Cognitive Informatics

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INTRODUCTION

Cognitive informatics (CI) is an emerging discipline that studies the natural intelligence and internal information processing mechanisms of the brain, as well as the processes involved in perception and cognition. CI provides a coherent set of fundamental theories and contemporary mathematics that form the foundation for most information- and knowledge-based science and engineering disciplines, such as computer science, cognitive science, neuropsychology, systems science, cybernetics, software engineering, and knowledge engineering.

The development of classical and contemporary informatics, the cross-fertilization between computer science, systems science, cybernetics, computer/software engineering, cognitive science, neuropsychology, knowledge engineering, and life science has led to an entire range of the extremely interesting new research field known as CI (Chan, Kinsner, Wang, & Miller, 2004; Kinsner, Zhang, Wang, & Tsai, 2005; Patel, Patel, Wang, 2003; Wang, 2002a, 2003, 2004, 2006a, 2006b, 2007b; Wang, Johnston, & Smith, 2002; Wang & Kinsner, 2006; Yao, Shi., Wang, & Kinsner, 2006). CI is a transdisciplinary study of cognitive and information sciences that investigates the internal information processing mechanisms and processes of the natural intelligence generated by the human brain. CI is a cutting-edge and profound interdisciplinary research area that tackles the fundamental problems shared among aforementioned disciplines. Almost all of the hard problems yet to be solved in these areas can be deduced onto the common root for understanding the mechanisms of natural intelligence and cognitive processes of the brain.

COGNITIVE INFORMATICS: A NEW TRANSDISCIPLINARY RESEARCH FIELD

CI is a new transdisciplinary field of research that investigates into the most common problems of how the brain processes information shared by almost all science and engineering disciplines. This section examines the nature of information and the historical development of the three-generation informatics that lead to the establishment of CI.

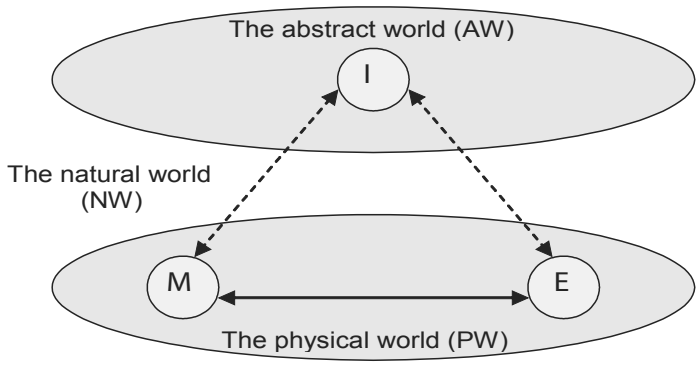
Informatics: A study on the third essence of the world. The basic characteristic of the human brain is information processing. Therefore, information is recognized as the third essence supplementing matter and energy to model the natural world (Wang, 2002a, 2003, 2007b).

Definition 1. Information is any property or attribute of the natural world that can be distinctly elicited, generally abstracted, quantitatively represented, and mentally processed by the brain.

Definition 2. Informatics is the science of information that studies the nature of information, its processing, and ways of transformation between information, matter and energy.

Theorem 1. A generic world view known as the Information-Matter-Energy (IME) model (Wang, 2007a, 2007b) states that the natural world (NW), which forms the context of human cognitive activities and the natural intelligence, is a dual world. One aspect of it is the physical or the concrete world (PW); the other is the abstract or the perceptive world (AW), where matter (M) and energy (E) are used to model the former, and information (I) to the latter.

Figure 1. The IME model of the world view



Theorem 1 can be illustrated in Figure 1. According to the IME model, information plays a vital role in connecting the physical world and the abstract world. Models of the natural world have been well studied in physics and other natural sciences. However, the modeling of the abstract world is still a fundamental issue yet to be explored in cognitive informatics, computing, software science, cognitive science, and brain sciences. Especially, the relationships between I-M-E and their transformations are perceived as one of the fundamental questions in CI.

From conventional information theory to CI. The theories of informatics and their perceptions on the object of information have evolved from the conventional information theory, to modern informatics, and to cognitive informatics in the last 6 decades. *Conventional information theories* (Bell, 1953; Shannon, 1948), particularly Shannon's information theory (Shannon, 1948), known as the first-generation informatics, study signals and channel behaviors, and they are statistics and probability based. *Modern informatics* (Wang, 2007a) known as the second-generation informatics studies *information* as properties or attributes of the natural world that can be generally abstracted, quantitatively represented, and mentally processed. The first- and second-generation informatics put emphases on external information processing that overlook the fundamental fact that human brains are the original sources and final destinations of information, and any information must be cognized by human beings before it is understood. This observation leads to the establishment of the third-generation informatics, a term coined as CI by Wang in 2002 (Wang, 2002a, 2003, 2007b).

Definition 3. CI is the transdisciplinary enquiry of cognitive and information sciences that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence, and their engineering applications via an interdisciplinary approach.

The definitions of information and their measurement in the three-generation informatics are summarized in Table 1. It is noteworthy that the *bit* in the 2nd- and 3rd-generation definitions has been shifted from a weighted sum of probability of signals to a more concrete and deterministic entity, and it is no longer probability-based as that of the conventional information theory. It is recognized in CI that cognitive information and knowledge being processing in the brain can be divided into five abstract levels, such as the levels of *analogue objects, diagrams, natural languages, professional notation systems,* and *mathematics* (*philosophy*) from the button-up.

THE THEORETICAL FRAMEWORK OF CI

In many disciplines of human knowledge, almost all of the hard problems yet to be solved share a common root in the understanding of the mechanisms of natural intelligence and the cognitive processes of the brain. Therefore, CI is a discipline that forges links between a number of natural science and life science disciplines with informatics and computing science. The structure of the theoretical framework of CI is described in Figure 2, which encompasses the fundamental theories of CI, descriptive mathematics for CI, and the key application areas of CI.

The fundamental theories of CI. The fundamental theories of CI have been developed in 10 aspects