【Grant-in-Aid for Transformative Research Areas（A）】

Section Ⅳ

Title of Project： Analysis and synthesis of deep SHITSUKAN information in the real world

NISHIDA Shin'ya
(Kyoto University, Graduate School of Informatics, Professor)

Number of Research Area：20A401　Researcher Number：20396162

【Purpose of the Research Project】

SHITSUKAN is an important research topic for informatics, neuroscience, and industry. We have learnt from our past research that we should realize not only the superficial SHITSUKAN processing that links the sensory information to SHITSUKAN attribute variables and/or linguistic labels, but also the underlying hidden processing that we call Deep SHITSUKAN. Specifically, what we consider Deep SHITSUKAN are: (A) The process of calculating the ecological values of things or events from SHITSUKAN, including the subsequent process to induce emotional body responses. (B) The process of constructing action-predictive models of the external world in the brain from SHITSUKAN. (C) Processes in which SHITSUKAN processing is influenced by the characteristics of the individuals, such as age, brain dysfunction, and personal experiences (D) The process of determining what are real and fake through multimodal sensory information of actual objects. Based on this idea, we aim to deepen our understanding of SHITSUKAN by scientifically revealing human Deep SHITSUKAN processing, and developing innovative Deep SHITSUKAN technologies.

【Content of the Research Project】

Planned Research consists of three research items, "A01: SHITSUKAN Machine Recognition," "B01: SHITSUKAN Biological Recognition," and "C01: SHITSUKAN Generation" (Fig. 1).

In A01, Nishino's group will develop machine vision to recognize Deep SHITSUKAN, including states, intentions, and semantic structures of people, objects, and places. Okatani's group will reveal the indescribable internal representation of Deep SHITSUKAN. Sato's group will use advanced physical measurement technology to determine the differences between real and fake artworks.

In B01, Kamitani's group will use brain decoding technology to reveal the three-dimensional model of the external world using functional MRI. Minamimoto's group will use the advanced neural manipulation methods (e.g., DREADD) to elucidate the brain's mechanism for computing value from SHITSUKAN. Suzuki's group will elucidate the neural basis of SHITSUKAN cognition from the perspective of clinical neurology, and explore ways to improve the SHITSUKAN environment. Nishida's group will examine the mechanism of SHITSUKAN recognition from visual, tactile, auditory, and lingual information from the perspectives of psychophysics and sensory engineering.

In C01, Iwai's group will modulate real-world SHITSUKAN with novel wearable light modulation glasses. Watanabe's group will realize Deep SHITSUKAN manipulation by high-speed projection mapping. Kakehi's group will generate new SHITSUKAN by multimodal control of real materials.

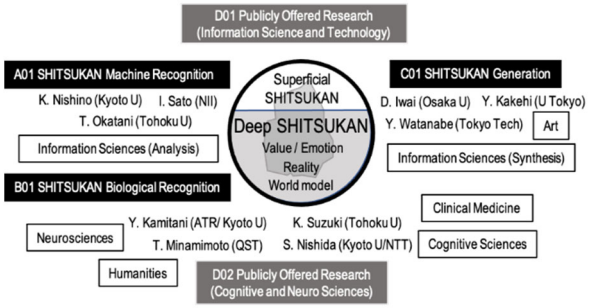

Fig. 1: Research formation

Planned Research will be supported by Publicly Offered Research groups belonging to either "D01: Information Science and Engineering for Deep SHITSUKAN" or "D02: Cognitive Neuroscience for Deep SHITSUKAN."

【Expected Research Achievements and Scientific Significance】

In informatics, we expect to develop technologies that can recognize Deep SHITSUKAN like humans do, recognize Deep SHITSUKAN that humans cannot perceive, and manipulate Deep SHITSUKAN in the real world as one wish. In art, we expect further fusion of art with science and the realization of ultimate cloned artworks. In cognitive neurosciences, we expect to make progress in understanding the neural mechanisms of Deep SHITSUKAN, the relationship between perception and emotion, and the nature of subjective reality. In clinical aspects, we expect to improve the quality of the living environment for people with brain dysfunction and to find universally comfortable SHITSUKAN environments.

【Key Words】

SHITSUKAN: A Japanese word that literarily means "the sense of quality." In this research project, we use this term to refer to the senses of physical properties, materials, and conditions of things and events, as well as the human ability to estimate the subjective values.

【Term of Project】 FY2020-2024

【Budget Allocation】 1,150,800 Thousand Yen

【Homepage Address and Other Contact Information】

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secretariate_Shitsukan2020@googlegroups.com

Title of Project： Creation and Organization of Innovative Algorithmic Foundations for Social Advancement

MINATO Shin-ichi
(Kyoto University, Graduate School of Informatics, Professor)

Number of Research Area：20A402　Researcher Number：10374612

【Purpose of the Research Project】

Algorithms, the theories, techniques and logical procedures of information processing, perform a key part of the recent sophisticated information society. Our project aims to develop and organize state-of-the-art techniques for algorithms. The results will be provided as open academic resources for many scientists and engineers in various fields, to be utilized for social advancement. Based on the recent drastic progress of computation power, upcoming innovative computation devices, and new concepts from social sense of values, we will reformulate and organize practical computation models to bridge theory and practice. We will also create and organize computational theories and state-of-the-art techniques for algorithms, such as discrete structure manipulation, constraint satisfaction problem solving, enumeration, discrete optimization, quantum computation theory, etc. Our results will be presented as the innovative *Algorithmic Foundations for Social Advancement* (AFSA).

【Content of the Research Project】

As shown in Fig 1, our AFSA-project consists of six research groups in two categories A and B. The groups in A (A01 and A02) investigate the interface layer to bridge theory and practice, and the groups in B (B01, B02, B03, and B04) investigate specific theories and techniques to support the interface layer. We also have a steering committee group and plan an open call for about 17 participants to work on additional related research topics. The contents of the six research groups are as shown below.

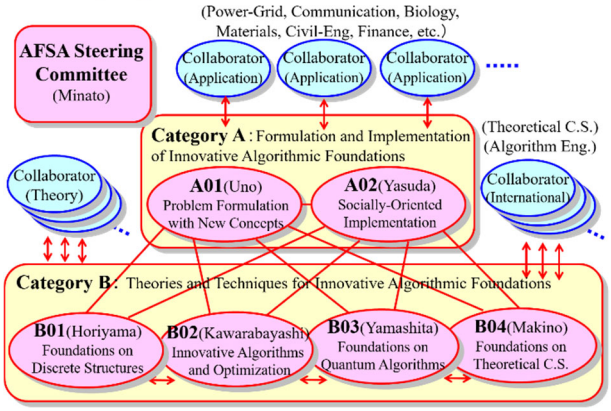

Fig. 1: Project Formation

A01: New Problem Formulation on Next Generation Informatics and Researches on their Algorithms

Collaborating with researchers in the application layer, this group discusses and formulates a set of new problems to be considered in the future society. We also design efficient algorithms based on a new approach.

A02: Socially-Oriented Algorithm Implementation

This group implements the algorithms proposed in our project and organizes the algorithmic foundations for social advancement. It provides an interface between theoretical researchers and application engineers.

B01: Algorithmic Foundations Based on Large-Scale Discrete Structures

By the collaboration of theoretical researchers and application engineers, this group tackles how to deal with exponentially large-scale discrete structures and develops new design methodologies of efficient algorithms.

B02: New Computational Models for Algorithms and Discrete Optimization

This group investigates basic research topics in the areas of discrete mathematics, combinatorial optimization, machine learning, etc. to develop efficient algorithms for solving very large-scale problems required in our society.

B03: Creation of Innovative Foundations to Bridge Theory and Practice of Quantum Algorithms

Combining the knowledge of classical computation and new quantum models, this group constructs useful algorithmic foundations to implement practically efficient quantum computers connected to conventional systems.

B04: Exploration and Development of the Basic Theory of Algorithms

This group investigates important problems in theoretical computer science, such as performance assurance, preserving fairness and stability, new computation models and design methodologies for social requirements.

【Expected Research Achievements and Scientific Significance】

This project will lead an active research community where theory and practice meet together. Our expected outputs are not only to produce top conference papers and journal publications, but also to contribute to real-life social problems by collaborating with application research engineers. These algorithmic foundations will be useful for various fields of science and technologies and aim to contribute to social advancement over the long-term.

【Key Words】

Algorithms: Techniques, procedures and strategies to produce valid and efficient computer programs.

【Term of Project】 FY2020-2024

【Budget Allocation】 856,800 Thousand Yen

【Homepage Address and Other Contact Information】

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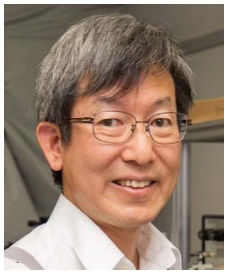

Title of Project： Molecular Cybernetics -Development of Minimal Artificial Brain by the Power of Chemistry

MURATA Satoshi
(Tohoku University, Graduate School of Engineering, Professor)

Number of Research Area：20A403　Researcher Number：10334533

【Purpose of the Research Project】

The project aims to establish a new methodology "how to assemble individual molecules and molecular devices into a system", by following the basic idea of the Innovative Area "Molecular Robotics" (2012-2016), but in far larger scale.

In practice, functional molecules acting as sensors, processors, or actuators are integrated to micrometer-sized compartment such as liposomes (artificial cells). The resulting artificial cells are further conjugated to each other to establish a methodology of engineering molecular systems with higher-ordered functions.

In contrast to typical robots or computers, which are assembled by wiring individual parts, the present "Molecular Systems Engineering" provides all the functions in bottom-up approach as chemical reactions between molecules in solutions.

【Content of the Research Project】

We construct micrometer-scale artificial molecular information processing system (Chemical AI or Minimal Artificial Brain), and make it process "Pavlovian Conditioned Reflex" to demonstrate the methodology of Molecular Cybernetics. To achieve this, we:

1. Develop microfluidic devices to align three individual artificial cells integrated with sensors, processors, and actuators in predetermined orders in each (Figure 1). They will be applied to a remotely controllable experimental system that records responses of the artificial cells exposed to various molecular stimuli. By sharing the system among the research community, we efficiently facilitate integration of research elements.
2. Develop "molecular information transfer devices (transducer)" to make artificial cells responsive to external stimuli or to transfer internal information of an artificial cell to adjacent one. To conjugate different kinds of artificial cells, proper transfer mechanisms of molecular information that do not require mixing of the internal solutions are necessary.
3. Establish design principle for molecular computing system with memory and learning ability using artificially synthesized nucleic acid molecules to demonstrate acquisition of "Pavlovian Conditioned Reflex" among aligned multiple artificial cells.
4. Develop "artificial actuator cells" to realize scalable information processing through formation of secondary connection (synapse) between multiple Minimal Artificial Brains by transforming their own shape.
5. Study the ethical, legal and social implications (ELSI) of Molecular Cybernetics through community-participating workshops and analyses on media and internet responses on the project.

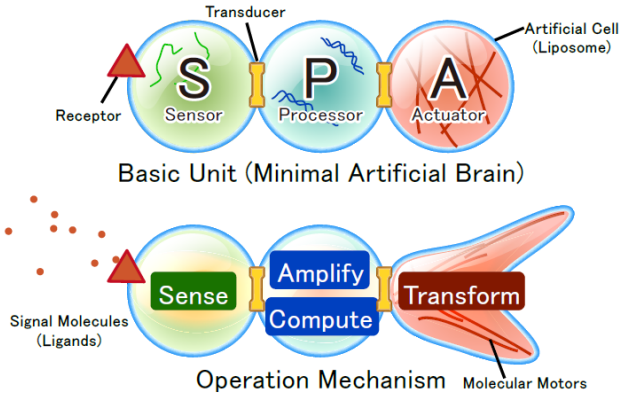

Figure 1 Chemical realization of Artificial Intelligence.

【Expected Research Achievements and Scientific Significance】

Molecular Cybernetics provide a foundation of versatile methodology to integrate various molecular devices into a system and may enable diverse application in the future. Feasible outcomes of the area include biosensors utilizing memory and learning function, artificial organs cultured as a hybrid between artificial and natural cells, and control of molecular swarm robots. Molecular Cybernetics is an attempt to reconstruct cybernetics (artificial intelligence) using principles in chemistry. This implies that cybernetics reach the level of molecules, that may revolutionize our outlook on matters and life.

【Key Words】

Molecular Cybernetics: A methodology to construct intelligent, information processing molecular systems by integrating individual molecular components or devices in large scale. Reconstruction of the concept of artificial intelligence in a material or molecular approach.

【Term of Project】

FY2020-2024

【Budget Allocation】

1,131,500 Thousand Yen

【Homepage Address and Other Contact Information】

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