Here begins our new MIRAI
MOONSHOT
RESEARCH & DEVELOPMENT PROGRAM

R&D Theme

Development of IoB Interfaces (IoB: Internet of Brains)

Progress until FY2022

1. Outline of the project

The goal of this theme is to develop technology to extract thoughts and mental states from brain activity using various devices and to implement it in society as an application, thereby promoting the use of brain-machine interface (BMI) technology. Specifically, we are developing algorithms that can extract thoughts and mental states in daily environments for short periods of time by combining gadget-type EEG sensors such as headphones and camera images from cell phones. Using these, we aim to disseminate BMI technology to society by creating applications that enable self-regulation by visualizing daily physical changes of which one is not conscious, and applications that support the communication of intentions of users who are in a state or situation where they are unable to express their intentions externally.

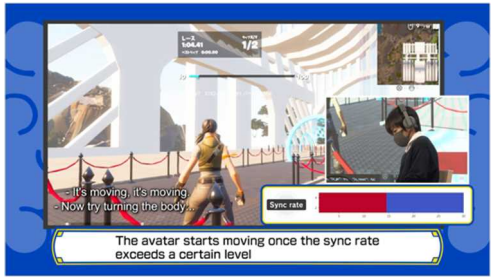
2. Outcome so far

Stylish design, cool to wear. Anyone can use it anywhere, anytime. We have also developed waveform classification AI and inference AI to deal with "sudden noise contamination" and "individual differences in brain wave response," and incorporated them into the system (domestic patent application completed, PCT application in process).

Avatar control

The "BMI Brainpic," in which people with cerebral palsy and neuromuscular intractable diseases and junior and senior high school students used these brainwave sensors to control avatars in the popular game "Fortnite" and compete against each other for time, was held to great success (viewed a total of 33,000 times in Japan and the United States within 3 months after being released on YouTube).

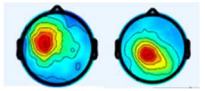
Recently, we have also succeeded in improving the accuracy of BMI control of avatars by using sensors to read "habits" that people do unconsciously, such as leaning or looking in the direction they want to go. We have also succeeded in combining this with technology that allows the AI to recognize obstacles in the avatar's surroundings and avoid collisions fully-automatically. In the future, we plan to apply the IoB interface, which "moves as smoothly as you want," not only to the metaverse but also to real-world environments.



Brain monitoring and training through Avatar

Troubles resulting from brain limitations are widely shared among musicians and music lovers. Performance is unstable from day to day, motor memory is difficult to consolidate, and disease signs are heightened by overtraining.... To solve these problems, we have developed an application to analyze and visualize the acoustics during performance recorded with a consumer microphone and hand posture with a consumer camera. In Japan, we have begun trials at the Music Excellence Project Academy and are planning joint research with the Hanover College of Music and the Munich College of Music. We have also developed and are testing a cognitive-behavioral app that normalizes memory consolidation for parties suffering from traumatic memories.

Furthermore, we are developing a large multidimensional database of functional magnetic resonance imaging, gait data, and diagnostic data for parties with signs of mental illness and have constructed technology to infer mental and physical conditions from the way they walk. We are now able to analyze brain activity components cleanly while walking, which is difficult to do with EEG measurements.



3. Future plans

This fiscal year, we were able to publish world-class academic papers, conduct international joint research activities, and standardize technologies. In the future, we will promote radical innovation while add-on industry-academia collaborative activities, aiming to realize "a society where everyone can pursue their dreams" and "a society where people can enjoy their lives until they are 100 years old without health concerns.

国立研究開発法人 科学技術振興機構
Japan Science and Technology Agency

R&D Theme

IoB Middleware

Progress until FY2022

1. Outline of the project

In order to build an AI-assisted Trusted BMI-CA (Brain-Machine Interface-Controlled Avatar) that can provide the desired support for individuals with physical disabilities, it is necessary to develop technology for transmitting information from the brain and body to the CA. Additionally, the development of CA technology that can provide assistance as desired by the user based on the transmitted information is essential. The 'IoB Middlewaret' is dedicated to the development of 'communication technology between the brain and CA,' using mathematical approaches such as machine learning and information theory.

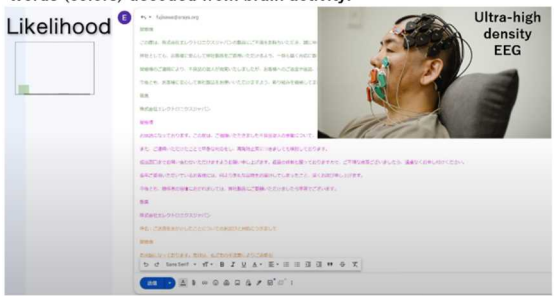
＊AI-assisted BMI-CA: A Cybernetic Avatar (CA) that can accurately decipher the words and actions imagined by the user through the use of machine learning in AI, depending on the combination of different BMI (Brain-Machine Interface) technologies..

In the 'IoB Middleware Development,' we aim to develop BMI technology that supports diverse communication needs, ranging from technologies that interpret speech intentions and serve as alternatives for interpersonal communication to communication of information that is difficult to convey through language, such as recalled images, physical manipulation, cognitive load, and fatigue.

2. Outcome so far

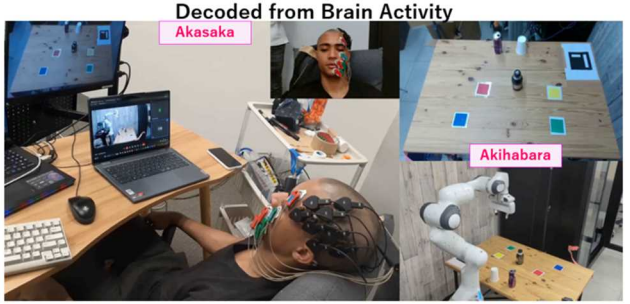
[ChatGPT-supported Brain-Gmail Interface]

ChatGPT proposes reply candidates based on received emails and past replies. Then the system selects and sends a reply based on words (colors) decoded from brain activity.



Generating AI has made remarkable progress in recent years. Unlike AI systems that select answers from given choices, generating AI can generate answers on its own. By integrating it with BMI, it is expected to enhance user functionality. The group led by Shuntaro Sasai, CRO of Alaya Inc., successfully developed a BMI system that can generate email replies through dialogue with users, leveraging ChatGPT, an AI capable of generating text through conversations. This system decodes colors spoken by users from brain activity and uses that information to manipulate web interfaces of email platforms such as Gmail. Furthermore, ChatGPT automatically generates reply candidates based on received email content and past reply history, allowing for semi-automatic email responses by selecting the desired reply from the candidates.

Automatic Control of a Remote Robot Arm Using Words Decoded from Brain Activity



[Language-based Automatic Control of Robotic Arm]

Shuntaro Sasai, and Alaya Inc's team leader Kai Arulkumaran have been developing an AI-assisted BMI that can semi-automatically operate a robotic arm based on decoded language from brain activity to perform tasks. The Arulkumaran team has been working on the development of an AI agent that can control a robotic arm automatically based on instructions given in natural language, eliminating the need for precise user control. They successfully conducted an experiment inputting decoded words from the user's brain activity into this AI agent via the Internet, enabling the remote execution of tasks by a robotic arm located in a distant place.

3. Future plans

In the future, we will focus on improving the accuracy of the AI-assisted BMI system currently under development and validating its feasibility and user experience by actual usage among individuals with speech or physical impairments.

国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency

R&D Theme

IoB Core technology

Progress until FY2022

1. Outline of the project

The ability to safely measure brain activity is a core technical element of all BMI development. The IoB Core Technology aims to develop BMI technology that enables users, if they wish, to expand their capabilities in daily life using safe and efficient invasive technology. We are developing the measurement and decoding technologies for human using animals (Figure 1).

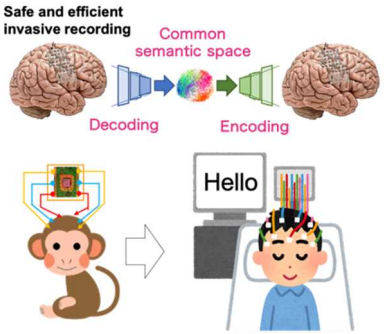


Figure 1: Overview of Invasive BMI Development

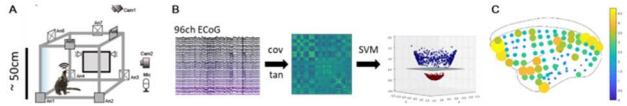
We will develop invasive BMI using animals and apply it to humans. In particular, we will develop technology that uses AI to decode imagery contents and intentions and input information into the brain.

We have developed a technology to record and manipulate neural activity with high precision by penetrating electrodes into the brains of marmosets and macaques. By measuring long-term stable neural activities, we have succeeded in decoding animal communication from brain signals. In collaboration with the IoB Middleware Development Group, we have developed brain decoding technology that utilizes AI technology on invasive brain signals to build an AI-assisted Trusted BMI-CA.

2. Outcome so far

[Decoding of multimodal information from the primate cerebral cortex]

A group led by Misako Komatsu, a special associate professor at Tokyo Institute of Technology, has been working on the development of a system for marmosets, primates that are vocal communicators, to enable animals to communicate online like humans. So far, the Komatsu group has successfully set up a wireless measurement system for wide-area ECoG of marmosets to measure speech, behavior, and neural activity during vocal communication with other individuals. They succeeded to decode behavioral categories and types of vocalizations of marmosets, and developed a system that will enable marmosets to communicate online like humans. They found that a higher cortical area called the association cortex commonly contributes to decode both types of information. This research shows the possibility of extending BMI, which has been developed in a single modality, to multimodal applications. These results were reported at an international conference of BMI.



Komatsu, Sato, Yoshida, Tsunada, Sasai., 2023 BCI Meeting, Belgium

Figure 2 Marmoset wide-area ECoG wireless measurement and decoding

[Displaying images on the screen that people have imagined]

A group led by Professor Takufumi Yanagisawa of Osaka University has been developing a technique to stably measure intracranial EEG in patients with epilepsy. Using this technique, the group has measured highly accurate intracranial EEG from human visual cortex and shown that the imagined image can be presented on the screen when the human imagined the image. This new BMI was reported in a peer-reviewed journal and will be applied to decode imagery contents and intentions for communication.

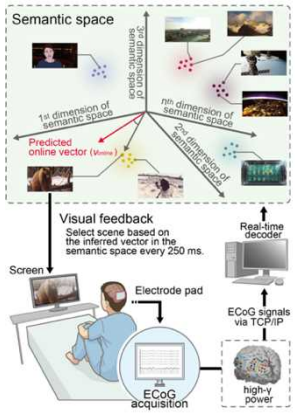


Figure 3 Imagery BMI

3. Future plans

- Nishimura Gr. will verify the long-term stability of the brain-muscle electrode implantation technique in macaque monkeys.
- Yanagisawa Gr. will develop a method to decode imagery contents and internal language from ECoG to generate speech and images.
- Komatsu Gr. will connect the multimodal decoder to the XR space for marmosets and realize real-time communication there.

国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency

R&D Theme

Study of issues common to the project and R&D for social implementation

Progress until FY2022

1. Outline of the project

We are establishing a foundation to facilitate the smooth progression and expansion of projects in other R&D themes. We have conducted literature-based searches and listings of novel technologies aimed at realizing Brain Assistant[1] and X Communication[2] applications. Among these, we are pursuing the development of new technologies in fields such as Stentrode and nanoneurobiology, and are in the process of selecting project proponents, including international research groups.
Additionally, we aim to promote a proper understanding of Brain-Machine Interface (BMI) technology by writing a Braintech Guidebook and Evidence Book for the public. We have completed the Japanese and English versions of the Guidebook, and plan to release the Evidence Book in FY2023. We also have been advancing discussions on the transformation of BMI-CA in both legal theory and practice, and have been promoting international exchange and domestic dissemination based on this research.

2. Outcome so far

Study of issues common to the project and R&D for social implementation

- To strengthen the international collaboration, we promoted participation of Professor Grayden of the University of Melbourne, Australia, who created the Stentrode.
- We have improved the prediction accuracy of brain measurement sites based on electrocorticogram (ECoG) features using deep learning and presented our findings at the Conference on Cognitive Computational Neuroscience.

Establishing the Social Infrastructure for Trusted BMI

- We created the BrainTech Guidebook, releasing the Japanese version in October 2022 and the English version in March 2023. We held a public workshop in conjunction with the release of the Japanese version, and we distributed an introductory article on the science news distribution site Eurekalert! to enhance the international presence.
- One completed systematic review[3] of the efficacy and safety of BMI products was accepted for publication in a peer-reviewed English journal, and another was published on a preprint server.

Legal Considerations in the Utilization of BMI-CA

- The "Internet of Brains"-Society (IoB-S) held meetings approximately once a month to discuss the latest developments in technology and to address ELSI (Ethical, Legal, and Social Implications) issues, and prepare ELSI reports.
- We have completed a total of twelve articles in a two-year series of "Dialogues with Engineers" in the well-known law journal "Law Seminar".
- We widely publicized our research findings both domestically and internationally through numerous symposiums, conferences, and publications. For example, IoB-S hosted three open forums and organized a concurrent session at the 2023 Global Summit on Constitutionalism held at the University of Texas at Austin, where we reported on our activities and research.

3. Future plans

- As part of strengthening international collaboration, we will proceed with the selection and addition of overseas project proponents.
- We will write and publish Japanese and English versions of the Braintech Evidence Book.
- We will explore and identify new technologies to ensure the safety and reliability of AI-assisted Trusted-BMI users.
- Considering the ethical, legal, and social aspects of AI-assisted Trusted-BMI technologies, we will identify challenges in invasive, non-invasive, and non-contact technologies and develop demonstration scenarios.
- To strengthen domestic and international collaboration, we will disseminate our results by holding symposiums and workshops in Japan and abroad and by issuing publications.

1. Brain Assistant: An AI-assisted BMI-CA application that helps manage health by monitoring the user's mental and physical states.
2. X Communication: An AI-assisted BMI-CA application that deciphers concepts and images that come to mind, allowing users to control service robots, personal mobility devices, avatars for VR.
3. systematic review: Scientific methods for systematically collecting, evaluating, and integrating the results of published studies

R&D Theme

Research and Development of Minimally Invasive BMI

Progress until FY2022

1. Outline of the project

Recently, the number of patients with brain-related diseases and diseases of the central nervous system has been increasing enormously, and the existing technologies to date have not even begun to solve the problems. This is due to the critical lack of measurement technology to accurately measure advanced brain activity, measurement results to statistically process brain activity, and means to construct brain big data.

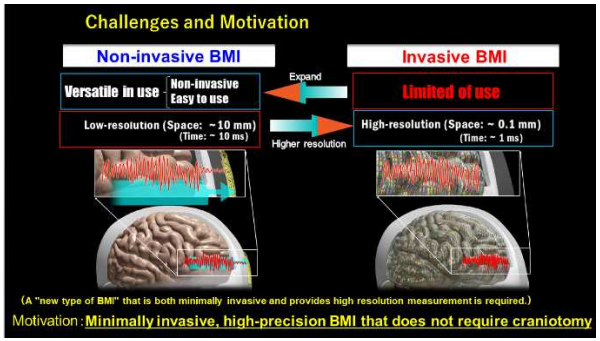


Figure 1: Overview of the goals of this research and development

Based on the above background, we are conducting research and development to build a "flexible ultra-thin BMI system" that achieves high measurement accuracy of brain information in an extremely minimally invasive manner (no craniotomy required).

2. Outcome so far

A research team at Osaka University is working toward minimally invasive and detailed measurement of brain activity. So far, two types of devices have been developed with the goal of realizing the following two types of devices. One is an "extremely minimally invasive BMI system" using an ultra-fine and soft intravascular implantable device, and the other is an "intravascular BMI transporter" to deliver the developed BMI system to the desired location within the blood vessel. Furthermore, a signal processing circuit and system to deliver the measured intravascular EEG signals to the outside of the body with high quality.

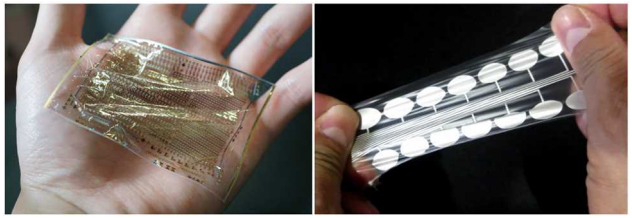


Figure 2: Ultra-thin film, lightweight electronic devices and flexible electrode technology

In order to realize accurate EEG signal measurement without damaging soft blood vessels in the body, R&D has been conducted utilizing thin-film electronics technology as shown in the above figure 2. Specifically, R&D has been conducted to realize a minimally invasive BMI system by utilizing ultra-thin and ultra-lightweight electronic devices with a thickness of 1 μm and stretchable and flexible electrode technology.

Examples of past R&D results include the realization of signal amplification circuits using biocompatible semiconductor materials, the development of technology to control the characteristics of flexible electronic circuits using optical technology. Publications are listed below.

・Science 380, 690 (2023)【IF: 63.832】
・Advanced Electronic Materials 2201333 (2023). 【IF: 7.633】
・Advanced Science 10, 220474 (2022).【IF: 17.521】
・Communication Biology 5, 1375 (2022).【IF: 6.548】
・ACS Applied Electronic Materials 4, 6308 (2022). 【IF: 4.494】
・Flexible and Printed Electronics 7, 44002 (2022). 【IF: 3.768】

3. Future plans

Development and evaluation of this device is currently underway at the preeminent medical device research and development facility. The team plans to verify the quality of EEG measurement signals using the minimally invasive BMI system currently under development, to verify the device and system, and to verify the stability of the system after long-term implantation.

In parallel, we will also develop a wireless transmission system to transmit the EEG measurement signals outside the body and a wireless power supply system to supply power to the measurement devices inside the body.

Through these efforts, a new type of BMI that can measure high-level brain activity over a long period of time without the need for craniotomy will be realized, contributing to medical care and health care.