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R&D Concept of "Realization of a society in which human beings can be free from limitations of body, brain, space, and time by 2050."

February 2020
Ministry of Education, Culture, Sports, Science and Technology

1. Moonshot Goals

Within the Moonshot Goals (decided on January 23rd, 2020, by Plenary session of Council for Science, Technology and Innovation), the Ministry of Education, Culture, Sports, Science and Technology ("MEXT"), with Japan Science and Technology Agency ("JST") as a research and development promotion agency, will undertake research and development activities for achieving of the following Goal.

＜Moonshot Goal＞
"Realization of a society in which human beings can be free from limitations of body, brain, space, and time by 2050"

○Cybernetic avatar[1] infrastructure for diversity and inclusion

- Development of technologies and infrastructure to carry out large-scale complex tasks combining large numbers of robots and avatars teleoperated by multiple persons by 2050.
- Development of technologies and infrastructure that allow one person to operate more than 10 avatars for one task at the same speed and accuracy as one avatar by 2030.

○Cybernetic avatar life

- Development of technologies that will allow anyone willing to augment their physical, cognitive, and perceptional capabilities to the top level, and spread

[1]Cybernetic Avatar is a concept that includes not only remote avatars using robots and 3D images as proxies but also augmentations of physical/cognitive abilities of humans using ICT and robotics. We aim to make Cybernetic Avatar active in the cyber-physical world of Society 5.0.

of a new lifestyle that will be welcomed by society, by 2050.

- Development of technologies that will allow anyone willing to augment their physical, cognitive, and perceptional capabilities for specific tasks, and proposal of a new lifestyle that will be welcomed by society, by 2030.

2. Direction of research and development

Based on the discussion and proposal made in the Moonshot International Symposium (held in December 17, 18, 2019), direction of research and development at present is shown as follows.

(1) Area and field to promote challenging R&D

To overcome the challenges of a declining birthrate and aging population, we must realize a society free from the constraints of body, brain, space, and time and allow people with various backgrounds and values – such as the elderly and those with responsibilities for nursing and childcare – to actively participate in society.

To realize such a society, as shown in Fig. 1, we will research and develop cyborg and avatar technology that will expand human physical, cognitive and perceptual ability, and aim to promote Cybernetic Avatar infrastructure and lifestyles. These are the fields in which challenging R&D will be promoted in the Moonshot Research & Development Program.

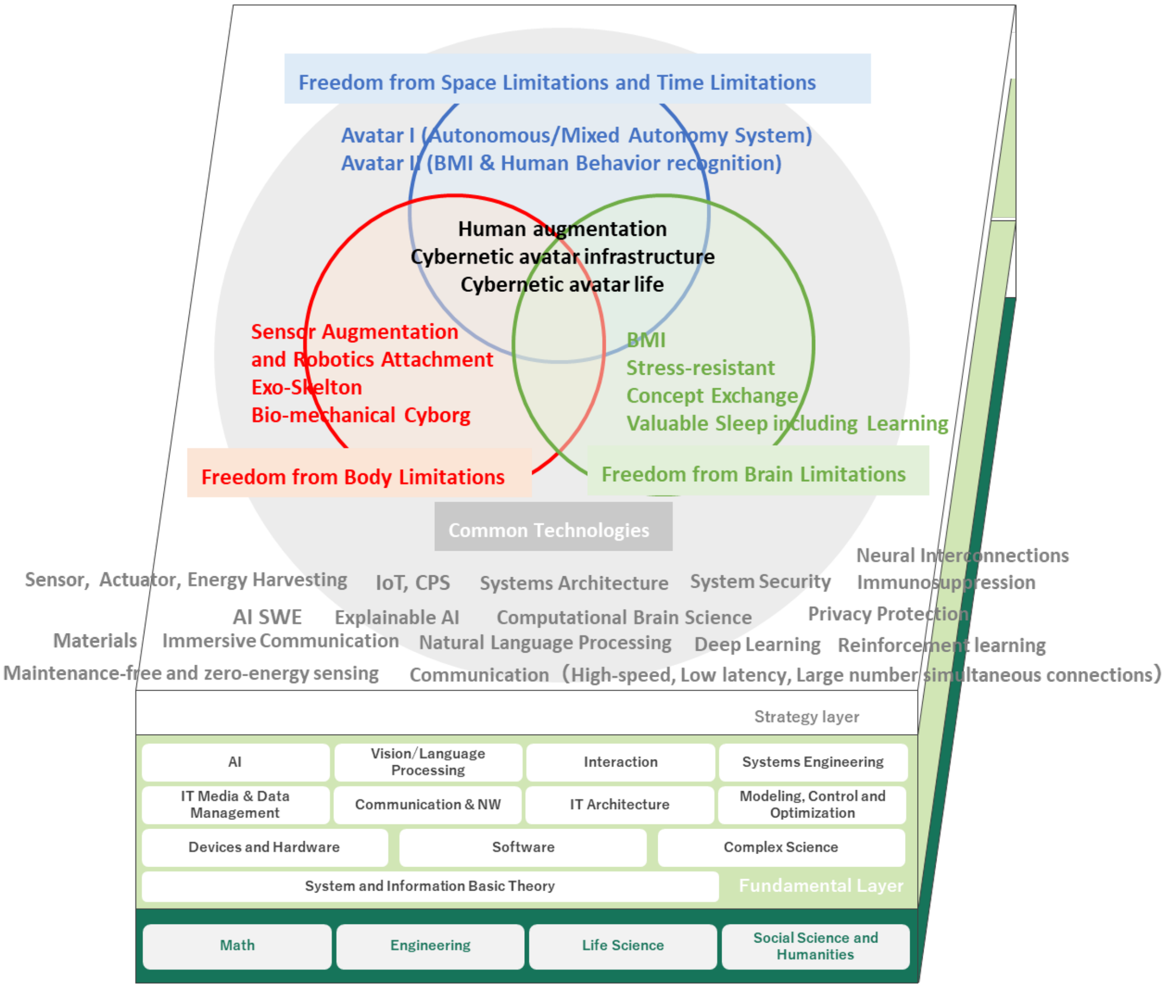

Fig.1 Main R&D fields required for Realization of a society in which human beings can be free from limitations of body, brain, space, and time

(2) Research subject for realization of MS Goal

The image in Fig.1 is the area and field for challenging R&D to be promoted under the Moonshot Research & Development Program. R&D that contribute to the achievement of this MS goal "realization of a society in which human beings can be free from limitations of body, brain, space, and time" should proceed. In order to have the most effective and efficient countermeasure, the most cutting-edge scientific trends shall be researched and used for R&D.

In concrete, such as the following research and development will be promoted.

<Cybernetic avatar infrastructure for diversity and inclusion>

R&D to realize an avatar that is deployed throughout society and enables various tasks to be performed by remote control, and the infrastructure necessary for its operation.

<Cybernetic avatar life>

R&D to realize technologies that can augment human physical, cognitive, and perceptual capabilities to the top level.

The creation of Cybernetic avatar infrastructure and Cybernetic avatar life require similar R&D, so there will be ample cooperation in their joint development.

In conducting R&D, various sources and types of knowledge and ideas will be adopted, stage gates will be established. And evaluation will be conducted to promote R&D to achieve Goal.

In addition, from the viewpoint of smoothly implementing research results in society, a system that enables researchers in various fields to participate in ethical, legal, and social issues will be considered.

(3) Direction of research and development for realization of the Goals

○ By 2030

<Cybernetic avatar infrastructure for diversity and inclusion>

Development of technologies and infrastructure that allow one person to operate more than 10 avatars for one task at the same speed and accuracy as one avatar.

<Cybernetic avatar life>

Development of technologies that will allow anyone willing to augment their physical, cognitive, and perceptional capabilities for specific tasks, and proposal of a new lifestyle that will be welcomed by society.

○ By 2050

<Cybernetic avatar infrastructure for diversity and inclusion>

Development of technologies and infrastructure to carry out large-scale complex tasks combining large numbers of robots and avatars teleoperated by multiple persons.

<Cybernetic avatar life>

Development of technologies that will allow anyone willing to augment their physical, cognitive, and perceptional capabilities to the top level, and spread of a new lifestyle that will be welcomed by society.

To realize a society free from the limitations of body, brain, space and time, it is necessary to realize Cybernetic avatar infrastructure and Cybernetic avatar life. For the Cybernetic avatar infrastructure, we must first develop technology that allows one person to operate multiple avatars for a single task, then multiple people operating multiple avatars at the same time on a single task. Eventually this will expand to multiple people operating a large number of avatars for multiple tasks. As a starting step, the goal in 2030 is to develop technologies and infrastructure that allow one person to operate more than 10 avatars for one task at the same speed and accuracy as one avatar.

For Cybernetic avatar life, we must first develop technologies that can augment physical, cognitive, and perceptual abilities for specific tasks, and then later technologies that can augment physical, cognitive, and perceptual abilities to the top level. As a starting step, the goal in 2030 is to develop technologies that can augment physical, cognitive, and perceptual abilities for specific tasks.

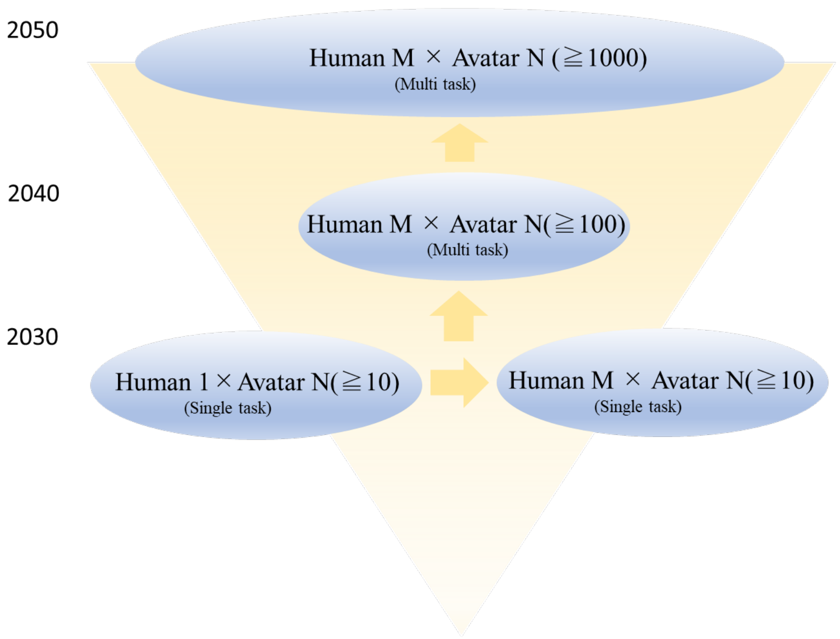

Fig.2 An example R&D process toward the realization of Cybernetic Avatar Infrastructure

＜Reference : Analysis for realization of the Goals＞

Summary of content which is analyzed in the Initiative Report presented in Moonshot International Symposium is shown, as follows:

(1) Structure of research fields and technologies

Fig. 3 shows the basic technologies required to realize the Cybernetic avatar infrastructure and Cybernetic avatar life, which are listed under “Freedom from Body Limitations”, “Freedom from Brain Limitations”, “Freedom from Space Limitations and Time Limitations”. As described above, it is necessary to research and develop necessary technical elements in various research fields such as materials, robotics, artificial intelligence, and life sciences, and to integrate them. Challenging R&D is therefore required.

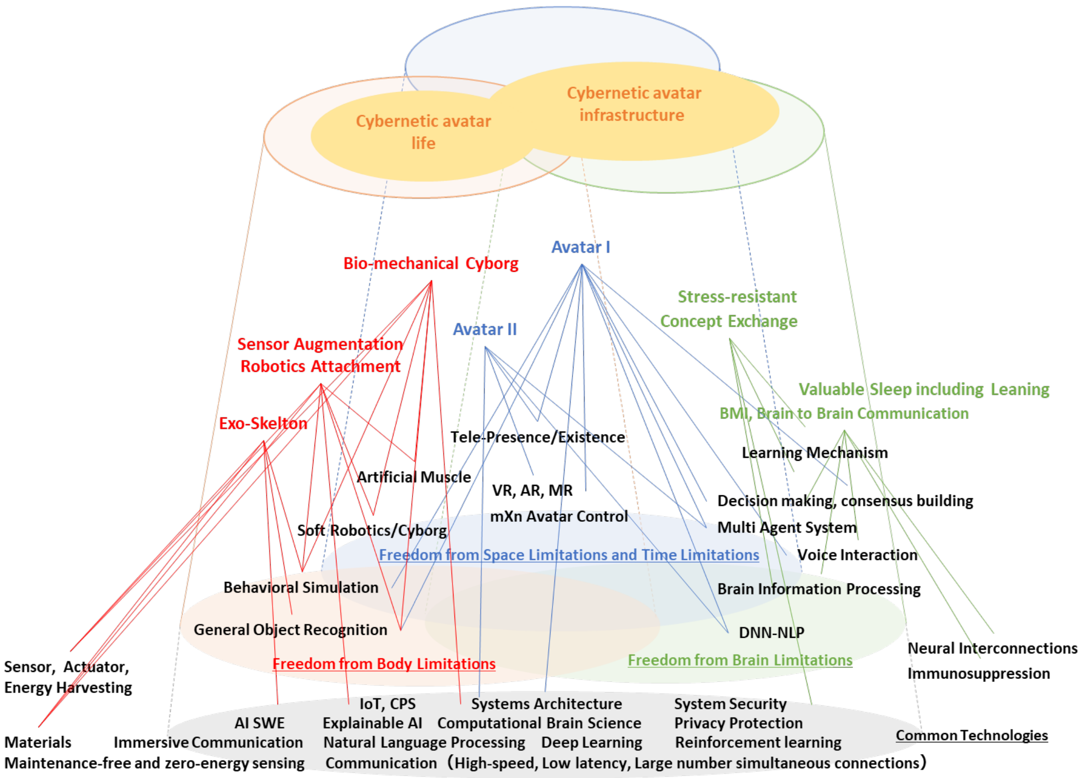

Fig.3 Structure of research fields and technologies mainly related to Cybernetic Avatar Infrastructure and Cybernetic Avatar Life

(2) R&D trends in related fields

The related R&D trends are shown in Fig.4. These technologies have been invented and developed to help human’s computational and memory skills, to cross space and time barriers and to compensate for limitations of the human body.

Based on these basic and general-purpose common technologies, more advanced technologies that reduce body, brain, time, and space constraints and further augment these capacities, as well as related systems and services, have been introduced to society.

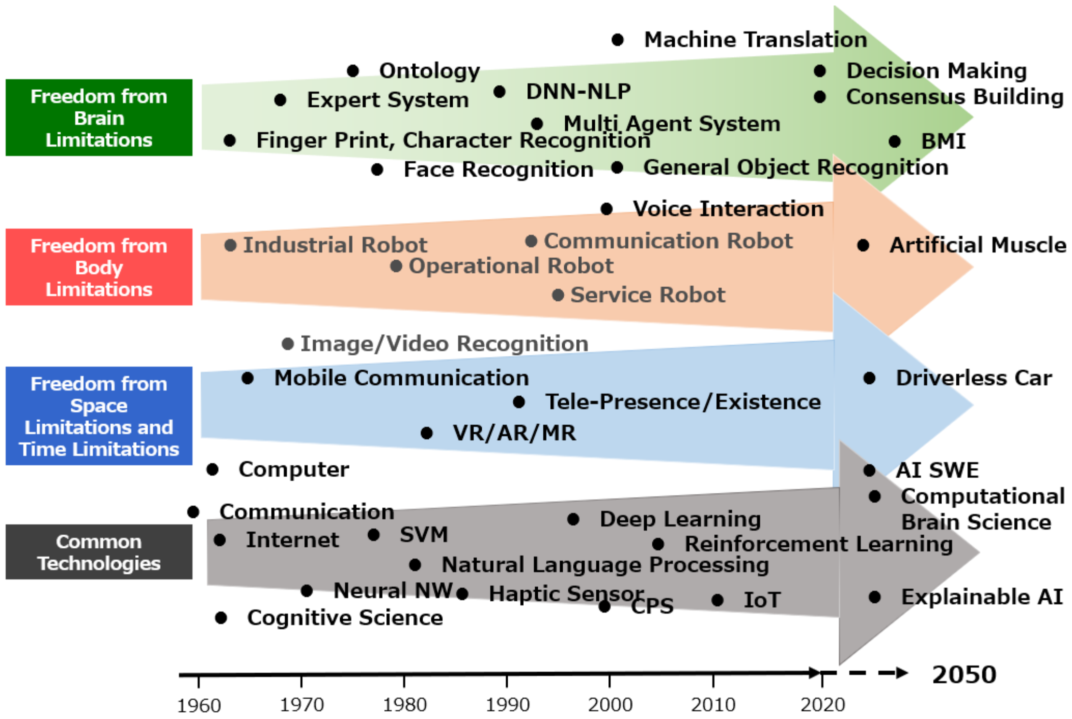

Fig.4. Related R&D trends so far

New theories of computational brain science and machine learning are particularly important from the perspective of augmenting human capabilities and freeing humans from the limitations of the body, brain, time, and space; hence, the development of new applications backed by these theories is essential. In addition, as the relation between man and machines is considerably strong, it is necessary to focus on social relationships, decision-making and consensus building, and the safety of artificial intelligence.

Furthermore, from a similar perspective, life support, welfare, and medical robots are also important. Unlike industrial robots that have been at the forefront of the robotics world in the past, service robots that deal with humans should have new characteristics such as kindness, softness, and flexibility. Therefore, basic research areas such as soft robotics and biologically inspired robots are important.

(3) Strengths of Japan, trends in global research community

Fig.5 depicts the annual trends in the number of conference papers with respect to countries, at the Augmented Human International Conference*, which is an international conference on human augmentation.

As shown in the figure, Japan has a high presence and continuous formation and enhancement of the research community.

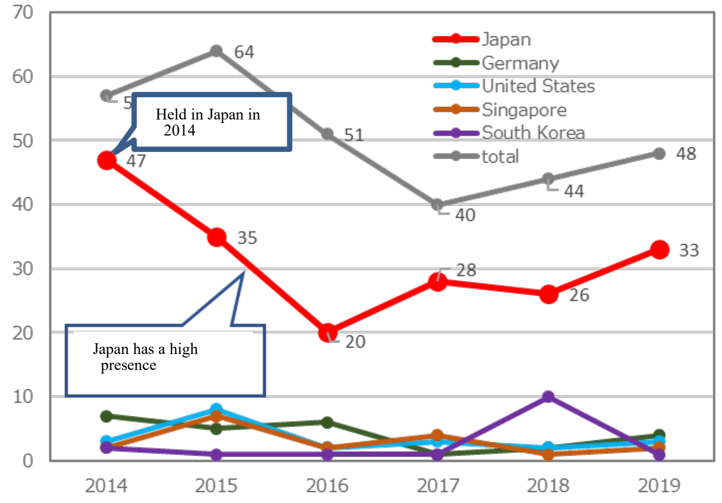

Fig.5. Number of conference papers by country at Augmented Human International Conference

＊Counts are duplicated for international joint presentations.

(Source) Calculated by JST based on Elsevier’s Scopus custom data.

In Fig.6, considering the individual elemental technologies related to human augmentation as the keywords, the number of documents worldwide (i.e., the number of presentations at the proceedings of this international conference) is plotted on the horizontal axis, and the share of Japan is plotted on the vertical axis; thus, Japan's strengths and weaknesses are extracted. In particular, the areas surrounded by dotted lines indicate the five areas where Japan has strengths. Japan is also leading the world in terms of research quality, including receiving international science awards. These elemental technologies are considered to be an important basis for achieving this MS goal.

Fig. 7 summarizes the annual trends in the number of the announcements in each country (the top 4 countries for each elemental technology) for a total of six fields, including BMI, which is considered to be an important elemental technology for human expansion.

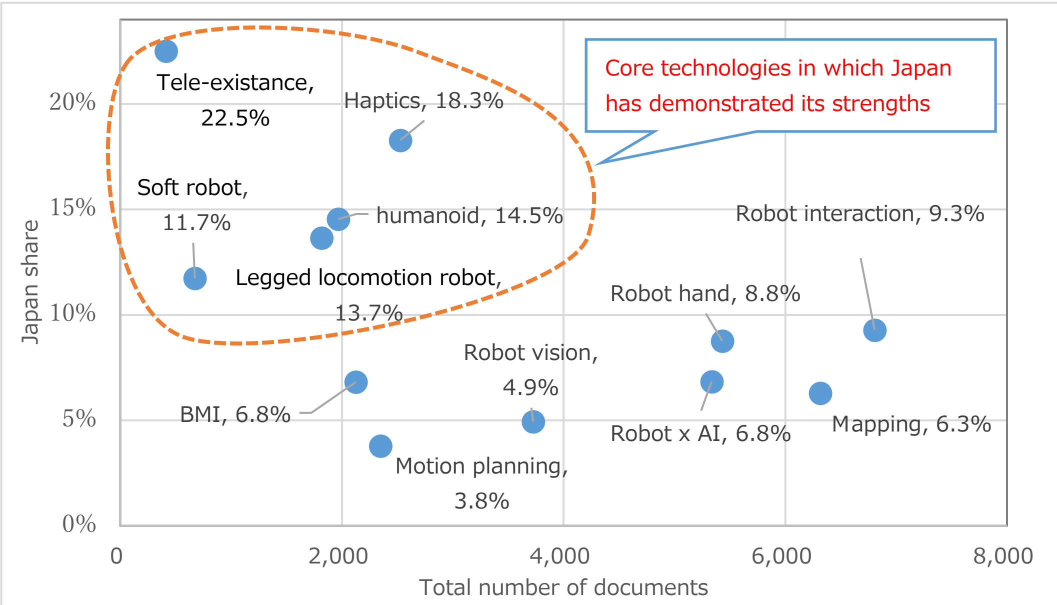

Fig.6. Japan's share in the number of conference papers for International Conference (2016-2018)

(Source) Calculated by JST based on Elsevier's Scopus custom data.

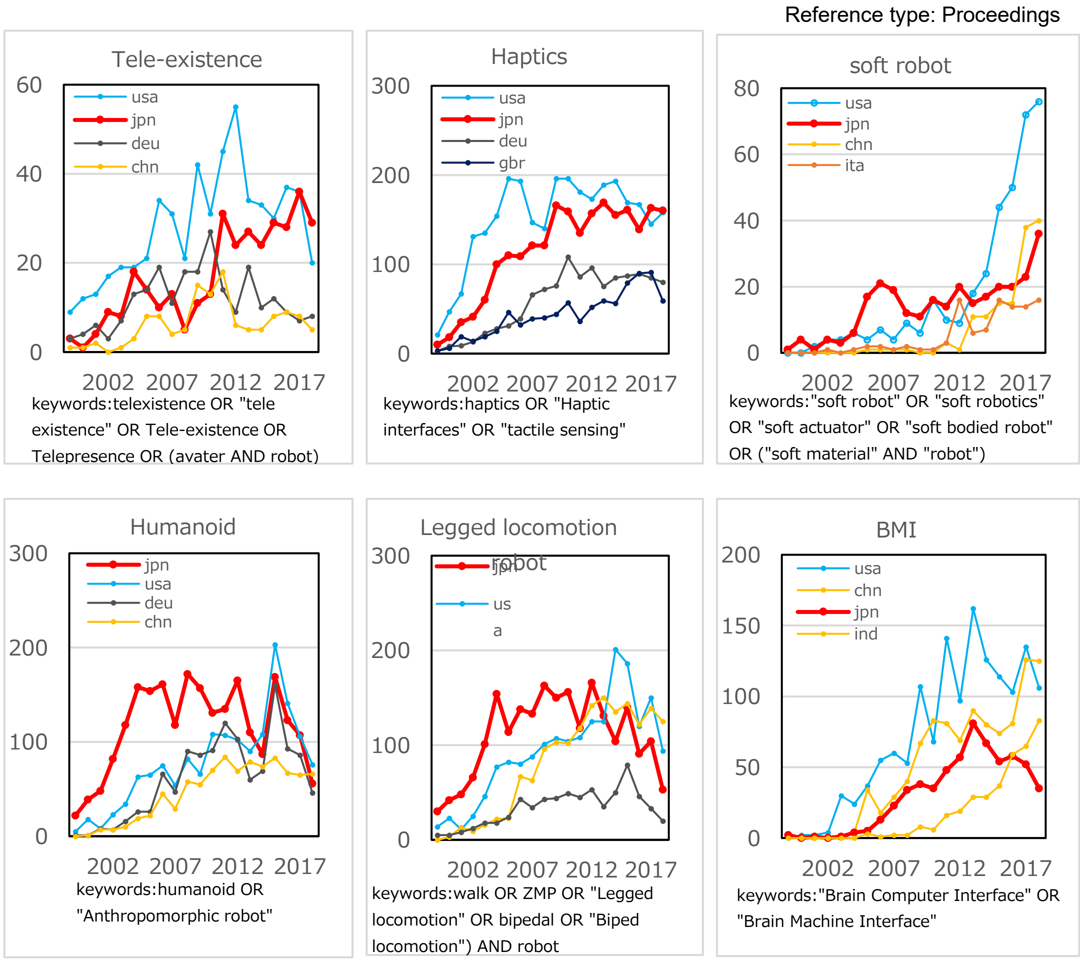

Fig.7. keywords Trends related to human augmentation

(Source) Calculated by JST based on Elsevier's Scopus custom data.

Table 1 shows that an international comparison of related technical fields was compiled based on the CRDS overview report. Regarding “Computational Brain Science”, which is the foundation of BMI, Japan has demonstrated its strength in basic research. Japan is at the forefront in creating basic methods for measuring and understanding the processing of brain information, such as the DecNef method and the whole brain simulation by K computer. The country promotes basic research projects pertaining to brain science at multiple levels, and it is recognized internationally as Brain / MINDS.

‘Life Support Robots’ need to be organically linked with robot technology, which has traditionally been a strength of Japan, along with interaction technologies which enable understanding of human behavior and appropriate interventions.

Japan has demonstrated a strength in basic research, such as improving interpersonal affinity and developing robot element technology using new materials.

'Soft robotics' is expected to be the fundamental technology to ensure that future tele-existence robots have the same degree of freedom and flexibility as humans and are capable of sharing living spaces with humans. Launched in 2014, the Softrobotics magazine presents the top impact factor in robot-related magazines. Similarly, the international conference IEEE RoboSoft was launched in 2018. Hence, this field is developing rapidly worldwide.

However, Japan has not been able to keep up with the current, rapid expansion of research in the United States and Europe, despite pioneering research in the 2000s. However, research is expected to accelerate in the future due to the establishment of the Robotics Research Special Committee of the Robotics Society of Japan in 2017 and the launch of the new scientific area "Soft Robotics" (2018-2022).

Table1. International comparison of related fields

	Country or region	Japan		United States		EU		China	
	Phase	Basic research	Applied research/ development	Basic research	Applied research/ development	Basic research	Applied research/ development	Basic research	Applied research/ development
Computational brain science	Current level	◎	○	◎	◎	◎	◎	○	○
	Trend	→	→	→	→	→	→	↗	↗
Life support robot	Current level	◎	○	○	◎	◎	◎	△	○
	Trend	↗	↗	→	↗	↗	↗	↗	↗
Soft robotics	Current level	○	○	◎	◎	○	○	△	×
	Trend	→	→	↗	→	→	→	→	→

(Note 1) Phase

Basic research phase: Range of basic research by universities, national laboratories, etc.

Applied research/development phase: Range of technology development (including development of prototypes)

(Note 2) Current level

*Absolute evaluation, not a relative evaluation based on the current level in Japan.

◎: Particularly remarkable activities and results ○: Remarkable activities and results

△: No remarkable activities or results ×: No activities or results.

(Note 3) Trend

↗ : Upward trend → : Maintaining current level ↘ : Downward trend

（Source）Panoramic View of the Systems and Information（2019）