Chapter 5
On the Mathematical Theories and Cognitive Foundations of Information

Yingxu Wang
University of Calgary, Canada

ABSTRACT

A recent discovery in computer and software sciences is that information in general is a deterministic abstract quantity rather than a probability-based property of the nature. Information is a general form of abstract objects represented by symbolical, mathematical, communication, computing, and cognitive systems. Therefore, information science is one of the contemporary scientific disciplines collectively known as abstract sciences such as system, information, cybernetics, cognition, knowledge, and intelligence sciences. This paper presents the cognitive foundations, mathematical models, and formal properties of information towards an extended theory of information science. From this point of view, information is classified into the categories of classic, computational, and cognitive information in the contexts of communication, computation, and cognition, respectively. Based on the three generations of information theories, a coherent framework of contemporary information is introduced, which reveals the nature of information and the fundamental principles of information science and engineering.

1. INTRODUCTION

It is recognized that *information* is a general form of abstract objects perceived by human brains and represented by symbolical, mathematical, communication, computing, and cognitive systems. Therefore, information is one of the essences of the physical and abstract worlds among matter, energy, and intelligence. *Information science* is one of the contemporary scientific disciplines beyond the traditional natural, engineering, and social sciences, which are collectively known as *abstract science* or science of sciences such as system, information, cybernetics, cognition, knowledge, intelligence sciences in addition to mathematics, logic, and philosophy. They are abstract science in common because human

knowledge in nature is a multi-layer hierarchical structure where only the lower-layer of knowledge is directly related to the material world.

The concept of information may be traced back to the work of Hartley, Shannon, Weaver, Bell, Goldman, and Ash during the 1920s to 1950s [Hartley, 1928; Shannon, 1948; Shannon and Weaver, 1949; Bell, 1953; Goldman, 1953; Ash, 1956]. Since then, information has been perceived quite diversely in sciences, engineering, society, and everyday lives. Typical perceptions on information have been such as communication signals, probable channel properties, messages, entropy, states, relations, knowledge, data, sensorial inputs, perceptions, semantics, reasoning products, and thinking threads [Gray, 1990; Zadeh, 1997; Wilson & Frank, 2001; Skowron & Stepaniuk, 2001; Cover & Thomas, 2006; Belkin & Robertson, 2007, Zhong, 2013; Wang, 2002, 2003, 2006, 2007b, 2012a; Wang & Fariello, 2012; Wang et al., 2009a, b, 2010].

The role and nature of information can be elaborated by *the universe of discourse of humanity* (*UDH*) [Wang, 2003; Wang et al., 2006], which reveals that the natural world is a dual encompassing both the physical world (*PW*) and the abstract world (*AW*) as shown in Figure 1. There are four essences for modeling the natural world (*NW*) in UDH known as *matter* (*M*), *energy* (*E*), *information* (*I*), and *intelligence* ($\dot{\mathbb{I}}$). Therefore, UDH can be denoted by the *information-matter-energy-information-intelligence* (MEII) model with the four essences of the natural world (*NW*).

The MEII model of UDH indicates that Information is an abstract denotation of objects in the physical or abstract world, which is one of the most primitive essences and the general form of abstract objects perceived by human brains. In the MEII model, the double arrows denote bi-directional relations between the essences in the dual universe of discourse where known relations are denoted by solid lines, and relations yet to be discovered are denoted by dash lines. According to the MEII model, information is the generic model for representing and embodying the abstract world perceived by human beings via symbolical, mathematical, communication, computing, and cognitive means. It is noteworthy that intelligence ($\dot{\mathbb{I}}$) plays an irreplaceable role in the transformation between information, matter, and energy according to the MEII model.

Figure 1. The MEII model of the universe of discourse of humanity (UDH)
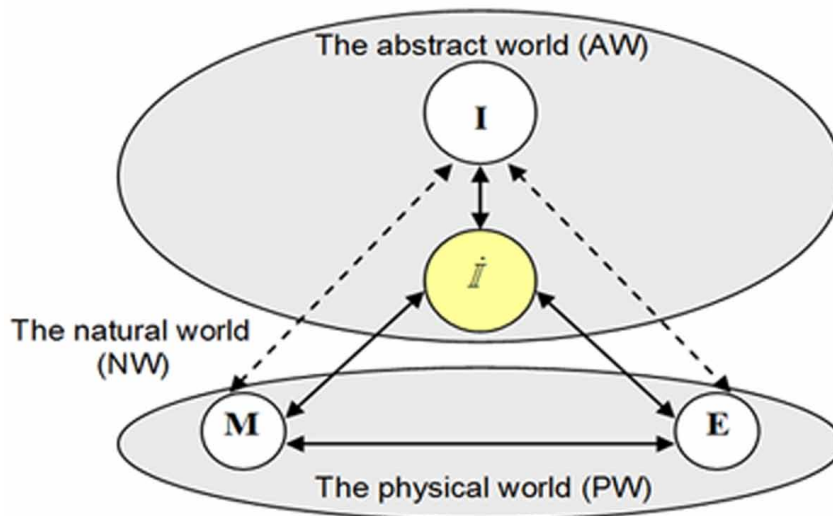
Related Content

A Neutrosophic Intelligent System for Heart Disease Diagnosis: Case Study in Developing Country
Nouran M. Radwanand Wael K. Hanna (2022). *International Journal of Fuzzy System Applications (pp. 1-13).*
www.irma-international.org/article/a-neutrosophic-intelligent-system-for-heart-disease-diagnosis/302121

An Intelligent Approach for Virtual Chemistry Laboratory
Shikha Mehta, Monika Bajajand Hema Banati (2016). *Handbook of Research on Advanced Hybrid Intelligent Techniques and Applications (pp. 483-517).*
www.irma-international.org/chapter/an-intelligent-approach-for-virtual-chemistry-laboratory/140465

Fog Computing as Solution for IoT-Based Agricultural Applications
Amany Sarhan (2021). *Smart Agricultural Services Using Deep Learning, Big Data, and IoT (pp. 46-68).*
www.irma-international.org/chapter/fog-computing-as-solution-for-iot-based-agricultural-applications/264958

Testing Exchangeability With Martingale for Change-Point Detection
Liang Daiand Mohamed-Rafik Bouguelia (2021). *International Journal of Ambient Computing and Intelligence (pp. 1-20).*
www.irma-international.org/article/testing-exchangeability-with-martingale-for-change-point-detection/275755

Embracing Generative AI in the Classroom Whilst Being Mindful of Academic Integrity
Lynsey A. Meakin (2024). *Academic Integrity in the Age of Artificial Intelligence (pp. 58-77).*
www.irma-international.org/chapter/embracing-generative-ai-in-the-classroom-whilst-being-mindful-of-academic-integrity/339219