Research area in Strategic Objective *"Research and Development in intelligent systems that flexibly responds to real-world environments"*

Fundamentals and Core Technologies for Embodied AI

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Overview

This research area aims to establish foundational theories and core technologies for constructing advanced intelligent systems that can flexibly and safely respond to diverse and unpredictable situational changes in real environments and physical spaces.

In recent years, AI generation technology based on large-scale deep learning has brought rapid changes to human intellectual activities, mainly in cyberspace. However, its social implementation in real environments and the physical world has not progressed sufficiently.

In this research area, we will promote research and development that contributes to the construction of intelligent systems capable of responding to real environments and physical spaces through the fusion and collaboration of academic fields such as intelligence, machinery, mathematics, control, computation, communication, and neuroscience. This includes endowing AI with physicality through the integration of AI technology with robotics and IoT technology.

Specifically, we will engage in innovative research and development through cross-disciplinary and international collaboration and co-creation on challenges such as development of AI models that can flexibly adapt to real environments, integration of intelligence with physical and driving function systems, and establishment of system infrastructures to support AI. This will contribute to solving social issues and creating innovations in future areas such as manufacturing, distribution, and mobility.

This research area participates in the Ministry of Education, Culture, Sports, Science and Technology (MEXT)'s Advanced Integrated Intelligence Platform Project on Artificial Intelligence/Big Data/IoT/Cybersecurity (AIP Project).

Research Supervisor's Policy on Call for Application, Selection, and Management of the Research Area

1. Background

In recent years, generative AI technology based on large-scale deep learning has rapidly transformed intellectual activities centered on cyberspace and is expected to be utilized in various industrial fields. In the academic field, AI-driven technological innovations are active in areas such as robotics, IoT, big data, and interaction. On the other hand, the social implementation of Generative AI technology in the real environment and physical world, which supports tasks in the physical realm requiring object manipulation and communication with people in areas such as manufacturing, distribution, and mobility, has not progressed sufficiently.

To solve real-world problems and create innovations that contribute to realizing a richer future society, it is expected that AI technology, which mainly targets cyberspace, will be integrated with robotics and IoT technology, focusing on the real environment and physical space, to achieve intelligent systems with physicality and overcome social acceptance challenges. Achieving this requires not only individual efforts across academic fields such as intelligence, machinery, mathematics, control, computing, communications, and neuroscience but also innovative research and development through cross-disciplinary and international cooperation and co-creation.

2. Research and development objective and research project examples

Based on the above background, this research area aims to advance research and development on intelligent systems that can flexibly adapt to real environments through the integration of AI with other fields, such as machinery (robots, IoT, etc.), and to create new foundational theories.

Specifically, we will undertake the following research activities, but we also welcome more innovative and challenging proposals that are not necessarily limited to these areas.

(1) Development of AI models that can flexibly adapt to real environments

We will address challenges associated with applying current foundational AI models in real environments, including inefficient resource utilization, dealing with unforeseen dynamic changes in real environments, and active learning. We aim to overcome these challenges and promote research and development of next-generation AI models.

- Construction of an autonomous multimodal robotic foundational model that integrates perception, action, and reasoning to adapt to real environments.

- Development of innovative AI models that acquire information through physical actions and learn and develop incrementally and continuously.
- Development of AI models that can flexibly interpret the ambiguous meanings of language based on real-world contexts.
- Development of AI models that acquire and extend their own bodily representations and demonstrate advanced skills using tools.

(2) Integration of intelligence with physical and driving function systems

We will promote research and development to achieve real-time integration of intelligence (AI) with physical and driving mechanism systems, and the intelligent of various parts (edges) of machinery.

- Development of advanced actuators suitable for AI-driven motion data collection, combining robustness (high torque) and flexibility.
- Development of durable and diverse sensor systems suitable for AI-driven motion data collection, capable of handling various movements and long-term use.
- Research and development of body structure design to reduce AI computational load, such as reservoir computing technology utilizing physical elements.
- Development of edge AI systems that support motion generation of real robots by performing local inference and prediction.

(3) Establishment of system infrastructures to support AI

We will conduct research and development on system component technologies with the aim of enhancing robustness, efficiency, and stability in the networks that integrate AI and sensor groups across various machinery.

- Research and development of data formats and management frameworks to efficiently advance the training of large-scale robotic foundational models.
- Research and development of communication networks that can reliably connect multiple AI robot systems with high-performance computing servers in real time.
- Research and development of distributed systems and robot operating systems (robot OS) for efficiently controlling multiple components within an AI robot.

<Relevant technical keywords>

(1) Robotic foundational models, End-to-End models, World models, Imitation learning, Reinforcement learning, Uncertainty handling, Active inference, Transfer learning, Continual learning, Long-term motion generation, Cognitive developmental robotics, Symbol emergence robotics, Agent cooperation, AI model security and risk analysis, etc.

(2) Pseudo-direct drive motors, Tactile sensors, Physical reservoir models, Compression, decentralization, and quantization of foundational models, etc.
(3) Computing (Edge AI devices, Robot OS, Distributed cooperative processing, Real-time processing, Network control, Operations management (ML-OPS)

3. How to pursue research

In this research area, we seek to create new fundamental principles through the integration and collaboration of the AI field with various other fields. This aims to fundamentally solve current challenges of AI related to resource efficiency and physical interaction in the real world. We also aspire to develop foundational technologies that enable the realization of intelligent systems capable of operating in "real environments," including aspects of reliability and social acceptability.

Moreover, by advancing the integration of AI with various fields within the academic community, we aim to systematically progress the discipline and cultivate future researchers who will lead this field. Therefore, researchers selected for this project are expected to actively collaborate not only among teams within this research area but also researchers conducting related projects under the same strategic objectives, such as PRESTO “Fundamental Innovation for Real-World Intelligent Systems”.

Furthermore, we promote collaboration with related research areas, projects, research hubs, academic societies, and both domestic and international communities. We expect active interaction and integration with society, industry, and various fields. Simultaneously, we aim to enhance Japan's presence in the international community within this research field.

In addition, we expect teams to open their deliverables and mutually utilize them within the area. We will consider setting benchmarks in the area to facilitate the construction and maximization of a technology platform.

4. Research periods and research funds

The research period shall be limited to no more than five and a half years. Research costs (direct expenses) submitted include the costs required to achieve the proposal content, with an upper limit of ¥300 million. Applications in excess of this sum may nonetheless be approved in cases where genuine need is recognized due to the content and character of the research. Please note that research costs may be adjusted during selection, subject to scrutiny by the supervisor.

5. Notes for applicants

This research area targets team-based research involving AI specialists and researchers from various other fields. While proposals focusing on any of the three research challenges exemplified in section 2 are acceptable, proposals that combine (1), (2), and (3) are also encouraged. During the selection process, emphasis will be placed on whether the proposal aims for essential and fundamental solutions

to technological challenges and whether it is a challenging proposal that seeks to break through the limits of existing technologies. Additionally, specific plans for integration with researchers from different fields will be highly evaluated if included in the proposal.

When applying for this research area, please clarify the real-world environment assumed for the proposed research, and clearly state the challenging technological issues and the vision for the intended social contributions. Additionally, provide as much detail as possible regarding the goals to be achieved over the 5.5-year period and the milestones anticipated in 3 years.

From the perspective of talent development, we consider it important to nurture young researchers within the team. Therefore, we also encourage challenging research proposals from young researchers.

Furthermore, this research area operates as part of the "AIP Network Lab" within the integrated Artificial Intelligence/Big Data/IoT/Cybersecurity Project (AIP Project) under the Ministry of Education, Culture, Sports, Science and Technology. It will actively contribute to initiatives conducted in collaboration with related research institutions, including the RIKEN Center for Advanced Intelligence Project (AIP).