The Operational Research Society of Hong Kong

The 2nd ORSHK Young Researchers Workshop

jointly organized by

Operational Research Society of Hong Kong

and

Hong Kong Society for Transportation Studies

and

Department of Systems Engineering,
School of Data Science,
Department of Management Sciences
City University of Hong Kong

Date: 9 December 2023
Time: 10:00 to 17:30
Venue: Yeung Kin Man Academic Building, City University of Hong Kong

Time	Event
10:15 - 10:40	**Registration** Venue: LT-16 (4/F, Purple zone)
10:40 - 11:00	**Opening Session** Venue: LT-16 (4/F, Purple zone) Welcome speeches by *Professor Yong-Hong Kuo* *President of Operational Research Society of Hong Kong (ORSHK)* *Department of Industrial and Manufacturing Systems Engineering* *The University of Hong Kong*

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Professor Zijun Zhang
Associate Dean, School of Data Science,
City University of Hong Kong
and

Professor Andy Chow
Chair of Organizing Committee, 2nd ORSHK Young Research Workshop
Associate Professor, Department of Systems Engineering
City University of Hong Kong</td></tr>
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On Deep Reinforcement Learning for Operations Research and Management Problems

Professor Frank Y.H. Chen
Chair Professor, Department of Management Sciences,
City University of Hong Kong</td></tr>
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	Dynamic Portfolio Selection and Asset Pricing under Neo-Additive Probability Weighting *Xuedong He, Yu Sun*	*Multiagent Deep Reinforcement Learning Approach for Coordinated Metro Train Rescheduling Under Disruptions* *Chengshuo Ying, Andy H.F. Chow*
	Anomalous Link Detection Using Conformal Prediction and Edge Exchangeability *Rui Luo, Buddhika Nettasinghe, Vikram Krishnamurthy*	*An intelligent rescheduling system for tutorial centers in Hong Kong* *Yang Yu, Vincent Tsz Fai Chow*
	Robust Asset Liquidation Strategies in Financial Systems *Dohyun Ahn, Hongyi Jiang*	*A Bi-Level Deep Reinforcement Learning Framework for Metro Train Scheduling and Speed Control under Stochastic Disturbances* *Shouyi Wang, Yanzuo Lin, Andy Chow*
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Tutorial

Venue: LT-16 (4/F, Purple zone), Time: 11:00 - 12:00

On Deep Reinforcement Learning for Operations Research and Management Problems

Professor Frank Y.H. Chen

Professor of Department of Management Sciences,
City University of Hong Kong

ABSTRACT

Machine learning (ML) pervades many academic disciplines and industries, and its impact is profound. For many years, operations research (OR)/operations management (OM) and machine learning (ML) have advanced as two non-overlapping academic fields. (I will use OR to represent both OR and OM.) Deep reinforcement learning (DRL) is an area of ML that focuses on sequential decision-making, which takes advantage of deep artificial neural network architectures. On the other hand, at its core lies the decision-making recommendation that OR is all about.

In this tutorial, I will regard DRL and OR each as a holistic topic, review the connections between them, and share my view (perhaps primitive and superficial) on some recent advances in the synergies between these two fields. At a high level, the connections between OR and DRL can be explained from three perspectives: OR helps train DRL models, DRL provides inputs to OR, and DRL improves OR solution approaches. I will explain each of these three perspectives.

I next give an overview of the literature on DRL applications in inventory/supply chain management, an important OR sub-field.

Specifically, several well-known supply chain (inventory) problems are conceptually simple but have "afflicted" generations of OR researchers. Their optimal policy structures are too complex to characterize, and traditional solution methods (such as dynamic programming) quickly become intractable due to the curse of dimensionality. Heuristics have, therefore, been developed. In recent years, the related OR field has explored general-purpose DRL methods, which have shown promising improvements in solutions relative to relevant heuristics. However, DRL is typically perceived as a black-box approach, which hinders its adoption in the OR community. More recently, OR researchers overcome this hurdle by introducing interpretable DRL methods and formulating OR problems using the deep neural network architecture. Moreover, some even establish performance guarantees such as worst-case bounds.

In the last part of the tutorial, I report my experience from two recent papers applying DRL to data-driven inventory problems. Such problems are notoriously difficult to optimize due to the curse of dimensionality, and the direct use of the DRL algorithm to solve it also results in poor performance. However, the solution performance is significantly improved after incorporating an approximation

(derived from analytical results) into the standard DRL algorithm. This tutorial ends with insight sharing, particularly views on OR/OM researchers' roles, how our domain knowledge can be incorporated into DRL methods, and how to leverage DRL to solve large-scale and complex OM/R problems.

BIO

Prof. CHEN Youhua (Frank) is currently Chair Professor of Management Sciences at the College of Business, City University of Hong Kong. His current research interests span healthcare operations management, logistics/supply chain management, data-driven operations, and machine learning applications to business problems. He has just completed a large-scale research project on healthcare management and is undertaking another project of a similar scale focusing on a new elderly care model (supported by the BOCHK Centenary Charity Programme). His publications appear in Operations Research, Management Science, POM, IEEE, and other journals. He teaches Operations Management, Supply Chain Management, and Logistics Management.

Project Management

Venue: LT-16 (4/F, Purple zone), *Time: 13:30 – 14:45*

Session Chair: Jin Qi

Design Good Liquidity Pools on Automated Market Makers Abstract

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ABSTRACT

Automated market makers are a popular type of decentralized exchanges in which users trade tokens with each other directly and automatically through a liquidity pool and a fixed pricing function. The liquidity provider contributes to the liquidity pool by supplying tokens to the pool and in return they earn transaction fees from users who trade through the pool. We proposed a model of optimal liquidity provision in which the risk-averse liquidity provider decides the number of tokens she would like to supply to the pool and trade in an open market and the amount of consumption in multiple periods. We derived the liquidity provider's optimal strategy by dynamic programming and proved the existence and uniqueness of the solution. Also, we studied the impact of the transaction fees and automated market makers pricing formula on the liquidity provider's optimal decision. In the class of constant mean pricing formula, we conducted numerical analysis to identify the optimal liquidity pool that maximizes the liquidity provider's utility and the LP's optimal allocation proportion to AMM. Additionally, we investigated the effects of market parameter variations on the optimal transaction fee and optimal pricing formula. These findings provide valuable guidance and insights for the design of AMM pools.

Keywords: automated market makers, stochastic control, decentralized finance, liquidity provision

Project Monitoring and Control Systems

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ABSTRACT

The global use of project management for a variety of traditional and modern applications has not eliminated widely observed problems of project delivery over schedule and over budget. To assist in the monitoring and control of projects, companies can take advantage of three alternative systems: earned value management, earned schedule, and earned duration.

We develop models of these systems to minimize the expected cost of the project. To solve these models, we identify optimal solutions for crashing the project at discrete time periods. This enables us to compare the expected cost in each case. We identify structural differences between the recommendations of the three systems. We also perform a distributionally robust analysis of the cost minimization problem, based on scenario-wise ambiguity sets. We extend our results to multiple projects that share a common expediting budget.

Our results enable us to identify the strengths and weaknesses of each monitoring system and offer recommendations to project managers about which monitoring system to use. The expected loss from a choice of the wrong system is shown to be significant.

Keywords: project management, monitoring and control, expediting, robust optimization.

Early Invasive Mechanical Ventilation Prediction in the Elderly Intensive Care Unit

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ABSTRACT

Invasive mechanical ventilation (IMV) is a critical medical procedure that uses a mechanical ventilator to assist patients with compromised respiratory function. It involves inserting a breathing tube into the patient's airway to deliver oxygen and remove carbon dioxide. Up to 40% of patients in the intensive care units (ICU) require IMV. Accurately predicting the need for early IMV is important for timely intervention and efficient allocation of critical resources.

Given the aging population, our research specifically focuses on elderly ICU patients. We collected clinical data from Guangdong Provincial People's Hospital between 2017 and 2019, comprising static data, vital signs data, and laboratory test results. However, predicting IMV are challenge due to the heterogeneity and limited availability of the data. The raw hospital data consists of multiple types and has varying sampling frequencies. To address these challenges, we propose a machine-learning framework that leverages both heterogeneous data and time-series information. We analyze the data to identify dynamic trends in patients and apply specific feature engineering techniques to capture these trend-related insights. To optimize the use of the limited dataset, we adopt a sliding window approach to generate datasets for model training and testing.

Our experiments indicate that certain tree-based models such as XGBoost, with a 6-hour observation window and a 1-hour gap window, yield robust performance with AUC up to 0.88. From numerical studies, we have gained valuable insights that can benefit healthcare professionals. For instance, we have identified certain indicators that are important for early IMV prediction but are not typically scrutinized by doctors in elderly ICUs (including our team members). This finding suggests some areas where doctors may direct their attention. Ultimately, this study provides a foundation for implementing an IMV prediction system.

Keywords: Invasive mechanical ventilation, machine learning, time window sliding, tree-based models

Data-Driven Robust Network Revenue Management

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ABSTRACT

In this research, we focus on data-driven distributionally robust controls for the quantity-based network revenue management (NRM) problem in which the decision maker accepts or rejects each arriving customer request irrevocably with the goal of maximizing the total expected revenue over a finite selling horizon given limited resources. Instead of the deterministic linear programming (DLP) formulation widely adopted in literature, we approximate the value function of dynamic programming (DP) for NRM problem as probabilistic nonlinear programming (PNLP) in order to capture the randomness in demand. We further take the uncertainty in distribution estimation resulting from either the limited information or the changing environment into account by incorporating the distributional ambiguity into the PNLP formulation. We therefore solve a distributionally robust optimization (DRO) problem to determine an optimal partitioned allocation of capacity to each product against a worst-case distribution in the ambiguity set. We assume that the decision maker does not know the distribution of demand but has access to historical data, which is assumed to be independent and identically distributed (i.i.d.). In this setting, we define our data-driven ambiguity set as a confidence region of a goodness-of-fit (GoF) hypothesis test and then formulate a tractable robust static model.

Furthermore, we extend our robust static NRM model to a multi-stage version. More specifically, we formulate the multi-stage robust NRM model as a robust DP and solve this robust DP using approximate dynamic programming (ADP) approach. The resulting robust ADP model generates robust dynamic bid prices from a conic optimization to help us construct capacity allocation policies. We also provide a constraint generation procedure for solving this robust ADP. To improve the efficiency of problem-solving, we further derive an equivalent reformulation for the robust ADP model, which is computationally tractable and of practical interpretation. By solving this reformulation that approximates the evolution of the selling system under demand uncertainty, we can construct a robust dynamic booking limit policy. We also verify the performance of both our robust static and dynamic policy via numerical experiments.

Keywords: distributionally robust optimization, data-driven optimization, network revenue management, robust approximate dynamic programming, goodness-of-fit test

Robust Optimization for Generalized Project Networks

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ABSTRACT

Completion time estimation is a key component for project management. In addition to uncertain task times, uncertain task outcomes also have a significant impact on the evaluation of completion time. For example, due to some uncontrolled factors in a project, certain task may have a probability of failure, which will result in full repetition or partial rework of the task. Introduction of new task or change of precedence relationships may occur during project execution as a contingency measure. Another example is probabilistic branching, i.e., after the project reaches a milestone, it may be necessary to choose among alternative plans by that time. However, these uncertainties are often ignored in standard approaches, e.g., the program evaluation and review technique (PERT). In this paper, we introduce the generalized project network to capture all the uncertainties in both task durations and task outcomes. A distributionally robust optimization model is developed to estimate the project completion time as well as the target-based measure of tardiness. An efficient algorithm is proposed to solve this optimization model. Numerical results demonstrate the practicality and versatility of our model in addressing completion time estimation problems that encompass all uncertainties associated with both task durations and task outcomes. Moreover, our proposed algorithm exhibits excellent efficiency in solving these problems.

Keywords: robust optimization, project management, completion time estimation, generalized project networks

Dynamic Optimization

Venue: LT-18 (4/F, Purple zone), *Time: 13:30 – 14:45*

Session Chair: Yong-Hong Kuo

Fast Bellman Updates for Wasserstein Distributionally Robust MDPs

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ABSTRACT

Markov decision processes (MDPs) often suffer from the sensitivity issue under model ambiguity. In recent years, robust MDPs have emerged as an effective framework to overcome this challenge. Distributionally robust MDPs extend the robust MDP framework by incorporating distributional information of the uncertain model parameters to alleviate the conservative nature of robust MDPs. This paper proposes a computationally efficient solution framework for solving distributionally robust MDPs with Wasserstein ambiguity sets. By exploiting the specific problem structure, the proposed framework decomposes the optimization problems associated with distributionally robust Bellman updates into smaller subproblems, which can be solved efficiently. The overall complexity of the proposed algorithm is quasi-linear in both the numbers of states and actions when the distance metric of the Wasserstein distance is chosen to be L1, L2, or L∞ norm, and so the computational cost of distributional robustness is substantially reduced. Our numerical experiments demonstrate that the proposed algorithms outperform other state-of-the-art solution methods.

Keywords: Distributionally robust optimization.

Deep Q-Networks for Optimal Resale of Canceled Orders: A Case Study in the Steel Slitting Industry

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ABSTRACT

In the face of operational inefficiencies in the steel industry, the need for optimizing the slitting and delivery process is growing. This paper tackles the Integrated Steel Slitting and Delivery Problem (ISSDP), a specific operational challenge in the industry. Utilizing a route-based Markov Decision Process framework, we employ a Deep Q-Network (DQN) to address the ISSDP. The applicability of this DQN-based approach are confirmed through empirical case studies within a steel-slitting enterprise. These studies illuminate the interrelations among unit pricing, routing decisions, and revenue outcomes. Comparative evaluations reveal that our method is competitive, showing better performance in revenue and cost-revenue optimization against existing benchmarks. The paper underscores the importance of a holistic approach, integrating both pricing and routing strategies, for effective sales operations. Moreover, our findings indicate that high levels of engagement with buyers by sales representatives may not be a prerequisite for achieving profitability with reduced travel expenses.

Keywords: Cancellations, Reassignments, Markov Decision Process, Q-learning, Food Delivery Problem

Robust Satisficing MDPs

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ABSTRACT

Despite being a fundamental building block for reinforcement learning, Markov decision processes (MDPs) often suffer from ambiguity in model parameters. Robust MDPs are proposed to overcome this challenge by optimizing the worst-case performance under ambiguity. While robust MDPs can provide reliable policies with limited data, their worst-case performances are often overly conservative, and so they do not offer practical insights into the actual performance of these reliable policies. This paper proposes robust satisficing MDPs (RSMDPs), where the expected returns of feasible policies are softly-constrained to achieve a user-specified target under ambiguity. We derive a tractable reformulation for RSMDPs and develop a first-order method for solving large instances. Experimental results demonstrate that RSMDPs can prescribe policies to achieve their targets, which are much higher than the optimal worst-case returns computed by robust MDPs. Moreover, the average and percentile performances of our model are competitive among other models. We also demonstrate the scalability of the proposed algorithm compared with a state-of-the-art commercial solver.

Keywords: Markov decision processes, robust satisficing, first-order method

A Policy Gradient Approach for Solving Dynamic Assignment Problem in On-Site Service Delivery

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ABSTRACT

This work studies the resource allocation problem for delivering on-site services in urban areas. Requests for services are received spontaneously, with deliveries to be assigned dynamically. Real-life examples of such applications include the dispatch of traffic officers to scenes of accidents and the deployment of mechanics to sites of maintenance works. The dynamic assignment problem is to be solved via a policy gradient approach that dynamically assigns workers to different locations so that each customer involved would experience a minimum delay. Our solution framework adopts the transformer architecture with layers of inter-task and inter-agent communications as the approximator. This approximator is trained with the vanilla policy gradient algorithm. To improve computational effectiveness, we introduce an option of withholding an assignment, where workers may not be assigned at a decision point even if a service request is received, to enhance the flexibility of actions. Extensive computational experiments with a varying number of orders, order frequencies, and spatial sparsity are conducted. Our proposed method is shown to outperform other benchmarking methods, including the genetic algorithm and other online heuristics, in terms of stability of effectiveness, computational efficiency, and solution quality. Our experimental results suggest that the proposed method would have a reduced advantage over other benchmarking algorithms if the on-site service time is long.

Keywords: On-site service delivery, Resource allocation, Dynamic assignment problem, Semi-Markov decision process, Policy gradient

Deep Reinforcement Learning for Inventory Management under Stochastic Demand

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ABSTRACT

Inventory management is a challenging problem that involves making a sequence of optimal decisions under uncertainty. Traditional methods often rely on heuristics or simplifying assumptions that may not capture the complexity and dynamics of real-world scenarios. Motivated by developing an automatic decision-making policy without over-reliance on developing special heuristics tailored to specific conditions, we investigate a framework in which Deep reinforcement learning (DRL) is applied to automatically search, feedback, and update, obtain the optimal policy for inventory management problems. DRL is a powerful technique that can learn from trial and error to handle high-dimensional and nonlinear problems. We will present our ongoing ideas and practices. First of all, to enhance the decision-making effectiveness to obtain long-term returns under stochastic demand environments, we explore how an agent can learn efficiently from historical information to infer the replenishment policy. Second, we will discuss how an effective deep learning model is designed to approximate the optimal policy that can discover the latent pattern between demand and replenishment due to the lead time. We will deploy our proposed reinforcement learning framework on a profit-maximizing lost-sales inventory management system with seasonal and non-seasonal demand environments. The proposed method will also be benchmarked against the policy known for demand information in advance and several well-known heuristics, like (r, Q) or base stock. Finally, we will discuss the challenges of applying DRL for inventory management in practice, as well as the opportunities that employ popular and emerging learning-based techniques, e.g., using Generative AI to infer uncertain scenarios and decision generation under context, for inventory management.

Keywords: inventory management, deep reinforcement learning, stochastic demand

Asset Management

Venue: LT-16 (4/F, Purple zone), *Time: 15:00 – 16:15*

Session Chair: Rui Luo

Robust Contextual Portfolio Optimization with Gaussian Mixture Models

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* *Equal contribution*

ABSTRACT

Problem definition: We consider the portfolio optimization problem with contextual information that is available to better quantify and predict the uncertain returns of assets. In particular, we consider the setting where the uncertain returns and the contextual information jointly follow a Gaussian Mixture (GM) distribution. Methodology/results: We show that this problem is equivalent to a nominal portfolio optimization problem where the means and the covariance matrix that are adjusted by the contextual information. To reduce the sensitivity that is caused by the model parameters of the Gaussian Mixture Model (GMM), we propose the robust contextual portfolio optimization problem and derive a tractable second-order cone program formulation to approximate this problem. We conduct numerical experiments in both US markets and global Exchange-Trades Funds market, and the results demonstrate the advantages of our proposed model against other benchmark methods. Managerial implications: We introduce a framework that provides a tractable solution to the portfolio optimization problem under uncertainty. Computational results affirm its superiority, outperforming alternative approaches across multiple metrics.

Keywords: Portfolio optimization, Contextual optimization, Robust optimization.

Dynamic Portfolio Selection and Asset Pricing under Neo-Additive Probability Weighting

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ABSTRACT

We study a dynamic portfolio selection problem in which an agent trades a stock and a risk-free asset with the objective of maximizing the rank-dependent utility of her wealth at the terminal time of the investment horizon. Due to time inconsistency, we consider three types of agents, pre-committed, sophisticated, and naive agents, who differ from each other in whether they are aware of the time inconsistency and whether they have self-control. Assuming a neo-additive probability weighting function, we turn the portfolio selection problem into a piecewise concave optimization problem and derive the strategies for all three types of agents. We find that a pre-committed agent takes a loss-exit strategy which reduces the stock holding following a prior loss and increases the stock holding following a prior gain, leading to a positively skewed terminal wealth. In addition, a sophisticated agent takes less risk at the initial time than pre-committed and naive agents do. A naive agent has a loss-exit initial plan but eventually fails to exit at losses as planned. We also study dynamic equilibrium asset pricing and find that the stock return with a pre-committed representative agent exhibits a reversal effect and the initial stock price is lower than those in the case of a naive representative agent and in the case of a sophisticated representative agent.

Keywords: rank-dependent utility, probability weighting, time inconsistency, portfolio selection, asset pricing

Anomalous Link Detection Using Conformal Prediction and Edge Exchangeability

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ABSTRACT

Conformal prediction is a user-friendly paradigm for generating set-valued predictions for machine learning models that are valid in a distribution-free sense. In this talk, we demonstrate how conformal prediction can be used to detect anomalous links in a graph by exploiting edge exchangeability as a criterion for distinguishing anomalous edges from normal ones. To quantify the difference between a given link and other links in the graph, we use variational inference to approximate the inverse link posterior probability, which serves as the non-conformity score.
We then present an anomaly detector based on conformal prediction that has a guaranteed upper bound for the false positive rate. Through numerical experiments, we show that the proposed algorithm achieves comparable performance in detecting anomalous links in a graph when compared to baseline methods. Our results demonstrate the effectiveness of using conformal prediction and variational inference for detecting anomalous links in graphs.

Keywords: conformal prediction, link prediction, edge exchangeable model, variational inference, Bayesian nonparametrics

Robust Asset Liquidation Strategies in Financial Systems

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ABSTRACT

In this paper, we study the problem of liquidation strategies in financial networks over two periods. Financial contagion arises when banks liquidate a substantial amount of their commonly held illiquid assets to raise funds for liability repayment, resulting in a significant depression in liquidation prices. If banks attempt to maintain solvency by strategically liquidating their assets, they encounter the challenge of incorporating other banks' two-period liquidation sizes, which are unknown. To address this issue, we propose a robust quantification for the cash position after liquidation and develop the optimal liquidation strategy under the worst-case scenario in the absence of interbank liabilities, which we refer to as the 'maxmin strategy'. We further demonstrate that the case in which all banks adopt their maxmin strategies is the unique Nash equilibrium of a simultaneous, non-cooperative liquidation game wherein all banks pre- determine the number of units of illiquid assets to sell over two periods. In addition, when interbank liabilities exist while the financial network is weakly interconnected, we devise a near-optimal liquidation strategy under the worst-case scenario by analyzing the shortfalls amplified by the network effects. Our results provide guidelines for developing robust liquidation strategies that alleviate losses from financial contagion and insights into evaluating the solvency of banks in the financial network for decision-makers.

Keywords: Financial Networks, Liquidation, Robust Quantification, Maxmin Strategy, Nash Equilibrium

Resilience-Oriented Planning for Islanded Microgrid Clusters Considering P2P Energy Trading and Extreme Events

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ABSTRACT

Bilateral transactions among multiple microgrids (MGs) are pivotal in optimizing the planning of MG clusters and promoting them to be configured more collaboratively and economically. Nevertheless, the escalating impacts of global climate change and the recurrent occurrence of extreme disaster events cast a profound shadow on the operational security of MGs. Transaction strategies formulated during the planning stage may be unattainable when confronted with the disruptive force of extreme events, thereby causing internal power outages within MGs. Therefore, it becomes imperative to balance economic interests and resilience requirements. This paper introduces a resiliency-oriented planning scheme for islanded MG clusters to tackle this challenge, integrating energy trading with uncertain extreme events. Firstly, it constructs an uncertainty set modeling the potential tie-line failures and stochastic occurrence time, based on which the security constraints during extreme events are established. Secondly, a novel bilateral trading shadow price, i.e., dual variables of transaction constraints, is cleared distributionally based on the dual consensus alternating direction multiplier method (DC-ADMM), which accommodates both equality and inequality coupling constraints among multiple entities. Then, the hybrid DC-ADMM and column-and- constraints generation (C&CG) approach is developed to solve the formulated multi-agent collaborative planning problem under uncertainties. Numerical simulations demonstrate the effectiveness of the proposed distributed shadow price strategy, ensuring the fair benefit sharing and privacy of MG entities. Bilateral trading can reduce the overall planning cost of MG clusters; however, as the resilience requirement increases, the economic benefits of bilateral trading may diminish. Consequently, MG investors have the flexibility to tailor their planning solutions and transaction contracts to meet specific resilience requirements, including the capacity to manage various types of extreme events and differing durations of failures.

Keywords: collaborative microgrid planning, resilience requirement, P2P energy trading, uncertainty, distributed shadow price

Scheduling and Assignment

Venue: LT-18 (4/F, Purple zone), *Time: 15:00 – 16:15*

Session Chair: Chengshuo Ying

Adaptive scheduling of electric bus services with stop-skipping pattern using a reinforcement learning approach

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ABSTRACT

This paper presents a real-time service scheduling framework for electric buses with stop-skipping pattern. The service schedules are driven by real-time passenger demand subject to designated service routes and available fleet sizes. The scheduling problem is formulated as a Markov decision process with bus operation constraints. The scheduling controller aims to minimize the passengers' waiting times, the in-vehicle travel times, and the bus operator's cost. To address the computational challenges, we develop a reinforcement learning-based solution algorithm with the use of a double deep Q network (DDQN) approach. The proposed computational framework is tested on a real-world scenario configured with actual data in Hong Kong. Experiment results illustrate the advantages of using the stop-skipping strategy in addressing the bus scheduling problem in peak hour. This study contributes to state-of-the-art real-time green transit operations with advanced computing and optimization techniques.

Keywords: Service scheduling, Stop-skipping, Markov decision process, Reinforcement learning

Multiagent Deep Reinforcement Learning Approach for Coordinated Metro Train Rescheduling Under Disruptions

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ABSTRACT

This paper presents a novel multi-agent deep reinforcement learning (MADRL) approach for real-time metro train rescheduling with short-turnings under a complete track blockage on a double-track metro corridor. The optimization problem is modeled as a Markov decision process with multiple control agents rescheduling for each directional line until system recovery. To ensure computational efficacy, we employ a multi-agent policy optimization structure, in which each control agent employs a decentralized policy function for deriving local decisions and a centralized value function approximation (VFA) for estimating the global system state value. Both the policy functions and VFAs are represented by multi-layer artificial neural networks (ANNs). A multi-agent proximal policy optimization gradient algorithm is developed for training the policies and VFAs through iterative simulated system transitions. The proposed framework is implemented and tested with real-world scenarios with data collected from the Victoria Lines of London Underground, UK. Computational results demonstrate the superiority of the developed framework in computational effectiveness and solution quality compared with previous distributed control algorithms and conventional heuristic search methods. Further analysis provides managerial implications for metro train rescheduling during disruptions of varying durations and locations. This study contributes to real-time metro train rescheduling with innovative multi-agent control and optimization techniques.

Keywords: Train rescheduling, short turning strategy, Markov decision process, multi-agent deep reinforcement learning, proximal policy optimization

An intelligent rescheduling system for tutorial centers in Hong Kong

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ABSTRACT

Scheduling is the problem of allocating resources to tasks or events in various domains. It is challenging because it involves many people and coordinates different independent jobs.

This talk is based on an on-going industrial project funded as a donation from a private tutorial center, which needs to schedule its tutors and rooms to match the demands and preferences of students, as well as to factor in the tutors' qualifications and workload balance. When attempting to construct an optimal timetable that satisfies as many operational rules as possible, this problem becomes exceedingly difficult, especially when done manually. For example, in practice, students' punctuality should be considered due to its domino effect on the subsequent lessons on the same day. The center tends to assign the first or last block of a day to chronically late students for greater flexibility. A data-driven approach based on attendance records is therefore needed. Furthermore, to facilitate preparations of examinations, lessons are rescheduled according to students' learning progress, examination dates, and tutors' availabilities. Given the space limit and that schools often share similar starting and ending dates for examinations, revising a schedule while ensuring it is free from spatial and temporal conflicts is extremely convoluted.

In this presentation, we will first discuss how operational requirements that can be easily described verbally but are hard to write mathematically, followed by an overview of the integer programming problem we have developed. Due to the computational complexity involved in solving real-world instances, we plan to use genetic algorithms to obtain near-optimal solutions in a shorter time. Lastly, we will discuss how schedules can be represented by chromosomes, describe the exploration-exploitation strategy, and give a sketch of our computational study.

Keywords: scheduling, tutorial center, optimization, genetic algorithm

Optimal Control Based Trajectory Planning under Uncertainty

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ABSTRACT

In this talk, we propose a constrained optimal control approach as a reference trajectory generator for a driving scenario with uncertainty. Given a scenario, this generator can produce a reference trajectory in order to make validations for autonomous vehicles decision-making problems. The con- strained optimal control problem guarantees to obtain a collision-free trajectory with safety and comfort based on the design of the objective function and the constraints of the vehicle. The uncertainty of environmental information provided by sensors is taken into account, and a stochastic optimization problem is proposed to limit the risk of violating safety requirements. Numerical experiments show that the stochastic model can better ensure the robustness of the obtained solutions.

Keywords

Stochastic Optimization; Optimal Control; Chance Constraints; Trajectory Planning; Autonomous Vehicle.

Optimizing Capacitated Multi-Trip Vehicle Routing with Time Windows: Joint Utilization of Route-Based and Trip-Based Formulations

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ABSTRACT

This research presents a novel exact algorithm for the capacitated multi-trip vehicle routing problem with time windows (CMTVRPTW). The CMTVRPTW extends the capacitated vehicle routing problem by allowing vehicles to make multiple trips while adhering to specified time windows for customer visits. Despite its wide applications, existing research on exact algorithms is limited. In this research, we adopt an exact price-cut-and-enumerate algorithm, utilizing two set-partitioning-like formulations of the CMTVRPTW, one based on routes and the other based on trips. This differs from the best-known algorithms for the CMTVRPTW, all of which also adopt the price-cut-and-enumerate algorithm but utilize only the route-based formulation. By incorporating various valid cuts, we strengthen the linear programming relaxations of both formulations. It enhances the effectiveness of applying a variable fixing technique to reduce the candidate set of routes and trips required for determining an optimal solution. Additionally, we develop a dynamic discretization procedure to obtain the optimal solution for the trip-based formulation. Extensive experiments show that our new exact algorithm achieves optimality for all CMTVRPTW benchmark instances with 100 customers, significantly outperforming a baseline price-cut-and-enumerate algorithm in the literature.

Keywords: vehicle routing, multi-trip, exact algorithm, column-and-cut generation, variable fixing

Control and Optimization

Venue: LT-16 (4/F, Purple zone), *Time: 16:30 – 17:30*

Session Chair: Clint Ho

Online Long-term Constrained Optimization

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ABSTRACT

In this paper, a novel Follow-the-Perturbed-Leader type algorithm is proposed and analyzed for solving general long-term constrained optimization problems in online manner, where the objective and constraints are not necessarily convex. In each period, random linear perturbation and strongly concave perturbation are incorporated in primal and dual directions, respectively, to the offline oracle, and a global minimax point is searched as solution. Based on two particular definitions of expected static cumulative regret, we derive the first sublinear $O(T^{8/9})$ regret complexity for this class of problems. The proposed algorithm is applied to tackle a long-term (risk) constrained river pollutant source identification problem, demonstrating the validity of the theoretical results and exhibiting superior performance compared to existing method.

Keywords: Online non-convex learning; Long-term constraints; Risk constrained optimization; Random perturbation; Global minimax point;

Ambiguous Chance Constrained Ferry Service Network Design with Scenario-Wise Distributional Information

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ABSTRACT

This paper addresses the service network design problem, specifically focusing on the ferry service network design (FSND) problem as an illustrative application. The FSND problem involves determining passenger flows and ferry service schedules for various origin-destination (OD) paths, in the aim of satisfying uncertain demands with a high probability. In practice, obtaining an accurate joint distribution of passenger demands, particularly considering the influence of different scenarios such as weather conditions, is often challenging. To tackle this issue, we introduce a scenario-based ambiguous joint chance constrained model that incorporates scenario-wise moment and support set information. Specifically, we examine FSND problems with both pessimistic and optimistic ambiguous joint chance constraint and transform the proposed models into conic reformulations, which can be efficiently solved by our proposed algorithm. In comparison to existing literature that employs a robust model by approximating the chance constraint with inequalities, our approach provides less conservative solutions, irrespective of considering the scenario information. Additionally, we utilize the sample average approximation (SAA) model as a baseline and evaluate the out-of-sample performance of these three models from a data-driven perspective, accounting for limited historical demand samples. The results demonstrate that our proposed model can achieve a higher probability guarantee across a broader range of demand dispersion.

Keywords: Service network design, Ferry transportation, Distributionally robust optimization, Joint chance constraints, Data-driven optimization

A Bi-Level Deep Reinforcement Learning Framework for Metro Train Scheduling and Speed Control under Stochastic Disturbances

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ABSTRACT

As cities grow in size and population, the need for efficient urban metro systems that are fast, high-capacity, and energy-saving is increasing. However, these systems face unpredictable disturbances during alighting, boarding and travelling. This paper introduces a bi-level model that uses deep reinforcement learning (DRL) to optimize train speed profile and operating timetable. The upper model optimizes the timetable by accounting for stochastic dwell times, ensuring energy efficiency and on-time arrival at the destination station. The optimized timetable is then passed down to the lower model as a reference. The lower model updates energy-saving driving regimes based on planned running time between station pairs provided by the upper model, overcoming deviations caused by unpredictable disturbances. The proposed framework is implemented and tested on a real-world scenario in Hong Kong East Rail Line (EAL). The results reveal the benefits of the proposed framework in reducing train energy consumption and improving system reliability. The study facilitates the system operator to deliver effective, reliable, and eco-efficient urban train services with emerging information and optimization technology.

Keywords: (Bi-level framework, Deep reinforcement learning, Metro train, Stochastic disturbances)

Transportation

Venue: LT-18 (4/F, Purple zone)*), Time: 16:30 – 17:30*

Session Chair: Andy Chow

Intelligent Traffic Control with the Use of Internet-of-Things and Reinforcement Learning Technologies

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ABSTRACT

This study presents an actor-critic deep reinforcement learning approach to integrate multiple adaptive traffic control methods for optimizing traffic performance. Traditionally, different traffic control methods have been studied independently, resulting in a lack of coordination between the road infrastructures supporting these measures and constraining the optimization potential of traffic performance. To address the current issue, we develop a centralized traffic control framework in which the decisions of signal phasing plan and network-wide speed limits are sought to minimize traffic delays on both urban roads and freeways. With a large amount of data to process and vast decision space in real-time, we introduce the actor-critic deep reinforcement learning solution framework to parameterize the traffic states and decision spaces by artificial neural networks. A deep deterministic policy gradient algorithm is proposed to train the artificial neural networks with the simulation data representing the network conditions and control settings before the actor-critic agent is applied for online control. To test and evaluate the performances of the proposed approach, we develop a microscopic simulation model on the Tung Chung road network in Hong Kong via the SUMO platform. Numerical experiment results indicate that the proposed approach could deliver significant improvement in terms of computation efficiency and traffic performance metrics. This study contributes to the field of transport management by exploring the potential for improving coordination between different traffic control methods using advanced transport network modelling and optimization techniques.

Keywords: Deep reinforcement learning, actor-critic architecture, traffic congestion management, adaptive traffic signal control, variable speed limit

Talk to Car with Cross-Modal Attention for Autonomous Driving: A Context-Aware Approach

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ABSTRACT

In the rapidly evolving field of autonomous vehicles (AVs), understanding the commander's intent and executing linguistic commands in a visual context remains a formidable challenge. This paper introduces an innovative encoder-decoder framework specifically designed to tackle the problem of speech grounding in AVs. Our model (CAVG) uniquely combines five core encoders—Text, Image, Context, and Cross-Modal—with a Multimodal decoder, enabling additional capture of contextual semantics and learning of human emotional features. The architecture is further bolstered by state-of-the-art multi-head cross-modal attention mechanisms and a specialized Region-Specific Dynamic layer for attention. The fusion of these elements allows our model to skillfully negotiate a variety of cross-modal inputs, offering a nuanced understanding of the relationships between spoken commands and visual scenes. Extensive evaluations of the real-world Talk2Car dataset demonstrate that our model sets new state-of-the-art benchmarks in terms of prediction accuracy and efficiency. Remarkably, our model consistently outperforms most of the baselines even when subjected to limited training datasets ranging from 50% to 75%. This underlines its efficacy and potential for practical applications in AV technologies. Importantly, it maintains competitive performance and showcases robustness and adaptability when tested in challenging environments such as long-text command scenarios, low-light night scenes, rainy days, and dense urban streets.

Keywords: Autonomous Driving, Image-text Retrieval, Multi-modality Perception, Vision-language Model, Interaction Understanding

Adaptive traffic Control for Connected Autonomous Vehicles at Signal-Free Intersections

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** corresponding author*

ABSTRACT

Urban traffic congestion often leads to longer travel times and increased city pollution. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications enable connected autonomous vehicles (CAVs) to coordinate movements in real-time, leading to smoother traffic flow and fewer on-road delays. In this context， this paper introduces a vehicle trajectory control method for CAVs at signal-free intersections. The problem is structured as a Markov decision process, incorporating various functional components. A speed mode is also designated for each vehicle to ensure reduced computational complexity and consistent speed maintenance. Then, we employ an approximate dynamic programming (ADP) approach to derive optimal speed profiles, ensuring both safety and efficiency. We evaluate the performance of our method by Simulation of Urban MObility (SUMO). The result shows that our model can reduce average delays and queueing time compared to traditional fixed-time control and First-Come-First-Serve (FCFS) strategies.

Keywords: Transportation, Markov decision process, Approximate dynamic programming, Connected automated vehicles

Traffic Prediction with Hybrid Model-Based and Data-Driven Approach

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ABSTRACT

Providing the statistical description of uncertainty along with the state prediction of traffic variables is crucial to the intelligent transportation system. However, the widely adopted model-based probabilistic filters often experience difficulties in obtaining accurate knowledge of underlying traffic systems while the data-driven models require a vast amount of data. In this paper, we present a novel approach for traffic prediction using a hybrid model-based and data-driven framework without explicit knowledge on the traffic system dynamics. The model-based component applies the dynamic linear regression statistical method to obtain the prior predictions of traffic variables. The data-driven component uses four Gated Recurrent Unit cells to track the changes of second-order statistical moments independently. These cells are interconnected by fully connected layers based on the calculation flow of the Kalman filter. The proposed model is trained using a Gaussian negative log-likelihood loss function, which allows us to obtain explicit uncertainty estimates represented as time-varying error covariance matrices. By applying Monte Carlo dropout during inference, the proposed algorithm quantifies both aleatoric and epistemic uncertainty of traffic forecasting. The proposed framework is implemented and tested with actual traffic data collected from the Hong Kong Strategic Route. The numerical study shows that the proposed hybrid model can simultaneously retain the interpretability of the statistical model and learn complex uncertainty from the data. This study contributes to the development of reliability-based intelligent transportation systems through the use of advanced statistical modelling and deep learning methods.

Keywords: (up to five) Kalman filter, artificial neural networks, dynamic linear regression, uncertainty

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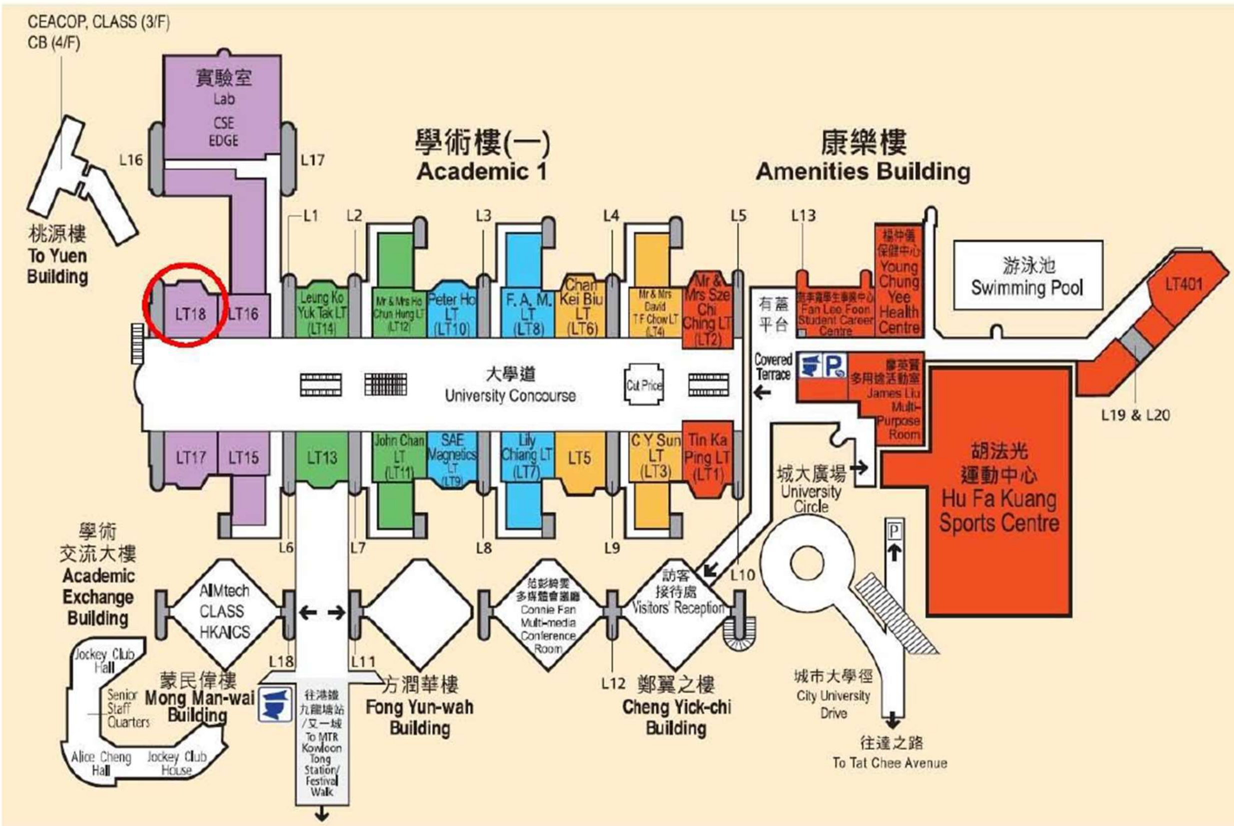

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