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

Fundamental Innovation for Real-World Intelligent Systems

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Overview

This research area aims to further advance AI and expand its application to real-world domains. It focuses on integrating AI with various fields, including mechanical engineering such as robotics and IoT devices, control theory, mathematics, neuroscience, and communications, thereby deepening fundamental scientific understanding and establishing core technologies.

To extend AI technologies, which are currently mainly deployed in cyberspace, to physical environments, several breakthroughs are needed to overcome technical limitations in computing resources, amount of training data, and inference performance, and to establish new methodologies that can flexibly respond to continuously changing and unpredictable situations. In this research area, we will work to achieve these breakthroughs and promote research and development aimed at realizing more advanced intelligent systems capable of performing various tasks in real-world environments at or beyond human capabilities.

Specifically, we will promote challenging research in areas including intelligent information processing that is adaptable to real-world environments, the integration of intelligence with physical functionality and actuation systems, and the establishment of system infrastructures to support AI.

In addition, this research area is operated as part of the Artificial Intelligence/Big Data/IoT/Cybersecurity Integrated Project (AIP Project) of the Ministry of Education, Culture, Sports, Science and Technology.

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

1. Background

In recent years, generative AI based on ultra large-scale deep learning has rapidly transformed a wide range of human intellectual activities in cyberspace, and its application in various industries is highly anticipated. Academic fields are also witnessing significant innovation through AI technology, particularly in areas such as drug discovery, protein structure prediction, enhanced physical simulations, and medical diagnosis support. However, the societal implementation of AI technologies in real-world environments or physical spaces-such as supporting tasks involving object manipulation and human interaction in manufacturing, logistics, and mobility-is still insufficient.

To address real-world challenges and create innovations that contribute to a more prosperous future society, it is essential to integrate AI technologies developed primarily for cyberspace with robotics and IoT technologies tailored for physical environments, thereby achieving embodied intelligent systems and overcoming challenges related to societal acceptance. Achieving this goal requires not only individual efforts from various academic fields-including intelligent information processing, mechanical engineering, mathematics, control theory, and communications-but also interdisciplinary collaboration and co-creation to drive breakthrough research and development.

2. Research and development objective and research project examples

Based on the background described above, this research area promotes interdisciplinary collaboration, especially between AI and mechanical fields (such as robotics and IoT), and supports ambitious research driven by the creative ideas of young researchers. Through this approach, we aim to advance research and development toward intelligent systems capable of flexibly adapting to changes in real-world environments, thereby establishing new fundamental scientific principles.

Specifically, we envision research topics that include, but are not limited to, the following examples. However, we strongly encourage more innovative and ambitious proposals.

(1) Intelligent information processing adaptable to real environments

This research aims to develop next-generation intelligent information-processing technologies to overcome technical challenges encountered when applying current AI to real-world environments, such as improving resource efficiency, handling unforeseen dynamic changes, and enabling active learning.

- Construction of active multimodal models and world models capable of adapting to real environments by integrating perception, action, and knowledge.
- Development of robust recognition and action-generation methods resilient to

unexpected situations.

- Creation of continual learning methods capable of immediately learning from vast multimodal data continuously collected from real-world environments, while simultaneously maintaining stable memory mechanisms.
- Realization of AI models and methodologies capable of sufficient learning even with limited data and computational resources.

(2) Integration of Intelligence with Physical Functionality and Actuation Systems

This research promotes the development of technologies for precise, efficient, and real-time integration of AI (intelligence) with physical functionality and actuation mechanisms of machines, as well as intelligent systems at the edge-level components.

- Innovative AI models and highly efficient, robust systems made possible through mutual interactions between intelligent information processing, actuation mechanisms, and sensing systems.
- Development of technologies optimizing the speed and accuracy of learning and inference through collaboration between edge-based AI and server-based AI.
- Development of next-generation AI robots that integrate intelligent information processing with high-performance hardware and advanced software.
- Elucidation and theoretical formulation of mechanisms underpinning the interaction between intelligence and physical embodiment.
- Development of AI robotic systems capable of performing tasks requiring dexterity, heavy labor tasks, or operations under harsh environmental conditions.

(3) Establishment of system infrastructures to support AI

This research focuses on the development of system-level technologies to achieve robustness, high efficiency, and stability in networks connecting intelligent components (AI) embedded in machinery and numerous sensors.

- Development of distributed cooperative processing theories, algorithms, and systems enabling multiple robots to collaboratively accomplish tasks challenging for an individual robot.
- Development of network systems that facilitate stable and high-speed communication of massive multimodal data among numerous robots and IoT devices.
- Development of theories and algorithms to protect privacy information obtained from real-world devices.
- Establishment of advanced security technologies for machines such as robots operating in real-world environments.

<Relevant technical keywords>

(1) Intelligent Information Processing Capable of Flexible Adaptation to Real Environments
Multimodal, Foundation Models, Symbolic Processing (Knowledge Processing, Symbol Manipulation), Uncertainty Handling (Prediction, Evaluation), Model Compression, Decentralization, Quantization, Reinforcement Learning, Imitation Learning, Meta-Learning, Transfer Learning, Continual Learning, Robust Learning, Motion and Task Planning, Causal Inference, Long-term Prediction, Time-Series Models, Self-awareness, Self-evolution and Emergence, Federated Learning, Multi-agent Systems, etc.

(2) Integration of Intelligence with Physical Functionality and Actuation Systems
AI Robotics, Dual-process Theory, Dynamic Control, Predictive Coding, Cross-environment Adaptation, Integration of Sensation-Motion-Emotion, World Models, Cognitive Developmental Robotics, Swarm Intelligence, Dynamic Knowledge Updating, Model Integration, Robust Control, Model-free Control, Data-driven and Model-driven Integration, etc.

(3) Establishment of System Infrastructure Supporting AI
Edge AI Devices, Distributed Cooperative Processing, Real-time Processing, Network Control, AI Security, Privacy Protection, etc.

3. How to pursue research

This research area emphasizes interdisciplinary collaboration between AI and various other fields to fundamentally address current challenges faced by AI—such as resource efficiency and real-world physical interaction (embodiment)—and to realize intelligent systems capable of operating effectively in real-world environments.

Moreover, by fostering integration between AI and various disciplines within the academic community, this research area aims to achieve systematic academic advancement and nurture the next generation of leading researchers in this field. Therefore, researchers selected for this project are expected to actively collaborate not only within this research area but also with researchers conducting related projects under the same strategic objectives, such as CREST “Fundamentals and Core Technologies for Embodied AI”.

Furthermore, active collaboration and integration with domestic and international communities, including other relevant research areas, programs, research hubs, and academic societies, as well as with industry and broader society, are highly encouraged. Through these activities, this research area aims to enhance Japan's presence within the international research community in this field.

4. Research periods and research funds

The total research budget is limited to a maximum of 40 million yen (direct costs) per proposal. The research period is 3.5 years or less.

5. Notes for applicants

In the PRESTO (Sakigake) research program, ambitious and impactful research proposals are expected—even those involving significant challenges—in order to foster the growth of next-generation research leaders and produce breakthrough outcomes. Therefore, bold and exploratory proposals aligned with the objectives of this research area, without fear of potential failure, are strongly encouraged.

Proposals may focus on one or span multiple research topics among the three examples described in section 2. Additionally, during evaluation, proposals detailing concrete strategies for interdisciplinary collaboration with researchers from different fields will be positively assessed.

When submitting applications to this research area, it is essential to clearly specify the envisioned real-world environment related to the proposed research, the technical challenges to be addressed, and the vision for societal contribution intended through the research outcomes.

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).