

Blockchainized Internet of Minds: A New Opportunity for Cyber–Physical–Social Systems

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WELCOME to the last issue of the IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS (IEEE TCSS) in 2018. Starting from the first issue next year, our Transactions will be a bimonthly publication, entering a new stage for the IEEE TCSS.

The 2018 IEEE International Conference on Systems, Man, and Cybernetics (SMC 2018) was held in Miyataki, Japan, during October 7–10. On behalf of Prof. V. Kreinovich, our Vice President for Publications, I organized the Associate Editor (AE) Luncheon Meeting during the conference to thank our AEs for their continuing efforts and contributions to our Transactions and Magazines. The Editors-in-Chief (EiCs) and over 30 AEs attended this luncheon meeting (see Figs. 1 and 2). The EiCs expressed their appreciation to the AEs for their excellent work in handling large amount of submissions and discussed the current progresses and future challenges of the SMC Society (SMCS) publications.

Following the luncheon, an Editorial Board Meeting for TCSS was held to develop the plans for improving publication quality and reducing review process length. We had a very constructive discussion and proposed many useful suggestions and concrete action plans. Specifically, we reached a consensus on several actionable schemes to make our Transactions better. First, new positions, called Senior Editors (SEs), will be created next year, and several SEs will be nominated to take charge in the review processes in specific areas. Second, a close collaboration with other IEEE SMC publications will be established, e.g., we will publish our editorials in the IEEE SMC Newsletter so that all the SMCS members can be informed with the content of each issue and involved with our publication development in real time. Third, TCSS will shorten its review cycle to 100 days for each submission. As such, starting from 2019, we will reduce the time for reviewer assignment to one week, manuscript review to four weeks, minor revisions to one week, major revisions to two weeks, and final file submission to one week. Fourth, we will create a task force to handle the overdue manuscripts in a faster and more efficient way and recruit new AEs for TCSS. If you are willing to serve as reviewers or AEs, please let me know. TCSS is now in a great shape and has published 1200 pages in 2018, five times more than last year. I believe these plans

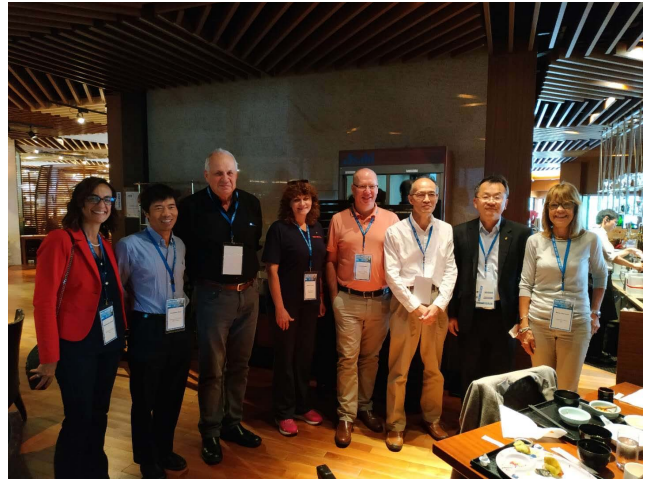


Fig. 1. EiCs of SMC Publications at the IEEE SMC 2018.



Fig. 2. AE Luncheon Meeting at the IEEE SMC 2018.

can take us to the next level toward a leading publication in the field of computational social systems.

During SMC 2018, I was invited to participate in the Editors' Panel (see Fig. 3). This panel provided a good opportunity for me to share my experience and vision for TCSS with our authors, reviewers, and editors. I am glad that our work has received many valuable suggestions and vast positive feedbacks from the audience.



Fig. 3. F.-Y. Wang introduces TCSS in the Editors' Panel at the IEEE SMC 2018.

We also attended the 2018 Workshop on Brain–Machine Interface Systems and Meeting of Global Current and Emerging Brain Initiatives, organized by Prof. M. H. Smith from the University of California at Berkeley, as well as the Brain–Computer Interface Hackathon Competition, where the participants are engaged in a brainstorming and collaborative round-the-clock marathon, designed to rapidly produce working prototypes. Michael has previously served as the President of the Intelligent Robotics Corporation, the IEEE SMCS, and the North American Fuzzy Information Processing Society. I am very interested in Michael's keynote presentation on “The Internet of Minds (IoM)” in the Founders' Forum Panel, a topic we discussed in the IEEE SMC 2017 in Banff, AB, Canada. IoM has been the focus of our research in the recent years, as indicated in my first TCSS editorial. We will share our useful discussions on IoM during SMC 2018, later in this editorial.

Scanning the Issue

1. Capturing Edge Attributes via Network Embedding

Palash Goyal, Homa Hosseinmardi, Emilio Ferrara, and Aram Galstyan

This paper proposes a novel embedding method that uses both network structure and edge attributes to learn better network representations. The proposed method jointly minimizes the reconstruction error for higher order node neighborhood, social roles, and edge attributes using a deep architecture that can adequately capture highly nonlinear interactions. The authors also demonstrate the efficacy of their model over the existing methods on a variety of real-world networks, including collaboration networks, and social networks, and the results show that using the edge attributes to inform network embedding yields better performance in downstream tasks, such as link prediction and node classification.

2. Location-Related Content Communications With Mobility Support in Vehicular Scenarios

Xiaonan Wang, Yanli Li, and Xingwei Wang

Taking into account the advantages of the name-centric mechanism and address-centric mechanism, this paper is motivated to integrate the address-centric mechanism with the name-centric mechanism and aims to overcome the above-mentioned limitations. The authors propose a location-related content communication method with mobility support in vehicular environments. Through acquiring contents from the nearest provider in a unicast way, the content communication failures caused by reverse-path disruption are avoided, and the communication cost and latency are lowered. Moreover, the proposed method achieves the provider and receiver handovers to guarantee that the content communications can be successfully performed. Finally, the experimental results show that the proposed method effectively improves the content communication success rate and reduces the cost and latency.

3. Price Competition of Spreaders in Profit-Maximizing Sponsored Viral Marketing

Zhiyi Lu, Victor O. K. Li, and Qiqi Shuai

This paper considers that the influence in the social networks is valued as the number of final “activations” under some existing information diffusion processes and focuses on the latter, namely, the price competition. The authors model the scenario as a pricing game where the profit-maximized spreaders compete with each other under selection policies of the profit-maximizing advertiser. Conclusions are drawn for three cases of the advertiser. First, an omniscient advertiser always selects the optimal set of spreaders. Second, the greedy advertiser selects spreaders using the simple greedy algorithm. Finally, the advertiser adopts a “double-greedy” method that greedily selects spreaders one by one according to their registration order.

4. Blockchain-Powered Parallel Healthcare Systems Based on the ACP Approach

Shuai Wang, Jing Wang, Xiao Wang, Tianyu Qiu, Yong Yuan, Liwei Ouyang, Yuanyuan Guo, and Fei-Yue Wang

This paper establishes a framework of parallel healthcare systems (PHSs) based on the artificial systems, computational experiments, and parallel execution approach. PHS uses artificial healthcare systems to model and represent the patients' conditions, diagnosis, and treatment process, then applies computational experiments to analyze various therapeutic regimens, and implements parallel execution for decision-making support and real-time optimization. In addition, the authors combine the emerging blockchain technology with PHS via constructing a consortium blockchain linking patients, hospitals, health bureaus, and healthcare communities for comprehensive healthcare data sharing, medical records review, and care audibility. Finally, a prototype, named parallel gout diagnosis and treatment system, is deployed to verify the effectiveness and efficiency of the blockchain-powered PHS framework.

5. Size Matters: A Comparative Analysis of Community Detection Algorithms

Paul Wagenseller III, Feng Wang, and Weili Wu

This paper proposes a systematic way of algorithm comparison by orthogonally integrating community size as a new dimension into existing structural metrics for consistently and holistically evaluating the community quality in the social media context. A heuristic clique-based algorithm is designed to control the size and overlap of communities with adjustable parameters and evaluate it along with the six state-of-the-art community detection algorithms on both Twitter and DBLP networks. Specifically, the authors divide the discovered communities based on their size into four classes, called close friend, casual friend, acquaintance, and just-a-face. They find that the communities in different classes exhibit diverse structural qualities, and many existing community detection algorithms tend to output extremely large communities.

6. On Identification of Organizational and Individual Users Based on Social Content Measurements

Shu-Sen Zhang, Xun Liang, Xuan Zhang, and Rui Xu

This paper studies the identities of social network users, divides them into organizational and individual users in terms of their identities, and explicitly defines and identifies both types of users according to the contents of text, multimedia, and their time series published in a social network. During the identification, the content (topic) complexity and normalization, and the picture features and time series content of the user are analyzed. The authors also propose a machine-operable method to identify a user from different perspectives. In order to verify the feasibility and effectiveness of the proposed method, they conduct an experiment using the data collected from Sina Weibo. Results indicate that the proposed method can effectively distinguish between a user as an organization or individual.

7. A Neural Network-Based Ensemble Approach for Spam Detection in Twitter

Sreekanth Madisetty and Maunendra Sankar Desarkar

This paper proposes an ensemble approach for spam detection at tweet level. Various deep learning models are developed based on convolutional neural networks (CNNs). Five CNNs and one feature based model are used in the ensemble. Each CNN uses a different word embedding (Glove, Word2vec) to train the model. Feature-based model uses content-based, user-based, and n-gram features. Their approach combines both deep learning and traditional feature-based models using a multilayer neural network that acts as a metaclassifier. The models are evaluated on two data sets, one data set is balanced, and another one is imbalanced. Experimental results show that the proposed method outperforms the existing methods.

8. A CPSS-Based Network Resource Optimization Mechanism for Wireless Heterogeneous Networks

Yuke Li, Jian Yang, Xiao Wang, Shuangshuang Han, Dongpu Cao, and Fei-Yue Wang

This paper proposes a novel resource allocation and access control mechanism based on the parallel network architecture, which provides a high-bandwidth connectivity with guaranteed quality of service (QoS) for mobile users in a seamless manner. In this mechanism, multiple users are classified into

several types according to their social property. Compared with the general received signal strength (RSS)-based method, the proposed user priority (UP)-based method achieves three main advantages, as follows: 1) it balances the load of base stations (BSs) when the resource is sufficient; 2) it provides a mechanism called high-priority users higher QoS when the network is heavily loaded compared to the RSS-based method; and 3) it hands over a few users from a heavily loaded BS to a lightly loaded one to allow more users to access this network. The simulation results confirm the advantages of the proposed UP-based mechanism.

9. A Bayesian Multiagent Trust Model for Social Networks

Noel Sardana, Robin Cohen, Jie Zhang, and Shuo Chen

This paper introduces a framework for modeling the trustworthiness of peers in the setting of online social networks. In these contexts, filtering the wealth of messages is achieved by constructing an intelligent agent that reasons about the message and each peer rater of the message, learning over time to properly gauge whether a message is good or bad to show a user, based on message ratings, rater similarity, and rater credibility. The proposed approach employs a partially observable Markov decision process for trust modeling, moving beyond the more traditional adoption of probabilistic reasoning using beta reputation functions. In addition, empirical studies are conducted to demonstrate the effectiveness of the methods, both in simulations featuring head-to-head comparisons with competitors and in the context of some existing online social networks where ground truth data are available.

10. Local Differential Privately Anonymizing Online Social Networks Under HRG-Based Model

Tianchong Gao, Feng Li, Yu Chen, and Xukai Zou

This paper mainly studies privacy issue in online social networks (OSNs). First, the notion of group-based local differential privacy is defined. By resolving the network into one-neighborhood graphs and applying the hierarchical random graph (HRG)-based methods, the proposed scheme can preserve differential privacy and reduce the noise scale on the local graphs. By deploying the grouping algorithm, the proposed scheme can also abandon the attempt to anonymize every relationship to be ordinary, and the authors focus on the similarities in HRG models. In the final released graph, each individual user in one group is not distinguishable, which greatly enhances the OSN privacy. Three real-world OSNs are used to experimentally evaluate the proposed approach, and the results show that the proposed approach can produce synthetic graphs that are more closely matched with the originals compared with the global differential-privacy results.

11. Community Detection in Complex Networks by Detecting and Expanding Core Nodes Through Extended Local-Similarity of Nodes

Kamal Berahmand, Asgarali Bouyer, and Mahdi Vasighi

In this paper, a local approach has been proposed based on the detection and expansion of core nodes in communities. First, a community's central node (core node), which has a high level of embeddedness, is detected based on the similarity between the graph's nodes. Then, the expansion of these nodes is considered by utilizing the concept of node's membership based on the definition of strong community for

weighted graphs. The proposed algorithm has the ability to detect all the graph's communities in a network using local information as well as identifying various roles of nodes, either being core or outlier. Test results on both real-world and artificial networks prove that the quality of the communities that are detected by the proposed algorithm is better than the results that are achieved by other state-of-the-art algorithms in the complex networks.

12. Recent Development in Pedestrian and Evacuation Dynamics: Bibliographic Analyses, Collaboration Patterns, and Future Directions

Min Zhou, Hairong Dong, Bin Ning, and Fei-Yue Wang

This paper mainly studies the recent development of the field of pedestrian and evacuation dynamics (PED). The statistical analyses of the most productive authors, institutions, countries/regions, and cited papers, as well as keywords and their trends are conducted. The most productive and high-impact authors, institutions, and countries are identified. The results of bibliographic analyses show that the European researchers dominate and guide the research of PED, and researchers from China and the USA have published nearly half of the papers in this field. In addition, they generate four networks to analyze the collaboration patterns and the evolution of PED research at different levels. The results of this paper provide a better understanding of patterns, trends, and other important factors as a basis for directing research activities, sharing knowledge, and collaborating in the field of PED research.

13. Enriching User Experience in Online Health Communities Through Thread Recommendations and Heterogeneous Information Network Mining

Christopher C. Yang and Ling Jiang

This paper proposes to recommend threads to users in Online Health Communities (OHCs) by exploiting the heterogeneous healthcare information network mining. The authors first construct a heterogeneous healthcare information network from OHCs data. Then, they extract features from the network to capture the basic network metrics, thread-thread relationship, and user-user relationship and utilize the features to train a binary classification model for thread recommendation. In addition, experiments are conducted using a data set collected from MedHelp. The proposed approach is proven to be effective in measuring user interests in online discussion threads. In addition, by testing the approaches using different settings, they find that the local similarity achieves better performance than the global similarity in heterogeneous information network. By incorporating thread-thread and user-user relationships, it can achieve the best performance.

14. Leveraging Online Word of Mouth for Personalized App Recommendation

Keng-Pei Lin, Yi-Wei Chang, Chih-Ya Shen, and Mei-Chu Lin

This paper proposes a personalized mobile app recommender system based on the textual data of user reviews on the app store. Topic modeling techniques are applied to extract hidden topics of user reviews, and the probability distributions of the topics are utilized to represent the features of the apps. Both the topic distributions of the apps and user preferences are taken into account to produce recommendation scores to generate recommendation lists for target users.

The real-world data sets are collected from app stores to evaluate the performance. The experimental results show that user reviews are effective for deriving the features of apps, and the proposed user-review-based app recommender system can improve the performance of existing approaches.

15. Propagation From Deceptive News Sources Who Shares, How Much, How Evenly, and How Quickly?

Maria Glenski, Tim Weninger, and Svitlana Volkova

This paper considers all content propagated by various news sources in social media. The authors also analyze and contrast population versus subpopulation behavior (by demographics) when spreading misinformation and distinguish between two types of propagation. Their evaluation examines how evenly, how many, how quickly, and which users propagate content from various types of news sources on Twitter. Analysis by demographics shows that the users with lower annual income and education share more from disinformation sources compared with their counterparts. News content is shared significantly more quickly from trusted, conspiracy, and disinformation sources. Older users propagate news from trusted sources more quickly than younger users but share from suspicious sources after longer delays. Finally, users interacting with Clickbait and conspiracy sources are likely to share from propaganda accounts but not the other way around.

16. Harnessing Twitter for Answering Opinion List Queries
Ankan Mullick, Pawan Goyal, Niloy Ganguly, and Manish Gupta

Opinion list queries, such as “valentine’s day gift ideas,” “best anniversary messages for your parents,” and so on, are quite popular on web search engines. Users expect instant answers comprising of a list of relevant items (opinion list) for such a query. Surprisingly, current search engines do not provide any crisp instant answers for queries in this critical query segment. The authors present the first system that tackles such queries. They present an end-to-end system to identify these “opinion lists” from a large number of Twitter hashtags using a classifier trained novel task-specific features and extract suitable list answers from relevant tweets using carefully designed regex patterns. The proposed system can also be used to present a ranked list of these items and handle tail lists using a novel algorithm to borrow list items from similar lists. Crowd-sourced evaluation shows that the proposed system can extract opinion lists with good accuracy.

17. MALT^P: Parallel Prediction of Malicious Tweets

Eric Lancaster, Tanmoy Chakraborty, and V. S. Subrahmanian

This paper predicts whether a tweet is malicious or not by examining five classes of features: textual content including sentiment, paths emanating from a URL mentioned in the tweet, attributes associated with URLs, and multimodal content in the tweet. A fifth class of features first constructs a novel “tweet graph” and then defines features by analyzing “metapaths” contained in the tweet graph. Next, the authors propose a MALicious Tweets in parallel collective classification algorithm. Experiments show that metapath-based approach outperforms past efforts at identifying malicious tweets, metapath-based features yield very high predictive accuracy, and metapath features significantly outperforms the other methods in isolation. In addition, they find that the presence of multimodal content is not a major factor, and

metapath-based features dominate in separating malicious from benign tweets.

18. Modeling Direct Transmission Diseases using Parallel Bitstring Agent-Based Models

Rogério Luis Rizzi, Wesley Luciano Kaizer, Claudia Brandelero Rizzi, Guilherme Galante, and Flávio Codeco Coelho

To address the memory issue, this paper designs and implements an agent-based model using an innovative feature: the bitstring approach. To cope with the high computational demands, the authors develop a parallel version of model aiming multicore CPUs and GPUs architectures using thrust parallel algorithms library. The results of the proposed model are validated comparing them with data of a spread of Influenza A in Cascavel, South Brazil, occurred in 2009. The model presents good qualitative results and an excellent performance on GPUs. The application of bitstring technique is proved to be relevant in economy of memory, allowing to store the same attributes using 41% less memory space and improving the data copy time between CPU and GPU up to 52%.

19. Structuring Mobility Transition With an Adaptive Graph Representation

Tianlong Gu, Minfeng Zhu, Wei Chen, Zhaosong Huang, Ross Maciejewski, and Liang Chang

This paper presents a graph-based approach for structuring crowd mobility transition over multiple granularities in the context of social behavior. The key to their approach is an adaptive data representation, the adaptive mobility transition graph (AMTG), which is globally generated from citywide human mobility data by defining the temporal trends of human mobility and the interleaved transitions between different mobility patterns. They describe the design, creation, and manipulation of the AMTG and introduce a visual analysis system that supports the multifaceted exploration of citywide human-mobility patterns.

20. Dynamic Security Risk Evaluation via Hybrid Bayesian Risk Graph in Cyber-Physical Social Systems

Shancang Li, Shanshan Zhao, Yong Yuan, Qindong Sun, and Kewang Zhang

This paper aims to investigate the risks for security threats in cyber-physical-social system (CPSS), which is generated by the increasing influence of cyber systems and social networks. They propose a hybrid Bayesian risk graph model to analyze the temporal attack activity patterns in dynamic cyber-physical-social networks and introduce a hidden Markov model to model the dynamic influence of activities, which then be mapped into a Bayesian risks graph model that can evaluate the risk propagation in a layered risk architecture. The numerical studies demonstrate that the framework can model and evaluate risks of user activity patterns that expose to CPSSs.

21. Fog Computing Approach for Music Cognition System Based on Machine Learning Algorithm

Lifei Lu, Lida Xu, Boyi Xu, Guoqiang Li, and Hongming Cai

This paper introduces a music cognition system to cognate music and automatically write score based on the machine learning methods. They first involve a number of music

devices in the cognition system through Internet and adopt fog computing to efficiently allocate computing resources. After collecting, preprocessing, and storing raw music data on the fringe nodes, the system will transmit these data from fog nodes to cloud servers to form music databases. Then, the machine learning algorithms are performed in cloud servers to recognize music melody. To verify the effectiveness of the proposed system, a case study of music score generation is conducted, and the results show that the proposed method can provide an effective support to generate music score, as well as a promising way for the research and application of music cognition.

22. Requirements Socio-Technical Graphs for Managing Practitioners' Traceability Questions

Nan Niu, Wentao Wang, Arushi Gupta, Mona Assarandaban, Li Da Xu, Juha Savolainen, and Jing-Ru C. Cheng

This paper proposes an automated approach for identifying questions from requirements repositories and examining their answering status in order to understand requirements traceability in practice. Applying the proposed approach to 345 open-source projects results in 20622 questions, among which 53% and 15% are classified as successfully and unsuccessfully answered, respectively. By constructing a novel requirements socio-technical graph, they explore the impact of stakeholder-artifact relationships on traceability. The results show that the number of people has little influence compared to other graph-theoretic measures, such as the clustering coefficient. Based on the repository mining results, they formulate a set of novel hypotheses about traceability and verify it with a case study.

23. Exploring the Users' Preference Pattern of Application Services Between Different Mobile Phone Brands

Hao Jiang, Zhiyi Hu, Xianlong Zhao, Lintao Yang, and Zhian Yang

This paper aims to analyze the preference of users with different brand phones for different APPs and proposes a concept of mobile Internet life personas (MILP) and the latent MILP indexing (LMILPI) model for the analysis of users' MILP. They build a framework of user portrait analysis based on the latent semantic indexing theme model, LMILPI model, and association rule mining to analyze the users' preference for APP content when using different mobile brands and the relationship among mobile brands, user access time, and MILPs to describe the users' Internet behavior. The proposed analytical framework can provide commercial solutions, such as application recommendations, market strategy formulation, Internet access, and other fields.

24. A 3-D Security Modeling Platform for Social IoT Environments

Bo Zhou, Curtis Maines, Stephen Tang, Qi Shi, Po Yang, Qiang Yang, and Jun Qi

This paper proposes a 3-D security modeling platform that can capture and model security requirements in Social Internet of Things (SIoT) environment. The modeling process is graphical notation based and works as a security extension to the business process model and notation. Still, it utilizes the latest 3-D game technology, and thus, the security extensions are generated through the third dimension. Consequently, the

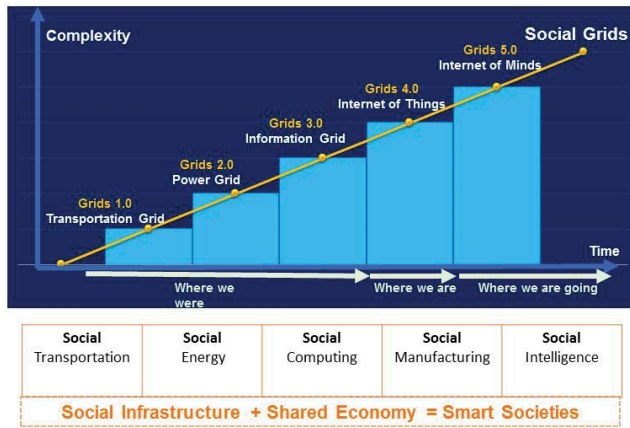


Fig. 4. Smart infrastructures for smart societies.

introduction of security extensions will not increase the complexity of the original SIoT scenario while keeping all the key information in the same platform. Together with the proposed security ontology, these comprehensive security notations created a unique platform that aims at addressing the ever complicated security issues in SIoT environment.

Blockchainized Internet of Minds: A New Opportunity for Cyber-Physical-Social Systems

Social Grids: IOT's Evolution in the New Era

In the classic of K. Jaspers (1883–1969), *The Origin and Goal of History*, he coined the term Axial Age to characterize the period of great humanity awaking and influential philosophers from about 800 to 200 BC in the Middle East, India, China, and Greco–Roman World. In 1978, K. Popper depicted his Three-World Model, which illustrates that the reality actually consists of three worlds: the physical, the mental and the artificial.

If Jasper's first axial age is perceived to correspond to the physical world, then Renaissance to 20th Century presents a period of great rationality awaking and influential scientists, i.e., the second axial age for the mental world. And now, the AI and New Intelligent Technology (IT) make the beginning of a new period of great intelligence awaking and significant technologic leaps for research and development, which is the third axial age for the artificial world.

In the coming third axial age, current social infrastructure will experience a revolutionary transformation, deeply impacting current existing social grids, such as transportation grids, power & energy grids, information grids, and the developing grid of Internet of Things (IoT). In the New IT era, all the social grids and the intelligence within are being integrated into One Grid, and Popper's Three-World Model is being extensively utilized and deeply explored. This technological evolution is being witnessed by recent emerging technologies, such as social transportation (from Uber to Mobike), social energy (from smart grids to Internet of Energy), social computing, social manufacturing, and social intelligence, gradually leading to society-wide intelligent economical systems, shared services, and eventually smart societies (see Fig. 4). We believe that the coming social grid in the new era is

featured by IoM, which provides connectivity to all the intelligence in our societies and eventually leads to the future smart social infrastructure.

IoM: A New Paradigm of Intelligence Cooperation

The emergence of IoM is a natural consequence from the development of the New IT, whose social foundation is the unification of Industrial Technology (Old IT), Information Technology (Past IT), and Intelligent Technology.

IoM utilizes Internet and IoT as its fundamental technologies, incorporating knowledge automation as its core systematic form, and knowledge computing as its core technique. IoM's key tasks include knowledge acquisition, knowledge representation, knowledge exchange, and knowledge association, aiming to build semantic connectivity among intelligent social entities.

In the sense of intelligence, IoM aims to realize “cooperative cognitive intelligence” or “cooperative knowledge automation,” that is, in a cooperative way, IoM accomplishes fundamental knowledge functionalities, such as knowledge acquisition, exchange, representation and association, and also automate cooperative high-level applications, such as reasoning, strategy, decision, scheduling, and management and controls.

Eventually, IoM enables knowledge functionalities and services for complex and large-scale socialized cooperation, substantially enhances operational efficiency, and makes feasible new social cooperation that is not possible with only human-to-human interactions.

We should mention that one initiative of such efforts at the IEEE SMCS, the IEEE Brain Initiative, is being developed, which aims to interpret responses and commands directly from the brain. Such capability enables full two-way communication directly between minds and machines, and by bypassing the limitations of our five senses, the brain–machine interface is expected to increase the bandwidth of the brain dramatically.

With such cooperative cognitive intelligence of IoM, developments in frontier application areas are enabled, such as software-defined systems, IoM for industries, and decentralized autonomous organization (DAO) being three representative examples.

IoM-Based CPSS: A New Opportunity

The phrase cyber–physical–social systems aims to describe the tightly conjoined, coordinated, and integrated information (or cyber), physical, and social resources, that is, systems that feature a tight integration between sensing computation, communication, control, and social and human context (see Fig. 5). In our view, CPSS will be an enabling infrastructure coordinating and integrating Popper's three interacting worlds and elevating artificial intelligence to complex intelligence. CPSS promises a conceptual infrastructure for advancing complex systems with philosophical implication, directly benefiting our society.

In essence, CPSS explores Popper's Three Worlds by establishing both the “virtual” and “real” parallel systems of a complex socio-technical system, and the virtual–real

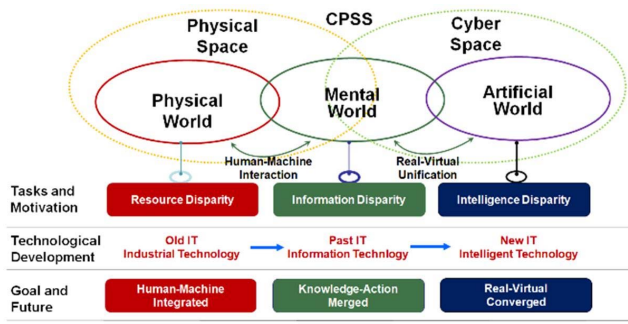


Fig. 5. CPSS: smart infrastructures for parallel intelligence.

system is utilized to solve the complex system problems through quantifiable and implementable real-time computing and interacting. Specifically, such methodology is named the ACP approach, which consists of three major steps: 1) using artificial systems to describe complex systems; 2) using computational experiments to evaluate complex systems; and 3) interacting the real physical systems with the virtual artificial systems. Through virtual-real system interactions, effective control and management over complex systems are realized and achieved.

IoM provides a whole new opportunity for operating CPSS. A CPSS is deemed as a socio-technical system that consists of intelligent entities that can be machines, technical systems, human beings, social organizations, and so on, and the environment of “things” where they sense, communicate, compute, percept interact, and actuate. IoM, together with its foundational IoT and Internet infrastructure, provides such mechanism in the physical space and provides a means of building an artificial virtual system of the CPSS in the cyberspace. Thus, IoM enables the exploration of the Three Worlds and, meanwhile, offers a handler for the ACP approach in management & control of complex socio-technical systems. The most recent development of Intelligent Technology, such as high-performance computing, high-throughput communication, and big data analytics, already provides a foundation for the prospective development of IoM-based CPSS.

Blockchainized IoM: Building Secure and Trustable DAO in CPSS

Blockchain, the technology behind cryptocurrencies, has far-reaching applications beyond cryptocurrencies and payment transactions. Blockchain technology is featured with Smart Contract, which is programed in all the participating entities as a protocol and allows credible transactions without centralized intermediaries. The original goal of creating smart contracts is to enable the trustable and secure transactions in the cyberspace and to decrease the transaction costs. Some cryptocurrencies have already embedded smart contracts in their blockchain. Ethereum, among others, is the most successful one to implement a platform of smart contracts making transactions via Ether, which is the cryptocurrency name of Ethereum, by three high-level computer languages, such as Solidity, Serpent, and LLL.

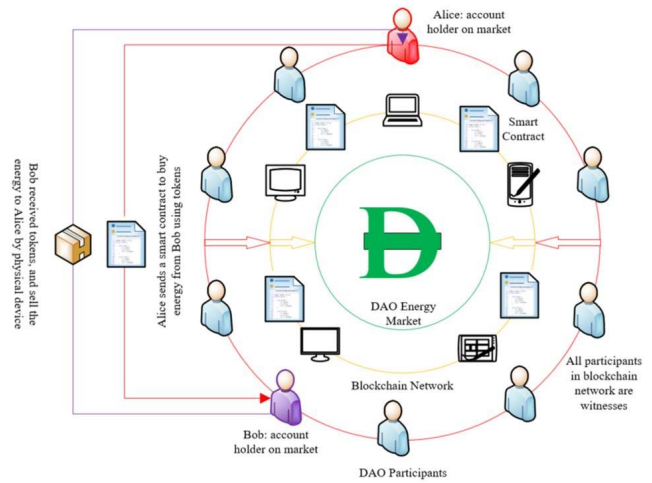


Fig. 6. DAO Model for CPSS.

DAO is a special application of blockchain, configured and operated by multiple sets of smart contracts. The DAO business model is shown in Fig. 6. DAOs have the ability to eliminate centralized intermediaries while supporting the autonomous operation of complex systems and networks. IoM is inherently such system that can be managed and operated on top of DAO. When such projection becomes true, intelligence and knowledge will be “blockchainized.” Such revolutionary technological development will create a truly trustable and secure society-wide AI infrastructure and ecological system, enables the new superior in efficiency and autonomy in social operation, and eventually realizing a higher level, new paradigm of CPSS.

Conclusion

While IoT enables easy access to sensing, communications, and control across automated systems, IoM enables connected and cooperative intelligence and knowledge. IoM provides a paradigm for establishing, developing, and operating CPSS in their physical, social, and cyber spaces and creating their corresponding virtual artificial systems. Using IoM as a supporting technology, utilizing the ACP approach, management, and control of socio-technical CPSS become feasible. Blockchainized IoM provides revolutionary capability from another dimension for creating a truly autonomous, trustable, and secure society-wide ecological CPSS, and we foresee this is a new historical opportunity in canonically and systematically reshaping and remodeling our society.

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computing, parallel intelligence, and knowledge automation.

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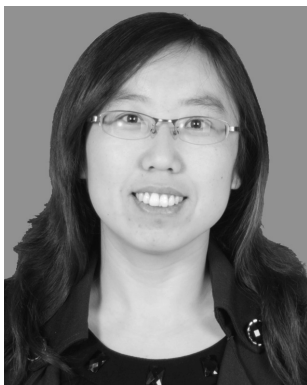
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