Moonshot Goal 3: PD Guidelines for PM Additional Applications

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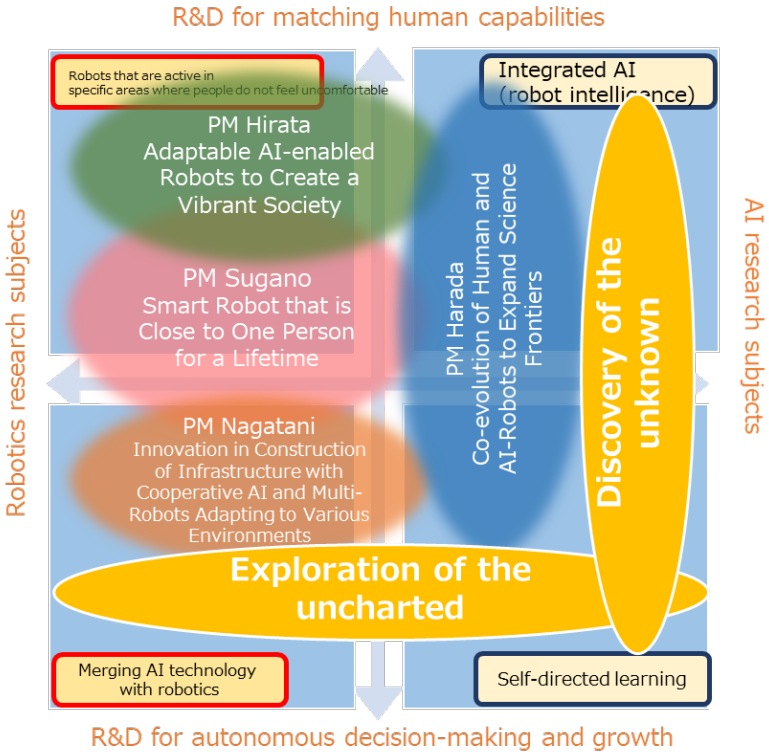
1. Overview of R&D program for achieving the Moonshot Goal

As the birthrate declines and the population ages, it is important to be able to utilize robots in all aspects of society, including work in dangerous and labor-intensive fields, development of frontiers for humanity, and support for daily life. A key point is to realize robots that can learn and act on their own through the co-evolution of AI and robots. In this research and development (R&D) program, we will promote R&D toward the realization of AI robots that combine the advanced physicality of robots with the self-evolving learning of AI.

2. Portfolio and status of initiatives

(1) Portfolio



In this diagram, the Horizontal Axis represents the main axis of each R&D project for AI robotics research, and the Vertical Axis, the spatial distance between humans and AI robots (wearable, supportive/assistive, tele-operated, and autonomous operation).

This R&D program sets these two axes and manages a portfolio of four R&D projects to cover all quadrants and realize the co-evolution of human, AI, and robot technologies.

(2) Status of current initiatives

To realize robots that can learn and act on their own and coexist with people through the co-evolution of AI and robots, we are promoting the development of (1) AI robots that people do not feel uncomfortable with, that have physical capabilities equal to or greater than those of humans, and that grow together with people as they accompany them through life (PM Shigeki Sugano, PM Yasuhisa Hirata); (2) AI robot systems that think and act on their own in the field of natural science and automatically aim to discover scientific principles and solutions (PM Kanako Harada); and (3) AI robots that make autonomous decisions and act and grow on their own in environments where it is difficult for people to work (PM Keiji Nagatani).

(3) Current research and development issues for achieving the goal

One year has passed since the start of the R&D program, and based on the status of existing R&D projects and recent overseas trends, it is important to continue the relevant work in the R&D domains of “exploration of the uncharted” and “discovery of the unknown” in our portfolio, to achieve Moonshot Goal 3.

The following is a list of specific issues that need to be addressed in each domain.

① AI robots to expand the sphere of human activity in environments where it is difficult for humans to work (“exploration of the uncharted” domain)

In this R&D program, we aim to build a new environment-adaptive AI robot technology that can recognize and make decisions based on its own interaction with its surroundings in “environments where human activities are difficult to sustain.”

Regarding such interactions with the environment, we are currently targeting natural disaster sites. However, to gain applicability to a wider range of applications, we need to consider, for example, environments in vacuums where it is difficult for people to enter, and extreme environments, such as space, where effective

communication is difficult.

The technical issues that need to be solved include AI robotics technology for adapting to unknown environments; collaborative robots with autonomous, distributed, and cooperative force operations; robust system technology that can self-repair and reconfigure; and smart technology for Material space structures.

② "Discovery of human knowledge" through co-evolution of humans and AI robots and "scientific discovery" through human-centered, human-participatory AI systems ("discovering the unknown" domain)

The targets of this R&D program are "AI robot systems that can think and act on their own and automatically discover scientific principles and solutions in the field of natural science," and "AI robots that people do not feel uncomfortable with, that have physical capabilities equal to or greater than those of humans, and that grow together with people by accompanying them through their lives," in addition to "AI to make robots smarter (intelligent robots)," we aim to develop "Robots for Advancing Human Intelligence," which will enable the co-evolution of humans and robots, by building advanced AI technologies that aim to improve human intelligence and promote human behavioral change.

However, to build advanced AI technology, we would need to undertake research and develop "AI that can infer hypotheses for new scientific discoveries," "AI that can promote new awareness," and "AI that can promote better choices and actions," although we are also currently working on the development of AI for scientific experiments, mainly targeting animals and plants, as well as for physical assistance, housework, and medical assistance.

Technical issues to be resolved include concept acquisition (including acquisition of language and action) based on human knowledge and experience, intention estimation (including semantic understanding) based on human behavior, speech, biometric information, and large-scale and comprehensive hypothesis reasoning (including hypothesis generation and exploration) that accounts for human blind spots.

3. R&D themes and their requirements in the application

(1) AI robot technology for building a base of operations in space

This R&D theme calls for R&D projects focusing on innovative AI robotics technologies that can efficiently construct a base (habitation module, infrastructure such as communication and energy supply, food production factory, and etc.) in the extreme environment of the lunar surface.

By 2050, the goal is to be able to build a lunar city that will give rise to a new civilization on the lunar surface through the collaboration and co-evolution of multiple AI robots and the robotization and intelligence of Material space structures. Achieving this goal will require the emergence of smart cooperative robot swarms and intelligent and robotized infrastructure for acquiring efficient lunar base construction technology by 2030.

For example, in consideration of future activities in the lunar environment, we expect to tackle the following research topics, and conduct on-site demonstration experiments at the end of the R&D project to show the approach to acquiring innovative AI robotics technology for the establishment of a lunar base. Through such efforts, the technology developed through this R&D program is expected to make a significant contribution to international space exploration, such as the Artemis program of NASA.

The following are examples of research topics:

- In consideration of the cost of space transportation, develop multiple small and lightweight multifunctional mobile AI robots, equip them to adapt to the environment, build distributed cooperative intelligence, and realize cooperative tasks, such as carrying and assembling heavy objects through the collaboration of multiple robots
- As repair of robots in space would be highly challenging, development of self-repair and reconfiguration functions to resolve failures, and realize robust collaborative work for infrastructure construction
- Realization of robotic and intelligent structures for building large-scale infrastructure by automatically deploying, autonomously moving, and merging compact structures on the lunar surface in consideration of being mounted on a lander
- For supporting the activities of AI robots in unknown environments, a power generation tower robot that automatically deploys and extends solar panels to

supply power efficiently, and a mobile relay tower robot that secures a communication environment to enable a wide range of activities

For the promotion of R&D after the adoption of the project, we expect collaboration with existing R&D projects (PM Kenji Nagatani, etc.) and other organizations in Japan and overseas for dynamic collaborative AI, growth-type AI robots, and self-modifying robot technology.

(2) AI technology to induce ideas, inspiration, and behavior change in people

This R&D theme calls for R&D projects on "awareness AI technology" to generate ideas and inspiration that lead to scientific discoveries and improved cognitive abilities, or to induce behavior change that increase the motivation of each individual.

By 2050, we aim to develop AI technologies that can provide as feedback knowledge and information obtained by AI robots to people through collaboration and co-evolution between people and AI robots. We also aim to promote awareness of important features and meaningful behavior change. Data informatization and visualization technologies are considered necessary for the smooth communication between humans and AI robots by 2030.

In consideration of the future automation of scientific research, we expect to formulate scientific principles and solutions through human-participatory AI systems, and to show the way to the amplification of humans' own intelligence through "awareness AI technology."

Specifically, we seek proposals for R&D in one or both of the following areas, aiming to develop a new AI that integrates knowledge from the humanities and social sciences as well as the human sciences, and includes not only human functions but also sence of values.

① AI that generates ideas and inspiration

To provide AI with awareness beyond human cognitive abilities, we aim to develop AI that can infer hypotheses beyond the thinking tendencies and cognitive biases formed by the knowledge and experience previously acquired by each individual.

The examples of technologies in the following non-exhaustive list are expected to

be necessary to achieve the above.

- AI technology that observes unexpected events to acquire new knowledge, constructs new hypotheses to explain the events, evaluates the validity of the new hypotheses and existing knowledge, and predicts the results of the new hypotheses
- AI technology that visualizes "latent information" that enables humans to determine correlations and causal relations between data in a vast amount of sensing data, experimental data, and papers, or that amplifies human intellectual capabilities in a highly efficient manner

② AI that induces behavior change
Realization of AI that triggers active motivation by analyzing and clarifying the extrinsic and intrinsic factors that cause, increase, maintain, and decrease the motivation of each individual, to change human behavior

The examples of technologies in the following non-exhaustive list are expected to be necessary to achieve the above.

- AI technology that promotes spontaneous behavioral change by visualizing ideal future scenarios, motivating recommendations, and nudge systems that eliminate anxiety and hesitation with respect to new goals
- AI technology that automatically measures behavioral patterns, habits, and daily behavior to avoid risks in each individual's living environment and health condition, and to sustain a favorable physical, mental, and social health condition such that people can live each day with energy and joy

In promoting this R&D program, we expect to collaborate with existing R&D projects, such as AI integrating science exploration and robot autonomy (PM Kanako Harada), AI for learning to improve self-efficacy (PM Yasuhisa Hirata), and emotional communication (PM Shigeki Sugano).

(Reference)
- Moonshot Goal 3 website
  https://www.jst.go.jp/moonshot/en/program/goal3/
- Moonshot Goal 1&3 Kickoff Symposium (held March 28, 2021)
  https://www.jst.go.jp/moonshot/news/20210328.html

・Moonshot International Symposium for Goal 1 and Goal 3 (held March 27-28, 2021)
https://www.jst.go.jp/moonshot/en/news/20210327.html
・JAXA Space Exploration Innovation Hub Website
https://www.ihub-tansa.jaxa.jp/english/
・JAXA International Space Exploration Project Website
https://humans-in-space.jaxa.jp/en/

(Reference) PD's Supplement in FY2020 PM Application

PD: Dr. FUKUDA, Toshio (Professor, Meijo University)

1. Policy for Selection and Proposal content

(1) Policy for Selection

Please submit a proposal of a scenario for the set MS Goal, "Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050." Including both the concept of "forecasting" that predicts the future from current society and technology, and the concept of "backcasting" that suggests what to do now considering 2050 society as a reference point, the proposal should contain an outlook for 3 years, 5 years and 10 years after PM selection, and an outlook for 2050. Please elaborate on feasibility in terms of achieving the MS Goal by 2050, implementing and adapting to society, being challenging and innovative, and integrating ELSI considerations for societal acceptance.

(2) Proposal content

① Thoughts on co-evolution of AI and robots

As indicated in the R&D concept, our aim is to fuse AI technology and robot technology so that they can co-evolve.

For this reason, please present issues for both AI technology and robot technology and propose efficient solutions for co-evolving them.

In addition, the proposal should address the co-evolution of AI and robots from the following two viewpoints in addition to the conventional viewpoint.

[Viewpoints]

- ✓ (AI technology and robot technology cooperate to improve their own performance)
- ✓ (AI technology and robot technology self-modify their own knowledge and functions to adapt to the environment, etc.)

②Regarding the proposal.

To achieve the MS Goal, I am considering R&D subjects 1, 2, 3 as follows. Proposals can be based on one R&D subject, but I will also accept content that

spans multiple subjects. While the below points describe example achievements of each R&D subject by 2030, proposals need not be limited to this, and I would like to welcome challenging and innovative ideas. Furthermore, I hope that the generality will become wider depending on the time, such as 2030, 2040, and 2050. As indicated in the R&D concept, the AI technology developed in subject 2) should be used to realize AI robots in subject 1) and 3).

1) AI robots that humans feel comfortable with, have physical abilities equivalent to or greater than humans, and grow in harmony with human life.

[Example accomplishments.]

In a specially prepared environment (without auxiliary sensors, markers, etc.), an AI robot that will be able to serve customers while communicating with people in stores, for example, will be realized. Based on information obtained from the five-sensory sensors equipped on the robot, we will achieve a technology that can learn and memorize human behavior patterns and understand human gestures and the meaning of facial expressions by image processing. By performing AI processing on this information, in a given environment, the created AI robot will intelligently interact and perform conversations and actions that do not cause feelings of unease in its human partner. By 2050, AI robots will be able to “grow” by advancing their knowledge structures to the next level through intelligent interaction with the environment and humans.

2) An automated AI robot system that aims to discover impactful scientific principles and solutions, by thinking and acting in the field of natural science.

[Example accomplishments.]

In the future, in a wide range of fields from natural sciences to humanities to social sciences, AI robots will intelligently construct their own experiments (planning) and autonomously perform a small number of experiments (trials) to find laws and rules (evaluation). In the process of developing, we will realize an AI robot that can discover scientific principles and solutions for specific problems given by humans (such as the development of new drugs and materials) by 2030.

(A) The AI robot formulates a hypothesis and an experiment plan for

verification from a vast amount of past papers and experimental data. (B) A human constructs a complex experimental system according to the experimental plan, and the AI robot performs a simplified experiment (preferably, the AI robot also constructs the experimental system). (C) We obtain and analyze experimental results, verify hypotheses, and establish further hypotheses.

By repeating the loop from (A) to (C) above, the AI robot does not simply support the 'parameter search' of the experiment, but also constructs and interprets the experiment and model itself, and has the intellectual capacity to continue the experiment and identify the 'structure of the issue' to solve the problem efficiently.

3) AI robots that autonomously make judgements and act in environments where it is difficult for humans to act.

[Example accomplishments.]

The development of AI robots that, on level ground and in calm conditions where weather and other factors do not change suddenly, autonomously perform construction work, agricultural work, logging work, or work in outer space that is difficult to remotely control. By 2050, the AI robots intelligently interact with the environment and other robots and humans to advance their knowledge structures to a higher level and quickly and safely plan and execute work in a dynamic environment. By 2030, the AI robots will decide their behavior by judging their surroundings and accurately predicting what will happen as a result of their motion. Instead of simple automation, multiple units cooperate to learn how to work. Through this learning, we will realize AI technology that can configure more efficient work procedures by itself.

2. Policy for promoting R&D

(1) Portfolio management

Taking into account the relationship between multiple R&D projects, portfolio management requires collaboration and competition between PMs. Therefore, for the period after being selected as a PM, the milestones to be achieved 3, 5 and

10 years from the time of being selected will be made clear, and a review of the progress and budget plan shall be conducted in consultation with the PD.

(2) International collaboration

In order to develop AI robots efficiently and promptly, I hope to keep consistent track of R&D trends in Japan and overseas, and if necessary conduct active R&D cooperation with overseas organizations.

(3) Industry – academia collaboration

We expect the progress of R&D to have beneficial ripple effects on industry. For this reason, we expect to build a cooperative system that will encourage the participation of industry groups in R&D projects.

(4) ELSI (Ethical, Legal, and Social Issues)

In the next 30 years until 2050, we expect the structure of society to change significantly. To ensure societal acceptance, some development issues may need to be handled delicately. We therefore encourage the participation of researchers investigating ethical, legal, and social issues related to AI technology, including robot technology.

(5) Collaboration and/or competition with other MS Goals and projects

Regarding AI technology and robot technology, there may be common R&D issues with other MS Goals. In this case, collaboration and competition with other R&D projects may be encouraged during the program.