

第四届仿真方法和应用研讨会

主题：复杂系统仿真

The 4th Annual Workshop on Simulation Methodologies and Applications

Theme: Simulation of Complex Systems

三年前，在国内外仿真学者的大力支持下，我们召开了第一届仿真方法和应用研讨会。研讨会的初衷是为我国仿真领域的学者提供一个分享研究成果、推动仿真研究和建立社会网络的平台。前三届的研讨会在上海（2017）、北京（2018）和深圳（2019）举办，分别由上海交通大学、北京大学、香港中文大学（深圳）承办，获得了巨大的成功。今年，因为新冠肺炎疫情的影响，组委会决定将研讨会搬到云端。这也给本届研讨会提供了一个特殊的机遇，邀请了更多的国外学者，也期盼着更多的参会人员。

今年研讨会由复旦大学管理学院承办，主题是“复杂系统仿真”，研讨会的报告人将涵盖医疗健康、共享经济、无人驾驶、港口设计运营、金融风险管理等领域的很多复杂系统仿真问题，探讨复杂系统对随机仿真领域研究所带来的挑战。研讨会还组织了两场论坛，第一场邀请多位国内外著名仿真学者探讨复杂系统仿真对随机仿真领域研究所带来的机遇和挑战，第二场邀请多名国内青年才俊探讨“青年教师的发展”。我们希望所有的会议参与人都能从本次会议中有所收获，满意而归。

The annual workshop on simulation methodologies and applications started three years ago, aiming to provide a platform to disseminate interesting research ideas, to promote simulation research and to create a community for simulation researchers in China. The first three workshops were held in Shanghai (2017), Beijing (2018) and Shenzhen (2019), organized by Shanghai Jiaotong University, Peking University and Chinese University of Hong Kong (Shenzhen), respectively. Due to the Covid-19 outbreak, the organizing committee has decided to bring this year's workshop online, giving us an opportunity to invite more speakers from overseas and to open the workshop to a greater audience.

This year's workshop is sponsored by School of Management at Fudan University. The theme is "Simulation of Complex Systems". The speakers will talk about complex systems in the area of healthcare, sharing economy, autonomous driving, port design and operation, financial risk management and etc., and discuss about the challenges of using simulation in modeling and analyzing complex systems. There will also be two panel discussions. The first one will focus on the research opportunities and challenges in simulation modeling of complex systems. The second one will focus on the early career development for junior faculty members. We sincerely hope that all workshop attendees will enjoy the workshop.

承办单位：复旦大学管理学院

Sponsor: School of Management, Fudan University

会议组委会

Organizing Committee:

复旦大学洪流（主席）

Jeff Hong, Fudan University (Chair)

复旦大学胡建强

Jianqiang Hu, Fudan University

同济大学胡照林

Zhaolin Hu, Tongji University

哈尔滨工业大学姜广鑫

Guangxin Jiang, Harbin Institute of Technology

上海交通大学罗俊

Jun Luo, Shanghai Jiaotong University

请在下列网站注册,我们将在会议前两天发送研讨会 ZOOM ID 或腾讯会议 ID。

Please register at the following website. We will send you the ZOOM ID two days before the workshop.

<https://events.fdsfm.fudan.edu.cn/mc/events/registration/8790>

Conference Schedule

会议日程

Saturday, June 6, 2020

Time	Content
8:00 – 8:15	Opening Remarks L. Jeff Hong (Fudan University)
8:15 – 9:15	Keynote 1: Perspectives on Simulation Optimization. Shane G. Henderson (Cornell University)
9:20 – 10:20	Keynote 2: Safety Evaluation of Intelligent Systems via Rare-Event Simulation. Henry Lam (Columbia University)
10:30 – 11:30	Panel Discussion: Simulation of Complex Systems: Opportunities and Challenges Moderator: Jianqiang Hu (Fudan University) Panelist: Shane G. Henderson (Cornell University) L. Jeff Hong (Fudan University) Henry Lam (Columbia University) Loo Hay Lee (National University of Singapore)
11:30 – 13:00	Lunch
13:00 – 14:00	Keynote 3: Development of Digital twin for Next Generation Container Port. Loo Hay Lee (National University of Singapore)
14:10 – 15:40	Parallel Session 1: Emerging Applications of Stochastic Simulation Session Chair: Li Xia (Sun Yat-sen University) 1. Joint Resource Allocation for Input Data Collection and Simulation Zeyu Zheng (University of California Berkeley) 2. Two Applications of Gaussian Mixture Models Zhaolin Hu (Tongji University) 3. Modeling Heterogeneous Disease-Behavior-Information Dynamics during Epidemics Qingpeng Zhang (City University of Hong Kong) Parallel Session 2: Financial Engineering and Risk Management Session Chair: Guangxin Jiang (Harbin Institute of Technology) 1. Sensitivity Estimation of Conditional Value at Risk Using Randomized Quasi-MC Zhijian He (South China University of Technology) 2. Optimal Tax-Timing with Inflation Risk and Indexed Capital Gains Jing Xu (Renmin University of China) 3. On Gamma Estimation via Matrix Kriging Xin Yun (Fudan University) Parallel Session 3: Simulation Optimization Session Chair: Siyang Gao (City University of Hong Kong) 1. Dynamic Repositioning in Free-Floating Bike Sharing Systems Lei Zhao (Tsinghua University)

	<p>2. Stochastic Gradient Estimation Yijie Peng (Peking University)</p> <p>3. Survey on Ranking and Selection: A New Perspective Weiwei Fan (Tongji University)</p>
15:50 – 16:50	<p>Panel Discussion 2: Youth Forum — Early Career Development Moderator:: Zhaolin Hu (Tongji University) Panelist: Siyang Gao (City University of Hong Kong) Hai Jiang (Tsinghua University) Yijie Peng (Peking University) Xiaowei Zhang (University of Hong Kong) Lu Zhen (Shanghai University)</p>
16:50 – 17:00	<p>Closing Remarks L. Jeff Hong (Fudan University)</p>

Keynote 1

Perspectives on Simulation Optimization

Shane G. Henderson, Cornell University

康奈尔大学 Shane Henderson 教授的报告分为三部分。首先，他将结合共享单车和救护车服务的案例介绍问题驱动的研究方法。其次，他将介绍如何使用有偏的梯度估计量解决仿真优化问题。最后，他将介绍 SimOpt 仿真优化测试库近期的重大变化。

Abstract:

I will present a talk in 3 parts. In Part 1 I'll briefly review my work in bike sharing with CitiBike and my work in ambulance services with St John and other organizations, with the goal of promoting problem-driven research. Problem-driven research takes time, but it enriches one's research agenda and leads to high-impact work. Not everyone should pursue it, but in my opinion such work is under-represented in our field. In Part 2 I'll reinforce this point by discussing recent work on using biased gradient estimators for simulation optimization. In Part 3 I'll discuss recent efforts to substantially renovate SimOpt, a repository of simulation-optimization test problems, including a move to github and a switch to python from Matlab. Joint work with many people whom I'll highlight along the way.



Bio:

Shane G. Henderson is professor and former Director of the School of Operations Research and Information Engineering at Cornell University. He has previously held positions in the Department of Industrial and Operations Engineering at the University of Michigan and the Department of Engineering Science at the University of Auckland. He is the editor in chief of *Stochastic Systems*. He has served as chair of the INFORMS Applied Probability Society, and as simulation area editor for *Operations Research*. He is an INFORMS Fellow. His research interests include discrete-event simulation, simulation optimization, and emergency services planning. He likes cats, climbing walls, biking, Harry Potter and being a Dad.

Keynote 2

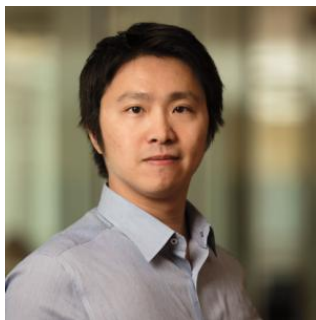
Safety Evaluation of Intelligent Systems via Rare-Event Simulation

Henry Lam, Columbia University

无人驾驶汽车和其它智能系统大规模部署之前的测试问题一直非常具有挑战。在本报告中，哥伦比亚大学 Henry Lam 教授将介绍如何使用小概率事件仿真工具解决这一类问题，并探讨所面临的挑战性问题。

Abstract:

We discuss recent rare-event simulation problems motivated from robustness and safety estimations of autonomous vehicles and other intelligent physical systems. In particular, we demonstrate how simulation provides a useful, if not unique, platform to evaluate their risks before massive deployments, and often results in new rare-event simulation problems that are of a "black-box" nature. We illustrate some methodological challenges for these problems beyond the reach of conventional variance reduction techniques, and discuss their connections with recent machine learning procedures both in terms of methodologies and estimation targets. We illustrate how addressing these problems utilizes tools ranging from mixed integer programming to potential new efficiency notions for rare-event simulation.



Bio:

Henry Lam is an Associate Professor in the Department of Industrial Engineering and Operations Research in Columbia University. He received his Ph.D. in statistics from Harvard University in 2011, and was on the faculty of Boston University and the University of Michigan before joining Columbia in 2017. Henry's research interests include Monte Carlo simulation, uncertainty quantification, risk and extremal analysis, and data-driven optimization. His work has been recognized by venues such as the JP Morgan Chase Faculty Research Award (2020), NSF CAREER Award (2017), the INFORMS JFIG Competition Second Prize (2016) and the Adobe Faculty Research Award (2016). He serves on the editorial boards of *Operations Research*, *INFORMS Journal on Computing*, and *Stochastic Models*.

Keynote 3

Development of Digital twin for Next Generation Container Port

Loo Hay Lee, National University of Singapore

新加坡港一直是世界著名的货柜码头。在本报告中，新加坡国立大学 Loo Hay Lee 将介绍新加坡下一代港口建设中的一些举措，并将着重介绍他所领导的团队在港口数字孪生系统开发领域所完成的开创性工作。

Abstract:

In this talk, we will introduce some new initiatives in Singapore in transforming the industry into the next generation industry, in particular in the logistics and maritime sectors. We will present our work in developing the digital twin for the port system. This digital twin is developed based on the framework O2DES which has the capability in incorporating optimization in the simulation, and optimizing the system parameters based on simulation output. The work has helped Singapore to explore different innovative concepts which will be used for their next generation container port.



Bio:

Loo Hay LEE is an Associate Professor in the Department of Industrial and Systems Engineering at National University of Singapore and was a visiting professor at the Department of Systems Engineering and Operations Research at George Mason University. Dr Lee has also been appointed as the Eastern Scholar Professor for the Shanghai Maritime University by the Shanghai Municipal Education Commission. He received his B.S (Electrical Engineering) degree from the National Taiwan University in 1992 and his S.M and PhD degrees in 1994 and 1997 from Harvard University. He has served as the associate editor for *IEEE Transactions on Automatic Control*, *TRB*, *IIEE Transactions*, among others. He is currently the co-editor for *Journal of Simulation* and is a member in the advisory board for *OR Spectrum*. He is a senior member of IEEE. His research focuses on the simulation-based optimization, maritime logistics which includes port operations and the modeling and analysis for the logistics and supply chain system. He has co-lead a team to win the grand prize for the next generation container port challenge in 2013 by proposing a revolutionary double storey container terminal design, called SINGA Port. He is currently the director of the Center for Maritime Studies and center of next generation logistics (C4NGL) and co-director for center of excellence for simulation and modelling for next generation port (C4NGP) in NUS. In 2018, he also received the supply chain educator award.

Panel Discussion 1

Simulation of Complex Systems: Opportunities and Challenges 复杂系统仿真的机遇与挑战

Moderator: Jianqiang Hu (Fudan University)

Panelists: Shane Henderson (Cornell University), L. Jeff Hong (Fudan University), Henry Lam (Columbia University), Loo Hay Lee (National University of Singapore)



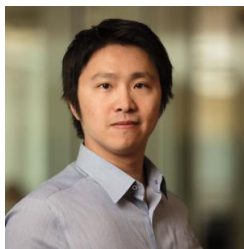
Jianqiang Hu
Hongyi Professor of Management Science
School of Management
Fudan University



Shane Henderson
Professor and INFORMS Fellow
Editor-in-Chief, *Stochastic Systems*
School of Operations Research and Information Engineering
Cornell University



Jeff Hong
Fudan Distinguished Professor
Area Editor, *Operations Research*
School of Management and School of Data Science
Fudan University



Henry Lam
Associate Professor
Associate Editor, *Operations Research*, *INFORMS JOC*
Department of Industrial Engineering and Operations Research
Columbia University



Loo Hay Lee
Associate Professor
Co-Editor, *Journal of Simulation*
Department of Industrial and Systems Engineering
National University of Singapore

Panel Discussion 2

Youth Forum: Early Career Development

青年学者论坛：学术生涯早期的规划与发展

Moderator: Zhaolin Hu (Tongji University)

Panelists: Siyang Gao (City University of Hong Kong), Hai Jiang (Tsinghua University), Yijie Peng (Peking University), Xiaowei Zhang (University of Hong Kong), Lu Zhen (Shanghai University)



Zhaolin Hu
Professor
NSFC 优秀青年基金获得者
Associate Editor, Journal of Management Science and Engineering
School of Economics and Management
Tongji University



Siyang Gao
Associate Professor
2019 IEEE-CASE Best Conference Paper Award
School of Data Science
City University of Hong Kong



Hai Jiang
Associate Professor (with tenure)
NSFC 优秀青年基金获得者
Area Editor, Computer & Industrial Engineering
Department of Industrial Engineering
Tsinghua University



Yijie Peng
Assistant Professor
2019 I-Sim Outstanding Simulation Publication Award
Associate Editor, Asia-Pacific Journal of Operational Research
Guanghua School of Management
Peking University



Xiaowei Zhang
Assistant Professor
Associate Editor, Asia-Pacific Journal of Operational Research
Faculty of Business and Economics
University of Hong Kong



Lu Zheng
NSFC 优秀青年基金获得者
Professor and Dean
Fellow of the Operational Research Society (U.K.)
School of Management
Shanghai University

Parallel Session 1: Emerging Applications of Stochastic Simulation

随机仿真领域的应用研究

Session Chair: Li Xia, Professor, School of Management, Sun Yat-sen University

Joint Resource Allocation for Input Data Collection and Simulation

Zeyu Zheng, University of California Berkeley

Abstract:

Simulation is often used to evaluate and compare performances of stochastic systems, where the underlying stochastic models are estimated from real-world input data. Collecting more input data can derive closer-to-reality stochastic models while generating more simulation replications can reduce stochastic errors. With the objective of selecting the system with the best performance, we propose a simple and general framework to analyze the joint resource allocation problem for collecting input data and generating simulation replications. Two commonly arised features, correlation in input data and common random numbers in simulation, are jointly exploited to save cost and enhance efficiency. A lower bound is proved on the expected input data collection costs to achieve a certain level of selection accuracy.

Bio:



Zeyu Zheng is an assistant professor in the Department of Industrial Engineering and Operations Research at the University of California Berkeley. He received his Ph.D. in Management Science and Engineering, Ph.D. minor in Statistics and M.A. in economics from Stanford University, and a B.S. in Mathematics from Peking University. He has done research in simulation, stochastic modeling, data analytics, statistical learning, and over-the-counter financial markets.

Two Applications of Gaussian Mixture Models

Zhaolin Hu, Tongji University

Abstract:

In this talk, we discuss two applications of Gaussian mixture models (GMM). In the first application, we use GMM to model asset returns in portfolio optimization. We show that the linear portfolio optimization problems with some risk measures, e.g., conditional value-at-risk and entropic risk measure, can essentially be reformulated as deterministic optimization problems, so that one can solve them based on deterministic optimization procedures. We conduct some empirical study to test this approach. In the second application, we use GMM to learn the system response surface in simulation optimization. We take GMM as sampling distributions and design integrated random search algorithms to solve simulation optimization problems.

Bio:



Zhaolin Hu is a professor of School of Economics and Management at Tongji University. His research interests include simulation, stochastic optimization, statistical learning, and risk management. He has published on journals such as *Management Science*, *Operations Research*, and *INFORMS Journal on Computing*. He serves as an associate editor of *Journal of Management Science and Engineering*.

Modeling the heterogeneous disease-behavior-information dynamics during epidemics

Qingpeng Zhang, City University of Hong Kong

Abstract:

The transmission of infectious diseases depends on the social networks among people and the personal protections that people have taken before being exposed to the disease. Traditional epidemiological models assume homogeneous relationships in the social network. In this study, we propose a multiplex network framework for the modeling of the heterogeneous disease-behavior-information dynamics during epidemics, such as the ongoing COVID-19 pandemic. In this framework, people's vulnerability to the disease is influenced by the transmissions of information, behavior, and disease in the social network. Analytical and simulation results are presented to validate the model.

Bio:



Qingpeng Zhang is an Assistant Professor with the School of Data Science at City University of Hong Kong. During 2014-2018, he was with the Department of Systems Engineering and Engineering Management, where he is still an affiliate member. Qingpeng received the B.S. degree in Automation from Huazhong University of Science and Technology and the Ph.D. degree in Systems and Industrial Engineering from The University of Arizona. Prior to joining CityU, he worked as a Postdoctoral Research Associate with The Tetherless World Constellation, Department of Computer Science at Rensselaer Polytechnic Institute. He also worked at the Pacific Northwest National Laboratory and Chinese Academy of Sciences during summers. His research interests include medical informatics and network science.

Parallel Session 2: Financial Engineering and Risk Management

金融工程与金融风险管理

Session Chair: Guangxin Jiang, Professor, School of Management, Harbin Institute of Technology

Sensitivity Estimation of Conditional Value at Risk Using Randomized Quasi-Monte Carlo

Zhijian He, South China University of Technology

Abstract:

Conditional value at risk (CVaR) is a popular measure for quantifying portfolio risk. Sensitivity analysis of CVaR is very useful in risk management and gradient-based optimization algorithms. In this paper, we study the infinitesimal perturbation analysis estimator for CVaR sensitivity using randomized quasi-Monte Carlo (RQMC) simulation. We first prove that the RQMC-based estimator is strong consistent. Under some technical conditions, RQMC that uses d -dimensional points in CVaR sensitivity estimation yields a mean error rate of $O(n^{-(1/2-1/(4d-2)+\epsilon)})$ for arbitrarily small $\epsilon > 0$. The numerical results show that the RQMC method performs better than the Monte Carlo method for all cases. The gain of plain RQMC declines as the dimension d increases, as predicted by the established theoretical error rate.

Bio:



Dr. Zhijian He is an associate Professor at School of Mathematics of South China University of Technology (SCUT). Before joining SCUT, he obtained a Ph.D. in Statistics from Department of Mathematical Science of Tsinghua University. His research interests are quasi-Monte Carlo methods and their applications in quantitative finance and statistics. Part of his research has published in the fields of statistics and computational mathematics, such as *Journal of the Royal Statistical Society: Series B*, *SIAM Journal on Numerical Analysis*, *SIAM Journal on Scientific Computing*, *Mathematics of Computation*.

Optimal Tax-Timing with Inflation Risk and Indexed Capital Gains

Jing Xu, Renmin University of China

Abstract:

We examine how indexing capital gains by inflation would affect investors' portfolio choices and welfare, using a dynamic model that incorporates capital gains tax and inflation risk. We offer several novel insights, including: (i) inflation risk can induce additional incentives to defer taxes, and indexation could make investors realize gains sooner (even later) if they can make full (limited) use of losses; (ii) tax revenue and investors' welfare could both be higher under indexation than under lower tax rates on nominal gains; and (iii) low income investors could benefit from indexation more than wealthy investors do by exploiting losses credit. This

is a joint work with Dr. Yaoting Lei.

Bio:



Dr. Jing Xu is an assistant professor of finance at School of Finance, Renmin University of China (2016-present). He obtained PhD degree from National University of Singapore in 2015, and worked as a postdoc research fellow at Risk Management Institute, NUS. His research focuses on the impact of market illiquidity on portfolio choice and asset pricing, and his works have been published in international academic journals such as *Management Science*, *Journal of Financial and Quantitative Analysis*, *Journal of Banking and Finance*, and *Journal of Economic Dynamics and Control*.

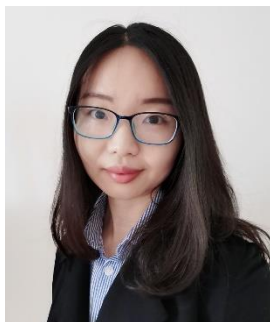
On Gamma Estimation via Matrix Kriging

Xin Yun, Fudan University

Abstract:

In financial engineering, sensitivities of derivative prices (also known as the Greeks) are important quantities in risk management, and stochastic gradient estimation methods are used to estimate them given the market parameters. In practice, the surface (function) of the Greeks with respect to the underlying parameters is much more desired, because it can be used in real-time risk management. In this paper, we consider derivatives with multiple underlying assets, and propose three stochastic kriging-based methods, the element-by-element, the importance mapping, and the Cholesky decomposition, to fit the surface of the gamma matrix that can fulfill the time constraint and the precision requirement in real-time risk management. Numerical experiments are provided to illustrate the effectiveness of the proposed methods.

Bio:



Xin Yun is a joint Postdoctoral Research Associate at School of Data Science, Fudan University, and Paul and Marcia Wythes Center on Contemporary China, Princeton University. She obtained her PhD degree in management science and engineering from University of Chinese Academy of Sciences, and joint PhD degree in financial engineering from City University of Hong Kong. Her research interests are simulation modelling and statistical analysis with application in financial engineering and risk management.

Parallel Session 3: Recent Advances in Simulation Optimization

仿真优化领域的新进展

Session Chair: Siyang Gao, Associate Professor, Department of Systems Engineering and Engineering Management / School of Data Science, City University of Hong Kong

Dynamic Repositioning in Free-Floating Bike Sharing Systems

Lei Zhao, Tsinghua University

Abstract:

In bike sharing systems, bike flows are dictated by customer flows, which are inherently imbalanced in space and time. The resulting spatiotemporal imbalance of bike flows leads to the shortage of bikes in some areas and overage in some others, depending on the time of the day. Repositioning should be performed timely to meet the stochastic & dynamic customer demands. We formulate a stochastic dynamic program for the dynamic repositioning of bikes, with explicit consideration of the characteristics of free-floating systems. We examine the effectiveness and efficiency of a policy function approximation (PFA) algorithm. Highlighting the time-dependent nature of stochastic bike demand and supply, we benchmark with several heuristic policies, conduct extensive numerical experiments, and gain useful managerial insights.

Bio:



Dr. Lei Zhao is an associate professor and the director of the Operation and Services (TOPS) Research Laboratory in the Department of Industrial Engineering at Tsinghua University. His research focuses on computational stochastic optimization methodologies and their applications in urban delivery, omni-channel retailing & logistics, transportation network design, supply chain risk management, and clinical decision making. His research has been funded by the National Natural Science Foundation of China (NSFC) and Ministry of Science and Technology of China (MoST) as well as industry collaborators such as Sinoair, Sinopec, COSCONET/COSCOTECH, Mitsubishi Heavy Industries, General Mills, IBM, etc. Dr. Zhao has publications in ANOR, COR, EJOR, M&SOM, OR Spectrum, TRB, TRC, TRE, and TS, etc.

Stochastic Gradient Estimation

Yijie Peng, Peking University

Abstract:

Stochastic gradient estimation is an actively studied field in simulation, because it plays a central role in gradient-based optimization and sensitivity analysis. Infinitesimal perturbation analysis (IPA) and the likelihood ratio (LR) method are two classic unbiased derivative estimation techniques. Traditional applications are in discrete event dynamic systems and financial engineering and risk management. Recently, the stochastic gradient estimation techniques have attracted attention in machine learning and artificial intelligence. A key

challenge in stochastic gradient estimation has been handling discontinuities in sample performance for structural parameters, which arise in wide variety of applications including financial engineering, production/inventory management, and training artificial neural networks. In this talk, the speaker will give a gentle introduction to this field, and present a new approach called generalized likelihood ratio (GLR) method, capable of dealing with a large scope of discontinuities in a general framework.

Bio:



Dr. Yijie Peng is currently an assistant professor of the Department of Management Science and Information Systems in Guanghua School of Management at Peking University (PKU). He received his Ph.D. from the Department of Management Science at Fudan University and his B.S. degree from the School of Mathematics at Wuhan University. Many of his publications appear in high-quality journals including *Operations Research*, *INFORMS Journal on Computing*, and *IEEE Transactions on Automatic Control*. He is awarded the 2019 Outstanding Simulation Publication Award of INFORMS simulation society. He serves as an Associate Editor for *Asia-Pacific Journal of Operational Research* and *IEEE Control Systems Society Conference Editorial Board*. His research interests include stochastic modeling and analysis, simulation optimization, machine learning, data analytics, and healthcare.

Survey on Ranking and Selection: A New Perspective

Weiwei Fan, Tongji University

Abstract:

In this talk, we briefly review the development of ranking-and-selection (R&S) in the past 70 years, especially the recent theoretical achievements and practical applications in the last 20 years. Different from the classification into the frequentist and Bayesian procedures in the previous papers, we categorize the R&S problems from the underlying methodological formulation foundations, i.e., the hypothesis testing and dynamic programming, respectively. Under these two formulations, we rewrite several well-known procedures in the literature into the unified frameworks. Besides, we discuss about practical integration of using R&S to solve various problems as well as emerging variations of new R&S problems.

Bio:



Dr. Weiwei Fan is an associate professor at the Advanced Institute of Business, Tongji University. She obtained the Bachelor degree from the University of Science and Technology of China, and the PhD degree from the Hong Kong University of Science and Technology. Her research interest includes simulation optimization, robust optimization and healthcare management. Her papers have been published on the *Operations Research* and *Management Science*.