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Theoretical approach to neural phenomena by using symmetry properties

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However the complex circuitry and nonlinear dynamics in neural systems, the neural behavior at high levels may obey simple and general rules. As an example, we show that the map formation phenomena at visual cortex can be understood systematically by using only symmetry properties. The highly ordered structure in the mammalian visual cortex has attracted much attention from theoretical neurobiologists and has been thoroughly with the expectation of providing the basis for neural dynamics and computational models. Even though there are quite a number of successful models with unique mechanisms, we show that the typical characteristics of emergent visual maps are so universal ones in other physical systems.

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Evolution-theoretic Approach to Synthetic Study of Intelligence

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1. INTRODUCTION

I want to state the following three points:

1. To study intelligence, we need internal observation (endo-system view).
2. A science with endo-system view requires a different methodology, a synthetic loop, from sciences with exo−system view that require analytic loops.
3. The essential driving force of a synthetic loop is the evolutionary method.

2. ENDO-SYSTEM VIEW

Study of intelligence needs different research methodology than natural sciences. In natural sciences, the target system of the study is isolated and observed. The observation should not interfere with the target system. Psychology once tried to apply the same methodology to the study of animal and human intelligence - behaviorism. Experimental psychology adopted methodology of analytical science and refused use of retrospection or introspection that is known to be incomplete and sometimes wrong.

Cognitive Science, on the contrary, talks about internal processes and representations of intelligent agents. Since we ourselves are the best examples of such intelligent agents, observation from inside (introspection) is useful. Artificial Intelligence (AI) is the research area that seeks for the definition of intelligence. The target is the concept of intelligence in the abstract level which does not rely on any particular hardware. The basic methodology of AI is to construct a program that exhibits intelligent behaviors. The behavior of the program is then compared with that of natural intelligence such as human.

We proposed to use endo-system view, a methodology in which a constituent of a system of interactions observes the whole system from inside[9]. Meta-cognition, cognition of its own cognitive processes, is an example of such endo-system view. This makes contrast to exo-system view implicitly employed for analytical science.

3. SYNTHETIC LOOP

AI is not a natural science. If it were a natural science, then the target of AI research would have been limited to naturally existing intelligent systems. But it seeks for the abstract definition, and its research methodology is closer to those of mathematics or philosophy. Harvard Simon proposed a science of the artificial along the same direction[11].

We are proposing a new way of science, "constructive science", in contrast to "analytical science". The basic methodology of analytical science is to divide a system into its simpler subsystems and recursively analyze them till we understand every subsystems and the structure of their connection. A precondition of doing this is that the analysis process does not affect the system being analyzed. Constructive science, on the other hand, starts from simple units and tries to construct a complex system. In this paradigm, therefore, the system is to be observed as it changes dynamically.

Cognitive system, in case of AI, includes researchers, a program and the environment of the execution of the program. It is important to note that the researcher is in the system. Why? Firstly, a programmed system largely differs from living intelligence. Therefore, a program shows intelligent behavior only under certain view frame that is set by the researcher. Secondly, and more importantly, a program seldom shows perfect behavior even under some restricted designed domains. It is thus important to fix the program to overcome some behavioral shortcomings in certain conditions. The programmer or the researcher is the integrated part of programs development.

Synthetic process consists of the loop of the following:

1. FN (A future noema[5]): the goal, or an initial plan
2. Generation: construction/synthesis of a system to realize the goal

3. NS (A noesis): actualization of noema
4. Interaction: interaction of NS with the environment (existence of this is very important)
5. Analysis: analysis of the interaction
6. CN (A current noema): analyzed characteristics of the system (may contain new theories)
7. Feedback: to feedback the analysis to the next plan For more detailed description of Noesis and Noema refer to other articles[7, 6].

Havel[3] claimed that intelligence is a scale thick system, which is impossible to be designed, and we have to rely on "emergence" to realize such scale-this systems. In our synthetic loop, the target intelligence is a FN. We construct a system NS hoping to realize this. However, since intelligence is a complex system, the system rarely behaves as desired. Interaction with the environment make this worse. Some new behavior "emerges" here. We have to analyze the resulting behavior to get a new view FN, and feed this back to the next cycle. In case of scale-thick systems, the diagram becomes multi-layered. In this case, interaction with the environment is further decomposed into lower-level FNS diagram, thus forming a fractal system[8]. There is no algorithmic procedure for neither of the three processes, generation, analysis and feedback, in the loop. We claim that each step recursively consists of a loop of trial and error[10].

4. EVOLUTIONARY METHOD

The FNS-diagram tells us the following:

We have to repeat a synthetic loop to approach our goal (future Noema). However, the goal itself may change during the process.

The process itself forms a complex and holistic system. We cannot directly control complex interactions. We have to harness[1] the system, as we do when we ride horses. Then the next question is how we can learn to harness a system. I believe that the answer lies in the evolution process. Evolution process simplified to its bone consists of the following two phases taking place one after another:

1. Random generation.
2. Selection (criteria changes dynamically).

Ichikawa[4] views evolution as a general process of ever changing systems and sets the following conditions for a system to be an evolutionary system:

1. Existence of self-replication unit (genome) to maintain regularity
2. Existence of a system structure of self-replication units
   (existence of elements and a system that connects those elements)
3. Possibility for mutation of the system structure

4. Interaction (competition) among replicator systems (for frequencyof replication)

5. Existence of external environment

It must be noted that the synthetic loop differs from natural evolution in two points:

1. Natural selection is just a result of blind selection - the system succeeded in outnumbering other systems in replicating itself remains[2].. Synthetic loop, on the other hand, has the goal and directionality.

2. Synthetic loop can employ several optimization methods for local improvements. Only big jumps must rely on random generation.

While the generation of candidates can be achieved mechanically, evaluation is more difficult in general. However, the various possibilities are not just generated randomly. Efficient search methods are necessary and the genetic algorithm is one example. Locally, hill-climb algorithm or optimization method for parameters of equations may be applicable, but those are limited to areas where analysis of the subject has completed.

Ichikawa claims that modern science and technology are comprised of an evolutionary system. This is evidence that evolutionary methodology is one of a synthetic method. On the other hand, it is difficult to argue that this is the only possible methodology. However, there are plenty of circumstantial evidences supporting the claim. Evolution in nature, for instance, succeeds by employing this method.

Acknowledgment

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5. REFERENCES

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Macroscopic relationship among robustness, evolvablity, and phenotypic fluctuations

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Characterization of biological plasticity, robustness, and evolvability in terms of dynamical systems and statistical analysis is an important issue in Complex Systems Biology. First, proportionality among evolution speed, phenotypic plasticity, and isogenic phenotypic fluctuation is derived as an extension of fluctuation-response relationship in physics. Following an evolutionary stability hypothesis we then derive a general proportionality relationship between the phenotypic fluctuations of epigenetic and genetic origin; The former is the variance of phenotype due to noise in developmental process, and the latter due to genetic mutation. The relationship suggests a link between robustness to noise and to mutation, as robustness can be defined by the sharpness of the distribution of phenotype. Second, the proportionality between the variances is demonstrated to hold also over different phenotypic traits, with which a measure for phenotypic plasticity is proposed. The obtained relationships are confirmed in models of gene expression dynamics, as well as in laboratory experiments. Third, evolutionary restoration of plasticity is investigated both theoretically and experimentally in terms of fluctuations.

Based on the results, we revisit Waddington's canalization and genetic assimilation, and discuss how consistency between evolutionary and developmental scales constrains robust developmental process and leads to universal laws on phenotypic fluctuations.