On Abstract Intelligence and Brain Informatics: Mapping Cognitive Functions of the Brain onto its Neural Structures

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ABSTRACT

A key notion in abstract intelligence and cognitive informatics is that the brain and natural intelligence may only be explained by a hierarchical and reductive theory that maps the brain through the embodied neurological, physiological, cognitive, and logical levels from bottom-up induction and top-down deduction. This paper presents an abstract intelligence framework for modeling the structures and functions of the brain across these four levels. A set of abstract intelligent model, cognitive functional model, and neurophysiological model of the brain is systematically developed. On the basis of the abstract intelligent models of the brain at different levels, the conventionally highly overlapped, redundant, and even contradicted empirical observations in brain studies and cognitive psychology may be rigorously clarified and neatly explained. The improved understanding about the brain has led to the development of a wide range of novel technologies and systems such as cognitive computers, cognitive robots, and other applied cognitive systems.

Keywords: *Abstract Intelligence, Brain Informatics, Cognitive Computing, Cognitive Informatics, Computational Intelligence, Denotational Mathematics, Natural Intelligence, Neurocomputing, Neuroinformatics*

1. INTRODUCTION

A fundamental challenge faced by almost all scientific disciplines is to explain how natural intelligence is generated by neurophysiological organs and what the logical function model of the brain is beyond its neurological structures. The human brain is not only a superbly marvelous organ, but also an extremely complicated neurological structure for embodying natural intelligence that transforms cognitive information into colorful behaviors. The brain is the most complex and interesting object in nature that requires scientific investigations by multidisciplinary methodologies and via transdisciplinary approaches where only low-level studies could not explain it.

The early doctrine about the functional allocation of the brain and natural intelligence was the dualism of brain and soul (Leahey, 1980). Rene Descartes attempted to treat brain studies as a

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scientific subject where he perceived that the brain was a hydraulic system and mental functions were generated by a spiritual entity in 1649 (Descartes, 1979). Franz Gall proposed phrenology as a study on the brain based on its external shapes and features in 1796. Paul Broca found that an area in the left frontal cortex, then is called Broca's area, is related to language processing for word meaning (front part) and word formation (back part) in 1861. Carl Wernicke identified another area of cerebrum that is in charge of language comprehension in 1876 lately known as Wernicke's area, which lies in upper temporal lobe adjacent to parietal and occipital lobes (Sternberg, 1998; Carter, 1999).

Although mankind has already been able to possess well developed knowledge about the universe at both macro and micro levels, there is still a lack of a deep and scientific understanding about the special organ that everybody possesses, the brain, despite rich anatomical observations and detail level studies in neuroscience, physiology, brain science, and cognitive psychology. The problem seems to be hard enough because it has existed since the beginning of human civilization. The main reasons that cause the lasting difficulty in brain studies can be classified in those of philosophically recursive, cognitively abstract, and mathematically inadequate categories (Wang, 2012a). The *philosophically recursive* reason refers to that the study on the brain is a *recursive* problem where people attempt to reveal the brain by using the same brain in which the problem complexity is higher than, or at least equal to, the intelligent capability attempting to solve it. This situation is much like that a computer scientist attempts to use an application program to understand the operating system that boosts and controls the program, when the principles of computing were unknown. The *cognitively abstract* reason is that the mental processes of the brain are virtually intangible and highly abstract. The problem is fundamentally different from those of almost all other scientific disciplines where the objects under study are in the physical world rather than in the mental or abstract information world. The third reason, *mathematically inadequate*, is the lack of a suitable mathematical means that may essentially reduce the problem complexity and increase reasoning efficiency in manipulating the extremely complex mental systems in the domain of hyper structures beyond the traditional mathematical domain of real numbers (Wang, 2012b).

The architectural framework of abstract intelligence encompass a wide range of coherent fields, as shown in Figure 1, from the computational, machinable, and artificial intelligence to natural intelligence in the horizontal scopes, and from the logical, cognitive, and physiological models to the neurological model in the vertical reductive hierarchy. Therefore, abstract intelligence forms the foundation of a transdisciplinary enquiry of intelligence science and brain science. The key notion in abstract intelligence and cognitive informatics is that the brain and natural intelligence may only be explained by a hierarchical and reductive theory that mapping the brain across the neurological, physiological, cognitive, and logical levels.

Abstract Intelligence (αI) is the general mathematical form of intelligence as a complex natural mechanism that transfers information into behaviors and knowledge at the embodied neurological, physiological, cognitive, and logical levels from bottom-up aggregations and top-down reductions. Towards formal explanation of the architectures and functions of the brain, as well as their intricate relations and interactions, a set of systematic and rigorous models are sought for revealing the principles and mechanisms of the brain at the neurological, physiological, cognitive, and logical (abstract) levels. Cognitive informatics and αI investigate into the brain via not only synergetic syntheses through the four cognitive levels from the bottom up in order to form theories on the basis of empirical observations, but also deductive analyses from the top down in order to explain various functional and behavioral instances according to the αI theory.

This paper presents a theoretical framework of αI for explaining the brain through the reductive levels of logical, cognitive, physiological, and neurological models. Section 2 introduces the

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