An opportunistic client user interface to support centralized ride share planning

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Opportunistic ride sharing example
State of the Art

- Various commercial and personal centralized ride-share applications: CoWaG (GER), flinc (GER), Avego (USA), Zimride (USA), Coseats (AUS)

- Require **precise** spatio-temporal information about the client’s origin and destination

- Apply **heuristics** for ride-matching

- Scale and **granularity** issues, e.g., rural vs. urban environments, exact pick-up or drop-off locations, or just the closest available.
State of the Art

-These require:

Additional private information, e.g., age, telephone numbers, first and last names, social media accounts (Facebook, Google+, etc.).

Additional communication channels for subsequent negotiations, e.g., to confirm pick-up and drop-off locations or visual identification, via e.g., voice or text.
Problem Statement

Existing ride-sharing systems are rigid. They rely on the communication of discrete spatio-temporal constraints and additional private information from both vehicle and client to perform ride-matching.

*Problematic for two reasons:*

1. Privacy issues, e.g. location, other meta data,
2. Ad-hoc communications cannot be immediately quantified.
Hypothesis

The proposed architecture provides an effective client user interface for use in ride-sharing applications.

Effective:
- The communication of all available rides satisfying a client’s spatio-temporal constraints.

- The protection of the vehicle’s current location and destination, and the client’s current location.
Timegeography

Vehicle movement can be represented using timegeography concepts

1. **Classical**
   Free space, Hägerstrand (1970)

2. **Modern extensions**
   Network space, Miller (1999)
   Probabilistic, Winter (2009)
Vehicle accessibility

Vehicle’s ‘flexibility bank’

Spatio-temporal query

Edge cost according to some metric, e.g., Euclidean distance
Option 1: 5 mins $4
Option 2: 10 mins $3

Launch pads visualized according to service stability
Launch Pads

- Communicate the vehicle’s *local accessibility*, within the spatio-temporal limits of its OD constraints

- Discrete points in space-time — ideal for describing pick-up and drop-off options

- Visualised according to the service stability of the location

- Removes visual clutter in 2D
Proposed Strategy

Allow the client to explore mobility options in a mobile context, without (1) knowing the individual destinations of vehicles and (2) without revealing their own location.

**OppRide** strategy:

1. Intuitive visualisation of vehicle accessibility
2. Architecture protecting privacy client ↔ vehicle
3. Either human or autonomic driver vehicles
OppRide Architecture

-Centralized authority (a trusted entity) performs ride-matching

-Client creates a mobility request, selecting their destination first

-Vehicle launch pads are only revealed to the client if all of their OD constraints in their request can be satisfied:
  - Origin point
  - Destination point
  - Departure time
  - Arrival time

-Individual vehicle IDs hidden – only their potential is shown

-Upon selecting a pad, the client can make a mobility contract with the corresponding vehicle. After which the positions of both parties are shared.
Experiment Design

- To test the effectiveness of our approach we develop a MAS
  - Repast, JAVA
  - Micro level

- Abstracted (grid) transportation network

- Client and vehicle agent types

- Shortest path calculation: Dijkstra’s algorithm
Service Coverage

- Observing vehicle accessibility only (we do not consider client constraints)
- Vehicle agents move between random O and D in zones 1-4, 6-9, around a centralized service area in zone 5.

- Observe the service coverage of vehicles with a flexibility of \( \frac{1}{3} \) their shortest path length:

- **Vehicle diversity**
  The mean number of different vehicle agents observed per vertex, per time step

- **Vehicle counts**
  The mean number of discrete vehicle agent visits per vertex, per time step
Probability of pick-up

- Introduce a client’s OD constraints and observe their success of getting a ride within zone 5.

- Vehicle agents again move between random O and D in zones 1-4, 6-9.

- Observe a client’s probability of pick-up whilst varying:

  ➔ Vehicle Agent Population size
  ➔ Vehicle Agent Flexibility
Results – Service Coverage

(P) 5 vehicles

(Q) 20 vehicles
## Results – Service Coverage

Vehicle flexibility: $\frac{1}{3}$

<table>
<thead>
<tr>
<th>Population Size</th>
<th>Diversity</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>0.55</td>
<td>1.22</td>
</tr>
<tr>
<td>10</td>
<td>1.11</td>
<td>2.52</td>
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<tr>
<td>20</td>
<td>2.21</td>
<td>4.96</td>
</tr>
<tr>
<td>40</td>
<td>4.47</td>
<td>10.07</td>
</tr>
</tbody>
</table>

- Significant service coverage exists with a sufficient population size
Results – Probability of pick-up

Pr(Pick-up): Vehicle Population

Flexibility: \( \frac{1}{3} \)

- ~0.96
- ~0.78
- ~0.59
- ~0.35
- ~0.06

Population size:
- 40
- 20
- 10
- 5
- 1
Results – Probability of pick-up

- Greater flexibility
- Larger launch pads
- Greater probability of pick-up
Discussion

-Ride matching is a complex task.

-The observed results reflect the behaviour of transportation in reality

<table>
<thead>
<tr>
<th><strong>Private taxi</strong></th>
<th><strong>Public bus</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unlimited flexibility</td>
<td>Fixed route, no flexibility</td>
</tr>
<tr>
<td>Can satisfying a client’s OD constraints with very high probability</td>
<td>Perchance intersection of client OD constraints with the bus’ accessibility</td>
</tr>
</tbody>
</table>

-It is a system designer’s responsibility to search for a balance between vehicle population size and flexibility
Proof of concept

- By quantifying flexibility and including this in a representation of a vehicle’s accessibility we can see that latent potential exists for exploitation by clients.

- Effective in regards to communicating potential using launch pads concept
- Effective in regards to protecting privacy using our OppRide architecture

- When used in a mobile context, OppRide can facilitate opportunistic ride-sharing behaviour.
Conclusion

- Key Contributions:
  - Formal incorporation of flexibility into a representation of vehicle accessibility
  - Communication of vehicle accessibility using launch pads
  - Architecture which protects privacy client ↔ vehicle

- Balance is required between flexibility and vehicle population size
Further Work

- Continuous representation using OSM data (in progress)

- Negotiation of discretised pick-up and drop-off locations client ↔ vehicle

- Alternative ride-sharing architectures, e.g., landing pads, re-negotiation process, and multiple clients

- Effects of heterogeneous vehicle flexibilities and client preferences

- Applications of utility measures, e.g., dynamic fare schemes, carbon emissions, etc.
Questions

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Example. Continuous WIP

Single client UI

Repast Simphony 2.0
Postgis 2.1