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Mutually trustworthy human-machine knowledge automation and hybrid augmented intelligence: mechanisms and applications of cognition, management, and control for complex systems

Key words: Complex systems; Human-machine knowledge automation; Parallel systems; Bulk power grid dispatch; Artificial intelligence; Internet of Minds (IoM)

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Motivation

- Complex system problems have the characteristics of complexity, uncertainty, relevance, and openness, all of which rely on human intelligence for high-level, abstract thinking and information technology for massive computational capability.
 - Human cognition capability is limited, information processing bandwidth is low, processing speed is low, and the ability of accurate calculation is limited. Therefore, complex system cognition, management, and control (CMC) based solely on human intelligence usually cannot support secure, efficient, and accurate decisions and operations.
 - The limitations of the new generation of information technology limitations are fully revealed. Current artificial intelligence (AI) techniques are normally applicable to decision problems with sufficient training data, clear objectives, and distinct boundary conditions of problem definition. However, complex system CMC problems are usually highly abstract and ambiguous, and cannot be solved solely by AI tools.
- In the process of complex system management and control, especially on critical decisions and execution, human minds need to divide problems into the ones with clear boundaries for machine intelligence based problem solvers.
- Appropriate mechanisms are needed to be designed and used for human-trustworthy information technology for massive computational tasks and precise decisions.

Main idea

- For a complex system CMC process, especially for a critical decision-making process in critical complex systems (such as energy, medicine, finance, and transportation), the human-machine hybrid system should meet all the needs of complexity, relevance, and criticality.
- Human intelligence and machine intelligence need to be able to achieve mutual understanding and trust. They also need to achieve automatic intelligence elevation and fusion of knowledge. Thus, on the basis of knowledge automation (KA), the concept of “mutually trustworthy human-machine knowledge automation (HM-KA)” is proposed in the paper.

Method

- On the basis of KA, the concept of “mutually trustworthy HM-KA” is proposed.
- The key points of the HM-KA include:
 - task and process based human-machine functionality deployment;
 - rule- and responsibility-based human-machine behavior regulations;
 - mutual interpretability based human-machine intelligence fusion;
 - empirical knowledge and parallel systems based human-machine decision verification.

Method (Cont'd)

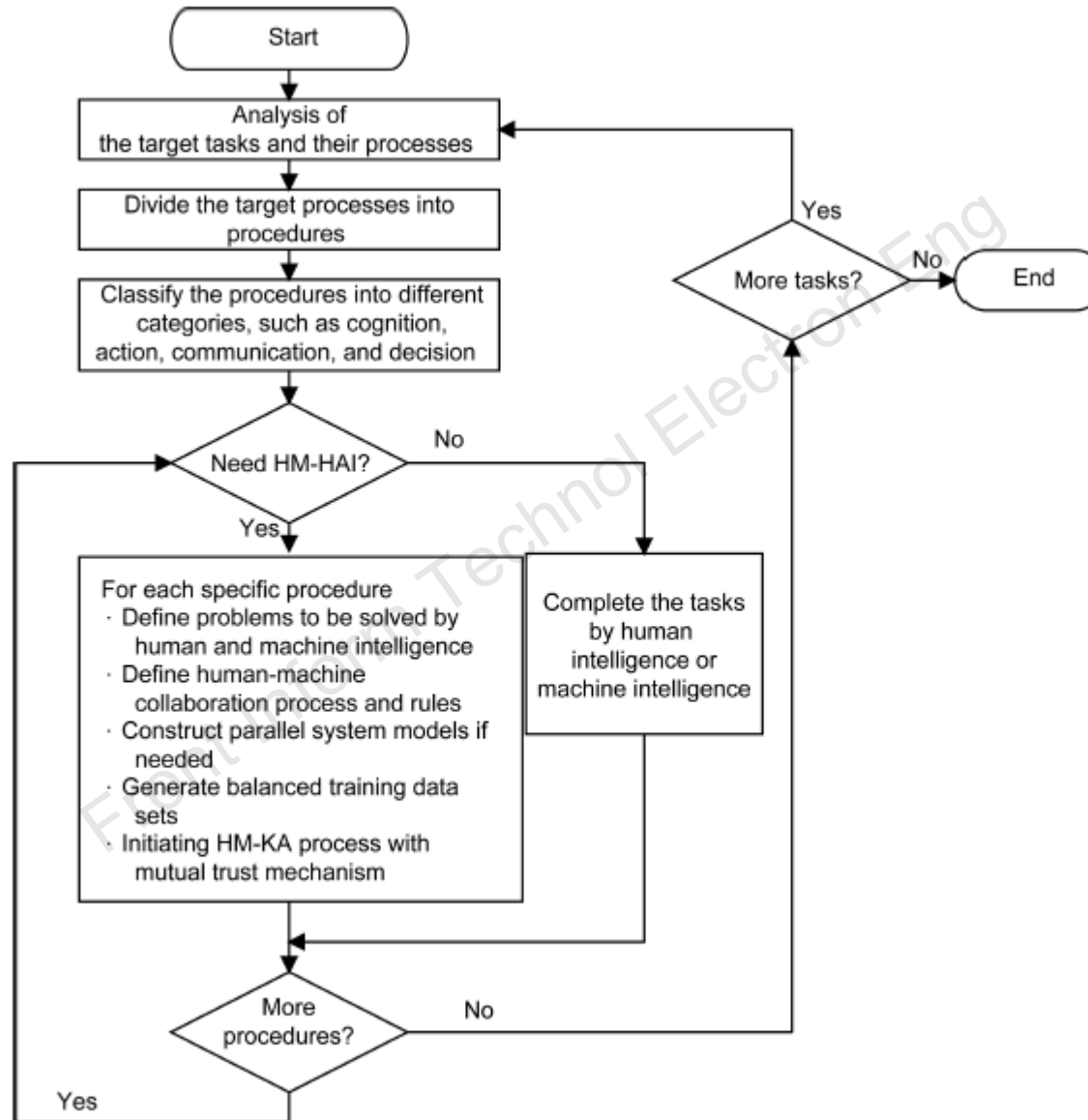


Fig. 3 A general human-machine knowledge automation (HM-KA) process in complex system cognition, management, and control (CMC) tasks

Major results

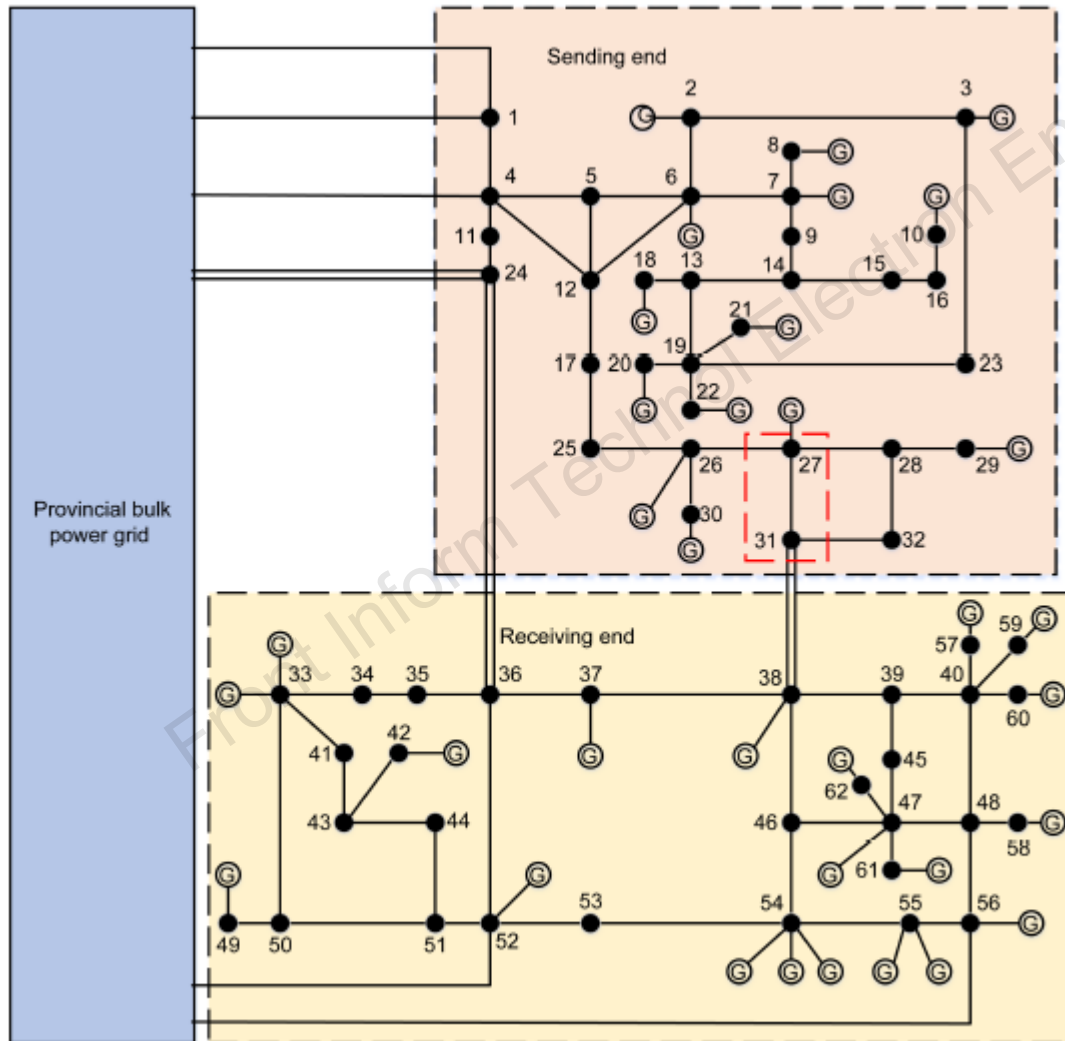


Fig. 7 Topology of the regional power network

Major results (Cont'd)

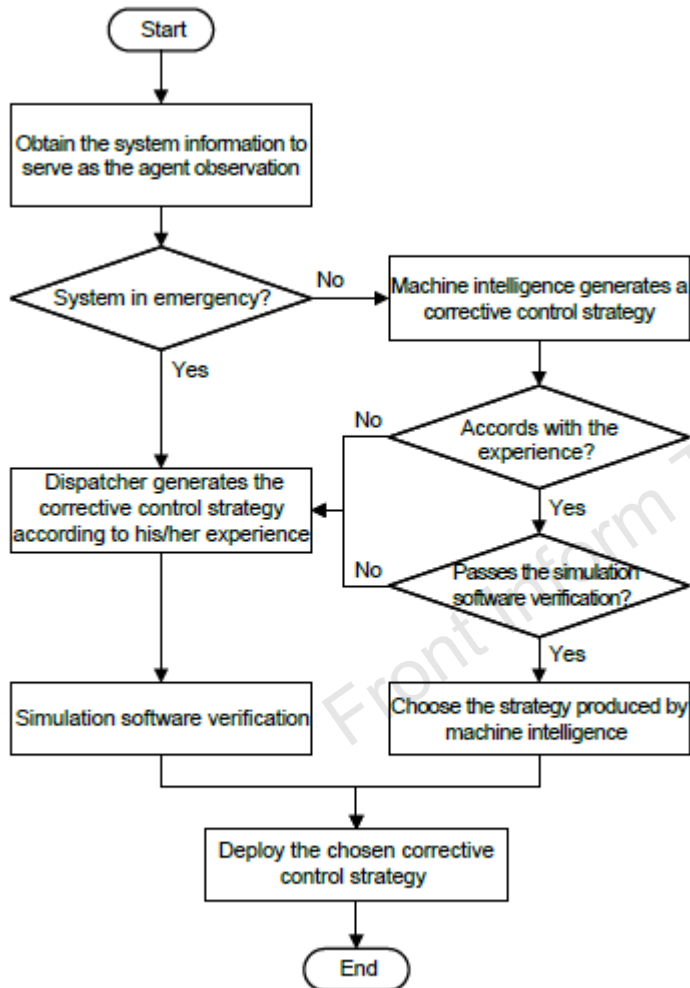


Fig. 8 Schematic of the human-machine cooperation mode

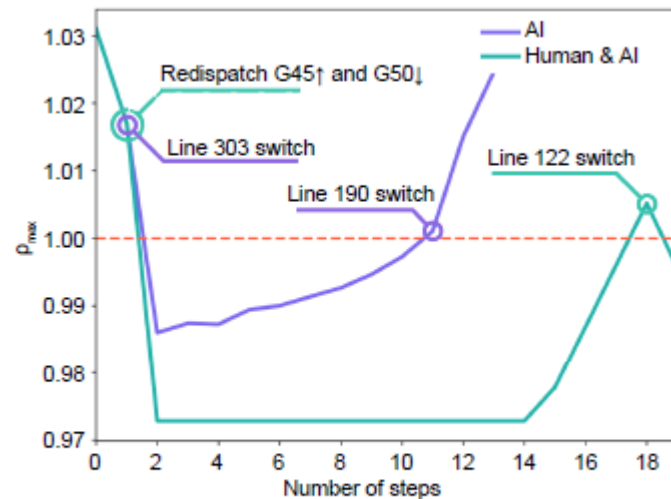


Fig. 9 Operating state of the power grid under different control modes (every step takes 5 min)

Conclusions

- Through this work, we provided a new mechanism, namely mutually trustworthy HM-KA, for the theory and methodology of complex system CMC based on HM-HAI.
- We discussed the core method, implementation process, and key supporting technologies for HM-KA. The development of this method will be a trans-disciplinary product, including results from system science, control science, management science, psychology, cognitive science, data science, and AI.
- We hope that in the process of digital transformation in typical complex social and industrial systems, such as aerospace, aviation, marine, energy, manufacturing, transportation, environmental protection, and other fields, the proposed theory, mechanisms, approaches, and techniques can play positive roles and make considerable contributions.



Fei-Yue WANG (IEEE Fellow) received his PhD degree in computer and systems engineering from the Rensselaer Polytechnic Institute, Troy, NY, USA, in 1990. He joined The University of Arizona, Tucson, AZ, USA, in 1990, where he became a professor and the director of the Robotics and Automation Laboratory and the Program in Advanced Research for Complex Systems. In 1999, he founded the Intelligent Control and Systems Engineering Center, Institute of Automation, Chinese Academy of Sciences (CAS), Beijing, China, under the support of the Outstanding Chinese Talents Program from the State Planning Council. In 2002, he was appointed as the director of the Key Laboratory of Complex Systems and Intelligence Science, CAS. In 2011, he became the State Specially Appointed Expert and the director of the State Key Laboratory for Management and Control of Complex Systems. His current research focuses on methods and applications for parallel intelligence, social computing, and knowledge automation.



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