# Guest Editorial Special Issue on Automation Science and Engineering for Smart and Interconnected Healthcare Delivery Systems

THERE has been growing interest in healthcare delivery systems worldwide coupled with a recent influx of funding into the area. Due to rapid development in information and network technology, smartness and interconnectivity have become a central issue in healthcare delivery. Automation is important for healthcare delivery systems engineering. In recent years, the significant changes in healthcare delivery and the rapid development in data analytics, artificial intelligence, robotics, and wearable devices have generated numerous opportunities for innovation in automation for smart and interconnected healthcare delivery systems. In addition, many new challenges have emerged in order to apply and implement these innovations. Such opportunities and challenges have significantly expanded the scopes of traditional automation science and engineering. Therefore, to show the state-of-the-art research and applications in the general area of healthcare delivery systems automation and to address the needs and challenges for the integration of new automation technologies in healthcare delivery, this Special Issue serves as a forum to bring together researchers, clinicians, and healthcare practitioners to present efficient scientific and engineering solutions and to provide visions for future research and development.

The central theme of this Special Issue is on emerging opportunities and future directions in automation science and engineering for healthcare delivery systems, which focuses on information technology-based modeling, analysis, control, and optimization, as well as broad aspects and issues in healthcare delivery. This Special Issue presents original, significant, and visionary automation papers describing scientific models, methods, and technologies with both solid theoretical development and practical importance that improve efficiency, quality, and safety in smart and interconnected healthcare systems.

The contributions in this Special Issue can be divided into the following categories in healthcare delivery: operation modeling and care improvement, scheduling problems, and clinical decision support through optimization and data analytics. Specifically, the following papers are included.

The first category addresses the issues related to modeling and analysis of patient care, including capacity planning and care management. For hospital management, Lee, Musa, Bain, Nelson, Baker, and Li, in their paper "A queueing network model for analysis of patient transitions within hospitals," present a queuing network model-based iteration method to model and analyze patient transitions between emergency department, intensive care unit (ICU), and general ward within a hospital. Routings with feedback flows are considered under general arrival and service processes, and the effects of blocking on performance measures are presented for both the mean and the variability, which can provide a quantitative tool for hospital capacity management.

For post-hospital care, Lee, Wang, Bain, Kundinger, Sommers, Baker, and Li, in their paper "Modeling and analysis of postdischarge intervention process to reduce chronic obstructive pulmonary disease (COPD) readmissions," introduce the modeling and analysis of intervention process for readmission reduction and propose an incentive policy to encourage COPD patients complying with a patient-specific intervention plan. An optimization model is developed to minimize a COPD readmission rate under incentive budget constraint and patients' readmission risks.

Concerning long-term care, Keno, Lou, Kong, Landry, and Callahan, in their paper "A history embedded accelerated failure time model to estimate nursing home length of stay," develop an accelerated failure time parametric survival model using the care transition data collected from a large cohort of older adults receiving coordinated care to characterize nursing home (NH) length of stay, which can aid in operational-level NH care transition and utilization policy development.

As referral is an important element in healthcare delivery systems to ensure appropriate and efficient care, optimizing the referral processes becomes critical. In this direction, Li, Teng, and Kong, in their paper, "Threshold control policy optimization for real-time reverse referral decision of Chinese comprehensive hospitals," study reverse referral that promotes patient flows from upper level hospitals to lower level ones to alleviate the imbalanced utilization of medical resources, and propose an easy-to-implement threshold policy for reverse referral decision for patients receiving post-discharge care.

Digital Object Identifier 10.1109/TASE.2018.2886059

Zhong, Prakash, Petty, and James, in their paper "Bottleneck analysis to reduce primary care to specialty care referral delay," introduce a semi-Markov process to describe information transition and use capacity constrained service queues to model operations of involved personnel at every stage of patients' primary care to specialty care referral pathway. The information flow along the pathway is analyzed, and the system bottlenecks are identified to enhance the workflow design and workforce configuration.

Scheduling has been one of the center topics in the healthcare operations management literature. Surgery, appointment, ambulance, and home service become the main application areas. In surgery scheduling direction, Pang, Xie, Song, and Luo, in their paper, "Surgery scheduling under case cancellation and surgery duration uncertainty," develop a stochastic integer programming model for multiple operation rooms that simultaneously consider the uncertainties of case cancellation and surgery duration. The proposed model can significantly outperform the current practice, which leads to substantial cost reduction in the case study.

Bargetto, Garaix, and Xie, in their paper "Dynamic insertion of emergency surgeries with different waiting time targets," address the problem of emergency surgery insertion into a given elective surgery schedule of an operating theater composed of multiple operating rooms. A stochastic optimization approach is proposed to dynamically prioritize emergency and elective surgeries in order to best balance meeting emergency surgery requirement, perturbation of elective schedule, and surgery team overtime.

For appointment scheduling, Song, Bai, and Wen, in their paper "Optimal appointment rule design in an outpatient department," use a renewal process model to evaluate interday appointment planning and design improved appointment rules, such as the length of booking window, block capacity, and block service, for hospitals with limited or insufficient resources to balance the waiting time and probability of access.

Pan, Song, and Zhang, in their paper "Dynamic recommendation of physician assortment with patient preference learning," present the model of recommending physicians to patients on a Web-based appointment system to achieve efficient and effective utilization of physician resources. A preference learning algorithm considering the heterogeneous illness conditions is proposed to learn the patient preference and optimize the recommendation at the same time.

For home care scheduling, Riazi, Wigstrom, Bengtsson, and Lennartson, in their paper "A column generation-based gossip algorithm for home healthcare routing and scheduling problems," employ a heuristic distributed gossip algorithm to solve home healthcare routing and scheduling problem, and integrate with a local solver based on column generation, which makes it an effective algorithm for larger problem instances.

Moreover, Zhang and Zeng, in their paper "Ambulance deployment with relocation through robust optimization," investigate the deployment of emergency medical service system to maintain preferred service coverages under two coverage levels for regular situation and situation with ambulance unavailable. Two-stage robust optimization models using a column and constraint generation method are introduced to design a reliable ambulance system subject to unavailability of the ambulances, with and without ambulance relocation.

Clinical decision support has been a prevailing area in healthcare systems research. Various optimization and analysis methods have been developed to reduce cost, predict disease, and help diagnosis. In these directions, Xie, Li, Liu, and Geng, in their paper "Optimal ICU admission control with premature discharge," develop an analytical framework to quantify the impact of a number of reserved beds in ICU for potential patients with most critical conditions, and suggest when to prematurely discharge current patients. A Markov decision process model is established to strike a balance between the rejection of incoming patient and the potential premature discharge.

Wang, Liu, Jiang, Yao, and Shen, in their paper "The optimization of combination chemotherapy schedules in the presence of drug resistance," devise efficient combination chemotherapy schedules using mathematical modeling and memetic algorithms with an advanced local search strategy to determine the dosages of drugs administered to cancer patients with drug resistance that may weaken the efficacy of chemotherapy.

To apply data analytic methods in healthcare systems to predict disease status, Yoon and Li, in their paper "A novel positive transfer learning approach for telemonitoring of Parkinson's disease," introduce a positive transfer learning method to leverage other patients' information when building a predictive model for a target patient. Such an approach can take into account of patient heterogeneity by intelligently selecting with patient to transfer from and, thus, preventing negative transfer.

In addition, Chehade and Liu, in their paper "Structural degradation modeling framework for sparse data sets with an application on Alzheimer's disease," propose a framework for modeling and predicting the degradation level and/or condition of units with time and apply it in a case study that involves the Alzheimer's disease neuroimaging initiative data set with satisfactory performance.

Finally, Hu, Hou, Ning, Guo, Deng, Yang, and Kwok, in their paper "On-chip hardware accelerator for automated diagnosis through human-machine interactions in healthcare delivery," address the issue of automated diagnosis, where they propose a novel optical network-on-chip (ONoC) solution of designing discrete cores to quickly understand biomarkers for early detecting abnormal pathophysiology, and analyze the performance of ONoC-based automated cyber-physical system accelerator for personalized healthcare.

The Guest Editors would like to thank all the authors and the reviewers for their outstanding work. We would also like to thank Michael Wang, Editor-in-Chief, Samantha Jacobs, Antonia Carl, and Rebecca Hytowitz, Editorial Assistants, and many others for their efforts devoted to this Special Issue.

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