超スマート社会推進コンソーシアム
TokyoTech Super Smart Society Promotion Consortium

Quantum Science

Smart Robotics

Smart Mobility

Super Smart Society Promotion Consortium

Activity Report

Smart Agriculture

Smart Workplace

Artificial Intelligence

2020

東京工業大学
Tokyo Institute of Technology

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Super Smart Society Promotion Consortium Activity Report (2020 Academic Year)

1. Overview of Activities in the Third Year (2020 Academic Year)

1-1 What is the Super Smart Society Promotion Consortium?

The Super Smart Society Promotion Consortium was established in October of 2018 to create a platform for next-generation social collaborative education and research, where everything from human resource development to R&D are integrated through a collaboration with industry, government, and academia in order to foster leaders who can lead the coming super smart society (Society 5.0.) As of April 2021, the 41 partners (not including individual members) shown in Table 1-1 including research institutes, local governments, and private companies are participating in this consortium to promote open innovation and open education for a super smart society.

The Super Smart Society Promotion Consortium has three committees, as shown in Figure 1-1.

1) The Super Smart Society Promotion Committee provides networking opportunities for a super smart society, plans and holds events such as the Super Smart Society Promotion Forum, and provides social enlightenment though One-Day Schools.

2) The Social Collaborative Education Steering Committee assists with human resource development and career support. It helps with human resource development in collaboration with the WISE Program (Doctoral Program for World-leading Innovative & Smart Education) for Super Smart Society (SSS) established at the Tokyo Institute of Technology (Tokyo Tech) in April 2020, and supports off-campus projects (internships).

3) The Interdisciplinary Research Promotion Committee helps to coordinate research and development teams, holds matching workshops, and helps develop SSS research and education fields.

The activities during the 2020 academic year are summarized in this report according to each committee.

Table1-1　Consortium partners（As of April, 2021）

1. Tokyo Institute of Technology
2. Japan Agency for Marine-Earth Science and Technology
3. RIKEN Center for Advanced Intelligence Project
4. National Institutes for Quantum and Radiological Science and Technology
5. The Wireless Networks Research Center, National Institute of Information and Communications Technology
6. Information Technology and Human Factors, National Institute of Advanced Industrial Science and Technology
7. National Agriculture and Food Research Organization
8. KDDI CORPORATION
9. SoftBank Corp.
10. NIPPON TELEGRAPH AND TELEPHONE CORPORATION
11. Rakuten Mobile, Inc.
12. Koden Electronics Co., Ltd.
13. Ricoh Company, Ltd.
14. TOSHIBA CORPORATION
15. NEC Corporation
16. Panasonic Corporation
17. FUJITSU LIMITED
18. Azbil Corporation
19. Yokogawa Electric Corporation
20. DENSO Corporation
21. Honda Research Institute Japan Co., Ltd.
22. Mazda Motor Corporation
23. JTEKT CORPORATION
24. Hitachi Industrial Equipment Systems Co., Ltd.
25. YASKAWA Electric Corporation
26. NSK Ltd.
27. Kawasaki Heavy Industries, Ltd.
28. Kubota Corporation
29. Komatsu Ltd.
30. AGC Inc.
31. Makino Seiki Co., Ltd.
32. SHO-BOND CORPORATION
33. Central Japan Railway Company
34. MITSUBISHI ESTATE CO., LTD.
35. The Bank of Yokohama, Ltd.
36. aiwell Inc.
37. Ministry of Agriculture, Forestry and Fisheries
38. Ota City
39. Kawasaki City
40. The Ecozzeria Association
41. Kanto Head Office, Organization for Small & Medium Enterprises and Regional Innovation, JAPAN

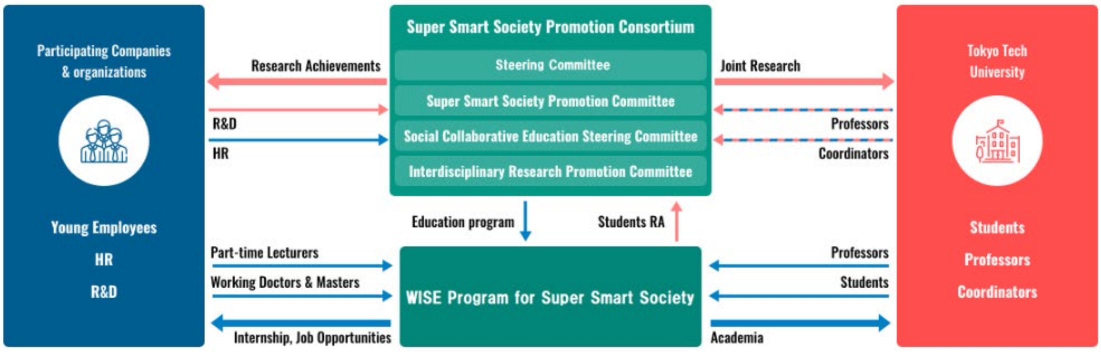


Figure 1-1 Organization of the Consortium

1-2 Activity highlights of the third year (2020 Academic year)

Table 1-2 gives an overview of the activities of the Super Smart Society Promotion Consortium during the third year (2020 academic year) along with a list of events and the corresponding committees. The various committees meet together four times a year in order to plan SSS promotion projects and various events. The 2020 academic year was greatly impacted by the spread of COVID-19. As a result, all consortium events had to be held online. In particular, the WISE-SSS Program, which is supported by this consortium and was newly established in April 2020, was launched a month behind schedule by relaxing some of the requirements and handling all lectures online. Despite this unprecedented situation, we are grateful to all the participating organizations for their cooperation in continuing the activities of the consortium. Details of each event are summarized in this activity report. The One-Day School, which was planned at the beginning of 2020 to enlighten society about the super smart society, was postponed until 2021 since it was intended for in-person implementation.

In-person events and off-campus projects were severely hampered by the spread of COVID-19, but the Super Smart Society Promotion Consortium utilized grants such as MEXT's WISE Program "Engineering Education Program for Super Smart Society Based on Advanced Quantum Science," and we developed the six SSS research and education fields shown in Table 1-3 in order to prepare for after COVID-19 is under control.

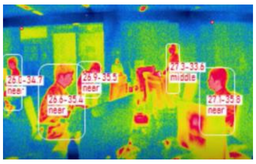
These research and education fields are positioned as microcosms of the ideal super smart society, and are open platforms that can be used for education and research by any Consortium Partner. The themes and structure of the research and education fields were determined by having open recruitment at various committees during the previous academic year and having discussions with related Consortium Partners. During the 2021 academic year, we are also planning to establish new research and education fields such as the Super Smart Town Ookayama concept, and we hope that Consortium Partners will be able to contribute to the construction and utilization of these research and education fields. We are looking forward to hearing ideas such as for solving social issues and verifying social implementation by means of these research and education fields.

Table1-2 Our activities in AY2020

Month	Events	Committee
June, 2020	6th Joint Committee meeting	①②③
June, July	Matching Workshop (Spring,2020)	③
June, July	Super Smart Society Innovation A2	②
July, August	Off-campus Project (Summer, 2020)	②
September	7th Joint Committee meeting	①②③
September	Tokyo Tech Academy for Super Smart Society holds opening ceremony	①
September	SSS Global Forum	①
October, November	Super Smart Society Innovation A1	②
November	8th Joint Committee meeting	①②③
November, December	Matching Workshop (Autumn, 2020)	③
January, February, 2021	Off-campus Project (Spring, 2021)	②
March	9th Joint Committee meeting	①②③
March	SSS Promotion Forum	①

① The Super Smart Society Promotion Committee
② The Social Collaborative Education Steering Committee
③ The Interdisciplinary Research Promotion Committee

Table1-3 SSS Research and Education fields

 **Automated car**	**Smart Mobility** A platform for smart mobility to utilizes automated driving and cutting-edge wireless systems such as millimeter-wave 5G.
 **Quadruped outdoor field robot**	**Smart Robotics** A platform for utilizing robots in the fields of land, air, water, and manufacturing. Conducting researches about four-legged robots for outdoor fields (land), drones(air), underwater robots and drones (water/underwater), and digital manufacturing technology, etc.
 **Cryogenic measurement system**	**Quantum Science** A platform for quantum computing and quantum sensors for the next generation. Conducting research and application of ultrafast next-generation quantum computers and ultrasensitive quantum sensors.
 **Supercomputer: TSUBAME3.0**	**Artificial Intelligence** A platform for artificial Intelligence (AI). The super computer "TSUBAME" and Wi-Fi6 are used to build a platform for the use of machine learning services.
 **Smart AI air conditioning based on thermal images**	**Smart Workplace** A platform for smart workplaces with the aim of establishing better workplaces. Building workplaces for the post COVID-19 era, including air conditioning control using a variety of sensors and AI.
 **Agricultural drone**	**Smart Agriculture** A platform for smart agriculture in response to problems related small-scale agriculture in Japan. Working on remote agricultural technology that enables automated and stable production of high-quality crops by fully utilizing AI, IoT, and robot technology.

2. Activities of the Super Smart Society Promotion Committee

2-1 SSS Global Forum

The Super Smart Society Promotion Consortium held the Online SSS Global Forum on September 12, 2020 to introduce the latest trends and technologies related to a super smart society, and it was an opportunity for international networking with Consortium Partners, students enrolled in the WISE-SSS Program, and overseas advisors. The program is shown in Figure 2-1. Since it was held online, in addition to lectures, a new initiative that combined lectures with group discussions was implemented. It was divided into morning and afternoon sessions since some participants were from Europe and North America.

Program	Main Topic: 5G & Beyond to realize super smart society
Session 1	
9:00-9:30	Invited talk by Dr. Ali Sadri (Vice President of SOLiD Gear, Inc.) Talk title: Role of mmWave Inteligent Repeaters in enhancing 5G coverage
9:30-10:30	Group discussion
Session 2	
16:00-16:30	Invited talk by Dr. Sumei SUN (Lead Principal Investigator of the Institute for Infocomm Research (I2R), Agency for Science, Technology, and Research (A*STAR)) Talk title: From 5G to 6G: What would be the key driving applications and enabling technologies?
16:30-17:30	Group discussion

Figure2-1 SSS Global Forum Program

The theme of the entire forum was “5G and beyond to realize a super smart society.” It combined lectures on cutting-edge technologies related to 5G and beyond with group discussions on contributing to the realization of a super smart society using 5G and beyond. In the morning session, Mr. Ali Sadri, Vice President of Solid Gear Inc. in the United States, gave a lecture on technologies for expanding service areas with millimeter wave that supports high-speed, large-capacity 5G. In the group discussions that followed, participants were divided into groups of six to seven people and overseas advisors were assigned to individual groups to talk about the future applications of 5G high-speed communication 10 years from now. Later, at the plenary meeting, the results from each group's discussions were presented. In the afternoon session, Dr. Sumei Sun, who is the Lead Principle Investigator of IIR (Institute for International Research) from Singapore gave a lecture on realizing 5G technology and technological developments leading to 6G, focusing on its applications. In the group discussions that followed, different overseas advisors from the morning session were assigned to individual groups to talk about future applications of IoT (Internet of Things) 10 years from now, and later, as in the morning session, the results of the discussions were presented.

Many of the participating students were not used to having discussions in English. It was a challenge for them to become facilitators and lead discussions among the participants with diversified majors from various parts of the world, but the forum was very fruitful with the support of overseas advisors.

An SSS Global Forum for the 2021 Academic Year is scheduled to be held in November 2021. We are considering using methods that will allow more Consortium Partners to attend.

2-2 SSS Promotion Forum

Digital technology is not only transforming the efficiency of manufacturing sites and offices, but also the way that the people there live and work. Based on these major trends, the Super Smart Society Promotion Consortium held the Third SSS Promotion Forum online on March 8, 2021 with the theme “The evolution of virtual space (Digital Twin) and new lifestyles.” This forum is sponsored by the Super Smart Society Promotion Consortium, co-sponsored by Tokyo Tech , and receives cooperation from the Society of Instrument and Control Engineers, the Information Processing Society of Japan, the Institute of Electronics, Information and Communication Engineers (IEICE), the Tokyo Tech Academy for Super Smart Society, MIRAI SOUZOU, and the IEEE Japan Council, with endorsements by the Ota Ward, Kawasaki City, Yokohama City Economic Bureau, and the Kuramae Kogyokai. The program is shown in Figure 2-2.

In the first half of the forum, after an opening speech by Professor Kei Sakaguchi, who is the coordinator of the consortium, a keynote speech entitled "Microsoft Technology for a Super Smart Society" was given by Mr. Akira Sakakibara of Microsoft Japan, that introduced tools for solving new social issues, and gave examples of using the latest technologies for the realization of a super smart society such as AI, IoT, digital twins, and XR. Next, Mr. Shinichiro Ueno of NTT Urban Solutions Inc., Mr. Yasuhito Omagari of Azbil Corporation, Mr. Hiromitsu Oikawa of Fujitsu Limited, and Specially Appointed Associate Professor Rei Kawakami gave lectures on such subjects as digital twins, AI, and AR/VR technology, and also introduced the latest technological trends that can contribute to the realization of the super smart society together with each company’s approach.

Figure2-2 3rd SSS Promotion Forum Program

In the second half of the forum, a panel discussion was held by Takeshi Hatanaka, Associate Professor of the School of Engineering as a moderator, where discussion was made among five presenters as well as Professor Kei Sakaguchi and Eisuke Fukuda (Specially Appointed Professor) regarding the utilization of future technologies in each specialized field. Here, they discussed the prospect of a future super smart society through the concrete application and utilization of digital twin technologies, human resource development for the future, and the expectations of the Super Smart Society Promotion Consortium.

Reflecting rapidly increasing expectations for DX (Digital Transformation), since a timely technical theme was chosen and discussed online, 346 people participated from inside and outside the university, sharing cutting-edge technologies.

3. Activities of the Social Collaborative Education Steering Committee

3-1 Implementation of cyber/physical off-campus projects

As part of the activities of the Social Collaborative Education Steering Committee, this consortium together with the Tokyo Tech Academy for Super Smart Society have planned cyber/physical off-campus projects (interdisciplinary internships for master's degree program and doctoral degree program students). Consortium Partner recruitment information was posted on the consortium website and it was made widely known to students. This internship is a key requirement for enrolling in and completing the WISE-SSS Program, and has encouraged highly motivated students to apply. Despite the difficulties during the state of emergency that was issued, 14 partners handled recruitment during the spring break period of 2020, and seven partners accepted internships for nine students. For the internship during the summer vacation period of 2020, six partners accepted internships for seven students. One of the challenges was having internships in English for international students. In 2021 academic year, we hope to continue discovering new fields where the needs of participating partners can be matched with the professional abilities of students, and that more internships can be accepted. The assumed period is during summer vacation (August 2021) and during the next spring vacation (March 2022). Also, because of the spread of globalization, we want to promote internships in English and plan overseas internships as we observe the world situation.

3-2 Courses related to Super Smart Society Innovation

The goal of the Tokyo Tech Academy for Super Smart Society is to cultivate the needed expertise and see the big picture for realizing a super smart society for students enrolled in the WISE-SSS Program or interested students (master's degree program and doctoral degree program), and to offer omnibus lectures on trending issues in the real world in collaboration with Consortium Partners. This will allow us to create original science and technologies in specialized fields spanning both cyber and physical fields, and resolve various social issues by having an overview of the path from quantum science to a super smart society, with the aim of developing students with leadership skills capable of leading each sector of industry, government, and academia. In the 2020 academic year, we held the “Super Smart Society Innovation A1: Frontiers in Quantum Technology” and “Super Smart Society Innovation A2: IoT / Robotics / Smart City” outreach courses with the cooperation of Consortium Partners. Because of the spread of COVID-19, omnibus lectures were given by researchers from participating partners using an on-demand distribution of lecture videos with discussions using a bulletin board system. A total of 40 students registered for A2 in the 2nd and 4th quarters of the 2020 academic year with 36 students earning credits, and 23 students registered for A1 in the 3rd quarter, with 21 students earning credits. Although this was the first time to use on-demand video-style lectures and have discussions using a bulletin board system, students were enthusiastic about taking the lectures and having discussions, and there was much positive feedback on the contents and implementation of the lectures. From the 2021 academic year, we will hold discussions with related organizations in order to open the “Super Smart Society Innovation A3: Frontiers in Smart Agriculture" related to smart agriculture.

3-3 Producing online educational content for a super smart society

For the 2020 academic year, we formulated a long-term development policy for online education. We considered effective online education implementation methods that can contribute to the promotion of a super smart society, and established a basic policy to provide future online education content using two types of frameworks; “SSS Professional Course” and “MOOC (Massive Open Online Course) and other OERs (Open Educational Resources) for general public.”

The “SSS Professional Course” will provide online courses mainly for working adults who belong to Consortium Partners of the Super Smart Society Promotion Consortium, allowing them to study highly specialized content centered on technical fields related to a super smart society. We started developing a “Smart Mobility” course as the first course, which is scheduled to begin in the fall of 2021. During the 2021 academic year, we plan to begin development of two more courses.

In “MOOC and other OERs for the general public,” the English version of “Introduction to Computer Science and Programming" was completed and implemented with edX (a free online education service launched jointly by Harvard University and MIT). By the end of the 2020 academic year, this course had become popular with 1,500 registrants in the Japanese version and 500 registrants in the

English version within the first three months. In addition, development of a “Learning programming with Shogi” course where you can learn programming in MATLAB language is underway and is planned to start in the fall of 2021.

4. Activities of the Interdisciplinary Research Promotion Committee

4-1 Matching workshops

The first semester’s interdisciplinary matching workshop was held online on June 17 and July 1, 2020. The S-Round on June 17th was the stage where students from Tokyo Tech offered the university’s research seeds (Fig. 4-1), while the N-Round on July 1st was the venue where Consortium Partners of the Super Smart Society Promotion Consortium presented their needs in an opposite way. There were lively discussions among the 34 participating students, researchers from 22 partners, and university faculty members. Mutual surveys were taken of both students and participating partners, based on which about eight bilateral matches were established. Similarly, on November 18 and December 2, 2020, the second semester’s interdisciplinary matching workshop was held using the same online format as the prior one. Twenty-nine students, researchers from 16 partners, and university faculty members participated, and six bilateral matches were established. In total from these two workshops, seven collaborative research projects were started in the 2020 academic year.

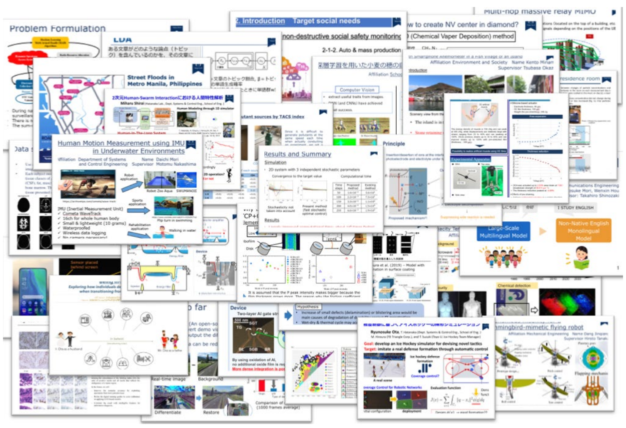


Figure4-1 Seeds presented by the students at S-Round

4-2 SSS research and education fields

4-2-1 Smart Mobility

We are building a platform to educate students enrolled in the WISE-SSS Program, and conduct collaborative research on automated driving and mobility services with Consortium Partners of the Super Smart Society Promotion Consortium.

During the 2020 academic year, we provided a practice program for enrolled students by allowing them to experience operating and riding in autonomous vehicles (Fig. 4-2). Road-side units (RSUs) equipped with 60 GHz millimeter-wave antennas, high-definition cameras, and LiDAR (Light Detection and Ranging) sensors were also installed on campus (Fig. 4-3). An RSU can monitor the surrounding environment as three-dimensional information through camera images and LiDAR point cloud. This sensor data are then transmitted to vehicles in real time via the millimeter-wave wireless link. The vehicle then combines camera images and point cloud as high-presence information enabling advanced detection of dangers that can contribute to safe and automated driving control. In addition, we have introduced a new hybrid vehicle (HV) having an automated driving function intended for driving tests on public roads (Fig. 4-4). This will also enable experimental demonstrations, including vehicle-to-vehicle communication in addition to owned-vehicles and will build an advanced exercise curriculum.

In the 2021 academic year, we plan to improve the RSU network and begin full-scale operations. Automated driving functions will be expanded to proceed with the research and development of smart mobility services. We are also planning to deploy a 5G network on Tokyo Tech campus. We expect to realize an open platform that can create a variety of new services and technologies through collaboration with other fields. These environments are widely open to Consortium Partners.

Figure4-2 Automated driving exercise

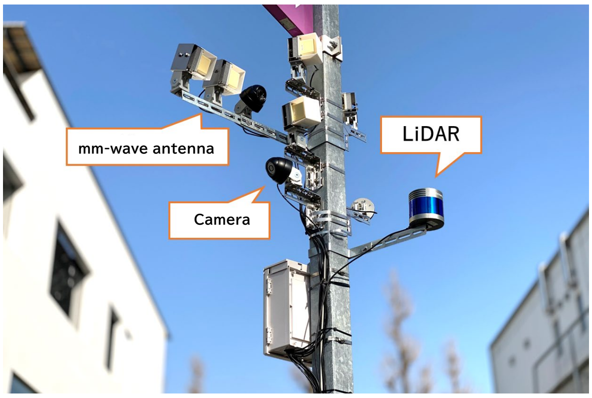


Figure4-3　RSU at the campus

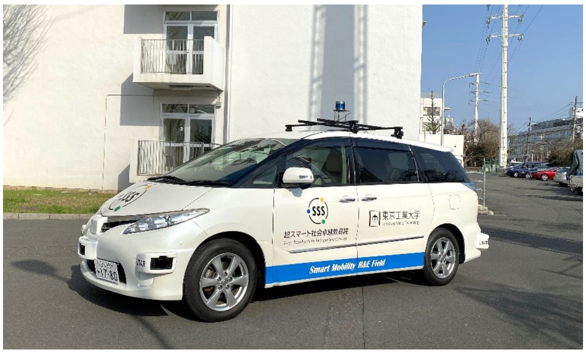


Figure4-4 Automated car designed for driving on public roads

4-2-2 Smart Robotics

● Robot Zoo Sky

During the 2019 academic year, we built Robot Zoo Sky as a platform to simultaneously control heterogeneous drones and mobile robots. The main purpose of this research and education field is to develop efficient and robust environmental monitoring technologies that contribute to supporting damage assessment after a natural disaster, and to contribute to the realization of a super smart society in the context of enhancing societal resilience. Also, through exercises in this field, students will be able to gain the skills to safely control and operate multiple systems connected via a network.

In the 2020 academic year, we worked on establishing a learning curriculum using this field. In particular, we completed a lecture curriculum for using a Robot Operating System (ROS), which forms the foundation for the field and is becoming widespread in society. In October, this ROS course was held for engineers from Consortium Partners and received a high reputation. We also implemented system construction, modeling, and basic control system design for ground robots purchased in the previous academic year for conducting exercises with actual machines, and confirmed that these can be used for education. Furthermore, we built a system for coordinated control of multiple ground robots (Fig. 4-5). In the future, we plan to develop a more attractive curriculum that links ROS training with actual robot experiments.

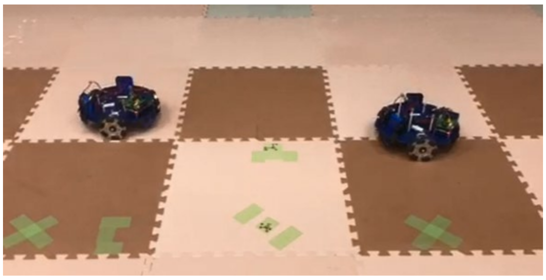


Figure4-5 System for coordinated control of multiple ground robots

Regarding the multi-drone coordinated control system, a new environment monitoring control algorithm was established from this research and education field. This manages possibly conflicting various specifications including target surveillance, target search, collision avoidance, and battery charging in a systematic way (Fig. 4-6). The results from this research were presented at the IEEE Conference on Control Technology and Applications, and received the Outstanding Student Paper Award. We also held a demonstration of the experiment for a Consortium Partner. Further collaborative research that utilizes this field is expected to be promoted in the future.

Figure4-6 New environmental monitoring control technology

● Robot Zoo Aqua

Robot Zoo Aqua aims to expand the active field of robots to water. In the 2019 academic year, we constructed basic equipment for this research and education field including a large water tank, optical motion capture system, and surface drones.

In the 2020 academic year, we introduced an inertial sensor type motion capture system to further enhance this field. This system can easily be attached to either the human body or a robot as shown in Fig. 4-7. In this figure, an inertia sensor is attached to each of the upper arm, forearm, and hand. The whole system is capable of measuring 16 inertia sensors simultaneously, and since it is waterproof, it can also measure underwater movement. Currently, we are working with underwater motion analysis simulation software, and once this is realized, it will be possible to measure and analyze the motion of the whole body for activities such as underwater sports and underwater exercise.

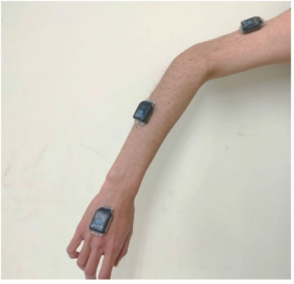


Figure4-7 Inertial sensor attached to the human body arm

We also installed the cameras of the optical motion capture system that was purchased the previous year to the ceiling (Fig. 4-8). This reduced the recalibration load due to minute changes in the stand position, enabling more accurate measurements. In addition, we achieved automation of actuation for configuring an auto control system for water surface drones. Specifically, it became possible to modify existing control devices and reflect control commands from the microcomputer in the robot movement.

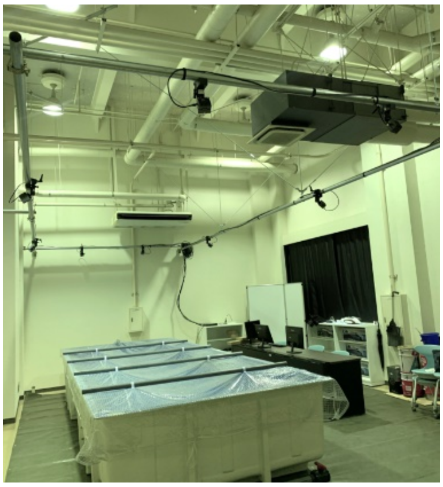


Figure4-8 Ceiling-mounted optical cameras of motion capture system

Moreover, in this research and education fields, we will invite visits from Consortium Partners to promote the concrete implementation of collaborative research using this field in the future.

●Robot Land

Robot Land consists of a group of robot platforms for education and research including collaborative robots, quadruped outdoor field robots developed by Tokyo Tech, and multifunctional robot modules, as well as a group of robot evaluation and control equipment including digital signal processors and controller devices, high-speed motion capture systems for control, and high precision GNSS + INS (Global Navigation Satellite System + Inertial Navigation System) hybrid equipment. Through these efforts, we aim to provide an education and research environment and educational program for smart robotics that utilizes 5G, IoT, and AI. We also seek to promote practical education and research that addresses social issues such as disaster response, infrastructure development, and aging.

Operation of each equipment began in the 2020 academic year, and the high-speed motion capture system for control was used to conduct motion analysis of various robots. We also succeeded in operating robots in real time with this system according to the movement of the operator, and demonstrated that collaborative work via remote control of robots is possible (Fig. 4-9). We also developed an indoor omnidirectional moving platform where collaborative robots can be transported and an outdoor rough terrain moving platform (Fig. 4-10). Moreover, we continued with research and development of quadruped outdoor field robots, and realized autonomous operation in the field with guidance by GNSS+INS (Fig. 4-11).

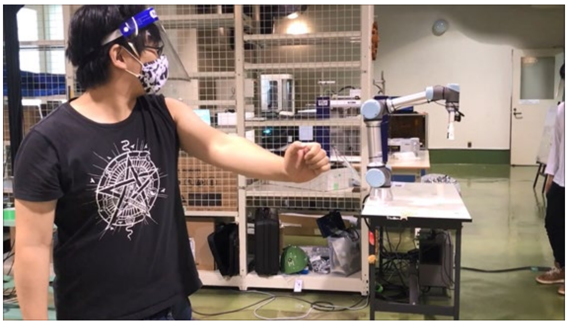


Figure4-9 Working remotely with a high-speed motion capture system for control

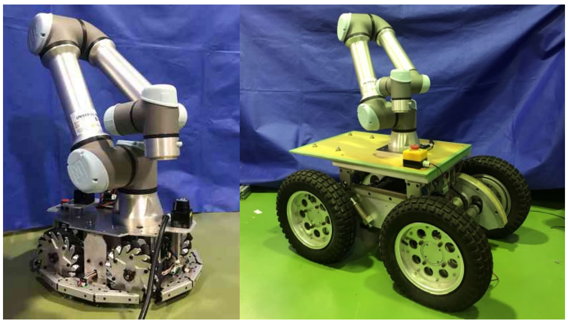


Figure4-10 Mobile Manipulator VR Teleoperation System (Left: indoor, right: outdoor)

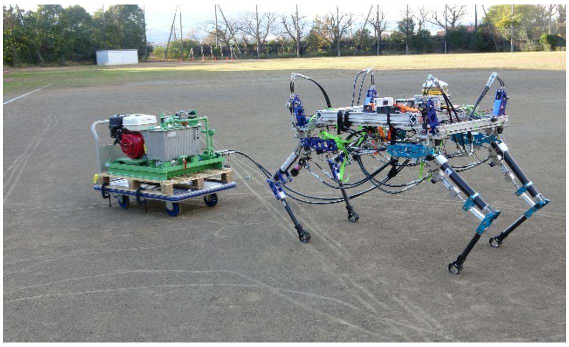


Figure4-11 Quadruped outdoor field robot

● Smart Manufacturing

In the Smart Manufacturing research and education field during the 2020 academic year, we prepared operation environments for various sensors including (1) establishing an environment where digital manufacturing can be experienced by linking a machine tool with a CAM (Computer-Aided Manufacturing) system which is used to generate a processing plan for complicated parts designed using 3D CAD (Computer-Aided Design), and (2) creating a system for defining shape data for processing targets on machine coordinates attached to the machine tool based on acquired 3D data obtained by a 3D camera installed outside the machine. In particular, about acquiring the position and orientation of the material using the camera, we improved the measurement accuracy by installing a light source and a tactile touch probe to supplement the 3D data from the camera (Fig. 4-12).

In order to proceed with research on cutting-edge themes in current machining and manufacturing fields, we introduced load sensors with high sampling frequencies and equipment for ultrasonic-assisted processing. Actual machining training by linking these devices helps with understanding upstream production system research topics such as machining process design and new downstream side machining technologies that are actually being introduced at machining sites such as ultrasonic vibration cutting. In particular, for students based in the cyber field, the opportunity to see processing in action and to be exposed to these leading-edge researches can provide hints for researches that combine different fields.

In the 2021 academic year, we will use newly installed equipment and existing equipment effectively to develop concrete training programs, and we will proceed with research in order to propose high-efficiency production systems that link conventional high-precision machining such as cutting with relatively new machining processes such as AM (Additive Manufacturing).

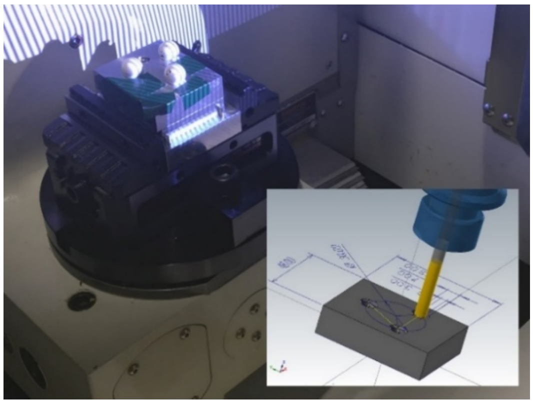


Figure4-12 Measurement of the position and position with 3D camera

4-2-3 Quantum Science

● Quantum Computing

Quantum computers are expected to be put into practical use as ultra-high-speed next-generation computers that are based on the principles of quantum mechanics. While a normal computer uses a state (bit) of either “0” or “1” for information processing, a quantum computer performs calculations by using a qubit that is a superposed state of 0 and 1. We already know that it is possible to perform massively parallel high-speed computation by operating qubits that are integrated on a large scale, and research into how to apply it is progressing. Such technology is also expected to contribute to solving the information processing problems required in a super smart society.

Research aimed at realizing qubits is being actively conducted in various physical systems. Although methods using superconductors are advancing, the spin in silicon quantum dots is also viewed as a promising system. This method will enable the integration of devices in the future via semiconductor processing technology. It also has the advantage of a long coherence time corresponding to the information retention time.

In this research and education field, while conducting research mainly on the spin system, we are cultivating human resources and conducting education and research for high-level quantum technology.

In the 2020 academic year, we constructed a measurement system for realizing and evaluating qubits as shown in the schematic diagram of Fig. 4-13 in combination with existing cryogenic refrigerators (cryogen/cryogen-free type) (Fig. 4-14), and gave a demonstration at the WISE-SSS opening ceremony (Fig. 4-15). To expand the high-precision, low-noise measurement system for observing quantum phenomena at extremely low temperatures, we installed new equipment for expanding the quantum computing device measurement system comprised of a vector signal generator, high-speed oscilloscope, and lock-in amplifier. In the 2021 academic year, we plan to hold a One-Day School for companies and provide practical training for measuring quantum states using the measurement system to students enrolled in the WISE-SSS Program in order to acquire technologies that are used in the latest quantum science research such as high-frequency technology, precision measurement technology, ultra-low temperature technology, and vacuum technology. It is also our desire that related companies and national research institutes will utilize this to promote collaborative research.

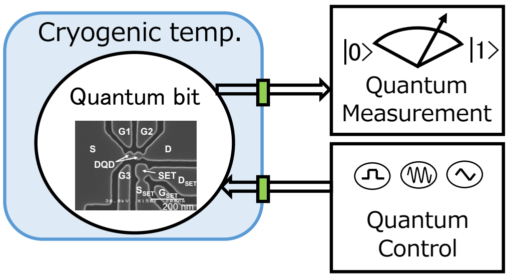


Figure4-13 Schematic image of quantum bit measurement system

Figure4-14 Measurement system with the existing cryogenic refrigerator

Figure4-15 Exercise on cryogenic technology and precision measurement

● Quantum Sensors

A sensor is defined as a device that converts a physical phenomenon or the state of an object into an electrical signal, while a quantum sensor is a sensor that uses quantum effects (a phenomenon appearing in quantum mechanics) to detect at a higher sensitivity than conventional sensors. Therefore, it should be possible to detect physical quantities that could not be detected previously. Consequently, these sensors are expected to contribute to building a super smart society.

Quantum sensors include Superconducting Quantum Interference Device (SQUID), Diamond Nitrogen-Vacancy Center (NV Center), and sensors that use atomic gas. Among these sensors, we are particularly focusing on SQUID sensors as shown in Fig. 4-16, which are able to detect minute magnetic fields. If highly sensitive detection is possible, it would be possible to detect the weak magnetic fields generated from the heart and brain. This would allow the technology to be applied to medical procedures such as magnetoencephalography and magnetocardiography. It would also be possible to conduct immune tests using magnetic markers. Thus, SQUID sensors are an important element of super smart medicine. However, there are technical issues with such sensors including low spatial resolution and the fact that they need to operate at very low temperatures.

Therefore, in order to develop SQUID sensors that are smaller and can operate at higher temperatures, in this research and education field, we are developing high-temperature superconductors with a thickness of several atomic layers. These superconductors will be used as materials in SQUID sensors. In order to promote this research, in the 2020 academic year, we conducted research on the high-temperature superconductivity of single-layer Feste thin films on $SrTiO_3$ substrates using equipment to evaluate superconducting thin film properties. As a result, it was found that changing the surface structure of the substrate systematically changes the size of the superconducting gap of the FeSe thin film. Moreover, we worked on developing a superconductor using graphene, which is a monatomic layer carbon sheet, using superconducting thin film fabrication equipment. We also began research on physical properties using a Diamond NV Center, which is capable of detecting minute magnetic fields similar to SQUID sensors.

In addition, practical training (Fig. 4-17) was given to students enrolled in the WISE-SSS Program using these devices. As mentioned above, in addition to engaging in research, we also develop human resource and provide education on quantum science in the quantum sensor research and education field. In the future, we hope that companies and national research institutes will utilize this field through One-Day Schools and collaborative research.

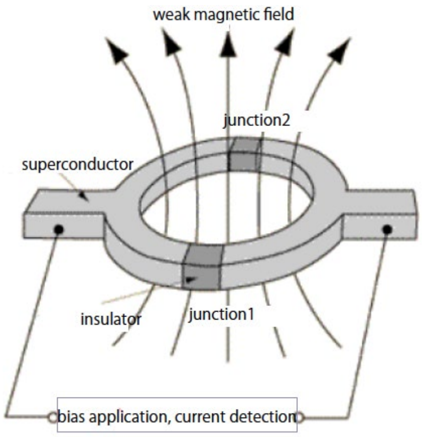


Figure4-16 Schematic drawing of a Superconducting Quantum Interference Device (SQUID)

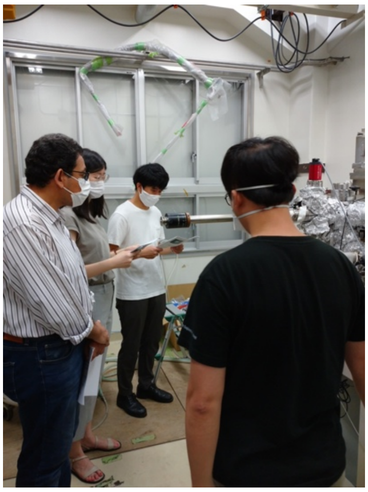


Figure4-17 Hands-on experience with quantum sensors

4-2-4 Artificial Intelligence

In a super-smart society, we expect every device that we use in our daily lives will become smart and connected to computers, resulting in a safer and more convenient life. Computer control requires a system that can operate by recognizing and understanding surrounding conditions via sensors and cameras. However, much of the information in the physical world is noisy and unclear. Therefore, in order to properly process these in the cyber world, it must be converted into symbolic information that is easy for computers to process.

At this Academy, we consider artificial intelligence technology to be a basic technology that can connect the cyber and physical worlds in a super smart society. Therefore, we are providing education with

of making it easier for enrolled students to master artificial intelligence technologies. Starting in the 2020 academic year, university-wide data science and AI (DSAI: Data Science and Artificial Intelligence) education for graduate students started at Tokyo Tech. Unlike existing classroom-only lessons, this allows students to practice while actually operating machine learning tools. For this purpose, in this research and education field, we established an education system using WiFi 6, and it has been operating since the 2020 academic year.

To ensure the efficient use of deep learning, which is an artificial intelligence technology, advanced computational resources called GPUs (Graphics Processing Units) are needed. Currently, GPUs are expensive for all students to buy, but cloud services can provide all students with the same computational resources at low cost. In this research and education field, students can easily access the learning environment in the cloud using WiFi from their own computers. On the cloud, it is possible to actually handle the materials and exercises presented by the teacher as a “moving textbook” using a Web service called Google Colaboratory (Note), allowing for comfortable learning (Fig. 4-18). This also allows the GPU of the university's supercomputer TSUBAME (Fig. 4-19) to be used.

(Note) Google Colaboratory: A development environment for machine learning education and research provided by Google.

Since the 2020 academic year, we have been working to make it possible for students enrolled in the WISE-SSS Program to access the latest research results, learn directly from faculty members through practical training, and to improve their skills through these exercises. In August 2020, we held exercises on speech recognition and speech synthesis, and a learning results presentation was held in October.

In addition to these, online support started in the 2020 academic year. We established a system that allows students to ask questions on technical problems that they face when actually using artificial intelligence for their research projects through a dedicated online bulletin board, and if necessary, they can hold direct meetings with faculty members to resolve the problems.

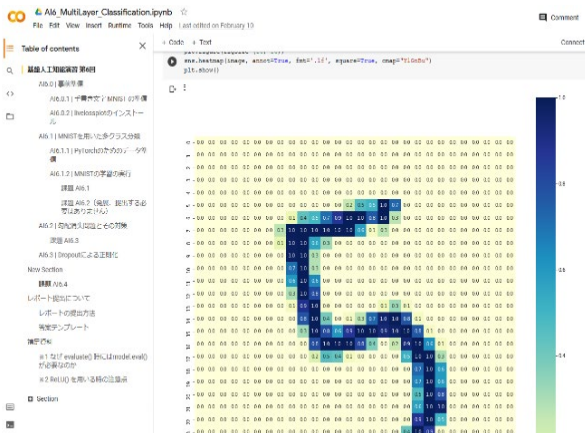


Figure4-18 Google Colaboratory

Figure4-19 TSUBAME

4-2-5 Smart Workplaces

In this research and education field, which was started in the 2020 academic year, a platform is being established under the theme "smart workplaces" with the aim of creating better places for work. Until now, we have had almost no choices but to work in the offices, and offices are focused solely on increasing work productivity. However, since there is greater interest in health management and due to the enforcement of laws related to work style reform in 2019, there is a real need for health management in the offices. Also, due to the COVID-19 pandemic in 2020, telecommuting has been rapidly implemented, making the home into a workplace. Therefore, in the research and education field of smart workplaces, we are determining what is the best way to work in offices and at home, and how to manage health.

As the first step, in the 2020 academic year, we began building a wireless sensor network for indoor environments and for the vital signs of workers at the Otemachi office (Fig. 4-20) (scheduled to be completed at the end of May 2021). Here, by smart

Figure4-20 Office with sensor network

air-conditioning using AI based on the sensing results, the goal is to create a more human- centered, comfortable, and highly productive environment that cannot be achieved through conventional room temperature control. Moreover, we will verify ideal health management methods in the office by sensing vital signs (Fig. 4-21).

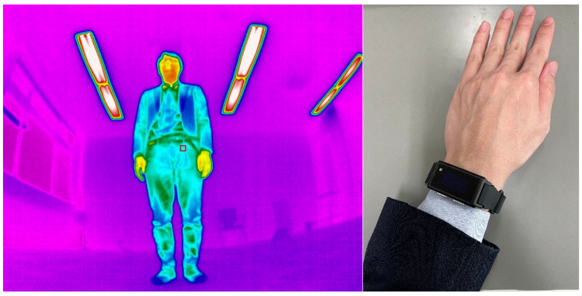


Figure4-21 Examples of Vital Signs Sensing

In the 2021 academic year, we will begin verifying what future office should be like by utilizing the above wireless sensor network. An urgent issue related health management at the office is controlling infection in a post COVID-19 world. We hope to propose infection control measures for the post COVID-19 era through computational fluid dynamics using thermal image sensor information as boundary conditions and by visualizing the behavior of droplet nuclei using signage and MR (Mixed Reality). We are also planning to reproduce work-from-home environments at the Suzukakedai campus of the university to verify work productivity and sleep efficiency at home, which have become another important workplace. Construction of work-from-home environments will take place during the 2021 academic year, and full-scale operation is expected to start in the 2022 academic year as a site for subject experiments.

4-2-6 Smart Agriculture

The goal of smart agriculture is to increase the productivity of the entire agriculture food chain, including breeding, production, processing, distribution, and consumption, by using robots, ICT (Information and Communication Technology), and AI (Artificial Intelligence). In Japan, it is difficult to improve efficiency because of the large number of small-scale agricultural fields, and due to the fact that the number of farmers is declining. Therefore, smart agriculture needs to be implemented as quickly as possible.

In this research and education field, by utilizing robot technology, ICT technology, and AI technology, which are Tokyo Tech's strengths, we will build edge AI and cloud AI that can acquire a large amount of data from various sensors and make decisions based on this. In the future, our goal is to achieve remote agriculture that can be operated autonomously.

We decided to construct a smart agricultural research and education field at the Tokyo Tech Suzukakedai Campus in the 2020 academic year. With the recent rapid spread of drones, it is possible to acquire a large amount of data for accurately measuring agricultural land. We are observing the research and education field we established and are using the data we obtain to develop a technical foundation for achieving highly productive agriculture. We will also develop advanced robot technology there capable of autonomously controlling multiple drones. A smart agricultural field with power, communication and water, equipped with a fixed-point observation sensor network will be completed in the 2021 academic year (Figures 4-22 and 4-23). The field is surrounded by safety nets for risk mitigation in drone flight operations. Later, we are planning to use this as a site for collaborative research with Consortium Partners.

Another goal of the Academy is to develop leaders who will promote smart agriculture, and we plan to hold lectures so that each element of the above-mentioned agricultural food chain can be learned in collaboration with Consortium Partners.

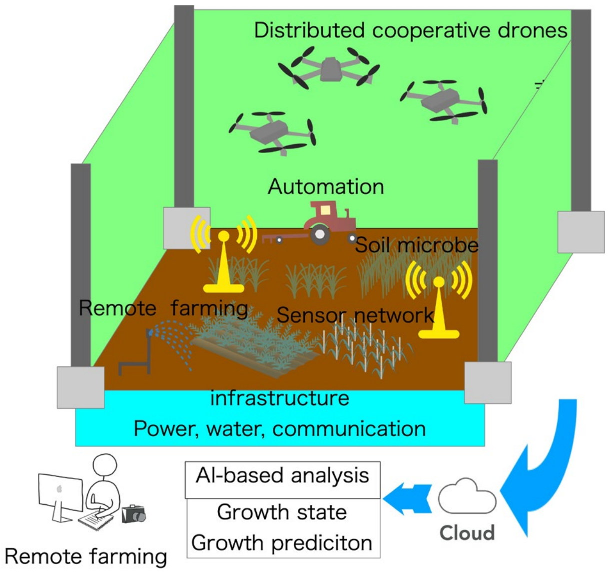


Figure4-22 Plan of Education and Research Filed for Small-Scale Open-Air Smart Agriculture

Figure 4-23 Projected view of the Smart Agriculture field site

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2020 Super Smart Society Promotion Consortium Activity Report

Date Of Issue August 30, 2021
The Issuer Nobuyuki Iwatsuki
Editor Super Smart Society Promotion Consortium Steering Committee

Issue Super Smart Society Promotion Consortium Secretariat
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