OR/OM Introduction

经管学院暑培

2025.8.11

Warm up

- 滴滴平台如何设计派单策略实现收益最大化?
- 京东在哪些城市建仓库才能让大部分用户在一天内收到货?
- 旅行商问题、投资组合优化
- etc.

——> **资源有限、需求变化等复杂约束情况下，如何做决策?**

OR -> OM：方法论、应用领域

- 统计/机器学习 VS OR(Operation Research)
  - 统计/机器学习：从样本出发的归纳
  - OR：从数学假设出发的演绎

- 经典OR方法论：optimization、applied probability...
- OR应用领域：金融工程、机器学习、交通、能源、运营管理（OM)
- OM(Operation Manmagement): 供应链管理、收益管理、机制设计

Example1

- linear optimization:在约束条件和目标函数都为线性的情况下，寻找最优解

$$\text{Maximize} \quad c^\top x$$

$$\text{subject to} \quad Ax \leq b, \quad x \geq 0$$

某工厂生产 **A 产品** 和 **B 产品**，每种产品的利润和所需资源如下：

产品	单位利润（元）	机器时间（小时）	原材料（kg）
A	40	2	3
B	30	1	4

工厂每周有：

- 机器时间不超过 **100 小时**
- 原材料不超过 **120 kg**

- 决策变量：
  - x_1：生产 A 产品的数量
  - x_2：生产 B 产品的数量
- 目标函数（最大化利润）：

$$\max 40x_1 + 30x_2$$

- 约束条件：

$$2x_1 + 1x_2 \leq 100 \quad \text{(机器时间约束)}$$

$$3x_1 + 4x_2 \leq 120 \quad \text{(原材料约束)}$$

$$x_1 \geq 0, \quad x_2 \geq 0$$

Example2

- Multi-armed bandit:
  - 想象有一排老虎机，每台机器的中奖概率不同，但你事先不知道具体是多少。你可以反复拉这些机器的拉杆，目标是在有限的次数内尽可能赢得最多的钱。

Setting: Finite-armed stochastic bandits

items/products/movies/news/...

CTR/profit/...

- There are L arms
  - Each arm a has an unknown reward distribution v_a with unknown mean $\alpha(a)$
  - The best arm is $a^* = \text{argmax}_a \alpha(a)$

- At each time t
  - The learning agent selects an arm a_t
  - Observes the reward $X_{a_t,t} \sim v_{a_t}$

bandit feedback

- Maximize the expected cumulative reward in T rounds

$$\mathbb{E}\left[\sum_{t=1}^{T} \alpha(a_t)\right]$$

- Minimize the regret in T rounds

$$R(T) = T \cdot \alpha(a^*) - \mathbb{E}\left[\sum_{t=1}^{T} \alpha(a_t)\right]$$

- Balance the trade-off between exploration and exploitation
  - Exploitation: Select arms that yield good results so far
  - Exploration: Select arms that have not been tried much before
- Smaller order of T in $R(T)$ is better

OR研究前沿

- &统计：experimental design, A/B tests
- &经济：information design
- &CS：diffusion model, LLM, generative model
- &finance：mean-field games

LLM研究上 CS VS OR?

- CS 更关注模型本身的能力、结构、训练与泛化；
- OR 更关注如何将这些生成模型嵌入到决策优化流程中，并分析其最优性、鲁棒性等性质。
  - Liang, K., Lu, Y., Mao, J., Sun, S., Zeng, C., Jin, X., Qin, H., Zhu, R. and Teo, C.P.. LLM for Large-Scale Optimization Model Auto-Formulation: A Lightweight Few-Shot Learning Approach. **LLM辅助OR**
  - Patrick Jaillet, Jiashuo Jiang, Konstantina Mellou, Marco Molinaro, Chara Podimata, Zijie Zhou. Online Scheduling for LLM Inference with KV Cache Constraints **OR优化LLM**

OR/OM PhD申请

- Applicant画像：Math / Stats / CS / 商科...
- 课程：

Columbia University

- Core Courses: Optimization I/II, Stochastic Modeling I/II, Dynamic Programming.
- Statistics: Statistical Inference and Econometrics, Information Theory, High-dimensional Statistics, Nonparametric Statistics.
- Machine Learning: Fair and Robust Algorithms, Generative AI, Differential Privacy, Computational Learning Theory.

Tsinghua University

- Operations Research: Operations Research, Probability and Mathematical Statistics, Numerical Analysis, Dynamic Systems Analysis and Control, Game, Decision Making and Queuing Theory, Convex Optimization.
- Statistics: Applied Time Series Analysis, Introduction to Nonparametric Statistics, Statistical Inference.
- Analysis: Probability Theory, Measure and Integration, Ordinary Differential Equation, Functional Analysis.
- Computer Science: Data Structures and Algorithms, Discrete Mathematics, Artificial Intelligence, Computer Systems Architecture, Pattern Recognition and Machine Learning.

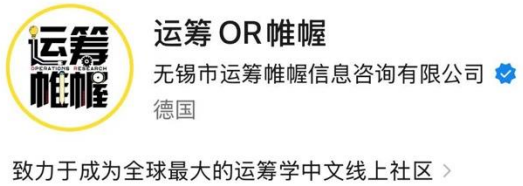
National University of Singapore

- Discrete Optimization, Stochastic Processes, Nonlinear Programming, Operations and Technology Management, Revenue Management.

- 科研：推荐信为主，申请者paper需求较少

OR/OM PhD 职业选择

- 教职：商学院 （e.g. 经管管理科学与工程系）、工学院（e.g. 工业工程）...
- 业界：
  - 传统运筹学，优化、排队论、博弈：航空/零售/交通公司 e.g. 京东、波音
  - data science/ai交叉：亚马逊、Uber、大厂的research lab、量化
- 如果感兴趣：
  - 媒体：知乎...



  - MIT ORC/IDSS、Stanford MS&E、Columbia IEOR、Cornell ORIE、Gatech ISYE...

- pros&cons