An Efficient Dispatch and Decision-making System for Taxi Booking Service

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Outline

1. Motivation
2. Model
3. Methodologies
4. Evaluation
5. Conclusion
Motivation

- **Rush Hour**
  - Limited taxicabs VS Many passengers need service

- **Non-rush Hour**
  - Abundant taxicabs VS Few urgent passengers
Solution Proposed So Far

- **Taxi-booking service**
  - Phone for taxi service in advance or in real time
  → Cumbersome maintenance and low success rate

- **Recommender system**
  - Recommend best places to wait for passengers based on historical location information
  → Do not handle the latest dynamic information.
In this paper

- We presented a systematic study of driver and passenger preference.

- We propose an evolutionary game approach to optimise the drivers’ revenue and passengers’ cost.

- An efficient dispatch model is proposed.
Preference learning

- **Passengers are willing to phone for taxi service:**
  - During rush hours, or
  - Location is remote and few taxis are available

- **Drivers prefer passengers that:**
  - Request a long-distance ride, or
  - Whose destination area is one of the driver’s preferred areas

![Diagram](image)
Model

- Reservation System
Model

- Architecture
Strategies

- Scene.

$S_{D2}$: stick by driving plan

$(E', L_1, P_1)$

$(E, L_2)$
Methodologies

- **Driver’s Preference E:** the knowledge level of the area
- **Utility Definition**
  - The driver’s utility function mainly contains three aspects: the time cost to locate passengers, the current trip and the next trip after reaching the destination. More formally:

    \[ U_D = U_{\text{tim}} + U_{\text{cur}} + U_{\text{nex}} \]

  - Passengers’ utility is the waiting time.
Research Problems

Under what circumstances are:

- the drivers willing to pick up the passengers?
- the passengers willing to wait for the taxi?
Evolutionary Game Theory

Model

- The drivers has two pure strategies:
  - Pick up the passengers within the limited time
  - Ignore the service request and stick to the driving plan
- The passengers has two pure strategies:
  - Wait until the taxi comes
  - Get in a taxi that passes by
Evolutionary Game Theory

- **Parameter Setting**
  - *Parameter based on historical data:*
    - Average occupied driving distance
    - Expected occupied driving distance after deal has completed
    - The probability that a taxi come across available passengers
  - *Parameter provided by the passengers:*
    - Driving distance, destination area.
Evolutionary Game Theory

Model

**TABLE II: Game model encompassing the strategies**

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<tr>
<th>Driver</th>
<th>Passenger</th>
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<td>$P_2(1 - y)$</td>
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<td>$(U_{12}, V_{21})$</td>
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<td>$(U_{22}, V_{22})$</td>
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Evolutionary Game Theory

- **Evolutionary Stable Strategy:**
  - A ESS is a strategy which if adopted by all members of a population cannot be invaded by a mutant strategy through the operation of natural selection.
Evolutionary Game Theory

- **Compute the Equilibrium**
  - We use the standard Jacobian Matrix to obtain the ESS values here.
  - Any solution pair that satisfies the following conditions is an ESS of the game:

\[
Tr(J) < 0, \ det(J) > 0
\]
Evolutionary Game Theory

- **Theorem 1**: No matter what actions the passengers will make, the driver's optimal actions are picking up the passengers if the following formula holds:

\[
E \geq \max \left( \frac{(1-P_c)(E'fL_2 + fL - fL^*) + LC_1}{L_2f(1-P_c)}, \frac{L_1-L^* + E'L_2}{L_2} - \frac{LC_1}{fL_2} \right)
\]

- **Theorem 2**: Without outside incentive, when shortest-path matching is applied by the driver, the passenger’s optimal action is waiting until the taxi comes, if the following formula holds:

\[
w \geq w_e
\]
# GPS Data

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GPS data Shown on the Map
GPS data Shown on the Map
Preparatory Phase before Simulation

- **Assumption**
  - We assume that a passenger has already been waiting there when a taxicab switched from cruising to occupied (0→1).
  - It is difficult to confirm the exact arriving time.
  - We set the observation time to be 5 minutes.
  - The sparseness and low-sampling-rate of the taxi trajectories discourage us to model it with a less than 5 minutes flow.
  - Passengers still appear to be unwilling to wait longer than 5 minutes.
Any Improvement?

- When passengers’ information are involved, we use the shortest-path route to calculate the distance and get the time consumption to pick up the passengers.
Evaluation

- *Improvement*

Fig. 7. Time consumption to locate passengers
Evaluation

- Suppose that a passenger send a request in 22:00 and his/her destination is 12 kilometer away, should the drivers pick up the passengers?
Convergence

- Convergence of participant
Convergence

- Average occupied driving distance and preference $E$ affect drivers’ final decision.
- The higher the preference $E$ of the destination, the more driver is willing to pick up the passengers.

![Critical convergence line](image)
Optimal Decision

For a driver with a preference $E=0.8$ and average occupied driving distance $L=12$, the optimal strategy is to follow CRS's guide and pick up the passenger.
Driver’s Profit

- As the percentage of drivers who accept a match increases, the profit the drivers will gain increases.

![Graph showing profit vs. percentage](image)

**Fig. 11: Profit**
How to dispatch taxi?

- After the driver send their willingness to pick up passengers to PC, how to dispatch a taxi when two or more taxis are in close proximity according to GPS information?
  - Willingness of drivers
  - Location of all participants
Shortest Path

- Shortest Path Route by Arcgis
Shortest Path

- Advantage by using Arcgis: identify the bad data
Conclusion

- **Dispatch Algorithm**

**Algorithm 1 MDP**

1. Let $I_{ij}$ be shortest distance of unoccupied taxi $i$ to available passenger $j$.
2. Let $W_{ij} \in [0, 1]$ be the willingness of driver $i$ to pick up the passenger $j$.
3. Let $s = \text{argmin}(I_{ij} + \alpha W_{ij})$ that $\alpha$ is a parameter that balance the magnitude unit.
4. **if** no such $s$ exists **then**.
5. random assign the chance to a driver .
6. **else**
7. assign the chance to the driver that subject to $s$.
8. **end if**
Comparison

- OMOR: Taxi could earn more by waiting in parking places, rather than cruising.
  - Detect parking places
  - Using a probabilistic model to calculate how likely the driver would be to pick up a passenger
Conclusion

- Comparing with the ground truth, our CRS system can:
  - The dispatch model could reduce time consumption to located passengers from 2% to as much as 46%.
  - The Game model could increase at least 18% of driver profit.
  - Lower the passengers’ waiting time.
Thanks!
Any Questions?