**FITEE**

***Editorial:***

# Secure control and filtering for industrial metaverse

Qing-Long HAN[†‡1], Derui DING[2], Xiaohua GE[1]

[1]*School of Science, Computing and Engineering Technologies, Swinburne University of Technology, Melbourne, VIC 3122, Australia*

[2]*Department of Control Science and Engineering, University of Shanghai for Science and Technology, Shanghai 200093, China*

[†]E-mail: qhan@swin.edu.au

Metaverse can be regarded as a socialized and virtualized cyberspace parallel yet interactive to the real world. Benefiting from the rapid development of cloud computing and digital twins, metaverse is transforming traditional control and filtering paradigms of industrial automation systems into cyber-physical social systems. Under this scenario, future industrial automation systems could be an integration of real-world ones and virtual twins combined with great computational power within a certain temporal and spatial range. The focused context of metaverse in this field involves information transmission management, behavior recognition of users, as well as control, filtering, and decision-making. Furthermore, the system performance and cost will be a synthetical reflection of the system behavior in cyberspace and the real world. It is indisputable that the intrinsic characteristics of information exchanges between the virtualized cyberspace and the real world, which responds to an urgent need for secure control and filtering, pose significant challenges toward guaranteeing desired system performance and realizing the ideal parameter design. Unfortunately, the current results on metaverse focus mainly on addressing its social significance and seeking its various application fields. The development in the control field still lies in its primary stage.

When information of interest is exchanged between cyberspace and the real world, malicious attacks are unavoidable, which can result in data unreliability or privacy disclosure. As such, it is of great significance to define suitable evaluation criteria to disclose the impact of cyberattacks and to provide engineering-oriented schemes of secure control and filtering. This special feature aims to advance the secure control and filtering theories and techniques in the industrial metaverse and to further promote research activities for realizing intelligent manufacturing.

Consensus represents a fundamental objective of cooperative control and finds its wide applications in multi-agent systems. In the paper entitled "*Towards resilient average consensus in multi-agent systems: a detection and compensation approach*" by Chongrong FANG et al., a deterministic detection-compensation-based consensus algorithm was developed to mitigate the adverse impact of misbehaving nodes in a distributed manner, and a stochastic extension was provided to achieve unbiased resilient average consensus in a statistical sense. In the paper entitled "*Modified dynamic event-triggered scaled formation control for multi-agent systems via a sparrow search algorithm based co-design algorithm*" by Yanping YANG et al., a co-design algorithm based on a sparrow search scheme was presented to design the control gains and triggering parameters jointly, where a resilient dynamic event-triggered mechanism was proposed to govern the information exchange. In the paper entitled "*Event-triggered distributed optimization*

---

[‡] Corresponding author

ⓘ ORCID: Qing-Long HAN, https://orcid.org/0000-0002-7207-0716

*for model-free multi-agent systems*" by Shanshan ZHENG et al., a model-free distributed optimization algorithm was proposed to address the consensus issue of multi-agent systems with unknown nonlinear dynamics, where the pseudo-partial-derivative matrix under event-triggered mechanisms was constructed via the received data.

Event-triggered schemes have proven to be promising in reducing energy consumption and enhancing resource utilization efficiency for resource-constrained cyber-physical systems (CPSs). The reliability and security of industrial CPSs can be greatly affected by cyberattacks or outliers. In the literature, various techniques have been developed to reduce the affected impacts on industrial CPSs. In the paper entitled "*Event-triggered finite-time command-filtered tracking control for nonlinear time-delay cyber-physical systems against cyber attacks*" by Yajing MA et al., an improved coordinate conversion was proposed by considering the attack gains and the reference signal simultaneously, and the finite-time tracking scheme was developed for nonlinear time-delayed CPSs under cyber attacks. In the paper entitled "*Outlier-resistant distributed fusion filtering for nonlinear discrete-time singular systems under dynamic event-triggered scheme*" by Zhibin HU et al., a fusion filtering algorithm was presented in terms of the inverse covariance intersection fusion rule, where a self-adaptive saturation function was used to relieve the effect of measurement outliers in data transmission. Moreover, the uniform boundedness of the filtering error was discussed, and a corresponding sufficient condition was presented. In the paper entitled "*Recursive filtering of multi-rate cyber-physical systems with unknown inputs under adaptive event-triggered mechanisms*" by Ying SUN et al., a joint recursive filtering scheme was developed to estimate both externally unknown inputs and system states for multirate CPSs. Local estimation was further fused via the covariance intersection based fusion conception.

System identification plays an important role in industrial metaverse. Noises in actual industrial processes are rarely white noises and may affect the applications of traditional identification approaches or control strategies. In the paper entitled "*Estimation of Hammerstein nonlinear systems with noises using filtering and recursive approaches for indus-*

*trial control*" by Mingguang ZHANG et al., a methodology was developed to estimate neural fuzzy Hammerstein nonlinear systems by using data filtering technology and recursive approaches. Two typical nonlinear processes, i.e., the pH actual nonlinear process and continuous stirred tank reactors, were adopted to verify the effectiveness. In the paper entitled "*Asynchronous gain-scheduled control of deepwater drilling riser system with hybrid event-triggered sampling and unreliable communication*" by Na PANG et al., an effective recoil controller in networked environments was designed for a deepwater drilling riser system with nonlinear tension forces and energy-bounded friction forces, described by an asynchronous linear parameter-varying model. The prescribed $H_\infty$ performance can be achieved when the controller gain satisfies the obtained sufficient condition.

We would like to thank all the authors for their contributions to this special feature, which will be an important asset to the field, and all the reviewers who volunteered their time to provide valuable feedback to the authors. We would also like to sincerely thank Prof. Fei-Yue WANG, an Executive Associate Editor-in-Chief of *Frontiers of Information Technology & Eelectronic Engineering*, for encouraging us to organize this special feature, and the editorial staff for the support in the entire process.



Qing-Long HAN received the BS degree in mathematics from Shandong Normal University, Jinan, China, in 1983, and the MS and PhD degrees in control engineering from East China University of Science and Technology, Shanghai, China, in 1992 and 1997, respectively. He is pro vice-chancellor (research quality) and a distinguished professor at Swinburne University of Technology, Melbourne, Australia. He held various academic and management positions at Griffith University and Central Queensland University, Australia. He was awarded the 2021 Norbert Wiener Award (the highest award in systems science and engineering, and cybernetics) and the 2021 M. A. Sargent Medal (the highest award of the Electrical College Board of Engineers Australia). He was the recipient of the Andrew P. Sage Best Transactions Paper Award of the IEEE Systems, Man, and Cybernetics Society in 2022, 2020, and 2019, the Norbert Wiener Review Award of *IEEE/CAA J Autom Sin* in 2020, and the Outstanding Paper Award of *IEEE Trans Ind Inform* in 2020.

He is a member of the Academia Europaea (the Academy of Europe). He is a fellow of the Institute of Electrical and Electronics Engineers, a fellow of the International Federation of Automatic Control, an honorary fellow of the Institution of Engineers Australia, and a fellow of the Chinese Association of Automation. He is a highly cited researcher in both engineering and computer science (Clarivate). He has served as an administrative committee member of the IEEE Industrial Electronics Society (IES), a member of the IEEE IES Fellows Committee, a member of the IEEE IES Publications Committee, and chair of the IEEE IES Technical Committee on Network-Based Control Systems and Applications. He is currently the Editor-in-Chief of *IEEE/CAA J Autom Sin*, a co-Editor-in-Chief of *IEEE Trans Ind Inform*, and a co-editor of *Austr J Electr Electron Eng*. His research interests include networked control systems, multi-agent systems, time-delay systems, smart grids, unmanned surface vehicles, and neural networks.

Derui DING received the BS degree in industry engineering in 2004 and the MS degree in detection technology and automation equipment in 2007 both from Anhui Polytechnic University, Wuhu, China, and the PhD degree in control theory and control engineering in 2014 from Donghua University, Shanghai, China. From July 2007 to December 2014, he was a teaching assistant and then a lecturer in the Department of Mathematics, Anhui Polytechnic University, Wuhu, China. From June 2012 to September 2012, he was a research assistant in the Department of Mechanical Engineering, the University of Hong Kong, Hong Kong, China. From March 2013 to March 2014, he was a visiting scholar in the Department of Information Systems and Computing, Brunel University London, UK. From June 2015 to August 2015, he was a research assistant in the Department of Mathematics, City University of Hong Kong, Hong Kong, China. He is currently a senior research fellow with the School of Science, Computing and Engineering Technologies, Swinburne University of Technology, Melbourne, VIC, Australia. He was the recipient of the 2021 Nobert Wiener Review Award from *IEEE/CAA J Autom Sin*, and the 2020 and 2022 Andrew P. Sage Best Transactions Paper Awards from the IEEE Systems, Man, and Cybernetics Society. He is a senior member of the Chinese Association of Automation. He is serving as an associate editor for *IEEE Trans Ind Inform*, *IEEE/CAA J Autom Sin*, *Neurocomputing*, and *IET Contr Theory Appl*. His research interests include nonlinear stochastic control and filtering, as well as distributed control, filtering, and optimization.

Xiaohua GE received the PhD degree in computer engineering from Central Queensland University, Rockhampton, QLD, Australia, in 2014. From 2015 to 2017, he was a research fellow with the Griffith School of Engineering, Griffith University, Gold Coast, QLD, Australia. He is currently a senior lecturer with the School of Science, Computing and Engineering Technologies, Swinburne University of Technology, Melbourne, VIC, Australia. He is an associate editor of *IEEE Trans Ind Inform*, *IEEE Trans Syst Man Cybern Syst*, *IEEE Trans Intell Veh*, *IEEE Trans Circ Syst II Expr Briefs*, and *IEEE/CAA J Autom Sin*. His research interests include networked, secure, and intelligent control and estimation theories, and their applications in electric vehicles, intelligent robotic vehicles, connected automated vehicles, intelligent transportation systems, and so on.