implemented, where the search for new substances using the construction of a data platform and informatics is conducted. Consortium activities, in which 40 corporations or more participate, have begun.
- As for SIP-Innovative Structural Material, the development of structural and functional materials has been implemented regarding aviation materials; in the field of materials integration, a study integrating materials and anticipation has been implemented. The construction of software to integrate results is also advancing.
- Between the desired substance found in research at each location and the actual developed materials, a large technological gap separates the virtual substance and the real substance. With this objective, the creation of research results that mend this gap is also expected. In other words, the research is expected to link the studies on both sides for each project; an efficient and effective material development platform can be realized by bridging this gap.

7.5 Advanced interaction technologies within networked intelligent information environment

Overview

A recent global goal is to realize a "super smart society" in which everyone has access to optimized high-quality services in natural forms through endeavors to fuse cyber space and society at a high level based on widespread use of artificial intelligence technologies, big data analysis technologies, and so forth. For this purpose, research and development in relation to "human to human" and "human to machine" interactions have been managed in a variety of ways as essential technologies; a great leap in the development of such research fields is expected to be made for the realization of a super smart society.

For this purpose, the research field of interaction is widely recognized as focusing on "mutual actions with the whole environment connected to a network." In this field, interactions in a variety of forms such as "human to human," "human to machine," and "human to the whole environment" are supported at a high level, and behaviors are understood and controlled to lead to the design of innovative systems that promote the optimization of social structures and human behaviors. Thus, interaction research aims to realize a highly optimized society in which everyone can enjoy the benefits of fast-growing artificial technologies.

Targets to Achieve

In these strategic objective, the purposes are to create new technologies for the enhancement of interactions and to attempt to further deepen the understanding of interactions for use in a variety of situations in society. Specifically, research engages in cooperation with other academic fields such as cognitive science, psychology, neuroscience, and primarily information science and technology to realize the following goals:
(1) The development of technology in relation to interfaces and the expansion of human abilities to support interactions.
(2) The solution of the principles and structures for understanding interactions and the development of the technology in relation to collection and analysis of the information to contribute to the above-mentioned goal.
(3) The development of technology to design the social structure and the environment that prompts the optimization of human behaviors using interactive technologies.

Future Vision of a Society to be looked at during the research promotion

Through the achievements of the items stated in paragraph 3, *Goals and Objectives,* contributions are made to the realization of the society described below.

- The society in which the enhancement of interaction contributes to realizing a super smart society and is spreading to various fields as a platform technology to support industrialization and a wide range of implementation of artificial intelligence technologies, big data analysis technologies, IoT technologies, and the like, the development of which has been advancing.
- The society in which mutual interaction data of "humans to humans," "humans to machines," and "humans to the whole

environment" is gathered in a variety of domains, and a variety of human, economic, and social resources including Cloud sourcing are maximized, and, thus, a large-scale change is caused in the ways in which the society wants and people work.

- The society optimized as a whole in which the advancement of personal fabrication based on the enhancement of interaction promotes natural alterations in behaviors along with a variety of individual ways of life and the like that are not understandable within the conventional societal models of mass production and mass consumption.

Specific Research Examples

(1) The development of technology in relation to the interfaces and the expansion of human abilities to support interactions.

The research aims to develop an intelligent agent to conduct continuous deep interactions with individuals and groups depending on place, situation, and past memory, and the research and development for high-level support of non-verbal communications that use wearable devices, etc. suitable to the human body.

(2) The solution of the principles and structures for understanding interactions and the development of the technology in relation to the collection and analysis of the information to contribute to the above-mentioned goal.

The collection and analysis of the data in relation to human behaviors in a specific domain such as life, medical care, nursing, fabrication, and infrastructure and of the data in relation to the processes of a variety of social symptoms, and research and development in relation to the modeling of human-to-human interactions.

(3) The development of technology to design social structures and environments that prompt the optimization of human behaviors by using interactive technologies.

This describes research and development for supporting creative activities enabling real-time and interactive designs, and research and development supporting the formation of groups and communities and high-level collaborative activities.

Domestic and Foreign Research Trends

(Trends in Japan)

- In addition to analytical research as a base for neuroscientific research or that of similar fields, "the cognitive interaction study of design (FY 2014 - FY 2018)" in the new academic field of the Grant-in-Aid for Scientific Research, is lively from the point of view of designing interactions.
- The research community working on multi-agent systems for analyzing and configuring group behaviors by recognizing humans and artificial objects as agents has been lively and has continued its activities since former days.
- As for agents that interact with humans, research not only on virtual agents that uses VR and/or voice communication technology, but also the development of communication robots that have their own bodies has been lively and active.

(Trends overseas)

- As for research on multi-modal interaction in the US, SimSensei, a mental palliative support system for depression, anxiety, PTSD, and the like (South California University), virtual agents that promote counseling and changes of behaviors to support nurses and patients (North Eastern University), and similar technologies have been continuously supported through funding bodies such as DARPA and NIH.
- In Europe, TARDIS (hosted by UPMC, France), which aims to strengthen the social skills necessary for finding a job, SSPNET, which aims to arrange and share a technological platform for the modeling, analysis, and use of social signals (hosted by University of Glasgow, UK), and similar projects are supported by the framework program. Besides practical research, cognitive science, developmental science, and endeavors to aim at a scientific outcome are lively.

Background of Consideration

The following surveys were conducted according to *Guideline for the Preparation of Strategic Objectives and the Like* (Resolution by Strategic Basic Research Subcommittee, Science and Technology Science Council, June 8, 2015)

(Preparation of analysis to examine domestic and overseas research trends with a scientometric method using the Grant-in-Aid for Scientific Research (KAKENHI) Database and similar information)

We prepared the analytic materials regarding research trends in Japan and overseas using a scientometric technique for analyzing research papers of co-citation relations or direct quotation relations in the Grant-in-Aid for Scientific Research Database, etc.

(Implementation of a questionnaire for specialists using analytical materials and preparation of notable research trends)

We implemented a questionnaire on noteworthy research trends based on the analytical materials that we had prepared for respective field units of the Center for Research and Development Strategy (CRDS) for the Japan Science and Technology Agency (JST), for the program directors etc., of the Japan Agency for Medical Research and Development (AMED) and for the experts participating in the expert network operated by the Science and Technology Foresight Center of the National Institute of Science and Technology Policy (NISTEP). We then analyzed responses to the questionnaire and identified "the enhancement of interaction with the environment that is connected to a network" as a noteworthy research trend.

(Holding of workshops and preparation of Strategic Objectives)

We held a workshop to bring together experts from industry and academia involved in "the enhancement of interaction with the environment that is connected to a network" which was identified as a noteworthy research trend. At the workshop, we focused on notable trends in Japan and overseas, the social and economic impacts of progress in research and technological developments, visions of society arising from these advances, and the objectives that should be met during the research period. We then prepared Strategic Objectives based on the discussions in the workshop.

Relevant Matters in Cabinet Decisions, etc.

Japan Revitalization Strategy 2016—to the Fourth Industrial Revolution (approved by the Cabinet on June 2, 2016)
II, 1-1, (2)-1), <2>, e)
The Government will push forward with technological development and demonstration for a wide range of fields, such as the transportation of people and goods including in an emergency, in response to a disaster, and in the management of infrastructure in order to realize a new robotic society in which multiple robots recognize their surroundings and work together autonomously.

5th Science and Technology Basic Plan (approved by the Cabinet on January 22, 2016)
Chapter 2, (2), 2
(Omitted) In order to realize a "super smart society," it is necessary for various "things" to connect over a network and for this to be systematized at a high level and, at the same time with this, to make a plurality of different systems link and collaborate. Accordingly, as it becomes possible to collect and analyze a variety of data and to make cross-sectional use of them among collaborative and cooperative systems, new values and services are generated one after another.

General Innovation Strategies for Science and Technology 2016 (approved by the Cabinet on May 24, 2016)
Chapter 1, (3), [A], 2)
Human interface technology: Besides virtual reality (VR), augmented reality (AR), *kansei* engineering, neuroscience, and the like, in consideration of the development of individual devices and technologies, research into the differences in social acceptability and the like, such as whether these technologies are equivalent to humans or are tools, is also important so that humans can cohabit with intelligent machines including robots, as typical examples.

Other

- In “the information environment in harmony with humans,” the strategic objective in FY 2009, and “intelligent information processing technology,” the strategic objective in FY 2014, the endeavors for the research and development of the technology to understand humans and groups at a high level were made.
- Furthermore, in *Asada Synergistic Intelligence*, ERATO, (FY 2005 - FY 2010) and *Center of Human-friendly Robotics Based on Cognitive Neuroscience,* COE, (FY 2009 - FY 2014), research to understand humans as a base for high-level interactions was performed.
- Moreover, research on hardware and robots in harmony with living bodies as a platform to support the above-mentioned goals was performed in the *Someya Bio-Harmonized Electronics Project,* ERATO (FY 2011 - FY 2016) and the *Ishiguro Symbiotic Human-Robot Interaction Project,* ERATO (FY 2014 - FY 2019).

In these strategic objective, while the achievements in these endeavors is used, it is expected that the endeavors for realizing continuous interactions among humans, groups, environments, and the whole society and changes in behaviors will be advanced through the enhancement and integration of interactions including endeavors for multi-modal applications and the integration of verbalism and non-verbalism.

7.6 Development of optical control technologies and elucidation of biological mechanisms

Overview

In recent years, technologies utilizing light properties have made rapid progress in controlling life functions. For example, optogenetics is a genetic engineering technique used to express photoreceptor proteins in a specific cell in order to manipulate the functions of the cell by irradiation with a specific wavelength of light at high temporal resolution. The use of this technique has rapidly increased in the field of neuroscience. The technique has enabled specific neural activities to be directly connected to behavior expression and has created a revolutionary paradigm shift in research of neuronal functions. Furthermore, optical control technologies are used in other fields in addition to neuroscience, including to manipulate enzymatic activity, intracellular signal transduction, gene expression, and even genome editing. The use of optical control technologies has increased from studies of neural activities to studies examining the general functions of the living body.

A Strategic Objective based on the background described above aim to develop new optical control technologies, improve existing technologies, and develop related control and measurement technologies. The development will be merged with technologies in other scientific fields for optical control technologies to evolve to universal techniques that can be used in life science research. In neuroscience, this Strategic Objective also aims to establish a seamless connection between cellular phenomena and the neural circuit, as well as the behavior of individuals in order to elucidate the principles of cerebral activities and the neural circuit involved in diseases and disorders. In the fields of developmental biology, regenerative medicine, immunology, metabolomics among others, this Strategic Objective aims to take advantage of the high spaciotemporal resolutions of optical control technologies in order to evaluate mechanisms of biological functions in various cells and tissues.

Targets to Achieve

The Strategic Objectives aim to use optical control technologies in order to understand life phenomena in various areas of life science as well as in neuroscience. The evolution of optical control technologies will enable the use of “universal technologies to elucidate underlying control of diverse functions of the living organisms” in collaboration with other scientific areas including physics, engineering, chemistry, and informatics. Specific objectives to be met include the following:

（1） To establish technologies underlying the control of life functions with light.
（2） To develop measurement and analytical technologies for functions emerging in optical control.