Construction of an AIoT-based universal emotional state space and evaluation of well-/ill-being states

R&D item

1. Constructing a Human Emotional State Space by AIoT

Progress until FY2023

1. Outline of the project

In this project, we aim to develop AIoT (AI × IoT) technology that enables the objective estimation of emotional states in daily life on a cloud platform using multidimensional psycho-physiological data (e.g., voice data, physical activity, heart rate, respiratory rate, and recording situations) measured by IoT devices. The project is divided into the following three research topics:

1. Development of human emotion estimation technology with clinical validity using multidimensional psycho-physiological data
   Summary: we develop technology with clinical validity that enables the objective estimation of various emotional states on a cloud platform. This is achieved by utilizing multidimensional psycho-physiological data (e.g., voice data, physical activity, heart rate, and respiratory rate) measured by IoT devices in daily life.
2. Assessment of psycho-physiological data in patients
   Summary: we collect psycho-physiological data from patients with mental disorders to construct a human emotional state space with clinical validity.
3. Development of a translational IoT cloud system
   Summary: we develop a cloud-based IoT system capable of acquiring continuous and real-time psycho-physiological data from both humans and animals (mice and rats) in real-world settings on a large scale.

2. Outcome so far

To develop human emotion estimation technology, we constructed machine learning models that estimate self-reported emotion scores recorded in daily life from simultaneously measured physiological signals using our existing database (Figure 1).

[Main Achievements by FY2022]

- Estimated scores for four emotions (depressed mood, anxiety, positive mood, and negative mood) from spontaneous physical activity data with an error margin of approximately 20%.
- Estimated nine emotions (“vigorous,” “gloomy,” “concerned,” “happy,” “unpleasant,” “anxious,” “cheerful,” “depressed,” and “worried”) from voice data with an average concordance correlation coefficient of 0.55 and a maximum of 0.61.

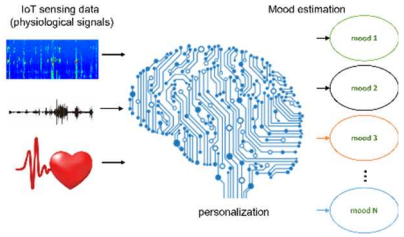

Figure 1

[Main Achievements in FY2023]

By introducing a personalized approach for the binary classification of the levels (high/low) of four emotions (depressed mood, positive mood, negative mood, anxiety) based on physical activity, we achieved an estimation accuracy exceeding 70% in terms of accuracy, recall, precision, and F1-score. Additionally, using a machine learning model combining a different personalized approach, we estimated subjective scores for nine emotions (“vigorous,” “gloomy,” “concerned,” “happy,” “unpleasant,” “anxious,” “cheerful,” “depressed,” and “worried”) from physical activity data with an average concordance correlation coefficient of 0.48. Furthermore, we successfully improved the estimation accuracy by constructing multimodal machine learning models that utilize multiple physiological signals (voice and physical activity).

To construct a translational IoT cloud system for humans and animals, we have been developing and implementing a ring-type device aimed at ″subtle″ sensing. In FY2023, we completed the integration of the device with the existing IoT cloud system. Additionally, we conducted a proof of concept (PoC) study for monitoring vital signs, stress, and sleep in residents of a dementia floor in a nursing home, with the aim of verifying the system and expanding it to service businesses (Figure 2).

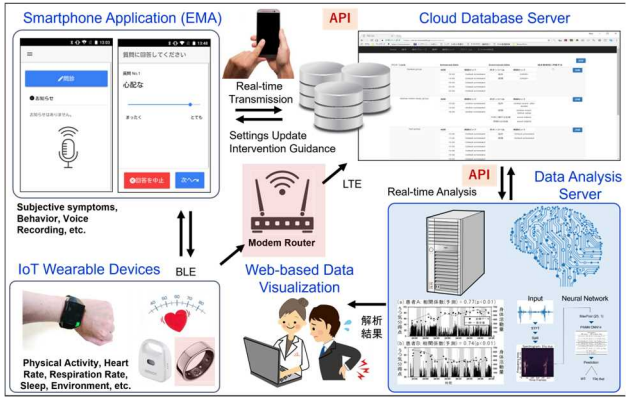

Figure 2

As an extension of this system to animal measurements, we created and validated a prototype sensor for mice.

3. Future plans

- We will continue to collect clinical data (from patients with mood disorders, anxiety disorders, and alexithymia) and use them to develop emotion estimation models with clinical validity.
- We plan to develop animal devices for animal IoT sensing.

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R&D item

2. Constructing a Universal Emotional State Space

Progress until FY2023

1. Outline of the project

This project aims to construct a 'universal' emotional state space that transcends animal species. To achieve this, we measure a variety of psycho-physiological data from both wild-type mice and disease model mice (e.g., autism model mice exhibiting increased anxiety and fear-related behavior, or mice with susceptibility or resilience to depression) under various conditions, including application of stimuli (Social Defeat Stress : SDS) or drug administrations that induce emotional responses. By combining psycho-physiological data obtained from both mice and humans, we aim to construct a universal emotional state space with biological validity. This project comprises the following two research topics.

1. Development of universal emotional state estimation technology
   Summary: by combining IoT measurement data obtained from both mice and humans, we develop a universal emotional state space that transcends animal species and possesses biological validity.
2. Assessment of physiological data and emotional states in animals
   Summary: to construct a universal emotional state space, it is essential to obtain psycho-physiological data from animals. Therefore, we will measure a variety of physiological signals from both wild-type mice and disease model mice (e.g., autism model mice exhibiting increased anxiety and fear-related behavior, or mice with susceptibility or resilience to depression) under various conditions, including application of stimuli (Social Defeat Stress : SDS) or drug administrations that induce emotional responses.

2. Outcome so far

To construct a universal emotional state space that transcends animal species, we investigated the application of transfer learning techniques to develop emotion estimation models for mice based on models originally developed for humans. Additionally, we examined how data from animals with specific conditions could be incorporated into the construction of emotion estimation models for humans. Furthermore, we collected foundational animal data for this study.

[Main Achievements by FY2022]

- An experimental protocol for the Social Defeat Stress (SDS) mouse model, a depression model was established.
- Surveyed a measurement system capable of continuously acquiring multiple physiological signals (e.g., electrocardiograms, body temperature, blood pressure, and acceleration) from mice over an extensive period, including the disease onset process.

[Main Achievements in FY2023]

We validated the protocol for SDS developed last year. Additionally, to evaluate the measurement system, we measured physiological signal (body temperature and activity levels) responses before and after restraint stress, confirming that the measurement data contained information related to stress responses. Following this, we conducted long-term continuous measurements spanning from before to after the onset of depression (Figure 1).

Furthermore, as a preliminary analysis, we analyzed alterations in the dynamical features of physiological signal fluctuations throughout the process from before to after the onset of the disease.

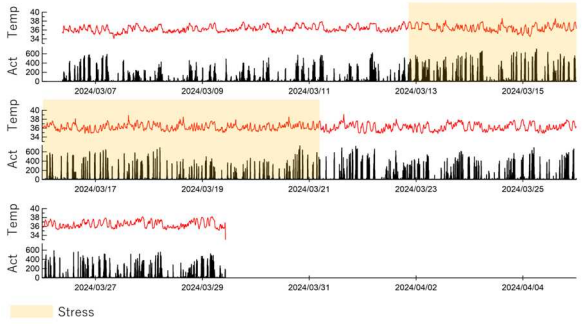

Figure 1

3. Future plans

- We will validate the applicability of the emotion estimation model developed for humans to mice.
- We will attempt to construct a new emotion estimation model utilizing data from both mice and humans.
- Physiological data will be collected from mice, including those subjected to SDS-induced stress.

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R&D item

3. Establishment of Well-being/Iii-being Detection Technology

Progress until FY2023

1. Outline of the project

Based on the outcomes of the research and development themes "Constructing a Human Emotional State Space by AIoT" and "Constructing a Universal Emotional State Space," we will develop technology to detect and evaluate mental well-being by characterizing the dynamical properties of emotional state transitions, such as transition matrices, transition frequencies, residence times, or first passage times) (Figure 1).

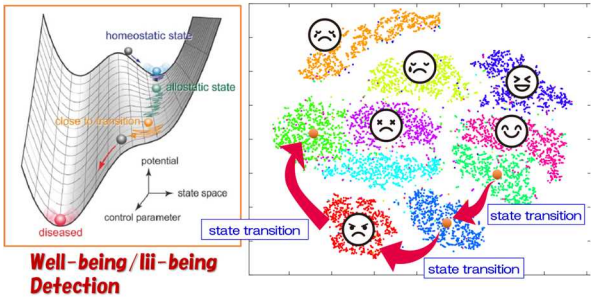

Figure 1

2. Outcome so far

In this year, we conducted preliminary analyses using several samples of physiological data measured from the Social Defeat Stress (SDS) mouse model, which are being acquired under the research and development theme "Constructing a Universal Emotional State Space." We examined the alterations in the dynamical properties of physiological signal fluctuations before and after onset and during transition states. The identified properties will be further investigated as indicators for detecting mental well-being and ill-being.

On the other hand, as a support technology for mental well-being, we analyzed research data obtained from an intervention study that monitored and evaluated daily sleep using the sleep tracker-linked cloud system developed under the research and development theme "Constructing a Human Emotional State Space by AIoT." Random push notifications aimed at improving sleep were sent to groups with unstable and stable sleep patterns (Figure 2). This intervention study is positioned as a Just-In-Time Adaptive Intervention using micro-randomization. As a result, feedback on the previous night's sleep duration led to a significant extension of sleep duration and improvements in mood and sleepiness upon waking. Furthermore, these effects were observed only in the unstable group.

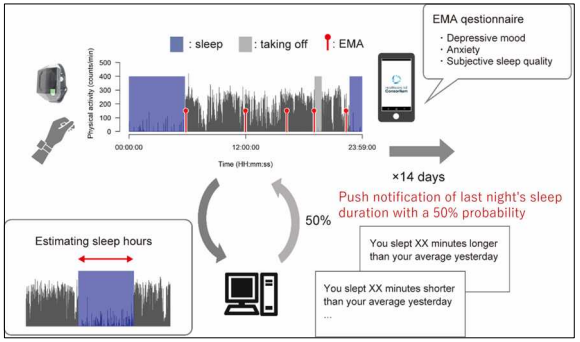

Figure 2

3. Future plans

We will develop technologies to detect and understand mental well-being by analyzing the transition characteristics of emotional states in healthy individuals, patients with diseases, and disease model mice.

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