Moonshot R&D MILLENNIA* Program

*Multifaceted investigation challenge for new normal initiatives program

「Investigation research on science and technology to overcome the division of human society and achieve harmony」 Initiative Report

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Contents

I. Concept

1. Proposed MS Goal

1.1 Proposed MS Goal title

「Realization of a society in which everyone will be individually happy as well as achieve harmony of humankind by 2050.」

1.2 Vision for 2050 society

On that day, I am wondering why I want to sing a song.

In response to my mumblings, the interface of self-awareness displays memories and characteristics from my data. As I filter through countless simulations of the future, I look at the major junctures and think about my happiness. I want to sing a song “for someone else” in an age when any music imaginable by humans can be generated on the spot. To do so, I find what I hope to achieve in the new land.

This morning, after reliving my situation through an embodied virtual reality interface, my friend was ready to empathize with me. I tell my friend about my mixed feelings and determination. I can tell him not only with words, but also with the scenes of the future that come to my mind and the sensations of music playing through me. My friend cognitively mirrors my senses and listens to the meaning of the song for me.

If I am to leave this land, we will have to change the roles of everyone. Perhaps the system began its calculations when I made my choice. As my friend and I connected to the consensus-building system, it continued to make suggestions that were finely tuned to the thoughts and wishes of all people involved in my leaving the land. We agree to the last proposal.

I know the new land I have yet to enter. We are used to being exposed to different cultures through our information diversity platform, even if their ideas are distant from mine. Most importantly, I know that there are people who will work with me to create the songs.

There are infinite ways to be happy in the world, one person at a time, and they are constantly being updated. Sometimes, major decisions are being made, such as mine today, and small decisions are being made every day. Sometimes I live my life by visualizing my happiness and that of everyone else, while dealing with my own and someone else's feelings. My friends and I are virtually flying, looking out at the world in 2050.

It is a “Harmony of Humankind" where my happiness and ours coexist.

Figure 1 Vision for 2050 society

2. Targets

The MS goal is to achieve "Harmony for Humankind" by 2050. In terms of interpersonal relations, harmony involves respecting and trying to understand each other's individuality and abilities without undermining their wellbeing. In group terms, harmony involves understanding diverse cultures, developing shared values together, and the fair allocation of resources. To realize a state of harmony, happiness coexists for all individuals as well as all humankind as a group, making it possible to realize a society in which everyone feels individually happy.

Harmony for humankind can be achieved by the characteristic of both "Individual as a part of a whole, and a whole individual." This allows individuals to understand their own happiness in-depth and renew it in their interaction with others, as well as understand how happiness should be viewed as a group that co-creates values (individuals yet whole). However, understanding happiness as a group does not mean that it is universal. Therefore, it does not deprive people of their autonomy by enhancing their identity and promoting division of labor (whole yet individual). By moving freely between the perspective of an "individual" who recognizes and renews their own happiness and that of a "whole" that can understand the happiness of the group, we can respect other people's individuality and different cultures and live without exploiting the limited earth's resources.

This new human characteristic that allows us to move back and forth between perspectives as an individual is referred to as "harmoniousness" in the MS goal. The structure of harmoniousness is in line with the 'philosophy of place' by Kitaro Nishida and others, where the intrinsic unconscious self can be limited by capturing a place formed by the workings of the self, and only then can it be aware [1]. Additionally, by designing a new concept of harmoniousness (conceptual engineering) in the research for the MS goal, we can accelerate R&D and social implementation to achieve the goal of human harmonization [2].

We set two scenes of achievement to reach this harmony and achieve harmony for humankind: at the interpersonal level (2.1) and at the group level (2.2).

(2.1) Interpersonal Level 'An Interface that Supports Interactions between Self and Others'

By 2050, we will be able to recognize and renew ourselves while developing a deep mutual understanding of the thoughts and feelings between ourselves and others.

(2.2) Group Level 'A System that Supports the Diverse Self-organization of the Collective'

By 2050, we will be able to maintain our autonomy within the group while achieving diverse harmony and co-creating values.

As deep mutual understanding at the interpersonal level and co-creation of values at the group level is achieved, individuals achieve "harmony" and change society as a whole from all

aspects through cooperative actions in the group. This causes a positive spiral, because interaction and self-organization become possible again in the changing society.

In the field of complex science systems, theories have been studied on the differentiation of elements with internal states and the change in the state of parts depending on the nature of the whole consisting of parts. Applying the theory of the complex system to humans and society has also had the prospect of considering a cyclical history where differentiation takes place as the number of human individuals increases, creating a hierarchical structure and giving rise to social norms [3]. The process of "self-organization" in the study of a complex science system and social systems is attracting attention; an overall order emerges in a system, which was initially disordered as a result of interaction between parts—parts that cannot have the overall view of the entire situation. For analogous to self-organization, an explanation has been proposed that order in society is generated from the order inherent to individuals, and that individuals live together in the generated order [4].

However, although there are attempts to explain the behavior of complex systems of individuals and societies, there are no effective solutions that actually work for humans and societies, and interaction and self-organization have been left to individual conscience and fulfillment. Consequently, we are confronted with a variety of doctrines and social problems that arise from them. Therefore, it is necessary to fundamentally change the situation by realizing an interface that supports interaction, which respects the individuality of others and does not harm their wellbeing (2.1) as well as a system that supports self-organization that co-creates values and distributes resources fairly (2.2). Additionally, these processes also enable humanity to acquire the characteristic of being "whole while being individual, and being individual while being whole" (harmony), which makes it possible to repeat interaction and self-organization in a society realized through harmony.

In the following, we describe technologies that have been developed and the achievements made by people in each achievement scene in conjunction with feasibility studies.

2.1 Interpersonal Level 'An Interface that Supports Interactions between Self and Others'

At the interpersonal level, the aim is to attain a deep mutual understanding of thoughts and emotions between oneself and others. The prerequisite to this is to acquire an understanding of one's own inner self and the ability to empathize with others. The aspects of "self-awareness and empathy" that work for the individual subject and those of "information input from others (information supplementation)" and "output of information to others (thought transfer)" to promote deep mutual understanding are included here.

2.1.1 Self-awareness and Empathy

To achieve mutual understanding in interpersonal relationships, we implement an interface that acts on individuals. Specifically, technologies are being realized to deepen self-awareness as a sender of information and enhance empathy as a receiver of information.

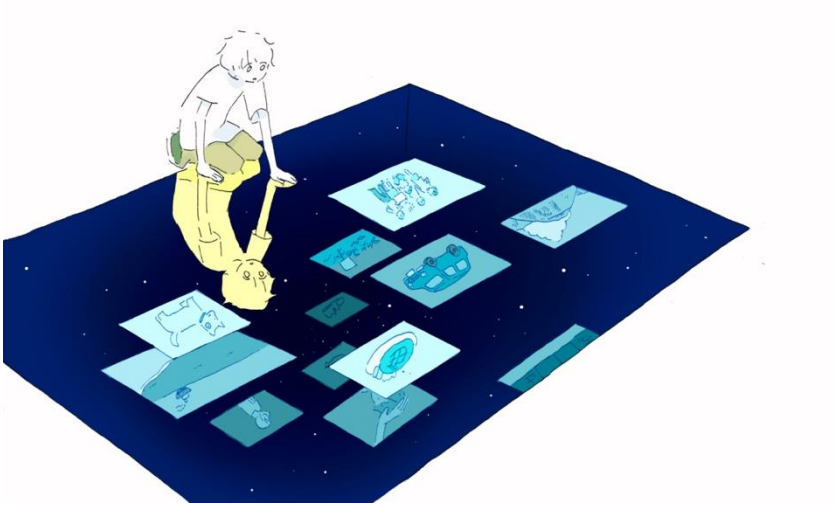

Figure 2 Self-awareness and Empathy

2.1.1.1 Self-awareness as a Sender

A sender of information is originally known to change their state based on psychological characteristics such as personality, attributes and ability, and recognition of past experiences, which in turn change the information conveyed; the recognition of these changes becomes a basis of mutual understanding [5]. Therefore, information technology, which facilitates self-recognition using an interface that analyzes and visualizes personalities and past experiences from the data from the past to the present, has been realized.

This technology not only analyzes from the past to present states but also considers factors and actions that cause physical and mental satisfaction by sensing and estimation in information technology, including biometric information, combined with one's subjective senses; this can help gain a deeper understanding of self-happiness. This allows people to

make efforts towards achieving happiness or ascertaining whether it has been achieved and also clarifying how mutual interaction should be.

In addition to self-awareness and understanding happiness by knowing one's own behavior as described above, self-cognition also requires knowing the kind of existence one has in the social environment by regarding oneself from the others' perspective (mirroring self-observation) [6]. This is where technology that accurately represents predictive models of brains based on brain activity while thinking or when experiencing something can be implemented. The parts in these predictive models that are common to most people form the base, and those that vary by person can be regarded as individuality. Utilizing and observing such prediction models of the brain will make it possible to understand our own behavior from the perspective of others.

2.1.1.2 Empathy as a Receiver

Recipients of information need to be motivated to try and understand others and to put themselves in other people's positions and consider the differences (empathy). Technologies such as simulation and virtual reality have been developed to enhance empathy.

The importance of empathy in communicating with others has also been pointed out in wellbeing studies [7]. There are a variety of ways in which technology can support online communication, including trying to provide an online experience as close as possible to face-to-face communication as well as designing and presenting graphics and stories that can make the experience more personal.

On a higher level, role-playing using the body is said to enhance sympathetic ability [8]. Virtual reality with advanced embodiment has made it possible to relive the lives of others in a short period of time and understand the existence of other people's wellbeing through stories compiled at a higher level. These technologies do not intervene in a paternalistic manner but ensure that empathy based on the individual's choice can lead to compassion and other altruistic behavior based on the person's will.

The simulation of interactions with others (estimation and modeling human behavior) can also enhance the fundamental ability to empathize/try to understand others by training sympathy and mutual understanding. Strengthening and supporting information technology to supplement the imagination of interaction has made learning possible not only in simulations but also in daily communication. This facilitates the development of the ability to accurately understand the state of communication in which diverse information is dynamically exchanged and to mutually understand and accept it with others.

2.1.2 Information Input from Others (Information Supplementation)

Thanks to technology that assists in receiving (input of) information from others, we determine what we want to know in a way that most promotes mutual understanding, especially in one-to-one interactions with ourselves and others.

Figure 3 Information Input from Others

Specifically, an interface that translates "concepts," including the background and context of the information that the partner is trying to convey, has been realized, leading to true mutual understanding. Although it is something that cannot be understood only through verbal information conveyed on the spot, mutual understanding can be supported by translating the context and cultural differences that the other person has in mind and presenting them as supplemental information.

Additionally, affective computing R&D has helped in the recognition and expression of everything from facial expressions to motion, significantly expanding our sensing capabilities when interacting with others. This makes it possible to receive information based on the other person's emotions and position, leading to communication that promotes mutual understanding.

Further, cognitive mirroring R&D will make possible communication that is based on an understanding of how the world appears to others by simulating the world as they see and feel [9]. For example, it is well known that patients with the autism spectrum disorder subjectively experience a world hypersensitive to the stimuli they see, thus, do not make eye contact during ambiguous communications.

The expansion of the possibilities of self-expression and increase in the selectivity of expression through the technology of information output may be both helpful and inhibiting for understanding. Therefore, technology has been applied to detect and morph information

from slander to information containing bias such as prejudice and discrimination. For information containing harm, we can distance ourselves from what we do not need to see. However, these filters do not recommend that we look at things that do not interest us, and ultimately it is important to use these technologies as autonomous individuals.

2.1.3 Information Output to Others (Thought Transfer)

Technologies that assist in transmitting (output of) information to others will facilitate science and technology that can read what we are thinking or feeling as well as complex information that is difficult to convey to others and communicate through the generation of media that utilizes the five senses.

Figure 4 Information Output to Others

Specifically, creating high-precision and high-efficiency brain-machine interfaces will allow the retrieval of information that is difficult to convey simply using words, including thoughts, feelings, ideas, perspectives, and experiences. Different types of BMIs are undergoing R&D. The first type, non-invasive BMI, which can make advanced guesses by sufficiently learning correspondence with the data obtained by invasive-type BMIs beforehand, is in general use. Invasive BMIs can retrieve particularly complex information in certain situations. They have mainly been developed for medical applications to bring a person from negative to near-zero; however, they are increasingly being used in situations to selectively bring a person to positive values.

Science and technology have been developed that can generate and transmit media that combines images and sounds at a higher order after the information is retrieved so that it can be easily understood by the other party. The generation of new multi-modal media that uses all five senses, including touch, in addition to video and sound, which can be generated at any

time, makes it possible to transmit information without physical and temporal constraints. Research and development of multi-modal machine learning and generation networks have allowed the generation of media, and various display devices such as AR glass, contacts, and holograms have made the presentation of this media possible.

Although this technology makes it possible to convey more information such as thoughts and experiences that cannot be conveyed using words alone, information must not be output (conveyed) to others without the consent of the individual, and the technology needs to be designed to facilitate the transmission of only what is desired. Hence, security technologies that prevent unintended output malfunctions and ethical aspects such as privacy protection need to be discussed properly and technologically resolved.

The scenarios of achievement and feasibility in the interim period (2030) toward the achievement of the 2050 target are described in more detail in (I.4). Changes in social and industrial structures that will result from the achievement of the target, (III.2) targets (milestones) to be achieved by 2030, 2040, and 2050, research and development (R&D) toward the achievement of the milestones, and ripple effects.

As of 2030, interfaces are being researched, developed, and socially implemented mainly in developed countries, including Japan, before their widespread use in the world. Based on the results of the analysis of one's characteristics, etc., it is possible to understand one's well-being, and depression and suicide are prevented by being able to seek necessary help in situations where one would not be aware of based on one's subjective perception alone. At this point, the interface functions mainly in communication in real space, and the incomprehension of language and context has been resolved. Embodied virtual reality, which reflects limited physical senses, enhances the ability to empathize with others, thus promoting mutual understanding and compassion. Interfaces are also being introduced at the organizational level, reducing the time it takes to communicate within and outside the organization, and improving operational efficiency. Service providers of all kinds, from restaurants to hospitals, can understand the wishes and medical conditions of their service recipients and try to avoid making them uncomfortable with less effort. They can communicate in detail when providing and receiving care and can engage with society on an ongoing basis.

By continually using these input and output technologies in the real world as corporeal actors and experiencing cycles of interaction between self and others, we can also capture the sense of inter-subjectivity that arises because of the existence of both self and others. From these techniques and intersubjective perspectives, we can understand others' wellbeing and renew our own, and mutually understand and co-create the wellbeing of ourselves and others

(harmony in interpersonal relationships). The continuous and cyclical use of these technologies will demonstrate the real value of science and technology that fosters one's ability to interact with others beyond the convenience of an immediate interface.

2.2 Group Level 'A System that Supports the Diverse Self-organization of the Collective'

At the group level, the aim is to realize self-organization by raising values to promote diversity, and maintain an autonomous self with respect to the technology and collective. Here, in addition to the "autonomous self in the group" that acts on the individual entity, it encompasses the aspect of "consensus building as a group" with the "integration and diversity in the group" to co-create consensus.

2.2.1 Autonomous Self in the Group

Even while realizing diverse harmony in groups and the formation of values and consensus, it is essential to ensure autonomy for groups and technology. Here, technologies such as simulation, visualization, and training are realized as technologies that work on the individual as well.

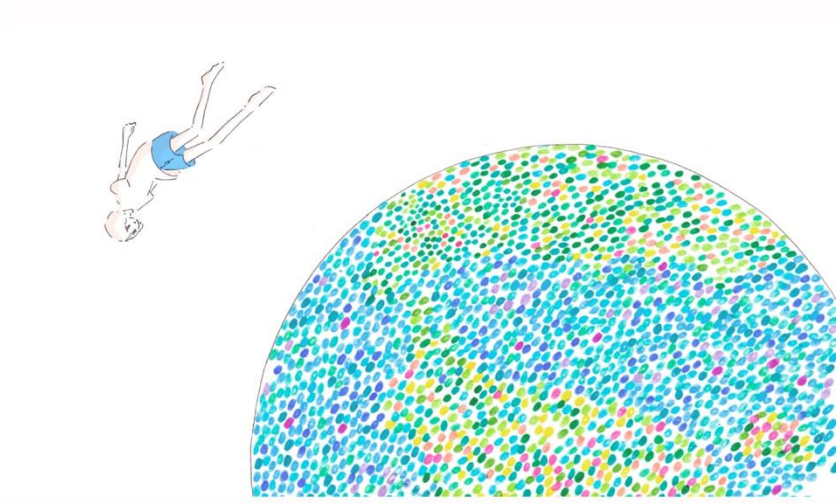

Figure 5 Autonomous Self in the Group

2.2.1.1 Autonomy for the Population

In addition to recognizing their identity, they can acquire a sense of relativization on being "autonomous yet a part of the group," which enables them to understand the wellbeing of the group and have a deeper understanding of the existence of the self and others in the social group. It also enables them to overcome in-group biases and interact with different values without biases.

Specifically, training through information technology, which enhances the ability to recognize one's own and group identity, is being implemented in society, making it feasible to live one's own life with confidence. Understanding one's identity is essential to prevent deindividuation, as is discussed below, where people behave violently when assimilated into a group and to reinforce people's identity within a group.

It also makes it possible to simulate one's or others' impact in society and the ripple effects of the information that is propagated. These social simulations and visualizations make it easier to relativize the self and others in a group. These are based on an agent-based model that examines the kind of macroscopic order that can be understood through microscopic interactions among agents by preparing multiple agents that have internal stakes and making decisions as well as research on simulations of information diffusion on social media [10].

However, in-group bias is considered to be integral to having the motivation to cooperate with the group, along with identity acquisition and recognition, social network construction and cooperation, etc. [11] To overcome the in-group bias without pushing a particular solution, it is necessary to set a higher-level goal among conflicting groups. Because a group has to be newly defined by the stakeholders involved in the problem in this MS goal, the consensus formed will always be an Aufheben-like upper-level solution.

2.2.1.2 Autonomy over Technology

It is possible to strengthen information literacy that enables the use of science and technology with a sense of conviction while remaining autonomous with regard to technology. The aforementioned technologies have made it possible to acquire and strengthen social skills through simulated training, which allows the propagation of information in groups and following its impact.

Currently, we are not adapting to the evolution of the information environment. Human beings are used in technologies that are supposed to be useful tools in nature, and in turn, they are creating new social problems. For example, the problem of reliance on smartphones and social networking services (SNS) and cyber bullying are becoming serious issues. Research and development are underway to strengthen information literacy to solve these issues [12].

Autonomy is also ensured by the fact that for all the information proposed by the system of consensus formation and reconciliation, it is possible to select the process by which these proposals are made, considering other options and information. For example, the information to be proposed as the next in line is always displayed in pairs; however it is not simply opt-in or opt-out. It is a system that allows individuals to make independent choices in all technologies.

2.2.2 Consensus Building as a Group

A support system for building consensus as a group has been realized as a system supporting self-organization based on a new policy of forming values and consensus. In various situations, the formation of an Aufheben-like consensus by all members continues, reflecting small claims that are often overlooked.

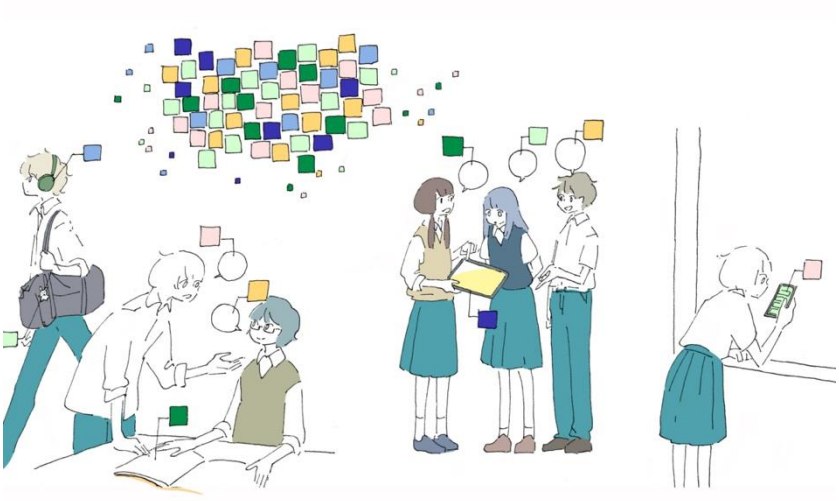

Figure 6 Consensus Building as a Group

In this system, the first step is the selection of stakeholders and the formation of the collective. The collective here is defined by all the stakeholders who need to form a consensus. The technology is in place to select stakeholders from those who threaten each other's living environment, or in other words, to select those who have competing objective functions. Despite the possibility of conflict among them, consensus building and proposals are made without external, or inter-group conflicts because existing externally defined groups, such as companies and organizations, are not adopted. We can simultaneously belong to multiple groups at different layers.

Furthermore, powerless assertions and opinions that are likely to be overlooked have led to the realization of an agreement formation system in which a variety of types of information can be picked up (measured and collected) through a sensing network integrated with SNS and urban architecture and coordinated (optimized) appropriately. This system is dynamic in time but operates slowly, eliminating the need for periodic and explicit consensus building. The system gradually perceives and considers typical attributes such as gender and race as well as current problems that we are not aware of (not surfaced or verbalized).

To realize this consensus-building system, it is necessary to model the objective functions of individuals and populations, to form a consensus by creating an agent that is pseudo-alternative to oneself, or directly calculate the optimization that can make those opinions the

most realistic. Incidentally, the happiness of an individual can be determined and perceived by the technology that realizes self-perception. By setting the one-person happiness as a sensing and objective function in various ways and coordinating with that of others, optimization as a group becomes possible. These consensus-building processes ensure resource allocation and evolution through sound competition that is not bound by undue demands for comparison and approval and they do not negatively affect each other.

Additionally, high security performance is required to prevent malicious users from rewriting and propagating comments. Blockchain systems linked to all users have been realized to ensure the reliability of each user participating in a distributed network, and enable the management and agreement formation of opinion data guaranteed for tampering and data privacy protection [13].

Although the computational complexity in these processes is a combinatorial explosion, it has been solved by research and development of supercomputers, performance improvement of processors, and dramatic advances in computers such as quantum computers. Moreover, in view of the computer performance in each era, the size of stakeholders and group formation on a computable scale is variable, and approximations of optimization calculations enable calculations on a realistic level.

2.2.3 Integration and Diversity in the Group

The ability to recognize a wide range of diversity and build consensus makes it possible to reconcile with all groups (all mankind) while maintaining diversity, including groups to which we belong, as well as distant unknown groups and those with whom we cannot directly agree.

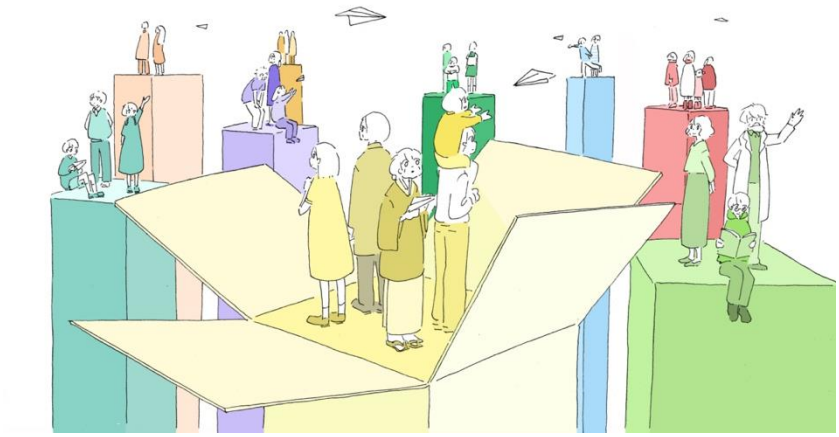

Figure 7 Integration and Diversity in the Group

First, the development of computational society technology will overcome problems such as filter bubbles, which provide biased information that each user prefers, and echo chambers, which reinforce values within those biased sources. Recommendation algorithms can work to reinforce individual values, leading to a loss of common values. The filter bubbles formed by the recommendation algorithms make it difficult to reach a consensus, so they are implemented to work in a way to prevent this from happening and dissipate it.

In other words, the transmission of information where diversity is ensured using information on the distribution of information and social network structure has been realized. This has made possible matching and information distribution control that best promotes mutual understanding. For example, it is now possible to analyze data of various modalities including text, images, and videos, and to examine the impact of community extraction and information propagation. It is also possible to represent the variance by vectors of the network. Based on this variance, it is possible to deliver information in a way that realizes diversity [14].

Additionally, with such systems that are responsible for matching and controlling information distribution, there is a question on guaranteeing their reliability. Specifically, it has become technically feasible to prevent the transmission of malicious lies and misinformation. For the credibility, blockchains tied to the originator can be used to achieve mutual trust among multiple users.

Regarding the technology that promotes this convergence, it is also essential to use technology autonomously after polishing the "autonomous self in the population" rather than the system intervening using paternalism. Furthermore, the technology of information expression to deepen mutual understanding following the control of matching and information distribution is realized by combining technology to translate the "concept" including background and context of information in the input of information from others, and multi-modal information transmission technology to be researched and developed in information output to others.

Additionally, details of the scenes of achievement and feasibility in the intermediate period (2030) toward the achievement of the 2050 goal will be discussed later (I.4 and III.2). However, research, development, and social implementation are progressing in developed countries and organizational units, including Japan. We can make autonomous choices toward technology by recognizing the visualized others and the influence of information. Moreover, consensus-building systems are being used in the operation of certain local governments and communities and within certain companies and organizations. Specifically, they can involve many stakeholders to connect ideas, capital, and labor, and to make decisions in fair meetings that can reflect powerless opinions. Newly emerging information distribution platforms are

eliminating the problems of filter bubbles and echo chambers, and companies and educational institutions use these platforms as tools to promote diversity and understanding of different cultures.

Systems that realize consensus formation and diverse harmony work complementarily to achieve self-organization that elevates diverse values (harmony in groups). Because the concept of a group arises from the consensus that needs to be formed, it can be considered similar to the concept of "place." Consensus within this place is different from the classical definition of a group, because it is created by all the stakeholders; the consensus is always proposed as Aufheben. Even among members that could not come to terms with it, matching and information distribution can be controlled to enable mutual understanding. Additionally, the system of harmonization is working to make us more agreeable in the first place. It is not in the form of sameness or integration, but rather in the form of the delivery of the information necessary to become an entity accepting diversity. Even in these times, we cannot allow ourselves to impose individualization or group thinking, nor can we give up on autonomy in technology. Therefore, technologies that support the autonomous self with respect to groups and technologies are becoming increasingly important.

2.3 Harmony for Humankind and the Individual Subject

The idea of a society where all of humanity is in harmony, as if it were a single life form, has been examined by various novels and movies. Among them, The Giver (Lois Lowry) and Brave New World (Aldous Huxley) represent harmony through the loss of individuality and creating class and a regulated society reinforcing the identity of people's genes and behaviors [15] [16]. In contrast, many Japanese science fiction works have shown harmony (overminds) in which people's consciousness disappears, their desires are adapted to behave as a group, and they behave super-individually through optimal division of labor like social insects; these ideas are included in "Childhood's End" (Arthur C Clark), "Harmony" (Project Itoh), and the anime "Evangelion" [17] [18] [19].

However, harmonization at the collective level in the MS target is not intended to be a loss of personality or identity. Rather, the aim is to develop science and technology to strengthen identities, prevent the idea of over mind, and prevent deindividuation. Realizing an autonomous self for the group that allows for deep self-awareness will enable us to remain an individualized, diversified, population while promoting mutual understanding and reconciliation. This was also considered ideal in enlightenment, and it is necessary to mutually understand the universal human dignity, while respecting uniqueness and the value of individual identities. Therefore, fostering the inner life and abilities of "individual actors" that

use technology is included as an important aspect. The creative aspect of the MS goals is that the R&D goal is structured to include elements for individuals to make autonomous decisions and actively use science and technology.

2.4 Physicality and "Collaboration"

Physicality is also important in the six technological directions described so far; however, the six technologies function more like cognition and information. Nevertheless, it is important that all technologies will be used by physical people in the real world.

These technologies of consensus building and reconciliation to realize diversity will be continuously used in the real world as individuals carrying out "collective action". In combination with interpersonal-level interactions, which can be referred to as intercommunication in the complex system of humanity, we, as actors with physicality, will create and change the real society for the better by cooperative action in groups. In such a society we will again utilize the six technologies, reflecting our physicality.

In other words, science and technology (2.1.2, 2.1.3) that works primarily on interpersonal relationships to maximize mutual understanding on a one-to-one basis, acts on groups that enable consensus and harmony in groups (2.2.2, 2.2.3), and develops the " individual subject" included in both targets, have multilayered interactions (2.1.1, 2.2.1) (Figure 8). Then, this individual subject grows as a physical actor, and experiences the interaction with others again. Individuals also acquire perspectives as a group through joint actions in groups, leading to consensus building and harmony in the newly defined group. These actions do not target only cognitive information, but can also change the actual economy and society. Through actions based on an understanding of the overlap between the self and others, and "joint actions" based on the recognition of the group as self and the self as the group, we can realize all kinds of changes toward harmony among humankind that transcend the boundaries of family, business, city, nation, and world.

This positive spiral is the evolution of humanity's acquisition of the concept of harmony, i.e., an inter-subjective perspective beyond altruism that moves back and forth between perspectives of the individual and the whole.

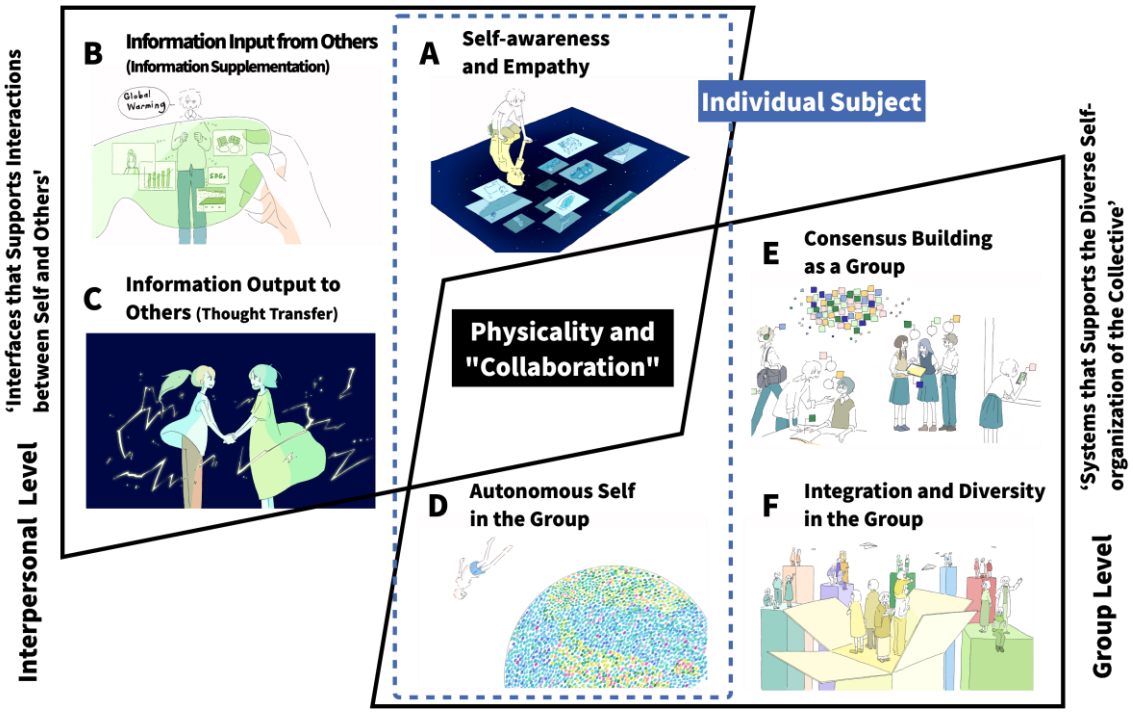

Figure 8 Structure of the levels and the six R&D aspects

3. Background

3.1 Why now?

The reason why diverse researchers in Japan and abroad need to come together and work towards "harmony for humankind" through science and technology as an MS Goal by 2050 can be explained from two perspectives: social and science and technology demands.

3.1.1 Social Demands

The impact of the novel coronavirus has manifested itself in "fragmentation" at various levels and domains, ranging from familiar human relationships to abuse on the Internet and new conflicts in the international society and global economy. Although such divisions existed before, the economic and social impacts of the pandemic that contemporary society has never faced have further increased political polarization and economic inequalities, the severity of which is increasing at an accelerating pace, as evidenced in the Black Lives Matter movement and female discrimination.

Enlightenment is also attracting renewed attention as a solution for the fundamental problem of human division. However, enlightenment relies heavily on individual 'tolerance' to find ways to recognize each other's individuality. The difficulty of reaching a mutual understanding with other people and different groups by expecting individuals to be tolerant

is becoming clear in a time when the divides are so wide. In these times of crisis, the awareness of how to change into "people who can overcome divisions" is a common thread of consciousness among humans.

Another reason for the emergence of the above-mentioned problems includes the development of information technology. Harmful information such as seditious fake news, conspiracies, trolling, and slander are particularly easy to spread through modern information networks that reach all over the world and have corrupted our minds [20]. There is supposedly a limit on the number of people with whom we can simultaneously have a stable social relationship, approximately 150 (the Dunbar number), which leads one to believe that humanity has been unable to adapt to an environment where we are openly connected to several billion people around the world through the Internet.

As mentioned above, the use of the Internet in a capitalist society has led to the development of recommendation algorithms to compete for the resource of disposable time, and problems have emerged, such as filter bubbles that have kept us ignorant of people we do not know. These issues on the Internet and SNS have resulted in the reinforcement of in-group biases and have become one of the major causes of our growing fragmentation. However, science and technology should be used to enrich humanity. It is necessary to support humanity in an increasingly sophisticated information society through science and technology based on the clear vision proposed through the MS goals.

Of course, reaching "harmony" will not only resolve mental segmentation. For example, the deterioration of the global environment, which is caused by the abuse of resources caused by the human instinct of population growth and the expansion of economic disparities due to capitalism that promotes it, are physical issues that cannot be ignored. Various solutions have been proposed for this from various fields, including sociology and economics. For example, it has been pointed out that capitalism cannot stop climate change, and economic affluence and happiness are not correlated after a certain point, so it can be solved only by achieving degrowth communism by fairly balancing global resources [21].

On this premise, the MS goal does not include the above-mentioned philosophy. However, it enables a gradual realization of a new philosophy for those societies in each age and if the collective as a whole desires it. In that sense, achieving harmony is a characteristic that can renew all our principles.

There is also an optimistic hypothesis that the development of science and technology will lead to an era where we will be able to live at a certain level without having to work. The MS goal of self-awareness and the realization of an autonomous self within a collective is essential because we still need to solve the desire for comparison and approval, which is the reason why

we cannot be happy even in such an age. Although there is a possibility in the future that disasters will be overcome, energy will be available, and all human beings will be able to live without having to cooperate with each other, the harmonious development of humanity will be essential in 2050, and this is an intermediate process to reach this era.

3.1.2 Scientific Demands

The concept proposed by the MS goals assumes not an "artificial intelligence" that can think like a person but rather intelligence as a tool for us to grow. In the research and development (R&D) of artificial intelligence and information and communication technology, as well as in the development of industrial products and services, emphasis has been placed on making machines smarter and more sophisticated. To give an example, Alpha-Go (Go AI) has been developed to demonstrate—in a simple way—that it can exceed human capabilities. The GPT-3 project, a large-scale natural language processing model for generating sentences, has also been claimed to achieve human levels of writing ability. This type of artificial intelligence tends to be broadly attributed—by researchers and the general public—for the image of developing an intelligence that surpasses that of humans.

However, the MS goals present R&D aims that focus on the fundamental value of "how people can change" rather than improving technology and performance. In the foreseeable future, human beings will passively use artificial intelligence and machines that will have become smarter and more efficient than humans. However, it is important for us to define, research, develop, and implement within society machines that can enhance human capabilities. Shogi AI represents a good example of this: it not only surpasses human capabilities but also serves as a training partner for the next generation of professional Shogi players, thereby contributing to the enhancement of the entire Shogi world. The MS goals also open up a new academic perspective: that we should develop systems that facilitate not only human–agent and human–computer interactions—which are currently receiving widespread interest—but also human–human interactions. The Budapest Declaration of 1999 states that science must play a role not only in knowledge creation but also in peace, development, and society.

Furthermore, in the R&D of artificial intelligence (and machine learning in particular), the collection and practical application of data are expected to progress without moonshot goals. However, it is also true that R&D led by private companies and based on competitive research funds is often focused upon solving short-term problems, without determining whether these technologies will ultimately lead to a better future for humanity. For example, the development of recommendation algorithms allows the content desired by users to be suggested, which may lead to the loss of autonomous decision-making abilities. In recent years,

it has been suggested that young people in particular are losing their autonomy as the development of recommendation systems externalizes their ability to select information and make decisions. The accumulation of "nudges" that encourage certain decisions, even if well-intended—from the perspective of each provider—to improve society, can lead to a loss of autonomy [12].

Conversely, insufficient understanding of our goals may produce unwarranted anxiety, leading to tighter regulations and a halt in R&D. For example, in Europe, the European Union has announced a comprehensive regulatory proposal to restrict the use of artificial intelligence; however, this is said to be out of step with the actual state of R&D in artificial intelligence, as envisioned by researchers and companies in the relevant field. The MS goals respond to this situation by proposing a vision that contributes to genuine human well-being, whilst also conducting scientific verification through interviews with academics and experts in various fields. We believe that sound R&D will be realized only when researchers and the general public share a common understanding of the MS goals. This idea also accords with the European Union's Responsible Research & Innovation (RRI) principles.

The MS goals encompass a number of scientific and technological issues, which will be discussed later; furthermore, these issues should be addressed across disciplines—from interfaces to consensus-building and reconciliation systems—and by research into the psycho-social principles of the "individual subject" that underlie them. This is not only difficult for individual, independent researchers but also for major private companies within a capitalist society, and it can only be achieved through nationwide efforts. In addition, the various social implications of research results from different fields should be mutually interacting, bearing in mind the cycle in which collaborative action changes society and the society so changed prompts R&D aspiration; this cannot be achieved by short-term R&D projects alone.

The MS goals were formulated in response to the demands of society and of science and technology, as described above. We are presently at a critical juncture where humanity can explicitly choose the direction of science and technology, and it is precisely at this time that we must chart a course for R&D that will harmonize humanity. From a long-term perspective, these scientific technologies will be researched, developed, and implemented in society, and we will conduct R&D with the aim of creating a society in which humans can truly understand each other. Using technology, we will attain harmony, and our collaborative actions toward harmony will change society; we will use technology again in this context. By merging society and science and technology together in a positive spiral, a shift from "division" to "harmony" will be realized.

3.2 Social significance

The MS goals are not based on any particular ideology or principle; instead, they serve as a platform that facilitates—if we so desire—the implementation of any ideology or principle at any given time. For example, this platform has the potential to help us transcend the limitations of our acquired language, or to break free of the monetary economy by sharing values besides money.

An initial example: We, *Homo sapiens*, have utilized the power of language to form societies and collaborate through communication, as well as to create and inherit various cultures. However, no one person can remember the complete form of a language (e.g., Japanese), and language varies depending on the context and the people with whom we are communicating. Human communication and inheritance has been deepened by the invention of language, which has generated the world of meaning. An interface that supports language input and output can take this transmission and storage of information to another level, facilitating new levels of inheritance.

Another example is the value of money—a human invention—and the monetary economy. The economic system and free-market mechanism (which are based on the monetary economy) can be considered as subject to a repeated optimal calculation (God's invisible hand) throughout society, via the coded prediction of supply and demand. This can be treated as the classical formation of values and consensus in the absence of the Internet. However, the system of consensus building and diverse reconciliation permits the co-creation of all values except money.

In other words, although the MS goals themselves do not include these principles and claims, they can create social change if we—as users of the system in this era—wish them to. The development from language to information completion and thought transfer can be realized through the interface of mutual understanding, and the transition from the monetary economy to a new value system can be realized through a system of self-organization.

In addition, achieving the MS goals will allow us to obtain our own happiness, through mutual understanding of the happiness of others. This discovery and interaction, as well as an understanding of what kind of physical and mental fulfillment and peer-to-peer and peer-to-group relationships we seek, has social significance as the "first step to attaining well-being." In addition, well-being is not something completed within one person but is rather a product of co-creation that can connect that one person with diverse others [22]. This is made possible by an interface that complements contexts and concepts, enhances our ability to empathize with others, and promotes mutual understanding. These are of great significance because they enable us to evolve into a socially-connected human species.

In recent years (more so than ever before), demands for diversity and the elimination of inequality have been made; however, no drastic solutions have been proposed to these issues asides from calling upon each of us to become more tolerant. The science and technology proposed by the MS goals will enable us to deepen our understanding of our interpersonal relationships (with the individuals and people we encounter) and the existence of ourselves and others in social groups; furthermore, they will help to realize consensus and reconciliation with all groups of people, from our neighbors to those far away. The social significance of this is that it facilitates the continual co-creation of consensus without damaging others' happiness in pursuit of one's own.

As mentioned above, humanity has not been able to adapt to the new information environment (e.g., the Internet and social networking services), and it can be said that we lack information literacy (i.e., the ability to recognize, understand, and respond to information) in a broad sense of the term. In contrast, science and technology—which nurtures the inner world and capabilities of the "individual subject"—plays an important role in actively promoting our evolution. Until now, very little work in science and technology has focused on the individual subject, owing to the limited data available and ethical issues. The MS goals are important in that they explicitly include R&D, indicating a new R&D method that works on our inner selves, rather than following and responding to the development of science and technology through legislation and education. This has a historical significance: for the first time, humanity can develop its own capabilities in a systematic and proactive manner, by focusing on the individual rather than using existing means to respond to the development of science and technology.

3.3 Action outline

Regardless of how advanced science and technology and their applications become, if we aim for the active social implementation of technology, then users and society must be prepared to accept it before social change can be realized. To achieve the MS goals, it is essential not only to promote academic R&D but also to implement it in society, through collaboration between "industry, academia, government, and the private sector," including the public and social sectors.

First, the most necessary step toward achieving the MS goals is to create a highly abstract concept of the "harmony of humankind" through science and technology, involving diverse participants. It is necessary to discuss and refine the concept with various stakeholders, integrate their views into a single concept that can be widely shared and understood, and promote this concept. The review team that proposes the MS goals—and all parties involved

in research, development, and support—should be participants in the social sector and should actively lead the discussion. Specifically, a non-profit consortium should be formed by inviting stakeholders from industry, academia, government, and the private sector, including users, workers, and non-profit organizations. In this consortium, we will not only develop and advocate the concept but also carefully consider the risk likelihood, precautions, and preventions, specifically in relation to personal information, privacy, data trust, and ethical issues. We believe that presenting an impactful initiative report in a form widely intelligible to industry, academia, and government represents the first step in this process. In addition to supporting consistent R&D, it is hoped that plans for R&D and social implementation will be revised through constant collaboration with such consortia, without neglecting the important underlying principle of "solving social issues."

Achieving the MS goals will require the assistance and co-creation of various existing industries (education, medicine, media, information and communication, social networking services, etc.). Thus, we should aim for each stakeholder to share the concept of the MS goal and to proactively utilize science and technology in their own businesses, rather than implementing it in society in a way that destroys specific industries. In addition, the MS goals—especially with respect to group-oriented science and technologies that facilitates consensus and reconciliation in groups (Sections 2.2.2 and 2.2.3)—should not be achieved by a single company (e.g., big-tech companies such as Amazon, Apple, Google, Facebook, or Microsoft) or by major domestic/international vendors. As well as aiming for co-creation (rather than industry disruption), collaboration with industry associations and the public sector (including major vendors) can considerably change society, even if a single company or startup cannot change it alone.

To realize the MS goals, it is necessary to collaborate with the aforementioned global big tech companies and Japanese startups with advanced technology seeds, such as Preferred Networks. Although their visions may differ, we believe that what these companies essentially aim for overlaps with the MS goals. Specifically, common technologies are found in the construction of networked platforms of distributed edge artificial intelligence, in the realization of social systems, and so on. We must strive to make the consortium neutral and not to favor any one company, as well as to have discussions with diverse stakeholders.

We will discuss the importance of the public sector in achieving the MS goals. The conventional method of developing science and technology and then leaving it until societal demand for it increases will result in delays of several decades before technologies can be implemented in society. Furthermore, these technologies may also fail to be implemented in

society, owing to conflicts with existing systems during the process of diffusion. Therefore, it is necessary to consider consistency with existing systems during the early stages of R&D implementation and—in some cases—to demand regulatory reform from the perspective of R&D developers. Thus, it is important to make proposals to and hold discussions with members, as well as to engage with politics through research groups and councils. In particular, laws and business regulations have sometimes prevented cutting-edge technologies from being implemented in society; however, we must remember that this does not indicate a problem in the Japanese social system: the lack of open discussion and examination by researchers and the tech industry is one reason for such limitations.

The public sector is also expected to provide financial and human support to non-profit organizations and social entrepreneurship. Not only the non-profit consortia (led by those involved in the aforementioned MS goals) but also initiatives such as proof-of-concept and living labs (to conduct R&D whilst verifying the possibility of social implementation) struggle to generate profits on their own. We believe that unceasing support for these initiatives until they achieve their goals will in turn support the Japanese economy and society. In Japan, the Toyota Motor Corporation's experimental "Woven City" is well known, and it is hoped that the MS goals will be able to stand alongside such efforts in a friendly competition.

Finally, we must openly discuss how science and technology—and their social implementations—can contribute to the "harmony of humankind," in cooperation with organizations and institutions such as the United Nations and the World Economic Forum. The Sustainable Development Goals (SDGs) have been formulated internationally; thus, Japan must take the lead in proposing the next vision (after the SDGs) to address the issue of divisions in humanity. The Time Well Spent concept is a famous example of such an international initiative. In our efforts to achieve the MS goals, we aim to make use of the Japan International Exposition (Osaka–Kansai Expo.) to be held in 2025, to present the social implementations of science and technology to the world.

As described above, the MS goals will be achieved by sharing their concepts across a wide range of sectors (from academia to the social and public sectors), working toward achieving them in society as a whole.

4. Benefits for industry and society

The changes in social and industrial structures that will result from the achievement of the MS goals are wide-ranging; in particular, as noted above, the year 2050 will see drastic changes in the social structures of humanity [23]. We can change all social and economic structures by co-creating consensus in groups and acting together as intentional actors. We can also realize mutual understanding through intercommunication (interpersonal relationships) within groups and a readiness to create the future as altruistic individuals. In such an era, there is little doubt that economic inequality, the provision of educational and employment opportunities, and the uneven distribution of knowledge will be eliminated. However, it is important to note that the MS goals themselves should not cover the principles and circumstances that support it. These should be determined by the future chosen through the joint actions of a new, compassionate humanity. Examples of fundamental changes potentially realizable in social and industrial structures by 2050 include communication and inheritance through interfaces that transcend language—as described above—and the transformation from the monetary economy to a new value system. The MS goals constitute a platform that serves as the premise for all change.

In 2030, R&D and its social implementations are expected to bring about—at very least—the following changes in social and industrial structures, even if they will not be as revolutionary as those in 2050.

First, the development of technologies relating to self-awareness (Section 2.1.1) will help people to become aware of their own strengths, preferences, and happiness. Even in situations where their subjective perceptions alone are not sufficient to provide awareness, people will be able to seek help in times of distress, which can help prevent depression and suicide. In addition to self-awareness, the ability to empathize with others will be enhanced such that mutual understanding and compassion will be realized within families and organizations.

Particularly, in business, the interface (Sections 2.1.2 and 2.1.3) will help support mutual understanding across all interpersonal scenarios. In companies, this will reduce the time spent in all kinds of meetings, sales, and creative communication, which will lead to improved operational efficiency. It will be offered as a solution to improve business operations, for purposes such as consensus-building toward desired results, both inside and outside the company; sales activities, to understand what the other party wants and make proposals; and communication between workers at factories and other sites.

The interface will also be implemented in society across a variety of scenarios involving consumers, companies, and service providers. Input-supporting technologies will make it easier for service providers—from restaurant owners to store clerks and insurance

salespeople—to anticipate consumers' wants and to avoid making them feel uncomfortable. Output-supporting technologies will make it possible to communicate detailed wishes and receive consultations. For example, in the medical field, it will inform doctors and nurses about symptoms and delicate sensations. When elderly people receive care, they will be able to communicate their wishes in detail (even despite cognitive issues) and engage with society on an ongoing basis.

Technology that preserves autonomy in respect to groups and technology (Section 2.2.1) will allow individuals to select information without being distracted by the media and filter bubbles. The ability to relativize oneself and others, to live without being influenced by comparisons and the desire for approval, and to visualize the impact of technology will make it easier to support consensus building and to implement opt-in and opt-out decisions across various information distribution and proposal situations.

Technology to support consensus building (Section 2.2.2) will be adopted first in local government and community management, or in organizations such as companies. In urban and suburban areas—in which people live together without geographical ties and blood relations—the technology will facilitate and realize consensus building, which is otherwise difficult. In rural areas where the population is decreasing, the technology will facilitate consensus building—without requiring people to live in the same place—and collaboration between depopulated areas, by connecting ideas, capital, and labor from Japan and abroad. Naturally, it will also make it possible to hold fair meetings inside companies, by reflecting the opinions of the powerless. Even under excessive competition within and between companies, it may prevent the otherwise-unavoidable loss of wealth.

Technology supporting diverse integration (Section 2.2.3) will be used to facilitate the examination of diversity, different cultures, and new business areas at the level of specific organizations. In society in general, new principles of information distribution will be implemented across a variety of platforms and societies, providing people with the tolerance to truly understand diversity and be ready to receive diverse information. These functions are complementary to consensus building and can prevent people from becoming over-immersed or misled, leading to our attainment of harmony.

It is a factual truth that in every era, there are those of us who live in that era, and, to make society as desirable as possible, we must move forward as "harmonious" human beings whilst avoiding extinction. We, who can help each other with the support of the interface, will gain a transcendental group perspective whilst still being individuals, because the group is organically redefined with the support of the system. We will create a society full of harmony

in all future possibilities, through the ability to move back and forth between these perspectives.

II. Analysis

1. Essential scientific/social components

The scientific and social issues to be addressed in achieving the MS goals will be described according to summaries of the interpersonal level ('Interfaces that Supports Interactions between Self and Others') and group level ('Systems that Supports the Diverse Self-organization of the Collective').

1.1 Interpersonal Level 'Interfaces that Supports Interactions between Self and Others'

The interpersonal target expressed in the MS goals is: "By 2050, we will be able to recognize and improve ourselves, and we will gain a deep mutual understanding of the thoughts and feelings of ourselves and others." In this section, we provide a comprehensive overview of the social, scientific, and technological issues that this target encompasses.

1.1.1 Self-awareness and Empathy

[Social issues]

■Studies regarding the situations in which technologies that enhance self-awareness and empathy are used, and the introduction of such technologies into education.

→No studies have yet considered the applicability of and rules for introducing sensing to deepen self-recognition and simulation and enhance empathy in society and education.

(Necessary effort) A wide range of stakeholders from industry, academia, government, and the private sector should be involved in formulating the rules; furthermore, it is necessary to conduct humanistic and sociological research on altruism and to consider the framework for empirical experiments.

■Studies regarding the likelihood that supporting self-awareness may infringe constitutional rights.

→Though how an individual feels happiness is ensured by the freedom of the inner mind, no studies have considered the possibility that sensing and analysis may reduce people's freedoms.

(Necessary effort) Compared to the conventional handling of personal information, more careful attention is required for the sensing of neuroscientific and biological information and the publication of well-being analysis results based on such information. It is also necessary to ensure informed consent.

[Scientific and technological issues]

(Self-awareness as a sender)

■Realization of technology to analyze and visualize one's own psychological attributes and past experiences from data

→Technology to support the recognition of one's own psychological attributes and past experiences to help enhance one's self-awareness as a sender—a prerequisite for communicating with others—has not been realized. This recognition is useful for self-perception as a sender, which is a prerequisite to communicating with someone; hence, technology which supports the recognition of one's own psychological characteristics and past experiences is required.

(Necessary effort) It is necessary to conduct R&D toward technologies that analyze and visualize psychological attributes and present them in a way that promotes self-awareness, whilst safely and efficiently collecting and managing data about one's personality, attributes, abilities, and more, from the past to the present.

■Realization of technology to present the factors and effects of physical and mental fulfillment, based on the sensing of biological information.

→A system for sensing and analyzing the factors and effects of one's own physical, mental, and social fulfillment—according to the definition of well-being—has not yet been put in place.

(Necessary effort) We need technologies that gather data regarding the nervous system of the brain, elucidate brain functions, and accumulate and analyze correlational data between a person's internal state and information that appears in measurable physical characteristics and biological response data.

■Realization of technology to build a predictive model of an individual's brain from brain signals and thoughts and action data.

→Technologies to create a predictive model of an individual's brain from a combination of brain signals and thought and action data—to infer one's own behavior from the perspectives of others (mirror-image observation of the self)—has not yet been realized.

(Necessary effort) We need technology to safely and efficiently collect and model individual brain signals and behavioral data, as well as to separate and extract the common components of the model as the common basis of humanity (or the group) and the different components as individual-specific, to use these as a decision-making reference and to observe ourselves from others' perspectives.

(Ability to empathize as a receiver)

■Realization of embodied virtual reality and body-sharing technologies that allow us to experience others' positions over short durations.

→Technology to facilitate empathy with embodied others—to thereby enable communication and mutual understanding based on the understanding of others' happiness—has not been realized.

(Necessary effort) To promote mutual understanding, it is necessary to research and develop virtual reality with embodiment—to simulate others' lives over short durations—and body-sharing technology that allows us to "stand in other people's shoes."

■Realization of gamification technology that can train individuals' communications with others

→ Technology for education and training schemes that assist mutual understanding of others (e.g., the system of gamification to simulate the behavior of others) has not been realized.

(Necessary effort) It is necessary to research and develop systems that can simulate communication with agents that have learned the behaviors of others, as well as training technologies that use gamification to mimic interpersonal relationships.

■Realization of technology to visualize whether communication is well established in daily interpersonal relationships

→Technology to support understanding of whether communication with others has been well established—when communicating with others in daily life—has not been realized.

(Necessary effort) It is necessary to perform R&D of cognitive human-enhancement technology and communication support, to help people to imagine the position of another by presenting the state of communication (i.e., whether it has been well established, etc.) for day-to-day, real-world interactions.

1.1.2 Information Input from Others (Information Supplementation)

[Social Issues]

■Studies into the possibility of social gap widening when technology is spread as an expensive tool.

→No studies have considered whether the use of tools will widen social disparities if the technology expands people's ability to accurately understand another person's wishes and to negotiate.

(Necessary effort) It is necessary for industry and government to consider regulations to be imposed on both input and output technologies, to prevent them becoming expensive tools

difficult to disseminate to the general public, as well as to limit the situations in which these technologies can be used, to prevent them from widening social gaps.

■Studies regarding the right to refuse to see what the receiver of the information does not wish to see
→Though the ability to sense information regarding the other party's emotions and position is being enhanced, insufficient consideration has been afforded to the right to not see what one does not wish to see.
(Necessary effort) It is necessary to clarify—from an ethical perspective—the voluntary rights of users when receiving information from others, and to examine how to prevent reception of what one does not want to see in a way that does not lead to a selection of self-centered information.

■Studies regarding the risk of a mismatch between the self you want to convey and the self the other person wants to know
→Insufficient studies have considered countermeasures against conflicts arising between the information or persona you want to convey to others and the information that the other person wants to know.
(Necessary effort) It is necessary to formulate rules regarding how to respond when a conflict arises between what you want to show and what the other person wants to see. In particular, it is necessary to guarantee the right not to be “guessed about” regarding information that one does not want to convey, and to take care not to expose one's persona.

[Scientific and Technological Issues]
■Realization of technology that translates and presents "concepts" including past information, contexts, and cultural backgrounds
→ The technology for translating and presenting concepts that include the informational background and context as well as the cultural backgrounds of the individuals involved has not yet been realized in a way that adequately promotes mutual understanding in interpersonal relationships.
(Necessary effort) It is necessary to perform R&D of technologies to safely and efficiently collect and store the background information of each user on each device and network, to translate concepts in a manner suitable to the communication at hand, and to present these in a way that complements the various lines of communication.

■Realization of technology that extends cognitive abilities to support estimation of the emotions and positions of others

→Technology to extend cognitive abilities (e.g., recognition of facial expressions and motions and presentation in an understandable form), to thereby convey information regarding the other person's emotions and position, has not been realized.

(Necessary effort) Further R&D in the field of affective computing is necessary, starting with visual and auditory sensing—which allows us to combine what is seen with the eyes with what is heard with the ears (via words)—as well as the comprehensive sensing, analysis, and presentation of facial expressions and motions.

■Realization of cognitive mirroring technology to simulate and relive the world as perceived by others

→Cognitive mirroring allows us to relive the cognitive processes of all people, including people with disabilities; however, the technology to support this has not yet been realized.

(Necessary effort) It is necessary to measure and quantify body–environment relationships, to facilitate objective observation of the cognitive processes from sensation to movement, as well as to research and develop an interface that facilitates the reliving of this cognition.

■ Realization of technology to detect, alter, and remove harmful biases, including prejudice and discrimination

→ Technology to detect information (ranging from slander to bias, including prejudice and discrimination) and distance the user from what does not need to be seen has not been realized.

(Necessary effort) It is necessary to collect and classify data to detect bias, including slander, prejudice, and discrimination. It is also necessary to research and develop technologies to understand these underlying biases and to allow users to use information autonomously, whilst complementing (converting) this information before exposure to the user.

1.1.3 Information Output to Others (Thought Transfer)

[Social issues]

■Study regarding the abilities and rights to control the output media

→While support is provided by technology, no measures have been taken to address the danger that individual's abilities to reflect their own inner world will be reduced, and that they will no longer be able to autonomously control the output media.

(Necessary effort) Educational programs must be established to allow people to carry out the difficult task of confronting their inner world and using output technology to express their

complex thoughts and feelings. It is also necessary to support users so that they can fully develop their abilities to use output technologies.

■Consideration of responsibilities regarding output media
→No consideration has been afforded to the cases where media is unintentionally generated by the interface and includes confidential, slanderous, or other information for which the sender is held responsible.
(Necessary effort) Education and legal systems must be adapted to ensure the aforementioned control capabilities and rights, and rules must be formulated to determine responsibility and solve problems where they occur.

[Scientific and technological issues]
■Realization of technologies that facilitate the reading of higher-order brain information that can also be applied to medical treatment (invasive).
→Technology (e.g., highly accurate and efficient brain-machine interfaces) capable of reading complex and difficult-to-communicate information, such as emotions and thoughts, have not been realized.
(Necessary effort) To measure brain information at a level sophisticated enough for high-accuracy and high-efficiency medical applications, it is necessary to research and develop an invasive brain–machine interface in the form of a small, externally powered, wirelessly connected chip to be embedded in the brain.

■Realization of non-invasive technology to read brain information with an accuracy almost identical to that of the invasive alternative.
→Non-invasive brain-machine interfaces that can read brain information with a high accuracy and can be applied safely and easily have not been realized.
(Necessary effort) It is necessary to perform R&D toward the construction of a machine learning model based on the pair data of a non-invasive patch-type electroencephalography and an invasive measurement device. In addition, it is necessary to examine new measurement methods, including ultrasonic echo equipment and nanorobot measurements of blood-flow concentration.

■Realization of technology to generate dynamic and multi-modal media
→Technology to generate higher-order media—that is, combining modalities (including the five senses) such that the information (input) to be transmitted to the other person (e.g., brain information) can be most easily understood by that person—has not yet been realized.

(Necessary effort) It is necessary to research and develop multimodal-information-generation systems that utilize the five senses, including visual, auditory, and tactile senses, as well as time-dynamic and interactive media and devices for presenting these to users during communication.

■Realization of distributed cooperative machine learning and data-management technologies to protect and utilize personal privacy information.
→Technologies to protect the privacy of learning data and actual data—which are necessary for reading brain information and generating multimodal media so that valuable data resources can be utilized—have not been realized.
(Necessary effort) It is necessary to research and develop distributed cooperative machine learning systems that store privacy-related data only on the user side and can be trained by edge artificial intelligence, as well as edge computing resources to enable such systems.

■Realization of security technology to prevent unintended malfunction of output
→Security technology to prevent the unintended disclosure of principles, claims, and personal information not intended for communication has not been realized.
(Necessary effort) It is necessary to research and develop security technologies to prevent unintended malfunction of the output, modeling techniques following the decision process (etiquette) of "better not to say" in society, and systems that comply with the laws and regulations regarding personal information protection.

1.2 Group Level 'Systems that Supports the Diverse Self-organization of the Collective'

As the group-level MS target goal, "By 2050, we will be able to co-create diversified harmony and values while maintaining an autonomous self within the group." This section provides an overview of the social and scientific/technological problems encompassed by this target.

1.2.1 Autonomous Self in the Group

[Social Issues]
■Considerations and measures against the complication of the user's right of choice for various systems
→There are concerns that giving an opt-in or opt-out choice will reduce the level of convenience, and no consideration or measures have been taken as to whom and to what extent technology should be provided to ensure user autonomy.
(Necessary Initiatives) Nudging users toward making a choice may deprive autonomy through the choice not to abandon such autonomy, and it is necessary to consider a way to achieve a

social implementation that gives users a variety of choices.

■Consideration of the use of technologies to support individual autonomy for groups
→It is insufficient to consider what types of situations in the workplace or what level of education should be reflected in new technologies that help in understanding and relativizing one's own identity or those of others and gain autonomy.
(Necessary Initiatives) It is necessary for stakeholders involved in the humanities, social sciences, and education to consider the scope of use and nature of technology, because this will be the first time for new technology to be implemented on the subject of the individual in supporting individual autonomy in relation to groups.

[Scientific and Technological Issues]
(Group Autonomy)
■Realization of cognitive acquisition support technologies relativizing one's identity in a group
→Technologies have not been achieved to recognize the identities of others and acquire the cognition of relativization of the self as being both autonomous and a part of the group.
(Necessary Initiatives) Research and development of technologies that extract and present the identities and relative positions of the self and others in the group, and training to define and present social biases toward others and different groups are presented to them in a contrasting manner.

■Realization of a technology to calculate, visualize, and recognize the influence of the self and others in a group
→The technology for visualizing and recognizing the influence that we have in society, to relativize ourselves and others, and to prevent us from becoming immersed and subordinate to groups has yet to be realized.
(Necessary Initiatives) R&D for simulation of possible decision making by an agent-based model, and simulation and training technologies capable of the propagation of decision-making and its effects within a group.

(Autonomy over Technology)
■Realization of technology that explicitly illustrates stakeholders who formed a consensus and the paths through which information was transmitted
→Technologies have not been achieved to support autonomy by enabling the confirmation of stakeholders involved in consensus-forming and the transmission path of information while

protecting privacy.
(Necessary Initiatives) It is necessary to conduct R&D to support the use of autonomous technologies to explicitly output rapidly developing information environments and calculation processes of system groups in the MS target, as well as methods to enhance user information literacy .

■Realization of training technologies that refine social abilities to continue using technologies autonomously
→Training technologies that acquire and strengthen social abilities to use science and technology while remaining autonomous and maintaining a sense of acceptance have yet to be realized.
(Necessary Initiatives) There is a need for research and development of technologies to support the selection of opt-in and opt-out choices in various systems, and to choose from a variety of second and third options for proposed agreements and information in various systems, as well as improving the usability of such systems allowing them to be applied without complications.

1.2.2 Consensus Building as a Group

[Social Issues]
■Examination of "Killer Applications" and Usage Situations to Realize Proactive Dissemination of Consensus-Building Systems
→Design of incentives that make users want to use consensus-forming systems on their own initiative when implementing science and technology for a large-scale consensus building system has not been considered.
(Necessary Initiatives) It is necessary to discuss the ideal way of a system that can withstand use, not only in Japan but in the rest of the world, while carefully acknowledging the right to control personal data with an eye toward the social implementation of killer applications to expand consensus formation systems in the world through collaboration among industry, academia, and government.

■Examination of the gap between the willingness to participate in consensus building and the sensing of personal data
→There is a gap between participation in consensus formation and allowing the sensing of personal data to extract opinions, and the issue of securing individual rights has yet to be sufficiently considered.
(Necessary Initiatives) Like bio-information sensors used for self-awareness, there is a

possibility of infringing on the freedom of the mind, and it is necessary ensure informed consent when participating in consensus building, as well as to discuss the scope and method of consent from a legal perspective.

■Measures to address the possibility of peer pressures and coerced participation in consensus-forming systems
→If it is widely shared that the consensus-building system yields socially beneficial results, there are no measures in place to prevent peer pressure participation in these systems.
(Necessary Initiatives) It is necessary for stakeholders in industry, academia, government, and the private sector to widely discuss the situations in which the consensus formation system will be used, and to declare and share the fact that all technologies are optional choices for users.

■Measures against issues where the system may output results differing from those of other systems, including democracy
→Even if a large-scale consensus-building system is used freely and extensively, it has not been considered whether the output agreement is inconsistent with the results of various systems based on democratic ideals.
(Necessary Initiatives) When introducing a consensus-building system under an indirect democracy, it is necessary for legislative, justice, and administrative agencies to consider ways to limit the situations where it can be used, and how to appropriately incorporate it into the current system.

[Scientific and Technological Issues]
■Creating a technique to select stakeholders for the consensus that needs to be formed
→The technology used to select stakeholders has yet to be realized with an interest in seeking individual objectives and recommending the use of consensus-forming systems.
(Necessary Initiatives) It is necessary to study and develop a system to select relevant stakeholders consisting of multiple users who are aware of the issues, based on a variety of information sources, and encourage their participation in the consensus formation.

■Realization of technologies to extract even powerless opinions through next-generation sensing networks
→The information technology that extracts even powerless assertions and opinions that may be overlooked through the sensing network integrated with SNS and urban architecture has yet to be realized.

(Necessary Initiatives) Research and development of sensing systems that combine complex sensing systems, materials and devices, ubiquitous computing, and Wi-Fi, 5G, and 6G sensing networks, and a system that extracts user opinions from such information.

■Realization of technologies for an agreement-building system for appropriate coordination from opinions

→An agreement-building system that models and coordinates or optimizes the objective function for individuals and groups based on sensed opinions has yet to be realized.

(Necessary Initiatives) Research and development on modeling individual and group objective functions, direct optimization calculations of objective functions of hyper-multivariables, or support of agreement formation by agent-based models that behave based on those objective functions to support consensus building, as well as applications to fair division theory systems.

■Realization of a blockchain system to prevent the rewriting of opinions and their propagation

→Technology to raise security against users who attempt to rewrite opinions and their and propagation to change the result of the consensus formation has yet to be realized.

(Necessary Initiatives) Technology is needed to detect malicious rewriting of opinions and their propagation, while ensuring the reliability and traceability of the users. For example, it is assumed that we need something similar to a blockchain system in which all senders who transmit extracted opinions and participate in consensus building can participate.

■Computing and computing models to solve combinatorial explosions

→Technology has yet to be realized that can solve in real time the enormous number of computations of combinatorial explosions, which arise when a dynamic consensus formation is carried out in a population of an arbitrary size over time.

(Necessary Initiatives) Research and development on how to implement systems corresponding to the development of computers, including quantum computers, examining computable mathematical models, variable sized groups, and an approximation of consensus building systems.

1.2.3 Integration and Diversity in the Group

[Social Issues]

■Discussion and examination of maintaining personalities and identities in harmony

→In the midst of the spread of information and communication technologies, including science and technology of harmony, discussions and countermeasures are required on the dangers of a loss of individuality (personality and identity).

(Necessary Initiatives) It is necessary to determine that studies and development related to harmony and the distribution of information will always be conducted simultaneously with research and development and the social implementation of an "autonomous self within in the group," as well as to consider ways to establish and maintain people's individuality and to continue receiving support from the public sector.

■Consideration of measures to disseminate a diverse system of harmony under arbitrary use

→Because technologies that recommend interesting information are more instinctively pleasant than receiving diverse information, measures to disseminate a system of harmonization, under arbitrary use, need to be considered.

(Necessary Initiatives) In addition to striving to build a society in which people can understand that receiving diverse information and acquiring tolerance for different cultures is good for them, it is also necessary to explore ways to achieve practical use in the workplace and in education, among other areas.

[Scientific and Technological Issues]

■Realization of technologies for controlling and matching information distribution that promote mutual understanding to the highest degree

→For problems such as filter bubbles, which provide biased information that each user prefers, there is a need for technology to provide information ensuring diversity.

(Necessary Initiatives) In addition to the distributed representation of networks based on multimodal information, it is necessary to achieve control and matching of information distribution utilizing information of the social network structure, research and development on information compression, and summarization technology to aid in the exchange of enormous amounts of information.

■Realization of technologies to support compromise in the event of a failure to reach consensus

→Technologies to support a compromise have yet to be developed for cases in which the conflict of opinions cannot be solved even if the consensus-building system is utilized.

(Necessary Initiatives) It is necessary to conduct research and development of technologies to support mutual understanding of consensus by visualizing the standpoints of others and presenting common and different parts in an acceptable manner, for agreements or conflicts of opinions that cannot otherwise be resolved.

■Realization of technology to detect and block fake news and incendiary information
→A system to detect and block malicious information and a blockchain system to identify malicious users has yet to be implemented.
(Necessary Initiatives) It is necessary to study and develop technologies that can detect and block malicious information in the group to suppress its propagation, as well as technologies that can clarify the sender and the process of propagation through a block chain system, based on the correct recognition of differences between malicious and negligent users.

2. Science and technology map

In the previous sections, the issues to be overcome through science and technology are “interfaces to support interactions between one’s self and others” at the interpersonal level and “systems to support diverse self-organization of groups” at the group level. This section gives an overview of this idea, categorizes the R&D, and provides details of the initiatives.

(1.1) Interpersonal Level ‘Interfaces that Supports Interactions between Self and Others'

(1.1.1) Self-awareness and Empathy

(Self-awareness as a sender)

■Realization of technology to analyze and visualize one’s psychological attributes and past experiences from data

■Realization of technology to present factors and effects of physical and mental satisfaction based on biological sensing information

■Realization of technology for producing a prediction model of an individual's brain from data based on brain signals and thoughts and behaviors

(Empathy as Receiver)

■Realization of a body-oriented virtual reality and body-sharing technologies that allow users to experience the position of others within a short period of time

■Realization of gamification technology that can train the communication with others

■Realization of technology to visualize whether communication is established in daily interpersonal relationships

(1.1.2) Information Input from Others (Information Supplementation)

■Realization of technology that translates and presents “concepts” including past information, contexts, and cultural backgrounds

■Realization of technology that extends cognitive skills to support and estimation of other people’s emotions and positions

■Realization of cognitive mirroring technology that simulates the world as perceived by others

■Realization of technology to detect, morph, and remove harmful biases, including prejudices and discrimination

(1.1.3) Information Output to Others (Thought Transfer)

■Realization of technologies that enable the reading of higher-order brain information that can also be applied to medical applications (invasive type)

■Realization of a non-invasive technique that reads brain information almost as well as an

invasive type

■Realization of technology to generate temporally dynamic and multi-modal media

■Realization of technologies for decentralized cooperative machine learning and data management to protect and utilize personal privacy information

■Realization of security technology to prevent unintentional malfunction of output

(1.2) Group Level 'Systems that Supports the Diverse Self-organization of the Collective'

(1.2.1) Autonomous Self in the Group

(Autonomous to Group)

■Realization of cognitive acquisition support technologies such as the relativization of one's identity in a group

■Realization of technology to recognize the influence of self and others in a group by calculating and visualizing it

(Autonomous to Technology)

■Realization of a technology that explicitly illustrates agreed-upon stakeholders and information transmission paths

■Realizing training technologies that refine social capabilities to continue using technologies autonomously

(1.2.2) Consensus Building as a Group

■Realization of a technique to extract stakeholders for a consensus that needs to be formed

■Realization of technologies to extract even powerless opinions through next-generation sensing networks

■Realization of technologies for an agreement-building system for appropriate coordination from opinions

■Realization of a blockchain system to prevent the rewriting of opinions and their propagation

■Computing and computational models to solve combinatorial explosions

(1.2.3) Integration and Diversity in the Group

■Realization of technologies for controlling and matching information distributions that achieve the highest promotion of mutual understanding

■Realization of technologies to support a compromise when failing to reach a consensus

■Realization of technology for detecting and blocking malicious information such as fake news and incendiary information

This is an overview of the problems to be overcome through science and technology. If we organize the structure of the cross-disciplinary efforts and the fields and technology groups involved in such R&D, they can be summarized into three main fields and dozens of technology groups: intelligent processing, sensing, and interfaces. In addition, psychology and society are integrally linked with the three fields (Figure 9).

The changes in communications and social systems brought about by such new interfaces and systems are also examined in "Perspectives: Contemporary Social Psychological Communications and Interpersonal Relationships" (Atsushi AIKAWA and Jiro TAKAI) [24]. Rather than making short-term judgments about new science and technology, it is necessary to utilize this document for achieving a good psychology and sociality, while exploring features and mechanisms such as social and non-verbal cues that do not require a difference in quality or physical and temporal sharing.

Therefore, with regard to psychology and sociality, it will not only be important to conduct research and development in science and technology related to the implementation of "Harmony" but also explore it through the integration of humanities and social sciences; in addition, it is expected that humanity and sociology science will be promoted in an integrated manner behind the research and development of all science and technology.

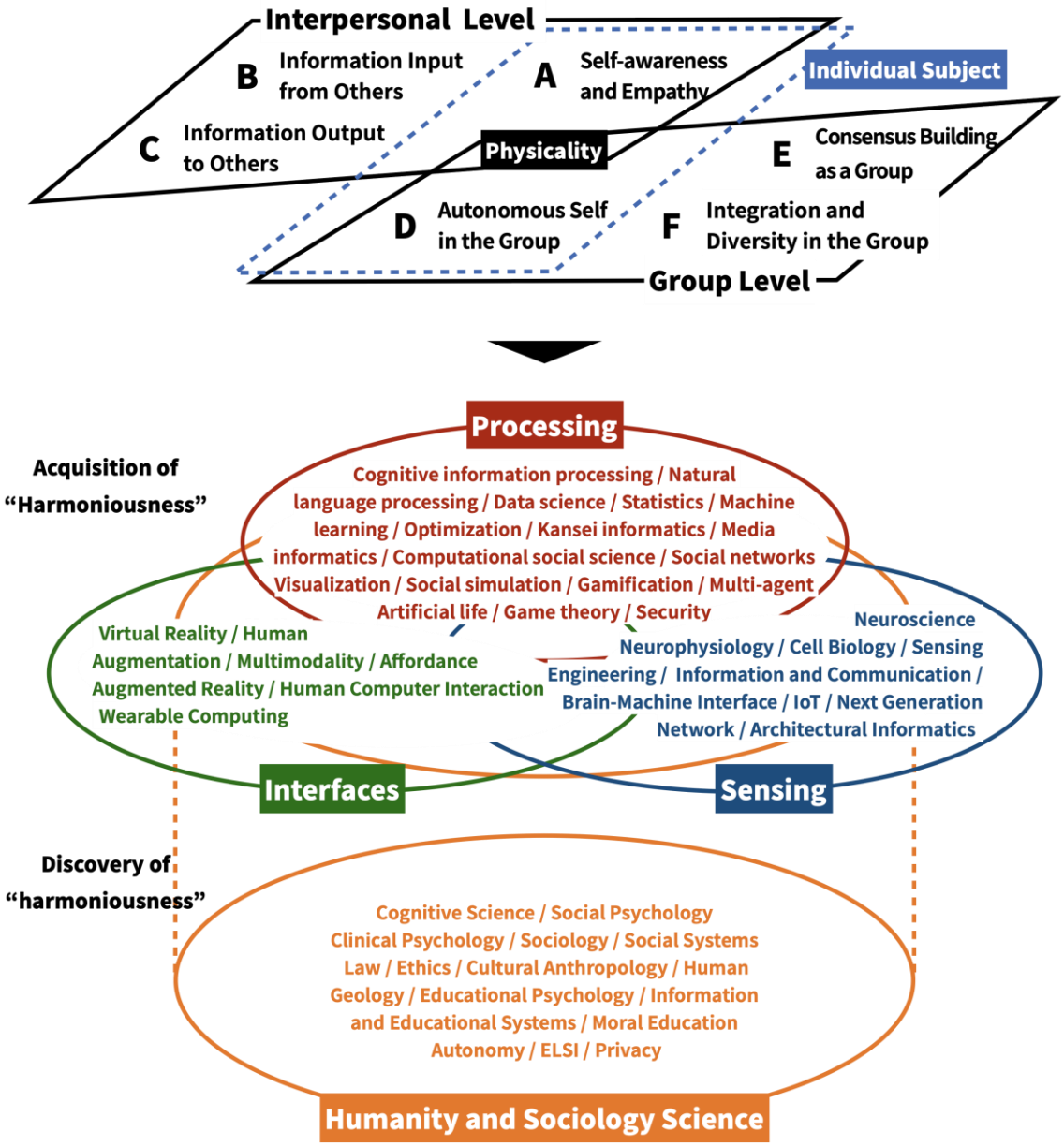

Figure 9 Overview of the MS goal and organization of fields and technology

3. Japan's position in overseas trends

This section introduces the trends of domestic and international R&D related to the MS goal. As for the comparison of the number of papers in each country in the core R&D area, the interpersonal level is shown in Figure 10 and the group level is shown in Figure 11. The top five countries in terms of the number of articles published between 1990 and 2020 were included in the measurement.

The following are the important research and development fields and areas that were identified through the interviews with 100 academics and experts. At the interpersonal level, virtual reality, interactive computer graphics, affective computing and Kansei engineering, human-computer interaction, brain-machine interface, and augmented reality were selected as areas (Fig. 10). For the group level, we selected visualization, artificial life, social simulation, wearable computing, combinatorial optimization, and evolutionary game theory (Fig. 11). For each of these, we compared the number of papers between major countries and Japan (based on Scopus data; search keywords are indicated in the figure).

In the Scopus search for all countries, Japan was ranked within the top five in all of the above 12 R&D areas, indicating that Japan has high potential in implementing the MS goals. In particular, interactive computer graphics was ranked second after the U.S., and Japan has high R&D capabilities in interfaces to enhance self-cognition and empathy, and in the generation of output multimodal media. It ranks first in the number of comprehensive papers on afferent computing and Kansei engineering, and second in the number of comprehensive papers on artificial life, and has been conducting the world's top research and development, especially around 2010.

In the following, we will discuss the domestic and international technological trends that were taken up as noteworthy examples in the 2050 Vision Study Group and the 100 interviews of academics and experts.

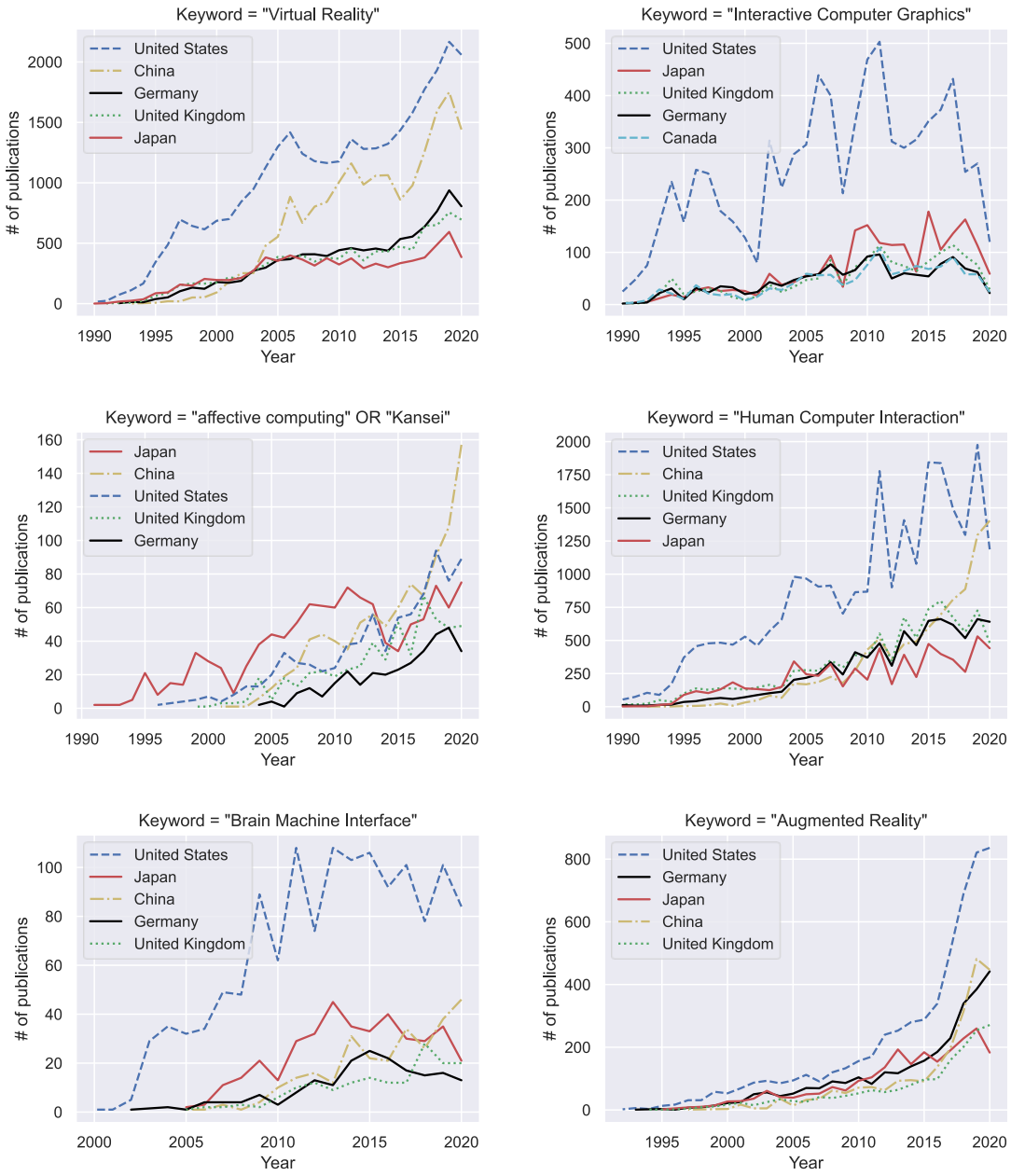

Figure 10 Trends in R&D areas at the interpersonal level (Top 5 countries)

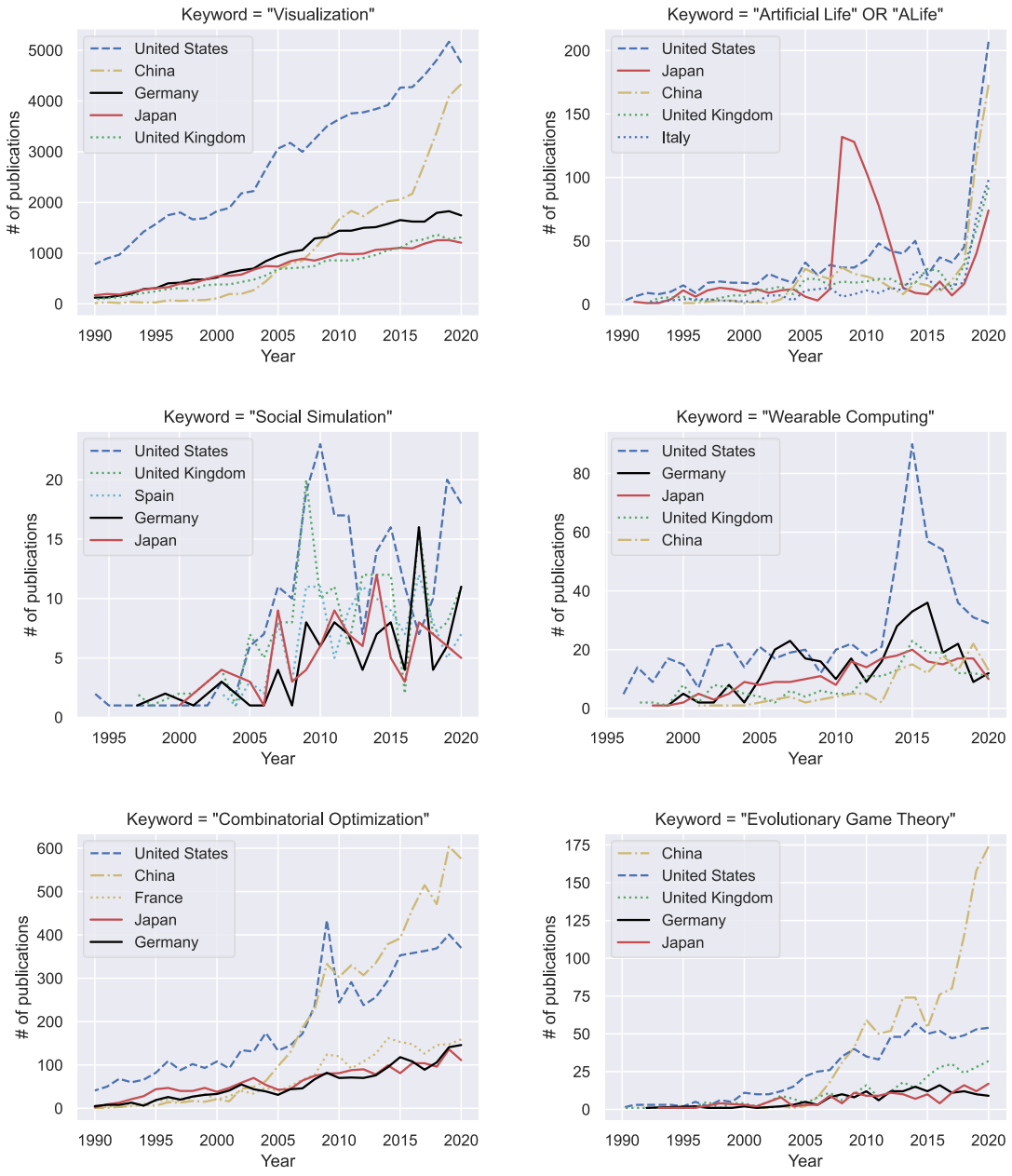

Figure 11 Trends in R&D areas at the group level (Top 5 countries)

■ Proteus effect and immersive virtual reality

The Proteus effect [25] affects the psychology, attitude, and behavior of users when they control avatars in highly immersive online games and virtual reality spaces. In this case, it is necessary that the bodily sensory transfer, which makes the user feel that the avatar is his/her own body, is operating and that the user recognizes the appearance of his/her avatar as seen by others. Research using immersive virtual reality, which reproduces full-body sensations, has also shown that white users wearing avatars of black appearance reduce discriminatory prejudice against blacks [26]. The development of such an experience may also help enhance the ability to empathize with others.

■Shared Body Avatar and Body Sharing

In Japan, research on shared-body avatars and body sharing is being actively conducted. A system was developed using body tracking and head-mounted displays in which two people can jointly control an avatar whose movements are averaged over the movements of two users [27]. With this shared body, it is known that the movement of reaching out to a random position is smoother than when a single person operates. Research on sharing the body with others from the level of sensory organs, "PossessedHand," which controls the movement of fingers by providing electrical stimulation, such as the signal of one user's muscle movement to another user's arm muscles, has been researched in Japan [28]. H2L Corporation was established to conduct research, develop, and socially implement assistive tools using this core technology.

■Social Virtual Reality platform and virtual SNS.

Immersive virtual reality (VR) platforms that use body tracking and head-mounted displays have already been realized, such as "VRChat", a social VR platform in the U.S., and "cluster", a virtual SNS in Japan [29]. This system allows users to communicate through avatars using desktop PCs and VR devices, and to experience 3DCG spaces (worlds) posted by the users themselves, to build a metaverse that will allow even economic activities in the virtual space. Japan is one of the countries with many users of these platforms, and "Virtual Shibuya," a distribution platform authorized by Shibuya Ward, was opened on the cluster, enabling the holding of events and interactions under the influence of the new coronavirus infection [30].

■Affective Computing

The field of "affective computing" was proposed to allow computers to infer and express human emotions and to support users based on those emotions [31]. In the field of affective computing, R&D are being conducted to infer the user's emotions through sensing and

analysis of images, videos, and audio, as well as various other information [32]. A wide range of applied research is also being conducted, such as the prevention of suicide and depression in people under severe stress, and the provision of tools that can support patients with autism. Kansei Engineering is a similar field and keyword in Japan, and interdisciplinary R&D are being conducted to sense, analyze, and apply Kansei and emotions.

■Invasive brain-machine interface (BMI)

In the R&D of an invasive brain-machine interface (BMI) that implants a small chip in the brain, the efforts of Neuralink in the United States are the best known. The goal is to enable paralyzed patients to operate computers quickly and easily using their brain neural activity. Experiments have already been conducted to predict the game behavior of monkeys with electrodes implanted in their heads based on their brain waves and to enable patients who have lost the ability to speak to communicate the words and images that come to mind by simply reminding them [33]. In Japan, research on invasive BMI is also being conducted under the Moonshot Goal 1 of the Moonshot-type R&D project, "Liberation from Physical Constraints by Expanding Physical and Perceptual Capabilities."

■Decoding brain information and non-invasive BMI

With regard to research on decoding brain information, research by a team at Kyoto University has attracted worldwide attention, including research on the ability to predict the perception of stimulus orientation from brain activity measured by functional magnetic resonance imaging (fMRI) [34], and research on decoding of brain information of images during sleep [35]. Additionally, as a non-invasive BMI, a patch-type electroencephalograph using ultra-thin electronic materials has been developed in Japan (Institute of Industrial Science, Osaka University and PGV Co., Ltd.), and has been applied to the determination of dementia and sleep quality by learning and analyzing big data of measured EEG [36]. In the future, it is expected that R&D will be conducted to learn pairs of detailed brain activity data from fMRI or high channel information obtained from invasive BMI and non-invasive BMI.

■Machine translation and multimodal caption generation

Regarding machine translation, the development of deep learning in natural language processing (NLP) has improved translation accuracy, and services such as DeepL translation and Google Translate have been put to practical use [37]. However, cultural anthropologists and other experts have pointed out that to understand the people of countries and regions with different cultures, it is necessary to have background knowledge (geographical, historical, political, demographic, etc.) and to recognize concepts that cannot be expressed using

stereotypes. Therefore, even if only the language is translated, there is a possibility that mutual understanding will not be achieved. Therefore, it is hoped that research on multimodal caption generation, such as generating text from images and images from text, will be conducted along with translation [38], and that technology will be able to translate "concepts" such as the background and culture of others.

■Transformer model

In recent years, remarkable progress has been made in the R&D of deep learning. The transformer model announced by Google contributed to the improvement in the performance of machine translation [39]. By introducing an attention mechanism, the transformer model eliminates the need for sequential processing of time-series data and has advantages such as a shorter training time. Especially in NLP, it has rewritten the entire scene of the use of recursive and convolutional neural networks. In NLP, the use of recursive neural networks and convolutional neural networks has changed. Because transformer models can be processed in parallel and trained using large-scale data, applications such as BERT and Open AI GPT-3, which are pre-trained using unlabeled data to obtain highly versatile language models, are known [40].

■Deep generative models and their applications

The best-known generative model based on deep learning is the generative adversarial network (GAN) [41]. The output of a generative network that generates the output from the input is trained together with a discriminative network that determines whether the output is close to the correct data. This enables the generation of highly accurate data, which is impossible with conventional generative models. In recent years, "StackGAN" has been proposed to train a combination of a first-stage GAN that outputs a low-resolution image from a text and a second-stage GAN that repairs the deficiencies of the low-resolution output image and makes it high-resolution, making it possible to generate realistic images from text [42].

■Use and protection of personal data

When constructing large-scale machine learning (ML) systems using personal data, the issues are thorough informed consent in a form that allows users to understand and protect personal information. In recent years, the EU's General Data Protection Regulation (GDPR) and the data free-with-flow discussed at G20 Japan 2019 are well known, but in both cases, the trade-off between protecting personal data and training useful models is significant. The trade-off between protecting personal data and training useful models becomes an issue [43]. In recent years, distributed cooperative ML and federated learning have been studied to

achieve both goals [44]. In this system, personal data are stored only on the user's device, and only the learned parameters are sent to the server.

■Fairness and impartiality in artificial intelligence

When training ML models or building systems using data from the real world, problems have been identified, such as bias in the process of recording data in the real world in the first place and the reproduction of discrimination when existing social structures are reflected in the data. How to deal with bias in data and how to protect minorities who do not appear in the data in the first place are issues to be addressed. Regarding gender, UNESCO has published a report on artificial intelligence and gender equality [45]. There is also the issue of the digital divide with poor and less developed countries that cannot participate in the collection of such data and, by extension, do not have the economic power to use learned models and various tools.

■Consensus-building support systems

A research team at Kyoto University, known internationally for its research on multi-agent systems, has announced a SaaS service for consensus building and opinion aggregation called D-Agree. D-Agree visualizes the consensus structure of discussions and intervenes with questions by agents [46]. Overseas, the digital platform "Decidim" is widely used in Europe, especially in the city of Barcelona, Spain. More than 40,000 people have participated, more than 10,000 proposals have been made, and approximately 1,500 have been adopted as policies. Demonstration experiments have been conducted in Yokohama City and other cities [47]. In the future, it is expected that the system will not only aggregate opinions posted on explicit issues, but also extract implicit opinions and select stakeholder groups.

■Computational Social Sciences

Since the publication of "Computational Social Science" in Science, the field of computational social science, which promotes the use of data in social science and makes use of the knowledge of computer science, has been established [48]. In 2021, the Association for Computational Social Science, formerly the group for computational social science, was established. Among the studies that have attracted attention in this field are methods for detecting malicious posts and fake news, and social simulation using agent-based models. In Japan, an effort is being made to simulate echo chambers by mapping speech spaces using textual information [49].

III. Plan for Realization

1. Area and field of challenging R&D, research subject for realization of the Goals

In this chapter, we describe the design of challenging R&D and the research tasks under the proposed MS goal, based on the two achievement scenes described in the concept of the proposed MS goal, the scientific and technological issues extracted and organized by statistical and bird's-eye analysis, and the efforts to address them.

(1) Areas and fields to promote challenging R&D.

The R&D related to the MS goal is organized into two achievement scenes and six aspects (areas), but the science and technology in each area are closely related to each other and require interdisciplinary efforts rather than independent R&D. For this reason, the three fields of intelligent processing, sensing, and interfaces, as well as the fields of psychology and sociality, which are inextricably linked to the fields, were established to organize the fields in which challenging R&D should be promoted. The science and technology in these fields are completely connected to the six areas, and the research tasks in each area will be promoted with reference to the development and expansion of the fields.

Two Achievement Scenes and Six Aspects of R&D (Domains)

Interpersonal Level ‘Interfaces that Supports Interactions between Self and Others'

By 2050, we will be able to recognize and update ourselves, as well as to have a deep mutual understanding of thoughts and feelings between ourselves and others.

A. Self-awareness and Empathy (self-awareness as sender + empathic ability as a receiver)

B. Information Input from Others (Information Supplementation)

C. Information Output to Others (Thought Transfer)

Group Level ‘Systems that Supports the Diverse Self-organization of the Collective’

By 2050, we will be able to maintain our autonomous selves in groups while engaging in diverse reconciliation and co-creation of values.

D. Autonomous Self in the Group (autonomy for groups + autonomy for technology)

E. Consensus Building as a Group

F. Integration and Diversity in the Group

(2) Research subject for the realization of MS goals

Based on the scientific and technological issues and efforts to address them, the following research subjects are envisioned for 2050, corresponding to R&D areas A through F (Figure 12).

Interpersonal Level 'Interfaces that Supports Interactions between Self and Others'

A. Self-awareness and Empathy (self-awareness as sender + empathic ability as a receiver)

A1: R&D of science and technology to deepen self-awareness by presenting a bird's eye view of one's psychological characteristics, with the factors and effects of physical and mental fulfillment.

A2 and (B2): R&D of science and technology to enhance empathy for others by experiencing the position of others through gamification with physicalizing and body sharing in a short time.

B. Information Input from Others (Information Supplementation)

B1: R&D of science and technology that extracts styles such as cultural backgrounds from big data platforms and translates and presents "concepts" as supplementary information.

B2: R&D of science and technology for sensory augmentation to assist in guessing the emotions and positions of others, and for mirroring the world as perceived by others.

B3 and (F2): R&D of science and technology to detect harmful information, including prejudice and discrimination, and to morph and remove it at the interface of the real world.

C. Information Output to Others (Thought Transfer)

C1: R&D of science and technology that can read out complex brain information through secure invasive or highly accurate non-invasive brain-machine interfaces.

C2: R&D of science and technology that can generate complex thoughts and emotions as multimodal media while ensuring the privacy of personal data.

Group Level 'Systems that Supports the Diverse Self-organization of the Collective'

D. Autonomous Self in the Group (autonomy for groups + autonomy for technology)

D1: R&D of science and technology that assists in extracting and recognizing the identities of self and others, as well as in simulating and experiencing influence.

D2: R&D of science and technology that explicitly shows the calculation process of consensus to be formed and the transmission path of information to be propagated, which assists people in making independent choices.

E. Consensus Building as a Group

E1: R&D of science and technology to extract even powerless opinions using next-generation sensing networks, and to select stakeholders for the consensus to be formed.

E2: R&D of science and technology for coordinating and proposing diverse opinions through computing and model building to develop a combinatorial explosion.

F. Integration and Diversity in the Group

F1: R&D of science and technology to enable the distribution of information that ensures the greatest diversity and matching that promotes mutual understanding, and to support the compromise of conflicting opinions.

F2: R&D of science and technology to detect and block malicious information, such as fake news and incendiary intentions, by understanding the distribution channels of information.

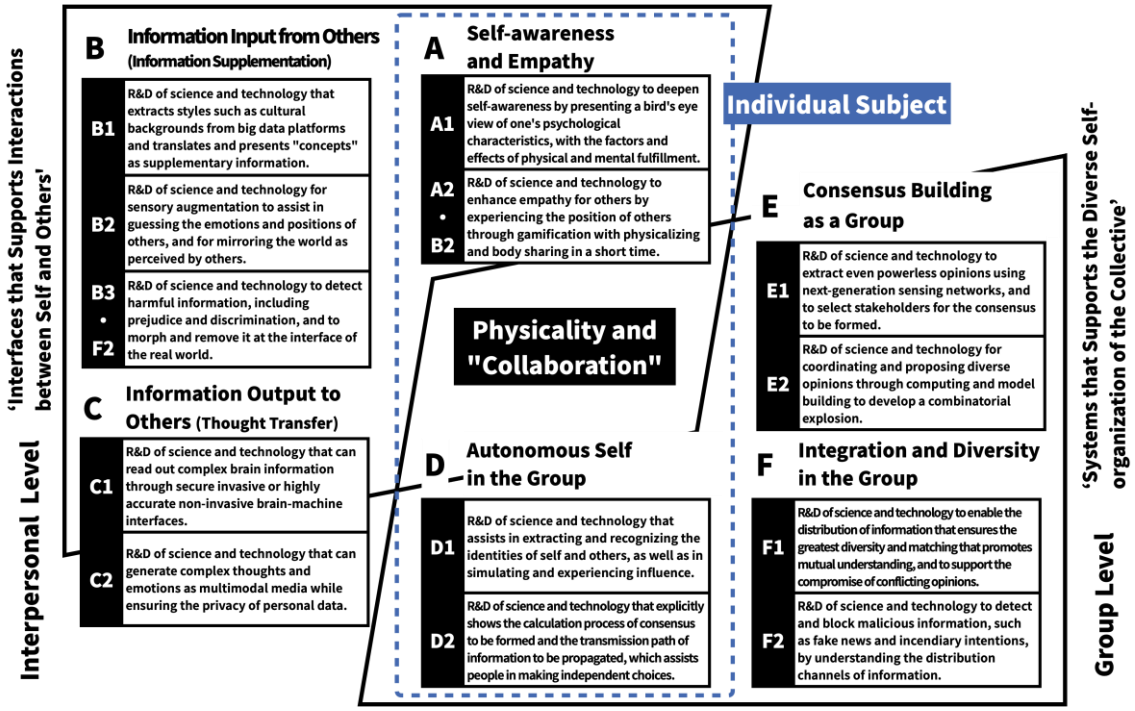

Figure 12 Overview of Research and Development Areas and Research Issues

2. Direction of R&D for realization of goals

This section describes the specific goals (milestones) to be achieved during the period from 2030 to 2050 and specific R&D themes to be addressed to achieve milestones for the two achievement scenes and the six areas and research topics from A to F mentioned above. The economic and industrial ripple effects that the achievement of these milestones will have on society will also be described.

The details of the achievement scenes, changes in social and industrial structures, and efforts related to the R&D themes in each era are described in achievement acenes of the MS goals (I.2), changes in social and industrial structures resulting from the achievement of the goals (I.4), and challenges to achieve the scientific, technological, and social issues and necessary actions to achieve MS goals (II.1).

2.1 Achievement scene in 2050 (moonshot target)

■Milestones in 2050

In 2050, the following will be achieved for all human beings in the world:

- All milestones (A to F) achieved in the 2040 milestones described below.
- Achievement of "harmony" between individual and collective perspectives, and transformation of all social and economic structures, including the provision of educational and employment opportunities, elimination of the uneven distribution of knowledge, and co-creation of a new sense of values that replaces the money economy (social significance of achieving the goal (I.3.2)).

However, the relevant MS goals do not encompass the specific philosophy and history that we will choose for 2050, but provide a foundation for us to choose the future we want for each era.

■R&D themes for 2050

- All research themes from A to F in the fields and areas of challenging R&D and research themes (1).

2.2 Scenes of achievement in 2040

■Milestones in 2040

In 2040, the following milestones were achieved in many countries worldwide.

- All milestones (A to F) were achieved in the 2030 milestones described below.
- All interface users have been able to spend their lives realizing their way of happiness while renewing themselves in interaction with others (A1 and D1).
- In both real and virtual spaces, regardless of nationality, communication is possible through various media and expressions, with a mutual understanding of multiple languages and contexts (A2, B1, B2, and B3).
- The user can make autonomous choices regarding all options presented by the system (D1 and D2).
- The consensus-building system can be used not only within a specific organization or group but also in situations other than explicit problem solving (E1 and E2).

→It is possible to select stakeholders for a consensus to be formed and propose its use.

→Next-generation sensing networks that can extract implicit opinions have been realized.

→Computation is possible even for large populations with more than 150 users.

- The company has been able to maintain an autonomous self for the group, while interfaces and systems are widely used (D1).
- The principle of diversity is introduced in all existing information distribution platforms, including big tech companies, and the problems of filter bubbles and echo chambers are eliminated (D1, F1, and F2).

■R&D themes for 2040 (example).

- Development of the scope and accuracy of the R&D themes for 2030 described below (A-F).
- Research on the acquisition of data on the brain's neural systems related to the factors and effects of physical and mental satisfaction and the elucidation of brain functions related to happiness (A1)
- Research on the safe and efficient collection and modeling of individual brain signals and behavior data to understand common human models and individuality (A1).
- Research on VR/AR interfaces for inferring one's behavior from the perspective of others (mirror-image observation of self) (A1).
- Research on a system that can simulate communication with agents that have learned the behavior of others (A2).
- Research on a learning model that can translate concepts such as the context in a style that is appropriate to the situation, and present various lines of text in a complementary manner

(B1).

- Research on technology that allows users to use information autonomously, but complete and convert harmful information before they are exposed to it (B3).
- Research on BMI with new measurement methods such as ultrasonic echo devices and nanorobot blood flow concentration measurement (C1).
- Research on security to prevent unintended malfunction of output in media generation from BMI (C2).
- Research on a distributed cooperative ML system that can store privacy-related data only on the user side and learn it with edge AI (C2).
- Research on modeling the decision-making process (etiquette) in society, and research on systems that comply with laws and regulations regarding the protection of personal information (C2).
- Research on the simulation and presentation of decision-making using agent-based models (D1).
- Research on a system that allows users to experience the propagation of decision-making and its effects in a group (D1).
- Research on a system that explicitly outputs and presents the computation process of a group of systems in the MS target (D2).
- Research on extracting the stakeholders involved in a problem that multiple users are aware of based on various information sources (E1).
- Research to model individual and group objective functions and to perform direct optimization calculations of objective functions with multiple variables (E1).
- Research on the mechanism of social reward systems in the human brain and its application to the design of social systems (E1).
- Research on technology for detecting malicious rewriting of opinions and their propagation, while ensuring the reliability and traceability of users (E2).
- Research on implementing systems that can cope with the development of computers, including quantum computers (E2)
- Research on information compression and summarization techniques to aid in the exchange of large amounts of information (F1).
- Research on technology that can reveal the sender and process of propagation in a blockchain system linked to the sender's information (F2).

2.3 Scenes of achievement in 2030

■Milestones in 2030

In 2030, the following will be achieved mainly in developed countries, including Japan.

- Understand what they are good at, what they like, and what their happiness should be (A1).
- The ability to seek necessary help in times of distress and prevent depression and suicide, even in situations where one is not aware of based on one's subjective perception alone (A1)
- The ability to communicate in a real space eliminates incomprehension of language and context (B1 and B3).
- The ability to empathize with others is enhanced, and mutual understanding and compassion are realized in families, communities, and organizations to which they belong (A2, B2, and B3).
- The time required for meetings, sales, and creative communication inside and outside the organization has been reduced, and mutual understanding and work efficiency have been improved (B1, C1, and C2).
- Smartphones and other widely used devices provide a choice of output technologies as new tools to accompany emojis and stamps (C1 and C2).
- All service providers, from restaurants to hospitals, can understand the wishes and medical conditions of service recipients and strive to avoid making service recipients uncomfortable with little effort (A2, B1, C1, and C2).
- Able to communicate in detail when providing and receiving care, and able to engage in social activities on an ongoing basis (B1, B2, C1, and C2).
- They can make autonomous choices about technology by recognizing the impact of visualized technology (D2).
- The consensus-building system is useful in the operation of a specific local government or community, or within a specific company or organization (E1 and E2).

→They can involve many stakeholders and connect ideas, capital, and labor.

→Make decisions and build consensus through fair meetings that can reflect powerless opinions.

→Preventing the loss of wealth owing to excessive competition that would otherwise be avoided.

- Newly created information distribution platforms for the public will eliminate the problems of filter bubbles and echo chambers (D1 and F1).
- Information distribution platforms will be introduced as a tool to promote diversity considerations and understanding of different cultures in companies and educational institutions (F1 and F2).

■R&D themes for 2030 (example)

- Research to analyze, visualize, and present psychological attributes by efficiently collecting and securely managing data on individual personalities, attributes, and abilities (A1).
- Research to collect and analyze data related to a person's internal state to information that appears in measurable physical characteristics and biological response data (A1).
- Research on VR with an embodiment, which enables us to simulate the life of another person in a short time (A2).
- Research on body sharing that enables us to stand in the shoes of others by sharing our somatic senses (A2).
- Research on technology to enhance communication skills by presenting the state of daily interaction with others (A2).
- Research on safe and efficient collection and storage of information about each user's background on each device and network (B1).
- Research on the extension of visual and auditory sensing to present information seen and heard together with text (B2).
- Research on affective computing to comprehensively sense facial expressions and emotions, and analyze and present them in a form that is easy to recognize (B2).
- Research on the measurement and quantification of the relationship between the body and the environment to enable objective observation of the cognitive process from sensation to movement (B2).
- Research on the interface that enables us to experience the cognitive process of others (cognitive mirroring) (B2).
- Research on data collection, classification, and detection of bias, including slander, prejudice, and discrimination (B3).
- Research on an invasive brain-machine interface that embeds a small chip with external power and wireless connectivity (C1).
- Construction of ML models based on paired data of non-invasive patch electroencephalography and invasive measurement data (C1).
- Research on the interactive generation of multimodal media using five senses, including video, audio, and touch (C2).
- Research on edge AI and edge computing to enable distributed learning and behavior (C1) (C2).
- Research on extracting and presenting the identity and the relative position of the self and others in a group (D1).
- Research on training technology that detects social bias toward other people and different groups, and then presents it in a contrasting manner (D1).

- Research on technologies to support the ability to choose opt-in or opt-out in various systems (D2).
- Research on ability to use opt-in/opt-out without complications (D2).
- Research on sensing networks that combine complex sensing systems, materials and devices, ubiquitous computing, Wi-Fi, 5G, and 6G communications (E1).
- Research on systems for extracting user opinions from various sensed information sources (E1).
- Research on consensus-building support using agent-based models that behave based on objective functions, and research on fair division theory systems (E1).
- Research on mathematical models of computable consensus-building systems, variable group size, and approximation of consensus-building systems (E2).
- Research on the distributed representation of networks based on multimodal information, and research on control and matching of information distribution using information on social network structures (F1).
- Research on technologies to support compromise by visualizing opinions and presenting common and different parts in abstract form (F1).
- Research on technologies for detecting and blocking malicious information in a group and suppressing its propagation by correctly recognizing the differences between users' intentions and negligence (F2).

2.4 Ripple effects of achieving the milestones on society

In this section, we will discuss the ripple effects on society of achieving the aforementioned milestones for the years 2030 to 2050.

In the 2030 milestone, we examined various social and economic impacts, but here we will focus on the prevention of depression and suicide, and the expected improvement of business operations by reducing the time required for communication to carry out business operations in organizations, including corporations. The effect on the Japanese economy will be estimated.

Regarding the prevention of depression, since it is estimated that about 53% of suicides in any age group are due to depression [50], it is assumed that the prevention of depression alone can prevent about half of all suicides. In this case, the estimated socioeconomic loss caused by suicide due to depression in 2030 would be approximately 1.3-2.1 trillion yen [51]. If the MS target technology alleviates depression and has the effect of reducing the number of suicides due to depression by half, then this socioeconomic loss can be expected to be halved.

In addition, in Japan, where labor productivity is low compared to other Organization for

Economic Co-operation and Development (OECD) countries, the effect of reducing the work time required for communication would be significant. It is said that if creative communication among diverse human resources is promoted, at least a 1-3% increase in earnings can be expected [52]. Thus, technologies that promote diversity and cross-cultural understanding could have a ripple effect of 3 to 8.5 trillion yen.

As these six technologies are integrated into society and the economy, we can expect to see further increases in added value in companies through 2050. According to estimates from the ESG assessment of diversity by the Japan Research Institute (JRI), value added is expected to increase by 8-15% from 2030 due to continued progress in diversity considerations and mutual understanding, and the ability to seize opportunities to create added value. If the total value added in Japan in 2016 is 289.535 trillion yen [53] and the estimate for 2020 is about 331 trillion yen, about 26 to 49 trillion yen of value added in the private sector will be created just by the expected increase in value added to the estimated amount for 2020. Even if the discount rate of 15% applied in the social impact assessment is applied, it is estimated to be between 22 and 42 trillion yen.

However, we have also discussed the possibility that we in 2050, having achieved harmonization, may have outgrown the current monetary economy (Chapter I (3.3) Social Implications of Achieving the Goals). Alternatively, we may have adopted a partially different economic system, and it may not even be appropriate to estimate it in monetary terms as an economic ripple effect. As just one example, we will make a rough estimation assuming that the six technologies are incorporated into an economic infrastructure that is equivalent to infrastructures such as electricity and water supply, without which economic activities and daily life would not be possible. If we assume that the economic and industrial effects are equivalent to those of water supply infrastructure, we can estimate that the economic and industrial ripple effects will be at least 300 trillion yen [54]. This is an estimate that does not include the additional economic benefits that will be generated by the economic infrastructure.

3. International cooperation

To achieve the MS target goals, it is crucial that researchers (innovators) in Japan and abroad; who understand the social vision of the MS goals, and share in its vision, lead its research and development. However, as recognized in domestic and overseas R&D trends, the MS goals do not consist solely of fields in which Japan has strengths. Therefore, it will be necessary that researchers take interest and participate globally. Considering that fundamental technologies exist; but without a vision to capture them in an integrated manner, the possibility of joint research is expected to expand via the formulation and implementation of a vision that is nonexistent.

First, domestic and international researchers should not only devote partial effort to research, but also ensure high R&D capacity by recruiting young PIs from worldwide and creating research institutes and centers for the relevant MS goals. In establishing a framework that facilitates the joint research, and the global participation of researchers, it is likely to encourage global participation by disseminating interim research results at the World Expo 2025 Japan EXPO 2025 Osaka, Kansai, Japan), and making presentations at several international conferences. More concrete measures to encourage joint research include: inviting overseas researchers to lodge at domestic universities during their sabbatical year (research holidays and overseas studies), and holding summer schools in Japan for students and the younger generation.]

Further, international collaboration, along with joint research is necessary. For example, utilizing the internet can promote competition for disposable time, its premise for individual optimization, and the configuration of filter bubbles. This is fundamental in maximizing the display time for advertisements in a capitalist society, and in increasing purchase motivation. However, it is necessary to collaborate with major platforms globally, to form an ideal society to address these issues. In cooperation with the United Nations and the World Economic Forum, it is feasible to set targets for harmonization, that are equivalent to the SDGs.

4. Interdisciplinary cooperation

To achieve the MS goals, it is necessary to take initiatives from various perspectives as described above; hence, the following are introduced: The proposal of a consortium in which the industry, academia, government, and private sectors work together; setting up a framework for advocating the comprehensive declarations, rules and visions; establishing moonshot R&D project connecting underlying technologies across various fields.

First, all industry-academia stakeholders in charge of promoting research and development, should thoroughly consider the ideal social implementation that the technology may cause. Users have the right to know what kind of societies they wish to live in, the most advanced technologies, and choose their own future. Legislative, judicial and administrative bodies should carefully and sufficiently examine, and respond to the rules that encourage such social implementation in anticipation of technological development. These stakeholders will form a nonprofit consortium, and play a proactive role in implementing ethical, legal and social issues, and their solutions in addressing the goals described below. In addition, the direction of R&D should be revised on a daily basis, to appropriately face constantly updated social issues.

Further, as noted above, the technologies encompassed by the MS Goals should be adaptable to a variety of industries and maintain co-creative relationships with industries such as education, healthcare, media, information, communications, and social networking services. Instead of disrupting an industry through innovation or dominating new industries by creating start-ups, all industries and enterprises should take the initiative in implementing the technical direction of the MS goals, and the innovations created in society. Therefore, it is important to provide neutral consortiums (or possibly several) for the industry's stakeholders, from big tech companies and major vendors to start-ups.

In addition to initiatives such as these consortiums, support from the public sector is also indispensable. Rather than following up on the R&D, it is necessary to examine the consistency with existing systems, and carry out regulatory reforms while running parallel with its state-of-the-art research and development. In these processes, researchers are also expected to approach politics through research groups and councils, and clarify issues through extensive discussions in consortiums. Funding and institutional support from the public sector is also required for initiatives such as proof-of-concept and living robots, which are difficult to generate profit on their own, but are indispensable for clarifying the ideal way of social implementation.

Finally, in order to integrate the underlying technologies across a wide range of fields; from intelligent processing, sensing, and interfaces, to psychology and sociality under a single R&D goal, it is necessary to construct a program unique to the Moonshot R&D project. In addition, it will not "integrate" technologies spanning diverse fields under the banner of a Moonshot

R&D project, but rather form a "comprehensive" intellectual foundation. Although, the ideal way of R&D across such diverse fields is described in other sections, it is necessary to clarify the concept of discovery and implementation of "harmonization"; and to attract the attention of a wide range of researchers through the aforementioned consortium, while working toward the realization of the MS goal.

5. ELSI (Ethical, Legal, Social Issues)

Regarding social issues, this study describes the "interfaces to support interaction between self and others" at the level of interpersonal relations, and "systems that support diverse self-organization of groups" at the group level. This section summarizes the overview and solutions; and the details of the initiatives are introduced in the above section of issues (scientific and technological issues) in achieving MS Goals.

Interpersonal Level 'Interfaces that Supports Interactions between Self and Others'

A. Self-awareness and Empathy

■Consideration of situations where technologies that enhance self-awareness and empathy are utilized, as well as their introduction into education

■Considering the possibility that supporting self-recognition may infringe upon constitutional rights

B. Information Input from Others (Information Supplementation)

■Study the possibility of expanding disparities if technology is spread as an expensive tool

■Considering the information recipient's right to refuse seeing what they do not wish to

■Considering the risk of inconsistency between the conveyer and recipient

C. Information Output to Others (Thought Transfer)

■Considering the ability and right to control the output media

■Considering the responsibilities of the output media

Group Level 'Systems that Supports the Diverse Self-organization of the Collective'

D. Autonomous Self in the Group

■Considerations and measures to complicate the users choice of various systems

■Consideration of situations in which technologies that support individual autonomy for groups are utilized

E. Consensus Building as a Group

■Examination of "Killer Applications" that realize the voluntary dissemination of consensus-building systems, and their Usage Situations
■Examination of the gap between the willingness to participate in consensus building, and the sensing of personal data
■Measures to address the possibility of sympathetic pressures, and coercing participation in the consensus-building system
■Measures against problems that may cause the production of results that differ from those of national systems, including democracy

F. Integration and Diversity in the Group

■Discussion on maintaining personalities and identities in harmony
■Considering measures to disseminate a diversified system of harmonization, while making its use voluntary

The overview of the ethical, legal and social issues was described above. This section summarizes the society's overall initiatives and solutions to these issues.

At the interpersonal level, the following measures are required: Legal measures on the right and responsibility of the use of interfaces, examining instances of their use, taking measures regarding the decline in the ability of understanding and expression, owing to the spread of interfaces, and measures to equalize opportunities for the use of the interface.

In the use of interfaces, it is necessary to examine the idea of shrinking freedoms of the mind from a constitutional law perspective, as we sense and analyze information from our inner thoughts and feelings. In addition, it is necessary to examine in detail; the state of rights, actual rules and technical responses in situations where there is conflict with the information about oneself, that one wishes to convey to others in output, and the information that others want to know as input. Legal review and legislative arrangements are required for liability of unintended outputs, such as confidentiality and slander.

In addition, as the interfaces supporting inputs and outputs become universal, the ability to express complex thinking by making full use of those technologies, and the ability to understand one's partner through the information properly received, may be attenuated depending on the characteristics of the user, and the generation of information. It is important to proceed with social implementation, while carefully considering the situations where such interfaces are adopted. Medium-and long-term impacts should also be considered, countermeasures taken, and in some cases, educational measures should be promoted. Regarding the opportunities for the use of such interfaces, it is necessary to examine the

possibility that opportunities may vary owing to high cost of the devices, which may lead to increased disparities in communication and negotiation skills, and to study the rules by the industry-government.

At the group level, it is necessary to examine and take counter measures regarding usage scenarios related to personal data and privacy, the balance between convenience and autonomy, proposal of a killer application; recommending its voluntary and voluntary use, and countermeasures to avoid peer pressure.

Regarding the system which supports the autonomous self for the group, the data of the individual will be utilized in order to catch the identity of self and others. It is necessary to thoroughly implement privacy measures, and informed consent for the collection and utilization of this data.

Further, If the system is designed to propose a second or third option for use; in order to ensure the autonomous self with respect to the technology, the choice may become complicated, and greatly impair convenience. One can also consider that nudging users towards uniform choices, rather than forcibly moving towards choices will deprive them of autonomy; hence, it is necessary to continue examining and take on counter measures towards the social implementation of these systems. It is expected that the technology that realize user autonomy created by the MS goal, will verify, update, and develop principles related to AI R&D, such as the Cabinet Office's "Principles for a Human-centric AI Society", and the International Council's "23 Asilomar AI Principles".

It is noted that users' voluntary and involuntary use is recommended as a prerequisite for the social implementation of consolidation systems with consensus formation and diversity. With such a premise, the key is how to design a global killer app or such incentives that will be utilized by everyone. This will not just require industry-academia collaboration, but also extensive consideration and advocacy between industry, academia, government and the private sector. Regarding harmony, there is also room to examine how much support can be provided to its introduction in situations ranging from the workplace to education.

However, even if the consensus-building system tends to make beneficial proposals for that population, it is important to avoid the peer pressure that forces individuals to participate in consensus-building. Therefore, various measures should be taken against it, and in some cases, declarations at the local and national levels are required. In addition, it is important to constantly discuss how legislation, justice, and administrative agencies will respond to various systems.

First, regarding "self-perception and sympathy capabilities", and "autonomous self-reliance in the group," it is necessary to proceed with careful discussions in a consortium that

comprises of a variety of stakeholders of industry, academia, government, and private sectors; because there is a possibility of sensing, or engaging in information on the inner surface of the entity (an individual). This is not limited to research and development set by the MS goals, but also technologies that have the potential to affect one's mind; hence, it is important that the aforementioned considerations and responses are carried out prior to the implementation of this technology by future-oriented stakeholders participating in the consortium, rather than chasing after those technologies as in the past and taking ethical, legal, and social responses to them.

IV. Conclusion

1. Conclusion

Our team conducted research to clarify the vision of society in 2050 when "harmony for humankind" will be realized, and examined what kind of research and development and social implementation will be needed to realize this vision. While analyzing technological and social trends in Japan and abroad, we have worked to clarify a social vision of 2050; identify the scientific, technological, and social problems; and formulate the R&D and targets based on such information.

Through the survey and research process described below, it was concluded that it is feasible to realize a state in which people respect and understand each other's individuality and abilities in interpersonal relationships, understand others without damaging their wellbeing, co-create values in the group, and distribute resources fairly. This is because, in 2050, interfaces that support interpersonal interaction by enhancing self-perception and deepening the levels of mutual understanding, such as thoughts and feelings, and a system supporting self-organization of diverse groups will enable diversified harmony and coexistence of values while maintaining an autonomous self. This research revealed that the discovery and implementation of "harmony" in diverse fields including intelligent processing, sensing, interface, psychology, and sociality will enable the research and development of such sciences and technologies as well as their social implementation.

Through the "Moonshot" target proposed above, we can acquire "harmony," i.e., an existence as an "individual" and an existence as a "whole," and by 2050, realize a society where everyone is happy as autonomous individuals, but also in harmony as a collective.

2. Process of this Research

This study was carried out and formulated through the "Harmony for Humankind" investigation team based on science and technology, which was adopted in the Moonshot R&D Multifaceted investigation challenge for new normal initiatives program". The study team aimed at development in 2050 and focused on generations that will be living during the 22nd Century, and conducted the investigation and research while ensuring a position that broadly reflects gender, diverse fields and identities, and the perspectives of industry, academia, government, and the private sector. The following is a description of the details of the study.

2.1 2050 Vision Study Group

In the survey research, investigation teams were organized into a leader and sub-leader, in various fields such as artificial intelligence, virtual reality, complex science, art, law, and science fiction. In addition to the study by researchers and diverse members including entrepreneurs and artists, a co-creation with SF writers was clarified through discussions with 100 academics and experts based on research and development themes, trends, and feasibility studies. These discussions were held between 19:00 to 20:00 on Mondays every week as the "2050 Vision Review Meeting."

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2.2 Science Fiction Realization Project

We asked science fiction writers Katsuie SHIBATA and Itsuki TSUKUI to participate in the Science Fiction Concept Realization. We asked them to write a science fiction plot about the social vision of 2050 that we wanted to clarify through this research, describing assumed scenes of achievement and R&D. With only fragmentary scenes of achievement and science and technology ideas, it is not possible to depict a coherent storyline, nor is it possible to capture scientific, technological, and social issues from a proactive perspective. Thus, the vision study group was held using an SF plot as a source for discussion, which was clarified

through the participation of science fiction writers, and interviews were conducted with 100 scholars and experts. Proactively participating in the discussion as if we were characters in an SF plot, through this research we were able to clarify the social vision and identify the scientific, technological, and social issues at a concrete level.

In addition, the interim results of the study were shared with the two authors intermittently so they could reflect the contents of the research in advancing their writing from the SF plot to an SF novel. The relationship of co-creation between the research reports and SF novels is a new form of SF prototyping created by the research team [55].

Katsuie SHIBATA's "Fortune Prediction" is a series of stories of people in the future, where advanced sensing and quantum computer predictions and optimizations have enabled people to reach their predicted fates and live smoothly with each other. The stories include a boy meeting a girl who changes his predicted unfortunate fate, an artist who resists the forecast while doubting his popularity, and a professional shogi player who finds enjoyment in a game by taking a panoramic view of the forecast and accepting it. Some feedback from these stories includes the scientific and technical challenge of chaos when recalculations are applied when people change their behavior depending on the prediction, and the concern of the danger in which many people will lose their autonomy when they become happy to follow such a forecast. This was helpful when examining the scenes of achievement, and also triggered the addition of "Autonomous Self within the Group" to the Moonshot targets.

By contrast, the short story "Pax Circularis," written by Itsuki TSUKUI, describes the coming-of-age process of children who have been implanted experimentally with an always-connected telepathic technology in their brains. It describes the suffering of the characters owing to the fact that even their unexpected thoughts will be transmitted if they are not careful, and because of the secrets that the experimental subjects, who are scattered around the world, are actually hiding, culminating in the prevention of a conflict as they come of age and begin working. Here, we asked the author to try a thought experiment of continuous connection and abstract information transmission, based on the suggestion that simple telepathy may already be realized by smartphones and the Internet. This story raised many social issues, and we received feedback that, in addition to science and technology, sharing ideals with each other was ultimately important. This led to adding "self-awareness and empathy" to the Moonshot target, which touches on the inside world of the user, and also triggered research from a philosophical and ethical perspective.

Of the novels, Shibata's consensus-building and harmonization system was written for interpersonal relations, whereas Tsukui's telepathy was written for groups. This was the opposite of what the investigation team had assumed, using consensus formation and harmony systems for the group, and a telepathy interface in the interpersonal relation. By

developing the story under the opposite situation, we were able to come up with the core idea that became the Moonshot target, which is that interpersonal relations and the groups are not at an independent level, but instead there is an "individual subject" with physicality where the interpersonal- and group-levels interact. As described above, the Science Fiction Realization Project provided many important hints and triggers for interviews with 100 academics and experts in this research area, and it was possible have a co-creative relationship in which the results of a survey study, such as through interviews, were useful as feedback for writing and re-interpreting and examining the work.

In a conference during which Japanese and international science fiction writers predicted the world a hundred years from now, discussions included technologies to support mutual understanding, such as telepathy to resolve misunderstandings, doubts, hostility, and a society that is always online. In mature societies, it is believed that people will be able to understand the efforts of the group, and that the discussion of this social vision and awareness of issues with it is consistent with the vision of science and technology and social implementation tackled by this study [56].

2.3 Interviews with 100 Academics and Experts

To collect a wide range of opinions on the feasibility of this social vision, research and development, and its trends for the formulation of this research report, we conducted interviews with more than 100 academic and experts with specialized knowledge and experience in each field (the affiliations as of the time of the interview are given in alphabetical order). The team leader attended all interviews, and the sub-leader also attended almost all interviews. Rather than conducting interviews with the same question items in parallel, a serial survey was conducted, updating the contents of the survey research for each interview.

In academia, we conducted interviews with researchers in various fields including humanities and social sciences, focusing on researchers in the fields of science, engineering, and information technology. We received opinions from a wide range of researchers, from experienced researchers engaged in research and development at universities and national laboratories for several decades, Nobel prize winners and college presidents, to young researchers promoting new research and development on their own. In industry we interviewed many executives, including several former representative directors, from a wide range of industries, including major telecommunication companies, manufacturers (e.g., electrical machinery, analysis and measurement, air conditioning equipment, electrical and electronic components, semiconductors, and chemical products), general construction companies, advertising agencies, general trading companies, and educational and publishing companies, mainly on social implementations.

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2.4 Symposiums and Workshops

In the formulation of this research report, we hosted and co-hosted symposiums and workshops as described below, and also gave lectures at conferences and symposiums sponsored by economic organizations and newspaper companies, seminars for the 2025 Japan World Expo, and major companies, and received feedback through detailed discussions with the participants.

In addition, we presented at the symposium "Technology to support human wellbeing through cross disciplinary fusion research" sponsored by "An ultra-diverse society that builds good relationships regardless of age, gender, or nationality, and leaves no one alone" (Team leader, Shima Okada) at the 60th annual meeting of the Japanese Society for Biomedical Engineering.

■Sakuma-GaJuku, Future Thinking Society
"Turning Fiction into Reality: Harmony"
[Date and time] March 21, 2021 (Sunday) 14:00 to 17:00
[Location] Online via Zoom
[Number of participants] Approximately 20, including university teachers and students.

■Programs for junior and senior high school students
SpringX Super School & Moonshot R&D Project Millennium Program
Investigation Team for "Harmony of Humankind" through science and technology
"Thinking about Society in 2050 with Gen-Z researchers"
[Date and time] May 29, 2021 (Saturday) 15:00 to 17:00
[Location] Online using Zoom

[Number of participants] Approximately 30 junior and senior high school students

■Tobitate! (Leap for Tomorrow) Study Abroad Initiative Learning Platform
"Prediction for 2050 Created with 100 Experts"
[Date and time] June 15, 2021 (Tuesday) 19:30 to 21:30
[Location] Online through Zoom
[Number of participants] Approximately 60 scholarship students from Tobitate! (Leap for Tomorrow) Study Abroad Initiative

■Online Press Seminar
Challenges for Gen-Z: Visualizing the Society in 2050 through Sci-Fi and Realizing it through Science and Technology
Presentation of research for realization of "Harmony for Humankind"
[Date and time] June 18, 2021 (Friday) 11:30 to 12:30
[Location] Online through Zoom
[Number of participants] Approximately 20 press members

■Moon-Shot R&D Project Millennium Program & Knowledge Capital
2050 Roadmap Drawn by Young Researchers
Symposium on "Harmony for Humankind" through Science and Technology
[Date and time] June 26, 2021 19:00 to 21:00
[Location] Hosted online using YouTube Live
[Number of participants] Approximately 500 persons from the general public

V. References（参考文献）

[1] 西田幾多郎, 西田幾多郎論文選 意識と意志, 書肆心水, 2012.

[2] 戸田山和久, 唐沢かおり, 橋本剛明, 鈴木貴之, 渡辺匠, 太田紘史, 遠藤由美 , 島村修平, 〈概念工学〉宣言！ 哲学×心理学による知のエンジニアリング, 名古屋大学出版会, 2019.

[3] 金子邦彦, 生命とは何か 第 2 版, 東京大学出版会, 2009.

[4] 清水博, 〈いのち〉の自己組織 共に生きていく原理に向かって, 東京大学出版会, 2016.

[5] 深田博己, インターパーソナル・コミュニケーション 対人コミュニケーションの心理学, 北大路書房, 1998.

[6] 唐沢かおり, 社会的認知 現状と展望, ナカニシヤ出版, 2020.

[7] ラファエル・A・カルヴォ , ドリアン・ピーターズ, ウェルビーイングの設計論 人がよりよく生きるための情報技術, ビー・エヌ・エヌ新社, 2017.

[8] ジェレミー・ベイレンソン, VR は脳をどう変えるか？ 仮想現実の心理学, 文藝春秋, 2018.

[9] 長井志江, "認知ミラーリング―認知過程の自己理解と社会的共有による発達障害者支援," *生体の科学,* vol. 69, no. 1, pp. 63-67, 2018.

[10] 横幹〈知の統合〉シリーズ編集委員会, 社会シミュレーション 世界を「見える化」する, 東京電機大学出版局, 2017.

[11] ニコラス・クリスタキス, ブループリント 「よい未来」を築くための進化論と人類史, ニューズピックス, 2020.

[12] 岡嶋裕史, 思考からの逃走, 日経 BP 日本経済新聞出版本部, 2021.

[13] 楊保華 , 陳昌, ブロックチェーン 理論と実践, マイナビ出版, 2021.

[14] 鳥海不二夫, 計算社会科学入門, 丸善出版, 2021.

[15] ロイス・ローリー, ギヴァー 記憶を注ぐ者, 新評論, 2010.

[16] オルダス・ハクスリー, すばらしい新世界〔新訳版〕, 早川書房, 2017.

[17] アーサー・C・クラーク, 幼年期の終り, 早川書房, 1979.

[18] 伊藤計劃, ハーモニー〔新版〕, 早川書房, 2014.

[19] 庵野秀明, 監督, *エヴァンゲリヲン新劇場版.* [録画物]. カラー, 2007.

[20] オリバー・ラケット , マイケル・ケーシー, ソーシャルメディアの生態系, 東洋経済新報社, 2019.

[21] 斎藤幸平, 人新世の「資本論」, 集英社, 2020.

[22] 渡邊淳司, ドミニク・チェン, 安藤英由樹, 坂倉杏介 , 村田藍子, わたしたちのウェルビーイングをつくりあうために その思想、実践、技術, ビー・エヌ・エヌ新社, 2020.

[23] 馬田隆明, 未来を実装する テクノロジーで社会を変革する 4 つの原則, 英治出版, 2021.

[24] 相川充 , 高井次郎, 展望現代の社会心理学 2 コミュニケーションと対人関係, 誠信書房, 2010.

[25] N. Yee and J. Bailenson, "The Proteus effect: The effect of transformed self-representation on behavior," *Human communication research,* vol. 33, no. 3, pp. 271-290, 2007.

[26] T. C. Peck, S. Seinfeld, S. M. Aglioti and M. Slater, "Putting yourself in the skin of a black avatar reduces implicit racial bias," *Consciousness and cognition,* vol. 22, no. 3, pp. 779-787, 2013.

[27] T. Hagiwara, G. Ganesh, M. Sugimoto, M. Inami and M. Kitazaki, "Individuals Prioritize the Reach Straightness and Hand Jerk of a Shared Avatar over Their Own," *Iscience,* vol. 23, no. 12, p. 101732, 2020.

[28] E. Tamaki, T. Miyaki and J. Rekimoto, "PossessedHand: techniques for controlling human hands using electrical muscles stimuli," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2011.

[29] 株式会社往来, 未来ビジネス図解 仮想空間と VR, エムディエヌコーポレーション, 2021.

[30] "バーチャル渋谷 | バーチャル SNS cluster（クラスター）," [Online]. Available: https://cluster.mu/w/79347fb9-05f5-429e-ab5f-8951ee8cd966. [Accessed 6 7 2021].

[31] R. W. Picard, Affective computing, MIT press, 2000.

[32] S. Poria, E. Cambria, R. Bajpai and A. Hussain, "A review of affective computing: From unimodal analysis to multimodal fusion," *Information Fusion,* vol. 37, pp. 98-125, 2017.

[33] "The first fully-implanted 1000+ channel brain-machine interface - Neuralink," [Online]. Available: https://neuralink.com/blog/. [Accessed 6 7 2021].

[34] Y. Kamitani and F. Tong, "Decoding the visual and subjective contents of the human brain," *Nature neuroscience,* vol. 8, no. 5, pp. 679-685, 2005.

[35] T. Horikawa, M. Tamaki, Y. Miyawaki and Y. Kamitani, "Neural decoding of visual imagery during sleep," *Science,* vol. 340, no. 6132, pp. 639-642, 2013.

[36] "PGV 株式会社," [Online]. Available: https://www.pgv.co.jp. [Accessed 7 6 2021].

[37] "DeepL Translate: The world's most accurate translator," [Online]. Available:

https://www.deepl.com/. [Accessed 6 7 2021].

[38] S. Uppal, S. Bhagat, D. Hazarika, N. Majumdar, S. Poria, R. Zimmermann , A. Zadeh, “Multimodal Research in Vision and Language: A Review of Current and Emerging Trends,” *arXiv preprint arXiv:2010.09522,* 2020.

[39] M. Jaderberg, K. Simonyan, A. Zisserman and others, "Spatial transformer networks," *Advances in neural information processing systems,* vol. 28, pp. 2017-2025, 2015.

[40] T. B. Brown, B. Mann, N. Ryder, M. Subbiah, J. Kaplan, P. Dhariwal, A. Neelakantan, P. Shyam, G. Sastry, A. Askell and others, "Language models are few-shot learners," *arXiv preprint arXiv:2005.14165,* 2020.

[41] I. Goodfellow, J. Pouget-Abadie, M. Mirza, B. Xu, D. Warde-Farley, S. Ozair, A. Courville and Y. Bengio, "Generative adversarial nets," *Advances in neural information processing systems,* vol. 27, 2014.

[42] H. Zhang, T. Xu, H. Li, S. Zhang, X. Wang, X. Huang and D. N. Metaxas, "Stackgan: Text to photo-realistic image synthesis with stacked generative adversarial networks," in *Proceedings of the IEEE international conference on computer vision*, 2017.

[43] "General Data Protection Regulation (GDPR) Compliance Guidelines," [Online]. Available: https://gdpr.eu. [Accessed 6 7 2021].

[44] T. Li, A. K. Sahu, A. Talwalkar and V. Smith, "Federated learning: Challenges, methods, and future directions," *IEEE Signal Processing Magazine,* vol. 37, no. 3, pp. 50-60.

[45] UNESCO, "Artificial Intelligence and Gender Equality," 2020.

[46] T. Ito, S. Suzuki, N. Yamaguchi, T. Nishida, K. Hiraishi and K. Yoshino, "D-Agree: Crowd Discussion Support System Based on Automated Facilitation Agent," in *Proceedings of the AAAI Conference on Artificial Intelligence*, 2020.

[47] "Decidim," [Online]. Available: https://decidim.org. [Accessed 6 7 2021].

[48] D. Lazer, A. Pentland, L. Adamic, S. Aral, A.-L. Barabasi, D. Brewer, N. Christakis, N. Contractor, J. Fowler, M. Gutmann and others, "Social science. Computational social science.," *Science (New York, NY),* vol. 323, no. 5915, pp. 721-723, 2009.

[49] "言論マッププロジェクト 東北大学 乾・岡崎研究室," [Online]. Available: http://www.cl.ecei.tohoku.ac.jp/stmap/. [Accessed 6 7 2021].

[50] 佐渡充洋, "うつ病による社会的損失はど゛の程度になるのか？ーうつ病の疾病費用研究ー," *精神神経学雑誌,* vol. 116, no. 2, pp. 107-115, 2014.

[51] 厚生労働省, "患者調査," [Online]. Available: https://www.mhlw.go.jp/toukei/list/10-20.html. [Accessed 6 7 2021].

[52] R. Lorenzo and M. Reeves, "How and where diversity drives financial performance," *Harvard Business Review,* vol. 30, pp. 1-5, 2018.

[53] 総務省統計局, "平成 28 年経済センサス－活動調査," [Online]. Available: https://www.stat.go.jp/data/e-census/2016/index.html. [Accessed 6 7 2021].

[54] "第 21 回原子力委員会定例会議（参考事例）世界の水ビジネス展開の動向," [Online]. Available: http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2010/siryo21/siryo1-2.pdf.

[55] 宮本道人, 難波優輝 , 大澤博隆, ＳＦプロトタイピング ＳＦからイノベーションを生み出す新戦略, 早川書房, 2021.

[56] 株式会社フジテレビジョン , 早川書房編集部, 世界ＳＦ作家会議, 早川書房, 2021.