A large-scale simulation platform for on-demand ride service operations and related AI algorithms

Jintao Ke

Department of Civil Engineering

The University of Hong Kong, HK

March 2025

Outline

- Background and Motivation
- The Simulation Platform and Algorithms
- Applications

Shared Mobility

- Shared mobility is on the rise
  - Ride-sourcing, e-hailing taxi service, bike sharing, etc.
- Emerging ride-sourcing platforms

  - Uber has completed over 20 billion trips in total in over 80 countries and 700 cities.
  - DiDi Chuxing is now serving over 20 million trips in each day in over 400 cities in China.

Hong Kong E-hailing Taxi Market

What

- Launch 5 fleets (3,500 taxis) by July.

How

- Use online booking with ratings.
- Install in-car monitoring.
- Offer standard and charter fares.

Benefits:

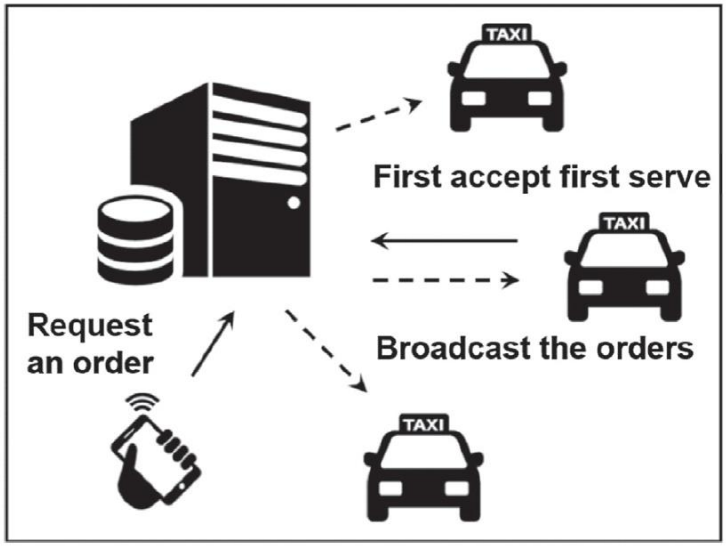
- Improved service and safety.
- Greater accessibility.
- Enhanced public trust.

Challenges & Questions

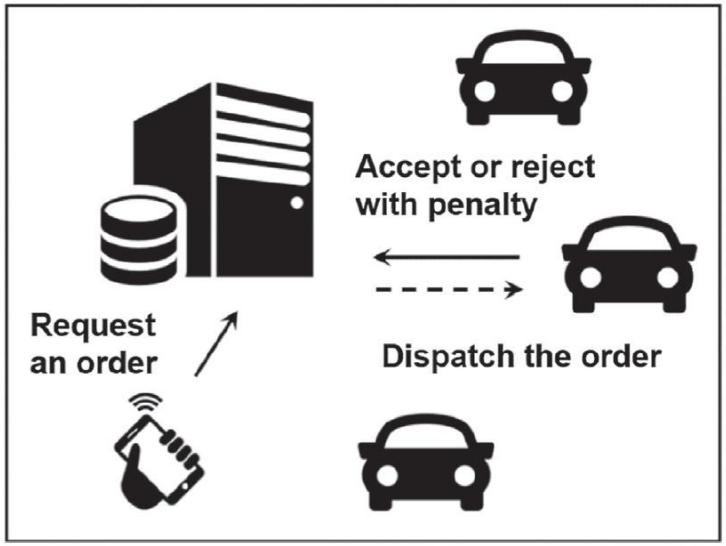
- Platform operations
  - How to estimate passenger demand?
  - How to match drivers and passengers in real-time?
  - How to set the price for passengers?
  - How to determine the wage for drivers?
  - How to relocate idle vehicles?
- Government regulations
  - What are the impacts of ride-sourcing services on traffic congestion and transit usage?
  - How to design appropriate regulations?
  - How to protect taxi drivers?

Two Matching Mechanisms

- **Broadcast mode**: the e-hailing firm broadcasts the requests received from passengers to taxi drivers, who have freedom to select an order
  - Used by common taxi hailing APPs in Hong Kong, such as HK Taxi, eTaxi and Uber Taxi



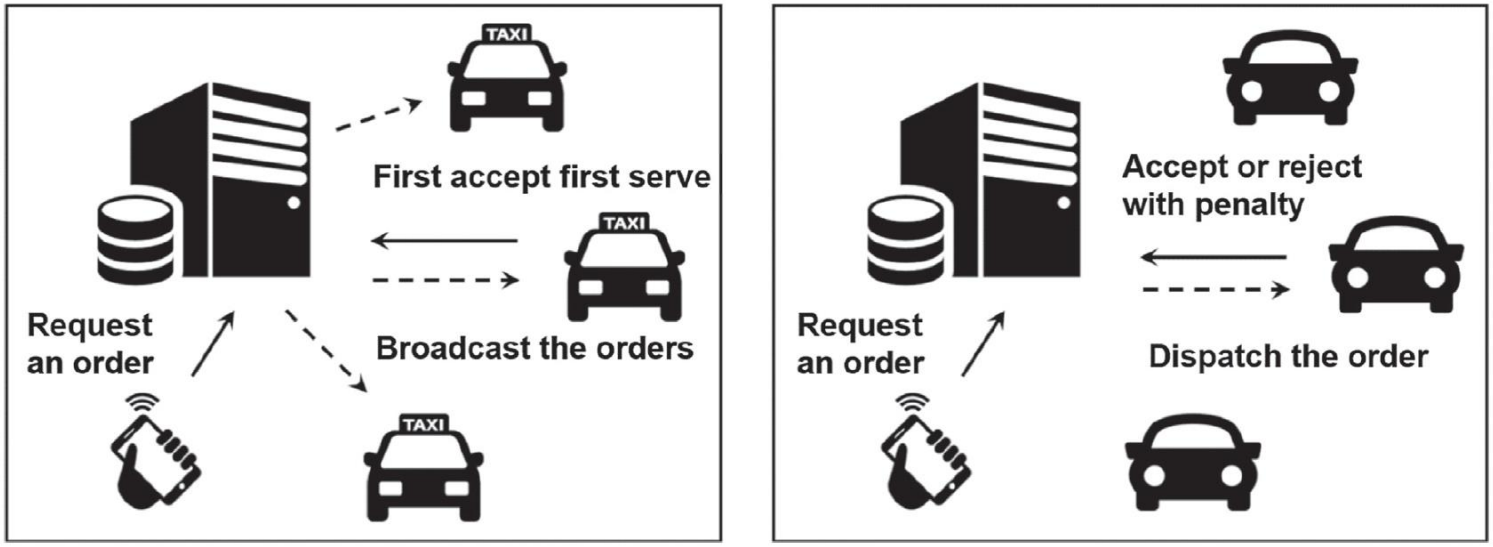
(a) Broadcast mode



(b) Dispatch mode

Two Matching Mechanisms

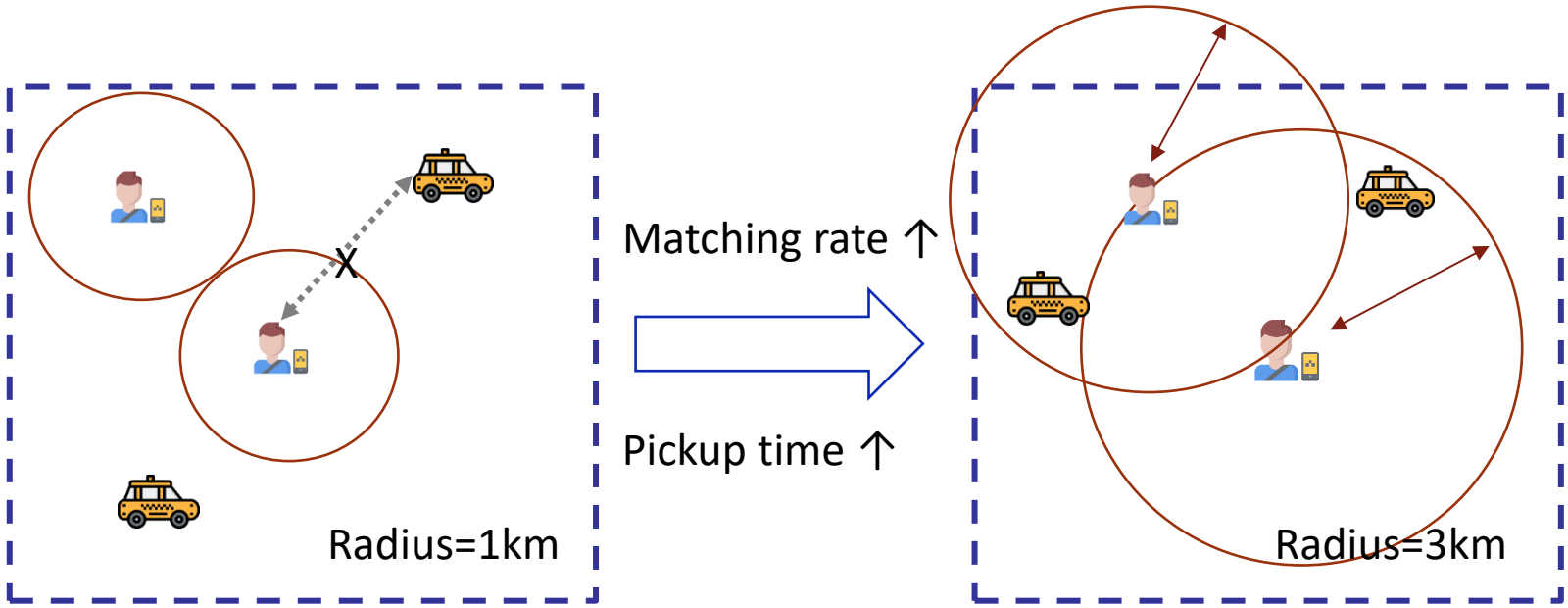
- **Dispatch mode**: the platform assigns the orders requested by passengers to specific drivers, who are normally not allowed to reject the assignment
  - Used by some taxi operators (e.g., SynCab), ride-hailing programs with private cars (e.g., Uber)



(a) Broadcast mode (b) Dispatch mode

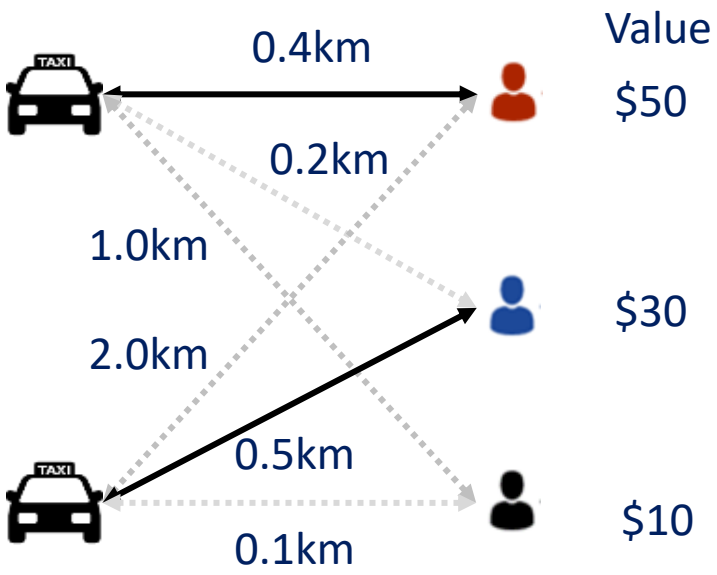
Operational Issues

- Broadcast Mode:
  - How frequently to broadcast orders to drivers, each 2s?
  - What is the optimal broadcasting radius?
    1) Too large: the order may be obtained by a faraway taxi driver
    2) Too small: taxi drivers may not receive orders for a long time

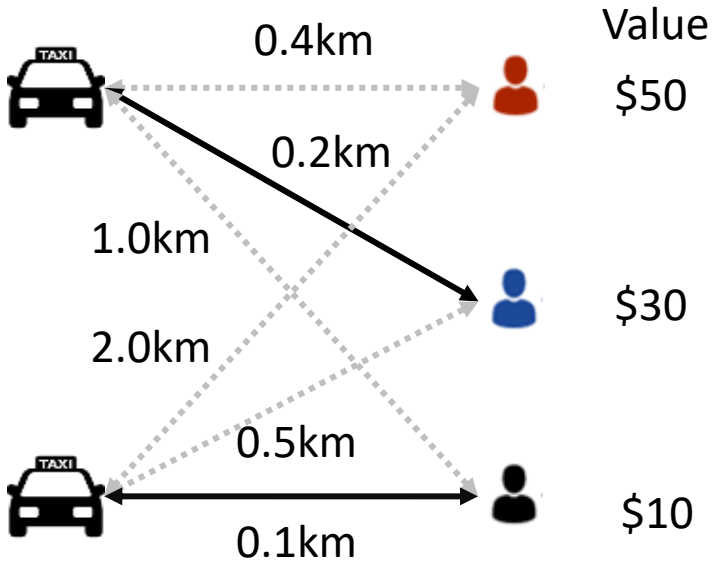


Operational Issues

- Dispatch mode:
  - How to dispatch multiple orders to multiple drivers?
  - How to balance the trade-off of multiple objectives, such as maximizing platform profit and minimizing pickup time?



Maximizing platform revenue



Minimizing pickup distance

Idle Taxi Reposition

- A large proportion of taxi time is spent on **idle cruising** on the street for searching passengers, which leads to a waste of taxi resource and contributes to traffic congestion
- Taxi drivers do not have enough information of where they can easily receive passenger orders
- Remedies:
  - The e-hailing firm/taxi operator recommends **an idle searching route**, following which taxi drivers have higher probability of getting orders
  - The firm displays the **"heat map"** showing the real-time supply and demand information in different locations

Challenges

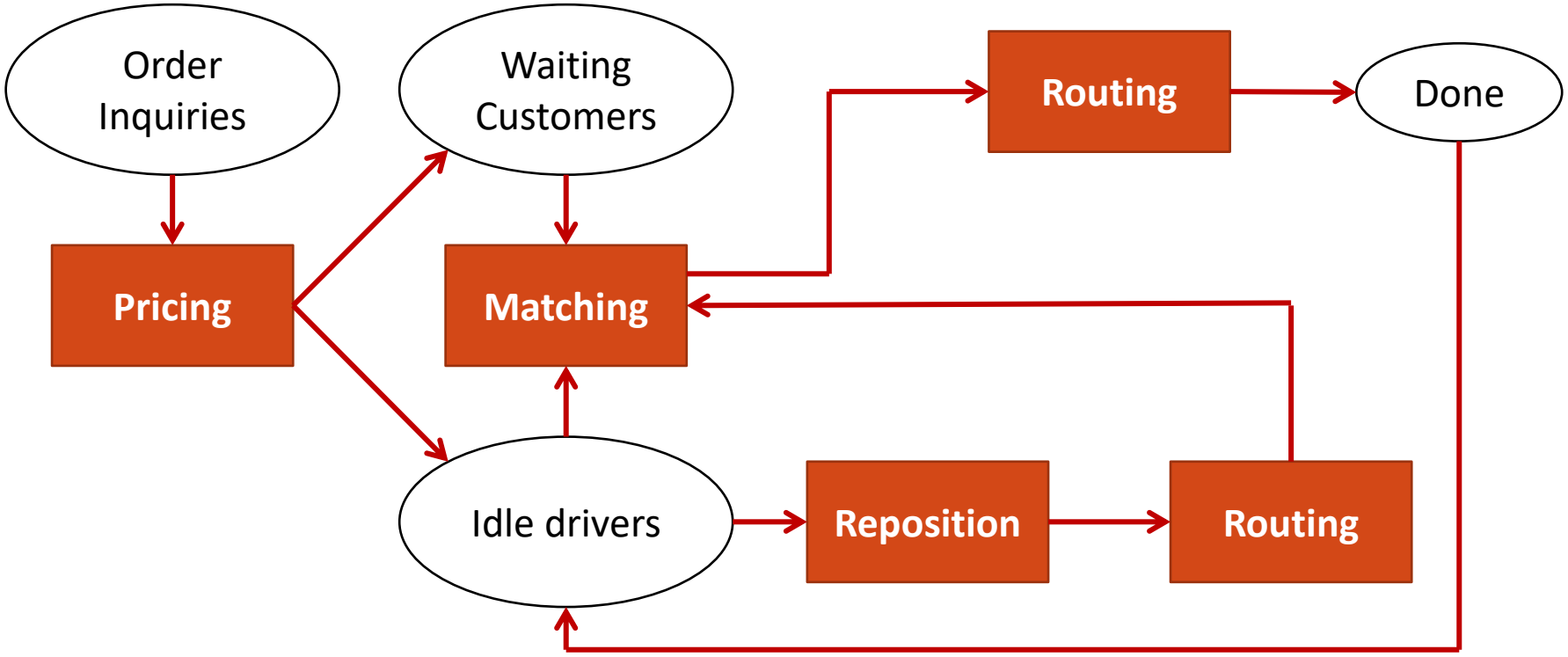
- The taxi system is an extremely **complex, dynamic and stochastic** system, so the static optimization models may not be enough for designing real-time operating strategies
- We can resort to **artificial intelligence (AI)**, such as reinforcement learning algorithms, which can learn from real-time data to dynamically adjust operating strategies
- However, AI requires **a testbed for trial and error**
- In addition, even though we use non-AI optimization models, we may want to **test various optimization models** and select the best one before we actually apply the models to the real market.

Outline

- Background and Motivation
- The Simulation Platform and Algorithms
- Applications

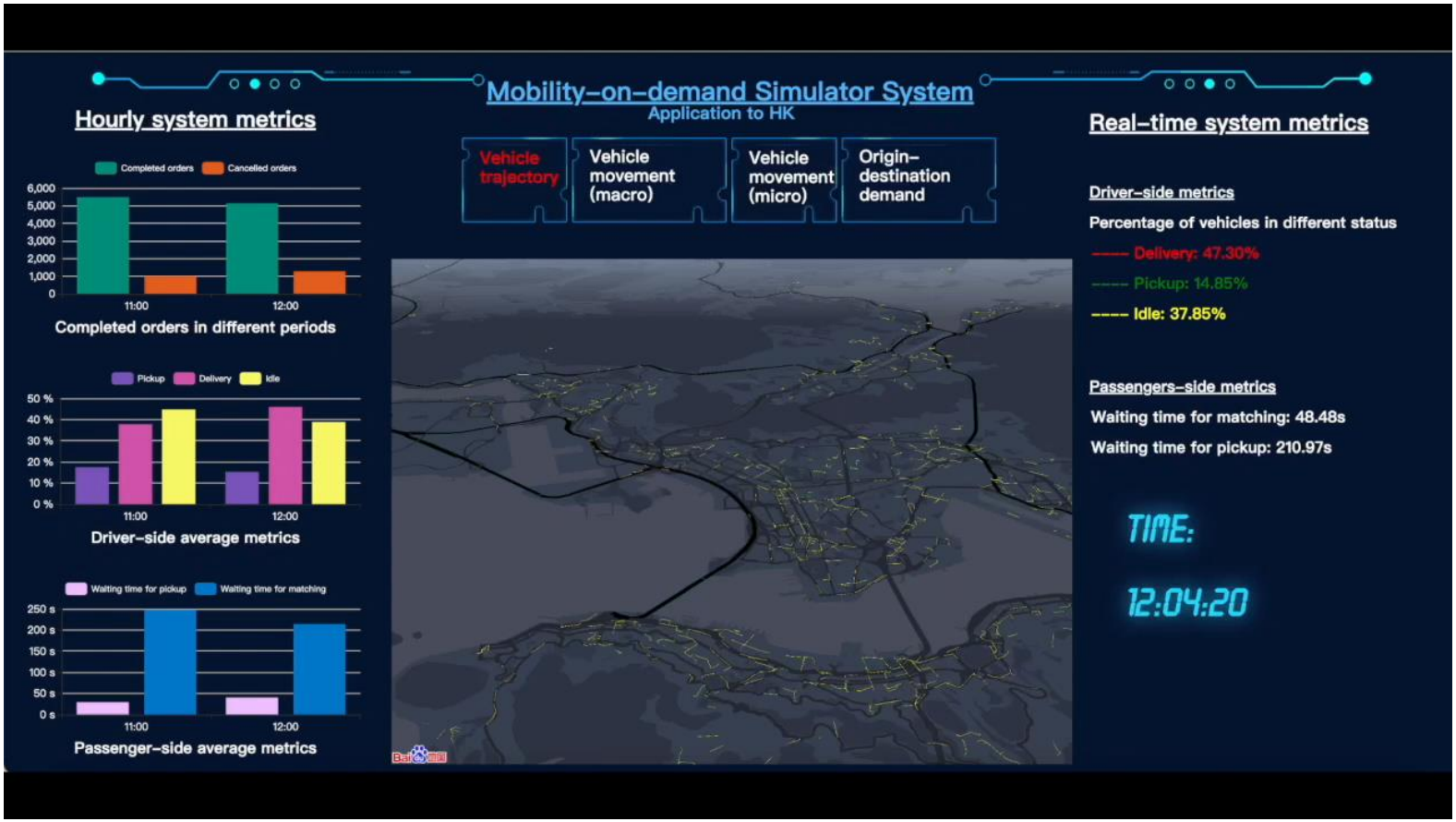
The Simulator

- It is operated in real transportation networks, and track dynamic movements of vehicles in real time
- Major modules: **Pricing**, **Matching**, **Reposition**, **Routing**



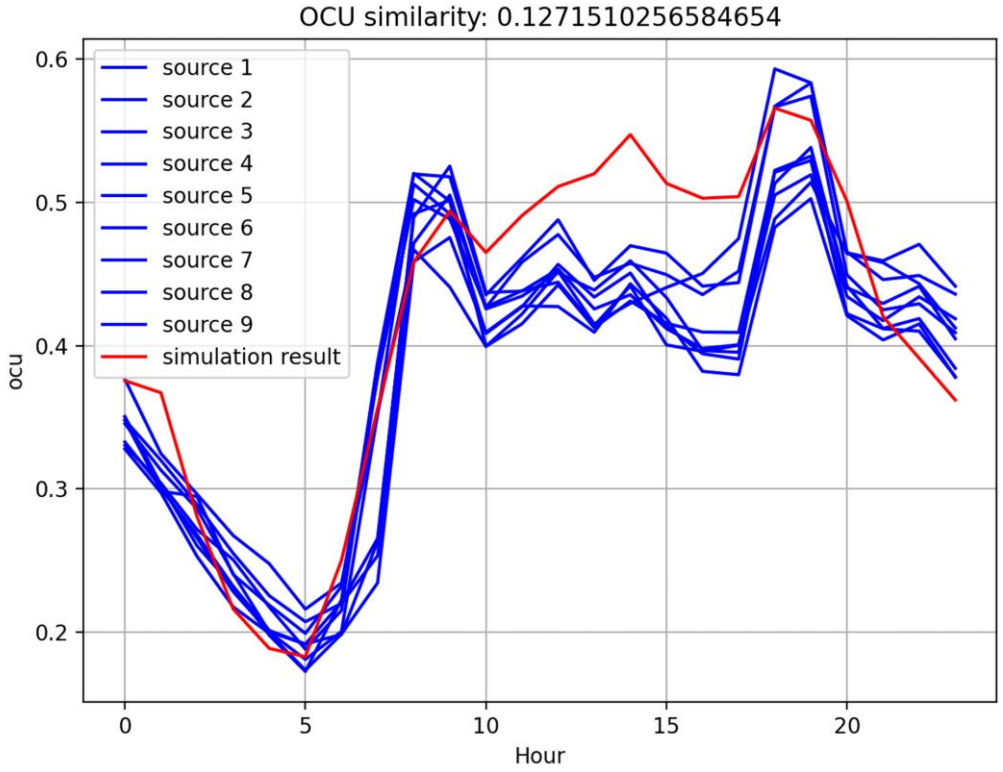
A Demo in HK

- The demo of the simulator in HK is shown below
- https://youtu.be/q25L7lr77ms

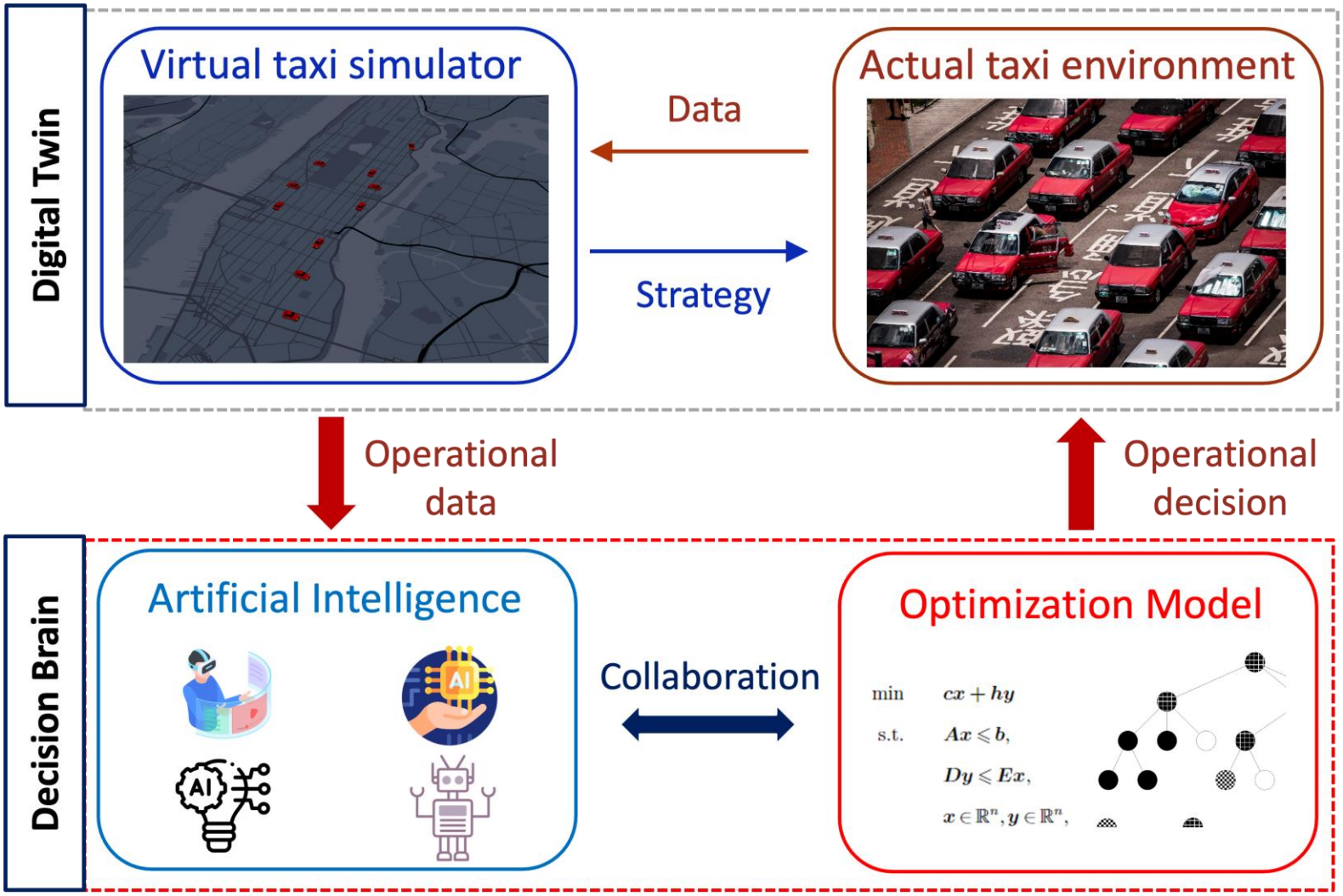


Accuracy of the Simulator

- Evaluated by a taxi trajectory dataset in Hong Kong, we find that the gap between our simulation platform and the real trajectory data is 12.72%



AI + OR Solution Framework



Outline

- Background and Motivation
- The Simulation Platform and Algorithms
- Applications

AI-assisted Matching Algorithm

有的士車隊稱用人工智能「派單」有車隊著重司機培訓

香港電台-港聞

2025年3月3日

政府舉行的士車隊啟動禮，有車隊本月底將投入服務，其餘會在本月至7月期間陸續「落地」。各車隊在啟動禮上展示新的士，包括6座位的豪華版的士，的士車身顏色亦不一定局限於傳統顏色，包括有黑色、粉紅色、黃紅漸變色。 其中「星群的士」去年12月中，已試行6座位豪華電動的士，至今共有約50部車隊的士行駛，已為乘客提供超過26000個車程。車隊負責人鄭敏怡說，乘客反應正面，車隊亦與港大合作，設計人工智能「派單」系統，為司機及乘客提供更便捷的體驗。至於車費方面，鄭敏怡說乘客透過手機程式預約行程，輸入時間、上落車地點資料後，系統會根據大數據計算出車資，並預先付款，乘客之後不需要擔心

香 港 大 學
THE UNIVERSITY OF HONG KONG

SynCab

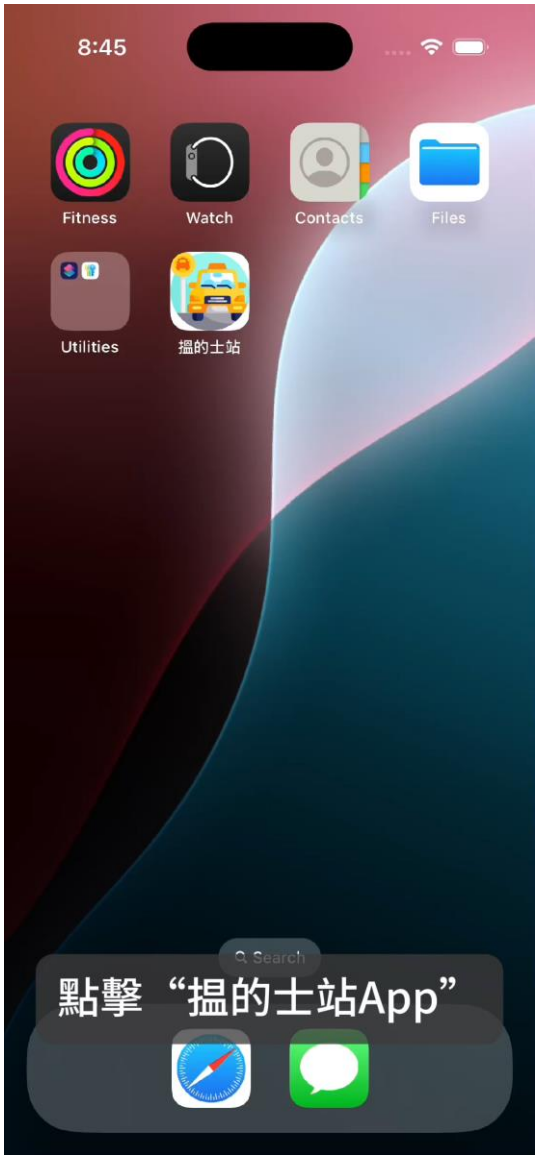
Idle Cruising Recommendation APP

- Our APP can recommend the optimal idle searching route to idle taxi drivers to increase their probability of getting the next passenger
- Taxi drivers can also search for nearby taxi stations for waiting

App Center

Download from App Store

Download QR codes for Android (left) and Apple (right)



Charge Express

- By 2025, HKG plans to expand the number of charging stations to 5,000, nearly doubling the current amount.
- **Charge Express** can help users quickly locate and navigate to nearby charging stations and taxi stands.

App Center

Download from App Store

Charging Deployment Optimization Toolbox

Input by user → **Data-driven optimization model** → **Real-time optimal results and visualization**

Budget constraint

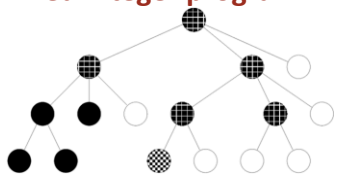
Planned charger **number**

Optimization **objective**

- Minimize cost
- Maximize Served Demand

$$\begin{aligned} \min \quad & cx + hy \\ \text{s.t.} \quad & Ax \leqslant b, \\ & Dy \leqslant Ex, \\ & x \in \mathbb{R}^n, y \in \mathbb{R}^n, \end{aligned}$$

Mixed integer programming



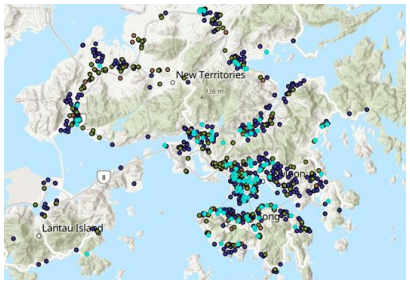
Branch-and-Cut tree

Optimization based on the real data of Hong Kong (traffic flow, price, land cost, etc.)

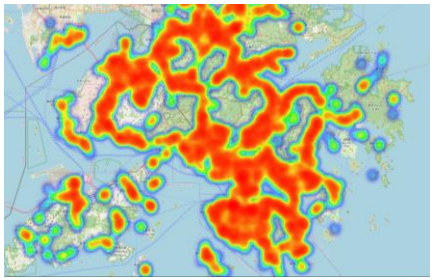
Locations **Numbers**

Types (Fast or slow charger)

Spatio-temporal data



Candidate station distribution



Transport demand distribution

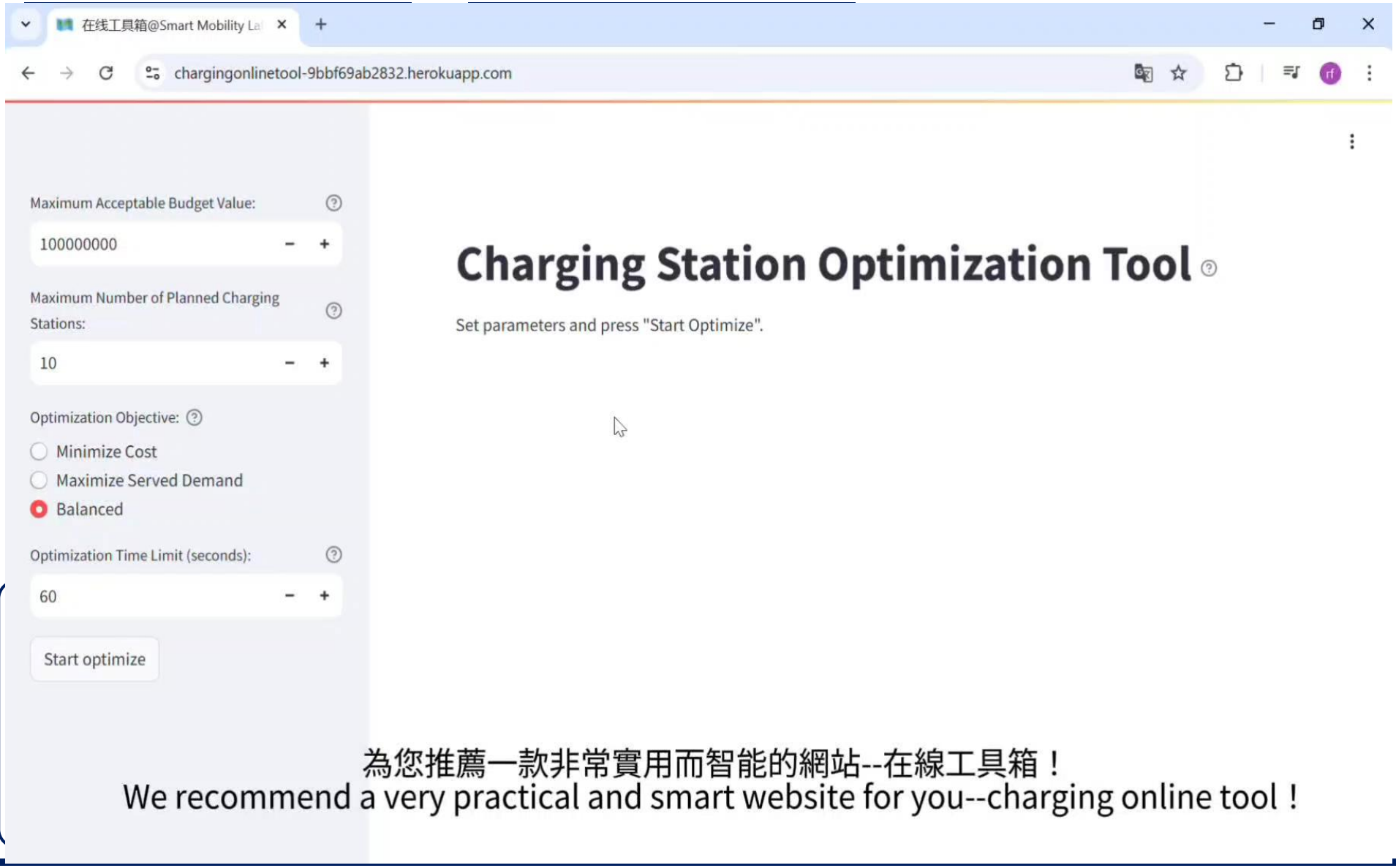
Online experience

http://demos.hkusmlab.com:3002/charging-go-online

Online link

QR Code

Charging Deployment Optimization Toolbox



Thank you for your attention!

Jintao Ke

Department of Civil Engineering

The University of Hong Kong, HK

Email: kejintao@hku.hk

Homepage: https://www.civil.hku.hk/kejintao/