



Title of Project : Cognitive Interaction Design: A Model-Based Understanding of Communication and its Application to Artifact Design

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Research Project Number : 26118001 Researcher Number : 60262101

【Purpose of the Research Project】

The mental model of others, which is used for understanding and predicting partners' actions under certain situations, plays an important role in human communication. In fact, we sometimes feel a gap in the conversation with a stranger, since we do not have such a mental model of others at first. This kind of phenomenon, namely the communication facilitation by the mental model of others, is expected to find in the interactions between humans and companion animals/artifacts as well as in human-human communication.

This research project is aiming at establishing a new academic field which we call "Cognitive Interaction Design (CID)". We strongly believe that the cognitive construction of "mental model of others" is a key to establish the design and implementation of artifacts that can adapt themselves to human users naturally and persistently. To this end, we focus especially on the common cognitive process among human-human communication as well as the interactions between humans and animals/artificial agents. Then we implement the mental model of others at an algorithmic level and utilize it for the design of artifacts.

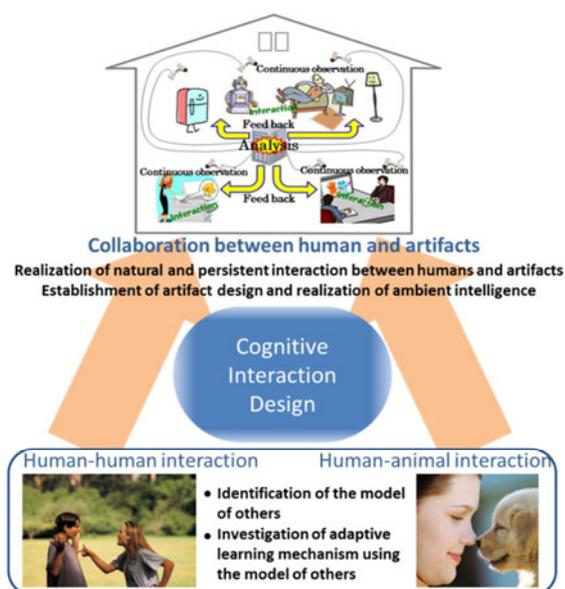


Fig.1 Overview of Cognitive Interaction Design

【Content of the Research Project】

We have three main challenges in this research project:

(1) Human-human interactions are cognitively analyzed to reveal 1) the mechanism of the mental model of others, 2) the way of interaction using the model, and 3) adaptation of the model in the course of interaction. We focus not only on the verbal communication but also on the nonverbal one. Both of adult-adult and child-adult interactions are analyzed.

(2) Human-animal interactions are analyzed to elucidate how companion animals such as dog or horse can learn the meaning of instructions through food (primary reinforcer) or prosodic features (secondary reinforcer). Moreover, we examine how animals estimate the internal states of their human partners using the acquired instructions, and how human change their interactions according to the internal states of the animals. These analyses lead to a cognitive model of mutual adaptation process, which includes the internal-model of others, in the human-animal interactions.

(3) Based on the above analyses, a methodology of designing artifacts that can adapt to users naturally and persistently is established. A novel design policy in terms of the adaptive and persistent interaction with human users will be provided. Furthermore, ambient intelligent systems including a user adaptable electric wheelchair, a concierge for online shopping, and so forth, will be developed.

【Expected Research Achievements and Scientific Significance】

Expected research achievements are 1) the establishment of CID at an algorithmic level, which is beyond the current interaction design framework, 2) the establishment of cognitive science of the interaction between humans and companion animals, which is not established yet, and 3) the application of these achievements to the design of artifacts that can adapt to users naturally and persistently.

【Key Words】 Human-Agent Interaction: a research field that aims to analyze and design interactions between humans and agents

【Term of Project】 FY2014-2018

【Budget Allocation】 668, 400 Thousand Yen

【Homepage Address and Other Contact Information】

<http://www.cognitive-interaction-design.org>

Grant-in-Aid for Scientific Research on Innovative Areas
 (Research in a proposed research area)

Interdisciplinary Area



Title of Project : Novel measurement techniques for visualizing 'live' protein molecules at work

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【Purpose of the Research Project】

Genomic DNA encodes the amino acid sequences of proteins. In the evolution of life, random mutations and natural selection have made the proteins molecular machines that autonomously form stable tertiary structures, for their functions as catalysts, sensors, actuators, and scaffolds in organisms. The 3D structures determined by X-ray crystallography are inevitably static, but they provide convenient explanations of the protein functions, as if they were macro-scale machines.

However, most structural biological techniques cannot properly convey the dynamic aspects of protein structures. In this research program, we aim to develop innovative measurement techniques, to vividly describe protein structures at their sites of action (Fig. 1).

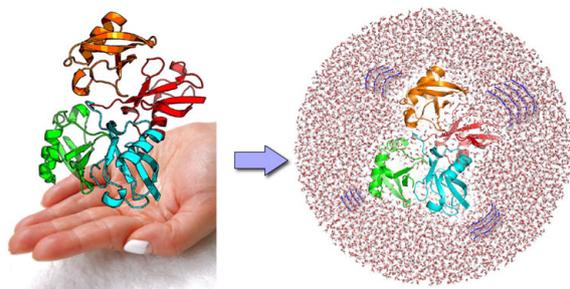


Figure 1: From a static view to a dynamic view.

【Content of the Research Project】

Nuclear magnetic resonance (NMR) and atomic force microscopy (AFM) are the methods of choice for characterizations of the time variations of protein structures. We must consider two fundamental problems, related to the "mean and distribution of motions" and the different structures between the "*in-vitro* and *in-situ* states" (See the Key Words section). We will solve the first problem by 1) "the integration of optical techniques into the high-speed AFM measurement" and 2) "the creation of crystal contact-free space in protein crystals" (Fig. 2). We will also address the second problem by 3) "the development of in-cell NMR measurement technology" and 4) "biologically-oriented application of optically detected magnetic resonance (ODMR), using nanodiamonds" (Fig. 2).

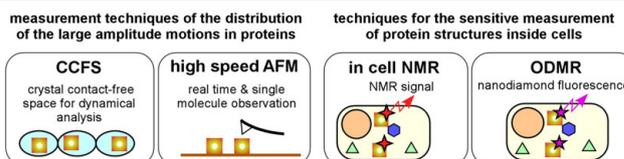


Figure 2: Measurement techniques for describing protein structures in action and on site.

Since new measurement techniques inevitably provide truly novel results, we will evaluate their precision by molecular dynamics simulations. We will also apply the new measurement techniques to specific biological targets to discover their potential applications and limitations, thus eventually accelerating the methodological development within a short time period.

【Expected Research Achievements and Scientific Significance】

The capabilities of Japanese life sciences research will be strengthened by developing innovative measurement techniques for protein dynamics. The applications of these novel techniques to a wide variety of biological problems will facilitate discoveries toward breakthroughs in life sciences.

【Key Words】

Problem of "mean and distribution of motions": Large motions give distorted mean structures. Therefore, the unbiased measurement of the distribution of motions is required.

Problem of "*in vitro* versus *in situ* states": A stable protein structure in a test tube and a biologically active structure in a cellular environment may differ, due to molecular crowding effects and interactions with other molecules.

【Term of Project】 FY2014-2018

【Budget Allocation】 1,171,000 Thousand Yen

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Title of Project : Understanding brain plasticity on body representations to promote their adaptive functions

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【Purpose of the Research Project】

As the Japanese society ages rapidly, we are experiencing a sharp increase in the number of patients of motor paralysis and other dysfunctions resulting from motor dysfunction, stroke, and neurodegenerative diseases. Thus, establishing effective rehabilitation techniques to overcome these motor dysfunctions is of paramount importance. The key to achieving this is to elucidate the mechanisms by which the brain adapts to changes in body functions. However, abnormalities in somatognosia can occur even in diseases that do not cause motor dysfunction. This indicates that we create and maintain a model of the body in the brain (body representation in the brain).

The purpose of this study is to elucidate the neural mechanisms of the body representation in the brain and the mechanism of the long-term changes in this representation and to apply these findings to rehabilitation interventions. In order to do this, we will attempt to combine brain science and rehabilitation medicine by using systems engineering (Fig. 1). We thereby intend to gain an integrated understanding of motor control and somatognosia in order to create a new academic discipline that is known as *embodied-brain systems science*.

【Content of the Research Project】

In order to achieve the above-mentioned goals of this study, we will establish nine research items (A01-03, B01-03, C01-03). In research items A01/02, we will conduct experiments on humans and monkeys by using methods that are based on interventional neuroscience in an attempt to understand the neural mechanisms of the body representation in the brain and the process by which it changes with respect to somatognosia (sense of agency, sense of ownership) and motor control (muscle synergy control, anticipatory postural control). We will use neural decoding and virus vector technology to investigate markers that reflect changes in the body representation in the brain. In research items B01/B02, we will create dynamic models of the differing time constants of the fast dynamics and slow dynamics of the body representation in the brain based on neurophysiological experimental data and clinical data from patients undergoing rehabilitation. In research items C01/C02, we will attempt to quantify the rehabilitative effects with the markers. By integrating this with a model of the body representation in the brain, we will implement model-based rehabilitation and create predictions of prognosis for intervention. The research items A03, B03, and C03 are those for subscribed research groups.

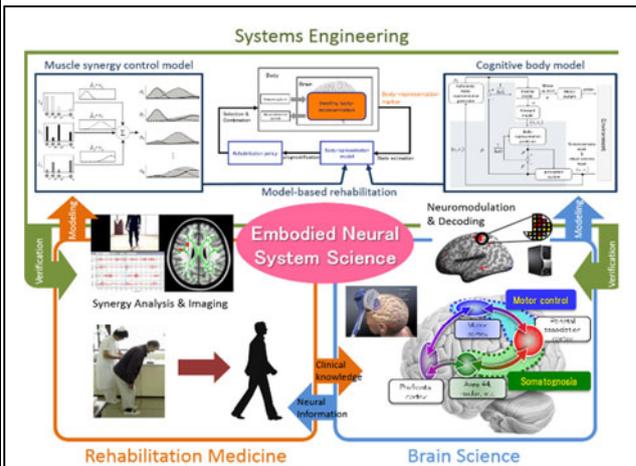


Fig. 1 Embodied-brain systems science area

【Expected Research Achievements and Scientific Significance】

Organically combining brain science and rehabilitation medicine by using systems engineering can be anticipated to yield the following three results:

1. By identifying the markers that reflect the moment-to-moment status and long-term changes in body representation in the brain, which govern somatognosia and motor control, it will be possible to quantitatively evaluate the effects of rehabilitation intervention.
2. By elucidating the slow dynamics of body representation in the brain and developing techniques that can be used to intervene in those dynamics, we will work toward developing innovative model-based rehabilitative techniques that permit predictions of prognosis.
3. We will describe the mechanisms of the important brain functions that are essential to the existence of somatognosia and motor control and pursue the computational principles of the brain that are shared by these functions.

【Key Words】

Body representation in the brain: Internal representation of the body. Indicators of posture and body structure that are updated moment-to-moment by a wide range of sensory inputs that are related to motor performance.

【Term of Project】 FY2014-2018

【Budget Allocation】 1,059,400 Thousand Yen

【Homepage Address and Other Contact Information】

<http://embodied-brain.org>