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A Cyber-Physical Social Approach

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To Jenny and Ryder.

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Preface

Parallel Population of Parallel Human in Metaverses

This book is a result of an ambitious research agenda I made for myself almost 30 years ago after reading Karl Popper's ***The Open Society and its Enemies***. To me, the open society should have no enemies, we must find a way to build the bridge between Popper's utopian social engineering and piecemeal social engineering, perhaps through the *Cyber-enabled Social Movement Organizations and Operations* (**CeSMO**), and that would be my research for the rest of my professional career. I had promised myself to write a book entitled ***The Open Society and its Friends***, and even created a new name for my ambition, ***Bemonad***, for *Becoming* and *Being* Gottfried Leibniz's *Monad*, which was redefined as the atom of intelligence for Popper's Artificial World in the sense of ancient Greek philosopher Democritus' atom for matters in the Physical World. Of course, I realized very soon that it is simply a dream and a mission impossible. However, this had dramatically changed my career path from intelligent control for robotic systems to a mixture of science, technology, engineering, and social studies for complex intelligent systems, or an interdisciplinary approach by today's term, starting from my technical report at *NASA/UA Space Engineering Research Center* (SERC) on *Shadow Systems* in 1994 and ending up with the creation of the *Program for Advanced Research in Complex Systems* (PARCS) at the University of Arizona, Tucson, Arizona in 1999.

During the late 1990s and entire 2000s, I spent all my energy and enthusiasm in building Sino-US research collaboration projects and programs for coming and future *Intelligent Science and Technology*, from the *US-China Joint Research Center on Intelligent Control and Systems to US-Sino Center for Advanced Research and Education* (US-CARE), including projects such as **FPGA** (*Foundational Platforms and Gateways for All*) to support start-ups and intelligent industries, **CASIA** (*Complex Adaptive Systems for Intelligence Analytics*) for Academic Intelligence to

be used for graduate students around the world for writing their theses and dissertations, and **PUREST** (*Parallel Universities for Research and Education in Science and Technology*) for helping future students in high schools and universities. Those efforts made me realize that we need to move fast and far beyond our conventional thinking on technology such as agents, robots, or shadow systems, and far beyond our general desire for virtual, mixed or enhanced reality, we must develop digital human technology for our sustainability. My vision for future is simple and straight: The world population would be 5% biological human, 15% robotic human, and 80% digital human. To this mission, over the last two decades, our research has been focused on ***Artificial Societies, Computational Experiments, and Parallel Execution*** (ACP), ***Cyber-Physical-Social Systems*** (CPSS), as well as their derivatives such as *Parallel Intelligence, Parallel Systems, Parallel Management, Parallel Economics, Parallel Manufacturing, Parallel Control, Parallel Agriculture, Parallel Transportation, Parallel Services, Parallel Energy, Parallel Mining, Parallel Medicine, Parallel Ecology*, …, spanning over 100 fields and leading to the establishment of the *State Key Laboratory for Management and Control of Complex Systems* in 2011.

Today, our vision for the future is more closing than ever and has becoming the past in quite a few places in our industries and societies. Digital twins, foundational or Big AI models, metaverses, web 3.0 or web3, DAO for decentralized autonomous organizations or operations, DeSci, DeEco, or DeSoc for decentralized autonomous sciences, economies, or societies, are emerging fast and receiving tremendous attention from researchers and entrepreneurs around the world. Therefore, I think the time is ready for publishing some of our research in the past decade on parallel human and parallel population for CPSS, we need more people to work and study in this field.

The central theme of this book concentrates on how to computationally model human individual's deliberation and thinking so that her/his behavior is prescribed to achieve the expected goal of management in cyber physical social systems. Our discussion will address the basic theory and methodology for modeling as well as some implementation techniques. Potential acceleration technologies will be also exploited in our prototype systems due to the high computational cost. Some application cases from different fields are also included to show preliminary validations. Though some chapters may concern about implementations, we generally follow the technological path rather than system component details to introduce our work concisely. Our discussion begins with the synthesis of basic population, which includes Chapters 2 and 3. These two progressive chapters elucidate how to generate a "static" set of virtual individuals with their personal attributes and mutual social relationships according to statistical results and optional micro samples. Chapter 2 only considers the individuals, while Chapter 3 further addresses social organizations. The resulting basic

population plays as a start state in the subsequent artificial population evolution. Next, we move to the micro level, concentrating on the individual cognition and behavioral modeling. This part includes four chapters, Chapters 4–7, where we address three intercoupling aspects of human intelligence and cognition: the representation of human knowledge, the acquisition of an individual's knowledge in a static/dynamic way, and the exploitation of one's knowledge to elicit a specific decision/action. These three aspects are also fundamental questions in general intelligence. Chapter 4 presents the cognitive architecture for agent decision cycle. It provides a unified container or framework that organizes knowledge segments and data flow in decision process. On the basis of such framework, Chapters 5 and 6 address the learning and reasoning which offer rudimentary solutions for knowledge acquisition and application. To model the mental heterogeneity in a time-variant human-in-loop environment specifically, we put our emphasis on adaptive learning through detected individual actions. The decision making based on reasoning via one's knowledge base adopts an evolutionary paradigm rather than classic reasoning in artificial intelligence (AI) research. This is in line with the philosophy from science of complexity and cognition where the deliberation results from a bottom-up emergence. We do not organize a separate chapter to the knowledge representation because existing relevant techniques are directly exploited. Instead, a brief introduction is included in Chapter 5. Interested readers can easily find corresponding details in other related literature. The last but not least problem for artificial human modeling is the parameter calibration and validation, which is essential for the reliable use of models. For a large-scale social system in particular, model calibration seems more important, since compared with a few agents, parameter values in such systems are difficult to be fully measured in a wide range. This sampling bias may cause the obtained parameters not representative enough and thus impacts the accuracy of the model. Several calibration methods have been be described in Chapter 7 in order to avoid such a dilemma. After establishing learning and reasoning mechanisms for artificial human, next we turn to their implementation. In Chapters 8 and 9, we consider acceleration approaches for a large-scale knowledge base that is computationally expensive. This is almost inevitable in practice since one's mental repository is usually complicated. Distributed reasoning and active strategy prescription via cloud computing are illustrated. Some theoretical foundations on the completeness and optimality in such a reasoning mode are also analyzed in these two chapters. The book concludes with some applications in Chapter 10, ranging from computational demography, urban transportation management and control, to evacuation in emergency. Some ethical and legal issues of parallel population/human are further discussed in Chapter 11.

I would like to take this opportunity to express my sincere thanks to my co-author Dr. Peijun Ye, a former PhD of mine and my colleague now at Chinese

Academy of Sciences. He did his project and dissertation on Intelligent Transportation Systems under my supervision, but was persuaded by me into doing research in parallel population and parallel human 10 years ago, starting from zero background in an area that was not "cold," but "frozen" at the time. It was really a tough choice (yes, a bad decision in the short term) for a young researcher then, especially considering the fact that he had to work alone since he was the only person I talked into this direction. I have graduated more than 100 PhD students in my career so far, but no one else is willing in working with me in this "dark" or even "crazy" field. I really appreciate Peijun's patience, dedication, and hard work. I am also extremely happy to see our efforts are very productive and, in addition to this book, our works on parallel cognition, digital personality of digital person, as well as CPSS are emerging with encouraging attraction and attention as promising and important new directions for research and development in intelligent science and technology.

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