Frontiers of Information Technology & Electronic Engineering
www.jzus.zju.edu.cn; engineering.cae.cn; www.springerlink.com
ISSN 2095-9184 (print); ISSN 2095-9230 (online)
E-mail: jzus@zju.edu.cn

Editorial:

Human–machine augmented intelligence: research and applications

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https://doi.org/10.1631/FITEE.2250000

Current research on artificial intelligence (AI) has been entering a new era, with AI technologies and AI-enabled applications emerging in almost every aspect of human life. Meanwhile, avoiding the risk caused by limitations of AI technologies has become a grand challenge. The main idea of human–machine augmented intelligence (HAI) is to adopt the role of humans or to embed human-like cognitive abilities into intelligent machines. Increasing attention and efforts from academia, industry, and governments are attracted by the HAI idea, whose effects are far-reaching.

Two fundamental formulations of HAI include human-in-the-loop HAI (HITL-HAI) and cognitive computing based HAI (CC-HAI), which have become hot and fundamental frontiers of AI, and an increasing amount of original research has emerged in recent years.

Recent existing research activities on HITL-HAI include theories for human–machine collaboration, human–brain interfaces, human–machine coordination and teaming, and advanced perception and smart environments for human–machine collaboration. In particular, HITL-HAI has been widely used in interactive simulation models in aviation, driving, and robotics. In such simulations, humans play an important role because they influence the simulated environment with their own actions. Brain–computer interfaces have become increasingly important among communication channels for human–machine collaboration.

CC-HAI aims to develop computational models to mimic the mechanism or function of the human brain and improve a machine's capabilities of perception, reasoning, and decision-making. We have witnessed an increasing amount of research work on casual models, intuitive reasoning models, and associative memories that are proposed with the forms of deep neural networks.

With this background, we organize a special feature in the journal *Frontiers of Information Technology & Electronic Engineering* as "Human–Machine Collaboration and Cognitive Computation." This special feature covers theories for human–machine collaboration, brain- and neuroscience-inspired augmented intelligence, human–machine coordination and teaming, and related applications. After a rigorous review process, three papers were selected.

The cognition, management, and control (CMC) of complex systems is a very challenging task. Thus, there is a critical need for developing innovative and comprehensive HAI approaches. Fei-Yue WANG and his collaborators proposed a novel concept called "mutually trustworthy human–machine knowledge

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automation (HM-KA)," which considers human intelligence, machine intelligence, and their interaction as a whole, to develop a general process for the CMC of complex systems. The technical process was explained in detail. A bulk power grid dispatch example was also provided to illustrate the proposed approach. As the complexity of practical systems continues to grow, this novel concept and its related technical methods can offer a unique solution to the CMC of complex systems and be applied in a variety of practical science/engineering disciplines.

Affective brain computer interfaces (BCIs) have been used to realize emotional intelligence for more harmonious human–machine collaboration. However, emotion is a complex concept, and stable personality traits usually influence the precision of an individual's emotion processing. To explore the influence of personality characteristics on emotion processing and implement more reliable affective BCIs, Bin HU and his collaborators proposed a novel personality-guided attention mechanism that can use Big-Five personality traits to guide the learning of spatial and temporal representations of electroencephalogram (EEG) signals. The experimental results showed that it can significantly improve the performance of subject-independent emotion recognition and outperform state-of-the-art methods. This method facilitates the development of affective BCIs and makes a further step towards affective interaction between humans and machines.

Human–multi-robot coordination systems play a key role in the development of human–machine hybrid intelligence. However, it is a challenging task to achieve a good balance between human participation and repeated intervention. Yutao CHEN and his collaborators proposed a novel method, named behavioral control task supervision with memory, by combining reinforcement learning, long short-term memory, and null-space-based behavioral control. The proposed method has good novelty. Experiments on several benchmark datasets indicated that compared with other methods, the proposed method achieved the best human–machine coordination performance.

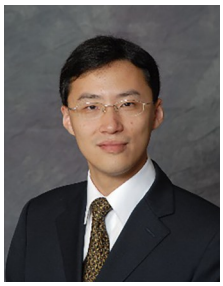
The aforementioned three studies cover many interesting HAI topics and complex tasks. They also provide a series of solutions to overcome the challenging problems of human–machine collaboration. We hope that this collection of topics and applications will be beneficial to those with an interest in HAI or in related areas.

Finally, we would like to express our special gratitude to the authors and reviewers for their great efforts and valuable contributions to this special feature.

Jianru XUE received his PhD degree from Xi'an Jiaotong University in 2003. From 2002 to 2003, he worked in FujiXerox, Tokyo, Japan. He visited the University of California, Los Angeles, from 2008 to 2009. He and his team won the National Natural Science Award (second class) in 2016, the National Technology Invention Award in 2007, the IEEE ITSS Institute Lead Award in 2014, and the Best Application Paper Award in Asian Conference on Computer Vision 2012. He has published over 100 papers in top cited journals and conferences, including *IEEE TPAMI*/*TIP*/*TSMCB*, CVPR, ICCV, ECCV, ACM MM, ICRA, and IROS. He had served as an organization chair or co-chair of international conferences, including VALSE2012, VLPR2011, VLPR2010, ACCV2010, and VSMM2006. His research interests include computer vision, pattern recognition and machine learning, and autonomous driving.

Bin HU received his PhD degree in computer science from the Institute of Computing Technology, Chinese Academy of Sciences, in 1998. He is currently a professor, and dean of the School of Medical Technology and the Institute of Engineering Medicine, Beijing Institute of Technology, China. He is also an adjunct professor, and a former dean of the School of Information Science and Engineering, Lanzhou University, Lanzhou, China. He is a steering committee member of the ACM China Council and a vice chair of the China Committee of the Society for Social Neuroscience. He has published over 300 papers in top cited journals, including *IEEE TCYB*/*TAC*/*JBHI*/*IoT-J*/*TNSRE*/*TII* and *NeuroImage*. He is currently serving as the Editor-in-Chief for *IEEE Trans Comput Soc Syst*. He is also the technical committee co-chair of computational psychophysiology in the IEEE Systems, Man, and Cybernetics Society (SMC), and the technical committee

co-chair of cognitive computing in IEEE SMC. His current research interests include pervasive computing, cognitive computing, and mental healthcare.



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Junping ZHANG received his BS, MS, and PhD degrees from Xiangtan University, Hunan University, and the Institute of Automation of Chinese Academy of Sciences, China, in 1992, 2000, and 2003, respectively. In 2006, he joined Fudan University as an associate professor and became a professor in the School of Computer Science in 2011. His research results have been published in highly ranked refereed journals, including the IEEE transactions *IEEE TPAMI*/*TNN*/*TCYB*/*TITS*, and the leading conferences ICML, CVPR, AAAI, and ECCV. His research interests include machine learning, intelligent transportation systems, image processing, and biometric authentication.