



Editorial

Cybermatics: Advanced Strategy and Technology for Cyber-Enabled Systems and Applications



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ABSTRACT

Recently, the physical, social, and mental space are seamlessly integrated together, due to the rapid development of several emerging technologies and computing paradigms, such as Social Computing, Internet of Things, and Mobile Computing. Cybermatics, which is a novel concept to address strategy and technology issues in the heterogeneous cyber-physical-social space, becomes a hotly discussed topic, and is attracting more and more researchers to be engaged in this interdisciplinary field. This special issue, aiming at enhancing the next generation of computational technologies, is introduced to provide both theoretical and algorithmic support across cyber-physical-social systems with cyber-enabled applications. A summary of the selected papers is presented, and a variety of cyber-related concerns and solutions are demonstrated in the hyper world. Topics among the selected papers include cyber-social data processing and network analysis, cyber-physical system architecture and platform design, cyber-enabled application development, and cyber security management, which may draw up a promising perspective for the future research.

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1. Introduction

With the high development of Ubiquitous Computing, Mobile Computing, and Social Computing, the physical, social and mental worlds are increasingly integrating and merging, which can be called the hyper world. Many research works have tried several computational approaches to realize the symbiosis of human-computers-things, ranging from artificial intelligence, information technology, user modeling, virtual reality, and robotics, which can provide people with more adaptive services. Specifically, among these outstanding researches, an emerging but significant field called Cybermatics [1], which aims at building systematic knowledge about new phenomena, behaviors, properties, and practices in the cyberspace and cyberization, is developed to model the human individual information processing along with the broad applications across cyber-physical-social systems.

As an emerging science forming from the new cyberspace along with the present physical, social and mental worlds, Cybermatics is a holistic field to systematically study cyber entities in the cyberspace, their properties and functions as well as their

relations and conjugations with entities in physical, social and mental spaces. Furthermore, comparing with the common computer science and information science, Cybermatics is concerned more with the basic attributes, properties, models, representations, interactions, and evolutions of cyber entities, and all their possible relations conjugated with real things. Specifically, it can be regarded as the interdisciplinary or trans-disciplinary research and practice focusing on five major aspects: the cyber entities in cyberspace, cyber-physical conjugation, cyber-social conjugation, cyber-mental conjugation, and cyber-physical-social-mental Integration. For this scientific and systematic study, numerous challenges are raised as: How to establish and improve the foundational theory and methodology for the basic models and data processing in the hyper world? How to find a unified way to study and represent the diversified cyber entities along with their tremendous associations and interconnections? How to systematically extract, create, and fuse the information, knowledge, and intelligence generated across the cyber-physical-social systems for the sustainable utilization? How to deal with the accompanying issues while producing numerous cyber things, such as security, reliability, and etc.

Thus, this special issue on Cybermatics: Advanced Strategy and Technology for Cyber-Enabled Systems and Applications, aims to

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review, investigate, and exchange the fundamental theories, computational models, and technological solutions across the cyber-physical-social systems in a holistic and trans-disciplinary view, which will have a great significance and profound impact on: (1) Addressing the emerging trends, issues, and studies in the trans-disciplinary domains to share the common goal of cyber-enabled world. (2) Providing fundamental theory, model, and methodology in the newly established field of cyber science, and pushing forward the practices with other related frontiers. (3) Exploring interesting and practical technologies and applications to provide foundational frameworks, new functions, and adaptive services across cyber-physical-social systems. (4) Bringing together all cyber-related researchers, engineers, and interested pioneers from both academia and industry, to draw up the future direction of Cybermatics, and service provision in the hyper world.

2. Distinctive elements and contributions

As more and more research efforts have been dedicated to the field of Cybermatics, a lot of papers and reports have been published in the representative journals and conferences during the last few years. The concept of Cybermatics brings new challenges in cyber science, cyber-physical computing, cyber-social networks and cyber-mind, and etc.

Thus, differing from other related special issues, such as “Special Issue on Cyber-Physical Systems (CPS), Internet of Things (IoT) and Big Data”, which only focuses on IoT technologies and big data methodologies in CPSs; “Special Issue on Cyber-Physical Social Systems: Integrating Human into Computing”, which concentrates more on the human-related computing paradigms in the cyberspace; and some security-focused special issues, e.g., “Special Issue on Cyber Security in the Critical Infrastructure: Advances and Future Directions”, “Special Issue on Security Data Science and Cyber Threat Management”, this special issue enhances the next generation of computational technologies including systematic modeling, heterogeneous data management, and practical analytics across cyber-physical-social systems with cyber-enabled applications.

Significantly, this special issue is expected to encourage the exchange of novel ideas and thoughts related to this emerging research area, and bring the research efforts together to provide the promising and significant research works for the related journals and conferences. Specifically, the potential contributions of this issue concentrate on both research and application aspects. The new ideas and research approaches will lead to explore new directions and key research topics towards the vision and achievement of the hyper world. The computational technologies and cyber-enabled applications will promote the implementation of intelligent systems and provision of promising services.

Eventually, the call for this special issue has received 34 submissions. After a two-phase review process based on an international editorial committee, during which each submission needs to be reviewed by at least three referees, a total of nine papers, presenting the majority of topics mentioned above, have been accepted for publication in this issue. An acceptance rate of 26% has resulted from this selection.

3. Content of this issue

Basically, papers accepted for this special issue addressed four major aspects relevant to the advanced strategy and technology for cyber-enabled systems and applications, ranging from data mining and network analysis in cyber-social space, to system model and platform design in cyber-physical environments. The detail contribution of each paper can be summarized as follows.

3.1. Cyber-social data processing and network analysis

Among a variety of representative social networks, event-based social networks have become increasingly popular along with the merging of physical, social, and mental space. Accordingly, the event detection technology is playing an important role in recommending upcoming events among real time social streams [2], especially when people share online and offline social interactions from multiple groups. The paper presented by Yijun Mo, Bixi Li, Bang Wang, Laurence T. Yang, and Minghua Xu, entitled “Event Recommendation in Social Networks based on Reverse Random Walk and Participant Scale Control” [3], proposes a graph theory based method for event recommendation in the cyber-physical world. The authors have described a heterogeneous graph model to represent factors of an event-based network, which also considers the scale control with the participant capacity of each event. The so-called reverse random walk and participant scale control algorithms are then developed to improve the event recommendation and arrangement. Experiments using the real world data from “Meetup” demonstrate the better recommendation performance that the proposed method can efficiently assign users with a series of upcoming events, compared with four other related research works.

Modeling of community structure is a key issue to analyze the feature of complex networks. Community detection has been extensively used to understand network functions and social dynamics when developing social applications and recommendation systems in cyberspace. Comparing with traditional community detection algorithms which are mostly based on network topology or spectral cluster, the paper addressed by weimin Li, Shu Jiang, and Qun Jin, entitled “Overlap Community Detection Using Spectral Algorithm Based on Node Convergence Degree” [4], considers a combination of network structure and node attributes. A node-degree-based method is presented for the detection of overlap communities. The so-called Spectral Clustering based on Node Convergence Degree (SCNCD) algorithm, which not only considers the topology of the whole network, but also the attribute of each node, is developed to identify the overlap community structure. Experiments based on two different data sets demonstrate the effective performance with high modularity.

3.2. Cyber-physical system architecture and platform design

With the high development of IoT technology, cloud computing has been proved as an effective way to store and share the computing resources, such as computer networks, servers, and applications [5]. Meanwhile, the Wireless Sensor Networks (WSNs) have increasingly integrated the cyber and physical worlds together. The integration of cloud computing and WSNs has become an important paradigm in cyber-physical systems and attract many researchers to develop the new architecture and system model [6]. Specifically, the paper presented by Chong Chen, Dan Chen, Yingnan Yan, Gaofeng Zhang, Qingguo Zhou, and Rui Zhou, entitled “Integration of numerical model and cloud computing” [7], proposes a three-dimensional numerical groundwater model to simulate the groundwater system in the middle reaches of the Heihe River Basin, northwestern China. An analysis method of sequential data with a newly designed architecture called Model as a Service (MaaS) is presented, and a Particle Filter based mechanism is developed to analyze parameters in the groundwater model. The MaaS is integrated with WSNs to observe and collect the data from the Heihe River Basin. Evaluation results demonstrate the effectiveness of the proposed method.

Behavior modeling and prediction have highly developed over the last few years. Benefiting from the rapid development of cloud computing technology, it offers us a cost-effective way to timely

deal with a large amount of geo-spatial data. In particular, the paper addressed by Saurabh Garg, Jagannath Aryal, Hao Wang, Tejal Shah, Gabor Kecskemeti, and Rajiv Ranjan, entitled “Cloud Computing Based Bushfire Prediction for Cyber-Physical Emergency Applications” [8], provides a system design for the bushfire prediction service. A cloud-based system framework, which allows the end user to predict fire probabilities in the required area within the user specified deadline, is proposed. A scheduling algorithm is developed with the so-called bushfire prediction model and profiling fire model. The authors have discussed the detailed architecture design, core services, and workflow in this system. Following a real world case study of bushfire prediction to serve multiple users, evaluations with different scheduling strategies demonstrate the effectiveness of the proposed system.

3.3. Cyber-enabled application development

Along with the merging process of the physical, social and cyber worlds, the mixing of mobile technologies and crowdsourcing has led to a new paradigm, called Mobile Crowdsensing (MCS), which can be viewed as a wisdom power of crowds combining both the strengths of humans and machines. Among numerous existing MCS applications in various fields, a major issue is to accommodate all stakeholders’ interests, and design an appropriate incentive mechanism. Thus, the paper presented by Wei Dai, Yufeng Wang, Qun Jin, and Jianhua Ma, entitled “Geo-QTI: A Quality aware Truthful Incentive mechanism for cyber-physical enabled Geographic crowdsensing” [9], focuses on a quality aware truthful incentive mechanism for cyber-physical enabled geographic crowdsensing called Geo-QTI, and designs a system model which incorporates utilities of various stakeholders including requesters, participants and the crowdsourcing platform. The Geo-QTI includes four components: requester selection, participant selection, pricing, and allocation, in which the PoI (Points of Interest) and QoI (Quality of Information) are jointly considered. Through the theoretical analysis and experiment simulations, the authors demonstrate that the Geo-QTI can achieve the following features: individual rationality, truthfulness, computational efficiency and budget balance.

In a railway transportation system, visual inspection is a significant task to guarantee the safety problem in terms of the maintenance of various railway infrastructures. As a typical cyber-enabled system, the modern railway inspection system applied with several advanced technologies [10], such as IoT and artificial intelligence, is providing us with a new vision of data collection and information processing. As an application case study for railway corrugation identification, the paper addressed by Qingyong Li, Zhiping Shi, Huayan Zhang, Yunqiang Tan, Shengwei Ren, Peng Dai, and Weiyi Li, entitled “A Cyber-Enabled Visual Inspection System for Rail Corrugation” [11], demonstrates a visual inspection system for rail corrugation (VIRC) based on the principle of cyber-physical system, which is actually tested in some railway networks in China. Specifically, a subsystem of on-board image acquisition is designed to capture the track images, and another subsystem of corrugation identification is used to judge whether a corrugation defect exists in an obtained rail image. A specific localization algorithm called rail localization based on weighted projection profile (RLWP), is developed based on the analysis of local frequency features. Experiment results using two different data sets demonstrate the high performance of the proposed method in real environments.

3.4. Cyber security management

As an important security technology in real time systems (e.g., cyber-physical systems), malware detection always works as a fundamental function against malware-based attacks in virtualized environments. The virtual machine introspection has been

viewed as an essential and effective security solution to detect malware among a large amount of data across various cyber-enabled applications. The paper presented by Ajay Kumara. M.A and Jaidhar C.D, entitled “Automated Multi-level Malware Detection System based on Reconstructed Semantic View of Executables using Machine Learning Techniques at VMM” [12], designs a virtual machine monitor (VMM) based automated multilevel malware detection system (AMMDS). The authors discuss the compositions and implementation of the proposed system, including an online malware detector and an offline malware classifier. Mechanisms for the malicious check are developed based on reconstructing semantic view processes with virtual machine introspection and memory forensic analysis technologies. Evaluation results demonstrate the high efficiency and accuracy of the implemented prototype system.

Access control plays a significant role in most big data management and resource arrangement in cyberspace. The policy update is one of key tasks for access control management. The paper addressed by Somchart Fugkeaw and Hiroyuki Sato, entitled “Scalable and Secure Access Control Policy Update for Outsourced Big Data” [13], builds a secure access control model for encrypted data in the big data environment. The authors introduce the detailed structure of the access control model, and develop a very lightweight proxy re-encryption (VL-PRE) technique with a policy updating algorithm to enable policies to be dynamically and effectively updated in the cloud server. Simulations demonstrate the feasibility of the proposed policy updating scheme in accordance with the correctness, accountability, and security requirement.

The vertical handover technology has been widely used for the integration of wireless networks, especially in the heterogeneous wireless network environment. In particular, security problems have become extremely significant in vertical handover along with the explosive growth of mobile data traffic. To enhance the security issue of cyber-enabled systems in mobile environments, the paper presented by Xiaohong Li, Feng Liu, Zhiyong Feng, Guangquan Xu, and Zhangjie Fu, entitled “A Novel Optimized Vertical Handover Framework for Seamless Networking Integration in Cyber-Enabled Systems” [14], introduces an optimized vertical handover (OVH) framework to secure and improve the handover process. A series of features, such as mobile nodes, network states, and security policies during the handover decision, are taken into account together within two processes. Specifically, candidates with incompatible security capabilities will be eliminated in the so-called pre-filtering process, while the static and dynamic attributes during the handover will be measured in the network selection process, using the advantages of Manhattan and Chebyshev distance. Simulation results show that the optimized algorithm can improve the performance in terms of the handover delay and execution time.

4. Conclusions

The accepted papers, attracting researchers from seven different countries, including Australia, the UK, Canada, India, Japan, China, and the US, have demonstrated the emerging trends, practical strategies, and advanced technologies through the development of various cyber-enabled systems and applications.

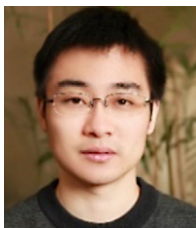
In general, almost all things in the conventional physical, social and mental worlds can be cyberized with some kinds of cyber existence. The process of producing numerous cyber things and equipping cybermatic functions into countless ordinary things and human bodies/brains is newly forming, and progressively involving us into the cyberspace. Thus, the special issue in this field will bring in a great significance and impact to establish a holistic field, and build systematic knowledge for the cyberization towards the hyper world.

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