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Multi-resource allocation and care sequence assignment in patient management: a stochastic programming approach

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Abstract
To mitigate outpatient care delivery inefficiencies induced by resource shortages and demand heterogeneity, this paper focuses on the problem of allocating and sequencing multiple medical resources so that patients scheduled for clinical care can experience efficient and coordinated care with minimum total waiting time. We leverage highly granular location data on people and medical resources collected via Real-Time Location System technologies to identify dominant patient care pathways. A novel two-stage Stochastic Mixed Integer Linear Programming model is proposed to determine the optimal patient sequence based on the available resources according to the care pathways that minimize patients' expected total waiting time. The model incorporates the uncertainty in care activity duration via sample average approximation. We employ a Monte Carlo Optimization procedure to determine the appropriate sample size to obtain solutions that provide a good trade-off between approximation accuracy and computational time. Compared to the conventional deterministic model, our proposed model would significantly reduce waiting time for patients in the clinic by 60%, on average, with acceptable computational resource requirements and time complexity. In summary, this paper proposes a computationally efficient formulation for the multi-resource allocation and care sequence assignment optimization problem under uncertainty. It uses continuous assignment decision variables without timestamp and position indices, enabling the data-driven solution of problems with real-time allocation adjustment in a dynamic outpatient environment with complex clinical coordination constraints.

About the Speaker
Xinyu Yao is a Ph.D. student in Information Systems and Management at Heinz College, Carnegie Mellon University. Her research interests lie in healthcare informatics and healthcare operations. Leveraging advanced approaches from machine learning and operations research, her work aims to facilitate medical decision-making and improve the efficiency of the health system in uncertain, dynamic, and heterogeneous clinical environments. During her Ph.D., she has conducted studies that optimize outpatient resource allocation with stochastic modeling methods, improve readmission and mortality prediction performance with interpretable deep learning techniques, and reconcile patient medications with graph-based AI algorithms incorporated with mathematical optimization approaches. Xinyu also interned at Amazon as a research scientist intern in the summers of 2022 and 2023. She holds a Master's Degree in Machine Learning from CMU (2021) and a B.S. in Industrial Engineering from Tsinghua University (2019).

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