論文の内容の要旨

論文題目: Time Scales, Synaptic Plasticity and Embodiment

(タイムスケール、シナプス可塑性、身体性認知)

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Abstract

The aim of this thesis is to approach a deeper understanding ofliving systems which exhibit amazing complexity and adaptivity, and to extract the essential logic underlying intelligence ofliving systems. The work of this thesis assumes that living organisms are products of self-organization. They are organized through natural evolution, which does not have goal nor intention. The functions that can be observed in living systems are not intended ones in advance, but spontaneously acquired through natural selection. The purpose of this thesis is to explore self-organized processes of behavior observed in living systems.

Especially, we focus on self-organization of time scales: The ability to regulate time scales is a fundamental requirement for living systems. Sensory perception, cognitive processing and motor control all require precise control on temporal information. The purpose of this thesis is to investigate 1) whether timescales can be self-organized in living systems, 2) whether having multiple time scales is efficient to generate adaptive behavior, and 3) how living organisms synthesize micro level time scales - or neuronal level and sensory / motor processing level - into macro level ones - or behavior.

This thesis has two basic backgrounds: artificial life (ALife) and embodied cognition. Those two share a motivation to create a theory for understanding natural intelligence from physical and dynamical aspects. The philosophy of ALife lies in creating life-like phenomena from non-living matters, such as computer simulation, robots, or biochemicals. The main focus of this research field is not on mimicking minute details ofliving systems, but creating abstracted features of them, such as self-reproduction, autonomy, enaction, sustainability, or evolvability. This methodology, we believe, will reveal essential principles underlying living organisms. Embodied cognition is a

philosophy to understand the nature of intelligence. This theory suggest that natural intelligence is not designed by an external observer, but spontaneously emerges from complex interaction between the body, brain and environment, as a process of self-organization.

Based on the two basis, we explore self-organization of time scales observed in living organisms by creating two artificial systems: one is a robot, and the other is a system composed of neurons *in vitro*. The robot is equipped with self-organized brain system, where we observed behavioral change during a course of learning. There are several time scales concerning the robotic system: the fastest time scale lies in sensory processing, followed by learning speed, and the largest time scale concerns the generation of behavior. We observe coherent behavior, i.e., solving a T-maze, can be self-organized from the multiple time scale system. In the experiment with the biological neuron, we hypothesize that material property of the biological neuron innately has intelligent properties to organize time scales. The biological neurons are cultured in *in vitro* and we recode spontaneous development of them with a micro-electrode array for several weeks. In both experiments, we observe and analyze self-organized patterns, to finally synthesize them into understanding of living systems.