Social Intelligence: The Way We Interact, The Way We Go

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WELCOME to the last issue of the IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS (TCSS) of this year, with a special focus on "blockchain-based secure and trusted computing for IoT." Here, we have 18 regular articles and a brief discussion on social intelligence. I would like to take this opportunity to thank and congratulate everyone, especially our editorial board for a great job well done. Looking forward to working with you all in 2020!

Scanning the Issue

1. Influence Maximization From Cascade Information Traces in Complex Networks in the Absence of Network Structure
Naimisha Kolli and Balakrishnan Narayanaswamy

This article proposes an influence maximization algorithm based on the observed cascades, in which the subset of nodes for influence maximization should be composed of nodes that are not only active and strong or influential by themselves but also independent of each other. Based on this premise, the problem has been cast as a quadratic integer programming problem, which is equivalent to a particular class of Max-GP problem, namely, max-not-cut (MNC) with size k, for which the state-of-the-art semidefinite programming (SDP) solution techniques exist with guaranteed performance ratios. The proposed new SDP-based method is tested on a number of synthetic as well as real-world data sets and has been shown to perform better than the state-of-the-art influence maximization algorithms. The results demonstrate its applicability in applications using Twitter, Blogosphere, and other social networks.

2. Group Influence Maximization Problem in Social Networks
Jianming Zhu, Smita Ghosh, and Weili Wu

This article studies an influence maximization (IM) problem that focuses on the number of groups activated by some concerned topic or information. Group IM (GIM) aims to select k seed users such that the number of eventually activated groups is maximized. They first analyze the complexity and approximability of GIM and then develop an upper bound problem and a lower bound problem whose objective functions are submodular. After that, an algorithm based on group coverage is proposed, and the Sandwich framework is formulated with theoretical analysis to solve GIM. Their experiments verify the effectiveness of the proposed method and its advantage against other heuristic methods.

3. Particle Subswarms Collaborative Clustering
Collins Census, Hongjun Wang, Ji Zhang, Ping Deng, and Tianrui Li

This article proposes a framework of collaborative clustering that does not require interaction coefficients to regulate the effect of collaboration and adapts the framework to cluster distributed data using crisp and fuzzy clustering algorithms. Particle swarm optimization techniques are used to inference the framework and, therefore, call it particle subswarms. Moreover, collaboration increases the number of particles in the swarm without increasing the number of clusters in the data set. This article provides theoretical foundations of particle subswarms and experimental results on several data sets.

4. STCS Lexicon: Spectral-Clustering-Based Topic-Specific Chinese Sentiment Lexicon Construction for Social Networks
Bo Zhang, Duo Xu, Huan Zhang, and Meizi Li

This article proposes a method for constructing a topic-specific sentiment lexicon comprising three models. The first one is a filtering text model, namely, the FT model, to calculate the text influence value and obtain topic-specific hot comments as a preprocessing data set. The second is a sentiment relationship graph model, namely, CRM model. They calculate three factors, i.e., the base sentiment similarity, topic sentiment similarity, and synonym sentiment similarity between each pair of sentiment words in their data set, and obtain the factor of final sentiment similarity by adding the three values in proportion. The third one is a spectral clustering model, namely, the SC model, to cluster the sentiment words on the basis of a sentiment relationship graph for obtaining the topic-specific sentiment lexicon, namely, STCS lexicon. Experiments show that their method is simple, flexible, and efficient. It can solve the problem of topic-related sentiment words and, thus, improve the accuracy of the sentiment lexicon.

5. k-Context Technique: A Method for Identifying Dense Subgraphs in a Heterogeneous Information Network
Debaditya Barman, Subhayan Bhattacharya, Ritam Sarkar, and Nirmalya Chowdhury

This article proposes a novel approach named the k-context technique for extracting dense subgraphs from different structural topologies of the heterogeneous information network. The approach has been evaluated using both synthetic and real-life data sets, and it compared the results with an existing algorithm for finding dense subgraphs from a homogeneous information network. Initially, the proposed methods have been evaluated using synthetic data sets. Finally, two

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real-life data networks, namely, the Association for Computing Machinery (ACM) citation network and the Yelp data network have been modeled as heterogeneous information networks using two real-life data sets, namely, the ACM Citation data set and the Yelp data set, respectively. The proposed k-context methods have been applied to extract dense subgraphs from these heterogeneous information networks. These proposed methods are unique and novel in identifying dense and informative structures from different types of heterogeneous information networks.

6. Minimizing Misinformation Profit in Social Networks

Tiantian Chen, Wenjing Liu, Qizhi Fang, Jianxiong Guo, and Ding-Zhu Du

This article proposes a novel problem, called profit minimization of misinformation (PMM), which is the first to analyze the profit of activity in the MC problem. Given a misinformation seed set, the PMM problem aims at selecting a node set satisfying the cardinality constraint to minimize the profit of edges starting from infected nodes but ending at infected or protected nodes. Based on the sandwich method, they design a data-dependent approximation scheme for the PMM problem. They approximate the upper and lower bounds of the objective in the equivalent problem by the reverse influence sampling technique. Their algorithm is verified on realistic data sets.

7. Multiobjective-Based Approach for Microblog Summarization

Naveen Saini, Sriparna Saha, and Pushpak Bhattacharyya

In this article, the concepts of multiobjective optimization in microblog summarization are employed to produce good quality summaries. Different statistical quality measures, namely, length, tf-idf score of the tweets, antiredundancy, and measuring different aspects of summary, are optimized simultaneously using the search capability of a multiobjective differential evolution technique. Different types of genetic operators, including recently developed self-organizing map (a type of neural network)-based operator, are explored in the proposed framework. To measure the similarity between tweets, word mover distance is utilized, which is capable of capturing the semantic similarity between tweets. For evaluation, four benchmark data sets related to disaster events are used, and the results obtained are compared with various state-of-the-art techniques using ROUGE measures. It has been found that the proposed algorithm improves by 62.37% and 5.65% in terms of ROUGE-2 and ROUGE-L scores, respectively, over the state-of-the-art techniques.

8. A Large-Scale Study of the Twitter Follower Network to Characterize the Spread of Prescription Drug Abuse Tweets

Ryan Sequeira, Avijit Gayen, Niloy Ganguly, Sourav Kumar Dandapat, and Joydeep Chandra

This article performs a large-scale study of the Twitter follower network, involving around 0.42 million users who justify drug abuse (DA), to characterize the spreading of DA tweets across the network. The authors identify active cascades over the network and observe that the cascades of DA tweets get spread over a long distance through the engagement of several closely connected groups of users. Moreover, a collective phenomenon is also revealed, involving a large set of active fringe nodes along with a small set of well-connected nonfringe nodes that work together toward such spread, thus potentially complicating the process of arresting such cascades. Besides, they discovered that the engagement of the users with respect to certain drugs, such as Vicodin, Percocet, and OxyContin, are most mentioned in Twitter is instantaneous. Furthermore, their research indicates that drug abusers engaged on Twitter remain vulnerable to adopting newer drugs, aggravating the problem further.

9. An Analysis of the Internal Organization of Facebook Groups

Andrea De Salve, Paolo Mori, Barbara Guidi, and Laura Ricci

This article studies the main properties of groups defined in online social networks (OSNs), taking as reference use cases 40 real Facebook groups of different categories that account for a total of about 500 000 users. In particular, the authors exploit interaction patterns among users and social network analysis to uncover interesting aspects related to the internal organization of groups. Experimental results reveal that the majority of the collected groups exhibit an internal structure where members can be clustered in four subgroups according to the level of tie strength of the relations they have. Furthermore, clusters identified on Facebook groups can provide relevant information about the importance of users within such groups.

10. Community Detection Based on Symbiotic Organisms Search and Neighborhood Information

Jing Xiao, Chao Wang, and Xiao-Ke Xu

In this article, a novel community detection method is proposed, named symbiotic organisms search community detection (SOSCD). The bioinspired metaheuristic [symbiotic organisms search (SOS)] is discretized and utilized as the optimization strategy to improve global convergence performance of modularity optimization. Meanwhile, by utilizing the neighborhood information of each node to guide community optimization, two different local search (LS) schemes are designed to intensify exploitation, thus assisting the global search, including the neighbor-based community modification (NCM) and the neighbor-based LS (NLS). Their experimental results based on both synthetic and real-world networks have validated the effectiveness and superiority of the proposed operations in SOSCD.

11. Thread Structure Learning on Online Health Forums With Partially Labeled Data

Yunzhong Liu, Jinhe Shi, and Yi Chen

Thread structures, the reply relationships between posts, in online forums are very important for readers to understand the thread content, as well as for improving the effectiveness of automated forum information retrieval, expert findings, and so on. To learn complete thread structures from partially labeled structures, this article proposes a statistical machine learning model named thread conditional random fields (threadCRF). Person resolution, the process of identifying the same person mentioned in different contexts, is used together with threadCRF for thread structure learning.

The effectiveness of the proposed approaches is empirically verified.

12. Signs of Heritage—An Agent-Based Model of the Dynamics of Heritage Categories

Rodrigo Nicolau Almeida, and Nuno David

This article conceptualizes the cultural dynamics of heritage, designs, and analyses a dedicated computational agent-based model of heritage engagement. They explore the role of communicative strategies and the specific topologies of interaction networks and understand what role mediation can play in producing different levels of consensus between tourists. The results suggest that topology plays the greatest role in generating consensus in the evolution of heritage meaning, with different patterns emerging according to the communicative strategies employed. The results have implications for the future direction of the study of heritage and heritage modeling, placing emphasis on the need to analyze tourist communication content, as well as being potentially useful for public policy with regard to heritage management.

13. Application of Blockchain in Collaborative Internet-of-Things Services

Li Da Xu and Wattana Viriyasitavat

In this article, a blockchain-based smart contract is presented for establishing the trust of process executions that fits into the Internet-of-Things (IoT) environment. The authors develop smart contract code to address trust of process executions. They also present a conceptual architecture that reduces, or eliminates, the prejudice of the selected validators for running consensus, suggest voting mechanism resided in the smart contract which purposefully designed to decrease the delay caused by prominence consensuses, and introduce a data structure that additionally expedites the response time of transactions being validated. In addition, the voting mechanism provides flexibility as business partners can specify the number of vote count per function, according to its importance, to be validly executed. The illustration is done by an example of a smart contract to encode a business process.

14. Topo2vec: A Novel Node Embedding Generation Based on Network Topology for Link Prediction

Koushik Mallick, Sanghamitra Bandyopadhyay, Subhasis Chakraborty, Rounaq Choudhuri, and Sayan Bose

This article proposes a naive and scalable approach for generating the node samples based on the principle of goal-oriented greedy searching. The generated node samples have low noisy structures that can represent the relation of edges of the network in a better way, compared to the state-of-the-art methods. Consequently, a better representation of feature embedding of nodes in the network is generated from the samples. The learned feature vectors are used for solving the link prediction problem using pairwise kernel support vector machine (SVM) classifier. As such, the random forest (RF) classifier with a new algebraic operation is deployed to obtain the symmetric pairwise feature representation of a node pair. Finally, the efficacy of the proposed Topo2vec is demonstrated by testing it against state-of-the-art network context generation algorithms in several real-world networks.

15. The Evolution of Turing Award Collaboration Network: Bibliometric level and Network-level Metrics

Xiangjie Kong, Yajie Shi, Wei Wang, Kai Ma, Liangtian Wan, and Feng Xia

This article studies the long-term evolution of the Turing Award Collaboration Network, and it can be considered as a microcosm of the computer science field from 1974 to 2016. First, scholars tend to publish articles by themselves at the early stages, and they began to focus on tight collaboration since the late 1980s. Second, compared with the same-scale random network, although the Turing Award Collaboration Network has small-world properties, it is not a scale-free network. Third, they propose a metric called the Turing Number to measure how far a scholar is from the Turing Award and find that the Turing Number decreases gradually over time, and scholars prefer to gather into groups to do research with the development of computer science. This article presents a new way to explore the evolution of academic collaboration network in the field of computer science by building and analyzing the Turing Award Collaboration Network for decades.

16. Effect of NO_2 on O_3 Using Complex Network Topology Analysis

Qiang Zhang, Dianxiang Xu, Tianze Gao, and Zhihe Wang

In order to study the variation law of the influence degree of air quality factors under time series, this article selects the hourly concentration values of NO_2 and O_3 from November 2017 to October 2018 in Lanzhou City as the research object. The correlation value of hourly concentration value is transformed into the influence degree symbol, and the network model is constructed by using the complex network theory to analyze the time series of NO_2 and O_3 influence degree series. The results show that: 1) NO_2 and O_3 are negatively correlated, and light and temperature are the main factors; 2) in the day of the time series, the conversion of NO_2 and O_3 in Lanzhou City is mainly dominated by different degrees of negative correlation; 3) the effect of NO_2 and O_3 in the original sequence is less stable; and 4) the influence of NO_2 and O_3 can be maintained for up to three days.

17. Behind the Mask: Understanding the Structural Forces That Make Social Graphs Vulnerable to Deanonymization

Sameera Horawalavithana, Juan Arroyo Flores, John Skvoretz, and Adriana Iamnitchi

This article proposes a framework that examines the interplay between graph properties and the vulnerability to deanonymization attacks. They demonstrate its applicability via extensive experiments on thousands of graphs with controlled properties generated from real data sets. In addition, they show empirically that there are structural properties that affect graph vulnerability to reidentification attacks independent of degree distribution. Their framework fills a gap between theoretical research and practice and provides a unifying platform for the development of new methodologies related to graph anonymization, deanonymization, and graph vulnerability quantification. Specifically, this framework can be used to select the particular tradeoff between acceptable vulnerability and needed utility in terms of graph metrics.

18. Managing QoS of Internet-of-Things Services Using Blockchain

Wattana Viriyasitavat, Li Da Xu, Zhuming Bi, Danupol Hoonsopon, and Nuttirudee Charoenruk

This article proposes to integrate the blockchain technologies with a multiagent approach to warrantee the trustiness of real-time data for the measurement of quality of service (QoS) in the Internet-of-Things (IoT) environment. The proposed approach is verified by some demonstrative examples in addressing the QoS specification patterns commonly found in service-based applications, where qualitative analyses are conducted for the evaluation of the patterns.

Social Intelligence

The virtual reality (VR), augmented reality (AR), artificial intelligence (AI), 5G, mobile social media, and other emerging technologies have been pushing the development of our society faster than ever. Since almost everyone plays a terminal in the huge network weaved by such techniques, we are driven to elevate our capacity of perception and information processing, to expand our scope of information access, and to speed up our interactions with other remote citizens. This facilitation of dissemination together with its customized content has greatly disrupted the social process and, ultimately, results in a faster and more volatile emergence of social choices. Consequently, how to analyze the formation of social choices as well as design the interactive systems that can socially interact with human users becomes a central topic in the research of social intelligence. Accordingly, this involves two levels, personal and social, which are sequentially focused in its two-phase history. In an early stage, psychological scholars first concerned with this field, treating social intelligence as a fundamental part of human intelligence. They referred it to the capacity to understand others according to your own similar experience in social contexts. Yet, in recent years, the tide shifts to the focus on the intelligence of social collective behaviors as a whole, where the interactions within modern society are seamless connected.

Cognitive Facets of Social Intelligence

Social intelligence is explicitly studied as early as the 1920s when Thorndike [1] postulated his framework of human intelligence by differentiating ideas, objects, and other people that someone has to deal with. In such a way, he distinguished intelligence as academic, mechanical, and social dimensions. Social intelligence is further defined as "the ability to understand and manage men and women, boys and girls, and to act wisely in human relations." This basic idea clearly laid the foundation of the research scope and played as a guideline in later studies. Unlike the distinction between cognitive (understand others) and behavioral (act wisely in human relations) components from Thorndike, Vernon [2] defined social intelligence as "knowledge of social matters and insight into the moods or personality traits of strangers" (cognition) and as the ability to "get along with others and ease in society" (behavior). Different from the two definitions that involve both cognition and behavior, other studies mostly focus on one of them, such as "the ability to get along with others" for Moss and Hunt [3], "judge correctly the feelings, moods, and motivation of individuals" for Wedeck [4], "ability to judge people with respect to feelings, motives, thoughts, intentions, attitudes, and so on" for O'Sullivan *et al.* [5], and "individuals' fund of knowledge about the social world" for Cantor and Kihlstrom [6]. In summary, the term "social intelligence" refers to the understanding and interpretation of other people's psychological state and the interaction with them for better emotional and mental support.

Though some disputes still exist in the academic community, social intelligence is mainly decomposed into five aspects in traditional studies: social understanding, social memory, social perception, social creativity, and social knowledge. Social understanding plays a central part in the social intelligence. It requires individuals to interpret given surrounded social stimuli that are represented as the implications for the situation and their underlying features. The point is well illustrated by a sample test requirement: understand correctly what a person wants to express via verbal communications as well as nonverbal hints. Researches mostly concentrate on measurement methods, such as the Geoge Washington Social Intelligence Test [7], the Chapin Social Insight Test [8], the broad test batteries [9] and the nonverbal decoding skills [10]. Social memory maintains both episodic and semantic memory contents with one's intention. Its performance is determined by the conscious recall of objectively and explicitly given a variously complex social circumstance. A representative study comes from Kosmitzki and John [11] who discovered the factor for names and faces in laypersons' implicit theories. Social perception, the ability to perceive social information in an agile way, could determine further information processing that is essential for social intelligence behaviors. Wong *et al.* [12] selected several predesigned tasks to operationalize the measure of social perception. Their experiments also involved interpretational demands that cannot be categorized into pure perceptual abilities. Analogous to the perceptual speed in models of academic intelligence, Carroll [13] further specified the perceptual speed in social perception. Social creativity, also called social flexibility, is the divergent production of individual behavioral contents. It is also reflected as the fluent production of possible interpretations of, or solutions for, a particular social situation. For quantitative evaluation, participant's performance is not based on the correct answer but on the number of diversity of ideas [14]. This measure is able to successfully distinguish the domain of social cognitive flexibility from academic intellectual abilities. Social knowledge has been operationalized by the knowledge of good etiquette on the one hand and by the social skills on the other hand. The latter is a concept similar to the taxonomy in AI, where knowledge is recognized as procedural and declarative parts according to its contents [15]. Procedural knowledge refers to the skills or tactics for specific tasks that could not be taught or recalled explicitly, whereas declarative knowledge reflects the world's fact and state and is stored in episodic and semantic memory. Social knowledge, in this

sense, refers to the procedural part that is distinct from social memory.

In general, it still needs to be studied in detail about how these cognitive determinants interact to enable people to exhibit socially intelligent behavior and which of them contribute to the ultimate behavior with a greater extent. Yet, with the latest development of AI, cognitive computation, focusing on the human cognitive process, might provide a new feasible direction for this basic issue [16]–[18].

Social Emergent Behaviors

As alluded earlier, social intelligence is defined at the microindividual level in the early stage. In particular, it investigates what cognitive facets together with their measurements that support people's interaction to make them more popular. One of the best summarizations might be Goleman's famous book that has been selling a million copies worldwide [19]. In recent years, however, academic communities turned to analyze the collective social behavior as a whole. In this sense, social intelligence is redefined as the rational decision-making that emerged from the whole society [20], [21]. Since the process stems from a bottom–up aggregation of social members' decisions, the macroemergent intelligence is also grounded on one's microcognitions as well as behaviors. However, as most social members are self-interested and only have access to local information, their "myopic" decisions may not lead to the optimal choice overall. Thus, scholars concentrate on the modeling and analyzing social behavior by capturing individual social dynamics, the interaction between actual social and physical systems, and the mechanism design that can guide the maximal utility of the society.

The new definition has endowed social intelligence with more comprehensive connotations. For modeling and analyzing, studies involve individual behaviors [22], social networks [23], or both of them [24]. Combined with electronic commerce and mobile social media, user's online behavior, commodity recommendation, social network evolution, social topic propagation, and so on are the most concerned issues. For the interaction of social and physical systems, researchers have proposed cyber–physical–social systems (CPSSs) as the promising direction [25]. Followed by such concept, related works have been conducted in urban transportation [26], intelligent manufacturing [27], smart cities [28], blockchain [29], and so on; we refer readers to [30] for a detailed review. The mechanism design for an "optimal" social choice is originally from game theory, where each member is modeled as a "greedy" agent that maximizes his own utility. Yet, with the increase of computational power and various social sensing technologies, agent-based social computing is introduced for complex problems. For instance, social trust mechanism [31], incentive design [32], supply chain [33], and so on become the main areas of applications.

Prescription of Social Intelligence

Game theory and mechanism design have provided us with a prototype to analyze distributed systems from the perspectives of the agent's optimal strategy selection and exogenous rule-making. For real social system, however, things could be worse. On the one hand, even if the game or mechanism model could be clearly established, these models involve too many decision factors that are sensitive to initial conditions and highly interdependent. Consequently, analysis by equilibrium computation for a large-scale population seems impossible in practice. On the other hand, social members are inclined to be "bounded rational." That is, without comparing every other candidate accurately, they tend to choose an "acceptable" strategy rather than the "optimal" one. Such a phenomenon cannot be strictly explained by the game model. Therefore, artificial society is introduced to directly simulate the systemic equilibrium as well as the evolutionary trajectories before reaching that equilibrium. Moving ahead, we are able to test various management policies for the target system via computational experiments and prescribe the social intelligence by inversely influencing individual's interaction and, thus, his behavior at cognitive levels. In essence, the new paradigm, called the artificial system, computational experiment, parallel execution (ACP) approach, returns to the microsources of social intelligence.

The ACP approach begins with building a multiagent artificial system that computationally simulates microsocial behaviors and individual's interactions. This step involves the basic population synthesis [34]–[37], which provides the artificial system a reasonable and reliable initial state, and the agent behavior modeling [16], [18], which endows the system with evolutionary capacity. The second step simulates complex social processes that how institutions, norms, and group behavior emerge from microlevel agent interactions based on the heterogeneous social contexts. By computational experiments, statistical methods could be used to analyze and predict the costs and benefits associated with various strategies, policies, and decision-making methods [38], [39]. At last, the artificial system is run in a parallel way with the actual one. Named parallel system, such virtual-real coevolutionary system can dynamically describe, predict, and prescribe the systemic intelligent behavior [40].

The ACP paradigm has linked microcognitive decisions with macrosocial intelligent behaviors and, thus, has converged the two research streams as mentioned in the last two sections. As 5G, VR/AR/AI, and other emerging technologies have been moving us to a new era, the ACP approach will transform the traditional psychology-based study into a new interdisciplinary field. Deeply and systematically facilitating the people's interaction and behavior prescription, ACP-based parallel systems are bound to accelerate the evolution of the social systems and, thus, the proper way where we go.

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