Guest Editorial
Special Issue on Challenges and Responses of Automation Science and Engineering to the COVID-19 Pandemic

THE COVID-19 pandemic has not only posed a significant threat to health, life, economy, and the whole society but also led to numerous new theoretical and practical challenges for automation science and engineering. The goal of this Special Issue is to bring together researchers and practitioners into a forum to show the state-of-the-art research and applications in responding to the challenges and opportunities of automation science and engineering to the pandemic, by presenting efficient scientific and engineering solutions, addressing the needs and difficulties for integration of new automation methodologies and technologies, and providing visions for future research and development.

The central theme of this Special Issue is on challenges and responses in automation science and engineering for fighting against the COVID-19 pandemic. It presents original, significant and visionary automation papers describing scientific models, methods and technologies with both solid theoretical development and practical importance in responding to the COVID-19 pandemic.

The contributions in this Special Issue can be divided into the following categories: epidemic spread and control; medical resource planning and scheduling; and health system design during the pandemic. Specifically, the following papers are included:

First, the epidemic spread and control problems are addressed in [A1]. Scarabaggio *et al.* propose a stochastic nonlinear model predictive controller to determine robust optimal nonpharmaceutical strategies to tackle COVID-19 pandemic waves, where a time-varying SIRCQTHE epidemiological model is used to predict pandemic dynamics. Then, based on a nonlinear stochastic model, predictive control actions, such as restrictions of mobility for different socioeconomic categories, are selected to minimize socioeconomic costs. Such a model is tested in the network of Italian regions using real data.

In [A2], Luo *et al.* propose a "Susceptible, Exposed, Infectious, No symptoms, Hospitalized and reported, Recovered, and Death (SEINRHD)" epidemic propagation model based on local community structures and social contact networks, according to the development characteristics and trend of COVID-19 in a Chinese community. Such a model can provide theoretical support for emergency work of relevant departments in different periods of an epidemic to help reduce the rate of viral transmission, and finally resulting in ending the epidemic.

In [A3], Chen *et al.* present a computationally efficient optimization framework, referred to as COSMOS COVID-19 Linear Programming (CC19LP), to study the delicate balance between the expected fatality rate and the level of normalcy in the community. By focusing on "key contact" to separate high-risk individuals from the rest of the population, CC19LP minimizes expected fatalities through optimizing the use of available personal protective equipment (PPE), vaccines, and social precautions. An online CC19LP tool to automatically access county-level data has been tested for all 3142 U.S. counties.

In [A4], Islam *et al.* introduce an agent-based simulation model of pedestrian dynamics for classroom-type indoor spaces, which will help evaluation of activity policies concerning contact-caused risks, such as physical distancing, seat assignment, and entry/exit policies, in these places during the pandemic. Both risk measures on average exposure duration and number of contacts, and logistic metrics are used for policy evaluation, and extensive simulation experiments are carried out to evaluate policies under different indoor layouts, class schedules, and occupancy levels, to ensure safe operations.

Second, the pandemic presents substantial new challenges to the health system, where the design and operation of healthcare facilities and activities need to respond to these challenges. Along this line, in [A5], Liu *et al.* study the patient admission control problem in buffer zones established in Chinese hospitals to prevent virus spread and transmission, where the patients who need hospitalizations after quick treatments can temporarily wait for COVID-19 tests and receive healthcare servOVIDices. Using the uniformization method to discretize the patient flow, iteration algorithms are introduced to solve the infinite- and finite-horizon Markov decision process (MDP) models and optimal policies.

In [A6], Prakash and Zhong investigate the management of primary care delivery with electronic visits (e-visits), which becomes popular during the pandemic, using queueing models. A novel analytical framework using different queueing

Digital Object Identifier 10.1109/TASE.2022.3148596

models is presented to analyze the primary care delivery system and obtain the equilibrium patient flows under different queue-joining behaviors. Such a model enables a rigorous analytical investigation of system configurations and their influence on system performance, and can provide actionable insights to facilitate e-visits, especially during the COVID pandemic.

To improve the efficiency and sensitivity of large-scale screening against COVID-19, in [A7], Xia *et al.* propose an Adaptive Group Testing (AdaGT) method to screen individuals having COVID-19 infections through RT-PCR tests with fewer tests and high testing sensitivities. Such a method can improve the efficiency for screening the SARS-CoV-2 virus by adaptively adjusting testing strategies based on an estimate of positive ratio, and guarantee a high sensitivity of the tests by determining group sizes to ensure at most one positive sample on average in a group. An appropriate threshold for positive ratio estimation can achieve a minimum average of tests to be deployed in practical applications.

In addition, medical resources, particularly, their planning and scheduling, become critical dealing with the pandemic. To address these issues, in [A8], Pei *et al.* introduce a multistage and multi-type medical service network model, which includes screening with nucleic acid testing, further testing, and treatment of patients with mild and severe symptoms and critical conditions. Then, a dynamic allocation strategy of the medical resources at each stage is proposed based on a stochastic optimization problem, which is solved using the fluid queueing approximation. Using the data from Wuhan, it is shown that the proposed algorithm could result in a guaranteed service level while keeping the healthcare system operational.

In [A9], Li *et al.* present a data-driven optimization approach for multiperiod resource planning during the spread of epidemics. Specifically, a new SEI3H2RD spread model is constructed to generate the most potential scenarios of an epidemic using historical information. Then risk-averse stochastic programming is used to obtain an optimal resource planning solution. It is shown that the model predictions closely fit the outbreak data in Wuhan and the decision approach can reduce the cost of available resources and achieve the goal of epidemic control.

In [A10], Li *et al.* investigate a new multiobjective order assignment and scheduling problem for personal protective equipment (PPE) production and distribution during the epidemics. First, a biobjective mixed-integer linear program for optimal order assignment and scheduling of PPE production is proposed. Then, a novel method to combine ϵ-constraint framework and the logic-based Benders decomposition is used to yield high-quality Pareto solutions.

Finally, in [A11], Liu *et al.* address the weekly physician scheduling problem. First, a pointwise stationary fluid flow approximation method is used to compute the queue length. Then an efficient two-phase approach that consists of a staffing standard and a branch-and-price algorithm is used to solve the problem. Such a model can help hospital managers obtain reasonable scheduling solutions to improve service quality without increasing physician workloads.

The Guest Editors would like to thank all the authors and reviewers for their outstanding work. The Guest Editors would also like to thank the Editors-in-Chief Michael Wang and Yu Sun, the Editorial Assistant Rebecca Hytowitz, and many others for their efforts devoted to this Special Issue.

JINGSHAN LI, *Lead Guest Editor*
Department of Industrial Engineering
Tsinghua University
Beijing 100084, China
e-mail: jsli@tsinghua.edu.cn

JIE SONG, *Guest Editor*
Department of Industrial Engineering and Management
Peking University
Beijing 100871, China
e-mail: songjie@coe.pku.edu.cn

YAN LI, *Guest Editor*
Icahn School of Medicine at Mount Sinai
New York City, NY 10029 USA
e-mail: yan.li1@mountsinai.org

XIANG ZHONG, *Guest Editor*
Department of Industrial and Systems Engineering
University of Florida
Gainesville, FL 32610 USA
e-mail: xiang.zhong@ise.ufl.edu

FENG CHU, *Guest Editor*
Laboratory IBISC
University of Evry
91000 Évry-Courcouronnes, France
University of Paris-Saclay
91190 Gif-sur-Yvette, France
e-mail: feng.chu@univ-evry.fr

JINGANG YI, *Guest Editor*
Department of Mechanical and Aerospace Engineering Rutgers
The State University of New Jersey
Piscataway, NJ 08854 USA
e-mail: jgyi@rutgers.edu

APPENDIX: RELATED ARTICLES

[A1] P. Scarabaggio, R. Carli, G. Cavone, N. Epicoco, and M. Dotoli, "Nonpharmaceutical stochastic optimal control strategies to mitigate the COVID-19 spread," *IEEE Trans. Autom. Sci. Eng.*, early access, Sep. 20, 2021, doi: 10.1109/TASE.2021.3111338.

[A2] T. Luo, Z. Cao, Y. Wang, D. Zeng, and Q. Zhang, "Role of asymptomatic COVID-19 cases in viral transmission: Findings from a hierarchical community contact network model," *IEEE Trans. Autom. Sci. Eng.*, early access, Sep. 3, 2021, doi: 10.1109/TASE.2021.3106782.

[A3] V. C. P. Chen, "An optimization framework to study the balance between expected fatalities due to COVID-19 and the reopening of U.S. communities," *IEEE Trans. Autom. Sci. Eng.*, early access, Oct. 26, 2021, doi: 10.1109/TASE.2021.3119930.

[A4] M. T. Islam, "An agent based simulation model to evaluate contacts, layout, and policies in entrance, exit, and seating in indoor activities under a pandemic situation," *IEEE Trans. Autom. Sci. Eng.*, early access, Oct. 19, 2021, doi: 10.1109/TASE.2021.3118008.

[A5] R. Liu, J. Xu, and Y. Liu, "Dynamic patient admission control with time-varying and uncertain demands in COVID-19 pandemic," *IEEE Trans. Autom. Sci. Eng.*, early access, Dec. 31, 2021, doi: 10.1109/TASE.2021.3138513.

[A6] A. Prakash and X. Zhong, "Queueing information management of primary care delivery with E-visits," *IEEE Trans. Autom. Sci. Eng.*, early access, Oct. 5, 2021, doi: 10.1109/TASE.2021.3115355.

[A7] X. Xia, Y. Liu, Y. Xiao, J. Cui, and B. Yang, "AdaGT: An adaptive group testing method for improving efficiency and sensitivity of large-scale screening against COVID-19," *IEEE Trans. Autom. Sci. Eng.*, early access, Dec. 10, 2021, doi: 10.1109/TASE.2021.3131585.

[A8] Z. Pei, Y. Yuan, T. Yu, and N. Li, "Dynamic allocation of medical resources during the outbreak of epidemics," *IEEE Trans. Autom. Sci. Eng.*, early access, Aug. 12, 2021, doi: 10.1109/TASE.2021.3102491.

[A9] N. Li, Z. Wang, and Z. Pei, "Sequential resource planning decisions in an epidemic based on an innovative spread model," *IEEE Trans. Autom. Sci. Eng.*, early access, Jul. 14, 2021, doi: 10.1109/TASE.2021.3092775.

[A10] Y. Li, Y. Li, J. Cheng, and P. Wu, "Order assignment and scheduling for personal protective equipment production during the outbreak of epidemics," *IEEE Trans. Autom. Sci. Eng.*, early access, Dec. 31, 2021, doi: 10.1109/TASE.2021.3137025.

[A11] R. Liu, X. Fan, Z. Wu, B. Pang, and X. Xie, "The physician scheduling of fever clinic in the Covid-19 pandemic," *IEEE Trans. Autom. Sci. Eng.*, early access, Sep. 30, 2021, doi: 10.1109/TASE.2021.3114339.

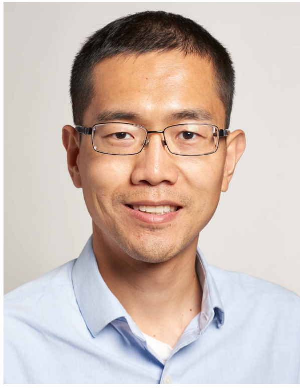
Jingshan Li (Fellow, IEEE) received the B.S. degree in automation from Tsinghua University, Beijing, China, in 1989, the M.S. degree in automation from the Chinese Academy of Sciences in 1992, and the Ph.D. degree in electrical engineering from the University of Michigan in 2000.

He was with General Motors Research and Development Center from 2000 to 2006, the University of Kentucky from 2006 to 2010, and the University of Wisconsin–Madison till 2021. He is now a Chair Professor with the Department of Industrial Engineering, Tsinghua University. He is the coauthor of *Production Systems Engineering* (Springer, Chinese edition by BIT Press, 2012), and the Co-Editor of seven book volumes. Up-to-date, he has published more than 200 refereed journal articles and peer-reviewed conference proceedings. His primary research interests are in design, analysis, improvement, and the control of production and healthcare systems.

Dr. Li is an IISE Fellow. He received the NSF CAREER Award (2010–2016), the IEEE Robotics and Automation Early Career Award (2006), and multiple best paper awards from the IEEE TRANSACTIONS, *IIE Transactions*, and many flagship international conferences. He was the General and Program Co-Chairs, and the Program Chair of the IEEE International Conference on Automation Science and Engineering in 2013, 2015, and 2019, respectively. He was the Founding Chair of the IEEE Technical Committee on Sustainable Production Automation (2012–2016). Since 2016, he has been the Chair of the IEEE Technical Committee on Automation for Healthcare Management. He has been a Senior Editor of the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING and the IEEE ROBOTICS AND AUTOMATION LETTERS, *IISE Transactions*, and *Flexible Services and Manufacturing Journal*, an Associate Editor of *International Journal of Production Research* and *International Journal of Automation Technology*, and the Editor-in-Chief of Conference Editorial Board of the IEEE International Conference on Automation Science and Engineering. He is an IEEE Distinguished Lecturer in robotics and automation.

Jie Song (Senior Member, IEEE) received the B.S. degree in applied mathematics from Peking University, Beijing, China, in 2004, and the M.S. and Ph.D. degrees in industrial engineering from Tsinghua University, Beijing, in 2007 and 2010, respectively.

She has been a Research Fellow with the Georgia Institute of Technology and the University of Wisconsin–Madison. She is currently a Professor with the Department of Industrial Engineering and Management, Peking University. Her current research interest is to develop novel methods/tools from an industrial engineering's perspective by sufficiently understanding the dynamic nature of the complex service engineering system in an information-rich environment, and appropriately integrating online learning knowledge to make real-time decisions with a purpose to improve the efficiency and effectiveness of service engineering systems. Her research is supported by the National Science Foundation of China. She has been honored with the Chang Jiang Youth Scholar Award by the Ministry of Education in China and many other faculty awards at Peking University. She is also a Professional Member of IEEE and INFORMS. She is also the Winner of the Best Paper Award of 2014 IEEE CASE. She is an Associate Editor of the IEEE TRANSACTIONS ON AUTOMATION OF SCIENCE AND ENGINEERING, *Flexible Services and Manufacturing Journal*, and *Asia–Pacific Journal of Operational Research*.



Yan Li is currently an Associate Professor with the Departments of Population Health Science and Policy, and Obstetrics, Gynecology, and Reproductive Science, Icahn School of Medicine at Mount Sinai. He is also the Director of the Health Policy Modeling Laboratory and a member of the Blavatnik Family Women's Health Research Institute at Mount Sinai. His research has been published in leading public health journals such as the *American Journal of Public Health*, *Health Affairs*, and *American Journal of Preventive Medicine*. His research has been supported by a number of funding agencies, such as the National Institutes of Health, Robert Wood Johnson Foundation, European Commission, American Heart Association, and the New York State Department of Health. His research interests include systems science modeling in population health and health care management, cost-effectiveness analysis, and big data analytics. He is a fellow of the New York Academy of Medicine.

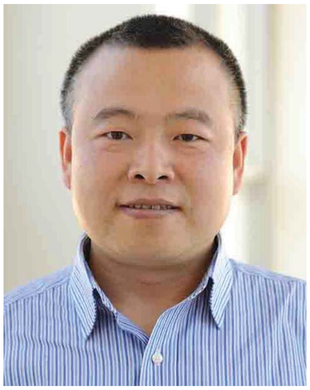
Xiang Zhong (Member, IEEE) received the B.S. degree from the Department of Automation, Tsinghua University, Beijing, China, in 2011, and the M.S. degree in statistics and the Ph.D. degree in industrial engineering from the University of Wisconsin–Madison, Madison, WI, USA, in 2014 and 2016, respectively.

She is currently an Assistant Professor with the Department of Industrial and Systems Engineering, University of Florida, Gainesville, FL, USA. Her research interests include stochastic modeling and control, and data analytics with the application in healthcare, service, and production systems.

Dr. Zhong is a member of IISE and INFORMS.

Feng Chu (Senior Member, IEEE) received the B.S. degree in electrical engineering from the Hefei University of Technology, Hefei, China, in 1986, the M.S. degree in metrology, automatic control, and electrical engineering from the National Polytechnic Institute of Lorraine, Lorraine, France, in 1991, and the Ph.D. degree in automatic control, computer science, and production management from the University of Metz, Metz, France, in 1995.

She is currently a Distinguished Professor of Operations Research with the University of Evry and the University of Paris-Saclay, Evry, France, and the Leader of the Algorithmic, Operations Research, Bioinformatics, and Statistical Learning Group. She is also a Chair Professor with Fuzhou University, Fuzhou, China. She has published more than 140 refereed articles in international journals. Her research interests include the modeling, analysis, and optimization of complex systems, such as intelligent transportation systems and logistic and production systems based on combinatorial optimization, operations research, and Petri nets. She is an IPC member of more than 90 international conferences. She has been awarded by the French Ministry of Education for her Ph.D. supervision and research activities (PEDR) since 2005. She was selected for the Foreign Hundred Talents Program of Anhui Province of China in 2013, Min Jian Scholar in Fujian Province in 2018, and Thousand Talents Program of Sichuan Province in 2016. She was an Associate Editor of the IEEE TRANSACTIONS ON SYSTEMS, MAN AND CYBERNETICS: SYSTEMS. She is also an Associate Editor of the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING, the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, and *International Journal of Production Research*.



Jingang Yi (Senior Member, IEEE) received the B.S. degree in electrical engineering from Zhejiang University, Hangzhou, China, in 1993, the M.Eng. degree in precision instruments from Tsinghua University, Beijing, China, in 1996, and the M.A. degree in mathematics and the Ph.D. degree in mechanical engineering from the University of California at Berkeley, Berkeley, CA, USA, in 2001 and 2002, respectively.

He is currently a Professor of Mechanical Engineering at Rutgers University. His research interests include autonomous robotic systems, dynamic systems and control, mechatronics, automation science, and engineering, with applications to biomedical systems, civil infrastructure, and transportation systems. He is a fellow of the American Society of Mechanical Engineers (ASME). He was a recipient of the 2010 U.S. NSF CAREER Award. He has coauthored papers that have been awarded several best papers in the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING, IEEE/ASME AIM, ASME DSCC, and IEEE ICRA. He also serves as a Senior Editor for the IEEE ROBOTICS AND AUTOMATION LETTERS and the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING, and as an Associate Editor for *International Journal of Intelligent Robotics and Applications*. He served as an Associate Editor for the IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING, the IEEE/ASME TRANSACTIONS ON MECHATRONICS, the IEEE ROBOTICS AND AUTOMATION LETTERS, *Mechatronics* (IFAC), *Control Engineering Practice* (IFAC), and *ASME Journal of Dynamic Systems, Measurement and Control*.