R&D Item

1． Body and control system for smart robots

Progress until FY2024

1. Outline of the project

Current robot hardware is extremely hard and heavy because it emphasizes its accuracy and durability (rigidity). Therefore, for example, it is not possible to essentially clear safety issues for supporting people in daily life, such as customer service, housework, welfare, nursing, and medical care. To solve the above problem, by making the robot hardware, including its constituent parts, skin, joints, etc., essentially “soft”, while having the power to support the whole body of a person, we design and manufacture a robot body that has arms, mobile mechanism and hands that can use various tools, with passive flexibility that does not harm humans even if it collides. Specifically, we develop dry/wet hybrid smart robots with self-repairing and maintenance functions by circulating bodily fluids such as oils, coolants and lubricants that can coexist with humans, in addition to flexible joints, flexible skin, magnetic fluid actuators, and high-precision tactile sensors.

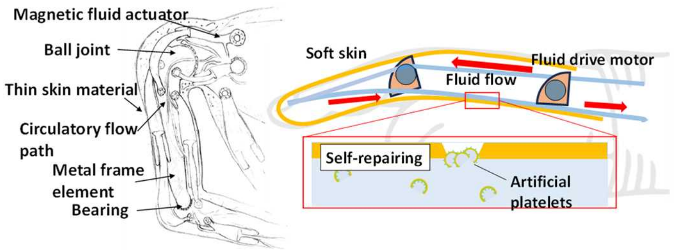


Fig. 1 Wet robot mechanism without gaps and concept of self-repairing function

2. Outcome so far

Sub theme 1: Soft robot hardware that can physically support humans with contact

We conducted various experiments on tasks involving physical contact with humans using the world's highest level human-friendly robot (Dry-AIREC). Furthermore, we conducted the following R&D to realize a new dry/wet hybrid smart robot that resembles the human body.

- By introducing semantic information based on the concept of the object, the robot can handle unknown object shapes and background environments. By using depth information, we have achieved reliable putting-on socks motions. (Fig.2).

Fig.2 Putting-on socks motion by Dry-AIREC

- We developed hardware for a robot system (upper body) using a rotary fluid actuator with a total of 18 degrees of freedom, and conducted an experiment to lift a heavy object (Fig. 3).

- We developed a four-fingered fluid-driven robot hand (total of 14 degrees of freedom) and conducted an experiment to crush an empty can(Fig. 4).

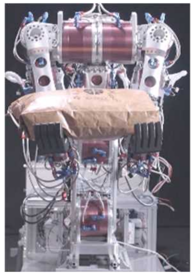


Fig.3 Robot syst (upper body) us rotary fluid actuat

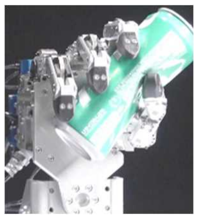


Fig.4 Four-fingered fluid-driven robot hand

- We developed a technology to polymerize hydrogel skin containing flow channels around a hard structure, achieving liquid circulation within the skin.

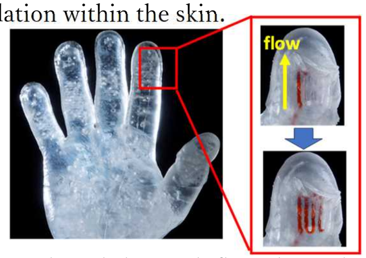


Fig.5 Hydrogel skin with flow channels

Sub theme 2: Robot middleware (OS) for smart robots

By improving the RT System Integration Framework, we have realized grasping operations and health monitoring motions that take into account the handling of multiple objects.

Sub theme 3: Development of a compiler-coordinated low-power-consumption AI processor that realizes the brains of smart robots

Aiming to speed up deep predictive learning processing, we experimentally integrated an embedded GPU into Dry-AIREC, and evaluation results showed that it achieved operation equivalent to that of a high-performance desktop PC.

3. Future plans

We will continue to implement AI into Dry-AIREC for various application situations involving human contact, develop an upper body system using a rotary fluid actuator, and create a flow path that can absorb capsules with a self-repairing function. Furthermore, we plan to proceed with the integrated development of robot hardware, middleware, and AI chips, including the introduction of a compiler-cooperative low-power AI processor into Dry-AIREC.

R&D Item

2． AI systems for smart robots

Progress until FY2024

1. Outline of the project

Moravec's paradox is a contradiction that tasks that are easy for humans are difficult for artificial intelligence and robots. This issue has become more pronounced with the recent development of large language models (LLMs). Leading AI companies, including Google DeepMind, OpenAI, and Tesla, have turned their attention to "(humanoid) robots" as the next target for LLMs, significantly expanding this field in 2023.

This study aims to realize robot intelligence that supports human manual labor, especially housework, by utilizing a unique approach called "deep prediction learning" based on the knowledge of neuroscience. Deep prediction learning is a framework that applies deep learning technology to predict high-dimensional changes in sensation and motion in real time and minimize prediction error. This method has already been used to handle clothes and food and move around the house.

2. Outcome so far

We conducted several motion learning studies using the human-collaborative robot Dry-AIREC developed in our project, as well as other robots. Here are some examples:

1) Learning multiple actions in cooking: In order for a robot to process multiple tasks in a sequential manner, we proposed a learning system that utilizes multiple deep learning models that have a "latent space" that represents the features of objects. The evaluation targets were the series of cooking tasks of pouring pasta or soup and stirring, and it was confirmed that the actions of pouring and stirring could be performed consecutively.

Figure 1: Pouring and stirring soup

2) Research on speeding up operations: We proposed a method to collect high-quality data over a long period of time, and then when the robot actually operates, the model performs inference several times faster than the real world, thereby achieving high-speed operation. By using this method to make inferences in the model three times faster during the teaching stage, we confirmed that an actual robot could stack randomly placed cups quickly and with an average success rate of 94%.

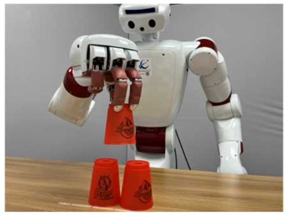


Figure 2: Speed up operations using deep predictive learning

3) Object Grasping in Diverse Environments: A demonstration of AIREC's multiple products picking technology based on visual force distribution estimation was conducted in a simulated convenience store environment at the National Institute of Advanced Industrial Science and Technology. The robot was able to continue the demonstration autonomously even in the presence of multiple people, and the success rate of the picking operation was confirmed to be over 85%.

Figure 3: Object grasping verification in a convenience store environment using Dry-AIREC

4) Basic model construction of smart robots for transfer learning: Aiming to build a robot basic model that can improve the efficiency of the task acquisition process for AI robots, we have produced a simplified dual-arm mobile manipulator, AIREC-Basic, and are developing and verifying a basic model for acquiring difficult tasks, such as picking up laundry from a drum-type washing machine.

Figure 4: AIREC-Basic and laundry picking up

3. Future plans

Starting in 2024, the University of Edinburgh in the UK, one of the world's leading AI institutions, will join us and conduct research into hierarchical motion planning for long-term tasks. We will implement this technology in Dry-AIREC and proceed with technical verification, while also disseminating the results internationally. Hitachi, Ltd. will also join the project from fiscal year 2024 and is conducting research into building a basic model construction of smart robots using AIREC-Basic. In the near future, we plan to learn and demonstrate a variety of tasks in order to put the technology into practical use in society.

R&D Item

3． Technologies for welfare and medical care with smart robots

Progress until FY2024

1. Outline of the project

Research and development have been conducted to develop a smart robot (AIREC, AI-driven Robot for Embrace and Care) to assist healthcare workers and visitors in healthcare facilities and hospitals where elderly care, nursing, and medical care are provided. As AIRECs interact with people, it is necessary for AIRECs to move gently and safely and to be able to use a variety of specialized tools for treatment. AIRECs are expected to play an active role in the medical and welfare fields, taking into consideration their affinity with people and safety.

2. Outcome so far

1) Information infrastructure system for health monitoring

A prototype system has been developed to gather biometric data such as body temperature and pulse, with future potential for managing various types of data from different manufacturers in one cloud-based platform. To enable natural, everyday interactions, a custom sensor was created for AIREC so it can gently approach people and collect health information by touch. A demonstration was carried out in which AIREC interacted with individuals while working together with the health data system to monitor their condition (Fig. 1).

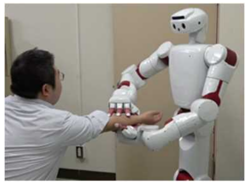


Fig.1 Demonstration of health monitoring

2) Developing robotic hand skin

Work is underway on a robotic skin that can function like a human hand. This includes the development of stretchable gels that resemble human skin and gels with self-repairing properties (Fig. 2, right). Channels for transporting necessary substances, similar to human blood vessels, have also been built into some of these materials (Fig. 2, left).

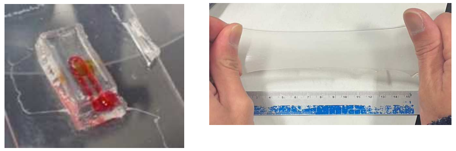


Fig. 2 Developed hydrogel materials for robotic skin

3) AIREC functions for facility guidance

To make hospital navigation more personal, AIREC was equipped with a feature that adjusts its arm height based on the person's body size, using body shape detection (Figure 3). It also turns its face toward the direction it's moving and lights up to make its path clearer to people nearby.

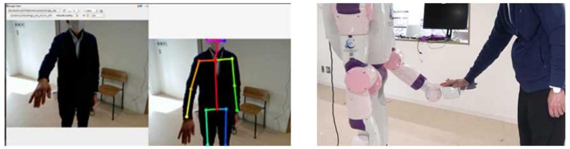


Fig. 3 Guided interaction with hand gestures based on skeletal detection

4) Ability to administer and manage medications correctly

A medication support system is being developed to help ensure the "5 Rights" of medicine administration: the right person, right drug, right dose, right method, and right timing. AIREC can deliver a medication case to the correct person, check the contents, and hand it over safely (Figure 4).

Fig.4 Medication handover performed by the robot

5) Robot hands that can be used in various places

Sensors combining self-repairing gel, cameras, and heat-sensitive particles have been developed to detect damage. An AI model was trained to identify when the gel is harmed (Figure 5, left). For detecting issues like lumps through touch, a new approach using vibrations in a two-finger robotic hand was explored (Figure 5, right). AIREC was also used to take ultrasound images, and an AI was created to evaluate the image quality and adjust the probe movements based on both image and force information (Figure 6, top left).

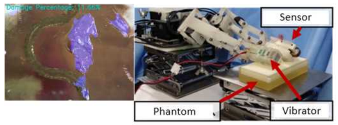


Fig. 5 Damage detection AI and palpation-capable robotic hand

6) Welfare and medical robot design, quality assurance, international standardization, and risk management

Movements involved in turning a person from lying on their back to their side were analyzed and modeled according to body shape, to support caregiving with less physical strain (Figure 6, top right). Discussions were held by a dedicated committee on safety standards for general-purpose robots like AIREC in medical settings.

To examine real-world safety, trials began in a care facility using AIREC. These revealed the importance of understanding both the people AIREC helps and its surrounding environment (Figure 6, bottom). A new sensor module was also developed for the robot hand, combining flexible motion sensors with force sensors, allowing AIREC to estimate arm condition based on how firm or soft the touched area feels.

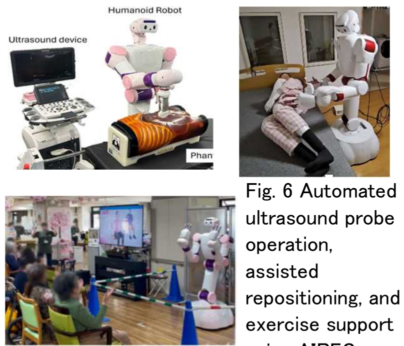


Fig. 6 Automated ultrasound probe operation, assisted repositioning, and exercise support using AIREC

3. Future plans

In the future, we plan to link AIREC with the development results we have achieved so far and introduce AI to enable AIREC to perform each function accurately and autonomously while interacting with people. We also promote research that considers social ethics to enable AIREC to work in society.

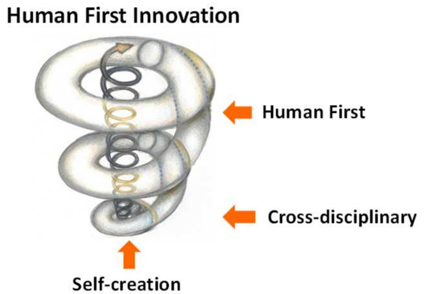
R&D Item

4． Practical measures for smart robots

Progress until FY2024

1. Outline of the project

This project is dedicated to devising strategies for the practical implementation of smart robots. We aim to contribute to social goodness through the realization of a future global society where individuals can lead good lives through the assistance of smart robots that are close to each person for a lifetime. In order to achieve this objective, the regional and cultural differences in the needs and social acceptance of smart robots have become international challenges. We are addressing this ambitious task based on the concept of Human First Innovation through theoretical research and international comparative surveys from the perspective of ethical, legal, and social issues (ELSI). The global acceptance of smart robots involves the following four steps. ① Understanding of diverse needs and societal acceptance of smart robots across different regions and cultures through international comparative investigations. ② Formulation of Smart Robot Development Principles taking into consideration diversity and inclusion. ③Implementation of the principles into the design and control of smart robots through empirical experiments④Development of a toolkit to enhance user literacy.



Toshie Takahashi (2019) "New Opportunities and Risks of AI" White paper information and Communications in Japan [Japanese Version], p.124, (Illustration: Yoichiro Kawaguchi)

2. Outcome so far

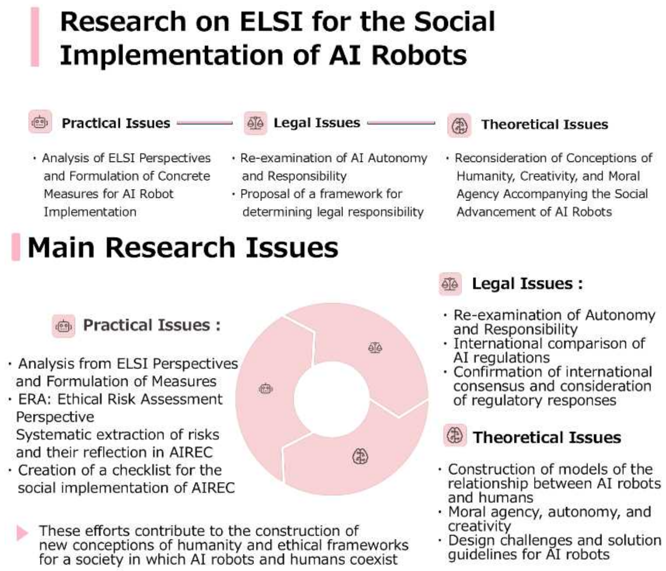
1) Practical Issues: Analysis from ELSI Perspectives and Formulation of Measures. We analyzed ELSI perspectives and developed concrete measures for the implementation of AI robots. Through this research, we established guidelines for addressing ethical challenges in social deployment. For each introduction scenario—such as caregiving, convenience stores, and household tasks—we analyzed use cases from ethical, legal, and social aspects, and created the ethical risk assessments (ERA) and checklists. The ERA systematically identified risks including physical, psychological, privacy, and environmental factors, which are planned to be incorporated into the design of AIREC.

2) Legal Issues: Re-examination of Autonomy and Responsibility

We theoretically examined the legal aspects of AI autonomy and responsibility. We highlighted the "instability of autonomy" that arises when AI robots participate in decision-making, and indicated the necessity of reconstructing autonomy not as an abstract attribute, but within relationships with others and contextual factors. We conducted international comparisons of AI regulations among Europe, the United States, Japan, and other regions, and confirmed the international consensus required for the development and utilization of AI robots.

3) Theoretical Issues: Modeling the Relationship Between AI Robots and Humans

We advanced techno-philosophical research on the moral agency of technical artifacts, as well as on autonomy and responsibility. Drawing on approaches that critically address the limitations of modern Western-centric conceptions of humanity, technology, nature, and life—including theories of technological diversity and multispecies/more-than-human anthropology and design studies—we outlined pathways for articulating values concerning good relationships between AI robots and humans. By employing the conceptual distinction between theoretical autonomy and practical autonomy, we adopted a media approach as a guideline for addressing design challenges and solutions for AI robots embedded in social systems, and constructed models of their mutual relationships.



Future plans

1) Practical Issues: Analyze the current state of smart robots from the perspective of human interaction, develop practical strategies and principles, and reflect them in AIREC demonstrations at the Osaka Expo.
2) Legal Issues: Investigate methods to safeguard individual autonomy and freedom during AI-assisted decision-making, proposing directions for legal regulations and guidelines to prevent manipulation.
3) Fundamental Issues: Consider the conditions for smart robots to contribute to human well-being for 2050 societal needs.