields of expertise. For example, data being collected from a number of pharmaceutical companies will be used to develop a simultaneous interpretation technology for healthcare practitioners. The use of these technologies is expected to facilitate international collaboration among healthcare practitioners around the world, allowing them to more effectively respond to pandemics.

A prolonged outbreak of an infectious disease makes it even more difficult for the public to cope with potential natural disasters. Evacuees are likely to have higher risks of being exposed to the three C conditions (i.e., Closed spaces, Crowds and Close contact with others) in evacuation facilities. NICT and its collaborators are developing SOCDA, a smartphone chatbot application designed to facilitate disaster relief organizations' efforts to efficiently collect information from people affected by natural disasters. The use of SOCDA will allow these organizations to comprehend the health of individual victims and the current capacity of evacuation facilities, enabling them to help victims avoid contracting infectious diseases by making appropriate recommendations. For example, they may be able to guide evacuees to facilities more resistant to the three C conditions. The usability of SOCDA in this pandemic context is scheduled to be tested during FY2020.

COVID-19 infection has been shown to be often life-threatening to senior citizens and a number of COVID-19 clusters have been detected in nursing facilities. NICT and collaborating companies are developing MICSUS, a spoken dialogue system capable of verbally interacting with the elderly (Figure). We have carried out several tests to verify the usability of MICSUS for elderly people. MICSUS is designed to accomplish two tasks. First, it automatically and thoroughly assesses the health of senior citizens and sends high-quality data to caretakers, thereby reducing their workloads. Second, it can engage in casual conversation with senior citizens living alone using information collected from the Web and other sources to free them from feeling socially isolated. In addition, the use of this dialogue system is expected to reduce the need of care managers to meet care receivers in person, thereby lowering the risk of spreading contagious diseases. This risk can also be minimized by presetting MICSUS to ask elderly users if they have noted any signs of infection. MICSUS is also able to detect health concerns from elderly people by recording video of them, possibly including infrared cinematography, and collecting other information with various types of sensors. This function can detect possible symptoms of infectious diseases (e.g., fever) from them even before they complain of ill health and transmit the information to healthcare providers.

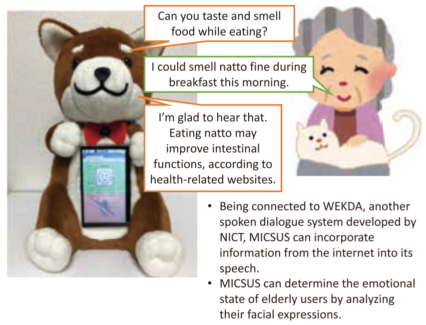


Figure MICSUS: a multimodal interactive system for the elderly

Enhancing Social and Economic Systems to Cope with COVID-19 Outbreaks

— Privacy-preserving data analysis —

MORIAI Shiho

Executive Researcher, Cybersecurity Research Institute and Managing Director of Strategic Planning Office, Strategic Planning Department

After graduating from University, she worked at NTT and Sony corporation. Entered NICT in 2012. Ph. D. (Engineering).

Japan's social and economic environment is rapidly changing in response to the persistent COVID-19 pandemic. Privacy-preserving data analysis is very important particularly in this period of coexistence with the coronavirus. Using data while protecting privacy is often challenging. I will describe the COVID-19 contact confirming application developed in Japan as an example of this challenge. I will then show some of NICT's privacy-preserving data analysis technologies.

Contact confirming application

Applications that use Bluetooth to track people in close contact with someone with or suspected to have COVID-19 began to be used overseas around March 2020. This led the Japanese government to develop its own effort to develop contact tracing applications, which prompted a sequence of events: the Cabinet Secretariat established an Anti-COVID-19 Tech Team on April 6; the Ministry of Health, Labour and Welfare announced on May 8 that the Ministry and the Tech Team would jointly develop a COVID-19 contact tracing application using the API developed by Apple and Google as a base technology; and the COVID-19 contact confirming application (COCOA) was released for public use on June 19.

Anyone can install COCOA on their smartphone on a voluntary basis. When two or more COCOA users come into close contact and stay within 1 meter of each other for more than 15 minutes, each other's identifiers (short-term, anonymous identifiers that do not include any personal information) are exchanged through Bluetooth and recorded on their smartphones. The recorded data is automatically erased after two weeks. If COCOA users take a COVID-19 test at a public health center and are notified to be COVID-19 positive, they can optionally input their testing results into their COCOA Warnings are then sent to all COCOA users who have come into close contact with them without disclosing their identities.

Different types of COVID-19 contact tracing systems have been adopted by different countries (Figure 1). The system Japan is using provides the highest level of privacy protection as it uses only anonymous identifiers and does not centrally collect any personal data from individuals, including those who have tested positive. As of September 30, 17.78 million people approximately 14% of the Japanese population—has downloaded COCOA. Only 948 COCOA users have registered their COVID-19 positive testing results. The effectiveness of COCOA-based COVID-19 surveys is limited because participation and the reporting of positive testing results are on a voluntary basis.

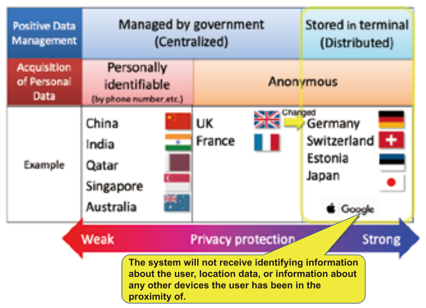


Figure 1 Different types of COVID-19 contact tracing applications adopted by countries

Privacy-preserving data analysis

Technology capable of analyzing encrypted data without first decrypting it is a valuable tool to protect privacy. NICT, which has been working on this technology for years, has issued several press releases related to this, including the January 14, 2016, *1 and the July 18, 2018, *2 In the project described in the second press release, we developed a method of analyzing encrypted medical data without revealing its content and preventing irrelevant data from being included in the analysis. We then demonstrated that the method was effective in securely analyzing the statistical relationship between patients' genetic data and their disease data without requiring a decryption process (Figure 2). We hope that these technologies will be implemented in the real world requiring the analysis of encrypted big data during the time of the COVID-19 crisis.

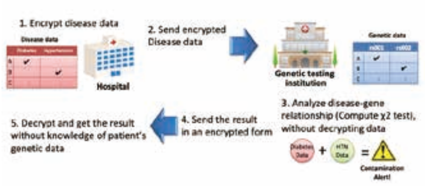


Figure 2 Privacy-preserving data analysis of medical data

(Following pages are written in Japanese.)

＊1 https://www.nict.go.jp/press/2016/01/14-1.html
＊2 https://www.nict.go.jp/press/2018/07/18-1.html

Issues with Existing ICT in Coping with COVID-19 and Possible Solutions

WADA Naoya

Director General, Advanced ICT Research Institute

Joined Communication Systems Laboratory (currently NICT) in 1996. Had engaged in reseach of photonic networks and optical transportation system. Ph.D.(Engineering).

ICT have been greatly benefitting us by enabling us to maintain social and economic activities while coping with the COVID-19 pandemic. On the other hand, we have identified many issues with the ICT currently used in remote working, online schooling and other online activities, such as transmission capacity, flexibility, stability and safety. To resolve these issues, NICT has been engaged in R&D activities to upgrade ICT (Table 1).

Unlike conventional communications networks, beyond-5G/6G are expected to be convergence technologies of wireless and wired systems, i.e., wired and wireless convergence networks. The use of technology capable of seamless and direct conversion between optical signals and mmW / THz signals can increase the transmission capacity for networks by 100 times. However, effective use of this conversion requires a significant increase in the capacity of optical fiber networks used in the areas of heavy network traffic. NICT will adopt a space-division multiplexing optical network technology with multicore fibers and multimode fibers, both of which employ multiple channels to transmit optical signals. We will design these fibers so that their outer diameters match those of existing single-channel optical fibers. These technologies are expected to increase the capacity of optical fiber networks by hundreds to thousands of times. We will also adopt highly extendable optical fiber networks with extensive branching capabilities to substantially increase the transmission capacity of access networks, making them adequate for use in populated urban areas. In addition, the number of antennas to be used in these areas is expected to increase considerably. We will miniaturize optical devices and simplify optical transmission systems, thereby making the networks workable with many of antennas.

Furthermore, we will have been working on ICN/CCN technologies that can be used to fully exploit limited physical layer resources and achieve efficient content distribution in the network by avoiding congested routes and servers. We have been developing a network automation technology that automatically allocates and orchestrates network resources in response to requests from different applications. These technologies will provide more flexible and stable network services.

Some people working remotely may need to exchange highly confidential information via networks from time to time. Therefore, networks need to be more secure than ever. Quantum cryptography is currently the only encryption technique unbreakable by any type of computer, not even by quantum computers. We will use network technologies that employ quantum cryptography to securely protect confidential information.

Even if many of the issues associated with remote working are successfully resolved, we still have concern over the safety of many other people who can not work remotely in places protected from COVID-19. It is therefore very important to develop technologies able to easily sterilize or disinfect areas potentially contaminated with COVID-19. Much attention has been paid to sterilization technologies capable of killing viruses using deep-ultraviolet (DUV) light without touching any objects in the surrounding environment. Conventional DUV light sources, such as mercury and gas lamps, have several disadvantages: large, inefficient in energy use, expensive, non-durable and contain toxic substances, such as mercury. By contrast, the DUV (LEDs) are free of these and are able to easily eliminate viruses from potentially contaminated areas. The high-output-power DUV-LEDs by a NICT research team can provide alternative DUV light sources with 265 nm emission—the most effective germicidal wavelength—and are also non-toxic to the environment.

NICT will continue to engage in advanced ICT R&D to make the everyday lives under the influence of the COVID-19 outbreak safer and more comfortable.

Table Key ICTs needed to solve current issues

Issues	Problem-solving technologies (selected examples)
Transmission capacity	• Beyond-5G technology • Optical fiber communications technology with space division multiplexing capabilities
Flexibility and stability	Programmable network technology
Safety	Quantum network technology

Cyber Physical System and Beyond 5G / 6G

HOSAKO Iwao

Director General of Wireless Network Research Center

After completing a doctoral program, Iwao HOSAKO worked for NKK Ltd. (currently JFE). In 1996, he joined the Communications Research Laboratory, Ministry of Posts and Telecommunications (currently NICT). He has been engaged in research and development of terahertz semiconductor devices and various application systems. Ph. D. (Science).

Mobile communications systems are rapidly increasing in sophistication. Cyberspace—composed of core networks that support mobile communications systems and servers on the internet—enables interactions between different people, between people and devices and between different devices. These interactions are becoming increasingly important in many aspects of our social activities. As commercial deployment of 5G networks is already underway, current R&D focuses are shifting to beyond-5G or 6G networks. In this article, I will describe our beyond-5G / 6G R&D in relation to various interactions mentioned above, which continue to grow in demand and which can be achieved through the integration of physical and cyber spaces.

Background

In response to the COVID-19 outbreak, the Japanese government issued a state of emergency declaration on April 7, 2020, to some severely affected prefectures, which was subsequently expanded to the entire nation on April 16 and was finally lifted for most prefectures on May 14. Even after the declaration was terminated, many people continue to refrain from making unnecessary outings to avoid the 3Cs (i.e., closed space, crowds, and close contact with others), work from home and use online schooling. This experience raised our awareness about the important role information and communications technologies (ICT) play in coping with infectious diseases and remote working. On the other hand, some experts view that the current technological levels and penetration rates of ICT in Japan are inadequate for people to maintain a "new normal" lifestyle. This view led to the July 17, 2020, cabinet approval of "Declaration to make Japan the most advanced digital technology nation in the world," a guideline promoting the implementation of adequate digital technologies to strengthen anti-COVID-19 measures and support a new normal lifestyle.

Integration of cyber and physical spaces: cyber-physical systems

The following insight came to me while working from home and experiencing increased online activities in response to the declaration of a state of emergency. People dispersed in space as they began working from home, using online schooling, and exercising other measures to avoid the 3Cs. Under the current circumstances, it is desirable to create a system in which spatially dispersed people can continue to be productive and engage in activities valuable to them by allowing them to remotely work together with other people, robots and avatars using ICT. Urgent efforts should be made to develop this system as soon as possible. The specific types of ICT I am referring to here are the internet and cyberspace composed of groups of interconnected servers (cloud). It is also important to develop a cyber-physical system in which various real-world events (e.g., COVID-19 outbreaks) are measured to collect data, which is then organized into big data and processed in cyberspace as the way of finding optimum solutions to social issues.

Greater role of beyond-5G networks

Mobile communications systems evolved from mere communications infrastructure (1G to 3G) to infrastructure vital to everyday life (4G). The role of the 5G network as social infrastructure is more diverse: it connects not only different people but also people and devices. Its use is expected to accelerate widespread adoption of the DX (digital transformation) initiative. Through beyond-5G/6G R&D, we plan to develop the artificial neural networks needed to bring Japan's Society 5.0 vision into reality by integrating physical space (real-world) and cyberspace.

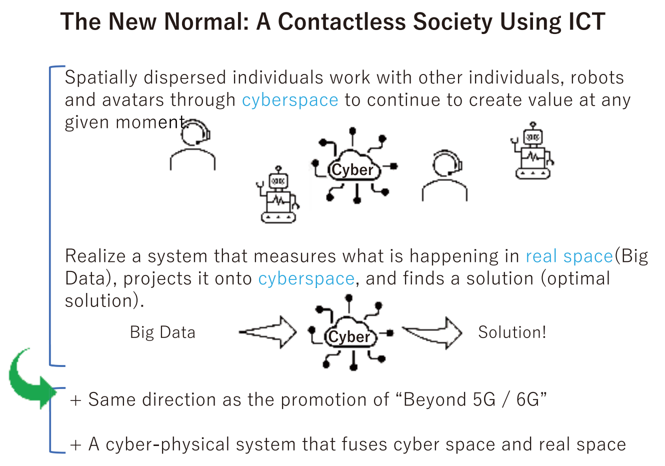


Figure 1 The "new normal": a contactless society using ICT

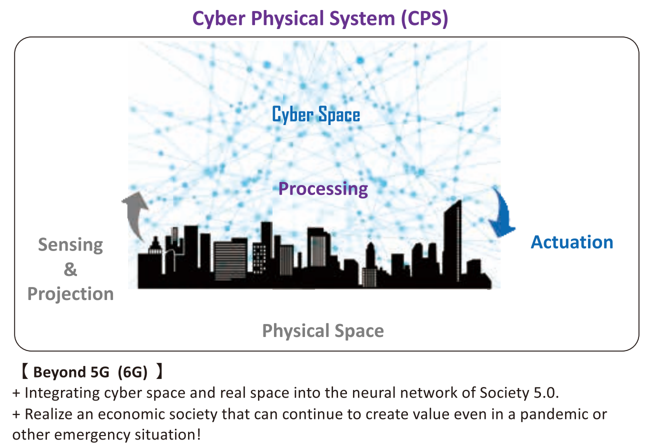


Figure 2 Cyber physical system

Specific R&D activities: radio wave emulator, spatial and temporal synchronization, and ultrahigh-speed wireless network

5G technology is expected to enable much faster communications, much larger capacity networks, reduced communication delays and increased connectivity. Developers of beyond-5G/6G networks are targeting to surpass 5G networks by increasing the parameter values of these functions by an order of magnitude. In addition, the scale of beyond-5G/6G networks is planned to be extended so that they become available for use in drone, aviation, outer space and marine operations. Because the number of wireless devices people use is exponentially increasing with the advances of communications technologies, design, testing and practical use of wireless systems using conventional methods are likely to become very difficult. Under the condition in which a vast number of wireless devices are densely used within a small space, monitoring of wireless communications in real space will be impractically expensive and time-consuming. One potential approach to monitoring this is to monitor wireless communications within cyberspace, which may enable efficient monitoring of complex, large-scale systems and detection of radio frequency interference that may occur between similar or dissimilar systems. An R&D project aiming at increasing radio wave resources was launched in FY2020 under the title "Research and development for the advancement of radio wave simulation system technology in virtual space." The project will be funded by the Ministry of Internal Affairs and Communications from 2020 to 2023.

Temporal synchronization of the cyber-physical system is critical to enable individuals to remotely work with other individuals, robots or avatars via cyberspace. Because reference signals used in wireless communications will become more accurate, it may be feasible to develop more energy-efficient mobile communications systems by coordinating multiple terminal devices and base stations. It may also be feasible to precisely synchronize actions taking place at distant locations using accurate reference signals. NICT has been researching and developing technology basses needed to achieve synchronization, such as optical lattice clocks, chip scale atomic clocks, traceability technologies and bidirectional wireless communications technologies.

White papers published by research organizations both in Japan and abroad suggest that ultrahigh-speed (100 Gbit/s) wireless communications using a terahertz band may be available in beyond-5G / 6G networks. Active efforts by NICT and others led to a momentous decision at the 2019 World Radiocommunication Conference: a total bandwidth of 137 GHz in the vicinities of 300 GHz and 400 GHz was decided to be used both in fixed and land mobile services. This international agreement on the adoption of the broadest bandwidth ever used in wireless networks is highly significant.

NICT has also been researching 300 GHz band hardware and working to establish ITU-R and IEEE 802 standards in collaboration with the industrial and academic sectors. In another project, NICT is developing an advanced core network needed to put 100 Gbit/s-class wireless communications into practice. We previously developed an extremely high speed optical fiber communications technology comprised of multicore fibers, which can be used as a base technology to develop a 100 Gbit/s-class wireless communications system, including a 100 Gbit/s-class access network.

Future prospects

One of our beyond-5G/6G R&D objectives is to develop artificial neural networks needed to bring Japan's Society 5.0 vision into reality by integrating physical space and cyberspace. In the face of a new normal way of living, this integrated technology may potentially enable us to create a system in which people dispersed in space can continue to be productive and engage in activities valuable to them by allowing them to remotely work together with other people, robots and avatars using ICT. To develop the technologies I described in this article with specific examples, we need to integrate various technology components, work together with researchers overseas and make efforts to reach international agreements. I look forward to collaborating with many researchers.

Creating the Cyber World Using Information in the Human Brain (Brain Language) and XR Technologies

YANAGIDA Toshio

Director General, Center for Information and Neural Networks

Professor, Osaka University after withdrawal from the Doctoral Program of the university. After working as a distinguished researcher at NICT, he has been in his current position since 2013. He researches on the mechanism of life based "Yuragi." Person of Cultural merit (Ministry of Education, Culture, Sports, Science and Technology in Japan: MEXT) in 2013. Doctor of Engineering Science

Due to the ongoing COVID-19 pandemic and other natural disasters, many of people have been forced to severely restrict their social activities. Because this type of catastrophe could reoccur in the future, it is desirable to fundamentally enhance the capability of our social systems so that we can more adequately cope with adversity while keeping our lives as close to normal as possible. The creation of a cyber world may potentially enable us to continue to engage in various activities (e.g., personal and occupational activities and social interaction with others) irrespective of real-world restrictions.

R&D brain-based communications

Recently, rapidly advancing ICT, such as AI and 5G, are bringing cyber world concept into reality.—Although the use of these technologies may increase the volume of information available to us, the human brain can efficiently process only a limited amount of information before feeling fatigue. Notably, stimulated brain information is often high in quality, not quantity. Interpreting the information processed in the brain—or what we call "brain language"—is the critical step in developing a brain-to-brain communications system. Here, we describe the concept of a hyperreal, cyber world, which may be developed using "brain language" and XR (cross reality) technologies (Figure 1).

How can we extract "brain language"? Research to interpret information in the human brain or "brain language" by analyzing brain activity is making significant progress in recent years. At(CiNet) we have been making major efforts in this research. This article describes some of our achievements.We measured brain activity of human subjects watching a video and attempted to reproduce the images they perceived by measuring brain activity. Performing cognitive tasks and tried to interpret their high-level cognitive processes, such as perception of semantics, emotion, and intention. Our results have shown success in interpreting brain activity in these experiments (Figure 2).

Efforts to interpret "brain language"

Our goal is to interpret "brain language" generated when humans perceive visual and other types of information. We then plan to build an extensive brain activity database and study brain activity patterns specific to the type of information perceived. Brain activity is usually measured using fMRI. However, this technique restricts the movement of human subjects in the MRI machine, making it impossible to measure brain activity under natural conditions. To resolve this problem, we plan to measure brain activity from many people staying in a virtual environment created using XR technologies. We also intend to measure brain activity under unconstrained conditions using several different methods—including EEG to record brain waves and ECoG to record electrical activity from the cerebral cortex—in collaboration with medical institutions. Because "brain language" varies between individuals, brain activity measurements need to take various personal differences into account (e.g., age, gender, living environment, interests, occupation, DNA pattern, cultural background, nationality and race) in order to link "brain language" to specific personal traits. One of our interests is to separate common and unique personal characteristics as a clue to understand the formation of personality and character. Understanding "brain language," which may contain personality-related information, through labor-intensive brain activity measurements requires enormous amounts of human resources, time and research funding. We believe that indicators of "brain language" can be found in the vast volume of information exchanged on social networking sites. We collect "brain language" data associated with unique personal characteristics by taking a combined approach of analyzing information on SNS and measuring brain activity from human subjects. We are also considering conducting large-scale "brain language" R&D in collaboration with a NICT center with expertise in analyzing information on SNS. Some companies, such as Neuralink and Facebook, have launched brain science R&D using ICTs. We expect that the use of ICTs in brain science will be a global trend.

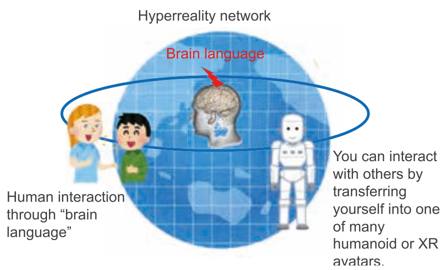


Figure 1 Creating a cyber world using "brain language" and XR technologies. This system will enable people around the world to 'telepathically' communicate with each other without being restricted by physical time and space.

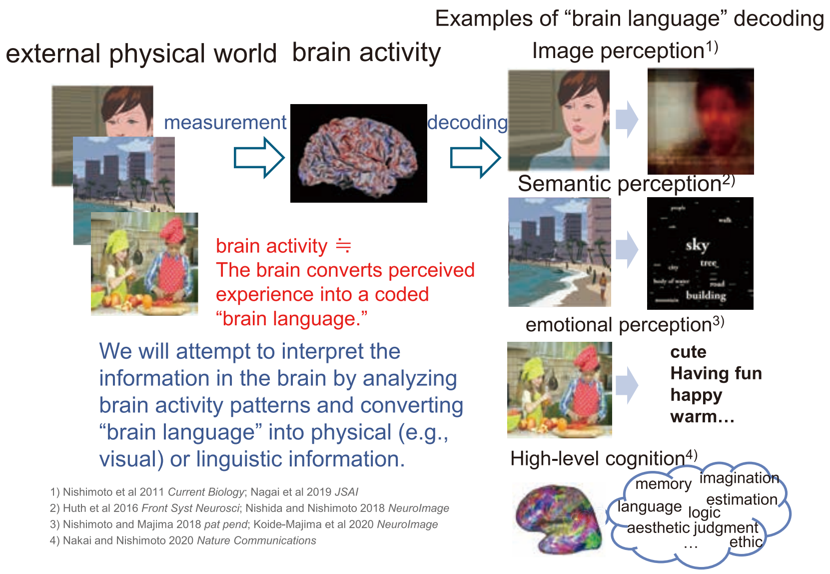


Figure 2 Example of "brain language" interpretation process

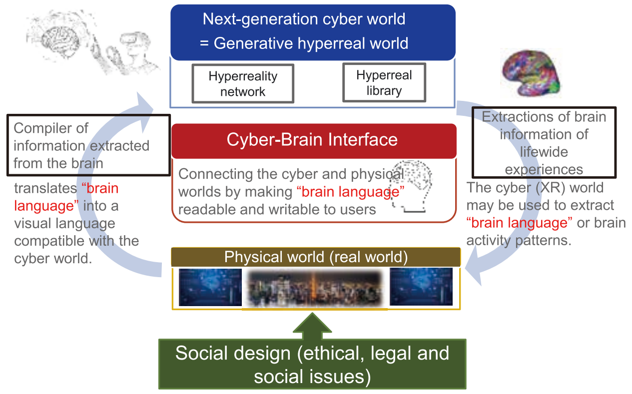


Figure 3 Development of a cyber world using "brain language" and XR technologies

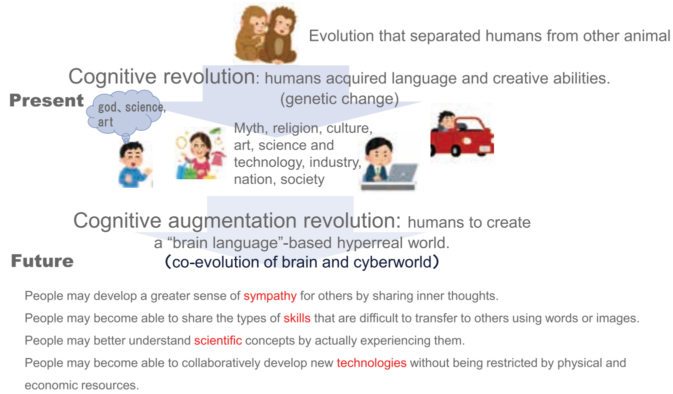


Figure 4 The new cyber world may potentially bring about a cognitive augmentation revolution.

Generative hyperreal world

Would it be possible to create a cyber world using "brain language" and XR technologies? It is not practical to continuously collect "brain language" data by measuring brain activity for continuous operation of the cyber world. Our plan is to collect a large amount of "brain language" data associated with unique personal characteristics and compile it into a database. We will then translate "brain language" into a different form of language workable in the cyber world. To achieve this, we envision developing a computer system capable of reading and interpreting "brain language" data collected in advance, thereby eliminating the need for repeatedly measuring human brain activity. We then plan to develop a new cyber world (i.e., generative hyperreal world)—a "brain language" data sharing network. "Brain language" data must be handled carefully and ethically, and the user community needs to set rules to ensure its proper use. We intend to address these issues thoughtfully with the Osaka University Research Center on Ethical, Legal and Social Issues (ELSI Center) (Figure 3).

What type of social change can "brain language" and an XR-based cyber world bring about? During the evolutionary history of humans, we acquired language ability and creativity through cultural, genetic and epigenetic changes, enabling us to develop a human society, which is fundamentally different from the social structures of other animals. This might sound like a bold statement, but I have high expectations for the new cyber world we are envisioning to develop using advanced technology as a trigger for a cognitive augmentation revolution. This system is expected to encourage people to interact with a greater sense of empathy, facilitate the sharing of the types of skills that are difficult to transfer to others using words and images, and promote deeper understanding of the world and the discovery of new forms of creativity (Figure 4). I also believe that this system, which functions as an information carrier through the use of both conventional and brain languages, will provide users with opportunities to expand their knowledge, better understand the perspectives of others, interact with a larger number of people and share emotions (e.g., happiness, distress and hope). This system may even promote the sharing of creative ideas leading to innovation. Traditionally, public infrastructure investment has been mainly focused on fulfilling industrial and public needs. However, after the establishment of the new cyber world, investment focus may shift to promoting the well-being of humanity.

The development of the cyber world we proposed will require an interdisciplinary approach to researching information in the brain using a variety of ICTs involving not only NICT researchers but also a wide range of external organizations. Practical implementation of the cyber world will require the cooperation of many companies relevant to this project. We are actively developing an open innovation system.

I wish to thank several associate researchers for helping me prepare this manuscript. They are the members of the NTT Data Institute of Management Consulting, the University of Tokyo Virtual Reality Educational Research Center, the Osaka University ELSI Center, and CiNet.

Distributed Deep Learning Framework for Extremely Large-scale Neural Networks

Biography
Born in Nara Prefecture in 1981.
Graduated from Kyoto University Undergraduate School of Informatics and Mathematical Science in 2004.
Earned a doctorate from Kyoto University Graduate School of Informatics in 2009
Jointed NICT in 2009.
Assumed his current position in 2016.

Awards, etc.
Co-recipient of the DOCOMO Mobile Science Award (2015) and the Maejima Hisoka Award (2016)

TANAKA Masahiro

Senior Researcher
Data-driven Intelligent System Research Center
Universal Communication Research Institute
Ph.D. (Informatics)

Q&As

Q What do you like the most about being a researcher?

A My current research position allows me to tackle unsolved technical problems in my own way. This is a very exciting aspect of my work.

Q What are you currently interested in outside of your research?

A I recently refurbished my viola, which hadn't been used for several years, and resumed playing it in my spare time. My daughter also recently started playing the piano, so we sometimes play together. I find playing music, even for a brief period of time, to be very refreshing.

Q What advice would you like to pass on to people aspiring to be researchers?

A Because graduate students can spend only a limited amount of time on research, they often feel rushed to complete their degrees. However, I recommend that they think carefully and pursue research that would be truly valuable in their fields. I believe this will be more rewarding for them over the long run.

Deep learning technology has been drawing a great deal of attention in recent years. It generally uses hardware accelerators, such as graphics processing units (GPUs). However, artificial neural networks used in deep learning are rapidly expanding in scale. Some recently proposed neural networks exceed the memory capacity of GPUs. For example, a network named BERT, proposed in 2018, which achieved a breakthrough in natural language processing, had 340 million parameters—among the largest number of parameters ever at the time. The number of parameters has continued to grow: T5, proposed in 2019, has a staggering 11 billion parameters.

We have been developing RaNNC (Rapid Neural Network Connector), a framework that automatically partitions an extremely large-scale neural network into smaller units and distributes them onto multiple GPUs. RaNNC can determine how to optimally partition a large neural network by estimating the computational loads and required GPU memory. We have already succeeded in training a neural network with several billion parameters more efficiently using RaNNC than is possible using existing deep learning frameworks in which a network partitioning has to be tuned manually. In the future, we plan to evaluate the applicability of RaNNC to a wide variety of neural networks and release it as open source software. We also plan to integrate trained large-scale neural networks into WISDOM X (a large-scale web information analytical system), WEKDA (a next-generation spoken dialogue system), MICSUS (a multimodal interactive care support system) and other systems to enhance their performance. We then intend to make trained networks available for use by private companies and other organizations.

I have been working mostly from home for the past three years for family reasons. Although it took me a while to become accustomed to this new working style, I eventually adapted to it with the support of the people around me. This experience is now helping me cope with the work-from-home practices widely adopted in response to the COVID-19 pandemic.

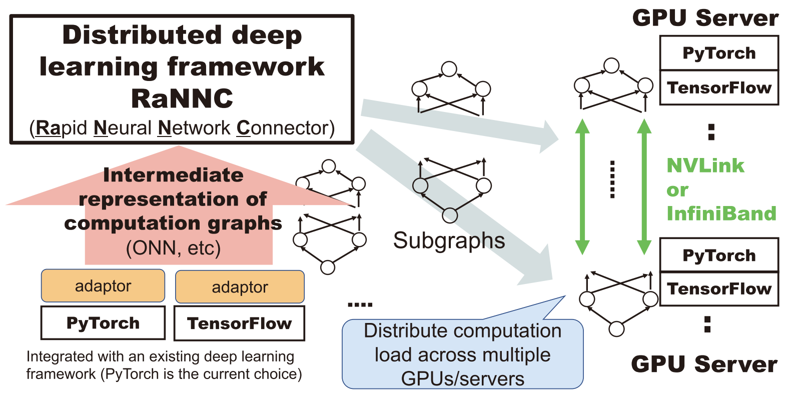


Figure Overview of RaNNC

NICT Fellow

NICT bestows the honorary fellow title on those who have made particularly outstanding achievements in research and development at NICT. This title was most recently awarded to TORISAWA Kentaro (Director General, Data-driven Intelligent System Research Center (DIRECT), Universal Communication Research Institute) on July 1, 2020.

TORISAWA Kentaro

Director General, Data-driven Intelligent System Research Center, Universal Communication Research Institute

In addition to being a computer scientist, Dr. TORISAWA is also knowledgeable about a wide range of subjects such as philosophy and history. He has been researching Natural Language Processing (NLP), a subdiscipline of AI, using his broad knowledge.

At NICT, he has led the development of a series of large-scale NLP systems: WISDOM X (a web information analysis system), DISAANA and D-SUMM (disaster information analysis systems) and WEKDA (a next-generation spoken dialogue system). His broad knowledge and high research skills in computer science and NLP enabled these achievements. Dr. TORISAWA's knowledge and skills also greatly contributed to the development, in collaboration with private firms and other national research centers, of MICSUS (a multimodal interactive care support system) and SOCDA (a disaster relief chatbot).

He exhibited excellent leadership in organizing a collaborative team effort by many researchers (including NLP researchers, parallel and distributed computing specialists and linguists), programmers and data creators to develop these complex, large-scale AI systems. Some of these systems have been used by local governments to carry out disaster drills and actual disaster relief operations. In addition, software licenses for these systems have been provided to private companies. His achievements and the concepts he devised have been highly valued by major organizations, leading him to receive many awards, including the JSPS (Japan Society for the Promotion of Science) Prize and the MEXT (Ministry of Education, Culture, Sports, Science and Technology) Minister Award in Science and Technology. He was also granted access to Twitter, Inc.'s large tweet dataset through "Twitter Data Grants."

65th Maejima Hisoka Award presented by the Tsushinbunka Association

The Maejima Hisoka Award was established in memory of Mr. Maejima, one of the founders of Japan's telecommunications industry, and to pass on and promote his spirit. The award is presented to those who have made outstanding contribution to the advancement of the information and communications industry (including postal services) or the broadcasting industry. Two parties of NICT researchers received this award in FY2020.

KADOWAKI Naoto

Vice President, Member of the Board of Directors, NICT

Area of Research: Research and development for the advancement of high-speed satellite network technology
Award reception date: September 18, 2020
Recipient's comment: I have engaged in satellite communications research since I joined the Radio Research Laboratory—a precursor of NICT. It is a great honor for me that my work—the development of broadband satellite network technologies, including the WINDS satellite—was highly received. I thank the many people who supported my research, including my seniors who provided me with guidance.

AWAJI Yoshinari

Research Executive Director, Universal Communication Research Institute
Research Manager, Photonic Network System Laboratory, Network System Research Institute

SAKAGUCHI Jun

Senior Researcher, Photonic Network System Laboratory, Network System Research Institute

Puttnam Ben

Senior Researcher, Photonic Network System Laboratory, Network System Research Institute

Soares Luís Ruben

Senior Researcher, Photonic Network System Laboratory, Network System Research Institute

Rademacher Georg Friedrich

Researcher, Photonic Network System Laboratory, Network System Research Institute

Area of Research: Research on and development of a space division multiplexing optical transmission technology
Award reception date: September 18, 2020
Recipients' comment: The amount of internet traffic is expected to increase rapidly as 5G and later-generation networks are adopted. Our research has been focused on significantly increasing the transmission capacity of optical fiber communications to meet expected future communications demand. In the process of working on this, we achieved several ICT-related world records through close collaboration with the industrial and academic sectors. We thank NICT for understanding and supporting our work. We will continue our effort to develop high performance technologies for this purpose together with and necessary strategy for putting them into practice.

from left, Georg Friedrich Rademacher, Luis Rube Soares, Ben Puttnam, and Yoshinari Awaji

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