Super Smart Society Promotion Consortium
TokyoTech

Tokyo Tech

2019 Academic Year

Super Smart Society Promotion Consortium Activity Report

(April, 2020)

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Super Smart Society Promotion Consortium Activity Report（2019 Academic Year）

1. Overview of Activities in the Second Year (2019 Academic Year)

The Super Smart Society Promotion Consortium was established in October 2018 to construct and evolve a Super Smart Society (SSS), and to cultivate through industry-government-academia collaboration the human resources who will lead these efforts.

In the 2019 academic year, in preparation for application to and adoption for the WISE Program (Doctoral Program for World-leading Innovative & Smart Education), which is a core project in SSS and is operated by the Ministry of Education, Culture, Sports, Science and Technology, we focused on developing the organizational structure of the Consortium, conveying information on SSS promotion activities, constructing the WISE Program curriculum for application, and attempting interdisciplinary research for an SSS.

First, we actively conducted recruitment and solicitation activities for participating organizations. As a result, the number of participating organizations increased from 34 at the end of the 2018 academic year to 41 at the end of the 2019 academic year. Each participating organization dispatched a member to one of the three major committees (Super Smart Society Promotion Committee, Social Collaborative Education Steering Committee, Interdisciplinary Research Promotion Committee) in the Consortium. These members also assumed supervisory positions (Special Advisors, Research Advisors, Corporate Advisors, etc.) in relation to the WISE Program. Furthermore, in addition to more than 60 faculty members from the Tokyo Institute of Technology (hereinafter, "Tokyo Tech"), these members established organizational structures for operation of the Consortium and the WISE Program.

Regarding the dissemination of information on activities, the first international forum was held in August. Under the theme of "AI for realizing Super Smart Society," we held lectures and information exchange meetings by experts from around the world to discuss the application and prospects of AI in a variety of fields.

Regarding the WISE Program curriculum, in order to cultivate the expertise and bird's-eye view necessary to achieve an SSS, we designed omnibus classes given by lecturers of participating organizations, designed subjects related to quantum science, produced and planned online education, and constructed research and education fields.

As part of these preparations, we applied to the WISE Program for the Engineering Education Program for Super Smart Society Based on Advanced Quantum Science and were selected in August. We would like to thank all the organizations and faculty members participating in the Consortium for their efforts in achieving selection. Next, on December 1, we established the Tokyo Tech Academy for Super Smart Society and began selecting students from April.

Finally, in November 2019, in regard to trials of interdisciplinary research for an SSS, we held a matching workshop between students who plan to apply for registration to the Tokyo Tech Academy for Super Smart Society and participating organizations. At the workshop, we shared information on the seeds of students and the needs of participating organizations, and requested internships at participating organizations. At the same time, several projects for interdisciplinary research are already being started with participating organizations.

Education in the Tokyo Tech Academy for Super Smart Society will finally start from the 2020 academic year. We would like to ask for even greater cooperation from all participating organizations in order to achieve the objectives of the collaborating Consortium.

2. Establishment of the Tokyo Tech Academy for Super Smart Society

2-1 Overview

In the 2019 academic year, we established the WISE Program for Super Smart Society in order to cultivate human resources in the SSS Promotion Project which is being advanced by the Consortium. In order to launch the WISE Program for SSS, we applied in 2019 for the WISE Program of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and were selected on August 9, 2019. <https://www.mext.go.jp/a_menu/koutou/kaikaku/takuetudaigakuin/> On December 1, 2019, as a school that implements and manages the WISE Program for SSS, the Tokyo Tech Academy for Super Smart Society was established inside the Tokyo Institute of Technology. Finally, from April 2020, we started the WISE-Super Smart Society

(SSS) Program as an integrated master's and doctoral degree program. <https://www.wise-sss.titech.ac.jp/>

2-2 Purpose of this educational program

Figure 2-1 shows the image of human resources cultivated in the WISE Program for SSS. For the future of our world, this educational program will target seven technological fields related to an SSS: (1) Smart Agriculture, (2) Smart City, (3) Smart Ocean, (4) Smart Manufacturing, (5) Smart Mobility, (6) Smart Energy, and (7) Smart Sky. The following abilities are defined as being necessary in human resources who will lead these fields.

(1) Make core skills rooted in quantum science and artificial intelligence available to all academics.
(2) Encourage original research spanning the domains of cyber and physical space.
(3) Enhance the big picture from quantum science to Super Smart Society.
(4) Innovate interdisciplinary research to create Super Smart Society.
(5) Promote a talented and seamless leadership between academia, government, and industry.

The purpose of the educational program is to cultivate knowledgeable professionals with these characteristics; in other words, "Super Doctors."

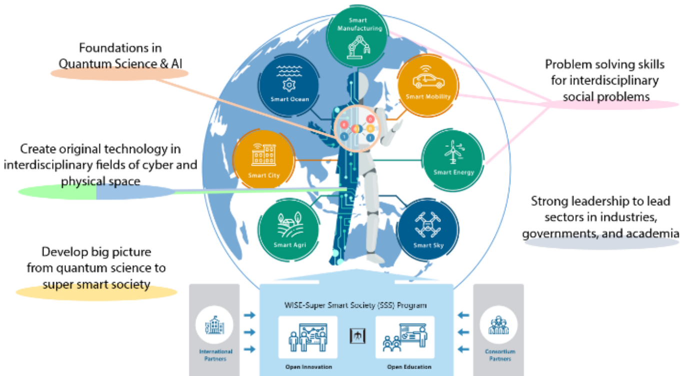

Figure 2-1 Image of human resources cultivated in the WISE–Super Smart Society (SSS) Program

2-3 Implementation structure of this educational program

As shown in Figure 2-1, in the field of SSS, it is essential to cultivate human resources through social collaborative education (open education) and interdisciplinary research (open innovation). The WISE Program for SSS will work closely with organizations participating in the Consortium to develop a bird's-eye view through social collaborative education and problem-solving ability through interdisciplinary research. Also, in cooperation with international partners, we conduct education for global leaders who possess specialized knowledge and high aspirations. Furthermore, from Tokyo Tech, education is conducted by faculty from a total of six schools and institutes, as well as from the Institute for Liberal Arts. In other words, integrated education will be implemented in which physical technology will mainly be handled by the School of Engineering, cyber technology by the School of Computing, and quantum technology by the School of Science. Specialized academic ability and creativity will be fostered across these fields.

2-4 Structure of the educational program

The structure of the educational program is shown in Figure 2-2. The orange section in the center represents the composition of the educational program, the blue on the right side represents organizations participating in the Consortium, and the green in the middle represents the Consortium itself. Here, the Consortium serves as a bridge between the organizations participating in the Consortium and the educational program. The red arrow connecting the organizations participating in the Consortium and the educational program indicates open innovation, while the blue arrow indicates open education.

Open education is planned by the Social Collaborative Education Steering Committee of the Consortium. Specifically, the Committee handles (1) cyber / physical off-campus projects (internships at organizations participating in the Consortium, (2) courses related to Super Smart Society Innovation taught by part-time lecturers invited from organizations participating in the Consortium, and (3) online distribution of educational content.

Open innovation is planned by the Interdisciplinary Research Promotion Committee of the Consortium. Specifically, the Committee handles (1) matching workshops for building a research team for interdisciplinary research, (2) the SSS Basic Technology Research Project for receiving advice from organizations participating in the Consortium, and (3) the SSS Innovation Research Project which is jointly implemented with organizations participating in the Consortium. As a platform to jointly execute these research projects, we are building research and education fields on the campus of Tokyo Tech.

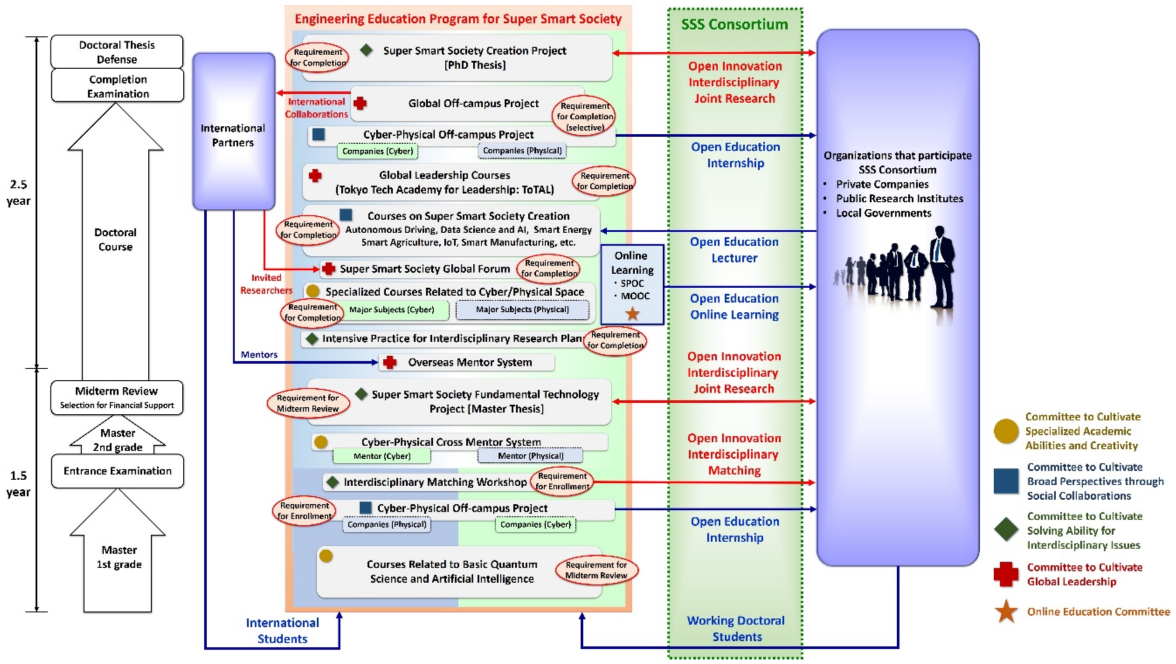

Figure 2-2 WISE–Super Smart Society (SSS) Program

3. Activities of the Super Smart Society Promotion Committee

3-1 Holding of the SSS Global Forum

On August 2, 2019, the Super Smart Society Promotion Consortium held the SSS Global Forum at Kuramae Hall on the Tokyo Tech campus. This international forum introduced the latest trends and advanced technologies related to an SSS, and provided an opportunity for international networking. This Forum was operated by the Super Smart Society Promotion Consortium, was sponsored by the Tokyo Institute of Technology, Solution Research Center for Advanced Energy Systems (AES), the Tokyo Institute of Technology, Research Center for the Earth Inclusive Sensing Emphathizing with Silent Voices (EISESiV), and received support from the Institute of Electronics, Information and Communication Engineers (IEICE), the IEEE Japan Council, and The Science News Ltd. The program is shown in Figure 3-1.

In the first part, under the theme of "AI for realizing Super Smart Society," we invited researchers and experts in various fields from Japan and overseas to give lectures on the prospects of an SSS that is achievable by utilizing and applying AI to a variety of onsite fields such as medicine, manufacturing, and services. In the first keynote lecture, Professor Shen of the North Carolina-Chapel Hill University in the United States introduced the latest research results on cancer detection methods via image processing using deep learning. In the second keynote lecture, Dr. Schulz-Zander of Fraunhofer Heinrich Hertz Institute (Germany) introduced artificial intelligence application examples and standardization trends for sensor fusion of IoT devices to realize smart factories in Europe. As invited lectures, Mr. Bacchiani of Google Japan discussed the latest technology of speech recognition developed by Google, and Professor Suzuki of the Tokyo Institute of Technology, Institute of Innovative Research presented the use of AI for medical treatment and conditions at the forefront of treatment. As requested lectures, organizations participating in the SSS Promotion Consortium introduced the three latest research results on AI application. In the

Program

【Part Ⅰ】
13:00-13:05 Opening Remarks
・Prof. Kazuya Masu (President, Tokyo Institute of Technology)

◆Keynote Talk
13:05-14:05 "Deep Learning in Brain Quantification and Cancer Radiotherapy"
・Prof. Dinggang Shen (University of North Carolina-Chapel Hill)
14:05-15:05 "Bringing the benefits of AI to industrial communication for smart factories"
・Dr. Julius Schulz-Zander (Fraunhofer HHI)
15:05-15:25 Break

◆Special Invited Talk
15:25-15:55 "End-to-end Speech Processing"
・Dr. Michiel Bacchiani (Google Inc.)
15:55-16:25 "Smart Medical Image Processing and Diagnostic Aid with Deep-Learning-Driven-AI"
・Prof. Kenji Suzuki (Specially Appointed Professor, Institute of Innovative Research (IIR), Tokyo Institute of Technology)
16:25-16:40 Break

◆Invited Talk
16:40-17:00 "Introduction of Big Data and AI utilization cases in Industrial/Commercial Printing Systems"
・Mr. Tetsuya Morita (RICOH COMPANY, LTD.)
17:00-17:20 "Cyber physical system construction using Bayesian network"
・Dr. Yoichi Motomura (National Institute of Advanced Industrial Science and Technology)
17:20-17:40 "Co-Design for Deep Learning"
・Prof. Koichi Shinoda (Professor, School of Computing, Tokyo Institute of Technology)
17:40-17:45 Closing Remarks
・Prof. Nobuyuki Iwatsuki (Professor, Dean/Super Smart Society Promotion Consortium Committee Chair, School of Engineering, Department of Mechanical Engineering, Tokyo Institute of Technology)

【Part Ⅱ】
18:00-19:30 Summer Reception

Figure 3-1 Global Forum Program

second part of the Forum, a party was held in order to facilitate exchange among participants and deepen interaction.

The SSS Global Forum for the 2020 academic year is scheduled to be held on September 12.

4. Activities of the Social Collaborative Education Steering Committee

4-1 Holding cyber / physical off-campus projects

As part of the activities of the Social Collaborative Education Steering Committee, the Consortium planned interdisciplinary internships during the spring vacation (February 10, 2020 to March 31, 2020) in the 2020 academic year, and requested that organizations participating in the Consortium perform recruiting for internships. At the time of recruitment, we posted recruitment information on the Consortium website for each organization in order to raise awareness among students. This internship is an accredited course, and we have encouraged application by highly-motivated students by making internships a requirement to participate in registration application for the WISE-SSS Program. As a result, we received recruitment offers from 14 organizations, which is equivalent to approximately one-third of the participating organizations. Of these, 7 organizations accepted internships by 9 students. Participating students consisted of 4 students in the first year of the master's program, 4 in the second year of the master's program, and 1 in the first year of the doctoral program. The length of the internships varied depending on the host organization, ranging from 2 to 4 weeks. The majority of the host organizations were manufacturers.

In order to prevent the spread of COVID-19, some organizations have cancelled or postponed internships for the time being. A future challenge which still needs to be addressed is finding internships which use English and assume participation from international students.

In the 2020 academic year, we will actively seek out new fields which match the needs of participating organizations and the professional abilities of students, and request the acceptance of more interns. The internships are envisioned to take place during summer vacation (August 2020) and during spring vacation of the 2021 academic year. Furthermore, in consideration for increased globalization, we will encourage internships in English and also plan overseas internships.

Table 4-1 Internship statistics (Spring 2020)

Recruitment offers	Accepted internships (Number of students)		No applicants, Cancellation due to COVID 19 etc.
14 institutions	National institute	1 institution (2)	1 institution
	Private company	6 institutions (7)	6 institutions
	total	7 institutions (9)	7 institutions

4-2 Building courses related to Super Smart Society Innovation

The Tokyo Tech Academy for Super Smart Society aims to foster the expertise and bird's-eye view to realize an SSS in students registered for the WISE-SSS Program, and in students in the master's program and doctoral program who wish to register. Through cooperation with organizations participating in the Consortium, we hold omnibus lectures related to advanced issues in actual society. In this way, we will create original scientific technology in specialized fields that straddle cyberspace and physical space. Furthermore, we will cultivate students with leadership skills who are capable of solving various social issues through a bird's-eye view of the path from quantum science to the SSS, and who will fulfill a leading role in the industry, government, and academic sectors.

In the 2020 academic year, we will offer courses on the forefront of quantum science and courses on IoT, robotics, and smart cities. Each course will consist of 7 lectures. Lectures will be given by frontline experts from organizations participating in the SSS Promotion Consortium. In regard to resolution of actual social issues and a discussion of issues for achieving an SSS, we have requested omnibus-style lectures from perspectives such as quantum science, fundamental technology, system implementation, and creation of a new society.

4-3 Production of SSS online educational contents

In order to achieve leading education for SSS, we plan to hold a total of 10 Massive Open Online Courses (MOOCs) and Small Private Online Courses (SPOCs) related to quantum science, AI, and “SSS research and education fields” by the 2025 academic year.

Prior to that, in the 2019 academic year, we developed the course "Introduction to Computer Science and Programming" and started to develop "Programming and AI through the Game of Shogi." The former course was designed to learn computer

science basics and key concepts while experiencing how to program and design computational algorithms; for example, encryption, decoding, and decryption which are the basis of information security, as well as computer simulation and data mining which are examples of practical utilization of computer science in modern society. The course was published on edX, which is a leading MOOC platform, and was taken by about 1,000 people. We have also started developing the English version of this course. It is scheduled to be published on edX around July 2020. (Note: edX is a free online education service launched jointly by Harvard University and MIT.)
The latter course is based on the concept of learning programming and AI by using the game of Shogi as an example. We have begun development of the course utilizing two major programming languages, Matlab and Python. The video recording was almost finished in March 2020. The course is scheduled to be released around autumn 2020.

5. Activities of the Interdisciplinary Research Promotion Committee

5-1 Holding a matching workshop

As part of the curriculum, the Super Smart Society Promotion Consortium and the Tokyo Tech Academy for Super Smart Society held a matching workshop on November 8, 2019. The aim of the workshop was to build an interdisciplinary research team that crosses fields by matching the needs of organizations participating in the Consortium with the technical and human resource seeds of faculty and students at Tokyo Tech. Participation in the matching workshop was a requirement in order for students to be eligible for selection to enroll in the first class of the WISE-SSS Program in the 2020 academic year. Accordingly, the workshop was also attended by students and academic supervisors from Tokyo Tech, and meaningful discussions were held with the participating organizations. Matching workshops were held twice in the 2018 academic year. In the 2019 academic year, in order to further enhance matching opportunities, two events were held on the same day: a round in which students conveyed their seeds (S-Round) and a round in which participating organizations advertised their needs (N-Round). The program is shown in Figure 5-1.

After the keynote lecture, a one-minute "shotgun presentation" and a poster presentation were given by participating students. 77 posters were exhibited to convey seeds in the S-Round. 80 students participated (including 3 observers). Conversely, in the Needs Round (N-Round), 3-minute shotgun lectures were given by 15 participating organizations. Afterwards, opinions were exchanged at a poster exhibition that doubled as a social gathering. Exhibitors introduced the status of activities, needs, etc., for achieving an SSS, and provided opportunities for active research and discussion. Finally, the participating organizations voted, and as a result, 7 students were awarded the Excellent Student Poster Presentation Prize from the Chair of the Interdisciplinary Research Promotion Committee.

Part 1 Venue：Kuramae Hall

◆ 13:00-13:10	Opening Remarks Overview ・Prof. Nobuyuki Iwatsuki（Professor, Dean/Super Smart Society Promotion Consortium Committee Chair, School of Engineering, Tokyo Institute of Technology）
◆ 13:10-13:50	Keynote presentation ・Mr. Yuichiro Odaka（Mitsubishi UFJ Financial Group, Inc.） "Digital Transformation and Democratization of Data analysis in MUFG Bank"
◆ 13:50-15:00	Students' shotgun presentation
◆ 15:00-16:30	Students' poster presentation / discussions
◆ 16:30-16:50	Break
◆ 16:50-17:50	Consortium members' shotgun presentation

Part 2 Venue：Royal Blue Hall

◆ 18:00-19:50	Consortium members' poster presentation / discussions
◆ 19:50-19:55	Award ceremony
◆ 19:55-20:00	Closing remarks ・Prof. Koichi Shinoda（Professor, School of Computing, Tokyo Institute of Technology）

Figure 5-1 SSS matching workshop Program

Furthermore, we conducted a questionnaire regarding the requests and existence of technical interest from organizations participating in S-Round and students participating in N-Round. By aligning the questionnaire results, we established 10 matches. We hope to link this initiative to future joint research and hiring activities.

Regarding matching workshops in the 2020 academic year, we plan to hold one on June 17 during the spring semester and one on November 11 during the fall semester. We are also considering using online meetings or other methods to help prevent the spread of COVID-19.

5-2 Construction of SSS research and education fields

5-2-1 Smart mobility

We build a research and education field for Smart Mobility as a platform to educate students enrolled in the WISE-SSS Program, and to conduct joint research on autonomous driving and mobility services together with organizations participating in the SSS Promotion Consortium. This research and education field provides electric vehicles equipped with Autoware, which is open source software for autonomous driving, cutting-edge wireless systems (5G, 60 GHz/28 GHz millimeter-wave radio), on-

Figure 5-2 Experiment of automated driving and video transmission

board cameras and Light Detection and Ranging (LiDAR), and other sensor devices. The purpose of the field is to contribute to the research and development of autonomous driving systems and mobility services that aggregate various sensor information. (Note: "Autoware" is a registered trademark of "The Autoware Foundation.")

In the 2019 academic year, we conducted a test run of autonomous driving at Ookayama Campus of Tokyo Tech. We also conducted an experiment to transmit videos to an on-board monitor using the camera and millimeter wave wireless system equipped in Road-Side Unit (RSU). (Fig. 5-2 and Fig. 5-3) For details, please refer to the following URL.
<https://www.youtube.com/watch?v=KO4SEPghtM0&feature=youtu.be>

In the 2020 academic year, we plan to further expand the wireless network including RSU, conduct intensive exercises in interdisciplinary research planning, hold recurrent education, and expand our efforts into research and development such as mobility services.

Figure 5-3 Experiment layout for automated driving and video transmission

5-2-2 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 primary purpose of this research and education field is to develop efficient and robust environmental monitoring technology using mobile sensor networks, which contributes to e.g. supporting the damage assessment after a natural disaster and enhances societal resilience. Meanwhile, in the field of agriculture and inspection of deteriorating infrastructure, monitoring technology contributes significantly to improved productivity, and can be a solution to the urgent social issue of a shrinking working-age population. Moreover, through exercises in this research and education field, students are able to acquire technology for safe control/operation of multiple systems interconnected by networks, which is essential in the IoT era.

This field was established in Room No. W101 in West Building 8 on the Ookayama Campus. The field is composed of five Bebop 2 (Parrot) drones, several self-manufactured drones, four mobile robots Scamper 0-308 (REVAST), two Mecanum Rover Ver. 2.0 (Vstone), a truss (5.4 m x 4.3 m x 3.8 m) with net for ensuring safety, twelve PrimeX 13 (OptiTrack) motion capture devices for measuring robot states, two computers for sensing and control respectively, and cameras for photography. It also equipped with two Surface Pro 7 (Microsoft) for the sake of the students' exercises. The measurements of the motion capture are sent to the control computer through the measurement computer at every several ms. The arbitrarily coded control algorithms are implementable via the robot software platform ROS, and command signals are transmitted to the robot in real-time. (Fig. 5-4 and Fig. 5-5)

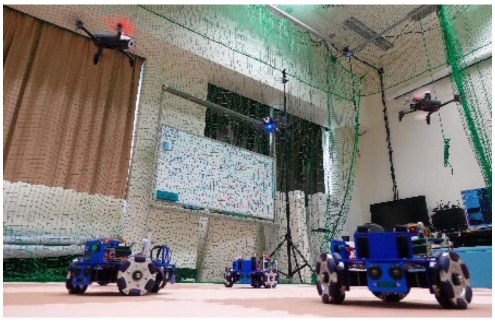

Figure 5-4 Overview of Robot Zoo Sky

Figure 5-5 Distributed Environmental Monitoring Control

Multiple companies including organizations participating in the Consortium have already joined in this research and education field. Moreover, interdisciplinary research projects based on this field has been launched, and systems mimicking this field are being constructed in participating organizations. We are also considering conducting intensive exercises in interdisciplinary research planning and recurrent education during the 2020 academic year.

● Robot Zoo Aqua

Robot Zoo Aqua aims to expand the active field of robots to water. Land has always been the main field of activity for humankind, so the aquatic environment has been neglected thus far. However, the oceans—that is, water—account for 70% of the Earth's surface. Much remains unknown about this aquatic environment. Marine nature exists on a large scale. Marine nature survey robots are needed to research such areas. Additionally, as more familiar examples on a life-size scale, there are many unclear points about underwater exercise by human beings; for example, underwater sports such as swimming and other underwater exercise. Robot Zoo Aqua uses the perspective of robotics as an approach for solving the aforementioned social issues. For example, in the case of marine nature survey robots, we are considering the deployment of multiple robots like a school of fish. However, the appropriate method of controlling that school has yet to be sufficiently clarified. Utilizing this research and education field of will make it possible to solve such problems.

In order to achieve the above objectives, we have established this research and education field in the School of Engineering's shared experimental room for the Systems and Control Engineering Department, which is located in Room No. W107 of Wing W, West Building 8, on the Ookayama campus. As the main equipment, we installed a large water tank made of fiber reinforced plastic. The dimensions of the tanks are length of 5.5 meters, width of 2 meters, and depth of 0.7 meters. We also introduced an optical motion capture system with eight infrared cameras (PrimeX 13 made by OptiTrack) and five underwater drones (PowerDolphin made by PowerVision). Figure 5-6 shows a panoramic view of the completed Robot Zoo Aqua. The motion capture system makes it possible to measure the position coordinates of the robot moving on the water surface with high accuracy.

This research and education field is positioned as a test platform between theory/simulation and the actual marine environment. Here, underwater robot control experiments can be performed using an actual water drone, thus enabling new exercises which are unprecedented in Japan and overseas.

Currently, there is one interdisciplinary joint research project using this research and education field in progress. In the future, students and faculty members will be in charge of theory, simulation, and model experiments in this research and education field, while external organizations will be in charge of full-scale experiments in actual fields such as marine environments, etc. It is expected that this will further promote collaborative research.

Figure 5-6 Panoramic view of Robot Zoo Aqua

● Robot Land

In addition to Robot Zoo Sky and Robot Zoo Aqua, we established Robot Land as a research and education field related to robots used on land in areas other than manufacturing. Specifically, this field consists of robot platform group which is used for education/research and is comprised of a collaborative robot (UR5e, manufactured by Universal Robots A/S) (Fig. 5-7), a quadruped outdoor field robot (developed by Tokyo Tech) (Fig. 5-8), and a multifunction robot module (manufactured by HEBI Robotics). There is also a robot evaluation and control facilities group which is comprised of a digital signal processor and controller device (manufactured by dSPACE), a high-speed motion capture system for control (manufactured by nac Image Technology) (Fig. 5-9), and a high-precision GNSS+INS hybrid device (manufactured by NIKON-TRIMBLE). 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.

The collaborative robot is a 7-axis redundant manipulator. It was introduced as a platform for conducting education and research on standard robot manipulators. Programming can be done using ROS. Education and research are possible for robot applications related to industrial applications, remote control, collaborative work with people, etc.

The outdoor field quadruped robot is a hydraulically driven robot that can operate in outdoor environments such as dust and rain. It was independently developed by Tokyo Tech. There are few walking robots that move ruggedly in real-world terrain. Our quadruped robot can perform practical education and research. Various modifications are possible. These modifications can also be used for education and research on robot mechanisms.

The multi-function robot module is a single-axis rotary motion joint module. This combination enables free configuring of the snake robot and robot arm. Robot Land has an 8-axis module. It can be used for education and research of robot configurations according to the work being performed. It also has an evaluation system for control system development, navigation, and high-speed real-time motion analysis of these robot platforms.

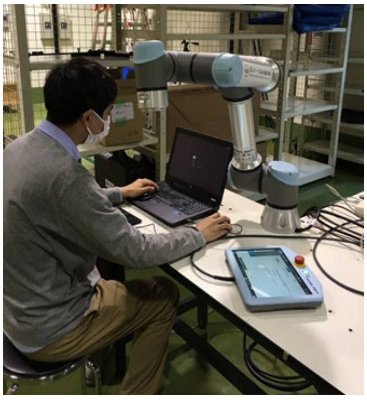

Figure 5-7 A collaborative robot

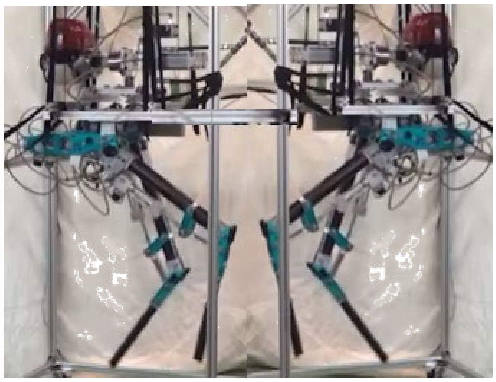

Figure 5-8 A quadruped outdoor field robot

Figure 5-9 A high-speed motion capture system and human support suits

● **Smart Manufacturing**

In the field of *monozukuri* (manufacturing), Additive Manufacturing (3D printers) has spread during the last 10 years or so. Furthermore, there have been proposals for the digitalization of *monozukuri* (digital manufacturing) as represented by keywords such as "IoT" and "Industry 4.0." Based on this backgrounds, a series of concepts have been proposed with the aim of improving production efficiency through collaboration with the internet and computers. Since the latter half of the 1990s, manufacturing equipment (machine tools, transferring devices, robots, etc.) in production sites such as factories have been mutually collaborating in order to respond swiftly to customer demands for a wide variety of parts. Several models for promoting automated production have been proposed. Now that computer and communication capabilities have increased, we have finally reached the stage where the effects of those models can be verified by implementing them in a practical system. In this respect, it can be said that there is an extremely high affinity between technology which will be important in the manufacturing field in the future and the capabilities which should be possessed in the next-generation leaders who are the ideal image of human resources produced by the Tokyo Tech Academy for Super Smart Society.

In the 2019 academic year, in the research and education field for Smart Manufacturing, we provided an environment to enable hands-on learning for the flow of the current production system, which is integrated seamlessly from computer digital design to component processing. This hands-on learning uses actual software and machines. We have also introduced the multi-axis modeling machine shown in Figure 5-10 as equipment for conducting basic research toward the development of intelligent machining systems that collaborate with various sensors. In addition to acquiring the position and posture of the workpiece with a 3D shape sensor, the system also can acquire 3D shape data of the workpiece/tool in real-time. This enables transition between production processes (individual processes for parts production) while maintaining high machining accuracy. Thus, we have established education and research facilities related to a system for avoiding interference by checking the positional relationship between the tool path and each component of the workpiece/machining device.

In the 2020 academic year, by effectively utilizing the installed equipment, we will develop a program to provide effective education to students with a basis in different fields. Additionally, by combining real-time machining status monitoring that uses various sensors, we plan to proceed with joint research aimed at Smart Manufacturing.

Figure 5-10 Equipment installed in research field for Smart Manufacturing

5-2-3 Quantum science

● Quantum computing

Quantum computers are expected to be put into practical use as ultra high-speed next-generation computer 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. Such technology is also expected to contribute to solving the information processing problems required in an SSS.

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 will cultivate human resources and conduct education and research for high-level quantum technology.

In the 2019 academic year, in order to promote this research, we constructed a measurement system for actual use and evaluation of qubits (refer to the model in Fig. 5-11). The system will be combined with the existing cryogenic refrigerator (liquid He type /cryo-free type). We have installed new equipment to build a high-precision and low-noise measurement system for observing quantum phenomena at cryogenic temperatures. Specifically, we built a quantum computing measurement system (Fig. 5-12 and Fig. 5-13) consisting of a vector signal generator, synchronizable 2-channel arbitrary waveform generator, signal analyzer, digitizer, etc. We have also installed a line for introducing high frequencies into the cryogenic refrigerator. In the 2020 academic year, through full-scale utilization of this equipment, we plan to construct a measurement system for introducing pulses and microwaves into a cryogenic refrigerator, and to enhance a measurement system for high-precision control of quantum states. We also plan to construct a system together with students registered in the WISE-SSS Program, and to hold practical training on using the system to measure quantum states. The purpose of these initiatives is to acquire proficiency in high-frequency technology, precision measurement technology, cryogenic technology, vacuum technology, and other technology used in cutting-edge quantum science research. Furthermore, in order to promote joint research, we aim to have such technology used by corporations, national research institutes, and other organizations.

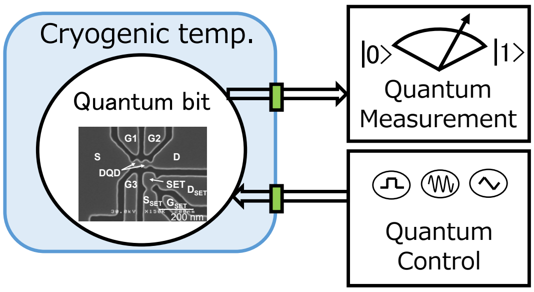

Figure 5-11 Schematic image of quantum bit measurement system


Figure 5-12 Measurement system with the existing cryogenic refrigerator


Figure 5-13 Magnified picture of the measurement system

● Quantum sensors

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

There are various types of quantum sensors. Examples include the Superconducting QUantum Interference Device (SQUID), Diamond Nitrogen-Vacancy Center (NV Center), and sensors using atomic gas. These sensors must be used appropriately according to the detection target and the situation. Among these sensors, we are particularly focusing on SQUID (Fig. 5-14), which can detect very small magnetic fields. Weak magnetic fields are also generated from the heart and brain. If highly sensitive detection is possible, this technology can be applied to medical procedures such as magnetoencephalography and magnetocardiography. It will also be possible to conduct immune tests using magnetic markers. Thus, SQUID sensors are an important element for super smart medicine. However, this type of sensor does face some current problems; namely, low spatial resolution and the need for cryogenic temperatures for operation.

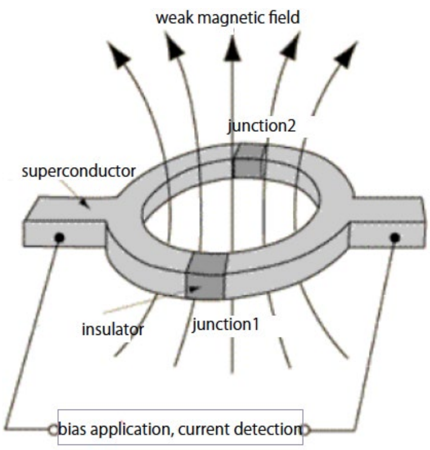

Figure 5-14 Schematic drawing of a Superconducting QUantum Interference Device (SQUID)

Therefore, in this research and education field, in order to develop SQUID sensors that are smaller and operate at high temperatures, we are developing high-temperature superconductors with a thickness of several atomic layers. These superconductors will be used as a material in SQUID sensors. In the 2019 fiscal year, we installed new equipment to promote this research. First, we updated the existing scanning tunneling microscope with a cutting-edge control system in order to enable evaluation of superconductor properties. This update improved the accuracy of our experiments. Next, in order to fabricate and evaluate an even wider variety of superconducting thin films, we installed a sample preparation device capable of vapor deposition via the Molecular Beam Epitaxy (MBE) method (Fig. 5-15). In the 2020 academic year, we plan to make full use of this new equipment in order to promote research of high-temperature superconductivity of single-layer FeSe thin films on $SrTiO_3$ substrate. We also plan to develop superconductors using graphene, which is a carbon sheet with a monoatomic layer. Moreover, students registered in the WISE-SSS Program will use this equipment to conduct practical exercises. In addition to experiencing fundamental quantum mechanics phenomena, the students will also acquire various testing techniques that can be used in cutting-edge quantum science research. At the same time, we plan to conduct research on the physical properties of magnetic materials and semiconductors using a Diamond NV Center, which can detect an extremely small magnetic field similar to SQUID sensors. This effort will be jointly promoted organizations which are participating in the Consortium and possess expertise on Diamond NV Centers.

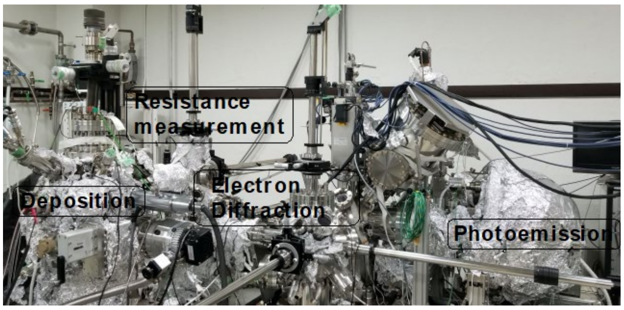

Figure 5-15 Fabrication & characterization facility of superconducting thin films

5-2-4 Artificial intelligence

The growth of AI technology in recent years has been remarkable. AI is considered to be one of the most important technologies to realize an SSS. This is because AI is utilized not only in the information field, but also in general engineering and the social science fields. In view of these circumstances, Tokyo Tech began AI education for graduate students from the 2019 academic year. Specifically, we started the Data Science & Artificial Intelligence Research Group for Social Good (DSAI). Also, from the 2020 academic year, we are preparing to implement university-wide AI education for all graduate students. The key to this AI education is not only classroom learning, but also the use of online learning materials in practical study, as well as technology learning by actually using machine learning tools.

Until now, students had practiced machine learning technology at the terminals in the computer room. However, the number of students was limited by the number of terminals and other factors. On the other hand, due to the commoditization of laptop computers and tablets, many students now own such devices. Therefore, it has become possible for many students to receive AI education through practical training using wireless LAN in a general lecture room. However, in AI education, in addition to downstream communication bandwidth for materials such as lecture notes and video teaching materials, upstream communication bandwidth is also important for uploading large data sets used in machine learning.

The current mainstream Wi-Fi 5 wireless LAN standard presents a problem because the upstream communication bandwidth is particularly low. For this reason, in the 2019 academic year, we introduced Wi-Fi 6 wireless LAN as a platform for AI education in four lecture rooms. From each lecture hall, by bringing in their own computers and tablets, students can now access a machine learning service on the cloud via a high-speed network. Wi-Fi 6 dramatically improves both downstream performance and upstream performance. Due to these characteristics, many students can bring their own devices, such as laptops and tablets to the general lecture room and engage in practical exercises for machine learning training in an environment with unrestricted communication bandwidth. By introducing this technology, theoretically, a maximum upstream and downstream communication speed of 10 Gbps can be achieved by link aggregation of a single lecture hall, while a maximum speed of 20 Gbps can be achieved for the aggregation value of the four lecture halls simultaneously.

Currently, we are studying the development of practical training materials and online teaching materials for machine learning. The materials will be specialized for each field. Students are expected to acquire machine learning technology through useful materials in each field. Utilization in each field will lead to significant research results. Furthermore, graduates who have acquired machine learning technology are expected to perform in society towards the achievement of an SSS.

6. Introducing the Steering Committee

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Professor, Dept. of Mechanical Engineering, School of Engineering

Field of Specialization：Synthesis and Control of Robotic Mechanisms, Acoustic environment, Actuator

Coordinator

Kei Sakaguchi

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Field of Specialization：5G, IoT, Millimeter-wave, Wireless power transmission, Connected Car, Automated Driving

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Super Smart Society Promotion Committee Chair and Overall secretary

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Specially Appointed Professor, School of Engineering

Field of Specialization：Wireless network, device for wireless communications

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Koichi Suzumori

Professor, Dept. of Mechanical Engineering, School of Engineering

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Evaluation Chair

Misako Takayasu

Professor, Advanced data analysis and modeling Unit, Institute of Innovative Research

Field of Specialization：Statistical physics, econophysics, sociophysics

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Global collaboration Chair

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