

Cyber-Physical-Social Intelligence

on

Human-Machine-Nature Symbiosis

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Forward

Artificial intelligence is likely to be the dominant force in science and society over the next 5-20 years. We will develop human intelligence and machine intelligence together towards a synergistic cyber-physical-social intelligence. This will lead to transformational developments in science and society, with a new multi-dimensional reality emerging and evolving with a rich set of interconnected realizations. Clearly, there is a fundamental scientific problem as to what are the essential mechanisms that structure and evolve the cyber-physical-social world.

This research monograph explores the fundamental concepts, rules, and principles of human-machine-nature symbiosis in the cyber-physical society that will exhibit cyber-physical-social intelligence. The monograph explores these ideas in three directions: link, dimension, and flow. The compelling argument builds on three innovative long-term research directions, where the author is a recognized pioneer. Firstly, there is the Semantic Link Network that is a highlight of the development of semantics modeling. Secondly, there is the multi-dimensional Resource Space Model that develops a non-relational data model for managing the various resources in the emergent cyber-physical-social world. Finally, there is the Knowledge Flow Network that significantly transforms the traditional representation of knowledge.

Taking a big-picture view of science, society, and reality, this work further studies the rules and the emerging patterns for recognizing, integrating and optimizing various flows (material flow, data flow, information flow, and knowledge flow) through cyberspace, physical space, and social space. Research unveils a reciprocal human-machine-nature symbiosis and the rules that structure and evolve reality. The monograph includes both the science underlying cyber-physical-social intelligence and an analysis of its implications in four different applications: Construction of a Symbiotic Network to Create Value; Recommendation of Things in a Cyber-Physical Society; the Evolution of Information Systems; and Healthcare and Medicine with a Human-Machine-Nature Symbiosis.

Hai Zhuge has been my inspirational friend for many years. I commend his remarkable vision to your attention. This work makes a fundamental contribution to the formation and development of the emerging research area of cyber-physical-social intelligence.

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Preface

A fundamental scientific challenge is how to recognize reality, including the nature, life and mind. All problems and curiosities come from lacking knowledge on reality.

As we cannot observe reality from the view outside the world, we have to rely on our organs with limited ability to sense reality directly or through machines and then interpret reality using our minds' information processing mechanisms based on the models that we have already built. But this opinion brings a new problem: Where do these models come from? There are two possibilities: One is that our minds have innate basic models, and the other is that our minds have the ability to generalize the sensory information into some basic components of models, compose the components into larger components, and finally compose the basic models that can interpret our observations. Our minds have the ability to zoom-in and zoom-out: Decompose an observation into smaller components that can be interpreted by existing models or compose existing models to interpret the observation.

The assumption of this component-based cognition can interpret many phenomena. Students learn a subject by learning its knowledge points taught in separate courses and then linking the knowledge points to a knowledge network on the subject. Our minds instruct the design of artificial system (e.g., buildings) by designing its components and then composing the components into the whole system. Computer system is constructed in this way. Software system (e.g., Service-Oriented Architecture) is designed in this way. The fundamental principles of the component-based system include the least effort principle, e.g., the component-based system can be constructed and maintained with the least effort of operations. 3D printing can construct artificial systems from a dimension that is different from the dimension of viewing components.

Individuals have different knowledge structures in minds due to their differences in experience and education and have different ways to represent understandings of reality so different models are often used by different individuals to interpret the same reality. As humans can only observe and experience a small space of reality, the models built by minds are usually unable to reflect reality nor the majority of reality.

The key to take a further step approaching reality is to build human-machine-nature symbiosis to enable humans to interact with the nature more significantly, widely and sustainably through a constant reciprocal development process. To reach this aim we need to understand the semantics of various interactions more profoundly (H. Zhuge, *Interactive Semantics, Artificial Intelligence*, 174(2010)190-204).

Symbiosis and competition are two basic driving forces that link and co-evolve cyberspace, physical space and social space, rendering cyber-physical-social space.

The evolution of cyber-physical-social space emerges and develops Cyber-Physical-Social Intelligence (CPSI).

Different from traditional artificial intelligence, the development of CPSI is driven by the fundamental interactions in cyberspace, physical space and social space. This book investigates the fundamental interactions such as linking and flowing, explores the driving forces of co-evolution, studies the principles and methods of cyber-physical-social space, and carries out strategic analysis on applying the concepts, rules, principles and methods to real applications.

The origin of the knowledge flow of this research is from my Keynote “Future Interconnection Environment — Dream, Principle, Challenge and Practice” at the 5th International Conference on Web-Age Information Management (WAIM 2004), which was extended to a paper “The Future Interconnection Environment, IEEE Computer 38(4)(2005)27-33” where an advanced infrastructure for cyber-physical-social space and the conception of ternary space were introduced. The concept of Cyber-Physical Society was introduced in my Keynote (Socio-Natural Thought Semantic Link Network: A Method of Semantic Networking in the Cyber Physical Society. AINA 2010: 19-26). The ternary space was extended to include psychological space, physiological space and mental space to form a Cyber-Physical-Physiological-Psychological-Socio-Mental Environment, where diverse spaces emerge, co-evolve, compete and cooperate with each other to extend machine intelligence and human intelligence in my paper “Semantic Linking through Spaces for Cyber-Physical-Socio Intelligence: A Methodology, Artificial Intelligence, 175(2011)988-1019”. The thought of Cyber-Physical Society was developed in my book “The Knowledge Grid: Toward Cyber-Physical Society, World Scientific Publishing Co. 2012”. The thought was applied to transform traditional text summarization method into a general summarization method as introduced in my book “Multi-Dimensional Summarization in Cyber-Physical Society, Morgan Kaufmann, 2016”.

It was the date of death of Karl Max who contributed his lifetime to finding the fundamental socioeconomic structure and development rules of society and also the date of birth of Albert Einstein who contributed his lifetime to find the fundamental relations and laws of the nature when I wrote this preface. I would like to take this opportunity to salute the two great men.

In the new century, human society co-evolves with cyberspace and physical space. More and more traditional production and services will be developed from fulfilling low-level social motivation to fulfilling high-level social motivation. Material flow, data flow, information flow and knowledge flow will coordinate to operate an efficient pattern of symbiosis among individuals, organizations, communities and spaces to render CPSI, with which humans are able to explore the unknown field.

This research monograph is to make a fundamental contribution to the study of CPSI, inspire researchers to explore the emerging principles on CPSI and relevant theories and methods, and provide reference framework and methods for researchers and practitioners to create new techniques that can transform the existing techniques in various applications with the evolution of Cyber-Physical Society. It

can be also used as an extended reading material of research-led teaching programs in university.

Hai Zhuge
14 March 2019

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