Annual Report 2019

Research Institute of Electrical Communication
Tohoku University

Annual report of Research Institute of Electrical Communication 2019

Contents

1. Introduction

It is the mission of RIEC to realize a new paradigm of communications that enriches people's lives. Communication is important in various ways in human society. Information communication technology (ICT) has been changing the way we deal with information drastically, overriding our biological limitations and expanding the world of communication from among people to among things as well as between people and things. Such ICT research is gathering attention for new normal after the coronavirus pandemic. RIEC is determined to work for future society with further advanced ICT, contributing to the welfare of human beings by opening up a new era of academically rooted innovation befitting a university.

The Japan's Fifth Science and Technology Basic Plan aims to realize a cycle of innovation toward a super-smart society. The plan sets out policies for strengthening the fundamental technologies that will support this, including cyber security, the "Internet of things (IoT)," big data, artificial intelligence, and devices. It goes without saying that these research fields fall under the RIEC's scope of expertise and that the institute must play a leading role in furthering them. Meanwhile, universities are expected to conduct basic researches, some of which would create innovations that enriches the society. We have such examples in the history of our institute, such as Professor Junichi Nishizawa's three elements of optical communication and Professor Shunichi Iwasaki's perpendicular magnetic recording. They started related basic researches at RIEC, which opened new fields in ICT eventually. A more recent case is spintronics, which Professor Hideo Ohno has led from basic science to application to new devices. Magnetoresistive Random Access Memory (MRAM) is a device that uses the spintronics technology, and is attracting public attention as the promising candidate of a critical and emerging device in the near future ICT. The environment in which Tohoku University and RIEC operate is constantly changing. Recognizing roles of university, RIEC must utilize resources efficiently to execute its mission and develop the environment for the purpose.

Since 2004, the institute's organizational structure has been organized into three units: four research divisions (Information Devices Division, Broadband Engineering Division, Human Information Systems Division, and Systems & Software Division), two laboratories (Laboratory for Nanoelectronics and

Spintronics, and Laboratory for Brainware Systems), and the Research Center for 21st Century Information Technology. These units are engaged in research aimed at achieving fruition over different time scales (Research Divisions: 20 years, Laboratories: 10 years, Research Center: 5 years). In addition, we collaborate closely with Tohoku University's graduate schools in subjects relating to electrical engineering (School of Engineering, Graduate School of Information Sciences, and Graduate School of Biomedical Engineering) in order to cover a wide range of cutting-edge research fields and foster the development of outstanding researchers and engineers.

RIEC has also been certified by the Ministry of Education, Culture, Sports, Science and Technology as a Joint Usage/Research Center for collaborative research in information science and technology. The current fiscal year marks the fourth year of the program's second term. As management expenses grants decrease, our role in advancing the information and communication community — both in Japan and overseas — will become increasingly important. To this end, we are collaborating on joint research projects with external researchers and engineers from industry, government, and academia in a systematic manner.

Today, information and communication technology are an essential part of the social infrastructure. We must therefore realize faster, higher-capacity telecommunications with greater energy efficiency performance, while the experience of the Great East Japan Earthquake of 2011 reemphasized the importance of ensuring that our social infrastructure has a high resilience to disaster. We are expected to contribute to a new paradigm of information processing and communication methods that interconnect people in a fundamentally different way. Developed by RIEC over more than 20 years, Brainware has become increasingly important with current trends in artificial intelligence (AI) research. We will continue to address these social needs by fully leveraging our strengths as a university-affiliated research center. In doing so, we hope to forge the path to a new world of communication, and through these efforts continue to promote education going forward.

To contribute to the improvement of our research activities and support future developments, we publish this Annual Report every year to make our activities relating to research, education, and social contribution widely available for public scrutiny. This edition contains reports on a range of

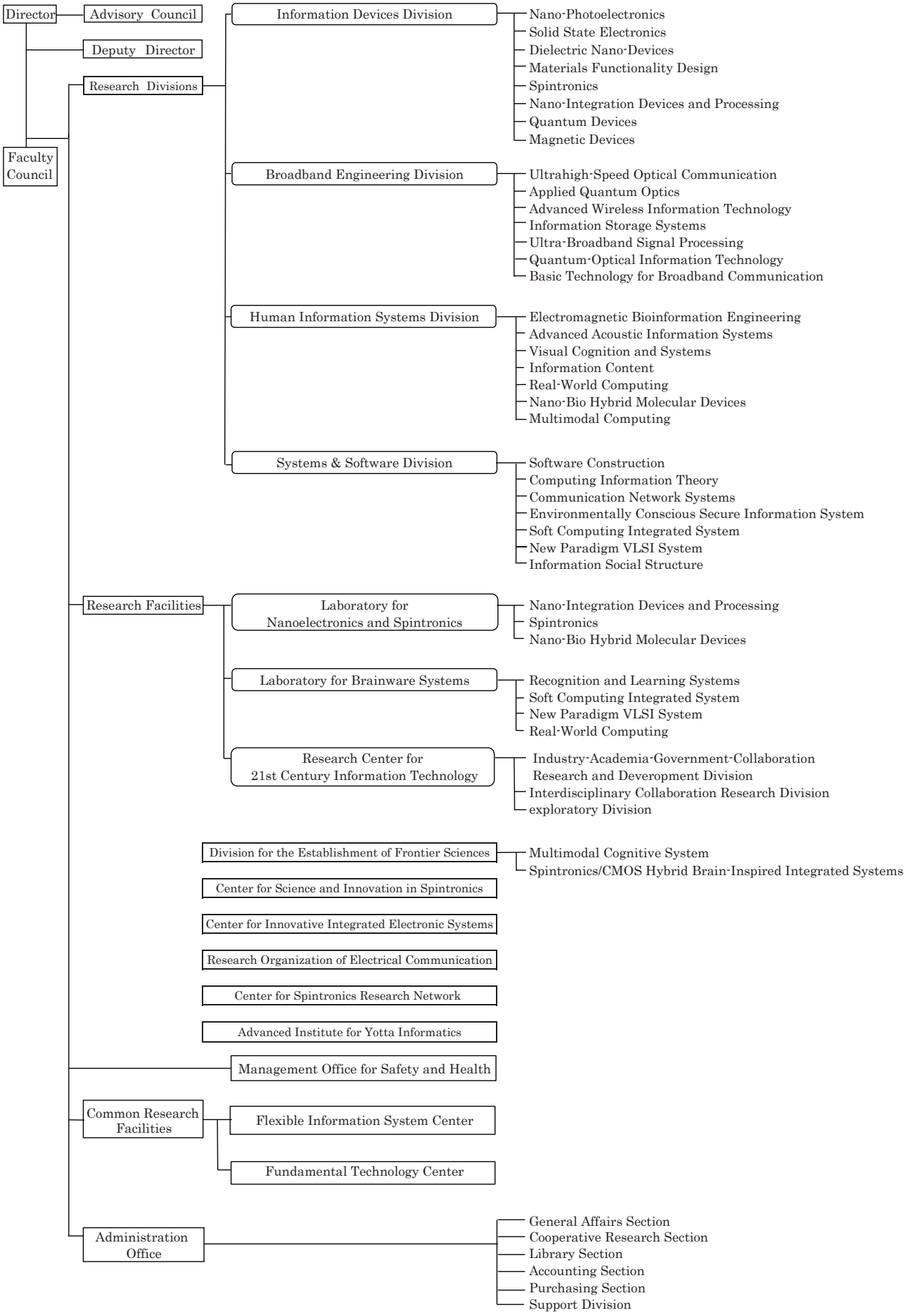
activities, including the research conducted by each of our departments and laboratories, collaborative research projects, international activities, social contributions, the RIEC symposia, activities of the engineering research association, and RIEC lectures. The bibliography section also includes data on the various activities we have conducted over the last five years.

We welcome your frank opinions regarding our activities, and look forward to your continued guidance and support in the future.

June 30, 2020

Satoshi Shioiri
Director, Research Institute of Electrical Communication

2. Organization Chart



3. Research Activities

Targets and achievements of the Information Devices Division

The main aim of the information devices division is to create advanced nano-information devices utilizing physical phenomena. To accomplish this goal, we conduct research on subjects related to material design, evaluation, process, device, and system. The research developed in this division provides an important basis for achieving the purpose of foundation of this research institute, and we aim to develop completely new functional information devices for next-generation information processing and communication. Thus we study new functionalities employing exotic materials and nanostructures, and apply such functionalities to nanophotoelectronic devices, new dielectrics-based nano-devices for information storage, quantum electronics devices, spintronics devices, and next generation semiconductor devices.

To achieve the goal, the following 8 laboratories are carrying out researches and developments.

1. Nano-Photoelectronics
2. Solid State Electronics
3. Dielectric Nano-Devices
4. Materials Functionality Design
5. Spintronics
6. Nano-Integration Devices and Processing
7. Quantum Devices
8. Magnetic Devices (Visitor Section)

The research target and the summary of activities of each sub-division in 2019 are described in the following pages.

Nanophotoelectronics

Exploring optical and electronic properties of nanometer-sized structures and their applications in photoelectronic devices

Nanophotoelectronics Yoichi Uehara, Professor
Nano photomolecular electronics Satoshi Katano, Associate Professor

[Research Target and Activities]

Our main interest lies in studying the physical and chemical phenomena that take place in nanometer-scale regions and their applications in nanophotoelectronic devices. The summary of our achievements in 2019 is as follows. (1) We have been developing time resolved STM light emission spectroscopy. Last year, we determined the temporal behaviors of vibrational modes of hydrogen atom of Ni (110) -ST (2 × 1) H, in which the vibrational energies appear as periods of fine structures in the STM emission spectra. This year, we have developed the theory that describe the mechanism for such periodic structures. (2) We previously reported the analytical electromagnetic theory that describes the mechanism for stepwise structures in the STM light emission spectra of surface adsorbates. However, the strengths of stepwise structures predicted by this theory are weaker by about one order of magnitude than experimentally expected ones. This year, we have developed the numerical method corresponding to the analytical theory within the framework of finite difference time domain analyses. It was clarified that the strengths of stepwise structures are increased to the experimentally expected levels when the tip has the protrusion having an appropriate shape and size, which cannot be treated by the analytical theory. (3) The reduction state and sheet structure of graphene oxide (GO) have been investigated using STM. Depending on the position, the π–π^* energy gap increased or decreased when scanned over GO at 3 V. Such changes in the energy gap are due to changes in the size of the sp^2 domain by the elimination of oxygen functional groups. It was found that the GO sheet disappeared when a higher voltage (4 V) was applied. Since GO disappears only in the region where a high voltage is applied, we proposed a new method that can achieve the nanoscale shaping of GO using STM. (4) Photo- and thermal-reactions of the polymer (PVP) coated on silver nanocubes (AgNCs) were investigated. We found that PVP was transformed to the sp^2 nanocarbon by photoreaction when the irradiated with 532 nm laser. The sample surface exhibits high surface-enhanced Raman scattering (SERS) activity since the shape of AgNC is maintained after the photoreaction. The same product was obtained by a thermal reaction though SERS activity becomes inhibited due to the deformation of AgNCs.

[Staff]

Professor	Yoichi Uehara, Dr.
Associate Professor	Satoshi Katano, Dr.

[Profile]

Dr. Yoichi Uehara obtained his D. Eng. degree from the Department of Engineering, University of Osaka prefecture in 1986, after which, he was initially appointed as an Assistant Professor at the Research Institute of Electrical Communication, Tohoku University. He eventually became a Full Professor at the institute in 2005. Dr. Uehara has worked on three main surface physics problems at Tohoku University: (1) light emission from metal-insulator-metal and metal-oxide-semiconductor (MOS) tunnel junctions, (2) low-energy electron spectroscopy, and (3) light emission spectroscopy of STM.

Dr. Satoshi Katano received his D. Sci. degree from Department of Electronic Chemistry, Tokyo Institute of Technology in 2003. He was a postdoctoral research fellow in RIKEN (2003-2006). He joined RIEC, Tohoku University as an assistant Professor in 2006 and was promoted to an associate Professor in 2012. His research interests include surface science and nano-scale molecular optoelectronics.

[Papers]

1. S. Katano, T. Sasajima, R. Kasama, T. Iwahori, and Y. Uehara, "Nanoscale Study of Luminescence from a Thermally-reduced Graphene Oxide", 21st International Vacuum Congress, Clarion Hotel & Congress Malmö Live, Malmö, Sweden, 4th July (2019).
2. T. Iwahori, R. Yamazaki, T. Sasajima, A. Mizuno, A. Ono, Y. Uehara, and S. Katano, "Plasmon-enhanced Photoreaction using Ag Nanocube Array", 27th International Colloquium on Scanning Probe Microscopy (ICSPM27), Hotel Laforet Shuzenji, Shizuoka, Japan, 5th December (2019).

Contact to Professor Yoichi UEHARA : uehara@riec.tohoku.ac.jp

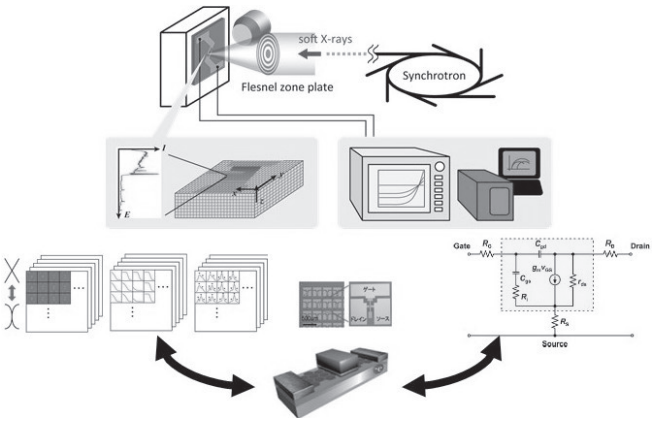
Solid State Electronics Laboratory

Paving a Way for Introducing SiC, Graphene, and 2DM into Si Technology

Solid State Physics for Electroncis Hirokazu Fukidome, Associate Professor

[Research Target and Activities]

Graphene is a 2D honeycomb network of carbon atoms. Its extremely high carrier mobility, which is ~100 times as high as that of silicon, makes graphene a dream material. We have developed a method to form an epitaxial graphene onto silicon substrates for the first time, which consists of 3C-SiC heteroepitaxy on Si and subsequent sublimation of surface Si atoms (graphene-on-Si). We are currently working on betterment of the GOS quality as well as on the development of graphene devices centered on RF field-effect transistors and optical devices.



In FY2018, we succeeded in raising up high-frequenecy graphene transistor by tuning graphene/dielectric interface and quantitatively evaluating a spatial distribution of surface electron trapping of GaN-HEMT, which causes operation instabilities, so-called current collapse phenomena. Furthermore, we developed spatiotemporal operando x-ray spectroscopy, enabling spatio-temporally examining electronic states of advanced devices.

[Staff]

Associate Professor : Hirokazu Fukidome, Dr.
Research Assistant : Fuminori Sasaki, Mr.
Technical Assistant : Kumi Namiiri
Technical Assistant : Misako Suzuki

[Profile]

Prof. Hirokazu Fukidome received Ph.D on chemistry from Osaka University. After serving for Bell Labs and RIKEN, he became assistant professor at RIEC in 2008. He has been associate professor at RIEC since 2012. He has been engaged on two-dimensional Dirac electron systems and their operando-microscopy analysis. He was awarded the Best Paper Award from the Surface Science Society of Japan (2011). M. Ishida Research Foundation Award (2015). RIEC Award (2016).

[Papers]

[1] K.-S. Kim, G.-H. Park, H. Fukidome, T. Someya, T. Iimori, F. Komori, I. Matsuda, and M. Suemitsu, “A table-top formation of bilayer quasi-free-standing epitaxialgraphene on SiC(0001) by microwave annealing in air” Carbon, 130. (2018), pp. 792-798.

[2] T. Someya, H. Fukidome, N. Endo, K. Takahashi, S. Yamamoto, and I. Matsuda, “Interfacial carrier dynamics of graphene on SiC, traced by the full-range time-resolved core-level photoemission spectroscopy”, Applied Physics Letters, 113 (2018), pp. 051601-1-051601-4.

[3] K. Omika, Y. Tateno, T. Kouchi, T. Komatani, S. Yaegassi, K. Yui, K. Nakata, N. Nagamura, M. Kotsugi, K. Horiba, M. Oshima, M. Suemitsu, and H. Fukidome, “Operation Mechanism of GaN-based Transistors Elucidated by Element-Specific X-ray Nanospectroscopy”, Scientific Reports, 8 (2018), 13268.

Dielectric Nano-Devices

Research on Dielectric Nano Science and Technology

Dielectric Nano-Devices Yasuo CHO, Professor
Dielectric Nanoscale Measurement Systems Kohei YAMASUE, Associate Professor

[Research Target and Activities]

Our main area of interest is evaluation and development of dielectric materials, including ferroelectric and piezoelectric materials and their application to communication devices and ferroelectric data storage systems. Our major contributions to advancement in these fields are the invention and the development of "Scanning Nonlinear Dielectric Microscope" (SNDM) which is the first successful purely electrical method for observing the ferroelectric polarization distribution and it has already been put into practical use. The resolution of the microscope has been improved up to atomic scale-order. Therefore, it has a great potential for realizing the ultra-high density ferroelectric recording system. In addition, SNDM can be used for the evaluation of various semiconductor materials and devices.

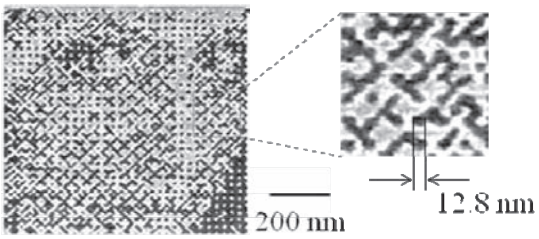


Fig.1 Digital bit data written on ferroelectric single crystal with the areal recording density of 4 Tbit/inch^2.

Major achievements of studies in 2019 are as follows: (1) We showed non-uniform interface defect distribution, which is commonly found on typical SiC wafers for power devices by our local DLTS method developed based on SNDM, can cause excessive decrease of channel mobility in SiC MOSFETs. (2) Signal-to-noise ratio of intermittent contact mode SNDM was significantly improved, which allowed nanoscale imaging of unintentional doping effects in an atomically-thin layered semiconductor. (3) We showed the usefulness of ultra-sharp tips in ferroelectric data storage. Spatial resolution in a ferroelectric domain imaging can be improved by up to almost 10 times with the ultra-sharp tips.

[Staff]

Professor : Yasuo Cho, Ph.D. Associate Professor : Kohei Yamasue, Ph. D.
Assist. Professor: Yoshiomi Hiranaga, Ph.D.

[Profile]

Yasuo Cho graduated in 1980 from Tohoku University in electrical engineering department. In 1985 he became a research associate at Research Institute of Electrical Communication, Tohoku University. In 1990, he received an associate professorship from Yamaguchi University. He then became an associate professor in 1997 and a full professor in 2001 at Research Institute of Electrical Communication Tohoku University. During this time, his main research interests included nonlinear phenomena in ferroelectric materials and their applications, research on the scanning nonlinear dielectric microscope, and research on using the nonlinear dielectric microscope in next-generation ultrahigh density ferroelectric data storage (SNDM ferroelectric probe memory).

Kohei Yamasue received the Ph. D degree in engineering from Kyoto University in 2007. He then became a postdoctoral fellow in 2007 and an assistant professor in 2008 at Venture Business Laboratory, Kyoto University. In 2010, he joined Research Institute of Electrical Communication, Tohoku University, as an assistant professor and, in 2016, became an associate professor. His main interests include the development of atomic resolution scanning nonlinear dielectric potentiometry and its applications to the evaluation of the next-generation electronic materials and devices.

[Papers]

[1] K. Yamasue and Y. Cho: "Optimization of signal intensity in intermittent contact scanning nonlinear dielectric microscopy", Microelectronics Reliab., Vol. 100-101, p. 113345, 2019.
[2] Y. Hiranaga and Y. Cho: "Carrier distribution imaging using $\partial C/\partial z$-mode scanning nonlinear dielectric microscopy", Rev. Sci. Instrum., Vol. 90, p.083705, 2019
[3] J. Woerle *et al.*: "Two-dimensional defect mapping of the SiO_2/4H-SiC interface", Phys. Rev. Mater., Vol. 3, p.084602, 2019.

Contact to Professor Yasuo CHO : yasuocho@riec.tohoku.ac.jp

Materials Functionality Design

Computational Design of Functional Materials for Information Devices

Materials Functionality Design: Masafumi Shirai, Professor
Materials Science under Extreme Conditions: Kazutaka Abe, Associate Professor

[Research Target and Activities]

Our research targets are as follows: (1) theoretical analyses of quantum phenomena in materials for advanced information devices, (2) computational design of new materials which possess novel functionalities for improvement of device performance, and (3) development of new design procedures based on large-scale computational simulation and machine learning techniques.
Our research activities in FY 2019 are as follows:

(1) Ferromagnetic semiconductors

We investigated the mechanism of ferromagnetism in Fe-based ferromagnetic semiconductors by using *ab initio* calculations. We found that the distribution of Fe atoms due to the spinodal decomposition plays an important role in the magnetism of (Ga,Fe)Sb and (In,Fe)Sb. The Curie temperature reaches up to 1,000 K for heavily Fe-doped GaSb or InSb with carrier doping. The results suggest that high-temperature ferromagnetism can be achieved by controlling nanostructures of magnetic ions doped in semiconductors [1].

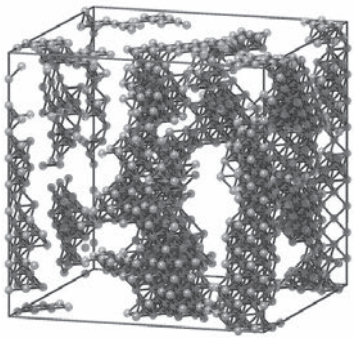


Fig. 1: The "Konbu" phase as a consequence of spinodal nano-decomposition in (In,Fe)Sb.

(2) Dense metallic hydrides

By using *ab initio* random structure searches, metallic phases of Al_2H and AlH are predicted to be stabilized above 155 and 175 GPa, respectively. While the estimated superconducting transition temperature of Al_2H is of the order of 1 K, that of AlH reaches 58 K at 180 GPa. The results suggest that although superconductivity is not observed experimentally in typical aluminum hydride AlH_3, it can be achieved in AlH [2].

[Staff]

Professor: Masafumi Shirai, Dr.
Associate Professor: Kazutaka Abe, Dr.
Assistant Professor: Masahito Tsujikawa, Dr.
Assistant Professor: Hikari Shinya, Dr.

[Profile]

Masafumi Shirai received the Doctor of Engineering degree from Osaka University in 1989. Since 2002, he has been a Professor at Tohoku University.
Kazutaka Abe received Doctor of Science degree from Osaka University in 1998. Since 2003, he has been at Tohoku University as a Research Associate and currently as an Associate Professor.

[Papers]

[1] T. Fukushima, H. Shinya, A. Masago, K. Sato, H. Katayama-Yoshida, "Theoretical prediction of maximum Curie temperatures of Fe-based dilute magnetic semiconductors by first-principles," Appl. Phys. Express, Vol. 12, Article no. 063006, pp. 1-5, 2019

[2] K. Abe, "*Ab initio* study of metallic aluminum hydrides at high pressures," Phys. Rev. B, Vol. 100, Article no. 174105, pp. 1-7, 2019

[3] T. Roy, M. Tsujikawa, T. Kanemura, and M. Shirai, "*Ab-initio* study of electronic and magnetic properties of CoIrMnZ (Z = Al, Si, Ga, Ge) Heusler alloys," J. Magn. Magn. Mater., Vol. 498, Article no. 166092, pp. 1-8, 2020

Spintronics

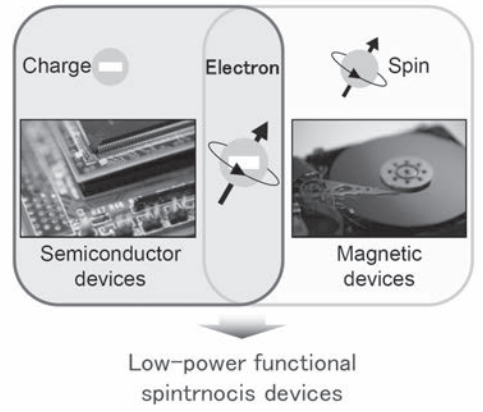
Advanced technology for spintronics-based devices

Nano-Spin Materials and Devices: Shunsuke Fukami, Professor

[Research Target and Activities]

We aim to deepen the understanding of spin-related physics and to develop new functional materials and devices in which electron and its spin states are controlled. We are also working on research and development of advanced technology for spintronics-based devices and unconventional computing, which offer high-performance and low-power information and communication tecnologies.

The outcomes in the last fiscal year include (1) development of artificial neuron and synapse devices using an antiferromagnet/ ferromagnet structure, (2) demonstration of probabilistic computing using developed unconventional spintronics devices, and (3) realization of synthetic antiferromagnetic skyrmions allowing current-induced motion without skyrmion Hall effect.



[Staff]

Professor: Shunsuke Fukami, Ph. D.
Assistant Professor: Shun Kanai, Ph. D., Justin Llandro, Ph. D.

[Profile]

Shunsuke Fukami received Ph. D. degree from Nagoya University in 2012. He joined NEC Corp (2005). He moved to Tohoku University as an Assistant Professor (2011) and then as an Associate Professor (2015). He received the JSAP Paper Award (2012), the RIEC Award for Tohoku University Researchers (2013), the Funai Research Incentive Award (2014), the JSAP Young Scientist Presentation Award (2014), the Young Scientists' Prize of Science and Technology by the MEXT (2015), the Harada Young Research Award (2015), DPS Paper Award (2016), ImPACT Symposium – Best Poster Award (2017), Aoba Foundation Award (2017), Asian Union of Magnetics Societies, Young Researchers Award (2018), the Outstanding Research Award of the Magnetics Society of Japan (2018), Gold Prize of Tanaka Kikinzoku Memorial Foundation (2019), and the JSAP Outstanding Paper Award (2019).

[Papers]

[1] A. Kurenkov, S. DuttaGupta, C. Zhang, S. Fukami, Y. Horio, and H. Ohno, "Artificial neuron and synapse realized in an antiferromagnet/ferromagnet heterostructure using dynamics of spin-orbit torque switching," Advanced Materials **31**, 1900636 (2019).
[2] W. A. Borders, A. Z. Pervaiz, S. Fukami, K. Y. Camsari, H. Ohno, and S. Datta, "Integer factorization using stochastic magnetic tunnel junctions," Nature **573**, 390-393 (2019).
[3] T. Dohi, S. DuttaGupta, S. Fukami, and H. Ohno, "Formation and current-induced motion of synthetic antiferromagnetic skyrmion bubbles," Nature Communications **10**, 5153 (2019).

Contact to Professor Shunsuke FUKAMI : s-fukami@riec.tohoku.ac.jp

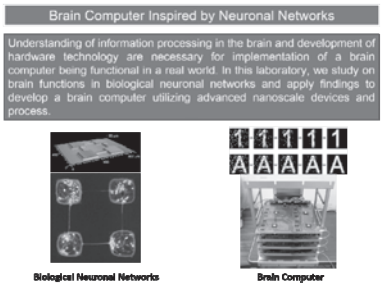
Nano-Integration Devices and Processing

Deepening of nano-integration technology and development of brain computer

Nano-Integration Devices — **Shigeo Sato, Professor**
Group IV Quantum Heterointegration — **Masao Sakuraba, Associate Professor**
Nano-Integration Neurocomputing Systems — **Hideaki Yamamoto, Associate Professor**

[Research Target and Activities]

In this laboratory, we focus on non-von Neumann computing such as brain computing and quantum computing, and study their hardware technology. We conduct research on various topics including device, process, circuit, algorithm, and neuroscience, and build revolutionary new computer technology by integrating our findings. In this year, following results have been obtained: (1) Toward the development of neuromorphic computation hardware, we fabricated a spiking neuron circuit that can reproduce various neuron pulses. We confirmed by electrical measurements that the analog MOS circuit, which is composed of about 40 MOS transistors, successfully operates in the strong inversion region. (2) For a problem of electrical activation ratio lowering in the Si films with high B concentration, the ratio can be improved successfully from 25% to 75% by low-energy Ar plasma irradiation at every nanometer-thick deposition, and low-resistive p-type Si film formation without substrate heating can be realized. (3) To investigate the effect of network structure-derived neural dynamics on time-series information processing, speech recognition task was performed by reservoir computing. Modular networks which generally possess robustness to noise and device variations, were used as reservoirs and achieved over 90% correct answer rate.



Towards the Realization of a Brain Computer

[Staff]

Professor :	Shigeo Sato, Dr.
Associate Professor :	Masao Sakuraba, Dr.
Associate Professor :	Hideaki Yamamoto, Dr.
Specially Appointed Assistant Professor:	Kwansoo Kim, Dr.

[Profile]

Shigeo Sato was received his B.E. and Ph.D. degrees from Tohoku University, in 1989 and 1994, respectively. In 1996, he joined the Research Institute of Electrical Communication, Tohoku University. Now, he studies brain computer and quantum computer as a professor.

Masao Sakuraba received his B.E. and Ph.D. degrees from Tohoku University in 1990 and 1995, respectively. In 1995, he joined the Research Institute of Electrical Communication, Tohoku University. Now, he studies group IV quantum heterointegration as an associate professor.

Hideaki Yamamoto received his B.E. and Ph.D. degrees from Waseda University in 2005 and 2009, respectively. In 2020, he joined the Research Institute of Electrical Communication, Tohoku University. Now, he studies neuronal network functions as an associate professor.

[Papers]

[1] S. Moriya, H. Yamamoto, A. Hirano-Iwata, S. Kubota, S. Sato, “Quantitative Analysis of Dynamical Complexity in Cultured Neuronal Network Models for Reservoir Computing Applications”, Proc. Int. Joint Conf. on Neural Networks (IJCNN 2019, Budapest, Hungary, July 14-19, 2019), 20275, 2019.
[2] W. Li, M. Sakuraba, S. Sato, “Electron-Cyclotron Resonance Ar Plasma-Induced Electrical Activation of B Atoms without Substrate Heating in B Doped Si Epitaxial Films on Si(100)”, Mat. Sci. Semicond. Process, 107, 104823, 2019.

Quantum Devices

Electronic properties of nanostructures and device applications

Quantum Devices: Tomohiro Otsuka, Associate Professor

[Research Target and Activities]

In solid-state nanostructures, exotic phenomena like quantum effects occur. We are exploring interesting properties of solid-state nanostructures utilizing precise and high-speed electric measurement and control techniques. We are also developing materials and devices using nanostructures.

Our research activities in FY 2019 are the following.

(1) Development of high-speed electric microprobes

We developed the local electronic sensors which can directly access local electronic states in nanostructures utilizing semiconductor quantum dots. We improved the performance by high-frequency measurement techniques and data informatics approaches.

(2) Measurement of local electronic states in nanostructures

We measured local electronic and spin states in semiconductor nanostructures. We revealed the detail of local charge and spin dynamics induced by the movement of a single electron [3].

(3) Quantum bit experiments

We conducted semiconductor quantum bit experiments for future quantum information processing. We demonstrated a reduction of nuclear-spin effects on quantum bit operations, simulations of quantum error corrections, and quantum non-demolition measurements [1, 2].

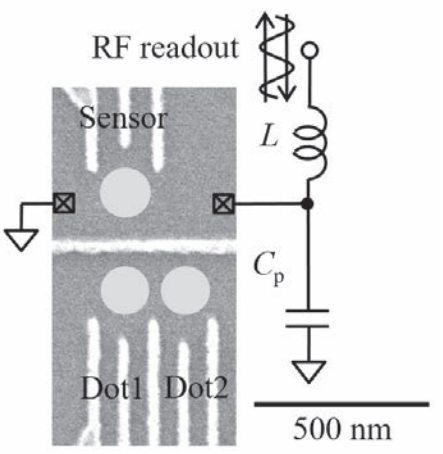


Figure: Scanning electron micrograph of a nanostructure device

[Staff]

Associate Professor: Tomohiro Otsuka, Ph. D.

[Profile]

Tomohiro Otsuka received Ph. D. degree from the University of Tokyo in 2010. After working for the University of Tokyo and RIKEN, he became an Associate Professor at Tohoku University in 2018. He received Research Encouraging Prize from School of Science, University of Tokyo (2010), NF Foundation R&D Encouragement Award (2016), Young Scientist Award of the Physical Society of Japan (2017), RIKEN Researcher Incentive Award (2017), Yazaki Memorial Foundation for Science and Technology Research Encouraging Award (2018), and the Young Scientists' Prize of Science and Technology by MEXT (2018).

[Papers]

[1] T. Nakajima, A. Noiri, K. Kawasaki, J. Yoneda, P. Stano, S. Amaha, T. Otsuka, K. Takeda, M. R. Delbecq, G. Allison, A. Ludwig, A. D. Wieck, D. Loss, and S. Tarucha, "Coherence of a driven electron spin qubit actively decoupled from quasistatic noise", Physical Review X 10, 011060 (2020).

[2] T. Nakajima, A. Noiri, J. Yoneda, M. R. Delbecq, P. Stano, T. Otsuka, K. Takeda, S. Amaha, G. Allison, K. Kawasaki, A. Ludwig, A. D. Wieck, D. Loss, and S. Tarucha, "Quantum non-demolition measurement of an electron spin qubit", Nature Nanotechnology 14, 555 (2019).

[3] T. Otsuka, T. Nakajima, M. R. Delbecq, P. Stano, S. Amaha, J. Yoneda, K. Takeda, G. Allison, S. Li, A. Noiri, T. Ito, D. Loss, A. Ludwig, A. D. Wieck, and S. Tarucha, "Measurement and Control of Single-electron Spins by Utilizing Semiconductor Quantum Dot", Symposium for The Core Research Clusters for Materials Science and Spintronics, Sendai, Japan, Feb. 10, 2020.

Contact to Associate Professor Tomohiro OTSUKA : tomohiro.otsuka@riec.tohoku.ac.jp

Broadband Engineering Division: Research Targets and Results

In order to establish future broadband communication systems and novel devices that can be flexibly applied to future ubiquitous ultra-high capacity information communications, research and development is being carried out over the wide spectrum of microwaves, millimeter/submillimeter waves, terahertz waves, and lightwaves with regard to information generation, transmission, processing, and storage technologies.

(1) Ultrahigh-Speed Optical Communication

We are engaged in research on ultrahigh-speed optical transmission, digital coherent transmission, and high-speed and spectrally efficient optical transmission by combining these two approaches. With a view to supporting innovative new ICT services such as 5G and IoT, our goal is also to develop novel transmission schemes integrating optical and wireless communications.

This year, we successfully achieved a single-channel 15.3 Tbit/s, 64 QAM coherent Nyquist pulse transmission over 150 km, in which the spectral efficiency reached as high as 8.3 bit/s/Hz. We also developed a bi-directional online digital coherent transmission system with an injection-locked homodyne receiver, and demonstrated 80 Gbit/s x 10 ch, 256 QAM WDM transmission over 10 km for application to mobile fronthaul with distributed antennas.

(2) Applied Quantum Optics

Novel functional semiconductor photonic devices including photonic integrated circuits are being investigated to explore next-generation photonic network systems.

A study on high speed semiconductor laser introducing hybrid modulation scheme was being continued. It was confirmed experimentally that the hybrid modulation semiconductor laser source we proposed had wide intrinsic small signal bandwidth of more than 66 GHz by using novel optical measurement system we proposed. Furthermore the study on compact and narrow linewidth semiconductor laser sources was also being proceeded by applying the optical negative feedback technology we proposed. A compact optical filter with Si waveguide was designed to enlarge a phase margin of the negative feedback system and enlarge a frequency discrimination efficiency. It was confirmed that the lasing spectral linewidth was reduced to 99.8 kHz by hybrid integration of the fabricated optical filter based on the design to a single mode semiconductor laser.

(3) Advanced Wireless Information Technology

We are actively engaged in research work on dependable wireless information technologies for next-generation wireless systems, which include terrestrial / satellite communications. The covered areas of us are all technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed-signal device, antenna, MODEM, and network technologies. This year, we have investigated (1) a millimeter-wave wireless body area network (WBAN) in a congested environment based on specific use cases and (2) Beyond-Nyquist-Band receiver using RF Under Sampling.

(4) Information Storage Systems

Research on next-generation perpendicular magnetic recording is being carried out to meet the strong demand for high density, low cost storage due to the rapid growth of the Internet and web services. To establish high performance data-intensive analytics, a computational storage analytics platform with unified computing and storage is targeted in the research and development.

We have been investigating novel, three-dimensional, energy-assisted recording technologies that enable selective recording on media with multiple, discrete recording layers. The optimal multiple recording conditions with microwave magnetic field assisting by spin-torque oscillation and heat assisting by near-field lights have been identified. Evaluation technology of simultaneous readout methods from multiple recorded layers has been studied. The potential that realizing the technology enabled to double the storage data capacity and data transfer rate has been confirmed. We have constructed preliminary visualization analytics platform for brain neuro structure with unified PB-class storage and computation functions. The three-dimensional visualization function of neurons by captured fluorescent microscope has been confirmed.

(5) Ultra-Broadband Signal Processing

We are developing novel, integrated electron devices and circuit systems operating in the terahertz region. One of our major concerns is a new material called “graphene”, a single-layered honeycomb-lattice carbon crystal.

First, towards the creation of novel current-injection graphene THz laser-transistors, we developed a graphene laser-transistor featured with our original asymmetric dual-grating gates demonstrating coherent amplification of THz radiation with the maximal gain of 9% at room temperature promoted by graphene plasmon instabilities driven by dc-channel current flow. Second, we developed InGaAs-channel plasmonic THz detectors,

which utilize hydrodynamic nonlinearities of two-dimensional plasmons, and demonstrated that the signal readout from the gate electrode enables the impedance matching to a 50-Ω interconnection systems and the scaling of the photovoltage with the size of the active area, both of which are impossible for the drain-readout.

(6) Quantum-Optical Information Technology

Our goal is to develop quantum information devices utilizing the quantum interaction between photons and electrons in solids.

In 2019, we have achieved (1) generation of frequency-entangled photons with two-period PPLN crystal, (2) development of a novel sensor for mg-scale gravity measurements, (3) observation of local-field effects on optical coherent transients of semiconductor bound excitons, and (4) controlled introduction of nano and micro particles to a nanofiber surface and the measurement of the chiral polarization response.

Research Laboratory of Ultrahigh-Speed Optical Communication

Toward Innovative Optical Transmission from Backbone to Access Networks

Research Area of Ultrahigh-Speed Optical Transmission Toshihiko Hirooka, Professor
Research Area of Lightwave Control System Keisuke Kasai, Associate Professor

[Research Target and Activities]

Advanced global ICT services such as ultrahigh-definition video transmission and ultra-realistic communication cannot be realized without high-speed and large-capacity optical transmission systems. At the same time, optical transmission schemes with high spectral efficiency are crucial in terms of the maximum utilization of limited bandwidth resources. In our laboratory, we are engaged in research on ultrahigh-speed optical transmission using optical time division multiplexing with a single-channel Tbit/s-class capacity, digital coherent QAM optical transmission, and high-speed and spectrally efficient optical transmission by combining these two approaches. With a view to supporting innovative new ICT services such as 5G and IoT, our goal is also to apply digital coherent transmission to access networks and mobile fronthaul, and to develop novel transmission schemes integrating optical and wireless communications. This year, we successfully achieved a single-channel 15.3 Tbit/s, 64 QAM coherent Nyquist pulse transmission over 150 km, in which the spectral efficiency reached as high as 8.3 bit/s/Hz (Fig. 1). We also developed a bi-directional online digital coherent transmission system with an injection-locked homodyne receiver, and demonstrated 80 Gbit/s x 10 ch, 256 QAM WDM transmission over 10 km for application to mobile fronthaul with distributed antennas.

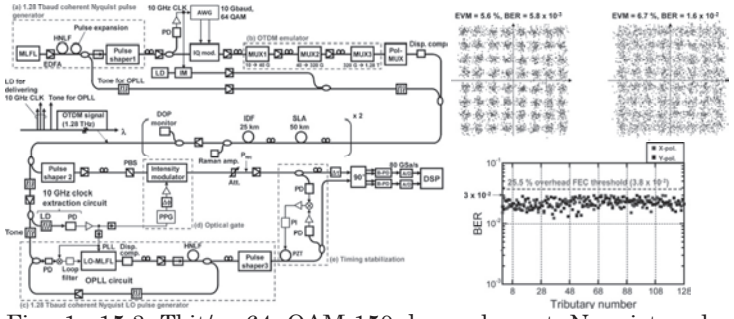


Fig. 1. 15.3 Tbit/s, 64 QAM-150 km coherent Nyquist pulse transmission.

[Staff]

Professor: Toshihiko Hirooka, Dr.
Associate Professor: Keisuke Kasai, Dr.

[Profile]

Toshihiko Hirooka received the Ph. D. degree from Osaka University in 2000. From 2000 to 2002, he was a Research Associate at University of Colorado at Boulder. He is currently a Professor at the Research Institute of Electrical Communication, Tohoku University. He has been engaged in research on ultrahigh-speed optical communications and nonlinear fiber optics.

Keisuke Kasai received the Ph. D. degree from Tohoku University in 2008. From 2009 to 2012, he was a Japan Society for the Promotion of Science Research Fellow. He is currently an Associate Professor at the Research Institute of Electrical Communication, Tohoku University. He has been engaged in research on lightwave control techniques and coherent optical communications.

[Papers]

[1] M. Yoshida, K. Kimura, T. Iwaya, K. Kasai, T. Hirooka, and M. Nakazawa, "Single-channel 15.3 Tbit/s, 64 QAM coherent Nyquist pulse transmission over 150 km with a spectral efficiency of 8.3 bit/s/Hz," Opt. Express vol. 27, no. 20, pp. 28952-28967, September (2019).
[2] T. Kan, M. Yoshida, K. Kasai, T. Hirooka, K. Iwatsuki, and M. Nakazawa, "Demonstration of on-line bi-directional 10-RRHs with an 80 Gbit/s/RRH capacity using 256 QAM WDM coherent transmission for next generation mobile fronthaul," ECOC 2019, M.1.C.4, September (2019).
[3] R. Hirata, T. Hirooka, M. Yoshida, and M. Nakazawa, "Wavelength-tunable sub-picosecond optical switch over entire C-band using nonlinear optical loop mirror," IEICE Electron. Express vol. 16, no. 23, 20190664, December (2019).

Contact to Professor Toshihiko HIROOKA : hirooka@riec.tohoku.ac.jp

Applied Quantum Optics

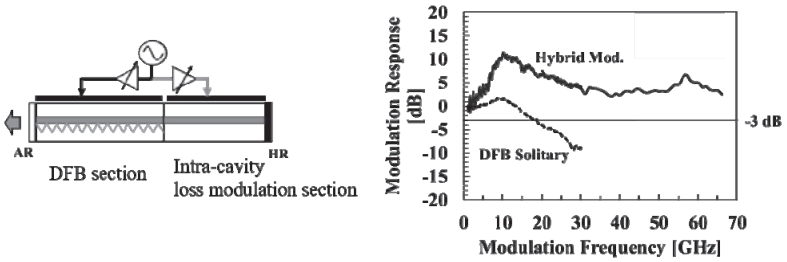
Research on Innovative Highly Functional Photonic Semiconductor Devices

Highly Functional Photonics **Hiroshi Yasaka, Professor**
High accuracy optical measurement **Masato Yoshida, Associate Professor**

[Research Target and Activities]

Novel functional photonic devices including high function laser diode (LD) sources are being investigated to explore new-generation photonic network systems.

The studies on ultra-high-speed semiconductor lasers are being continued. It was confirmed experimentally that the hybrid modulation semiconductor laser source we proposed had wide intrinsic small signal bandwidth of more than 66 GHz by using optical measurement system we proposed. Furthermore the study on compact and narrow linewidth semiconductor laser sources is also being proceeded by applying the optical negative feedback technology we proposed.



Schematic structure of hybrid modulation laser source (left), and its modulation RF frequency dependence of intrinsic small signal response (right).

[Staff]

Professor : Hiroshi Yasaka, Dr.
Associate Professor : Masato Yoshida, Dr.
Assistant Professor : Nobuhide Yokota, Dr.

[Profile]

Hiroshi Yasaka received M.S. degrees in physics from Kyusyu University in 1985, and Ph.D. degree in electronic engineering from Hokkaido University in 1993. In 1985 he joined Nippon Telegraph and Telephone (NTT) Corporation. Since then, he has been engaging in research and development on semiconductor photonic devices for optical fiber communication systems. From 2008 he has been a professor of Tohoku University.

Masato Yoshida received Ph.D. degree in electronic engineering from Tohoku University in 2001. In 2001, he joined the Research Institute of Electrical Communication, Tohoku University. He is currently an Associate Professor of the Institute. He has been engaging in research on fiber lasers and their application to optical measurements.

[Papers]

[1] N. Yokota, K. Komukai, M. Yoshida, and H. Yasaka, "Numerical Investigation of Mutually Injection-Locked Semiconductor Lasers for Direct IQ-Signal Generation," IEEE Photonics Journal, vol. 11, No. 5, 6602611, 2019. (Oct.) / DOI:10.1109/JPHOT.2019.2934480

[2] N. Yokota, and H. Yasaka, "Multi-wavelength discrete pulse train generation using chromatic aberration of time lens for ultrafast single-shot optical imaging," Optical Review, vol. 26, No. 6, pp. 713-718, 2019. (Nov.) / DOI 10.1007/s10043-019-00560-0

[3] S. Sato, G. Aizawa, N. Yokota, and H. Yasaka, "Performance Improvement of Optical Negative Feedback Laser by Reducing Feedback Loop Length," IEICE Electronics Express, vol. 17, No. 4, 20190750, 2020. (Feb.) / DOI 10.1587/elex.17.20190750

Advanced Wireless Information Technology

For realization of the next generation mobile network

Advanced Wireless Information Technology **Noriharu Suematsu, Professor**
Advanced Wireless Network Technology **Suguru Kameda, Associate Professor**

[Research Target and Activities]

Toward the realization of a ubiquitous and broad-band wireless network, we are actively engaged in the research work on dependable and low power consumption advanced wireless IT. We cover the whole technical fields from the lower to higher layers, i.e., signal processing, RF/Mixed signal device, antenna, MODEM and network technologies.

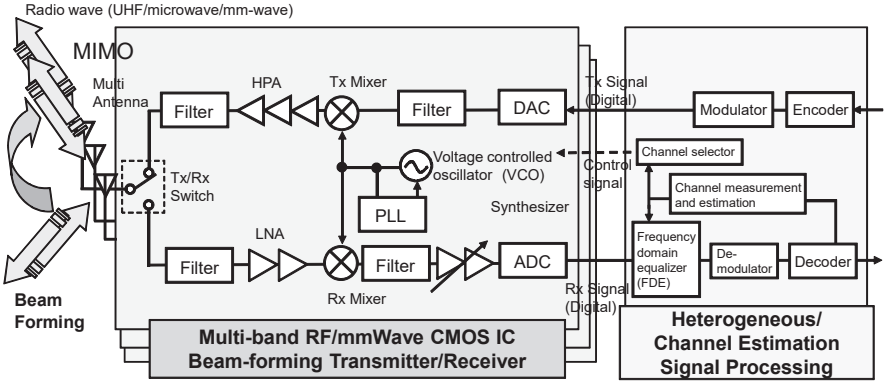


Fig. The target system of
Advanced Wireless Information Technology Laboratory.

We have developed load balancing method using route estimation of mobile terminal. We have also developed RF-IC and modules like sample-hold circuit for high speed and low power wireless communication system.

[Staff]

Professor: Noriharu Suematsu, Ph. D
Associate Professor: Suguru Kameda, Ph. D
Assistant Professor: Mizuki Motoyoshi, Ph.D

[Profile]

Noriharu Suematsu received the M.S. and Ph.D. degrees in Electronics and Communication Engineering from Waseda University in 1987 and 2000. From 1987 to 2010, he had been with the R&D center of Mitsubishi Electric, Japan. Since 2010, he has been a professor of Research Institute of Electrical Communication (RIEC), Tohoku University. He received the OHM technology award from the promotion foundation for electrical science and engineering in 2002 and Prize for Science and Technology, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology in 2009.

Suguru Kameda received the B.S., M.S. and Ph.D. degrees in Electronics Engineering from Tohoku University in 1997, 1999 and 2001, respectively. From 2001, he was an assistant professor of the RIEC. From 2012, he has been currently an associate professor.

[Papers]

[1] S. Kameda, *et al.*, "Evaluation of Synchronized SS-CDMA for QZSS Safety Confirmation System," IEEE Transactions on Vehicular Technology, vol. 68, Issus 5, pp. 4846-4856, May 2019.
[2] T. Yokouchi, *et al.*, "Evaluation of Channel Capacity of Millimeter-Wave WBAN Considering Human Body Blocking in User-Dense Condition," 2019 Eleventh International Conference on Ubiquitous and Future Networks (ICUFN), pp. 1-4, July 2-5, 2019.
[3] T. Furuichi, *et al.*, "28 GHz Band Direct RF Undersampling Broadband Receiver for Ka-Band HTS On-Board Unit," 2019 12th Global Symposium on Millimeter Waves (GSMM), May 22-24, 2019.
[4] K. Ono, *et al.*, "Traffic Navigation & Relay: System-Wide Load Balancing Method for Heterogeneous Network Using Route Direction and Packets Relay," URSI Asia-Pacific Radio Science Conference, pp. 349-352, Mar. 9-15, 2019.

Contact to Professor Noriharu SUEMATSU : suematsu@riec.tohoku.ac.jp

Information Storage System Laboratory

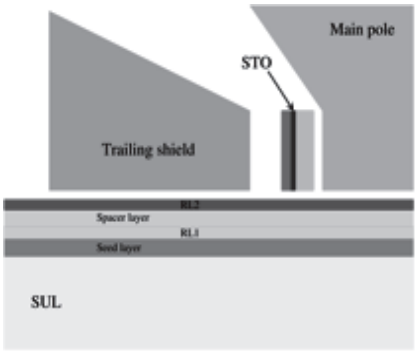
High Density and High Speed Energy Assisted Magnetic Recording, and Computational Storage System Research

Information Storage・Computing Systems, Yoichiro Tanaka, Professor
Recording Theory Computation, Simon Greaves, Associate Professor

[Research Target and Activities]

Research on next-generation perpendicular magnetic recording is being carried out to meet the strong demand for high density, low cost storage due to the rapid growth of the Internet and web services. In this field, we use computer simulations to study recording systems and novel technologies to realize high speed, high density data storage. For achieving high performance data-intensive analytics, an intelligent computational storage analytics platform with unified computing and storage is targeted in the research and development.

We investigate novel, three-dimensional, energy-assisted recording technologies that enable selective recording on media with multiple, discrete recording layers. During this year research was concentrated on microwave-assisted magnetic recording (MAMR). In a MAMR system it is possible to record information on a medium consisting of multiple, discrete storage layers by utilizing storage layers with different ferromagnetic resonance frequencies. Optimal recording conditions using a microwave magnetic field generated by a spin-torque oscillator have been identified. The possibility of recording without a write head, using only a spin torque oscillator, was also confirmed by simulations. We have constructed a preliminary visualization platform for brain neuro structure analytics motif with unified PB-class storage and computation functions. Computation based on the GPU and attached storage nodes enabled the three-dimensional visualization function of neuron structures captured by fluorescent microscope.



MAMR with multiple recording layers

[Staff]

Professor: Yoichiro Tanaka, Ph.D.
Associate Professor: Simon Greaves, Ph.D.

[Profile]

Yoichiro Tanaka received his BE, MS, and Ph.D. from Tohoku University in 1981, 1983, and 2006, respectively. He joined Toshiba Corporation in 1983 and Yamagata University in 2016. He has been at RIEC, Tohoku University since 2019. His research focus has been on high density perpendicular magnetic recording and information storage systems. He received Nikkei BP Technology Award (2006), the Japan Magnetic Society Achievement Award (2006) and Okochi Memorial Prize (2007). He is a fellow of the Japan Magnetic Society.

Simon Greaves has been at Tohoku University since 2003. He developed micromagnetic simulation software to model magnetic recording and to investigate the potential of magnetic, information storage devices. He received his Ph.D. in 1993 from Salford University, UK.

[Papers]

[1] S. J. Greaves, K. S. Chan and Y. Kanai, "Optimisation of dual structure recording media for microwave assisted magnetic recording", IEEE Transactions on Magnetics 55(7), 3001305-1-5, (2019), doi 10.1109/TMAG.2018.2889317.

[2] K. S. Chan, S. Greaves and S. Rahardja, "Techniques for addressing saddle points in the response surface methodology (RSM)", IEEE Access 7, p85613-85621, (2019), doi 10.1109/ACCESS.2019.2922975.

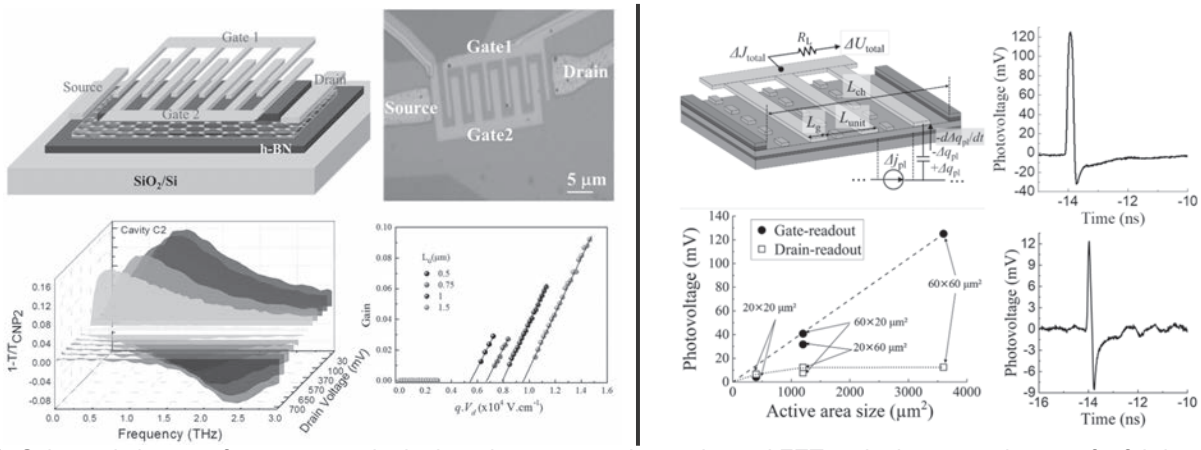
[3] K. S. Chan, S. Greaves and S. Rahardja, "Optimization of the 3D MAMR stack", IEEE Transactions on Magnetics 55(9), 7204905-1-5, (2019), doi 10.1109/TMAG.2019.2916748.

Ultra-broadband Signal Processing

Novel Millimeter-wave and Terahertz Integrated Electron Devices and Systems

Ultra-Broadband Devices and Systems: Taiichi OTSUJI, Professor
Ultra-Broadband Device Physics: Akira SATOU, Associate Professor

[Research Target and Activities]



Left: Schematic image of an asymmetric dual-grating gate graphene-channel FET and microscope image of a fabricated device (top), extinction/gain spectra measured at room temperature demonstrating coherent amplification of THz radiation (bottom left, negative value for gain), and the drain-voltage dependence of the maximum gain (bottom right), right: schematic view of the signal readout from the gate electrode of a InGaAs-based grating-gate plasmonic THz detector (top left), photovoltage vs size of the active area for the gate-readout (bottom left), and waveforms of photovoltage for the gate-readout (top right) and drain-readout (bottom right) (the waveform distortion associated with the impedance mismatching to the measurement system does not appear in the former).

We are developing novel, integrated electron devices and circuit systems operating in the terahertz (THz) region. First, towards the creation of novel current-injection graphene THz laser-transistors, we developed a graphene laser-transistor featured with our original asymmetric dual-grating gates demonstrating coherent amplification of THz radiation with the maximal gain of 9% at room temperature promoted by graphene plasmon instabilities driven by dc-channel current flow. Second, we demonstrated that the signal readout from the gate electrode of InGaAs-based plasmonic THz detectors enables the impedance matching to 50-Ω interconnection systems and the scaling of the photovoltage with the size of the active area, both of which are impossible for the usual drain-readout.

[Staff]

Professor: Taiichi OTSUJI, Dr. Eng.
Associate Professor: Akira SATOU, Dr. Comp. Sci.
Assistant Professor: Takayuki WATANABE, Dr. Eng.
Research Fellow: Victor RYZHII, Ph.D., Juan Antonio DELGADO NOTARIO, Ph.D. Secretary: Kayo UENO

[Profile]

Taiichi OTSUJI: received the Dr. Eng. deg. from Tokyo Tech., Japan, in 1994. After working for NTT Labs., Japan, since 1984, he joined Kyutech in 1999, as an Assoc. Prof., being a prof. from 2002. Since 2005, he has been a Prof. at RIEC, Tohoku Univ., Japan. Recipient of the 2019 Prizes for Science and Technology, the Commendation for Science and Technology, MEXT, Japan. A Distinguished Lecturer, Electron Device Society, IEEE. A member of IEEE (Fellow), OSA (Fellow), JSAP (Fellow), IEICE (Senior), MRS, and SPIE.

Akira SATOU: received Dr. Comp. Sci. from Univ. of Aizu, Japan, in 2008. He was an Assistant Lecturer, ISTC, Univ. of Aizu, in 2008 and CAIST, Univ. of Aizu, in 2009. He joined RIEC, Tohoku Univ., Japan, in 2010 as an Assistant Professor and was promoted to an Associate Professor in 2017. He is a member of IEEE (Senior), APS, JSAP, and IEICE.

[Papers]

[1] V. Ryzhii, T. Otsuji, M. Ryzhii, A. A. Dubinov, V. Ya. Aleshkin, V. E. Karasik, and M. S. Shur, Phys. Rev. B, vol. 100, pp. 115436-1-13, Sept. 2019.
[2] V. Ryzhii, M. Ryzhii, T. Otsuji, V. E. Karasik, V. G. Leiman, V. Mitin, and M. S. Shur, IEEE J. Select. Top. Quantum Electron., vol. 25, iss. 6, pp. 2000209-1-9, Sept. 2019.
[3] Y. Omori, T. Hosotani, T. Otsuji, K. Iwatsuki, and A. Satou, CSW: Compound Semiconductor Week Dig., WeE2-4, Nara, Japan, May 19-23, 2019.

Contact to Professor Taiichi OTSUJI : otsuji@riec.tohoku.ac.jp

Quantum-Optical Information Technology

Development of optoelectronic devices for quantum information and communication technology

Quantum-Optical Information Technology: Keiichi Edamatsu, Professor
Quantum Laser Spectroscopy: Yasuyoshi Mitsumori, Associate professor

[Research Target and Activities]

Our goal is to develop quantum information devices utilizing quantum interaction between photons and electrons in solids. In 2018, we have achieved (1) generation of frequency-entangled photons with two-period PPLN crystal, (2) development of a novel sensor for mg-scale gravity measurements, (3) observation of local-field effects on optical coherent transients of semiconductor bound excitons, and (4) controlled introduction of nano and micro particles to a nanofiber surface and the measurement of the chiral polarization response.

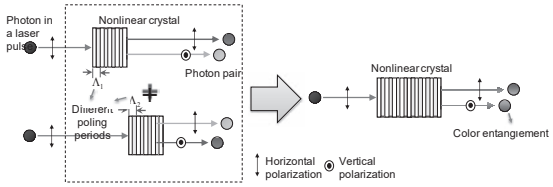


Fig. 1. An illustration of the scheme for producing frequency-entangled photons. A nonlinear crystal has two different poling periods so that produced photon pairs with orthogonally polarized photon pairs can be frequency entangled.

[Staff]

Professor: Keiichi Edamatsu, Dr.
Associate Professor: Yasuyoshi Mitsumori, Dr.

[Profile]

Keiichi Edamatsu received B.S., M.S., and D.S. degrees in Physics from Tohoku University. He was a Research Associate in Faculty of Engineering, Tohoku University, a Visiting Associate in California Institute of Technology, and an Associate Professor in Graduate School of Engineering Science, Osaka University.

Yasuyoshi Mitsumori received B.S., M.S. and D.S. degrees in Applied Physics from Tokyo Institute of Technology. He was a Research Fellow of the Japan Society for the Promotion of Science, a Researcher in NTT Basic Research Laboratories, a Postdoctoral Fellow in Tokyo Institute of Technology, a Postdoctoral Fellow in Communications Research Laboratory, a Research Associate in Research Institute of Electrical Communication, Tohoku University.

[Papers]

[1] F. Kaneda, H. Suzuki, R. Shimizu, and K. Edamatsu, "Direct generation of frequency-bin entangled photons via two-period quasi-phase-matched parametric downconversion", Opt. Exp. **27**, 001416 (2019).
[2] N. Matsumoto, S. B. Cataño-Lopez, M. Sugawara, S. Suzuki, N. Abe, K. Komori, Y. Michimura, Y. Aso, and K. Edamatsu, "Demonstration of Displacement Sensing of a mg-Scale Pendulum for mm- and mg- Scale Gravity Measurements", Phys. Rev. Lett. **122**, 071101 (2019).
[3] F. Kaneda, P. G. Kwiat, "High-efficiency single-photon generation via large-scale active time multiplexing", Science Advances, **5**, eaaw8586 (2019).
[4] S.B. Cataño-Lopez, J.G. Santiago-Condori, K. Edamatsu, N. Matsumoto, "High Q mg-scale monolithic pendulum for quantum-limited gravity measurements", arXiv: 1912.12567, to appear in Phys. Rev. Lett. (2020).
[5] M. Sugawara, Y. Mitsumori, K. Edamatsu, M. Sadgrove, "Optical detection of nano-particle characteristics using coupling to a nano-waveguide", arXiv:2005.07369, to appear in Opt. Exp. (2020).

Aims and Achievements of Human Information Systems Division

To realize advanced information communications systems, it is essential to understand and apply sophisticated information processing mechanisms of human being as well as to establish communications environments in that human can communicate anywhere, anytime without recognizing the communications tools. The aim of this division is to research and develop core and system technologies essential to advanced human friendly information and communications systems through understanding biological information generation mechanisms, human information processing mechanisms focusing on acoustic and visual inputs, and optimizing the communications environments.

To achieve the goal of the Division, six laboratories have been carrying out researches and developments in the following areas: (1) Electromagnetic Bioinformation Engineering, (2) Advanced Acoustic Information Systems, (3) Visual Cognition and Systems, (4) Information Content, (5) Real-world computing, (6) Nano-Bio Hybrid Molecular Devices, (7) Multimodal Cognitive System Laboratory.

The goals and achievements in the fiscal year 2019 of each laboratory are described in detail below.

(1) Electromagnetic Bioinformation Engineering

(Aims) This laboratory aims at obtaining the high accuracy sensor system for the signals from the human body or electric devices and at obtaining the system for approaching action to the human body by using the nano-scale controlled magnetic materials and by the development of the devices under the functions of the magnetics.

(Achievements) To develop a high sensitive microvibration measuring system, we worked on the fabrication of high sensitive strain sensors on a Si wafer and the design of detection circuits with ultra-low noise. The obtained proto-type system shows extra-high sensitivity compare with the commercial products. On the work of high frequency magnetic field measuring system, we have succeeded in imaging the distribution of up to 6GHz magnetic field generated from electronic circuits by our proposed system. This system could visualize the high-frequency field distribution of the circuits. The study about micro-power generator with vibration system clarified the system using FeSi material has high efficiency of power generation. This results also shows the crystal texture and the magnetic anisotropy is important for the system.

(2) Advanced Acoustic Information Systems

(Aims) To propose high-definition communication systems that convey a rich and natural sense of presence. To this end, we are developing acoustic information processing technologies based on well-grounded knowledge of the human auditory system and the multimodal perception processes related to hearing.

(Achievements) We have focused on how humans extract target speech information from

distractor sounds by using auditory selective attention. In this fiscal year, the effect of auditory selective attention in the spatial domain was investigated. The auditory spatial attention is one of the important mechanisms to realize cocktail party effects. By directing the attention to the specific direction, humans can extract the speech sound easily in multi-talker environment. We measured the shape of spatial window of auditory spatial attention and found that the shape does not depend on the direction where listeners direct their attention. These findings could be applied to the diagnosis of auditory processing disorders (APD). In addition, we develop advanced acoustic systems, such as 3D virtual auditory displays, sound acquisition and presentation systems. We proposed advanced version of auditory displays based on the virtual sphere model (ADVISE) which can synthesize 3D sound field accurately including sound intensity.

(3) Visual Cognition and Systems

(Aims) To understand the vision-related brain functions in order to apply the knowledge to realize human oriented information communication systems.

(Achievements) Firstly, we investigated the mechanisms underlying saccadic suppression od displacement and found a peculiar result, that is, detection sensitivity of displacement decreased with the increase of stimulus contrast. We succeeded to explain the results with a model of interaction between the two major pathways of early vision: parvo-pathway and magno-pathway. Secondly, we constructed a model based on differences between motion signals from the left and right retinas as the first model for motion in depth direction. The model predicts many psychophysical experiment results investigating spatial and temporal factors, including direction of motion in depth and discrimination ability of motion directions.

(4) Information Content

(Aims) As the Internet of Things (IoT) expands, everything around us coming online and joining integrated networks. Even everyday items like furniture are going digital. We view all artifacts, physical and digital, as content. Honoring the unique perspectives of people, systems, and the environments they inhabit, we study the interactions between types of content, with the ultimate goal of formulating cohesive, holistic, and intuitive approaches that promote efficiency, ease of use, and effective communication, we focus on content design to enhance living.

(Achievements) This year, we mainly contributed novel spatial user interfaces. First, we presented novel findings for children’s stress assessment using sensor toy blocks. Second, we proposed a spatial user interface that offers haptic environment for room-scale virtual reality, where multiple robotic props are dynamically coordinated based on user’s motions. Finally, we also propose novel mechanisms that expand existing 2D touch and 3D motion tracking technologies.

(5) Real-world computing

(Aims) This laboratory aims at understanding the mechanism underlying adaptive and resilient behavior of animals from the viewpoint of decentralized control schemes.

(Achievements) The main contributions achieved in 2019 are summarized as follows: (1) we have clarified a decentralized control mechanism underlying amphibious locomotion of centipedes; (2) we have developed a brittle star-like robot that can coordinate flexible limbs; (3) we have proposed a decentralized control mechanism for the body-limb coordination underlying quadruped locomotion; (4) we have proposed a decentralized control scheme for versatile locomotion of snakes.

(6) Nano-Bio Hybrid Molecular Devices

(Aims) Our research activities focus on development of sophisticated molecular-scale devices through the combination of well-established microfabrication techniques and various soft materials, such as biomaterials and organic materials.

(Achievements) We constructed a bilayer lipid membrane (BLM) sensor through the combination of microfabrication, phospholipids and cell-free protein synthesis. Using the sensor, we quantified drug side-effects on the cardiac hERG channels. We also fabricated a novel BLM system, in which a lateral bias can be applied along the BLM. We succeeded in forming a transistor-like BLM device, showing modulation of the photoresponse by a lateral bias. Finally, we developed a novel culturing system for primary neurons on an ultrasoft silicone gel with an elastic modulus resembling that of the brain tissue. We showed that the hypersychronous network activity could be suppressed on the ultrasoft gel surface.

(7) Multimodal Cognitive System

(Aims) This group aims to study the basic mechanisms underlying multimodal cognitive systems, including vision, audition, tactile sensation, gustation and olfaction, together with the related groups such as the Advanced Acoustic Information Systems and the Visual Cognition and Systems groups.

(Achievements) In this year, we have done some experiments about the followings; the interaction between food texture and kinetic sensation of masticatory muscle; the difference of olfactory perception via orthonasal route with retronasal route; the effects of visual stimuli on olfactory brain processing investigated by fMRI and fNIRS, etc. We have also started the cognitive studies about the effect of audition on binocular rivalry, the differences of attentional system of vision and of audition, the interactive mechanisms of audition with somatosensation, and the comparison of the effects of vision with audition on affection and arousal.

Electromagnetic Bioinformation Engineering

Communication with human body

Electromagnetic Bioinformation Engineering, Kazushi Ishiyama, Professor
Electromagnetic Biomaterial Engineering, Shuichiro Hashi, Associate Professor

[Research Target and Activities]

To develop a high sensitive microvibration measurement system, fabrication of high sensitive strain sensors on Si wafer and the design of detection circuits with low noise were carried out. Imaging sensitivity of high frequency magnetic field measuring system was promoted by applying new technologies. In addition, wireless magnetic motion capture system with four-excitation-coils was studied to improve its detection accuracy. We revealed that (100)[001] silicon steel sheet or (110)[001] silicon steel sheet were useful as magnetostrictive materials for a magnetostrictive power generator to convert vibrational energy into electric energy.

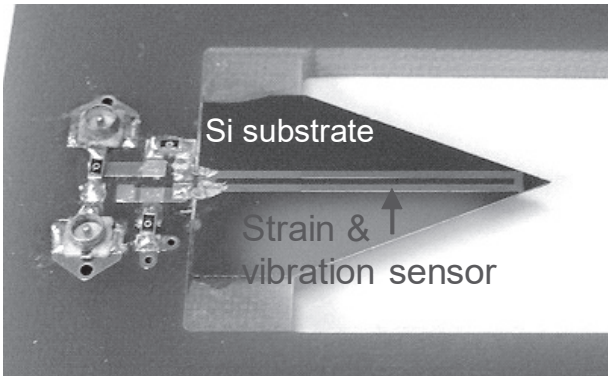


Fig. 1 Strain and vibration sensor using inverse-magnetostrictive effect.

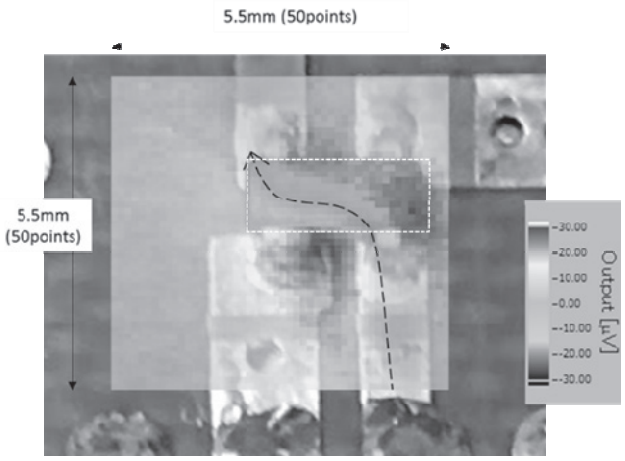


Fig. 2 Image of high frequency magnetic field distribution for internal circuit of voltage controlled oscillator (@623MHz).

[Staff]

Professor: Kazushi Ishiyama, Dr.
Associate Professor: Shuichiro Hashi, Dr.

[Profile]

Kazushi Ishiyama received his MS and PhD degrees in Electrical Engineering from Tohoku University in 1986 and 1993, respectively. His research interests are in the area of magnetics and magnetic applications.

Shuichiro Hashi received the DE degree in Electrical Engineering from Tohoku University in 1998. His research interests are in the area of magnetic measurement and magnetic materials.

[Papers]

[1] Sho, Muroga, Jingyan, Ma, Yasushi, Endo, Shuichiro, Hashi, Masayuki, Naoe, Motoshi, Tanaka, Hiroo, Yokoyama, Kazushi, Ishiyama, "Crosstalk suppression of magnetic films covered on two parallel micro-strip lines," Japanese Journal of Applied Physics, Rapid Communication, Vol.58, No. 8, 080902, (2019).
[2] Shuichiro Hashi, Daisuke Sora, Kazushi Ishiyama, "Strain and vibration sensor using inverse magnetostrictive effect of amorphous magnetostrictive films," IEEE Magnetics Letters, Vol. 10, 8110604 (2019).
[3] Fumiya Osanai, Shuichiro Hashi, Shun Fujieda, Kazushi Ishiyama, “Study on energy harvesting with (100) [001] silicon steel sheet,” 24th Soft Magnetic Materials Conference, P-071, (2019).
[4] Shun Fujieda, Shuichiro Hashi, Kazushi Ishiyama, Tsuguo Fukuda, Shigeru Suzuki, Materia Japan, Vol. 59, No. 1, pp. 10-15 (2020).

Advanced Acoustic Information Systems

Towards high-level acoustic information communication systems

Advanced Acoustic Information Systems: Shuichi Sakamoto, Professor

[Research Target and Activities]

Our research goal is to clarify how humans process information through "hearing," which is one of the most important modalities in human perception. In addition, we investigate the multimodal processing of auditory and visual information, as well as proprioception. Our findings are applied towards the development of advanced acoustic communication systems and user interfaces, including the realistic and comfortable expression of three-dimensional (3D) sound spaces. One typical example is the development of new type of 3D auditory displays, which present spatial sound images by simulating the transfer functions for the sound paths from the sound sources to the listeners' external ears. Another example is the proposal of 3D sound field information sensing systems. These systems are expected to convey a high-quality virtual sound space, which is keenly sought for multimedia communications, cyberspace systems and virtual reality systems.

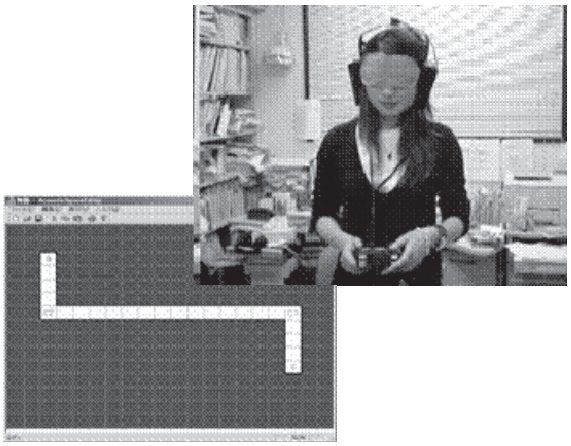


Fig. 1 Application for the training of spatial cognition using a high-definition virtual auditory display

In FY2019, we focused on how humans extract target speech information from distractor sounds by using auditory selective attention. In this year, the effect of auditory selective attention in the spatial domain was analyzed. The auditory spatial attention is one of the important mechanisms to realize cocktail party effects. By directing the attention to the specific direction, humans can extract the speech sound easily in multitalker environment. We measured the shape of spatial window of auditory spatial attention and found that the shape does not depend on the direction where listeners direct their attention.

[Staff]

Professor: Dr. Shuichi Sakamoto
Assistant professors: Dr. Zheng Lie Cui, Dr. Jorge Trevino

[Profile]

Shuichi Sakamoto graduated from Tohoku University in 1997 and received his Ph. D. degree in 2004 also from Tohoku University. His research interests include human auditory and multisensory information processing and development of advanced multimodal information systems. From 2016 to 2019, he was serving as a board member of the Acoustical Society of Japan.

[Papers]

[1] R. Teraoka, S. Sakamoto, Z. Cui, Y. Suzuki and S. Shioiri, “Directional selectivity of auditory attentional spotlight in complex listening environment,” Proc. The 23rd International Congress on Acoustics, 5764-5770 (2019).
[2] R. Teraoka, S. Sakamoto, Z. Cui, Y. Suzuki and S. Shioiri, “Temporal characteristics of auditory spatial attention on word intelligibility,” Acoustical Science and Technology, 41(1), 394-395 (2020).
[3] J. Trevino, S. Sakamoto and Y. Suzuki, “Revisiting the theory of auditory displays based on the virtual sphere model,” Acoustical Science and Technology, 41(1), 276-281 (2020). (invited paper)
[4] S. Abe, Z. Cui, S. Sakamoto, Y. Suzuki and J. Gyoba, “Influence of full-body vibration adapted to the foreground components on the high-level perception of reality,” Proc. The 23rd International Congress on Acoustics, 5869-5876 (2019).

Contact to Professor Shuichi SAKAMOTO : saka@ais.riec.tohoku.ac.jp

Visual Cognition and Systems Laboratory

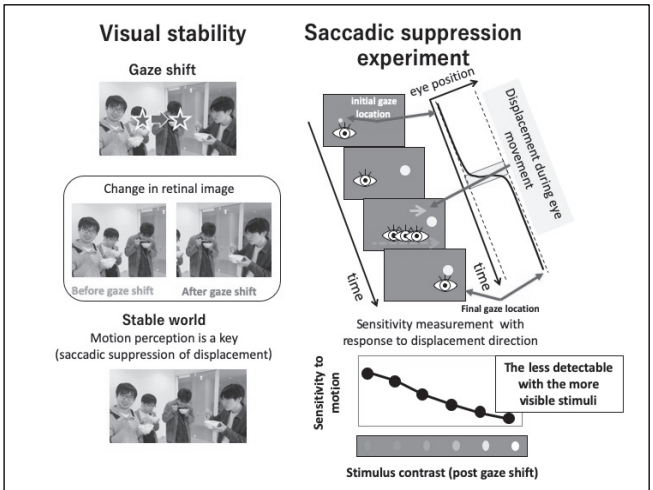
Understanding human visual system for the better communication with visual information

Visual Cognition and Systems: Satoshi SHIOIRI, Professor
Cognitive Brain Functions: Ichiro KURIKI, Associate Professor
Attention and Learning Systems: Chia-huei TSENG, Associate Professor

[Research Target and Activities]

Our target is to understand the vision-related brain functions in order to apply the knowledge to realize human oriented information communication systems. We made achievements in the fields of visual attention, depth perception, and color perception.

Firstly, we move our eyes several times every second, and these eye movements, called saccades, create large image shifts on the retina. This poses a big challenge for our visual system to keep a stable perceptual world, i.e. the problem of the visual stability. A key factor to solve the problem is a phenomenon, called saccadic suppression of displacement (SSD). We investigate the mechanisms underlying SSD and found a peculiar result, that is, detection sensitivity of displacement decreased with the increase of stimulus contrast. We succeeded to explain the results with a model of interaction between the two major pathways of early vision: parvo-pathway and magno-pathway. Secondly, we constructed a model based on differences between motion signals from the left and right retinas as the first model for motion in depth direction. The model predicts many psychophysical experiment results investigating spatial and temporal factors, including direction of motion in depth and discrimination ability of motion directions.



Left: Visual stability. Large shifts due to gaze shifts are not perceived as motion of the world. Right: Saccadic suppression experiment. The detection sensitivity measured during the gaze shift is reduced with stimulus contrast increase (i.e. improvement in visibility).

[Staff]

Professor : Satoshi Shioiri, Ph.D.
Associate Professor : Ichiro Kuriki, Ph.D.
Associate Professor : Chia-huei Tseng, Ph.D.

[Profile]

Satoshi SHIOIRI Professor Shioiri graduated from Tokyo Institute of Technology and received Dr. Eng in 1986. Then, he was a postdoctoral researcher at University of Montreal until May of 1989. From June of 1989 to April of 1990, he was a research fellow at Auditory and Visual Perception Laboratories of Advanced Telecommunications Research Institute. He moved to Chiba University at May of 1990, where he spent 15 years as an assistant professor, an associate professor, and a professor of Department of Image Sciences Department of Image, Information Sciences and Department of Medical Systems. In 2005, he moved to Tohoku University. Since then, he has been a professor of Research Institute of Electrical Communication of Tohoku University.

Ichiro KURIKI Dr. Kuriki received Ph.D. degree from Tokyo Institute of Technology in 1996. After that, he worked at Imaging Science and Engineering Laboratory, Tokyo Institute of Technology as a research associate until October, 1999. He worked as a research associate at the Department of Mathematical Engineering and Information Physics, Graduate School of Engineering, the University of Tokyo until March, 2001. He worked as a researcher in Communication Science Laboratories of NTT Corporation until December, 2005. He joined the Research Institute of Electrical Communication, Tohoku University as an Associate Professor in January, 2006.

Chia-huei TSENG Dr. Tseng is an expert on visual attention, perception, and learning. She received her B.S. and B.M.S. from National Taiwan University and PhD from The University of California, Irvine, U.S.A.. She was a post-doc researcher at Laboratory of Vision Research at the Center for Cognitive Science, Rutgers University, New Jersey. She has designed science outreach activities to engage community participation in many Asian cities. She was the founder and director of Baby Scientist Program and Infant Research Lab in Hong Kong. Before joining Tohoku University as associate professor in 2016, she was a university professor in Taiwan and Hong Kong.

Information Content

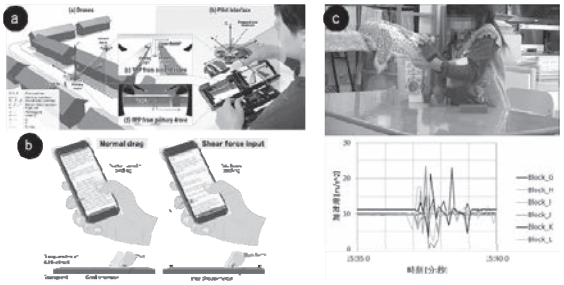
Technologies for Interactive Content

Interactive Content Design Yoshifumi KITAMURA, Professor
Human-Content Interaction Kazuki TAKASHIMA, Associate Professor

[Research Target and Activities]

As the Internet of Things (IoT) expands, everything around us coming online and joining integrated networks. Even everyday items like furniture are going digital. We view all artifacts, physical and digital, as content. Honoring the unique perspectives of people, systems, and the environments they inhabit, we study the interactions between types of content, with the ultimate goal of formulating cohesive, holistic, and intuitive approaches that promote efficiency, ease of use, and effective communication, we focus on content design to enhance living.

In this year, we primarily worked on three topics; first, we proposed a new drone control interface that increases situational awareness during piloting by spatially coupled two drones [3]; Second, we explored a novel mobile interface enabling tangential force input on a touchscreen using a rubber-mounted slim transparent sheet; finally, we proposed a new children's inter-sate assessment method using sensor-embedded toy blocks[1].



[Staff]

Professor: Yoshifumi Kitamura, Dr.
Associate Professor: Kazuki Takashima, Dr.
Assistant Professor: Kazuyuki Fujita, Dr.

[Profile]

Yoshifumi Kitamura: Since 2010, Yoshifumi Kitamura has been Professor in the Research Institute of Electrical Communication, Tohoku University. Prior to arriving at Tohoku, he was an Associate Professor at Graduate School of Engineering, and Graduate School of Information Science and Technology, Osaka University. While working at ATR Communication Systems Research Laboratories, he focused on sophisticated user interfaces in virtual environments. His first formal appointment was in the Information Systems Research Center Canon Inc., where he was involved in research on artificial intelligence, image processing, computer vision, and 3D data processing. His formal education was obtained at Osaka University, B.Sc (1985); M.Sc. (1987); and Ph.D. (1996).

Kazuki Takashima: He received a Ph.D from the Information Science and Technology at Osaka University in 2008. After working at Osaka University (2008 - 2011). He joined the Research Institute of Electrical Communication, Tohoku University as an assistant professor in 2011, and became an Associate Professor in 2018.

[Papers]

[1] Xiyue Wang, Kazuki Takashima, Tomoaki Adachi, Patrick Finn, Ehud Sharlin, Yoshifumi Kitamura. AssessBlocks: Exploring Toy Block Play Features for Assessing Stress in Young Children after Natural Disasters. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT)*, 4, 1, Article 30, 29 pages, March 2020.

[2] Mengting Huang, Kazuyuki Fujita, Kazuki Takashima, Taichi Tsuchida, Hiroyuki Manabe, Yoshifumi Kitamura. ShearSheet: Low-Cost Shear Force Input with Elastic Feedback for Augmenting Touch Interaction, *Proceedings of Interactive Surfaces and Spaces (ISS)*, 77-87, November 2019. [Best demo award].

[3] Ryotaro Temma, Kazuki Takashima, Kazuyuki Fujita, Koh Sueda, Yoshifumi Kitamura. Third-Person Piloting: Increasing Situational Awareness using a Spatially Coupled Second Drone, *Proceedings of User Interface Software and Technology (UIST)*, 507-519, October 2019.

Contact to Professor Yoshifumi KITAMURA : kitamura@riec.tohoku.ac.jp

Real-world Computing

Toward Understanding Design Principle for Life-like Resilient Systems

Real-world Computing, Akio Ishiguro, Professor

[Research Target and Activities]

Living organisms exhibit surprisingly adaptive and versatile behavior in real time under unpredictable and unstructured real world constraints. Such behaviors are achieved via spatiotemporal coordination of a significantly large number of bodily degrees of freedom. Clarifying these remarkable abilities enable us to understand life-like complex adaptive systems as well as to construct truly intelligent artificial systems. A prominent concept for addressing this issue is "autonomous decentralized control", in which non-trivial macroscopic functionalities are emerged via spatiotemporal coordination among vast amount of autonomous components that cannot be explained solely in terms of individual functionality. We study the design principle of autonomous decentralized systems that exhibit life-like resilient behaviors from the viewpoints of robotics, mathematics, nonlinear science, and physics.

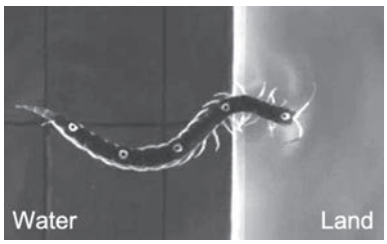


Fig.1: Amphibious locomotion of centipedes

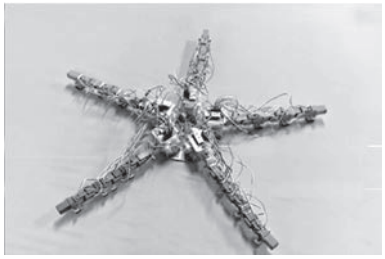


Fig.2: Brittle-star-like robot with flexible arms

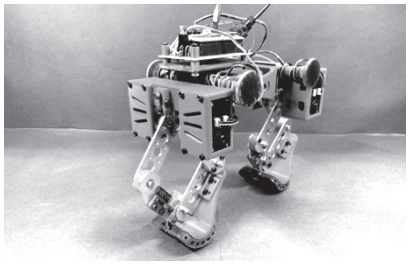


Fig.3: Legged robot that can coordinate between body and limbs for fast running

[Staff]

Professor: Akio ISHIGURO, Dr.
Associate Professor: Takeshi KANO, Dr.
Assistant Professor: Akira FUKUHARA, Dr.

[Profile]

Akio ISHIGURO received B.E., M.E., and Ph.D. degrees from Nagoya University in 1987, 1989, and 1991, respectively. From 1991 to 1997, he was with Nagoya University as an assistant professor. From May 1997 to 2006, he was an associate professor, Nagoya University. From 2006 to 2011, he was a professor of the Graduate School of Engineering, Tohoku University. Since April 2011, he has been a professor of Research Institute of Electrical Communication, Tohoku University. His main research interests are in bio-inspired robotics, nonlinear dynamics. He received 2004 IROS Best Paper Award, 2008 Ig Nobel Prize (Cognitive Science Prize), 2012 IEEE/RSJ JCTF Novel Technology Paper Award for Amusement Culture Finalist, Living Machines 2012 Best Paper Award.

[Papers]

[1] K. Yasui, et al. , "Decoding the essential interplay between central and peripheral control in adaptive locomotion of amphibious centipedes," Scientific Reports, 9, 18288, 2019. doi: 10.1038/s41598-019-53258-3
[2] T. Kano, et al., " Flexible Coordination of Flexible Limbs: Decentralized Control Scheme for Inter- and Intra-limb Coordination in Brittle Stars' Locomotion," Frontiers in Neurorobotics, 13:104, doi: 10.3389/fnbot.2019.00104
[3] A. Fukuhara, et al., "Decentralized control mechanism for body–limb coordination in quadruped running," Adaptive Behavior, doi:10.1177/1059712319865180.

Nano-Bio Hybrid Molecular Devices

Development of novel bio-devices through the combination of nanotechnology and biomaterials

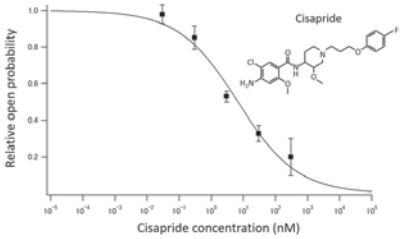
Nano-Bio Hybrid Molecular Devices: Ayumi Hirano-Iwata, Professor

[Research Target and Activities]

Our research activities focus on development of sophisticated molecular-scale devices through the combination of well-established microfabrication techniques and various soft materials.

1. Development of a biosensor for evaluating drug side-effects on hERG channels based on artificial bilayer lipid membranes

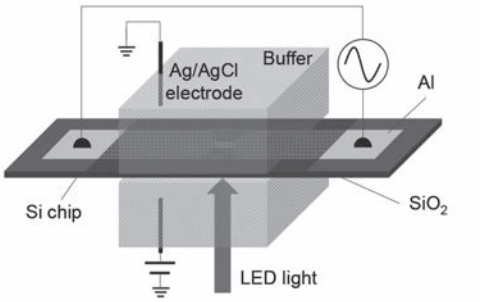
We developed a biosensor for quantitatively evaluating drug side-effects on hERG channels, to which binding of drugs leads to lethal arrhythmia. The biosensor utilized a bilayer lipid membrane (BLM) combined with a cell-free synthesized proteins. Using this system, we succeeded in quantifying drug inhibition effects on the hERG channels in terms of 50% inhibitory concentration. [Chem. Rec., **20**, 1-14 (2020).]



Quantitative evaluation of drug side-effects on hERG channels.

2. Novel "transistor-like" devices based on a bio/organic hybrid membrane

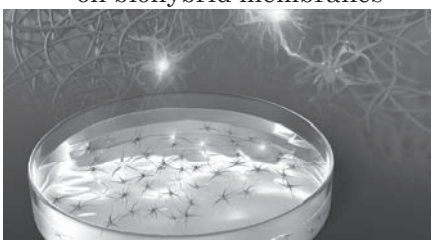
We fabricated an electrode-equipped Si chip, on which a fullerene-derivative-doped BLM was formed. Using this system, we were able to modulate the photoresponse of the membrane using the lateral bias applied from the electrodes on Si chip. [ACS Omega, **4**, 18299-18303 (2019).]



A "transistor-like" nano-device based on biohybrid membranes

3. Biomimetic culture of primary neurons using an ultrasoft silicone gel

We developed a novel system for culturing primary neurons on an ultrasoft silicone gel with an elastic modulus resembling that of the brain tissue. We showed that the hypersynchronous network activity could be suppressed on the gel surface. [Soft Matter, **16,** 3195-3202 (2020); Adv. Biosyst., **3**, 1900130 (2019).]



Cultured neuronal network on ultrasoft silicone gel.

[Staff]

Professor: Ayumi Hirano-Iwata, Dr.

[Profile]

Ayumi Hirano-Iwata 2016 – RIEC, Tohoku University, Japan, Professor, Doctorate of Science. Memberships: The Japan Society of Applied Physics, The Japan Society of Vacuum and Surface Science.

[Papers]

[1] M. Komiya, M. Kato, D. Tadaki, T. Ma, H. Yamamoto, R. Tero, Y. Tozawa, M. Niwano, A. Hirano-Iwata, "Advances in Artificial Cell Membrane Systems as a Platform for Reconstituting Ion Channels", Chem. Rec., **20**, 1–14 (2020).

[2] T. Ma, X. Feng, T. Deguchi, T. Ohori, D. Yamaura, R. Miyata, D. Tadaki, M. Komiya, K. Kanomata, F. Hirose, M. Niwano, A. Hirano-Iwata, "Modulation of photoinduced transmembrane currents in a fullerene-doped freestanding lipid bilayer by a lateral bias", ACS Omega, **4**, 18299–18303 (2019).

[3] T. Sumi, H. Yamamoto, A. Hirano-Iwata, "Suppression of hypersynchronous network activity in cultured cortical neurons using an ultrasoft silicone scaffold", Soft Matter, **16**, 3195-3202 (2020).

Contact to Professor Ayumi HIRANO : ayumi.hirano.a5@tohoku.ac.jp

Research Targets and Activities of Systems & Software Division

The goal of System & Software Division is to realize ideal ubiquitous environment where everyone can freely communicate in real-time with anyone, anywhere, and at any time through any kind of information. With the reorganization of RIEC in FY2016, our division has the following seven research fields related to such high-level ubiquitous systems, software and contents by integrating computer and communication:

— Software Construction: Reliable and high-level software.
— Computing Information Theory: Fundamental theory of new software.
— Communication Network: Symbiotic computing.
— Environmentally Conscious Secure Information System: Embedded system security
— Soft Computing Integrated System: Brainmorphic hardware.
— New Paradigm VLSI System: Post-binary CMOS-based VLSI computing.
— Structure of Information Society (Visitor Section).

An overview of research results from Apr. 2019 to Mar. 2020 of these fields except the visitor section is described in this section.

(1) Software Construction

We research on theoretical foundations for flexible and reliable programming languages. We also develop SML#, a new programming language in the ML family that embodies our foundational research results. The major results of the 2019 academic year include the following. On theoretical foundations, we have developed a method for inductive theorem proving in non-terminating rewriting systems and its application to program transformation. On practical implementation methodology. we have developed a parallel and concurrent garbage collection method that enables a functional language to scale millions of light-weight threads, and a method to integrate dynamic typing seamlessly in an ML-style polymorphic type system, and have implemented these methods in the SML# compiler.

(2) Computing Information Theory

We proceed with studying formal language theory, which can be theoretical foundations for efficient development and static verification of software, and its application to bidirectional transformation. First, we have shown the decidability of the functional equivalence of a particular class of tree transducers that is a formal model of recursive transformation over tree-structured data. The class is a streaming transducer model that computes a tree-to-tree transformation efficiently in both time and space. Second, we have discovered that an introduction of a stack device does not preserve a hierarchy of classes of classical tree transducers. Since the stack device is introduced for representing practical computation, the extension enables us to optimize and verify existing programs. Our discovery implies that techniques for classic models cannot be applied to practical programs directly. Additionally, we have studied a theory of bidirectional transformation, which is a basis of data synchronization. We have shown a precise relationship between many formalizations of bidirectional transformation. This result will be applied to an optimized verification of tools of bidirectional transformation.

(3) Communication Network Systems

We promoted the following research on information networking technologies that support various human activities and its application. In the area of mobile core network architecture, we proposed the control-plane signaling method for controlling the demand on the server resources for accommodating massive IoT devices, gave mathematical analysis for function splitting in 5G networks, and presented performance evaluation methods of mobile cellular networks considering the interactions between wireless access networks and core networks. For NFV architecture, we proposed a biochemically-inspired control mechanism for virtual network functions and evaluated its effectiveness on the NFV framework. Furthermore, in the research on agent-based IoT (AIoT) and its applications, we designed a distributed blackboard model. It is as an inter-agent information exchange infrastructure on which IoT devices detect each other, make an organization, and build a combined service autonomously in a bottom-up manner. And also, as an example of a particular service, a mock-up of a security camera service was implemented by combining devices such as a human-detecting sensor, a camera, a smart light, and an image recognition device.

(4) Environmentally Conscious Secure Information System

We are studying future secure information communication systems from theories to implementation technologies for constructing advanced information and communication infrastructures in a safe and secure manner. In this year, as security computing technology for IoT devices, we developed a hardware architecture that executes the international standard cryptography AES (Advanced Encryption Standard) with the world's smallest energy operation. We also developed a new method to significantly improve the stability and efficiency of information communication systems based on physically unclonable functions extracted from hardware, which are applied to individual identification and secret key generation, and showed its effectiveness from both theories and experiments. Furthermore we developed a technique for quantitatively evaluating electromagnetic security (i.e., risk on information security by electromagnetic leakage) of smart devices such as tablets, etc., and validated it by experiments using actual devices.

(5) Soft Computing Integrated System

We are working on a novel high-performance, highly-efficient, flexible, and robust brain-inspired brainmorphic computer hardware system, in particular, through physical complex-networked dynamical process using an analog VLSI as a core component. Results of this year include the followings. (i) We proposed the chaotic neural network reservoir, which naturally introduces high-dimensional chaotic dynamics into a reservoir network without losing the echo-state property. We confirmed the ability of the proposed network using time-series prediction and speech recognition. (ii) We proposed compact mathematical models for neuron-like and synapse-like spintronics devices based on the device temperature dynamics. (iii) We proposed an efficient method to implement small and high-speed cryptographic hardware based on the augmented Lorenz-map, and validated it using FPGA experiments.

(6) New Paradigm VLSI System

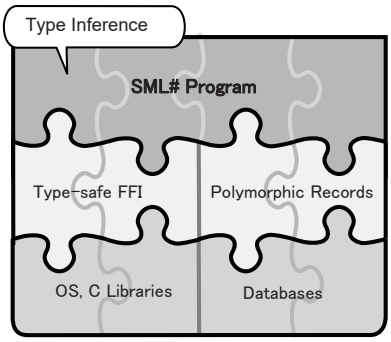
Our research activity is to solve the several limitations such as power dissipation, performance and reliability due to the present binary-CMOS-based VLSI computing. The key approach to breaking through such limitations is primarily the following two ways: the logic-in-memory architecture based on nonvolatile logic, and the brainware LSI (BLSI) computing, which would open up a novel VLSI chip paradigm, called a “new-paradigm VLSI system.” In FY 2019, we have preliminarily achieved the following two activities. (a) In order to implement artificial intelligence technology for IoT (Internet of Things) sensor nodes, we have designed energy-saving and area-saving neural network hardware that uses nonvolatile storage elements. Area reduction is realized by combining weight quantization technology and non-volatile logic-in-memory circuit technology, and power consumption is reduced due to intermittent operation based on non-volatility, and high reliability is realized by on-chip programing the resistance values in non-volatile elements. As a result, it has been clarified that the multiply-accumulate operation circuit in the proposed technique can reduce the energy-delay product (EDP) by 99.9% and the circuit area by 72.2% compared to those of a conventional CMOS-only-based implementation while maintaining high circuit reliability. (b) We have also developed a novel hardware implementation method, called "CMOS Invertible Logic (CIL)" that realizes bidirectional computation based on a CMOS-logic hardware platform. In CIL, the desired function is converted into an energy function, called "Hamiltonian", and stochastic computation at each CIL node is realized by stochastic operation. As a result of implementing a factorization process, which is a type of bidirectional computation, on a CMOS integrated circuit, it is confirmed that bidirectional computation is realized on a standard CMOS-based VLSI chip. As this fiscal-year research results including the above topics, we have reported 7 academic journal papers including IEEE TCAS-I (which is one of the best journals in the field of circuits and systems), 8 peer-reviewed international conference papers, and 7 invited talks (5 invited talks in international conferences).

Software Construction Laboratory

Foundations for Developing High-level and Reliable Programming Languages

Software Construction Atsushi Ohori, Professor
Reliable Software Development Katsuhiro Ueno, Associate Professor

[Research Target and Activities]



SML#: a high-level and reliable language

Today's software systems are becoming more and more complicated due to the need of integrating various computation resources available in the Internet. A key to control the complexity and to enhance the reliability of such a system is to develop a high-level programming language that can directly represent various resources and automatically detect potential inconsistencies among the components in a system. Based on this general observation, our research aims at establishing both firm theoretical basis and implementation method for flexible yet reliable programming languages for advanced applications. Research topics on theoretical foundations include: logical foundations for compilation and type-directed compilation for polymorphic languages. We are also developing a new practical ML-style programming language, SML#, which embodies some of our recent results such as record polymorphism, direct C interface, and seamless integration of SQL.

A major result of the 2019 academic year is a theorem proving method in non-terminating rewriting systems and its application to program transformation. We generalized the notion of implicit induction through our novel method that relaxes the conventional sufficient completeness condition to local sufficient completeness, and obtained a method that has wider applicability in inductive theorem proving. Another result is an implementation method for dynamic typing in an ML style polymorphic language. We applied our method and integrated dynamic typing in the SML# compiler.

[Staff]

Professor : Atsushi Ohori, Ph.D.
Associate Professor : Katsuhiro Ueno, Dr.
Assistant Professor : Kentaro Kikuchi, Dr.

[Profile]

Atsushi Ohori. He was born in 1957. He received his BA degree in Philosophy from University of Tokyo, 1981; Ph.D. degree in Computer and Information Science from University of Pennsylvania, 1989. He worked for Oki Electric Industry from 1981 until 1993. In 1993, he joined RIMS, Kyoto University as an Associate Professor. In 2000, he joined Japan Advanced Institute of Science and Technology as a Professor. In 2005, he moved to RIEC, Tohoku University as a Professor.

Katsuhiro Ueno. He was born in 1981. He received the Doctor of Philosophy (Information Sciences) degree from Tohoku University, 2009. He joined Research Institute of Electrical Communication (RIEC), Tohoku University as an assistant professor in 2009. Since 2016, he has been an associate professor at the same institute.

[Papers (conference presentations)]

[1] Kentaro Kikuchi, Takahito Aoto, Isao Sasano: Inductive Theorem Proving in Non-terminating Rewriting Systems and Its application to Program Transformation. In Proceedings of the International Symposium on Principles and Practice of Declarative Programming (PPDP'19), 2019, DOI:10.1145/3354166.3354178.
[2] Atsushi Ohori, Katsuhiro Ueno: Dynamic typing in SML# (in Japanese), Proceedings of the 36th annual meeting of Japan Society for Software Science and Technology, 6 pages、July, 2019.
[3] Katsuhiro Ueno: Compiling a polymorphic language with natural data representation to LLVM IR (in Japanese), Proceedings of the 22nd workshop of Programming and Programing Languages (PPL2020), March 2020.

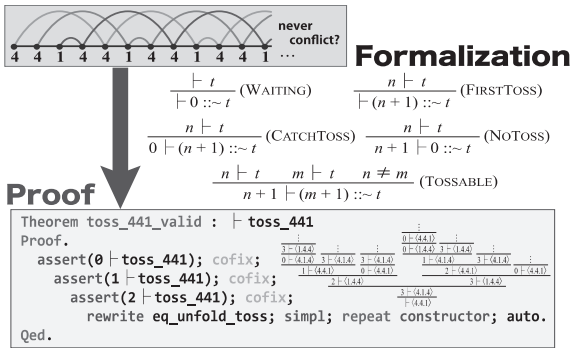
Contact to Professor Atsushi OHORI : ohori@riec.tohoku.ac.jp

Computing Information Theory

Filling the Gap between Humans and Computers

Computing Information Theory Keisuke Nakano, Professor

[Research Target and Activities]



Notwithstanding that programming is one of the most typical methods for a human to communicate with a computer, there is a significant gap between programs that are recognizable for humans and those that are efficiently executed by computers. Programs described as humans think are highly readable but are not always efficient. On the other hand, programs described with carefully considering the behavior of computers show much better performance in time and space but are very complicated and hardly maintainable. Our ultimate goal is to fill the gap between humans and computers in programming.

More specifically, our research topics include *program transformation* and *program verification*. Program transformation is to automatically derive well-tuned and efficient programs from human-readable ones; Program verification is to statically (that is, without running) check if human-written but well-tuned complicated programs behave as the programmers expect for any input. To this end, we deeply study the theory of formal tree languages, such as tree automata and tree transducers, which has a close relationship with the program transformation and verification. Besides that, we are working on formalizing relevant results in mathematics and theoretical computer science on a proof assistant to make our theory more robust.

[Staff]

Professor : Keisuke Nakano, Dr.
Assistant Professor : Kazuyuki Asada, Dr.

[Profile]

Keisuke Nakano received his Ph.D. from Kyoto University in 2006. He worked as a researcher at the University of Tokyo from 2003 to 2008. He has been an assistant professor from 2008 to 2012 and an associate professor from 2012 to 2018 at the University of Electro-Communications. Since 2018, he has been a professor at the Research Institute of Electrical Communication. His research interests include formal language theory, programming language theory, and functional programming. He is a member of ACM, JSSST, and IPSJ.

[Papers]

[1] Yuta Takahashi, Kazuyuki Asada, and Keisuke Nakano, “Streaming Ranked-Tree-to-String Transducers”, International Conference on Implementation and Application of Automata, 235-247.
[2] Keisuke Nakano, “Towards a Complete Picture of Lens Laws”, 3rd Workshop on Software Foundations for Data Interoperability (SFDI2019+), Fukuoka, Japan, 2019.
[3] Yasunori Ishihara, Hiroyuki Kato, Keisuke Nakano, Makoto Onizuka, and Yuya Sasaki, “Toward BX-based Architecture for Controlling and Sharing Distributed Data”, 2nd Workshop on Software Foundations for Data Interoperability (SFDI 2019), Kyoto, Japan, 2019.
[4] Yasuhito Asano, Dennis-Florian Herr, Yasunori Ishihara, Hiroyuki Kato, Keisuke Nakano, Makoto Onizuka, and Yuya Sasaki, “Flexible framework for data integration and update propagation: system aspect”, 2nd Workshop on Software Foundations for Data Interoperability (SFDI 2019), Kyoto, Japan, 2019.

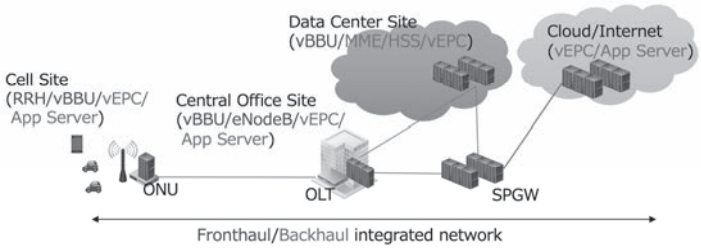
Communication Network Systems

Information Network Architecture for the IoT Society

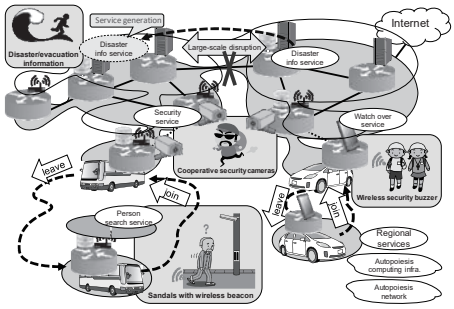
Information Network Architecture: Go Hasegawa, Professor
Intelligent Network: Gen Kitagata, Associate Professor

[Research Target and Activities]

In this year, the following studies had been done. (a) Research on mobile network architecture to efficiently accommodate a large number of Internet of Things (IoT) terminals. (b) Research on Network Function Virtualization (NFV) systems that autonomously and decisively control the placement of virtualized network functions and the allocation of server resources, based on a spatial diffusion model using chemical reaction equations. (c) Research and development of basic technologies for autopoietic computing platforms that allow various IoT devices, including mobile devices, to autonomously configure computing platforms for the next generation of IoT themselves.



Flexible function deployment for mobile networks.



An image of autopoietic networking.

[Staff]

Professor : Go Hasegawa, Dr.
Associate Professor : Gen Kitagata, Dr.

[Profile]

Go Hasegawa received the M.E. and D.E. degrees in Information and Computer Sciences from Osaka University, Japan, in 1997 and 2000, respectively. From July 1997 to June 2000, he was Research Assistant of Graduate School of Economics, Osaka University. From 2000 to 2018, he was an Associate Professor of Cybermedia Center, Osaka University. He is now a Professor of Research Institute of Electrical Communication, Tohoku University. His research work is in the area of information network architecture. He is a member of the IEEE and IEICE.

Gen Kitagata is an associate professor of the Research Institute of Electrical Communication of Tohoku University, Japan. He received a doctoral degree from the Graduate School of Information Sciences, Tohoku University in 2002. His research interests include agent-based computing, intelligent networking, and resilient networking. He is a member of IEICE, IPSJ.

[Papers]

[1] Xun Shao, Go Hasegawa, Noriaki Kamiyama, Zhi Liu, Hiroshi Masui and Yusheng Ji, "Joint Optimization of Computing Resources and Data Allocation for MEC: An Online Approach," in Proceedings of IEEE ICCCN 2019, August 2019.
[2] Go Hasegawa, Rina Yamasaki, and Masayuki Murata, "System and application performance of function placement strategies for virtualized mobile fronthaul/backhaul networks," in Proceedings of IEEE ICIN 2020, February 2020.
[3] A. Satoh, Y. Nakamura, Y. Fukuda, K. Sasai and G. Kitagata, "A Cause-Based Classification Approach for Malicious DNS Queries Detected Through Blacklists," IEEE Access, vol. 7, pp. 142991-143001, 2019.
[4] A. Satoh, Y. Nakamura, D. Nobayashi, K. Sasai and G. Kitagata, T. Ikenaga, Clustering Malicious DNS Queries for Blacklist-Based Detection, IEICE Trans. Inf. & Syst., 2019, Volume E102.D, Issue 7, pp.1404-1407, July 01, 2019.

Contact to Professor Go HASEGAWA : hasegawa@riec.tohoku.ac.jp

Environmentally Conscious Secure Information System

Advanced information security technology

Environmentally Conscious Secure Information System, Naofumi Homma, Professor

[Research Target and Activities]

We are studying future secure information communication systems from theories to implementation technologies for constructing advanced information and communication infrastructures in a safe and secure manner. In this year, we have developed energy-efficient cryptographic hardware for AES, which is the most commonly used cipher in the world. We have discovered practical attacks on a digital signature algorithm with experimental validation (Fig. 1) and developed its countermeasure. We have also developed a new methodology for detecting malicious hardware Trojans, which are stealthily inserted to cryptographic hardware during its design/fabrication. In addition, we have developed secure and efficient hardware authentication systems based on hardware-intrinsic ID from physically unclonable function (PUF).

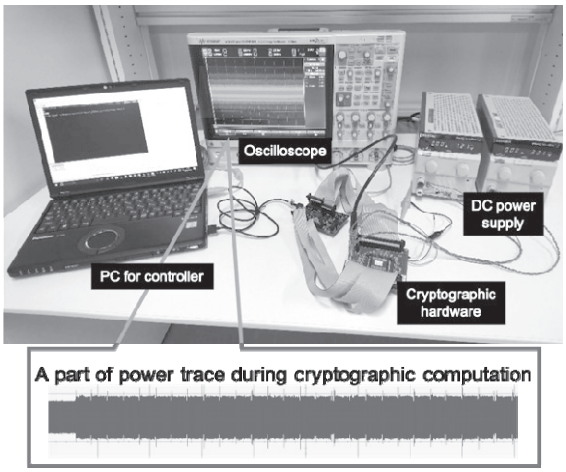


Fig. 1: Experiment for security evaluation of cryptographic hardware

[Staff]

Professor: Naofumi Homma, Ph. D
Assistant Professor: Rei Ueno, Ph. D
Specially Appointed Assistant Professor: Ville Yli-Mäyry, Ph. D

[Profile]

Naofumi Homma received the PhD degrees in information sciences from Tohoku University, Sendai, Japan, in 2001. Since 2016, he has been a Professor in the Research Institute of Electrical Communication, Tohoku University. In 2009-2010 and 2016-2017, he was a visiting professor at Telecom ParisTech, Paris, France. He received a number of awards including the IACR CHES Best Paper Award in 2014, the JSPS Prize in 2018, and the German Innovation Award in 2018.

[Papers]

[1] R. Ueno *et al*., "Highly Efficient AES Hardware Architectures Based on Datapath Compression," *IEEE Transactions on Computers*, Vol. 69, Issue 4, pp. 534—548, 2020.
[2] R. Ueno *et al*., "Highly Efficient $GF(2^8)$ Inversion Circuit Based on Hybrid GF Arithmetic," *Journal of Cryptographic Engineering*, Vol. 9, No. 2, pp. 101—113, 2019.
[3] Kosuke Koiwa *et al*., "Collision-Based EM Analysis on ECDSA Hardware and a Countermeasure," *Joint IEEE International Symposium on Electromagnetic Compatibility and Asia-Pacific Electromagnetic Compatibility*, pp. 793—796, 2019.
[4] Rei Ueno *et al*., "Tackling Biased PUFs Through Biased Masking: A Debiasing Method for Efficient Fuzzy Extractor," *IEEE Transactions on Computers*, Vol. 68, Issue 7, pp. 1091—1104, 2019.
[5] K. Kazumori *et al*., "Debiasing Method for Efficient Ternary Fuzzy Extractors and Ternary Physically Unclonable Functions," *IEEE 50th International Symposium on Multiple-Valued Logic*, 2020. (to appear)
[6] A. Ito *et al*., "Effective Formal Verification for Galois-Field Arithmetic Circuits with Multiple-Valued Characteristics," *IEEE 50th International Symposium on Multiple-Valued Logic*, 2020. (to appear)
[7] Ville Yli-Mäyry *et al*., "On the Evaluation of Electromagnetic Information Leakage from Mobile Device Screens," *IEEE Transactions on Electromagnetic Compatibility*, Vol. 61, Issue 4, pp. 1107—1114, 2019.

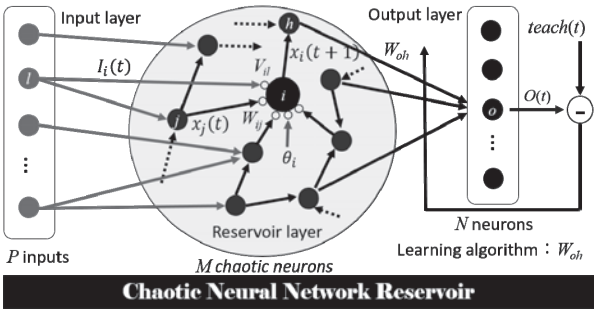
Soft Computing Integrated System

Brainmorphic Computing Hardware System

Soft Computing Integrated System Yoshihiko Horio, Professor

[Research Target and Activities]

We are working on a novel high-performance, highly-efficient, flexible, and robust "brainmorphic" computing hardware system through physical complex-networked dynamical process using novel nano-scale devices. Toward the final goal, we are developing integrated circuit and device technologies suitable for the brainmorphic computer systems, ultra-low-power asynchronous neural network systems, neuron-like and synapse-like spintronics devices, and a brainmorphic system architecture. During the FIY 2019, 1) we proposed the chaotic neural network reservoir, which naturally introduces high-dimensional chaotic dynamics into a reservoir network without losing the echo-state property. We confirmed the ability of the proposed network using time-series prediction and speech recognition; 2) we proposed compact mathematical models for neuron-like and synapse-like spintronics devices based on the device temperature dynamics; and 3) we proposed an efficient method to implement small and high-speed cryptographic hardware based on the augmented Lorenz-map, and validated it using FPGA experiments.



[Staff]

Professor : Yoshihiko Horio, Ph.D.

[Profile]

Yoshihiko Horio received the B.E., M.E., and Ph.D. degrees in electrical engineering from Keio University, Japan, in 1982, 1984, and 1987, respectively. He is currently a Professor with the Research Institute of Electrical Communication, Tohoku University, Japan. From 1987 to 2016, he was with Department of Electronic Engineering, Tokyo Denki University, Japan, being a Professor from 2000. From April 1992 to March 1994, he was a Visiting Professor at Center for Telecommunications Research, Columbia University, U.S.A. His current research interests are in the area of neuromorphic and brainmorphic hardware systems based on complex physical dynamics, mixed analog/digital VLSI circuit design, and high-order brain-inspired VLSI systems with consciousness, self, and embodiment. Dr. Horio received the 3rd Hiroshi Ando Memorial Young Engineer Award (1990), the IEEE Myril B. Reed Best Paper Award (1991), NCSP Best Paper Awards (2005, 2007, 2008, 2013, 2020), IEEE NDES Best Paper Awards (2005, 2007), ISCS-ISIS Best Paper Award (2008), JSAP Outstanding Paper Award (2019), IEICE NOLTA Lifetime Achievement Award (2016), and Fellow, IEICE (2018).

[Papers]

[1] Kurenkov, S. DuttaGupta, C. Zhang, S. Fukami, Y. Horio, and H. Ohno, "Artificial neuron and synapse realized in an antiferromagnet/ferromagnet heterostructure using dynamics of spin-orbit torque switching," Advanced Materials, 1900636, DOI: 10.1002/adma.201900636, 2019.
[2] Y. Horio, "A brainmorphic computing hardware paradigm through complex nonlinear dynamics," in Understanding Complex Systems, Springer, pp. 36-43, DOI: 10.1007/987-3-030-10892-2_5, 2019.
[3] Y. Horio, "Chaotic neural network reservoir," in Proc. of IEEE The International Joint Conference on Neural Networks, paper no. N-19290 (5 pages), 2019.

Contact to Professor Yoshihiko HORIO : horio@riec.tohoku.ac.jp

New Paradigm VLSI System Research Group

Realization of a New-Paradigm VLSI-Computing World

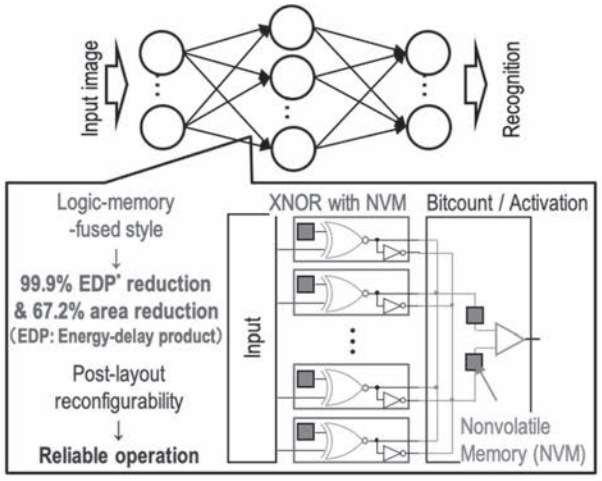


Fig. 1. A multiply-accumulate circuit utilizing nonvolatile logic-in-memory architecture achieving 99.9% energy-delay-product reduction and 67.2% area reduction while maintaining enough operation reliability.

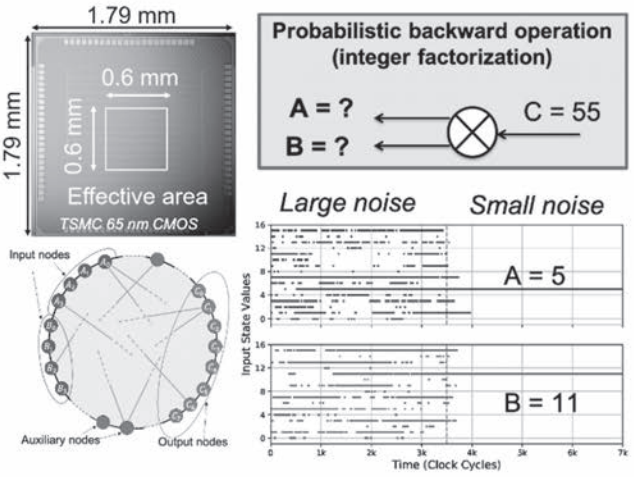


Fig. 2. CMOS invertible logic based on stochastic logic realizes bidirectional computing: factorization performs on the CMOS invertible logic chip as a typical example

New Paradigm VLSI System: Takahiro Hanyu, Professor
New Paradigm VLSI Design: Masanori Natsui, Associate Professor

[Research Target and Activities]

Rapid progress in recent deep submicron regime has led the capability to realize giga-scaled embedded systems on a chip (SoC), while performance degradation of SoCs due to wiring complexity, power dissipation and device-characteristic variation are increasingly getting serious problems in the recent Very Large Scale Integration (VLSI) chip. Our research activity is to solve the above problems primarily by the following two ways: the logic-in-memory architecture based on nonvolatile logic, and the brainware LSI (BLSI) computing, which would open up a novel VLSI chip paradigm, called a "new-paradigm VLSI system."

This year, we have succeeded to design and implement the magnetic tunnel junction (MTJ)-based nonvolatile logic-in-memory circuit for neural networks (Fig. 1), and the stochastic-computing based CMOS invertible logic that realizes bidirectional computing for several applications, such as factorization (Fig. 2).

[Staff]

Professor : Takahiro Hanyu, Dr.
Associate Professor : Masanori Natsui, Dr.
Assistant Professor : Naoya Onizawa, Dr.

[Profile]

Takahiro Hanyu received the D.E. degrees in Electronic engineering from Tohoku University, Sendai, Japan, in 1989. His general research interests include multiple-valued current-mode logic and its application to high performance and low-power arithmetic VLSIs.

Masanori Natsui received the Ph.D. degrees in information Sciences from Tohoku University, Sendai, Japan, in 2005. His research interest includes automated circuit design technique, nonvolatile-based circuit architecture and its application, and design of high speed low-power integrated circuits.

[Papers]

[1] M. Natsui, et al., IEEE JSSC, vol. 54, no. 11, pp. 2991-3004, Nov. 2019.

[2] S. Smithson, et al., IEEE TCAS-I vol.66, no. 6, pp. 2263-2274, June. 2019.

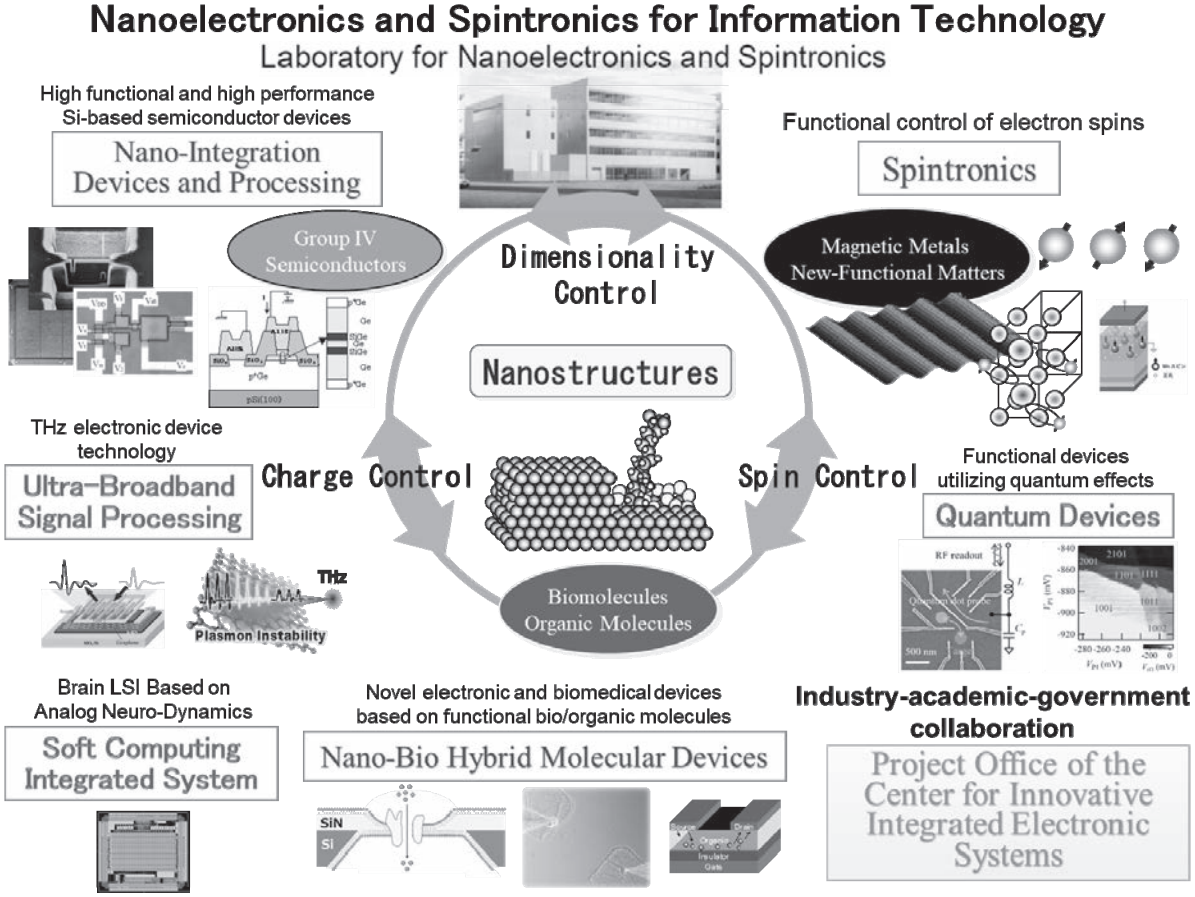
[3] N. Onizawa, et al., Journal of Applied Logics, vol.7, no.1, pp.41-58, Jan. 2020.

[4] D. Suzuki and T. Hanyu, JJAP, vol. 58, no. SB, pp.SBBB10~1-SBBB10~7, Apr. 2019

Laboratory for Nanoelectronics and Spintronics

The Laboratory for Nanoelectronics and Spintronics of the Research Institute of Electrical Communication (RIEC) was established in April of 2004. Its purpose is to develop and establish the science and technology of nanoelectronics and spintronics for information technology. Utilizing the facilities installed in the Nanoelectronics-and-Spintronics building and under collaboration between RIEC and related laboratories of the Graduate Schools of Engineering, Information Sciences, Biomedical Engineering, of Tohoku University, R&D on nanotechnologies of materials and devices in Nanoelectronics and Spintronics are continued extensively. Furthermore, nation-wide and world-wide collaboration research projects are conducted to build a systematic database in electrical communication research.

The Laboratory for Nanoelectronics and Spintronics mainly consists of laboratories of Nano-Integration Devices and Processing, Spintronics, and Nano-Bio Hybrid Molecular Devices; together with the project office of the Center for Innovative Integrated Electronic Systems, and the groups of Ultra-Broadband Signal Processing, Soft Computing Integrated System and Quantum Devices. These groups cooperatively carry out the research aimed at establishing a world-wide Center of Excellence (COE) in the research area of nanoelectronics and spintronics.



Highlights of our research activities in 2019 are shown below.

Nano Integration

● Nano-Integration Devices and Processing (S. Sato, M. Sakuraba, and H. Yamamoto)

(1) Toward the development of neuromorphic computation hardware, we fabricated a spiking neuron circuit that can reproduce various neuron pulses. We confirmed by electrical measurements that the analog MOS circuit, which is composed of about 40 MOS transistors, successfully operates in the strong inversion region.

(2) By low-energy Ar plasma irradiation at every nanometer-thick deposition of high B concentration Si film, electrical activation ratio can be improved to 75% successfully, and low-resistive p-type Si film formation without substrate heating can be realized.

(3) By development of fabrication process of SiC Schottky barrier diode, significant modulation effect in the rectifying characteristics which was dependent on metal work function was confirmed, and it was clarified that information on SiC crystal defect could be estimated from the characteristics.

(4) To investigate the effect of network structure-derived neural dynamics on time-series information processing, speech recognition task was performed by reservoir computing and its performance was evaluated from the correctness of the TI-46 sound dataset. Modular networks which generally possess robustness to noise and device variations, were used as reservoirs and achieved over 90% correct answer rate.

(5) We studied by numerical simulations on the saturation behavior in quantum Hebb / anti-Hebb learning with our quantum associative memory model, which is inspired by neuromorphic computation, and confirmed that this behavior is originated from quantum dynamics.

● Soft Computing Integrated System (Y. Horio)

(1) We proposed the chaotic neural network reservoir, which naturally introduces high-dimensional chaotic dynamics into a reservoir network without losing the echo-state property. We confirmed the ability of the proposed network using time-series prediction and speech recognition. We also analyzed dynamics of the chaotic neural network reservoir using entropies, Lyapunov spectrum, and mutual information. In addition, we proposed an interleave-cyclic circuit architecture to embed the reservoir networks in a 3D VLSI.

(2) We proposed compact mathematical models for neuron-like and synapse-like spintronics devices based on the temperature dynamics. We tuned the model parameters using experimental data, and showed that our model can well reproduce device characteristics and dynamics. In addition, we confirmed through network simulations using our models that the spintronics synapse-like device can be used in a STDP learning neural network.

(3) We proposed an efficient method to implement small and high-speed cryptographic hardware based on the augmented Lorenz-map, and validated it using FPGA experiments. Furthermore, we investigated the performance and dynamics of the hardware system with truncated bit-lengths.

Spintronics and Information Technology

● Spintronics (S. Fukami)

Our research activities focus on realizing low-power functional spintronic devices. The outcomes in the last fiscal year are as follows: (1) Developing artificial neuron and synapse devices based on antiferromagnet/ferromagnet heterostructure operated by spin-orbit torque, (2) putting forward a scheme to reliably determine spin-orbit torque efficiency by means of ferromagnetic resonance free from spurious effects, (3) developing new-concept spintronics that utilizes thermal fluctuation and demonstrating proof-of-concept of probabilistic bit that has compatibility with quantum bit and probabilistic computers that functions like quantum annealing machine, (4) measuring spin-transfer torque switching error rate systematically and revealing unknown mechanism that governs the spin-transfer torque switching error rate, (5) finding giant perpendicular magnetic anisotropy of Ir/Co/Pt multilayer and elucidating underlying mechanism, (6) developing synthetic antiferromagnetically coupled skyrmions and demonstrating current-induced motion without the skyrmion Hall effect which has been one of the biggest obstacle of applications of magnetic skyrmions, (7) preparing successfully epitaxial thin films of noncollinear antiferromagnet Mn_3Sn and clarifying the relationship between the spin transport properties and crystalline structure, (8) evaluating spin-orbit torque in PtMn/CoFeB heterostructures as a function of stack structure and temperature and discussing the underlying mechanism of the generation of spin-orbit torque in this material system.

● Ultra-Broadband Signal Processing (T. Otsuji and A. Satou)

The goal of our research is to explore the terahertz frequency range by creating novel integrated electron devices and circuit systems. III-V- and graphene-based active plasmonic heterostructures for creating new types of terahertz lasers and ultrafast transistors are major concerns. By making full use of these world-leading device/circuit technologies, we are developing future ultra-broadband wireless communication systems as well as spectroscopic/imaging systems for safety and security. The followings are the major achievements in 2017FSY.

1. Creation of graphene-based current-injection terahertz lasers

Graphene, a monolayer sheet of honeycomb carbon crystal, exhibits unique carrier transport properties owing to the massless and gapless energy spectra, which is expected to break through the limit on conventional device operating speed/frequency performances. Towards the creation of novel current-injection graphene THz laser-transistors, we developed a graphene laser-transistor featured with our original asymmetric dual-grating gates demonstrating coherent amplification of THz radiation with the maximal gain of 9% at room temperature promoted by graphene plasmon instabilities driven by dc-channel current flow.

2. Development of plasmonic terahertz detectors

For future ultrahigh-speed wireless communications, we have developed plasmonic terahertz detectors with original metallic diffraction-grating structures, which utilize

hydrodynamic nonlinearities of two-dimensional plasmons in the channels of InGaAs high-electron-mobility transistors (InGaAs-HEMTs). This fiscal year, we experimentally demonstrated that the photovoltage readout from the gate electrode of a plasmonic terahertz detector, instead of the conventional drain-readout, enables the impedance matching to a 50-Ω interconnection systems and the scaling of the photovoltage with the size of the active area, both of which are impossible for the drain-readout.

● **Quantum Devices (T. Otsuka)**

We are exploring interesting properties of solid-state nanostructures utilizing precise and high-speed electric measurement and control techniques. We are also developing materials and devices using nanostructures. Our research activities in FY 2019 are the following.

(1) We developed the local electronic sensors which can directly access local electronic states in nanostructures utilizing semiconductor quantum dots. We improved the performance by high-frequency measurement techniques and data informatics approaches.

(2) We measured local electronic and spin states in semiconductor nanostructures. We revealed the detail of local charge and spin dynamics induced by the movement of a single electron.

(3) We conducted semiconductor quantum bit experiments for future quantum information processing. We demonstrated a reduction of nuclear-spin effects on quantum bit operations, simulations of quantum error corrections, and quantum non-demolition measurements.

Nano-Bio Hybrid Molecular Devices

● **Nano-Bio Molecular Devices (A. Hirano-Iwata)**

Our research activities focus on development of sophisticated molecular-scale devices through the combination of well-established microfabrication techniques and various soft materials, such as biomaterials and organic materials.

1. Development of a biosensor for evaluating drug side-effects on hERG channels based on artificial bilayer lipid membranes

   We developed a biosensor for quantitatively evaluating drug side-effects on hERG channels, to which binding of drugs leads to lethal arrhythmia. The biosensor utilized a bilayer lipid membrane (BLM) combined with a cell-free synthesized proteins. Using this system, we succeeded in quantifying drug inhibition effects on the hERG channels in terms of 50% inhibitory concentration.

2. Novel “transistor-like” devices based on a bio/organic hybrid membrane

   We fabricated an electrode-equipped Si chip, on which a fullerene-derivative-doped BLM was formed. Using this system, we were able to modulate the photoresponse of the membrane using the lateral bias applied from the electrodes on Si chip.

3. Biomimetic culture of primary neurons using an ultrasoft silicone gel

   We developed a novel system for culturing primary neurons on an ultrasoft silicone gel with an elastic modulus resembling that of the brain tissue. We showed that the hypersynchronous network activity could be suppressed on the gel surface.

Research Targets and Activities of Laboratory for Brainware Systems

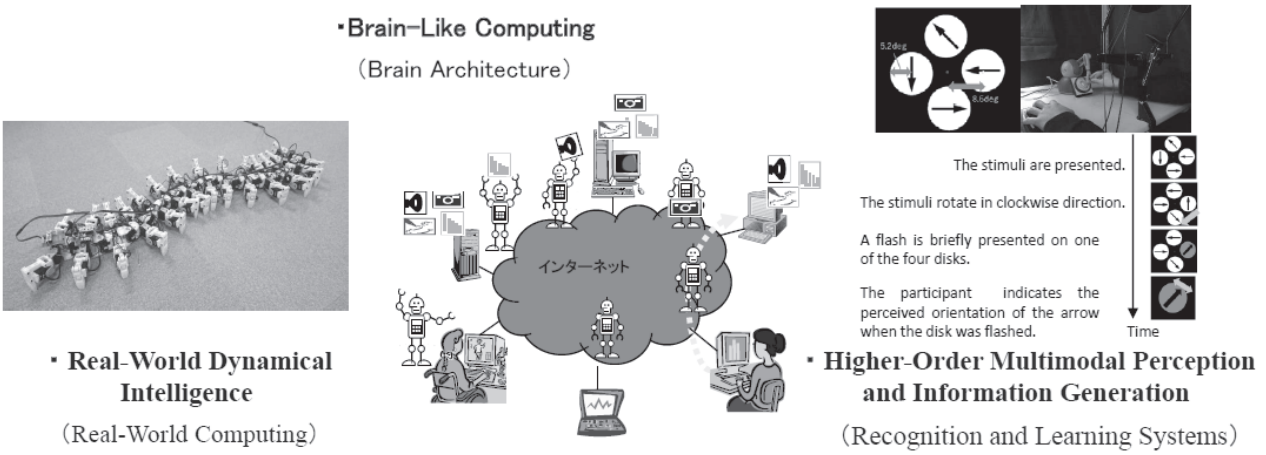
The Laboratory for Brainware Systems of the Research Institute of Electrical Communication was established in 2004 and renewed in 2014. Its purpose is to contribute to the research and development of advanced information science and technology for Brainware systems which realize a seamless fusion of the changeable and complex real world and the cyber space.

We aim at establishing scientific and technological foundations and at exploring human-like brainware computing applications for Adaptive Cognition and Action Systems Division (Recognition and Learning Systems Group), Autonomous Decentralized Control Systems Division (Real-World Computing Group), Brainware LSI Systems Division (New Paradigm VLSI System Group and Soft Computing Integrated System Group), and Brain Architecture Division. The Laboratory for Brainware Systems consists of the above four divisions which cooperatively carry out the research. At the same time, they serve as a laboratory for nation-wide cooperative research in the field of Brainware systems.

The technology developed in the Laboratory is expected to enhance the research carried out in the four Divisions of the Institute, and the research conducted in the Divisions, in turn, is expected to provide scientific basis for the information technology developed in the Laboratory.

Physical and Adaptive Hardware Environment

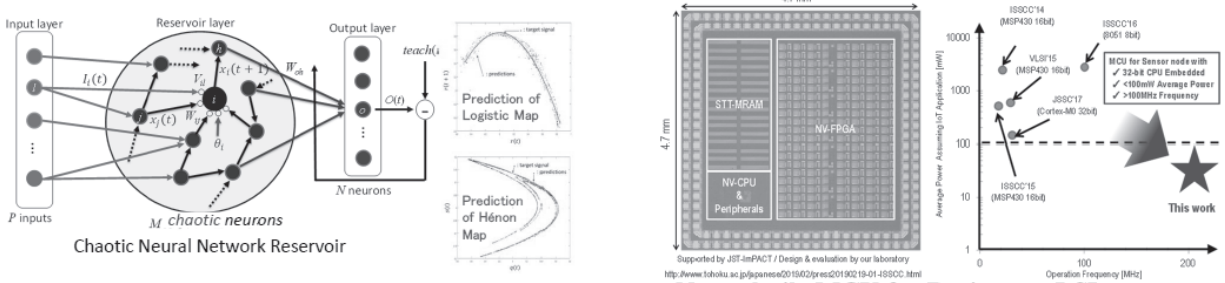
Seamless Fusion of Real World and Multi-Modal Computing



・**Real-World Dynamical Intelligence**
(Real-World Computing)

・**Higher-Order Multimodal Perception and Information Generation**
(Recognition and Learning Systems)

Hardware Environment with Massively Parallel Brain LSI



・**Brain Computing Based on Analog Neuro-Dynamics**
(Soft Computing Integrated System)

・**Nonvolatile MCU for Brainware LSI system**
(New Paradigm VLSI System)

[Research Target]

The goal of this facility is to develop fundamental technologies and their applications that will lead the world to the next-generation information system that seamlessly integrates the cyber-physical world and the ever-changing real world. In order to realize this goal, each laboratory participating in this facility has set the following individual goals and promotes research activities as follows:

Real-World Computing Section: The main contributions achieved in 2019 are summarized as follows: (1) we have clarified a decentralized control mechanism underlying amphibious locomotion of centipedes; (2) we have developed a brittle star-like robot that can coordinate flexible limbs; (3) we have proposed a decentralized control mechanism for the body-limb coordination underlying quadruped locomotion; (4) we have proposed a decentralized control scheme for versatile locomotion of snakes.

Contact to Professor Takahiro HANYU : hanyu@riec.tohoku.ac.jp

New Paradigm VLSI System Section: Rapid progress in recent deep submicron regime has led the capability to realize giga-scaled embedded systems on a chip (SoC), while performance degradation of SoCs due to wiring complexity, power dissipation and device-characteristic variation are increasingly getting serious problems in the recent VLSI chip. Our research activity is to solve the above problems primarily by the following two ways: the use of logic-in-memory architecture based on nonvolatile logic, and the use of asynchronous data-transfer schemes based on multiple-valued current-mode logic, which would open up a novel VLSI chip paradigm, called a "new-paradigm VLSI system."

Recognition and Learning Systems Section: Humans can perform various actions based on the recognition of the outside world that is constructed through multiple sensory inputs such as vision and touch, even though they frequently move their own body parts in the environment. Here we investigate the adaptive-process and functions of the human cognitive system for action through psychophysical experiments. On the basis of the experimental evidence, we aim to create computational models of the recognition and learning processes in the human brain.

Soft Computing Integrated System Section: We are working on a novel high-performance, highly-efficient, flexible, and robust brain-inspired brainmorphic computer hardware system, in particular, through physical complex-networked dynamical process using an analog VLSI as a core component. Toward the final goal, we are developing integrated circuit and device technologies suitable for the brainmorphic computer systems. We further intend to realize an autonomous brain-inspired computer with a sense of self and consciousness based on dynamic and complex changes in spatiotemporal network state and structure.

[Research Activities]

Aiming at the seamless integration of the cyber-physical world and the real world, which is the goal of Laboratory of Brainware Systems, the following research results were obtained. In particular, the following research results in fiscal year 2019 are an important step towards the goal as:

--Real-World Computing Section demonstrates "Navigating Land and Water: How Centipedes Walk and Swim" reported in Scientific Reports.
https://www.tohoku.ac.jp/en/press/navigating_land_and_water.html

--New Paradigm VLSI System Section achieves "Average 47μW Operation at 200MHz in a Nonvolatile Microcontroller Unit for Sensor-Node Applications" reported in Nikkei BP news.
https://xtech.nikkei.com/atcl/nxt/mag/ne/18/00001/00073/

--Recognition and Learning Systems Section demonstrates "Directional selectivity of auditory spatial attention" presented at ICA2019.
http://pub.dega-akustik.de/ICA2019/data/articles/001167.pdf

--Soft Computing Integrated System Section develops "Neuron and Synapse-Mimetic Spintronics Devices" reported in Advanced Materials.
http://www.tohoku.ac.jp/japanese/2019/04/press-20190415-AdvMater.html

The more detailed research results of each section (laboratory) are shown as follows:

Real-World Computing Section:
(refer to Real-World Computing Laboratory in Human Information Systems Division)

New Paradigm VLSI System Section:
(refer to New Paradigm VLSI System Laboratory in Systems & Software Division)

Recognition and Learning Systems Section:
(refer to Visual Cognition and Systems Laboratory in Human Information Systems Division)
(refer to Advanced Acoustic Information Systems Laboratory in Human Information Systems Division)

Soft Computing Integrated System Section:
(refer to Soft Computing Integrated System Laboratory in Systems & Software Division)

Recognition and Learning Systems Laboratory

Understanding the human recognition and learning systems

(Visual Cognition and Systems, Satoshi Shioiri, Professor)
(Advanced Acoustic Information Systems, Shuichi Sakamoto, Professor)

[Research Target and Activities]

To create computational models of the process that the human brain integrates multiple sensory inputs from the outside world, we are investigating the visual and auditory functions in the human brain for implementing these functions in hardware under biologically plausible settings. Our approaches include psychophysics, brain wave measurements, and computer simulations.

First, we applied the model of motion in depth based on interocular velocity difference (IOVD) we have proposed to a variety of psychophysical experiments of human perception. We found from the prexition that the IOVD model can explain higher sensitivity for direction in depth around the motion direction approaching directly to the head. The visual system is suggested to use IOVD cues to analyze motion in depth information for catching a ball approaching the head or avoiding being hit by an approaching rock.

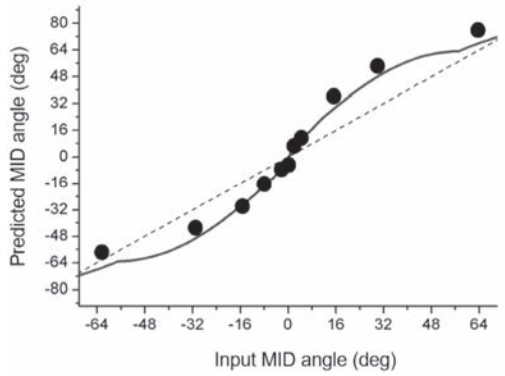


Figure. Model prediction (red line) of perceived motion direction in depth measured by human psychophysical experiment (black dots). The dashed line shows the veridical direction and the human data suggest higher sensitivity to the direction around zero, which is predicted the proposed model.

Second, we investigated how humans extract target speech information from distractor sounds by using auditory selective attention. We especially analyzed the effect of auditory selective attention in the spatial domain. The auditory spatial attention is one of the important mechanisms to realize cocktail party effects. By directing the attention to the specific direction, humans can extract the speech sound easily in multi-talker environment. We measured the shape of spatial window of auditory spatial attention and revealed that the shape does not depend on the direction where listeners direct their attention.

[Staff]

Professor: Satoshi Shioiri, Ph.D.
Professor: Shuichi Sakamoto, Ph.D.

[Papers]

1. R. Teraoka, S. Sakamoto, Z. Cui, Y. Suzuki, & S. Shioiri, “Directional selectivity of auditory attentional spotlight in complex listening environment,” Proc. The 23rd International Congress on Acoustics, 5764 - 5770 (2019)
2. R. Teraoka, S. Sakamoto, Z. Cui, Y. Suzuki, & S. Shioiri, “Temporal characteristics of auditory spatial attention on word intelligibility,” Acoustical Science and Technology 41(1) 394 - 395 (2020)
3. W. Wu, Y. Hatori, CH Tseng, K. Matsumiya, I. Kuriki, & S. Shioiri, “A Motion-in-depth model based on inter-ocular velocity to estimate direction in depth,” Vision Research (in press)
4. M. Harasawa, Y. Sawahata, K. Kominem, & S. Shioiri, “Effects of content and viewing distance on the preferred size of moving images,” Journal of vision 20(3) 6 - 6 (2020)

Research Center for 21st Century Information Technology

Research and Development of the IT-Based Practical Technology by the Industry-Academia-Government Collaboration

[Research Target and Activities]

The purpose of the IT-21 center is development of practical technologies for IT based on the advanced technologies of RIEC with the partnership among Industry, Government and University. The term of development is limited less than 5 years. The projects are planned on matching with both basic technologies in the University and application in the Industry. Combination of the technologies of the University and Industry makes practical technologies with availability for the commercial products. The center actively accelerates to obtain the intellectual properties generated from the development of practical technology to the Industry. Last year, the center was reformed and two divisions are newly established. One is "Interdisciplinary Collaboration Research Division" and it consists of two projects, "Research project of human value estimation of multimodal information based on informatics paradigm to manage both quality and value" and "Research project of spintronics/CMOS-hybrid brain-inspired integrated system". Another is "Challenging and Exploratory Research Division" and it consists of two projects, "Interactive drone content for entertainment / wildlife symbiosis" and "Wireless IoT Technology for a safe & secure mediciation management system". Former "Technology Development Division" was renamed to "Industry-Academia-Government-Collaboration Research and Development Division" and it consists of one group, "Wireless ICT platform project". Presently, following projects are carried out in this group.

・R&D on Technologies to Densely and Efficiently Utilize Radio Resources of Unlicensed Bands

From 2017, the mobile wireless technology group has started a project "R&D on Technologies to Densely and Efficiently Utilize Radio Resources of Unlicensed Bands in Dedicated Areas" supported by the Ministry of Internal Affairs and Communications. In this project, we are going to develop a real-time frequency monitor to avoid the interference between different wireless systems in dedicated areas such as factory or office. This year, we have developed an engineering model of miniaturized 0.8 to 6GHz-band/real-time spectrum monitor which can detect ms order burst signal/noise.

・R&D on Adaptive Media Access Control for Increasing the Capacity of Wireless IoT Devices in Factory Sites

From 2019, the mobile wireless technology group has started a new project "R&D on Adaptive Media Access Control for Increasing the Capacity of Wireless IoT Devices in Factory Sites" supported by the Ministry of Internal Affairs and Communications. In this project, we are going to develop a 5GHz-band simplified beam forming wireless IoT communication system using Wi-Fi backscatter.

[Staff]

Director: Noriharu Suematsu, Professor

Industry-Academia-Government-Collaboration Research and Development Division
(Wireless ICT platform project)

Noriharu Suematsu, Leader, Professor
Suguru Kameda, Associate Professor
Mizuki Motoyoshi, Assistant Professor
Takashi Shiba, Specially Appointed Professor
Yasunori Suzuki, Visiting Professor

Interdisciplinary Collaboration Research Division

Satoshi Shioiri, Project Leader, Professor
Takahiro Hanyu, Project Leader, Professor

Challenging and Exploratory Research Division

Yoshifumi Kitamura, Project Leader, Professor
Suguru Kameda, Project Leader, Associate Professor

IT21 Center Industry-Academia-Government-Collaboration Research and Development Division, Wireless ICT Platform Project

Dependable Air

Noriharu Suematsu, Professor (Project Leader)
Suguru Kameda, Associate Professor
Mizuki Motoyoshi, Assistant Professor
Takashi Shiba, Specially Appointed Professor

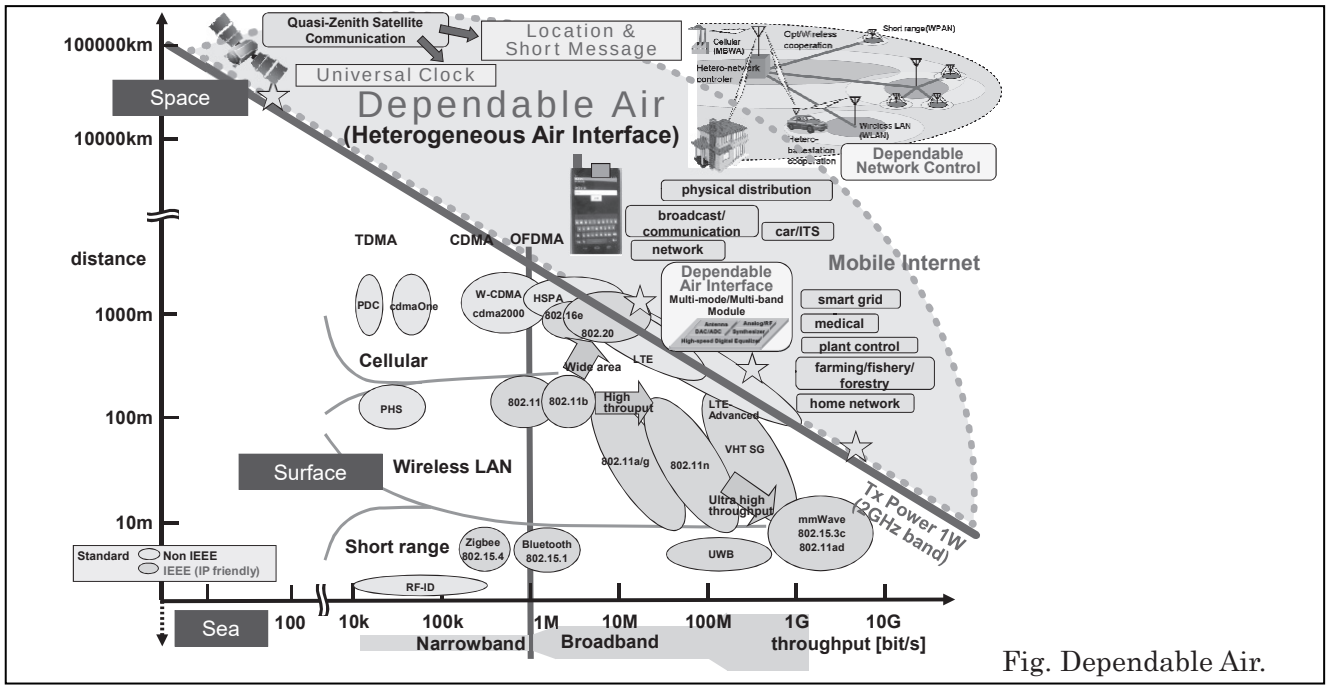


Fig. Dependable Air.

[Research Target and Activities]

Mobile wireless communication technology is one of the significant communication technologies that support the Information and Communication Technology (ICT) society, connected with the high-speed backbone network using optical fiber. Evolution of the mobile wireless communication technology in Japan is indispensable to keep the leadership in this technology area in the world. The mobile wireless technology group has been proposing the concept of "Dependable Air," which is a heterogeneous and highly-reliable wireless network. The Dependable Air is able to work even in the event of a big disaster. The group has started a R&D project "R&D on Technologies to Densely and Efficiently Utilize Radio Resources of Unlicensed Bands in Dedicated Areas" supported by the Ministry of Internal Affairs and Communications from 2017. The group has also started a new R&D project "R&D on Adaptive Media Access Control for Increasing the Capacity of Wireless IoT Devices in Factory Sites" supported by the Ministry of Internal Affairs and Communications from 2019.

[Staff]

Professor: Noriharu Suematsu, Ph.D
Associate Professor: Suguru Kameda, Ph.D
Assistant Professor: Mizuki Motoyoshi, Ph.D
Specially Appointed Professor: Takashi Shiba, Ph.D

[Papers]

[1] N. Suematsu, M. Motoyoshi, S. Kameda, N. Suematsu, Invited Paper, "Direct Digital RF Technology," IEICE Trans. Commun., Vol. J102–C, No. 11, pp. 297–304, Nov. 2019

Interdisciplinary Collaboration Research Division

Research project of human value estimation of multimodal information based on informatics paradigm to manage both quality

Satoshi Shioiri, Dr. Professor
Nobuyuki Sakai, Dr. Professor

[Research Target and Activities]

Human facial expression is related to emotion, perception, cognition, decision and so on. We attempted to predict human preference judgments of images using machine learning methods from facial expression while participants were evaluating image contents. We compared performance of three machine learning methods, and found that facial expression provides useful information for estimating human judgments.

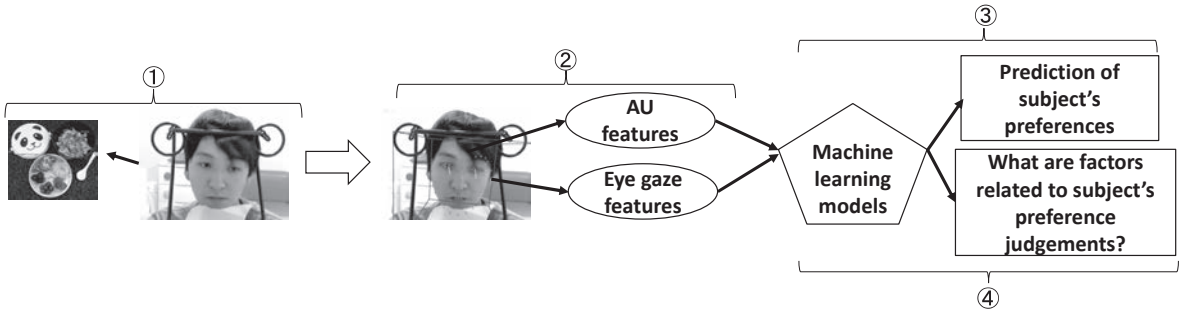


Fig. 1 Estimation of human preference judgments from facial expressions and eye gazes.① Subjective judgments: evaluation of two questions for lunch box images. ② Facial expression analysis ③ Prediction of subject's preference by some machine learning models. ④ Investigation of the factors related to subject's preference judgements.

[Staff]

Professor : Satoshi Shioiri, Dr.
Professor : Nobuyuki Sakai, Dr.
Assistant Professor : Kosuke Yamamoto, Dr.

[Profile]

Satoshi SHIOIRI Professor Shioiri graduated Tokyo Institute of Technology and received Dr. Eng in 1986. In 2005, he joined Tohoku University and he has been a professor of Research Institute of Electrical Communication of Tohoku University since then.

Nobuyuki Sakai graduated from Graduate School of Human Sciences, Osaka University in 1998. Then he worked at Hiroshima Shudo University and National Institute of Advanced and Industrial Science and Technology (AIST) , Kobe Shoin Women's University. He, then, moved to Sendai in October 2011, and he is a professor of Graduate School of Arts and Letters of Tohoku University now.

[Papers]

[1] H. Mattout, H. Wang, Y. Hatori, Y. Sato, K. Matsubara, Y. Wada, C. H. Tseng, I. Kuriki, S. Shioiri, Convolutional Neural Networks for humanlike Image Assessment, I-PERCEPTION 10 170 - 170, September, 2019, APCV 2019, Osaka
[2] Y. Horaguchi, Y. Sato, CH Tseng, I. Kuriki S. Shioiri, Estimation of preferences to images by facial expression analysis, IEICE Technical Report, vol. 119, no. 348, HIP2019-66, pp. 7-12
[3] N. Sakai, Top-down processing in food perception: Beyond the multisensory processing,Acoustical Science and Technology, 42, 182-188, 2020, DOI: 10.1250/ast.41.182

Exploratory Research Division

Interactive Drone Content for Entertainment / Wildlife Symbiosis

Yoshifumi KITAMURA, Professor

[Research Target and Activities]

This project aims to develop core technologies of interactive drone content for real industrial use including entertainment and wildlife symbiosis, through close industry/academia/government cooperation. It is expected to support continuous development of drone technologies through this innovation and produce new industry and services in response to societal needs.
The followings are current research projects:
(1) Development of intuitive user interface for a drone pilot
(2) Development of crow-type-drone to communicate with crows.
(3) Techniques for video sharing and distribution for enhancing entertainment of drone race.

[Staff]

Professor: Yoshifumi Kitamura, Dr.

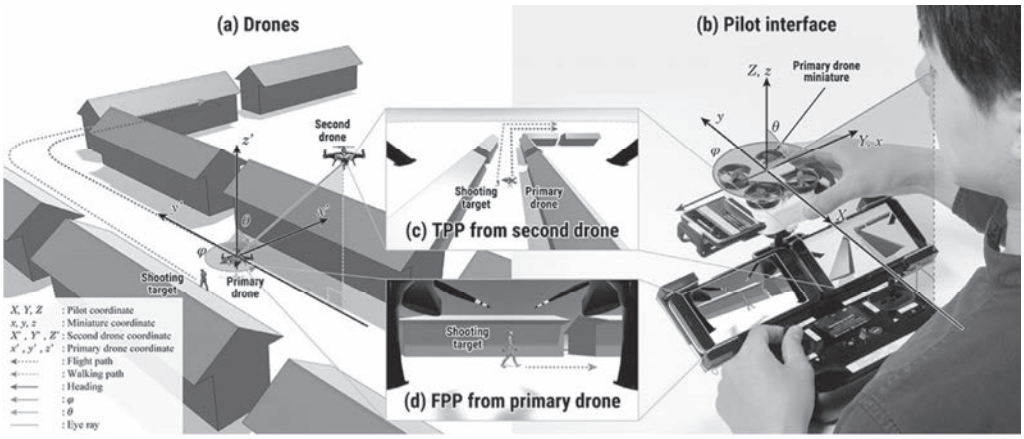
[Profile]

Yoshifumi Kitamura: Since 2010, Yoshifumi Kitamura has been Professor in the Research Institute of Electrical Communication, Tohoku University. Prior to arriving at Tohoku, he was an Associate Professor at Graduate School of Engineering, and Graduate School of Information Science and Technology, Osaka University. While working at ATR Communication Systems Research Laboratories, he focused on sophisticated user interfaces in virtual environments. His first formal appointment was in the Information Systems Research Center Canon Inc., where he was involved in research on artificial intelligence, image processing, computer vision, and 3D data processing. His formal education was obtained at Osaka University, B.Sc (1985); M.Sc. (1987); and Ph.D. (1996).

[Papers]

[1] Ryotaro Temma, Kazuki Takashima, Kazuyuki Fujita, Koh Sueda, Yoshifumi Kitamura: Third-Person Piloting: Increasing Situational Awareness using a Spatially Coupled Second Drone, P*roceedings of User Interface Software and Technology (UIST)*, 507-519, October 2019.

[2] Keisuke Imoto, Naoki Tsukahara, Ken Nagataand Koh Sueda: Crow sound detection based on gated convolutional recurrent neural network, Acoustical Science, Vol. 75, No. 10, 559-567, 2019.



IT21 Center
Exploratory Research Division

Wireless IoT Technology for a Safe & Secure Medication Management System

Safe & Secure Medication Management System using Wireless IoT Technology

Suguru Kameda, Associate Professor (Project Leader)
Noriharu Suematsu, Professor
Takahiro Hanyu, Professor
Kazushi Ishiyama, Professor
Naofumi Homma, Professor
Qiand Chen, Professor
Mizuki Motoyoshi, Assistant Professor

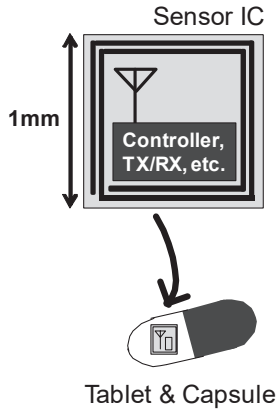


Fig.1 Battery-less tablet-pasting-type sensor

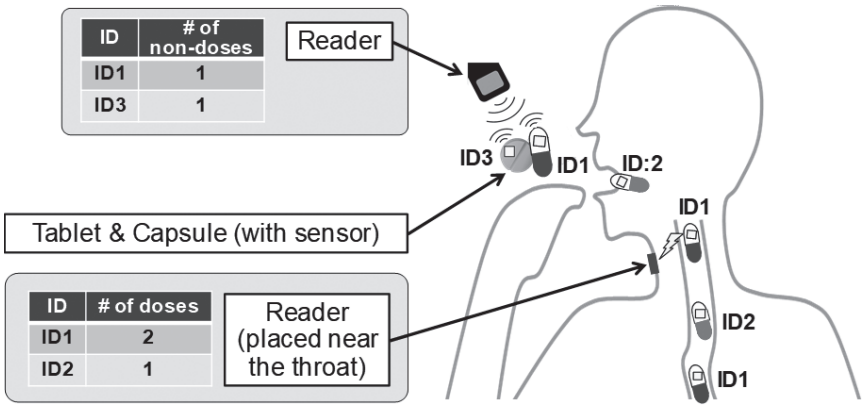


Fig.2 Safe medication management system

[Research Target and Activities]

Medical costs that continue to increase with progress in aging society and medical advances are serious social problems on the worldwide scale. In order to reduce medical expenses, it is indispensable to construct a medication management system that enables inventory control and confirmation of ingestion.

This division conducts exploratory research on establishing a safe medication management system using wireless IoT technology. The goal of this research is the realization and practical implementation of system construction that allows patients to take medication management just by taking tablet-type medicine. In this research, we are now studying for the battery-less tablet-pasting-type sensor by applying wireless IoT technology.

In this year, we developed low power ASK transmitter for wireless transceiver of battery-less sensor node. The fabricated IC using 65nm bulk CMOS process performs 60.7 GHz with 180 μW power consumption with 50 Mbps.

[Papers]

[1] M. Motoyoshi, *et al.*, "60 GHz 180 μW Power Consumption CMOS ASK Transmitter Using Combined On-Chip Resonator and Antenna," IEICE TRANSACTIONS on Electronics , vol. E102-C, no. 10, pp. 725-739, Oct. 2019.

Management Office for Safety and Health

Realizing and Maintaining a Safe and Comfortable Environment to Support Research

[Research Target and Activities]

Safety and health seminar

First aid training course

1. Outline of the Management Office for Safety and Health

The Management Office for Safety and Health is established to maintain the safety and health of students and staff working at the institute. The use of chemicals, high-pressure gas and radiation in research activities at the institute entails many risks. The Management Office for Safety and Health provides support for safety and health management in research laboratories, experimental facilities and the Fundamental Technology Center through various activities to ensure safe and smooth research activities within the institute.

2. Activities by the Management Office for Safety and Health

For the actual management of safety and health at the office, the Safety and Health Committee first presents the basic policies of safety management at the institute, and the Management Office for Safety and Health then plans and executes activities based on them. At the institute, laboratories and other individual sections are highly independent of each other; unlike a general corporate organization, top-down safety management is not suitable and measures appropriate for independent sections need to be taken. Various considerations are also necessary for students, researchers, and other members engaged in research activities as well as faculty staff. At this institute, extremely hazardous materials and facilities are used, including chemicals, high-pressure gas, and X-ray devices. Since there is also a clean room and other special workplaces, safety management should be extended by considering them. In these circumstances, the Management Office for Safety and Health will monitor situations and characteristics in each section at the institute, plan and recommend practical management methods and improvement measures, and support their implementation for the efficient and effective management of safety and health. The main activities in this fiscal year are as follows:

- ○ Holding safety and health seminar and high-pressure gas seminar for staff and students at the institute
- ○ Inspection of and assistance in improving the safety and health management system and working environment within the institute
- ○ Holding first aid training course
- ○ Investigation of laws related to safety and health and collection of information regarding safety and health management
- ○ Providing advice and information to safety and health personnel in each department

[Staff]

Manager: Kazushi Ishiyama, Professor

Deputy Manager: Yoichi Uehara, Professor

Nobuyuki Sato, Assistant Professor

Maho Abe, Technical Staff　　Haruka Takahashi, Clerk

Flexible Information System Center

Development and Management of Flexible Information System

[Research Target and Activities]

The present information systems represented by computers are inflexible systems, because their uses are predefined and they provide only the fixed processing and functions. The flexible information system on the other hand, is a system which can perform the flexible information processing adapted to the human intention and situation of its environment beyond the limitations of the principles of the inflexible information processing. The aims of this center are to manage and operate information networks and systems based on the concept of the flexible information system, and support smooth research activities of RIEC.

Figure 1 RIEC network system

Moreover, utilizing technical know-how acquired through applying the information networks and systems to practical use, we also design and construct a leading-edge system for advanced organization, utilization, administration, operation and dispatching of scientific information.

1. Information collection, organization, dispatching, utilization and research support environment.
2. Advanced maintenance, management and operation of network.
3. Technical supports for information networks and systems in the institute.

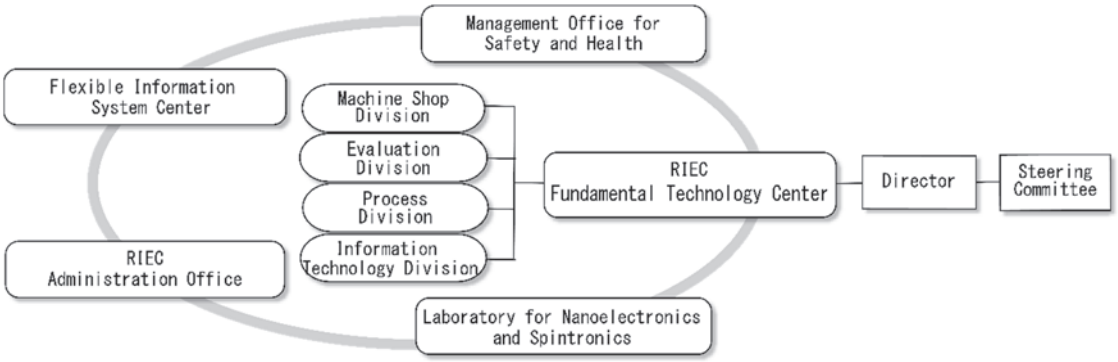
[Staff]

(1) Steering Committee
Professor: Atushi Ohori, Dr., Masafumi Shirai, Dr., Takuo Suganuma, Dr., Hiroshi Yasaka, Dr., Akio Ishiguro, Dr., Go Hasegawa, Dr.

(2) Regular Staff
Associate Professor: Gen Kitagata, Dr.
Technical Official: Masahiko Sato, Kenji Ota
Technical Support Member: Mutumi Syutou, Riho Ooizumi

Fundamental Technology Center

Supporting research with high-level specialized knowledge and technology



Overview of the Fundamental Technology Center

[Research Target and Activities]

The Fundamental Technology Center provides a wide range of technical support for research and development through four divisions: Machine Shop Division, Evaluation Division, Process Division, and Information Technology Division. The following is a summary of the activities of the divisions of the Fundamental Technology Center for the current year.

1. Machine Shop Division

Following requests from researchers, the Machine Shop Division supplied 128 machining products. About 27% of the requests were from outside the institute.

2. Evaluation Division

The 22 laboratories utilized the evaluation and measurement apparatuses for shared usage (the utilization time was 4585 hours). Four glass processing products were supplied. Technical assistance was provided on the use of liquid helium and 583 liters of liquid nitrogen were supplied. In cooperation with the administration and the management offices for safety and health, this division also engaged in safety maintenance of the institute.

3. Process Division

In cooperation with the technical office, a section of the Laboratory for Nanoelectronics and Spintronics, 141217 Electron-beam lithographic products, of 141 and photomask of 25 photomasks and 8 focused-ion-beam micro products were supplied in cooperation with the technical office, a section of Laboratory for Nanoelectronics and Spintronics. Technical supports were provided for operating the clean room of the Laboratory for Nanoelectronics and Spintronics.

4. Information Technology Division

This division operated the in-house network at the institute and maintained shared-use-information-equipment, in cooperation with the Flexible Information System Center. This division also engaged in the contracting aspects of collaborative research based on intellectual property rights and gave advice to researchers who tried to apply for the grant of patents.

[Staff]

Director (Professor): Shigeo SATO.

Assistant Professor: Nobuyuki SATO.

Technical Officials: Tamotsu SUENAGA, Kento ABE, Yasuaki MAEDA, Kana SEKIYA, Maho ABE, Takenori TANNO, Hiroyuki YAGYU, Iori MORITA, Rikima ONO, Michimasa MUSHA, Masahiko SATO, Yuko MARUYAMA, Kenji OHTA, Koichi SHOJI.

Ad-hoc research groups

Taking advantage of the wide range of expertise in the institute, ad-hoc research groups are formed outside of the formal organizational structure to investigate challenging exploratory topics and needs-based, cutting-edge subjects.

[Group of multimodal attention]

Selecting information obtained through sensory organs by attention is inevitable to live the complicated world with dynamic changes. A number of studies have investigated the mechanisms of attention related to cognitive processes, and little is known about attention effect on action. This research group investigates representation of space in the brain, which expresses the outside space based on multiple sensory information. We hypothesize that attention in the multi-sensory spatial representation is crucial to select action. We investigated interaction between visual and auditory attention and found the effect of visual attention on auditory perception. We also started to investigate method to measure self-initiated attention as the KAKENHI (Grant-in-Aid for Scientific Research (A)) project entitled 'Control of audiovisual attention by spontaneous attention,' which was accepted in 2019.

[Cyber-Physical Security Research Group]

For the next-generation information and communication infrastructures such as IoT, M2M, and CPS, we aim to developing advanced information security technologies to ensure security and reliability at the level of vast and diverse information sources (i.e., embedded devices such as sensor terminals) in a vertically integrated manner by various researchers from the viewpoints of software constitutive theory, system security, hardware security, circuit architecture, next-generation microprocessor, and so on. In this year, we continued discussion about our goal and research direction with several seminars and meetings.

[Brainmorphic Nano-Devices and Circuits Research Group]

Brain-inspired hardware systems have been actively developed recently. However, a big break-through to the true brain-like system has not been reached yet. This research group aims at development and implementation of novel brainmorphic computational hardware that reproduces the bio-physics and dynamics in the brain directly through dynamics and physics of nano-devices and ultra-low-power integrated circuits based on the latest physiological knowledge. In this year, we continued discussions on a basic strategy to propel collaborative researches on brainmorphic hardware and biotronics from broad perspective that includes brain science, spintronics, analog/digital integrated circuits, cultured neurocyte, and nonlinear complex dynamics. As a result, we succeeded to obtain large research grants including JST CREST, JSPS KAKENHI (Grant-in-Aid for Scientific Research (S) and (A)). In addition, our activities lead to further applications for KAKENHI (Grant-in-Aid for Transformative Research Areas, and another Grant-in-Aid for Scientific Research (S) (Both of them are under examination)).

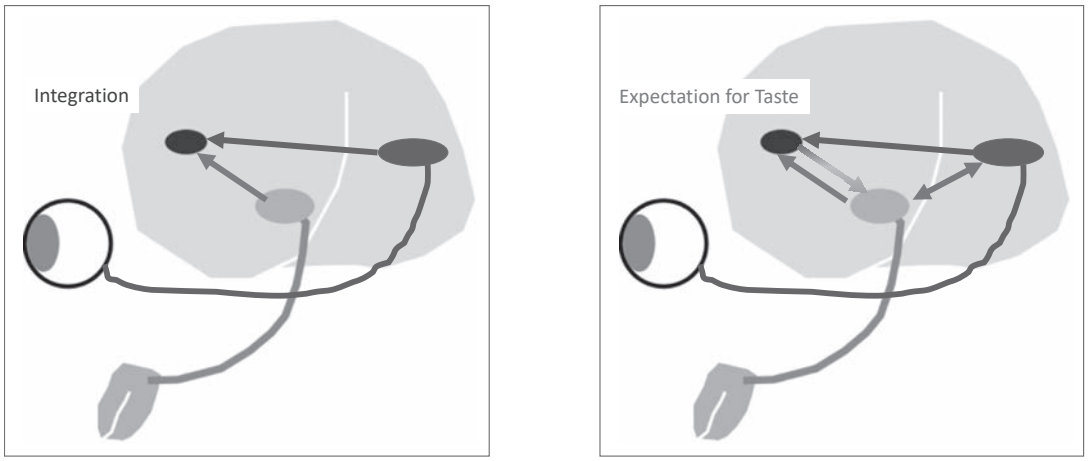
[Group of developing the AI clone system]

The aim of the group is to adopt knowledge of the cognitive science to AI (artificial intelligence) and AR (augmented reality) technology. Specifically, we develop "AI clone", which is the model of recognition and action characteristics of a person. AI clone enables others to re-experience the target person's recognition and action with AR interface. Our goal is to establish the new communication technology that improves mutual understanding among people with differences in a variety of aspects, using AI clone and AR interface. We applied KAKENHI (Grant-in-Aid for Challenging Research) grant to investigate action property of person with visual deficits.

Division for the Establishment of Frontier Sciences

Multimodal Cognitive System Division

Research project on multimodal information integration based on food perception.



Classical Bottom-Up model for perception of food

Top-down model for perception of food in this research

Fig. 1 The model adapted in this research is shown in right panel. The perception of food is based on interactive top-down processing of multimodal sensory inputs, not on simple integration of sensory inputs.

Nobuyuki Sakai, Dr. Professor

[Research Target and Activities]

In this year, we have done some experiments about the followings; the interaction between food texture and kinetic sensation of masticatory muscle; the difference of olfactory perception via orthonasal route with retronasal route; the effects of visual stimuli on olfactory brain processing investigated by fMRI and fNIRS, etc. We have also started the cognitive studies about the effect of audition on binocular rivalry, the differences of attentional system of vision and of audition, the interactive mechanisms of audition with somatosensation, and the comparison of the effects of vision with audition on affection and arousal.

[Staff]

Professor : Nobuyuki Sakai, Dr.
Assistant Professor : Kosuke Yamamoto

[Profile]

Nobuyuki Sakai graduated from Graduate School of Human Sciences, Osaka University in 1998. Then he worked at Hiroshima Shudo University and National Institute of Advanced and Industrial Science and Technology (AIST) , Kobe Shoin Women's University. He, then, moved to Sendai in October 2011, and he is a professor of Graduate School of Arts and Letters of Tohoku University now.

[Papers]

[1] T. Onuma and N. Sakai, Choosing from an Optimal Number of Options Makes Curry and Tea More Palatable, Foods, 8, 145, 2019 doi:10.3390/foods8050145
[2] N. Sakai, Top-down processing in food perception: Beyond the multisensory processing, Acoustical Science and Technology, 42, 182-188, 2020, DOI: 10.1250/ast.41.182
[3] N. Sasaki and N. Sakai, Activity in the cerebral corticies accompanying emotional arousal, Tohoku Psychologica Folia, 78, 34-45, 2020

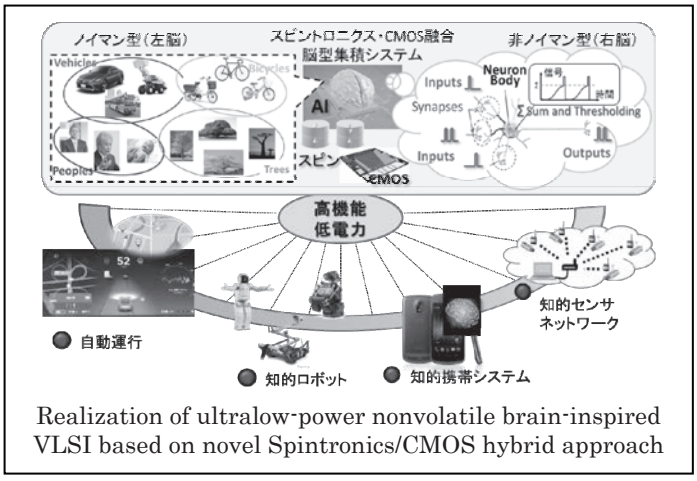
Spintronics/CMOS Hybrid Brain-Inspired Integrated Systems

Ultralow-power Spintronics/CMOS hybrid Brain-inspired VLSI for Edge Devices

Spintronics/CMOS Hybrid Brain-Inspired Integrated Systems　Tetsuo Endoh, Professor

[Research Target and Activities]

The purpose of our research activity is to break ground for a new AI hardware approach across from the fundamental science of material and information to the devices, circuits, architecture and software technology to develop the novel high efficient and low power brain-inspired computing hardware system for precise and real-time processing of information value judgment, choice, and refusal. This year, we completed building the design platform for 300-wafer 55nm-MTJ Spintronics/CMOS hybrid Brain-inspired circuit. Moreover, in the "von Neumann" approach, we well established the key component technology – "spike-driven high-speed power gating" with the demonstration of our previously designed nonvolatile multi-core associative processor system for the power consumption reduction of VLSI engines employing spike neural network architecture. Furthermore, in the "non-von Neumann" approach, we proposed and elementarily verified our novel nonvolatile mixed-signal SNN core architecture based on the 4T-2MTJ synapses for ultralow-power object recognition accelerators in battery-driven edge devices.



Realization of ultralow-power nonvolatile brain-inspired VLSI based on novel Spintronics/CMOS hybrid approach

[Staff]

Professor : Tetsuo Endoh, Ph.D.
Assistant Professor: Yitao Ma, Ph.D.

[Profile]

Tetsuo Endoh received the Ph.D. degree in electronic engineering from Tohoku University in 1995. He joined Toshiba Corporation in 1987 and became a Lecturer at the RIEC, Tohoku University, in 1995, an Associate Professor in 1997, and a Professor in April 2008. From 2012, he has been a Professor at the Graduate School of Engineering and director of CIES and CSIS, Tohoku University. He is a JSAP Fellow. He was the recipient of the LSI IP Design Award (2001), the JJAP Paper Award (2009), the 6th Fellow Award of the JSAP (2012), and the SSDM Paper Award (2012), the 14th Prime Minister's Award for its Contribution to Industry-Academia-Government Collaboration (2016), and National Invention Award (2017).

Yitao Ma received the Ph.D. degree in electronic engineering from The University of Tokyo, in 2011. He works in Tohoku University as an Assistant Professor of the Graduate School of Engineering from 2018, and then an Assistant Professor of the RIEC since 2019. He has been the key member of many projects such as JST-CREST, CSTI-FISRT, JST-ACCEL, CSTI-ImPACT, JST-OPERA, and CSTI-SIP.

[Papers]

[1] Tetsuo Endoh, ISSCC 2020 Forum, San Francisco, USA, February 16 2020.
[2] Tetsuo Endoh, IEEE CPMT Symposium Japan 2019, Kyoto, Japan, November 19 2020.
[3] Yitao Ma, et al., JJAP, Vol. 59, No. 59, SGGB18(1-11), March 2020.
[4] Yitao Ma, et al., SSDM 2019 , Nagoya University, Aichi, Japan, September 4-9 2019.

Center for Science and Innovation in Spintronics (CSIS)

＜Overview＞

Establishment: January 30, 2018

Organization: Director: Yoshio Hirayama (Professor, Graduate School of Science)
Number of academic members: 39 (concurrent members from Grad. School of Science, Grad. School of Engineering, IMR, RIEC, IMRAM, AIMR, FRIS, CSIS, CIES, and CSRN, Tohoku University)

Mission: Creation of world-leading research center pioneering in so-called “Spin-Centered Science” by strategic consolidation of excellent researchers from foreign leading universities in fundamental and applied fields.

Research activities:
Spin-centered fundamental science, advanced spintronic materials, spintronic devices, and integration technology of spintronic devices.

＜Major activities in FY2019＞

・Leading innovation in spintronics

Excellent 15 proposals were adopted to the cooperative research projects in CSIS were adopted to promote international collaborations as well as those beyond the organizations at Tohoku University. In particular, additional budget was provided to the 4 most excellent proposals to accelerate the collaborations.

・Employing excellent young researchers

Excellent young researchers including 4 assistant professors from foreign countries and 2 posdoc researchers were employed in CSIS to promote collaborations beyond the organization at Tohoku University.

・Promoting international academic exchange

International workshops were held to promote academic exchange between CSIS and foreign leading universities; University of York (in May, 2019), Purdue University, Lorraine University, and Mainz University (in September, 2019). The 3rd Symposium for the Core Research Clusters for Materials Science and Spintronics was held at Sendai International Center in February, 2020. More than 250 participants including speakers invited from 10 countries attended the symposium.

Center for Innovative Integrated Electronic Systems (CIES)

＜Overview＞

Establishment: The CIES was established in October 2012 to enhance industry-academia collaborations and contribute to further development of the electronics industry. The building of the CIES was constructed in March 2013 as the first Science Park in this country by a private donation located in Aobayama New Campus at Tohoku University.

Organization: Director: Tetsuo Endoh (Professor, Graduate School of Engineering)

Number of staff: 80 (including appointments across Graduate School of Engineering, Graduate School of Information Sciences, RIEC etc.)

Mission: The CEIS researches and develops integrated electronic technologies with various research seeds that Tohoku University has and abundant results of industry-academia collaboration as centripetal force. And the CIES pursues to contribute to the enhancement of global competitiveness in the field of next generation integrated electronics systems by establishing an international industry-academia collaboration base. Further, the CIES aims for practical use of the technologies in this field and is aiming to create new industries.

Research topics: Research and development by industry-academia joint research projects, national research projects, community-based cooperation projects and so on, the CIES promotes the following research and development themes; 1) IT field centered on from next-generation semiconductor memory to electronic device components such as high-performance printed-circuit board, packaging, and image processing technologies, and 2) car-electronics field including electronic automotive components.

＜Major activities in FY2019＞

CIES has managed the “CIES consortium” which consists of industry–academic collaborations, major national projects (CAO SIP 2nd, JST OPERA, JSPS Core-to-Core, NEDO projects and JAXA Space Exploration Innovation Hub) and community-based cooperation projects in cooperation with various international and domestic companies from material, equipment, devices and system aiming for the practical applications of innovative core technologies created by Tohoku University. The research and development field has been expanded from spintronics to AI hardware and power electronics, and the industry-academic collaborations have been significantly expanded from seven to eighteen. Companies participating in the CIES consortium have been steadily increasing and the consortium has grown into the world's largest one in this research field. Here, these companies utilized “a special private-sector investment promotion zone system (for information service-related industries)” under a joint application from Miyagi prefecture and local municipalities, and “financial assistance according to the amount of property tax paid (created under an agreement between Tohoku University and Sendai City)”.

CIES has developed a variety of innovative technologies with world-first 300mm wafer process line and facilities operated by the university for prototype manufacturing and characterizing spintronics integrated circuits compatible with world-class companies, and has made progress in developing IoT and AI systems that

require ultra-low power consumption. Specifically, we succeeded in developing a 128Mb STT-MRAM for cache applications with the world's highest write speed performance (14 ns), and a highly reliable magnetic tunnel junction device (MTJ) for the 1Xnm generation that can extend the data retention time by one million times compared to the conventional technology at 125°C under the environment of 150°C which is the automotive specification. We have also demonstrated the world's first high-performance, low-power, non-volatile spintronics microcomputer with less than 50μW at 200MHz. Industry-academic collaborations on next-generation power devices has also made significant progress, confirming the high-frequency operation of ultra-small inverters using GaN on Si power devices, which is expected to greatly contribute to the electrification of automotives and power savings in data centers. We utilize the two core technologies of spintronics technology and power electronics technology, which are the world's most advanced technologies that we have researched and developed at CIES, and aim to develop IoT / AI systems that are indispensable for the realization of Society 5.0 and require ultra-low power consumption.

In addition, aiming to contribute to the development of the innovative integrated electronics business and further advancement of industry-academia collaboration, Prof. Tetsuo Endoh founded Tohoku University venture, "Power Spin Corporation". In the regional collaboration, we promoted a technology matching program for regional and local companies with cooperation of Miyagi Prefecture, Iwate Prefecture etc., which resulted in a progress of commercialization and contributed to rebuild the Tohoku area and assist the region.

In order to establish world leading R&D base for integrated electronic systems and AI hardware, we will continue to create innovative core technologies and contribute to the industry and the enhancement of global competitiveness by the practical applications, and “new creation and innovation” through global and regional partnership.

Research Organization of Electrical Communication（ROEC）

Towards Construction of Disaster-Resistant Information Communication Network

[Purpose of our establishment]

Many serious problems have become clear as a result of the Great East Japan Earthquake, which exposed the weaknesses of the most advanced information communications network in the world by severing the mobile phone and optical fiber lines thus cutting off essential telecommunications services. To solve these problems, Tohoku University's Disaster Reconstruction and Regeneration Research Project includes an ICT Reconstruction Project for restoring information communication. The mission given to the researchers in the Electrical Engineering and Information Sciences group after the disaster was to achieve a disaster-resistant information communication network through the ICT Reconstruction Project, taking the needs of the disaster areas into consideration.

To realize this network, we needed to employ the combined strength of our problem-solving abilities by linking researchers in electrical engineering and the information sciences across multiple faculties, including the School of Engineering, the Graduate School of Information Sciences, the Graduate School of Biomedical Engineering, the Cyberscience Center, and the Research Institute of Electrical Communication. These faculties and schools came together to form a new organization that could create close and flexible links between researchers and organizations, and on October 1, 2011 we established the Research Organization of Electrical Communication (ROEC) (Fig.1). The ROEC intends to take an all-Japan approach based on collaboration between industry, academia and government, and assemble expertise from the university with the participation of related local governments, private companies, public research organizations, and other universities with the goal of developing the most advanced disaster-resistant information communication network in the world (Fig.2).

[Main Activities]

Since 2012, we have been promoting 12 disaster-resilient ICT projects supported by the Ministry of Internal Affairs and Communications. In 2019, seven ongoing and three novel projects were promoted. We have also been engaged in project supported by OPERA, JST. In addition, we carried out lecture to the local governments, etc with "Disaster-resistant ICT introduction guidelines" revised by the Disaster Resistant ICT Research Council. The research results produced by the promoted projects were presented in ROEC Newsletters published in 2019.

Fig.1 Research Organization of Electrical Communication.

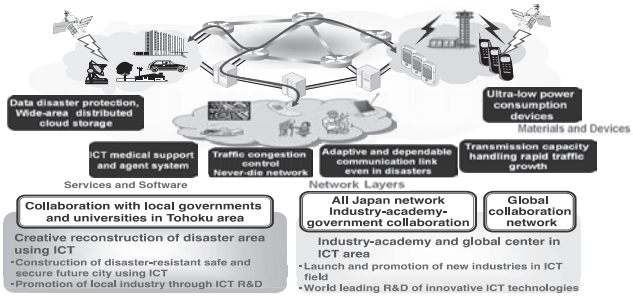


Fig.2 Overview of ICT Reconstruction Project.

[Staff]

Prof. Hirohito Yamada (Executive Director)
Prof. Taiichi Otsuji (Vice Executive Director)
Specially Appointed Prof. Hiroyuki Ogawa (Vice Executive Director)
Specially Appointed Prof. Katsumi Iwatsuki (Research Administrator)
Mr. Masato Kaneko (Office Manager)
Ms. Ayako Murakami (Manager)
Ms. Izumi Ishikawa (Secretary)

[Papers]

[1] F. Adachi, "Wireless Evolution Towards 5G," (Keynote) International Symposium on Networks, Computers and Communications, Nisantasi University, Istanbul, Turkey, 18-20 June, 2019..

[2] Morihiko Minowa, Hiroyuki Seki, Yukihiko Okumura, Satoshi Suyama, Jun Terada, Satoshi Shigematsu, Yasushi Takatori, Hiroaki Asano, Yukio Hirano, Yasushi Yamao, Fumiyuki Adachi, and Masataka Nakazawa, "5G R&D Activities for High Capacity Technologies with Ultra High-Density Multi-Band and Multi-Access Layered Cells," in Proc. IEEE VTC Spring 2019, Kuala Lumpur, Malaysia, April, (2019).

[3] T. Kan, M. Yoshida, K. Kasai, T. Hirooka, K. Iwatsuki, and M. Nakazawa, "Demonstration of on-line bi-directional 10-RRHs with an 80Gbit/s/RRH capacity using 256 QAM WDM coherent transmission for next generation mobile fronthaul", presented in Radio Access Networks Session, ECOC2019.

Center for Spintronics Research Network (CSRN)

＜Overview＞

Establishment: April 1, 2016

Organization: Director: Koki Takanashi (Director, Professor, IMR)

Number of academic members: 67 (including 2 full-time members and the other concurrent members from Grad. School of Science, Grad. School of Engineering, IMR, RIEC, IMRAM, AIMR, CSIS, CIES, and FRIS, Tohoku University)

Mission: The center will be the hub of a network to promote collaborations with other research institutions within Japan and overseas, aiming to (1) improve competitiveness of world-leading spintronics research in Japan, (2) create new branches and enhance existing areas of industry, and (3) foster the next- generation human resources.

Research activities:

[Spintronics Device Creation Division]

We develop advanced systems and devices for energy creation and energy saving by using spintronics technology to provide eco-friendly infrastructure and to innovate conventional information and communication technology.

[Spintronics Device Characterization Division]

We develop advanced measurement techniques to characterize the behavior of spins in integrated spintronics devices. We also clarify the physical mechanism of the behavior of spins in spintronics devices theoretically to propose innovative spintronics devices.

＜Major activities in FY2019＞

・Cooperative Research Project

We adopt 58 cooperative research projects to promote collaborations with other spintronics researchers. The collaborators belong 40 institutions in Japan and 22 overseas institutions (in 11 countries). For detail, see the following URL: http://www.csrn.tohoku.ac.jp/

・Academic Meetings

For promoting exchange and fostering human resources of spintronics researchers, CSRN jointly hosted 6 international conferences, 4 domestic workshops, and 6 seminars/schools. A series of CSRN seminars has been started as a new activity. In FY2019 three CSRN seminars were held by inviting the speakers from domestic and overseas institutions.

Advanced Institute for Yotta Informatics

＜About the Center＞

Establishment：April 1, 2018

Based on research activities as a Program for Key Interdisciplinary Research of Tohoku University from 2015 to 2017, Advanced Institute for Yotta Informatics was granted by MEXT in 2018.

Organization：Director: Satoshi Shioiri (Director, Professor, RIEC)

Number of members: 34 (RIEC, Graduate School of Engineering, CIES, Graduate School of Arts & Letters, Graduate School of Information Sciences, Graduate School of Economics and Management, Graduate School of Biomedical Engineering, Graduate School of Education, Graduate School of Life Sciences)

Research Target：Novel science and technology to manage both quantity and quality of yotta-scale information, in order to establish the future ICT technology and new humanics by collaborative work of engineering and human and social science.

Research Activities：The amount of information is rapidly increasing, which is projected to reach to the amount of one yotta (10^{24}) bytes. Ordinary extension technology of the conventional ICT cannot cope with such gigantic amount of information, therefore essential paradigm change for the information processing is indispensable. In this institute, we aim at the new information science, which can manage the quality of information as well as the information amount. For the sake, experts of information engineering, human and social science from departments are discussing about interdisciplinary collaborating works to understand the quality and value of information, as well as the quantity. The value information is the key properties for the future informatics to receive the full benefit of the information in the upcoming “beyond the big data” era.

＜Major Achievements in 2019＞

1. We have started or continued 9 interdisciplinary projects that lead the new information science, which can manage the quality of information as well as the information amount and select important information appropriately. We published 81 papers and 125 presentations (including 35 invited talks), and proceeded with 19 external grants in this year.
2. We co-organized a RIEC international symposium “Tohoku U - NTU Symposium: When AI Meets Human Science," and planed, but postponed due to covid-19 pandemic, an international symposium “Symposium of Yotta Informatics – Research Platform for Yotta-Scale Data Science 2020”.
3. We continued RIEC Nation-wide Cooperative Research Projects (International Cooperative Research Project), proceeding cooperative research with an overseas research institute. To establish an open innovation platform for information-quality informatics studies, we continued an interdisciplinary project with the IT-21 Center in collaboration with Division for Interdisciplinary Advanced Research and Education.

Leading Graduate Program “Interdepartmental Doctoral Degree Program for Multi-Dimensional Materials Science Leaders”

＜Overview＞

Establishment: October, 2013

Organization; Program manager: Masahiro Yamaguchi (Vice President for Educational Reforms and International Strategy)

Program coordinator: Tetsuya Nagasaka (Professor, Grad. School of Engineering)

Program members: about 60 academic staffs in Tohoku University

Mission; Cultivating human resources through creating leaders who have a firm grasp of the fundamentals of material science and extensive research experience.

The term “multi-dimensional” (MD) refers to the extensive, panoramic perception of materials through dimensions such as functionalities, characteristics, processes, environmental compatibility, economics, safety, and assessment techniques.

＜Major activities in FY2019＞

In FY2019, 4 new students joined the program and 50 students in total learned the fundamental and specialized subjects and joined long-term internship at domestic corporations and foreign institutions.

The leading program accomplishment debriefing meeting was held at the Graduate School of Engineering, Tohoku University on September 20, 2019. Three elected students form the MD program gave presentations in the meeting and the prize for 2019 excellent students was in the program was awarded.

The 5th Symposium between the MD program and Ambitious Leaders program (Hokkaido University) was held at Katahira campus of Tohoku University during October 11-13, 2019. Presentations by finished trainees and lectures on venture companies followed by a workshop of group activities for preparing business plans were carried out during the symposium.

Graduate Program in Spintronics (GP-Spin)

＜Overview＞

Establishment: April 1, 2015

Organization: Head of the Division for International Joint Graduate School Programs : Masahiro Yamaguchi (Vice President for Education Reform and Global Engagement)
Graduate Program in Spintronics (GP-Spin) Program Director: Yoshiro Hirayama (Professor, Graduate School of Science)
Program members: 21 academic staffs in Tohoku University
Foreign organization: Johannes Gutenberg Univ. Mainz (Germany), Univ. Regensburg (Germany), Tech. Univ. Kaiserslautern (Germany), Tech. Univ. München (Germany), Univ. Lorraine (France), Univ. Chicago (USA), Tech. Univ. Delft (The Netherland), Univ. Groningen (The Netherland), Tsinghua University (Chaina)

Mission: Education of world-class leaders in spintronics from fundamental to applications

Activities: (1) Education by world-leading professors from all departments and institute in Tohoku University with participation from all over the world
(2) Joint education with foreign organization including joint supervised degree/joint degree, mutual visit and long-term internship, international school/workshop, qualifying examination to guarantee the educational quality

＜Major activities in FY2019＞

In FY2019, seminars and lectures were given by world-leading researchers invited from University of York, NIST, Polish Academy of Science, and so on, during their stays in Tohoku University.

A workshop was held at Tohoku University on August 30, 2019 for improving presentation skills of GP-Spin students. International workshops were held in Purdue University (September 11, 2019) and University of Lorraine (September 17-20, 2019). In Lorraine, students organized meeting was also held. The international symposium was held at Sendai from February 9 to 11, 2020, together with material science group and one of the session was organized by GP-Spin program. A seminar organized by GP-Spin students was held during February 20-21, 2020 at AIMR, Tohoku University. Lectures were given by researchers invited from Korea University, Ewha Womans University, University of New South Wales and MIT. Poster presentations were also given by students and young researchers in Tohoku University.

Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan
WISE Program (Doctoral Program for World-leading Innovative & Smart Education)
Advanced Graduate Program for AI Electronics

＜About the Center＞

Establishment：Adopted October, 2018.
It has been adopted by the WISE Program (Doctoral Program for World-leading Innovative & Smart Education) of MEXT. This program is a new education program that starts from FY 2018.

Organization：Chief executive: Hideo Ohno (President of Tohoku University)
Program leader: Masahiro Yamaguchi (Vise-President of Tohoku University (Education Reform / International Strategy))
Program coordinator: Toshiro Kaneko (School of engineering, Professor)
Program manager: Approximately 60 people (including managers and a coordinator)

Target of Program：In this Graduate School Program, we will foster world-class talented doctors who can make an innovation continuously through the learning of “an practical ability”, “solving of social problems”, “creation of novel value”, and “an ability that can see real space and cyber space in Society 5.0 with wide perspectives”.

＜Major Achievements in 2019＞

For the first year students, "Interdisciplinary Education" and "Industry-Academia Collaboration Education" were conducted, and PBL (Project Based Learning) course was started. In addition, we have promoted the development of basic facilities and curricula necessary for industry-university cooperation education. In addition, we held a symposium on the results of learning. We recruited and selected 20 new students (7 new M1, 6 new M2, and 7 new D1) for the second year (2020) of the program.

4. Nation-wide Cooperative Research Projects

The Institute has a long history of fundamental contributions in many fields of engineering and science that include the fields of semiconductor materials and devices, magnetic recording, optical communication, electromagnetic technology, wireless communication, applications of ultrasonic communication and acoustic communication, non-linear physics and engineering, and computer software. On the basis of this rich historical background the Institute was designated as a National Center for Cooperative Research in 1994. Accompanying Tohoku University's transformation to "a national university juridical entity" in April, 2004, this institution plays a leading role on the world stage, as its researchers, both domestic and foreign, continue the task of "investigating the theory and application of universal science and technology to realize communication, to the enrichment of humanity."

With this background, the Institute organizes Nation-wide Cooperative Research Projects by coordinating its activities with research workers. The main themes for Cooperative Research are selected annually by the Committee for Cooperative Research Projects. Then invitations for project proposals and participation are extended to university faculties and government laboratories as well as industrial research groups. Each project approved by the Faculty Council of the Institute is carried out by a team of researchers that include members of the Institute as well as outside participants.

The Advisory Council which includes members from other institutions has an advisory function to the Director in defining the general direction of the research at the Institute and its Nation-wide Cooperative Research Projects.

The Project Selection Committee that includes members from outside of Tohoku University has a Judging function for project proposals. The purpose of the Project Steering Committee is the proper operation of approved projects.

Nation-wide Cooperative Research Projects List 2019

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/A02	Development of low-loss flexible metamaterials	**UCHINO Takashi** Department of Electrical and Electronic Engineering, Faculty of Engineering, Tohoku Institute of Technology	**OTSUJI Taiichi**
H29/A07	Study on single-crystal graphene devices	**NAGASE Masao** Graduate School of Technology, Industrial and Social Sciences, Tokushima University	**OTSUJI Taiichi**
H29/A08	Atomic Control in New Group-IV Semiconductor Nanostructures for High- Performance Device	**SAKURABA Masao** Research Institute of Electrical Communication, Tohoku University	**SAKURABA Masao**
H29/A09	Study of the effect of post-deposition processing on various type high-k/Ge structure	**OKAMOTO Hiroshi** Graduate School of Science and Technology, Hirosaki University	**SATO Shigeo**
H29/A10	Development of graphene based devices for terahertz applications	**MEZIANI Yahya Moubarak** Fisica Aplicada, Salamanca University	**OTSUJI Taiichi**
H29/A12	Massive Connect IoT Using a Precision Position and Time Information on QZSS	**OGUMA Hiroshi** Department of Electronics and Computer Engineering, National Institute of Technology, Toyama College	**KAMEDA Suguru**
H29/A13	Studies on direct digital RF transceivers	**SUEMATSU Noriharu** Research Institute of Electrical Communication, Tohoku University	**SUEMATSU Noriharu**
H29/A16	Cultural and individual differences in color lexicon	**TOKUNAGA Rumi** College of Liberal Arts and Sciences, Chiba University	**KURIKI Ichiro**
H29/A17	Development of Ion channel sensing system with high sensitivity and high accuracy based on silicon microfabrication and lipid bilayers	**TERO Ryugo** Department of Environmental and Life Sciences, Toyohashi University of Technology	**HIRANO Ayumi**
H29/A18	Speech intelligibility evaluation and its estimation for development of outdoor public address system.	**KOBAYASHI Yosuke** Graduate School of Engineering, Muroran Institute of Technology	**SAKAMOTO Shuichi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/A19	Gaze Visualization in Cooperative Work	**KIYOKAWA Kiyoshi** Graduate School of Information Science, Nara institute of science and technology	**KITAMURA Yoshifumi**
H29/A21	Practical applications of nonlinear and complex systems theory to nonlinear-complex engineering systems	**HORIO Yoshihiko** Research Institute of Electrical Communication, Tohoku University	**HORIO Yoshihiko**
H29/A22	Temporal characteristics of multisensory auditory space perception	**HONDA Akio** Faculty of Informatics, Shizuoka Institute of Science and Technology	**SAKAMOTO Shuichi**
H29/A23	Immersive experience of virtual auditory environment: investigating influence of physical parameters of height ambiences	**KIM, Sungyoung** Electrical, Computer and Telecommunications Engineering Technology, Rochester Institute of Technology	**SAKAMOTO Shuichi**
H29/A25	The effect of attention on the integration of image components in the human visual system	**CHEN Chien-Chung** Department of Psychology, National Taiwan University	**TSENG Chia-huei**
H29/A26	Social communication: behavioral and brain representations	**TSENG Chia-huei** Research Institute of Electrical Communication, Tohoku University	**TSENG Chia-huei**
H29/A27	Next Generation Information Flow Processing Platform for Human-in-the-loop IoT	**YAMAGUCHI Hirozumi** Graduate School of Information Science and Technology, Osaka University	**KITAGATA Gen**
H29/A28	The source-direction dependency of pinna shape and acoustic transfer function	**ITO Masashi** Faculty of Engineering, Tohoku Institute of Technology	**SAKAMOTO Shuichi**
H29/A29	Research on the development of a new generation IoT platform	**ZABIR Salahuddin Muhammad Salim** Department of Creative Engineering, National Institute of Technology, Tsuruoka College	**KITAGATA Gen**
H29/A32	Formation of MEMS with BiFeO3 thin films and wireless communication technology	**IMAIZUMI Fuminobu** Department of Mechanical Engineering, National Institute of Technology, Oyama College	**KAMEDA Suguru**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/A33	Development study on high sensitive gas sensors with titania nanotubes	**NIWANO Michio** Kansei Fukushi Research Institute, Tohoku Fukushi University	**HIRANO Ayumi**
H29/A34	Analyzing the relationship between network structure and function in cortex	**KUBOTA Shigeru** Graduate School of Science and Engineering, Yamagata University	**HIRANO Ayumi**
H29/A35	Understanding and reconstruction of minimal brain	**KAMIYA Haruyuki** Graduate School of Medicine, Hokkaido University	**HIRANO Ayumi**
H29/A36	Creative Application of 3D Magnetic Motion Tracking System to Music: the CubeHarmonic	**KITAMURA Yoshifumi** Research Institute of Electrical Communication, Tohoku University	**KITAMURA Yoshifumi**
H30/A01	Study on advanced devices using operando spatiotemporal x-ray spectroscopy	**FUKIDOME Hirokazu** Research Institute of Electrical Communication, Tohoku University	**FUKIDOME Hirokazu**
H30/A02	Creation of Bio-Medical Devices Using Gas-Liquid Interfacial Plasmas	**KANEKO Toshiro** Graduate School of Engineering, Tohoku University	**HIRANO Ayumi**
H30/A05	Development of vibrational spectroscopy having high temporal and spatial resolution and its application to devices	**INAOKA Takeshi** Department of Physics and Earth Sciences, Faculty of Science, University of the Ryukyus	**UEHARA Yoichi**
H30/A06	Development of general control techniques of quantum systems	**FUKUHARA Takeshi** Center for Emergent Matter Science, RIKEN	**OTSUKA Tomohiro**
H30/A07	Control of spin state in semiconductor using photon-spin conversion	**ISHIHARA Jun** Department of Applied Physics, Faculty of Science, Tokyo University of Science	**KANAI Shun**
H30/A08	Nanoscale optical measurement and ultimate photoelectronic control of carbon nanomaterials	**KATANO Satoshi** Research Institute of Electrical Communication, Tohoku University	**KATANO Satoshi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A09	Informatics approaches in quantum devices	**SHIGA Motoki** Faculty of Engineering, Gifu University	**OTSUKA Tomohiro**
H30/A11	Energy Harvest applied Active Reflectarray for Mobile IoT search range expansion	**MARUYAMA Tamami** Department of Production Systems Engineering, National Institute of Technology, Hakodate College	**SUEMATSU Noriharu**
H30/A12	A Study of delay-sensitive access network configuration using widely frequency selectable optoelectronics devices	**YOSHIMOTO Naoto** Faculty of Science and Technology, Chitose Institute of Science and Technology	**OTSUJI Taiichi**
H30/A13	Single and coupled hard-type oscillators using resonant tunneling diodes and their application to THz signal processing	**MAEZAWA Koichi** Graduate School of Science and Engineering, University of Toyama	**OTSUJI Taiichi**
H30/A14	Loss Analysis of High Efficient Contactless Power Transmission	**INAMORI Mamiko** Department of Electrical and Electronic Engineering, Tokai University	**KAMEDA Suguru**
H30/A15	Study on method for modulating emotional experience by choice.	**ONUMA Takuya** Faculty of Humanity-oriented Science and Engineering, Kindai University	**SHIOIRI Satoshi**
H30/A16	Modulation of peripersonal space representation by self-motion information	**TERAMOTO Wataru** Graduate School of Social and Cultural Sciences, Kumamoto University	**SAKAMOTO Shuichi**
H30/A17	Study of difference between monaural listening and binaural listening on sound space perception	**MORIKAWA Daisuke** Faculty of Engineering, Toyama Prefectural University	**SAKAMOTO Shuichi**
H30/A18	Emergency vital measurement using flexible fiber electrode under electromagnetic environment	**TORIMITSU Keiichi** Research Organization of Electrical Communication, Tohoku University	**SUEMATSU Noriharu**
H30/A19	Research on gravimetric technology for monitoring volcanic activities using an optical fiber network	**ARAYA Akito** Earthquake Research Institute, The University of Tokyo	**YOSHIDA Masato**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A20	Hardware Technology for Brain Computation	**SATO Shigeo** Research Institute of Electrical Communication, Tohoku University	**SATO Shigeo**
H30/A24	Research on development of flexible pressure sensors based on PVDF thin films	**TADAKI Daisuke** Research Institute of Electrical Communication, Tohoku University	**TADAKI Daisuke**
H30/A26	Basic study on Perceptual User Interfaces for Interaction with IoT	**OMATA Masaki** Graduate Faculty of Interdisciplinary Research, Yamanashi University	**KITAGATA Gen**
H30/A28	Brain-like Integrated System using Thin-Film Devices	**KIMURA Mutsumi** Faculty of Science and Technology, Ryukoku University	**HORIO Yoshihiko**
H30/A29	Hardware security technologies for IoT	**OGUMA Hiroshi** Department of Electronics and Computer Engineering, National Institute of Technology, Toyama College	**HOMMA Naofumi**
H30/A30	Advanced IoT Infrastructure Based on Intelligent Edge	**SATO Fumiaki** Faculty of Science, Toho University	**OHORI Atsushi**
H30/A32	A Malware Detection System for Secure Campus BYODs	**SATOH Akihiro** Information Science Center, Kyushu Institute of Technology	**KITAGATA Gen**
H30/A33	Research of human life support based on agent IOT	**UCHIYA Takahiro** Information Technology Center, Nagoya Institute of Technology	**SAKAMOTO Shuichi**
H30/A34	Development of Metal Source/Drain CMOS on Ge-on-Insulator	**NAKASHIMA Hiroshi** Global Innovation Center, Kyushu University	**SAKURABA Masao**
H30/A35	Research about quantum devices utilizing phonon	**TAKADA Shintaro** National Metrology Institute of Japan, Research Institute for Physical Measurement, National Institute of Advanced Industrial Science and Technology	**OTSUKA Tomohiro**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/A37	Research of on-chip terahertz antenna for ultra-wideband communication	**KANAYA Haruichi** Graduate School of Information Science and Electrical Engineering, Kyushu University	**SUEMATSU Noriharu**
H30/A38	Millimeter-wave array antenna using multi-layered substrate	**YOSHIDA Satoshi** Research Field in Engineering, Science and Engineering Area, Research and Education Assembly, Kagoshima University	**MOTOYOSHI Mizuki**
H30/A40	High-frequency/Broadband Magnetic Film-type Noise Suppressor for Next-generation Mobile Communication	**MUROGA Sho** Graduate School of Engineering Science, Akita University	**HASHI Shuichiro**
H30/A41	Quantification of basic visual properties in high dynamic range scenes	**NAGAI Takehiro** School of Engineering, Tokyo Institute of Technology	**KURIKI Ichiro**
H31/A01	Japan-USA International Collaborative Research on Terahertz Devices based on Graphene-Phosphorene van der Waals Heterostructures	**MITIN, Vladimir** Department of Electrical Engineering, University at Buffalo, The State University of New York	**OTSUJI Taiichi**
H31/A02	Fabrication of high performance quantum device with atomically thin layered materials	**KATO Toshiaki** Graduate School of Engineering, Tohoku University	**OTSUKA Tomohiro**
H31/A04	Formation of Self-Aligned Si-Ge based Quantum Dots and Characterization of Their Electrical Properties	**MIYAZAKI Seiichi** Graduate School of Engineering, Nagoya University	**SATO Shigeo**
H31/A05	Dynamics of spin-orbit torque induced switching of metallic antiferromagnet/non-magnet heterostructures	**TRETIAKOV Oleg** School of Physics, University of New South Wales	**FUKAMI Shunsuke**
H31/A06	Study on spin transport properties and development of highly efficient magnetization switching devices using transition metal compounds with 2p-orbital light elements	**ISOGAMI Shinji** Research Center for Magnetic and Spintronic Materials, National Institute for Materials Science	**SHIRAI Masafumi**
H31/A07	Development of high Q microwave resonators for quantum detection	**INOMATA Kunihiro** Nanoelectronics research institute, Advanced Industrial Science and Technology	**SATO Shigeo**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H31/A08	Quantum state estimation by 2-dimensional Fourier transform coherent spectroscopy	**OGAWA Yoshihiro** Mathematics and Science Education, National Institute of Technology, Joetsu University of Education	**MITSUMORI Yasuyoshi**
H31/A09	Development of non-volatile phase transition oxide elements targeting application for optoelectronics	**SAKAI Joe** Oxide Nanophysics Group, Catalan Institute of Nanoscience and Nanotechnology	**UEHARA Yoichi**
H31/A10	Study of ferromagnetic resonance induced by spin orbit torque and the phase rockling via spin waves for dc drive microwave oscillators	**KODA Tetsunori** General Education Division, National Institute of Technology, Oshima College	**HASHI Shuichiro**
H31/A11	High-Speed Driver for Optical Modulators using InGaAs HEMTs with Slant Field Plates	**UMEDA Yohtaro** Faculty of Science and Technology, Tokyo University of Science	**SATOU Akira**
H31/A12	Study of the open environment for sharing vision models	**SAKAI Ko** Faculty of Engineering Information and Systems, Tsukbua University	**SHIOIRI Satoshi**
H31/A13	Communication system for controlling human cognition and behavior from kansei information speech	**TANAKA Akihiro** Department of Psychology, Tokyo Woman's Christian University	**SAKAMOTO Shuichi**
H31/A14	Pre-verbal infant learning: Infants' preference and understanding from eye movements and pupil dilation	**CINDY Chiu** Department of Community Health, Tohoku University	**TSENG Chia-huei**
H31/A15	Home reproduction of three-dimensional sound	**ANDO Akio** Graduate School of Science and Engineering for Research, University of Toyama	**SAKAMOTO Shuichi**
H31/A16	Improvement of outdoor mass notification sound systems by reconstructing speech structures	**CUI Zhenglie** Media Informatics, Aichi University of Technology	**SAKAMOTO Shuichi**
H31/A17	Performance Evaluation of Congestion-based Congestion Control over Heterogeneous Wireless Networks	**UTSUMI Satoshi** Faculty of Symbiotic Systems Science, Fukushima University	**KITAGATA Gen**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H31/A18	Development of compact quantum light source using a gain-switching laser diode	**MATSUDA Nobuyuki** Graduate School of Engineering, Tohoku University	**EDAMATSU Keiichi**
H31/A19	Exploration of a new electrical detection method of magnetization dynamics in CoFeB-MgO magnetic tunnel junction structure with perpendicular anisotropy	**Eli Christopher Inocencio Enobio** Department of Physics, Mindanao State University -Iligan Institute of Technology	**FUKAMI Shunsuke**
H31/A20	high-dimensional quantum optics via multi-pixel photon detection	**KANEDA Fumihiro** The Frontier Research Institute for Interdisciplinary Sciences, Tohoku University	**BAEK Soyoung**
H31/A21	A Study on Time Synchronization Performance of Software Defined Radio for Rapid Prototyping	**YAMADA Yoji** Department of Electronics and Information Engineering, National Institute of Technology, Ishikawa College	**KAMEDA Suguru**
H31/A22	Interactive Content for Emergent Users	**JOSHI Anirudha** IDC School of Design, IIT Bombay	**KITAMURA Yoshifumi**
H31/A23	Development of a re-experiencing system for learning supports	**SHIOIRI Satoshi** Research Institute of Electrical Communication, Tohoku University	**SHIOIRI Satoshi**
H31/A24	Performance Analysis for Heterogeneous Environment of Internet Congestion Control	**UTSUMI Satoshi** Faculty of Symbiotic Systems Science, Fukushima University	**HASEGAWA Go**
H31/A25	Development and improvement of wireless medication compliance monitoring system	**HOSHI Kenji** Faculty of Pharmaceutical Sciences, Tohoku Medical and Pharmaceutical University	**KITAGATA Gen**
H31/A26	Study of 2D nanomaterial devices for terahertz applications	**AMINE El Moutaouakil** Department of Electrical Engineering, United Arab Emirates University	**OTSUJI Taiichi**
H31/A27	Collaborative Study on the Development of Fixed Observing equipment for Disaster Risk Reduction used by IoT :Focus on the connected operation of daily and emergency situations	**SUGIYASU Kazuya** International Research Institute of Disaster Science, Tohoku University	**YOKOTA Nobuhide**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H31/A28	Wireless Propagation Channel for Body Ara Network	**AKIMOTO Kohei** Department of Intelligent Mechatronics, Faculty of Systems Science and Technology, Akita Prefectural University	**MOTOYOSHI Mizuki**
H31/A29	Redesigning the D-FLIP system: a photo management system for the elderly and the technologically inexperienced	**CHINTAKOVID/Thippaya** Department of Library Science, Faculty of Arts, Chulalongkorn University	**KITAMURA Yoshifumi**
H31/A31	Japan-Russia International collaborative research on high sensitive and tunable room-temperature plasmonic photoconductive antenna-detector	**DMITRY Ponomarev** Laboratory of high-power microwave and mm-wave applications, Institute of ultra high frequency semiconductor electronics of Russian academy of sciences	**OTSUJI Taiichi**
H29/B02	Research on magnetic device for advanced communications equipment by observation and control of microstructure of magnetic material	**IKEDA Shinji** Faculty of Production Systems Engineering and Sciences, Komatsu University	**ISHIYAMA Kazushi**
H29/B03	Study on Semiconductor Device and its Integrated Electronics Systems for High Efficiency Energy Utilization	**CHIKYOW Toyohiro** Center for Material Research by Information Integration , National Institute for Materials Science	**HANYU Takahiro**
H29/B05	Research on new concept devices with nano materials / silicon integrated circuit hybrid technology and its application for information processing	**WATANABE Heiji** Graduate School of Engineering, Osaka University	**HANYU Takahiro**
H29/B06	Smart Spectrum and Its Applications for IoT Era	**FUJII Takeo** Advanced Wireless and Communication Research Center, The University of Electro-Communications	**KAMEDA Suguru**
H29/B07	Advanced high-frequency circuit technology for realizing wireless IoT and its application	**ITOH Nobuyuki** Faculty of Computer Science and Systems Engineering, Okayama Prefectural University	**SUEMATSU Noriharu**
H29/B08	Full-Coherent Communication and Measurement Systems Aiming at Seamless Interface Between Light- and Micro-Waves	**TSUCHIDA Hidemi** Electronics and Photonics Research Institute, National Institute of Advanced Industrial Science and Technology	**HIROOKA Toshihiko**
H29/B09	Spatial User Interface by Understanding Human's Physical and Spatial Behaviors	**YAMAMOTO Goshiro** Kyoto University Hospital, Kyoto University	**TAKASHIMA Kazuki**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H29/B11	Multisensory integration including self-motion perception	**SAKURAI Kenzo** Faculty of Liberal Arts, Tohoku Gakuin University	**SAKAMOTO Shuichi**
H29/B12	Search Science: an interdisciplinary endeavor	**TSENG Chia-huei** Research Institute of Electrical Communication, Tohoku University	**TSENG Chia-huei**
H29/B15	Neuromorphic computing utilizing novel solid-state devices and circuits	**FUKAMI Shunsuke** Research Institute of Electrical Communication, Tohoku University	**FUKAMI Shunsuke**
H29/B17	International Research Collaboration of Brainware LSI and Its Applications	**HANYU Takahiro** Research Institute of Electrical Communication, Tohoku University	**HANYU Takahiro**
H29/B18	Advanced Hardware Security Technology	**HOMMA Naofumi** Research Institute of Electrical Communication, Tohoku University	**HOMMA Naofumi**
H29/B20	New developments and applications of semiconductor technologies based on university-industry collaboration	**UEHARA Yoichi** Research Institute of Electrical Communication, Tohoku University	**UEHARA Yoichi**
H29/B21	Development of wide area vocal system for crows' beh	**TSUKAHARA Naoki** Center for Bioscience Research and Education, Utsunomiya University	**KITAMURA Yoshifumi**
H30/B04	Formation of spatial and temporal structures and various reactive fields in plasma flows	**ANDO Akira** Graduate School of Engineering, Tohoku University	**ISHIYAMA Kazushi**
H30/B06	Research on optical space mode	**HAMAMOTO Kiichi** Faculty of Engineering Sciences, Kyushu University	**YOSHIDA Masato**
H30/B07	Functionalization of oxide surfaces and its application to nanodevices	**HIROSE Fumihiko** Graduate School of Science and Engineering, Yamagata University	**HIRANO Ayumi**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H30/B08	Establishment of information science approach and psychological verification method for intellectual productivity acquisition in group discussion	**ITOH Yuichi** Graduate school of Information Science and Technology, Osaka University	**TAKASHIMA Kazuki**
H30/B12	Establishments of Optimal Design and High-Efficiency Control Scheme for High-Frequency Wireless Power Transfer Systems	**SEKIYA Hiroo** Graduate School of Engineering, Chiba University	**HORIO Yoshihiko**
H30/B13	High-dimensional neural dynamics to develop next-generation neural hardware	**HIROSE Akira** Graduate School of Engineering, Tokyo University	**SATO Shigeo**
H30/B14	Future Office Space and Interaction	**FUJITA Kazuyuki** Research Institute of Electrical Communication, Tohoku University	**FUJITA Kazuyuki**
H30/B15	The study of interactive entertainment systems for drone race	**SUEDA Koh** Media Science Laboratory, Digital Hollywood University	**KITAMURA Yoshifumi**
H30/B17	Development of Swarm Intelligence Optimization based on Nonlinear Dynamical Systems Theory and Its Application	**JINNO Kenya** Faculty of Knowledge Engineering,Department of Information and Communication Engineering Tokyo City University	**HORIO Yoshihiko**
H30/B18	Empirical Research on Infrastructurization of Ubiquitous Computing	**MURAO Kazuya** College of Information Science and Engineering, Ritsumeikan University	**KITAGATA Gen**
H30/B20	Understanding the brain mechanisms of "mind"	**TSUTSUI Ken-Ichiro** Graduate School of Life Sciences, Tohoku University	**SHIOIRI Satoshi**
H31/B01	Information-related Functional Expression in Hybrid Plasmas of Physical and Chemical Systems	**KOGA Kazunori** Faculty of Information Science and Electrical Engineering, Kyushu University	**SATO Shigeo**
H31/B02	Precise understanding and function development of non-equilibrium dynamics in solid state devices	**KOBAYASHI Kensuke** Graduate School of Science, Osaka University	**FUKAMI Shunsuke**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H31/B03	Studies on Elemental Technologies for Development of The Next Generation Wireless Communication Systems	**KONNO Keisuke** Graduate School of Engineering, Tohoku University	**MOTOYOSHI Mizuki**
H31/B04	Development of next-generation academic community that applies human-computer interaction researches	**SAKAMOTO Daisuke** Graduate School of Information Science and Technology, Hokkaido University	**KITAMURA Yoshifumi**
H31/B05	HCI Research Community Development in Asia	**KITAMURA Yoshifumi** Research Institute of Electrical Communication, Tohoku University	**KITAMURA Yoshifumi**
H31/B06	Visual KANSEI mechanisms for SHITSUKAN and color perception	**OKAJIMA Katsunori** Faculty of Environment and Information Sciences, Yokohama National University	**KURIKI Ichiro**
H31/B07	Croatia - Japan Electromagnetic Compatibility Workshop	**HAYASHI Yuichi** Graduate School of Information Science, Nara Institute of Science and Technology	**ISHIYAMA Kazushi**
H31/B08	Study group on UAV application/technology and its social implementation for regional revitalization	**SUEDA Koh** Smart System Institute, National University of Singapore	**KITAMURA Yoshifumi**
H31/B09	New development of practical research on microwave and laser-based synthetic aperture radar	**KOGI Yuichiro** Department of Engineering, Fukuoka Institute of Technology	**YASAKA Hiroshi**
H31/B10	Wide-area Distributed Cooperation and International Deployment of Edge Computing Infrastructures	**KASHIWAZAKI Hiroki** Center for Cybersecurity Research and Development, National Institute of Informatics	**KITAGATA Gen**
H31/B11	A study on static analysis for a dynamic language and its realization	**MATSUMOTO Yukihiro** Board, Ruby Association	**UENO Katsuhiro**
H31/B12	User Interface for Viewing and Editing Complex Graph Contents	**FUJITA Kazuyuki** Research Institute of Electrical Communication, Tohoku University	**FUJITA Kazuyuki**

Grant Number	Title of Research	Principal Investigator	Research Collaborator of RIEC
H31/B13	Spin-orbit induced spin dynamics and its manipulation in solid states	**KOHDA Makoto** Graduate School of Engineering, Tohoku university	**KANAI Shun**
H31/B14	Building a design platform for energy magnetics equipment	**YAMAGUCHI Masahiro** Graduate School of Engineering, Tohoku University	**ISHIYAMA Kazushi**
H31/B15	Studies on Generative Technology for Enriched Multimedia	**SONODA Kotaro** Graduate School of Engineering, Nagasaki University	**SAKAMOTO Shuichi**
H31/B16	Reliable Software Construction based on Type-directed Compilation	**MORIHATA Akimasa** Graduate School of Arts and Sciences, Tokyo University	**UENO Katsuhiro**
H31/B17	PSDL: Physical Security of Deep Learning	**BHASIN Shivam** Temasek laboratories, Nanyang Technological University	**HOMMA Naofumi**
H31/B18	Study of Dynamic Service Orchestration for Mobile Edge Computing	**SHAO Xun** Division of Information and Communication Engineering, Kitami Institute of Technology	**HASEGAWA Go**
H31/B19	Securing IoT devices against EM Fault Injection	**VERBAUWHEDE Ingrid** Electrical Engineering, COSIC research group, KU Leuven	**HOMMA Naofumi**
H29/S1	Project for creation of interdisciplinary, advanced science and technology based on coherent wave	**MIMURA Hidenori** Research Institute of Electronics, Shizuoka University	**YASAKA Hiroshi**
H29/S2	Collaborative Research on Nano-electronics	**UDAKA Katsuyuki** Research Organization for Nano & Life Innovation, Waseda University	**UEHARA Yoichi**
H30/SI1	AI and Human Studies	**Su-Ling Yeh** AI and Advanced Robotics Center, Institute Graduate School National Taiwan University	**SHIOIRI Satoshi**

5. Symposium organized by the Institute

This Symposium is planned to exchange relevant information on current important topics concerning Electrical Eng., Electrical Communications, Electronic Eng., and Information Eng. Many related researchers inside and outside Tohoku University participate the Symposium and stimulate discussion.

Symposium In Past

	Title	Date
1	Quantum Electronics of Liglht Waves and Micro Waves	Feb. 6- 8, 1964
	Magnetic Recording	Feb.14-15, 1964
2	Ultra-High Frequency Acoustelectronics	Feb.11-12, 1965
3	Artificial lntelligence	Mar. 8- 9, 1966
4	Thin Film Electronics	Jan.26-27, 1967
5	Crystal Growth	Dec. 19-20, 1967
6	1968 Sendai Svmoosium on Acoustelectronics	Aug.19-20, 1968
7	Current Status and Future Trends of Superconductivitv	Jan.22-24, 1970
8	Soeech Information Processing	Feb.24-26, 1971
9	Surface Acoustic Wave Technology	May.25-26, 1972
10	Liquid Crystals ·Their Molecular Orientations and Application to Display Devices	Dec.13-14, 1974
11	Computer Network	Mar.17-18, 1975
12	The Memorial Symposium on the 40th Anniversarv of the Foundation of RIEC	Sep.25-26, 1975
13	Application of Amorphous Ferromagnetic Materials	Mar.10-11, 1977
14	Stoichiometry of Compound Crystals	Nov.24-25, 1977
15	Submillimeter Waves	Nov.16-17, 1978
16	Solid State Chemical Sensors	Feb. 1- 2, 1980
17	Graph Theory and Algorithms	Oct.24-25, 1980
18	Perpendicular Magnetic Recording	Mar.11-12, 1982
19	Approach to Optical Computer	Mar.10-11, 1983
20	Plasma Non-Linear Phenomena - Basic Problems for Fusion Plasmas	Mar. 8- 9, 1984
21	New Computer Architecture	Jul.25-26, 1985
22	Guided Wave Technology and Its Application at Mid-Infrared	Mar.13-14,1986
23	Physics and Applications of Tunnelling Phenomena	Mar.12-14, 1987
24	Biomagnetics and Bioelectronics	Feb.26-27, 1988
25	Ultrasonic Electronics - New Applications of Piezoelectricity	Feb. 2- 3, 1989
26	Boundaries between Light and Electromagnetic Wave	Feb. 1-2, 1990

	Title	Date
27	Issues and Realization of Pattern Recognition and Understanding	Feb.28-Mar.1,1991
28	Discrete Algorithms	Oct.17-18, 1991
29	Perspective for New Computing Paradigm	Feb. 4- 5, 1993
	Current Status and Future Prospects of System Control	Mar. 3- 4, 1993
30	Future Prospects of Electron Beam Devices	Nov. 1- 2, 1993
31	Discharge and EMC	Dec.20-21, 1994
32	Statistical Physics and Information Science	Mar.22-23,1995
33	Photo-and Plasma-Excited Processes on Surfaces	Nov.30-Dec.1,1995
34	Nano Spinics and Power Electronics	Feb.15-16, 1996
35	Potential Formation and Related Nonlinear Phenomena in Plasmas	Sep.17-19, 1996
36	New Trend in Ultrasonic Measurements	Feb. 3- 4, 1997
37	Toward the Realization of the High-Definition Multi-Media Communication	Nov. 4- 6, 1997

International Symposium Organized by the Institute

	Title	Date
1	Intrinsic Josephson Effect and THz Plasma Oscillation in High T_c Superconductors	Feb.23-25, 1997
2	Design and Architecture of Information Processing Systems Based on The Brain Information Principle	Mar.16-18, 1998
3	Novel Techniques and Applications of Millimeter-Waves	Dec.14-16, 1998
4	The International Joint Conference on Silicon Epitaxy and Heterostructures	Sep.13-17, 1999
5	International Workshop on Photonic and Electromagnetic Crystal Structures	Mar.8-10, 2000
6	Physics and Application Spin Related Phenomena in Semiconductors	Sep.13-15, 2000
7	Rewriting in Proof and Computation	Oct.25-27, 2001
8	Nonlinear Theory and its Applications	Oct.28-Nov.1, 2001
9	New Paradigm VLSI Computing	Dec.12-14, 2002
10	Ultra High Density Spinic Storage System	Oct.23-24, 2003
11	3rd International Workshop on New Group IV (Si-Ge-C) Semiconductors	Oct.12-13, 2004
12	3rd International Workshop on High Freaqency Micromagnetic Devices and Materials (MMDM3)	Apr.11-12, 2005
13	4th International Conference on Silicon Epitaxy and Heterostructures (lCSl-4)	May 23-26, 2005
14	1st International WorkShop on New Group IV Semiconductor Nanoelectronics	May 27-28. 2005
15	GSIS International Symposium on Information Sciences of New Era: Brain, Mind and Society	Sep.26-27, 2005
16	The 1st RIEC International Workshop on Spintronics -Spin Transfer Phenomena-	Feb.8-9, 2006
17	4th International Workshop on High Frequency Micromagnetic Devices and Materials (MMDM4)	May 8,2006
18	4th International Conference on Physics and Applications of Spin-Related Phenomena in Semiconductors (PASPS-lV)	Aug.15-18,2006
19	2nd International Workshop on New Group IV Semiconductor Nanoelectronics	Oct.2-3,2006
20	2nd RIEC International Workshop on Spintronics	Feb.15-16,2007
21	Japan-China Joint Conference on acoustics, JCA2007	Jun.4-6,2007
22	International Conference on Discovery Science/ International Conference on Algorithmic Learning Theory	Oct.1-4,2007
23	The 3rd RIEC International Workshop on Spintronics	Oct. 31-Nov.1,2007
24	3rd International Workshop on New Group ⅣSemiconductor Nanoelectronics	Nov.8-9,2007
25	International Workshop on Nanostructures & Nanoelectronics	Nov.21-22,2007
26	The 18th International Symposium on Algorithms and Computation(ISAAC2007)	Dec.17-19,2007
27	International Interdisciplinary-Symposium on Gaseous and Liquid Plasmas (ISGLP 2008)	Sep.5-6,2008
28	4th International Workshop on New Group IV Semiconductor Nanoelectronics	Sep.25-27,2008

	Title	Date
29	The 4th RIEC International Workshop on Spintronics	Oct.9-10,2008
30	Global Symposium on Millimeter Waves 2009 (GSMM2009)	Apr.20-22,2009
31	Mini R.I.E.C. workshop on multimodal perception	Apr.24,2009
32	The 4th International Symposium on Ultrafast Photonic Technologies	Aug.4-5,2009
33	PIMRC2009 Personal Indoor and Mobile Radio Communications Symposium 2009	Sep.13-16,2009
34	2nd RIEC-CNSI Workshop on Nanoelectronics,Spintronics and Photonics (5th RIEC Symposium on Spintronics)	Oct.22-23,2009
35	International Workshop on the principles and applications of spatial hearing 2009 (IWPASH2009)	Nov.11-13,2009
36	5th International Workshop on New Group IV Semiconductor Nanoelectronics	Jan.29-30,2010
37	6th RIEC International on Spintronics	Feb.5-6,2010
38	2nd International Workshop on Nanostructure & Nanoelectronics	Mar.11-12,2010
39	2nd RIEC International Symposium on Graphene Devices (ISGD2010)	Oct.27-29,2010
40	9th Japan-Korea Symposium on Surface Nanostructures	Nov.15-16,2010
41	The 7th RIEC International Workshop on Spintronics	Feb.3-4,2011
42	The 42nd RIEC International Symposium 12th International Multisensory Research Forum (IMRF2011)	Oct.17-20,2011
43	The 8th RIEC International Workshop on Spintronics	Feb.2-3,2012
44	The Sixth International Symposium on Medical, Bio- and Nano-Electronics	Mar.8,2012
45	3rd International Workshop on Nanostructures & Nanoelectronics	Mar.21-22,2012
46	9th RIEC International Workshop on Spintronics	May 31-Jun.2,2012
47	The 1st International Workshop on Smart Technologies for Energy, Information and Communication (STEIC2012)	Oct.18-19,2012
48	Technical University of Dresden and Tohoku University Symposium 2012	Nov.2,2012
49	The 1st RIEC International Symposium on Brain Functions and Brain Computer	Nov.15-16,2012
50	Tohoku – Harvard Joint Workshop New Directions in Materials for anoelectronics,Spintronics and Photonics （10th RIEC International Workshop on Spintronics）	Jan.15-16,2013
51	11th RIEC International Workshop on Spintronics & 3rdCSISInternationalSymposiumonSpintronics-based VLSIs	Jan.31-Feb.1,2013
52	7th International Symposium on Medical, Bio- and Nano-Electronics	Mar.7,2013
53	6th Global　Symposium on Millimeter Wave 2013	Apr.22-23,2013
54	The 2nd RIEC International Symposium on Brain Functions and Brain Computer	Feb.21-22,2014
55	8th International Symposium on Medical,Bio- and Nano-Electro	Mar.6-7,2014

	Title	Date
56	5th International Workshop on Nanostructures and Nanoelectronics	Mar.6-7,2014
57	12th RIEC International Workshop on Spintronics	Jun.25-27,2014
58	The IEEE International Conference on Microwave Magnetics	Jun.29-Jul.2,2014
59	RIEC International Symposium on Perception and Communication	Jul.24,2014
60	APMC 2014(2014 Asia-Pacific Microwave Conference)	Nov.4-7,2014
61	The 3rd RIEC International Symposium on Brain Functions and Brain Computer	Feb.18-19,2015
62	International Symposium on Brainware LSI	Mar.2-3,2015
63	The 9th International Symposium on Medical, Bio- and Nano-Electronics	Mar.2-4,2015
64	The 6th International Workshop on Nanostructures and Nanoelectronics	Mar.2-4,2015
65	RIEC International Symposium on Vision and Cognition	Mar.20,2015
66	The 23rd Symposium of the International Colour Vision Society (ICVS 2015)	Jul. 3-7, 2015
67	RIEC International Symposium on Computer Graphics and Interactive Techniques: New Horizon	Sep. 26-27,2015
68	13th RIEC International Workshop on Spintronics	Nov. 18-20,2015
69	The 4th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 23-24,2016
70	International Symposium on Brainware LSI	Feb. 26-27,2016
71	The 10th International Symposium on Medical, Bio- and Nano-Electronics	Mar. 1-3,2016
72	The 7th International Workshop on Nanostructures and Nanoelectronic	Mar. 1-3,2016
73	RIEC International Symposium on Ultra-Realistic Interactive Acoustic Communications 2016	May 20-21,2016
74	RJUSE TeraTech-2016: The 5th Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RIEC International Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies)	Oct.31-Nov.4,2016
75	Dependable Wireless Workshop 2016	Nov.9-10,2016
76	14th RIEC International Workshop on Spintronics	Nov.17-19,2016
77	The 4th RIEC International Symposium on Brainware LSI	Feb. 24-25,2017
78	The 5th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 27-28,2017
79	RIEC International Workshop on Biomedical Optics 2017	Mar. 6,2017
80	The 8th RIEC International Workshop on Nanostructures and Nanoelectronics	Mar. 6-7,2017
81	RIEC Russia-Japan Joint International Microwave Workshop 2017	Oct.19-20,2017

	Title	Date
82	International Symposium on Photonics and Optical Communications (ISPOC 2017)	Oct.25-26,2017
83	RIEC International Symposium on Experience Design and Cognitive Science (The Second ACM SIGCHI Asian Symposium)	Nov. 18-19,2017
84	15th RIEC International Workshop on Spintronics	Dec.13-14,2017
85	The 6th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 1-2,2018
86	The 5th International Symposium on Brainware LSI	Feb. 23-24,2018
87	The 9th International Workshop on Nanostructures and Nanoelectronics	Mar. 1-2,2018
88	Japan-Korea International Symposium on Magnetic Devices and Materials	Aug.24,2018
89	International Symposium on Universal Acoustical Communication 2018	Oct.22-24,2018
90	Asian Wireless Power Transfer Workshop (AWPT2018)	Nov. 2-4,2018
91	3rd Japan-EU Flagship Workshop on Graphene and Related 2D Materials	Nov. 19-21,2018
92	The 2nd Tohoku-NTU U Symposium on Interdisciplinary AI and Human Studies	Nov. 24,2018
93	The 14th International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP2018)	Nov. 26-28,2018
94	RIEC International Symposium on Human-Computer Interaction (The Third ACM SIGCHI Asian Symposium)	Dec.12-13,2018
95	16th RIEC International Workshop on Spintronics	Jan.9-10,2019
96	The 7th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 22-23,2019
97	The 6th International Symposium on Brainware LSI	Mar. 1-2,2019
98	The 10th International Workshop on Nanostructures and Nanoelectronics	Mar. 6-7,2019
99	12th Global Symposium on Millimeter Waves 2019 (GSMM2019)	May. 22-24,2019
100	The 16th International Workshop on Emerging ICT	Oct. 31- Nov. 2,2019
101	17th RIEC International Workshop on Spintronics	Dec. 3-6,2019
102	RIEC International Symposium on Human-Computer Interaction - Welcome CHI 2021, thinking of the future of HCI together -	Jan. 24-25,2020
103	The 8th RIEC International Symposium on Brain Functions and Brain Computer	Feb. 13-15,2020

6. Study Groups on Electrical Communication

Study Groups on Electrical Communication are organized to solve scientific and technological problems and to promote research and development through the collaboration of the Research Institute of Electrical Communication, Group of ECEI (Electrical Engineering, Communication Engineering, Electronic Engineering, and Information Engineering) in Graduate Schools of Engineering, Information Sciences, Biomedical Engineering, related scientists and engineers inside and outside Tohoku University. The Study Groups on Electrical Communication consist of 15 Sub-Groups as listed, to deal with specific subjects. Each Sub-Group holds workshops and the abstracts of the workshops are published annually in The Record of Electrical and Communication Engineering Conversazione Tohoku University.

Many scientists and engineers not only from universities but also from government laboratories and industries attend the workshops, present papers, and discuss issues actively. We are pleased to provide information on these activities upon request. Please contact the General Chairman or each Sub-Group Chairman for general information or more specific questions.

Electromagnetic and Optical Waves Engineering	
Chair	Prof. Yuji Matsuura
Manager	Prof. Yuji Matsuura

Acoustic Engineering	
Chair	Prof. Akinori Ito
Manager	Associate Prof. Takashi Nose
Manager	Prof. Shuichi Sakamoto

Sendai "Plasma Forum"	
Chair	Prof. Akira Ando
Manager	Prof. Toshiro Kaneko

Sendai Seminar on EMC	
Chair	Prof. Hideaki Sone
Manager	Prof. Masahiro Yamaguchi

Computer Science	
Chair	Prof. Eijiro Sumii
Manager	Associate Prof. Kazutaka Matsuda

Systems Control	
Chair	Prof. Makoto Yoshizawa
Manager	Associate Prof. Norihiro Sugita

Information-biotronics	
Chair	Prof. Ayumi Hirano
Manager	Prof. Ayumi Hirano

Spinics	
Chair	Prof. Masahiro Yamaguchi
Manager	Associate Prof. Tomoyuki Ogawa
Manager	Assistant Prof. Ton That Loi

New Paradigm Computing	
Chair	Prof. Masanori Hariyama
Manager	Associate Prof. Masanori Natsui

Ultrasonic Electronics	
Chair	Prof. Hiroshi Kanai
Manager	Associate Prof . Mototaka Arakawa

Brainware	
Chair	Prof. Akio Ishiguro
Manager	Associate Prof. Takeshi Kano

Mathematical Physics and its Application to Information Sciences	
Chair	Prof. Kazuyuki Tanaka
Manager	Associate Prof. Masayuki Ohzeki
Manager	Assistant Prof. Manaka Okuyama

Biocybernetics and Bioinformatics	
Chair	Prof. Satoshi Shioiri
Manager	Associate Prof. Takeshi Obayashi
Manager	Assistant Prof. Yasuhiro Hatori

Nanoelectronics and Spintronics	
Chair	Prof. Shigeo Sato
Manager	Prof. Syunsuke Fukami

7. International Activities

Many of the staff in RIEC contribute to the development of technology and science in the world by serving as editors of referees of international journals or by chairing or programming international conferences. In some fields in electronics, electrical communications, or information engineering RIEC serves as a Center of Excellence (COE), which attracts researchers and students from all over the world every year. Several academic exchange programs with foreign colleges or institutes are in operation.

International academic exchange programs

- Institute of Physics, Polish Academy of Sciences (Poland)
- IHP-Innovations for High Performance Microelectronics (Germany)
- The Interdisciplinary Center on Nanoscience of Marseille, National Center of Scientific Research (France)
- Institute of Semiconductors, Chinese Academy of Sciences (China)
- WINLAB, Rutgers University (U.S.A.)
- University of Vigo (Spain)
- Research and Educational Center "Photonics and Infrared Technology" and Institute of Radio Electronics and Laser Technology , Bauman Moscow State Technical University (Russia)
- Research Laboratory of Electronics, Massachusetts Institute of Technology (U.S.A.)
- St. Petersburg Electrotechnical University (Russia)
- Telecom ParisTech (France)
- Faculty of Physics, M.V.Lomonosov Moscow State University (Russia)
- Center for Artificial Intelligence and Advanced Robotics, National Taiwan University (Taiwan)
- University of Calfornia, Santa Barbara (U.S.A.)
- The University of York (U.K.)
- The Technische Universität Dresden (Germany)
- Berlin Institute of Technology (Germany)
- National Tsing Hua University (Taiwan)
- Harvard University (U.S.A.)
- The University of Kaiserslautern (Germany)
- Johannes Gutenberg University of Mainz (Germany)
- Chemnitz University of Technology (Germany)
- University of Regensburg (Germany)
- Carl von Ossietzky University of Oldenburg (Germany)
- Purdue University (U.S.A.)
- University of Salamanca (Spain)
- St. Petersburg Electrotechnical University (Russia)

International journals in which a staff in RIEC participates as an editor

1	IACR Transactions on Cryptographic Hardware and Embedded Systems
2	IEEE Transactions on Circuits and Systems I: Regular Papers
3	IEICE Elecronics Letter (ELEX)
4	IEICE Transactions on Communications (EB)
5	IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences
6	Journal of Cryptographic Engineering
7	Nonlinear Theory and Its Applications, IEICE (NOLTA)
8	PLOS ONE
9	Soft robotics

Recent international conferences programmed by a staff in RIEC

1	10th IEEE-GCC Conference (GCC 2019)
2	10th International Symposium on Metallic multilayers (MML2019)
3	11th MRAM Global Innovation Forum
4	17th RIEC International Workshop on Spintronics
5	2019 IEEE International Reliability Physics Symposium
6	2019 International Symposium on Nonlinear Theory and Its Applications
7	2019 MRS Fall Meeting
8	2019 Spintronics Workshop on LSI
9	2020 Asia-Pacific Workshop on Fundamentals and Applications of Advanced Semiconductor Devices
10	24th Soft Magnetic Materials Conference
11	8th Int. Symp. on Control of Semiconductor Interfaces (ISCSI-VIII) & 13th Int. WorkShop on New Group IV Semiconductor Nanoelectronics
12	ACM Conference on Human-Computer Interaction with Mobile Devices and Services 2019
13	ACM Conference on Interactive Surfaces and Spaces 2019
14	ACM SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia 2019
15	ACM Symposium on Virtual Reality Software and Technology (VRST) 2019
16	APCV 2019 Asia-Pacific Conference on Vision
17	Asian CHI Symposium 2020: Emerging HCI Research Collection
18	Auditory Perception and Cognition
19	Compound Semiconductor Week / International Symposium on Compound Semiconductors (CSW/ISCS2019)
20	Global Symposium on Millimeter Waves (GSMM)
21	IEEE 5G World Forum (WF-5G 2019)
22	IEEE International Conference on Communications (IEEE ICC 2019)
23	IEEE International Symposium on Radio-Frequency Integrated Technology (RFIT)
24	IEEE Symposium on Computers and Communications (ISCC 2019)
25	IEEE Virtual Reality 2020
26	International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments (ICAT-EGVE 2019)
27	International Conference on Cryptographic Hardware and Embedded Systems 2019

28	International Conference on Recent Progress in Graphene Research (RPGR2019)
29	International Conferences on Modern Materials & Technologies in Montecatini Terme (CIMTEC 2020)
30	International Congress on Graphene, 2D Materials and Applications (2DM 2019)
31	International Symposium on Adaptive Motion of Animals and Machines 2019
32	Purdue-Tohoku Spintronics Workshop II
33	Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RJUSE 2019)
34	Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RJUSE 2020)
35	SICE annual conference 2020
36	SPICE Workshop on Antiferromagnetic Spintronics
37	SPIE International Conference on Photonics Europe, Conference on Terahertz Photonics (SPIE Photonics-EU)
38	The 10th International Conference on Metamaterials, Photonic Crystals and Plasmonics (META 19)
39	The 10th International Conference on Ubiquitous and Future Networks (ICUFN 2019)
40	The 11th International Conference on ICT Convergence (ICTC 2019)
41	The 1st International Sympoisum on Designing Human-Centric IoT Society
42	The 2018 IEEE Global Communications Conference (IEEE GLOBECOM 2019)
43	The 2018 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT 2019)
44	The 2019 International Communications Quality and Reliability Workshop (IEEE CQR 2019)
45	The 2019 International Conference on Advanced Technologies for Communications (ATC 2019)
46	The 2020 International Workshop on Pervasive Information Flow (PerFlow'20)
47	The 2020 Wireless Communications Networking Conference (WCNC 2019)
48	The 23rd IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (IEEE CAMAD 2019)
49	The 3rd Symposium for The Core Research Clusters for Materials Science and Spintronics
50	The 44th International Conference on Infrared, Millimeter, and Terahertz Waves (IRMMW-THz 2019)
51	The 4th Graphene Flagship EU-Japan Workshop on Graphene and Related 2D Materials (EU-JP G-Flagship)
52	The 8th RIEC International Symposium on Brain Fucntions and Brain Computer
53	The ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2019)
54	The International Conference on Information Networking 2019 (ICOIN 2019)
55	The Seventh International Symposium on Computing and Networking (CANDAR 2019)
56	Tohoku-York-Kaiserslautern 10th Core-to-core Workshop on "New-Concept Spintronics Devices"
57	Topical Workshop on Heterostructure Microelectronics (TWHM 2019)
58	When AI Meets Human Science: The 3rd NTU-Tohoku International Symposium on Interdisciplinary AI and Human Studies
59	Workshop Spintronic Tohoku-Mainz Lorraine 2019

8. Periodicals Published by the Institute

The Institute publishes the following two periodicals to inform readers on recent research results of the Institute.

1. The Record of Electrical and Communication Engineering Conversazione Tohoku University

This journal aims at providing an opportunity to publish research results of the Institute as well as the result of the Graduate School of Engineering, Information Sciences, Biomedical Engineering. Since the journal also aims at publishing general research activities of the Institute and of the Graduate School such as records of the final lectures of retiring professors, records of the Institute Symposium, and reviews.

The name of the Journal 'Conversazione' is attributable to the 'Tuesday Conversazione' at the Department of Electrical Engineering, which had been held once a week on Tuesday since around 1920. Minutes of the meetings had been distributed to researchers outside of the University via various routes and therefore some of them had been referred to as 'Records of Tuesday Electrical Engineering Conversazione Tohoku University' with the result that they came to be treated as official publications.

Though the meeting was once interrupted by World War Two, it was restarted in 1947. In 1952, the publication of the records was succeeded by the Institute and the records have been published as periodicals, two or three times a year recently, since No. 1 Vol. 21 was published in July, 1952.

2. The Annual Report of Research Activity at the Research Institute of Electrical Communication, Tohoku University

Published annually since 1995. This report details the activities of each research division and research facility. Also included are reports on nation-wide co-operative research projects, international symposium and seminars organized by members of RIEC, and the reports and evaluation on the RIEC advisory board members. English edition(digest version of Japanese edition) has been published since 2007.

3. RIEC News

As a part of RIEC's publication service, "RIEC News" is published.

With the 75th anniversary of the establishment of RIEC, RIEC News introduces cutting-edge's research and the vision of the future from RIEC's contributions to the progression of science and technology in Japan. RIEC News was first launched in March 2011. In fiscal year 2018, 23th, 24st and 25nd issues were published. Every issue introduces special topics such as large scale projects and Specially-Promoted Research, etc. RIEC News also includes current information about each laboratory and center, all kinds of RIEC events, research exchange meetings, laboratories open to the public (RIEC Open Day), etc. English version was also launched in March 2014. Further, RIEC News offers a notification service by mail whenever a new issue is released and an electronic version of every issue published so far can be downloaded by following the link below.

http://www.riec.tohoku.ac.jp/riecnews/

With the 26th issue of RIEC News, it has finished multi-monthly publication style as before. From April 2020, in order to bring you the latest research results and event information as quickly as possible, RIEC News was renewed to a new web-based publication style. The new RIEC News is published by the following link.

http://www.riec.tohoku.ac.jp/riecpr/

9. Staff, Budget

1. Faculty & Staff

as of May 1, 2019

Professors	21
Associate Professors	21
Assistant Professors	23
Research Fellows	9
Specially Appointed Professors	1
Specially Appointed Assistant Professors	1
Administrative Staff（Including Limited Regular Employees）	25
Technical Staff（Including Limited Regular Employees）	16
Total	117

2. Researchers (FY2019)

Foreign Researchers	Visiting Professors	8
	Visiting Asociate Professors	2
Cooperative Researchers of Private Company etc		10
JSPS Research Fellowship for Young Scientists		10
JSPS Postdoctral Fellowship for Overseas Researchers		1
Invitation Fellowship for Research in Japan		0
Contract Researchers		4
Contract Trainees		1
Total		36

3. Students

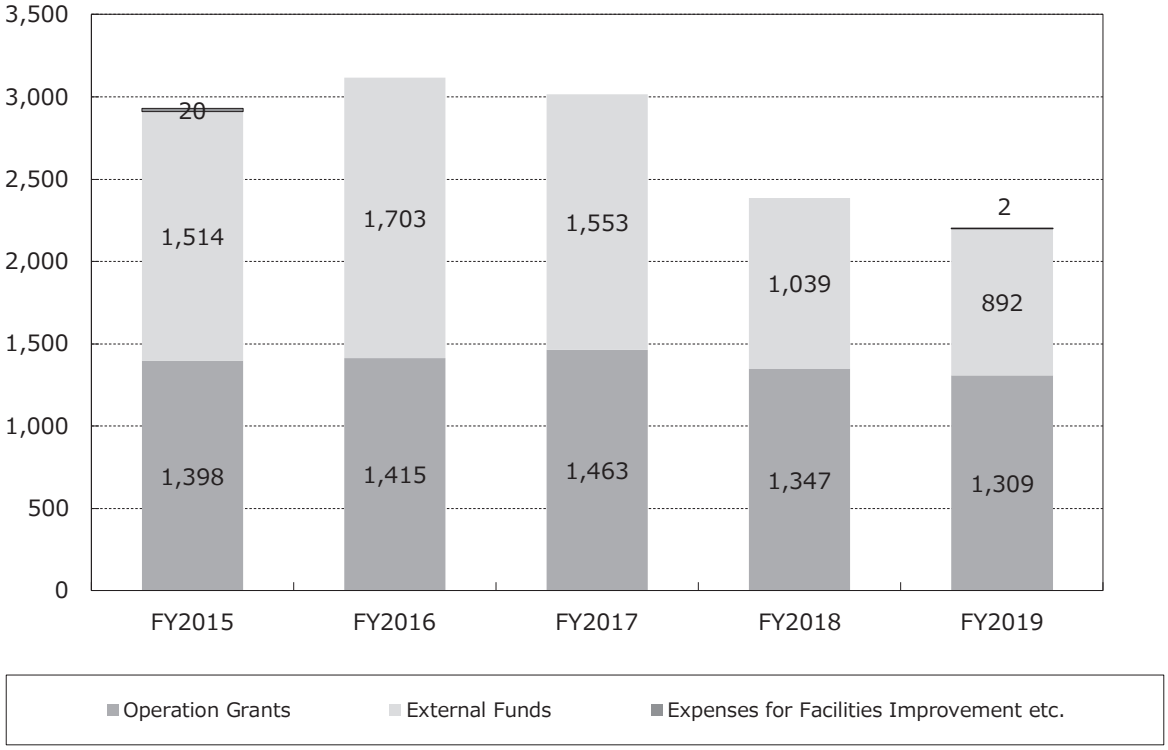
as of May 1, 2019

	School of Engineering	Graduate School of Information Science	Graduate School of Biomedical Engineering	RIEC	Total
Undergraduate Students	49 (1)				49 (1)
Master Course Students	85 (8)	42 (8)	5		132 (16)
Doctor Course Students	19 (4)	10 (4)	1		30 (8)
Institute Reserch Students				4 (3)	4 (3)
Total	153 (13)	52 (12)	6	4 (3)	215 (28)

4. Budget

Budget Shift

million yen



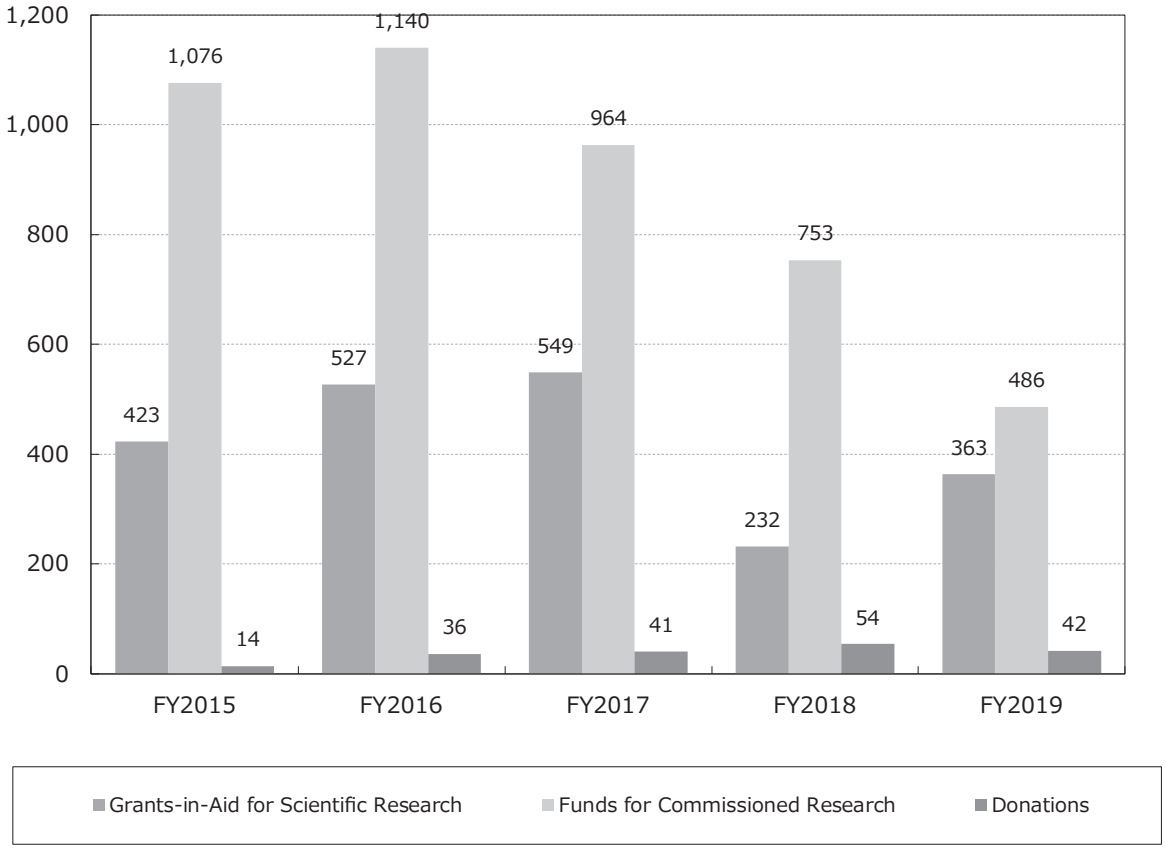
■ Budget Summary

thousand yen

Categories		FY2015	FY2016	FY2017	FY2018	FY2019
Operation Grants	Personnel Expenses	730,537	808,066	835,904	790,118	742,128
	Non-Personnel Expenses	667,582	606,599	626,824	556,937	566,533
Operation Grants Total		1,398,119	1,414,665	1,462,728	1,347,055	1,308,661
External Funds	Grants-in-Aid for Scientific Research	422,846	526,718	549,034	231,643	363,325
	Funds for Commissioned Research	1,076,220	1,140,386	963,585	753,391	486,053
	Donations	14,490	36,190	40,541	54,344	42,436
	Indirect Expenses	219,886	244,413	220,733	134,311	155,852
External Funds Total		1,513,556	1,703,294	1,553,160	1,039,378	891,814
Expenses for Reconstruction		0	0	0	0	1,936
Expenses for Relocation		20,011	0	0	0	0
Expenses for Facilities Improvement		0	0	0	0	0
Expenses for Facilities Improvement etc. Total		20,011	0	0	0	1,936
Total		2,931,686	3,117,959	3,015,888	2,386,433	2,202,411

External Funds

million yen



■ External Funds

thousand yen

Categories	FY2015	FY2016	FY2017	FY2018	FY2019
Grants-in-Aid for Scientific Research	422,846	526,718	549,034	231,643	363,325
Funds for Commissioned Research	1,076,220	1,140,386	963,585	753,391	486,053
Donations	14,490	36,190	40,541	54,344	42,436
Total	1,513,556	1,703,294	1,553,160	1,039,378	891,814

Annual Report 2019

Research Institute of Electrical Communication
Tohoku University

2-1-1Katahira, Aobaku, Sendai 980-8577, Japan
Tel. +81-(0)22-217-5422 Fax. +81-(0)22-217-5426
http://www.riec.tohoku.ac.jp/en/

Research Institute of Electrical Communication
Tohoku University

2-1-1 Katahira,Aobaku,Sendai 980-8577, Japan
Tel. +81-(0)22-217-5420　Fax.+81-(0)22-217-5426
http://www.riec.tohoku.ac.jp/en/