Location-Based Taxi Service in Wireless Communication Environment

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University of Ottawa, April 2003
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The Problem

Context

- Mobile users appear at different locations randomly over time
- They need to be transported to different destination points
- There is a fleet of taxi that performs the transport
Objective

- Allocation Algorithm
  - To define which taxi should be assigned ⇒ mobile user
  - To minimize the running distance and time of both
The Simulator

- Applet form and a stand-alone application
- Java 2 SDK 1.3.1 on a SuSe Linux 7.1 platform
- It is responsible for:
  1. generating new requests according to statistical distribution
  2. running the taxi allocation algorithm
  3. assigning taxis to mobile users
  4. updating the current dispatching situation
Simulator Components

• Map
• Approaches
• Time Management
• Mobile Users
• Taxis
• User Interface
Simulator Components

Map

- Euclidean area ⇒ rectangular grid 300 pixels X 300 pixels
- road map of Belo Horizonte’s central region
- scale is 1:12000
- area 3.36 km x 3.36 km square
- road network ⇒ directed graph
  - each edge depicts an one-way road
  - each node depicts an intersection
  - weights ⇔ edges ⇒ distance
  - avenues and street ⇒ speed limits
  - each edge ≡ avenue or street ⇔ θ angle
Current Approach Modelling

Fig.1 and Fig.2: Zone Layout
New Approach

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1.1: mulocation = GetMulocation()  
5.1: AM = assignmentMatrix()  
6.2: send(MUDP)  
4: RunFloyd(molocation, taxilocaiton)  
4.1: SDM = distanceMatrix()  
4.2: RM = routeMatrix()  
6: send(TDP)  
1: taxilocaiton = GetTaxilocaiton()  
3: Getdatalocation()  
6.1: send(ACK)  
6.3: send(ACK)  
3: Getdatalocation()  
5: RunAssignmentAlgorithm(SDM,RM)  
5.1: AM = assignmentMatrix()  

: GPS

: Mobile User

: Gateway

: Taxi

: Floyd–Warshall Algorithm

: AssignmentAlgorithm
Taxi Assignment Problem Model

\[ Min \sum_{i=1}^{n} \sum_{j=1}^{m} d_{i,j} X_{i,j} \]  \hspace{1cm} (1)

subject to

\[ \sum_{i=1}^{n} X_{i,j} = 1 \quad j \in \{1,2, \ldots ,m\} \]  \hspace{1cm} (2)

\[ \sum_{j=1}^{m} X_{i,j} \leq 1 \quad i \in \{1,2, \ldots ,n\} \]  \hspace{1cm} (3)

\[ X_{i,j} \in \{0, 1\} \]  \hspace{1cm} (4)
Assignment Process
Simulator Components

Time Management

- discrete time steps
- time horizon ⇒ the entire day ⇒ 24 hours
- a day is divided into five periods:

<table>
<thead>
<tr>
<th>Periods</th>
<th>Interval Time</th>
<th>Probability %</th>
</tr>
</thead>
<tbody>
<tr>
<td>early-morning</td>
<td>00:00 - 06:00</td>
<td>10</td>
</tr>
<tr>
<td>late-morning</td>
<td>06:00 - 12:00</td>
<td>38</td>
</tr>
<tr>
<td>lunch-time</td>
<td>12:00 - 14:00</td>
<td>05</td>
</tr>
<tr>
<td>early-afternoon</td>
<td>14:00 - 17:00</td>
<td>40</td>
</tr>
<tr>
<td>late-afternoon</td>
<td>17:00 - 24:00</td>
<td>07</td>
</tr>
</tbody>
</table>

Table: Service request probability definition per periods
Simulator Components

Mobile Users

- arrival process ⇒ Poisson model
- interarrival time ⇒ Exponential distribution
- random location ⇒ random destination
Mobile Users

Fig: Mobile users states transition diagram
Simulator Components

Taxis

- random location
- each taxi ⇒ carry one mobile user at a time
- taxis speed ⇔ speed limit allowed on the road map
- the driving method does not follow any standard movement
Taxis

Fig: Taxis states transition diagram
Simulator Components

User Interface

- The interface consists of three sections:
  - the left portion ⇒ setup simulation parameters
  - the central portion ⇒ taxi service in action
  - the right portion ⇒ information about the current simulation
Simulator Components

User Interface

Fig: Simulator user interface
Experimental Results

- Each simulation has been done for days of 24 hours
- Terminologies definition
  - **Pickup**: a link that directs from the taxi’s current location to user’s origin
  - **Dropoff**: a link that directs from the user’s origin to the user’s destination
  - **Transport**: $\text{Transport} = \text{Pickup} + \text{Dropoff}$
Average Total Distance Traveled for Both Approaches Per Number of Users

![Graph showing average total distance traveled for both approaches per number of users. The graph compares the Current Approach and the New Approach, with the New Approach generally showing a lower average total distance traveled as the number of mobile users increases.](image-url)
Experimental Results

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Average Travel Time for Both Approaches Per Number of Users

![Graph showing average travel time for both approaches per number of mobile users. The graph compares the current approach with the new approach, illustrating a decrease in average travel time as the number of mobile users increases.]
Average Pickup Time Per Different Time Windows

![Experimental Results](image-url)
Average Pickup Time For New Approach For Two Simulation Runs

Fig 1: Time Window = 1000

Fig 2: Time Window = 2000
Conclusions

- The integration of taxi service with mobile environment
- This work models and develops a distributed environment ⇒ Mobile Users and Taxis
- We have compared the new approach with the current approach
- Our results have showed gains with the new approach, which is able to locate and dispatch the nearest taxi.
Conclusions

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• Without location technologies the current taxi companies cannot manage all of the vehicles
• Location-based taxi service reduces cost and provides minimum time and distance routing for pickup
• Computing, wireless communications and location information can be combined to provide location-based services.
This Work Did Not Consider:

- demand forecasting
- additional stochastic elements
- transportation of multiple mobile users
- direct communication between mobile users and taxis
- strategy for other kinds of transportation
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Questions