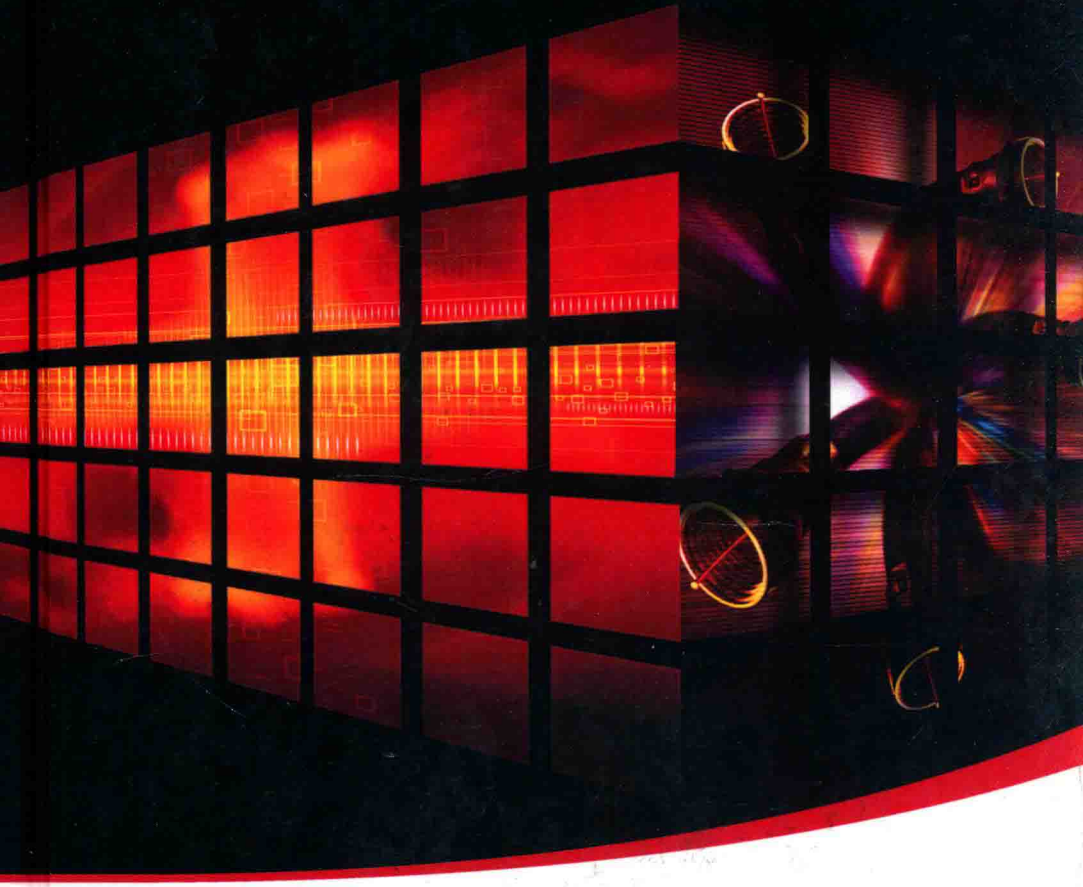
The Knowledge Grid

Second Edition

Toward Cyber-Physical Society

Hai Zhuge



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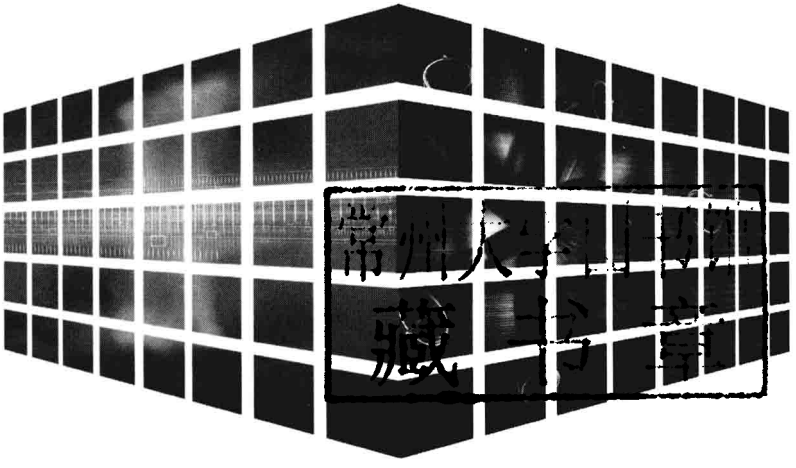

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THE KNOWLEDGE GRID Second Edition

Toward Cyber-Physical Society

Foreword

The Knowledge Grid — Toward Cyber-Physical Society advances the vision of human-machine-nature symbiosis. Covering methodology as well as technologies, this innovative book aims to spur innovation.

First, the book puts forward a complex semantic space model that targets the effective management of diverse resources. This is enabled by an integration of a semantic link network model and a resource space model into a unified semantic framework that supports the fundamental concepts of generalization and specialization through multi-dimensional classifications, and also supports important aspects such as semantic self-organization, community discovery, and complex reasoning. The resulting framework offers a semantic foundation for the management of resources. Second, it advances a self-organizing, semantic environment for the sharing and management of knowledge that features a knowledge flow model, social networking methods and principles, and semantic peer-to-peer networking mechanisms.

While the first edition of this book introduced the methodology, models, and technologies, the present edition extends these within the context of the cyber-physical society, which concerns not only cyber-space, but also the physical and social spaces. The book reports on a range of disciplinary innovations that relate in different ways to semantics, knowledge, and intelligence. As a result, the book can inspire novel research in different fields, which may in turn result in new technologies that benefit humanity. I recommend the book to anybody with a deep interest in human-machine-nature symbiosis and its advancement.

Christian S. Jensen
ACM Fellow, IEEE Fellow, Aarhus University, Denmark

Preface

Exploring the source and essence of knowledge and intelligence, promoting knowledge generation and sharing, facilitating knowledge management, and extending human intelligence are the grand scientific challenges.

The Internet connects computers all around the world to support data transmission. The Web makes informative pages conveniently available to Internet users everywhere. The initial aim of the Knowledge Grid is to facilitate knowledge sharing and evolution by meaningfully linking and efficiently managing globally distributed resources.

The Knowledge Grid is an optimized human-machine environment, and will be a large-scale man-machine-nature symbiosis environment, where people, society, artifacts, minds, and nature can productively coexist and harmoniously evolve. It stands for the ideal of a live, autonomous, humanized, efficient, systematic, optimal, harmonious, and sustainable social environment.

The Knowledge Grid bases its methodology on multi-disciplinary thinking because any single disciplinary method cannot solve the issues in this complex environment. Recognizing the essence, source and principle of knowledge and mind is essential to implementing the Knowledge Grid.

The 1st edition of this book published in 2004 actually founded a specific research area. The 2nd edition completes its theory, model and method by significantly enhancing previous contents and increasing four chapters (Chapter 7, 8, 9, and 10). Applications and philosophical discussion are added to help render the ideas.

This new edition puts the Knowledge Grid research into the Cyber-Physical Society environment consisting of cyber space, physical space, socio space and mental space. The ideal goes beyond the scope of the Web, Grid computing, cloud computing, Internet/Web of Things, cyber-physical systems, social network, smart Grid, and machine intelligence.

The research work was supported by many foundations and organizations, especially the Key Discipline Fund of National 211 Project (Southwest University: NSKD11013), the Natural Science Foundation of Chongqing (cstc2012jjB40012), the Chongqing Municipal Government, the National Science Foundation of China (61075074), National Basic Research Program of China, the Nanjing University of Posts and Telecommunications, and scholar programs of Ministry of Education of China and Chinese Academy of Sciences.

I would like to thank joint and visiting professorships from the Southwest University in China, the University of New Brunswick in Canada, the University of Hong Kong, the University of Queensland in Australia, and the Kyoto University in Japan.

I sincerely thank the members of the Knowledge Grid Research Group at the Key Lab of Intelligent Information Processing, Institute of Computing Technology in Chinese Academy of Sciences for their cooperative work, especially my former students Xiaoping Sun, Xue Chen, Xiang Li, Liang Feng, Junsheng Zhang, Yunchuan Sun, Yunpeng Xing, Ruixiang Jia, Weiyu Guo, and Bei Xu.

I would like to take this opportunity to thank my parents, parents in law, and daughter. Special thank gives to my wife for her consistent support at every stage of my academic career.

Finally, I hope this book will help in promoting research of the Knowledge Grid and the Cyber-Physical Society.

Hai Zhuge
Spring in 2012

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Chapter 1

The Knowledge Grid Methodology

The development of science and technology has extended human behavior and sensation, accelerated the progress of society, and enabled people to understand the physical space and themselves more profoundly. But, we still have much to find out, especially about knowledge.

What is knowledge?

How is knowledge generated?

How does knowledge evolve?

Can knowledge be inherited?

How is knowledge shared effectively?

How is knowledge stored and retrieved?

How to enable machines to obtain knowledge so that they can act intelligently?

How to create an environment to enable, facilitate, or improve knowledge creation, evolution, inheritance, sharing and service?

These are fundamental philosophic, scientific and technologic issues relevant to the Knowledge Grid methodology.

1.1 The Knowledge Space — Knowledge as a Space

Knowledge is a multi-dimensional complex space, where dimensions emerge, evolve structures (from simple to complex, or from complex to simple at higher abstraction level), and influence each other. A

dimension can be viewed as a space, and a space can be viewed as a dimension. The dimensions include time, the physical space, the socio space, and the mental space. Each space includes individuals, structures, rules and statuses. The mental space reflects the other spaces, builds mental semantic images, and carries out reasoning while various individuals interact with each other. A point in the space is the reflection of a set of individuals, which share one set of projections on all dimensions.

According to the new notion, knowledge is not just in the mental space, it is reflected by the cyber space, physical space and social space, and it evolves with the interaction between individuals in various spaces. Minds can reflect, discover and link knowledge in these spaces through experiencing and thinking. Machines can help discover some rules in the cyber space by statistical approaches.

The knowledge space has the following characteristics.

(1) *There are multiple origin points.* The first one is the generation of the physical space and time. The generation of mind and society is the remarkable point of the development of human beings.
(2) *A dimension can be linear or nonlinear structure of coordinates.* A coordinate can be a tree structure. A dimension can be as simple as time or as complicated as a large-scale complex system. A dimension can be regarded as a space.
(3) *Projections of points on dimensions evolve with time.* Some points do not have projections on some dimensions at certain time. For example, some rules in the physical space have no projection on the dimension of the mental space. Therefore, these rules are currently unknown.
(4) *Projection on some dimensions may concern a complex process.* For example, the projection of a point onto the dimension of the mental space involves in a complex process of perception, learning, communication, association, and reasoning.
(5) *Knowledge transition between individuals also involves in the processes in and through multiple spaces.*

Fig. 1.1.1 depicts a knowledge space, where O_0 denotes the origin of generating the universe and time, and O_h denotes the origin of generating the mental space and the social space. The generated spaces evolve with time according to different rules.

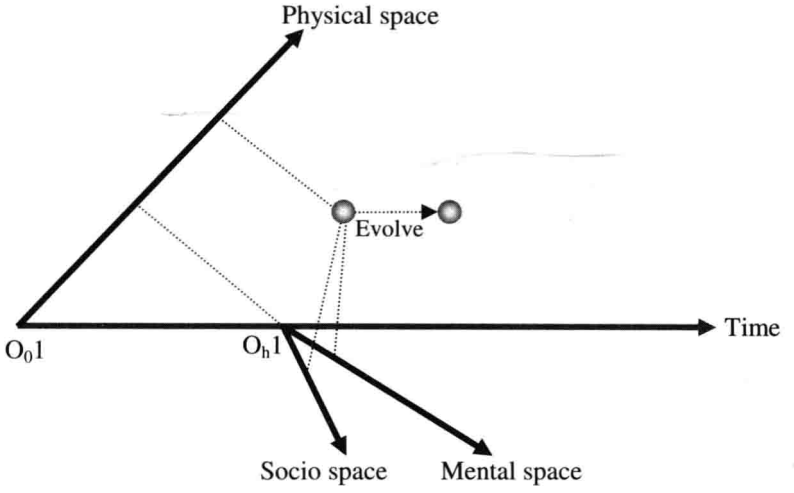

Fig. 1.1.1 A macroscopic knowledge space.

This notion of knowledge space extends the generation of knowledge not only to the origin of the mental space and the socio space but also to the origin of the physical space and time. The notion implies that knowledge is not only subjective but also objective, not only in individual mental processes but also in social processes. The links between knowledge points in and through spaces play an important role in forming and evolving the space structure.

This knowledge space notion opens new door to explore knowledge.

The generation of any space accompanies the creation of its dimensions. The evolution of spaces accompanies the expansion or shrink of dimensions. *A dimension can be viewed as a space from its coordinates. A space can be viewed as a dimension from its super-space.*