Parallel Societies: A Computing Perspective of Social Digital Twins and Virtual–Real Interactions

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WELCOME to the first issue of the IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS (TCSS) of 2020, and Happy New Year to You! We would like to take this opportunity to express our sincere thanks to our editors, reviewers, authors, and readers for your great support and effort devoted to the TCSS, along with our best wish and hope that everyone has a happy, healthy, and fruitful 2020.

In this issue, we publish eight regular articles, a brief discussion on parallel societies, and a special issue entitled "Social Sensing and Privacy Computing in Intelligent Social Systems" is published, which includes 16 articles.

I would like to share some latest news of the IEEE TCSS with you. In October 2019, we completed our first five-year review cycle (2014–2018) carried out by the Periodicals Review and Advisory Committee (PRAC), and on November 21, I went to a face-to-face review in Boston, MA, USA (see Fig. 1). Our effort on the TCSS is unanimously and highly recognized by the PRAC, and they concluded that we had made a significant progress over the last two years (2017–2018).

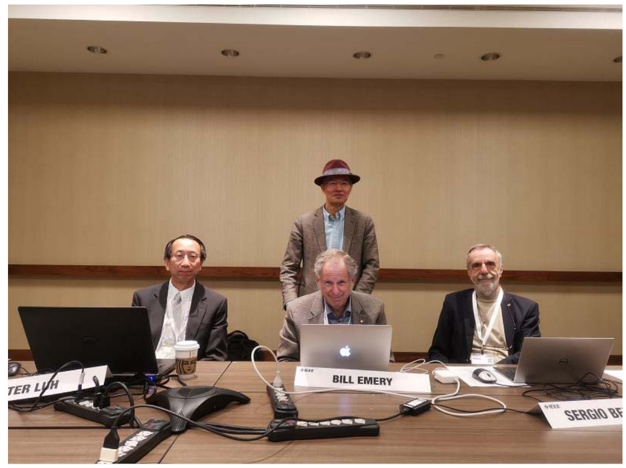

Fig. 1. EiC Fei-Yue Wang (Standing) and The IEEE PRAC Committee on November 21, 2019 at Boston.

Scanning the Issue

1. Multilevel Event Detection, Storyline Generation, and Summarization for Tweet Streams

Poonam Goyal, Prerna Kaushik, Pranjal Gupta, Dev Vashisth, Shavak Agarwal, and Navneet Goyal

This article proposes a novel approach Mythos that detects events and subevents within an event and generates abstract summary and storyline to provide different perspectives for an event. There are three modules in Mythos. Online incremental clustering algorithm identifies small-scale events in the form of small clusters, the event hierarchy generator generates bigger events in the form of hierarchies, and the summarization module produces the summary of events/subevents. The summarization module uses a long short-term memory (LSTM)-based learning model to generate summaries at different levels—from the most abstracted to the most detailed. The summaries at different levels are used to generate a storyline for the event. The experimental analysis on a variety of twitter data sets from different domains compares Mythos against the known existing approaches for event detection and summarization. It outperforms the baseline approaches for both. The generated summaries are evaluated against summaries provided by external reference sources, such as Guardian and Wikipedia.

2. Recommender System-Based Diffusion Inferring for Open Social Networks

Xiao Yang, Mianxiong Dong, Xiuzhen Chen, and Kaoru Ota

Several models of information diffusion in an open social network (OSN) have been proposed to infer the diffusion process and reproduce the diffusion network. However, these methods have two critical problems: 1) ignoring the effects of user social characteristics and 2) inaccuracy resulted from calculating the influence of different features independently. To address these limitations, a diffusion inferring method based on a recommender system (DIM-SPTF) is proposed in this article. The DIM-SPTF method considers the propagation process between the users as the recommendation process of information and employs a recommender system to infer the propagation relationship. Through determining the propagation relations among all users in the observed topic data set, an information diffusion network can be finally obtained. Experimental results show that DIM-SPTF leads to the improvements in performance compared with the state-of-the-art methods.

3. Modeling Reliability of Threshold Weighted Indecisive Voting Systems

Hainan Zhang and Hoang Pham

In industry, the method of hypothesis acceptance based on available information is widely used in applications, such as system modeling. Xie and Pham modeled the reliability of weighted threshold voting systems with a general recursive

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reliability function in human organization systems. As an extended study, this article introduces a generalized weighted indecisive voting n-unit system using a new decision rule consisting of both a threshold parameter τ and a new indecisive parameter θ. In general, indecision happens due to the limited information, and an indecisive parameter is then applied if no decision is made. System reliability R is calculated to show the system performance. The main results imply a strong dependence of system performance on decision rule and large potential of model adjustment via parameter initialization. The contribution of this article is that they introduce indecisive effect to make the model more adjustable for specific needs.

4. PIE: A Data-Driven Payoff Inference Engine for Strategic Security Applications

Haipeng Chen, Mohammad T. Hajiaghayi, Sarit Kraus, Anshul Sawant, Edoardo Serra, V. S. Subrahmanian, and Yanhai Xiong

Although most game theory models assume that payoff matrices are provided as input, getting payoff matrices in strategic games has proven difficult. To tackle this challenge, this article proposes a payoff inference engine (PIE) that finds payoffs, assuming that players in a game follow a myopic best response or a regret minimization heuristic. This assumption yields a set of constraints on the payoffs with a multiplicity of solutions. Toward this end, they propose three heuristics that may be used to learn payoffs of players in multiplayer real-world games. Unlike past work on payoff inference, PIE can support reasoning about multiplayer games, can use short histories, can improve scalability to two orders of magnitude, and do not require all players to be fully rational. Their experiments show that PIE has both higher accuracy and much shorter runtime compared with the recent work on payoff inference.

5. Convex Edges in Social Networks

Xiaoping Zhou, Xun Liang, Xu Zhu, and Zhi Tang

This article quantitatively defines convex edges using hidden geometry space defined by the Ricci curvature and shows their ability to predict highly interacted edges in social networks. From empirical studies of social networks, they find that convex edges often occur on two connected nodes with similar popularity and allow for frenemy (or versatile node) identification and almost all nodes maintain an upper bound of convex edges. These findings present further evidence of the limited attention in an attention economy from a different perspective. Using three well-known synthetic networks, they show that convex edges can reflect the formation of a network from scatter (concave) to aggregation (convex). Their results show that convex edges are a novel mechanism to investigate social networks from different disciplines and offer insights into many network phenomena.

6. A Model for Social Communication Network in Mobile Instant Messaging Systems

Ebrahim Sahafizadeh and Behrouz Tork Ladani

Considering different communication patterns in mobile instant messaging (MIM) systems, this article introduces the concept of social communication network (SCN) to be able to consider special structural properties of communications in MIM systems and propose a model for representing and generating the SCN in MIM systems. The proposed model covers all social communications between users, groups, and channels and exhibits the statistics observed in real-world data. We also redefine some existing properties and introduce some new properties of the MIM network that earlier models of complex networks do not capture. To evaluate the proposed model, they conduct a number of simulation experiments on the model and compare the results with a real-world graph extracted from Telegram. The results show that SCN derived by the model is highly compatible with the real-world graph. The proposed model provides a useful basis for analysis and evaluation of MIM network properties.

7. A Lightweight Blockchain-Based Model for Data Quality Assessment in Crowdsensing

Jian An, Jindong Cheng, Xiaolin Gui, Wendong Zhang, Dong Liao, Lin Jiang, Ruowei Gui, and Xin He

Considering the problem of unfair payment, negative work of participants, and cooperative cheating, how to assess the data quality of tasks reliably is an important problem in crowdsensing. Therefore, a lightweight blockchain-based model for data quality assessment is proposed in this article. First, there are two data quality assessment processes in the model. One is implemented in the selection of participants and the other is implemented in data quality assessment. Second, the consensus mechanism and smart contracts are redesigned to be suitable for crowdsensing. The lightweight consensus mechanism, delegated proof of reputation (DPoR), is proposed in the blockchain-based model instead of proof of work (PoW). Furthermore, three smart contracts, verifiers selection contract (VSC), participants employment contract (PEC), and data verify contract (DVC), are generated to constrain the behaviors of the involved parties. Finally, the expectation–maximization (EM) algorithm with multiverifiers is proposed to evaluate the performance of task participants. Experiments on the open data sets, Wine Quality, show that this new method outperforms the existing methods in improving the quality of the sensing task.

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Is the Society Computable? A Brief History of Social Computing

With the continuous popularization of social network and big data technologies in recent years, the speed and scale of changes in social dynamics have been witnessed to reach an unprecedented level. Just like the solution of modern scientific problems needs modern scientific theories and methods, and the networked social problems also need corresponding new social scientific theories and methods. Therefore, in order to improve the safety, effectiveness, efficiency, as well as sustainability of our society, we should develop computable, experimentable, and comparable social research methods beyond the traditional qualitative analysis of social problems.

As such, social computing had become a novel research area in the intersection of social sciences and information sciences. In the literature, social computing was proposed in 1994, but it actually means "social software" [1]. In 2004, Fei-Yue Wang proposed the concept of social computing in a new sense, which means "computational social sciences" or "computational sociology" [2], which is a computational theory and method dedicated to studies on social activities, social processes, social structures, social organizations, and social functionalities. Typically, it models social problems with an artificial society, uses computers as a social laboratory, and studies the social problems via interactions and coevolution between the real and virtual societies, so as to realize a novel paradigm of parallel management and control [3].

A series of academic activities was organized to promote the development of social computing after this concept was coined in 2004. In 2006, we founded the Research Center for Social Computing and Parallel Management at the Institute of Automation, CAS, aiming at developing ACP (Artificial Societies, Computational Experiments, Parallel Execution) methods and systems for social issues, which became a key laboratory of CAS in 2008, and then a part of the State Key Laboratory for Management and Control of Complex Systems since 2011. In 2006 and 2007, we organized the first special issue of social computing in the "Communications of the China Computer Federation" and the "IEEE Intelligent Systems," respectively. In 2006, we organized the first workshop on social computing in Beijing, China, entitled "ACM Workshop on Societal Security and Computing." In 2007, we organized the 299th Xiangshan Conference with the theme of "Basic Theories and Applications of Social Computing." In 2008, we held the first international workshop on social computing, entitled "IEEE Social Computing Workshop (SOCO)" and the first Academic Salon of China Association for Science and Technology, with the theme of "Social Computing—Is the Society Computable?" [4]. In 2009, we launched the "IEEE International Conference on Social Computing" and the "First National Social Computing Conference" in China. In 2010, with the help of Jim Hender of RPI and Katherine Cayley of CMU, Wang put forward a proposal to Spring Verlag for an academic journal on Social Computing, which then became a proposal to IEEE Computer Society for TRANSACTIONS ON SOCIAL COMPUTING, and finally merged with the effort from IEEE Systems, Man, and Cybernetics Society and led to the establishment of our IEEE TRANSACTIONS ON SOCIAL COMPUTING in 2014.

In USA, the first social computing-related conference was the seminar on "Computing Social Sciences" held by Harvard University in late 2007. In 2008, the U.S. Air Force and other funding agencies held a seminar on "Social Computing, Behavior Modeling and Prediction" in AZ, USA. In the same year, there was also a seminar on "Social Computing and Cultural Modeling" sponsored by the U.S. Navy. In 2009, "Science" published a summary of the 2007 Harvard Seminar, which greatly promoted the research of computational sociology or social computing. In 2010, the "Workshop on Social Computing and Cultural Modeling" was held in Thailand [5]. Since 2010, social computing has become a global research hotspot.

In China, social computing rapidly evolved to be a novel discipline. With the support from the Graduate School of Chinese Academy of Sciences [today's University of Chinese Academy of Sciences (UCAS)], social computing has become a cross-field discipline that spans three major disciplines, including management, control engineering, and computer science.

To summarize, social computing is a young interdisciplinary research area and will coevolve with other related disciplines to become mature. Especially, the emerging research works on big data, artificial intelligence, and social manufacturing will undoubtedly bring a new impact to social computing. Therefore, more researchers are expected to participate in this field and jointly promote its in-depth development and wide applications.

From Digital Twins to Parallel Systems

Digital twins and parallel systems are two well-known and intensively studied approaches in social computing research. In comparison, digital twins are frequently discussed and used in industry, especially in the cyber–physical systems (CPS) in Industries 4.0, while the parallel system, originated from the "shadow systems" in 1994, is a much broader concept in the literature than digital twins and also contains social aspects of CPS, resulting in the cyber–physical–social systems (CPSS) [12]. In this section, we will briefly discuss these two approaches.

Digital twins are the key technology aiming at realizing the mapping of physical systems to digital models in the information space. It makes full use of sensors arranged in each part of the systems to analyze and model physical entity data, forming a multidisciplinary, multiphysical-quantity, multitime-scale, multiprobability simulation process [6]–[8] and reflects the full-life process in different real scenes. Digital twins mainly include three parts, which are a physical entity in the physical space, virtual entity in the artificial space, and connection data and the information between them [9].

Parallel systems are the extension and innovation of complex adaptive system theory and complexity science into CPSSs [10], which are a new technical framework combining the actual and artificial systems, as well as the qualitative and quantitative analyses. The core of parallel systems is the Artificial societies + Computational experiments + Parallel execution (ACP) method. More specially, the ACP method is the integration of artificial societies for modeling, computational experiments for analysis and evaluation, and parallel execution for control and management, thus forms a theoretical and methodological framework for studying complex systems in a computational way, and can be especially effective in solving socioeconomic problems. Parallel systems can generate virtual–real "big data" in artificial systems based on the input "small data" from actual systems [11] and then extract "precise knowledge" through coevolutionary learning via the interactions and feedbacks between actual and artificial systems.

Technically speaking, parallel systems and digital twins are similar methodologies essentially, and their key idea in common is to build the artificial counterparts to the physical entities and thus optimize and control the complex virtual–real systems through experiments in the artificial systems. However, parallel system is an earlier and much broader concept than digital twins and can be considered as a research paradigm of "social digital twins," that is, beyond the cyber–physical systems in the research scope of digital twins, parallel systems also take into consideration those uncertain, diversified, and complex issues in social spaces caused by individual-level human psychology, behavior, and system-wide interactions. As such, parallel systems' approach has the potential of evolving the CPS-based "Industries 4.0" to the CPSS-based "Industries 5.0," and its goal is from UDC to AFC, that is, dealing with issues of uncertainty, diversity, and complexity with the capacity of agility, focus, and convergence.

Parallel Societies and the Vision

The unprecedented development of the next-generation information technologies is profoundly changing the relationship between humans and their physical environments and society. The resulting emergence of big data, diversified social networks, and online community, and increasingly coupled CPSS spaces, is leading to a more computable society and thus calling for the parallel-system-based research methodology for social computing and computational social systems [13]. In this new era, we can expect that everything in the future will have its digital avatars living or running in parallel with the physical entity. For instance, every microscopic person, physical device, or macroscopic systems (e.g., transportation, education, manufacturing, and agriculture) will have its online digital twins. As such, artificial digital assets will become the most important strategic resources in the future parallel societies. Possessing how many artificial digital assets, instead of possessing how much data, might become the key criterion to evaluate the strength of organizations, corporations, or countries. I believe these parallel societies will be realized in this coming new decade.

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