Smart Route Recommendations based on Historical GPS Trajectories and Weather Information

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• Introduction

• Approach Overview
  – Intersections detection
  – Features extraction
  – Route planning

• Results
• Introduction

• Approach Overview
  – Trajectory segmentation
  – Features extraction
  – Route planning

• Results
Room layout exploring and behavior analysis from people's trajectories in smart environments

Cameras setup in a smart meeting room

Initial image

Trajectories

- Person 1
- Person 2
- Person 3
About my research

Initial image

Trajectories

Occupancy map for walking space

Occupancy map for sitting space

Chair locations

Table location
Trajectories from a multi-camera tracking system

Smart meeting room

GPS tracks

Beijing city
Aim: find the optimal route between two places
Traditional method:
the shortest geographic route

Our method with consideration of:

- the prior users' experience
- environmental factors
OpenStreetMap (OSM): A collaborative mapping data contain many types of GIS data including:

- Road locations and names
- Points of Interest
- Natural Features
- Bodies of Water
- Political boundaries
- …..
GeoLife Dataset from Microsoft Research Asia:

**Version 1.3**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time span of the collection</td>
<td>04/2007 – 8/2012</td>
</tr>
<tr>
<td>Number of users</td>
<td>182</td>
</tr>
<tr>
<td>Number of trajectories</td>
<td>18,670</td>
</tr>
<tr>
<td>Number of points</td>
<td>24,876,978</td>
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<td>Total distance</td>
<td>1,292,951 km</td>
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<tr>
<td>Total duration</td>
<td>50,176 hour</td>
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<td>Effective days</td>
<td>11,129</td>
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</table>

**Transportation mode**

<table>
<thead>
<tr>
<th>Transportation mode</th>
<th>Distance (km)</th>
<th>Duration (hour)</th>
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</thead>
<tbody>
<tr>
<td>Walk</td>
<td>10.123</td>
<td>5.460</td>
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<tr>
<td>Bike</td>
<td>6.495</td>
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<td>Bus</td>
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<td>1.507</td>
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<td>Car &amp; taxi</td>
<td>32.866</td>
<td>2.384</td>
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<tr>
<td>Train</td>
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<td>Airplane</td>
<td>24,789</td>
<td>40</td>
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<td>Other</td>
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Weather information in Beijing from 2007 to 2012

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<tr>
<th>#Year</th>
<th>Day</th>
<th>Solar</th>
<th>T-max</th>
<th>T-min</th>
<th>Humidity</th>
<th>Precipitation</th>
<th>Evaporation</th>
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<td>1</td>
<td>8.08</td>
<td>-3.8</td>
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<td>-10.1</td>
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<td>0.4</td>
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<td>0.2</td>
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<td>-17.5</td>
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<td>0.2</td>
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<td>0.6</td>
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<tr>
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<td>-20.2</td>
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<tr>
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<td>12</td>
<td>10.1</td>
<td>-8.2</td>
<td>-20.3</td>
<td>59</td>
<td>2</td>
<td>0.7</td>
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</tbody>
</table>

......
Overview

• Introduction

• Approach Overview
  – Intersections detection
  – Features extraction
  – Route planning

• Results

OpenStreetMap (OSM)
OpenStreetMap (OSM)

Road 1:
Node1
Node2
Node3
Node4
Node5
Node6
......

Road 2:
Node5
Node7
Node8
Node9
Node10
Node11
......
calculate the shortest route based on the connectivity between each pair of nodes, and the distance between them.
OpenStreetMap (OSM)

Road 1:
Node1
Node2
Node3
Node4
Node5
Node6
......

Road 2:
Node5
Node7
Node8
Node9
Node10
Node11
......

Road 3:
Node78
Node89
Node45
Node9
Node20
Node21
......

Connectivity calculation
## Connectivity matrix

<table>
<thead>
<tr>
<th></th>
<th>Node1</th>
<th>Node2</th>
<th>Node3</th>
<th>Node4</th>
<th>Node5</th>
<th>Node6</th>
<th>......</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Node2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Node3</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
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<tr>
<td>Node4</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Node6</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
<td>......</td>
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</tbody>
</table>
## Distance matrix

<table>
<thead>
<tr>
<th></th>
<th>Node1</th>
<th>Node2</th>
<th>Node3</th>
<th>Node4</th>
<th>Node5</th>
<th>Node6</th>
<th>......</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node1</td>
<td>0</td>
<td>500m</td>
<td>0</td>
<td>0</td>
<td>70m</td>
<td>0</td>
<td>......</td>
</tr>
<tr>
<td>Node2</td>
<td>500m</td>
<td>0</td>
<td>4500m</td>
<td>230m</td>
<td>0</td>
<td>0</td>
<td>......</td>
</tr>
<tr>
<td>Node3</td>
<td>0</td>
<td>4500m</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>......</td>
</tr>
<tr>
<td>Node4</td>
<td>0</td>
<td>230m</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100m</td>
<td>......</td>
</tr>
<tr>
<td>Node5</td>
<td>70m</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>......</td>
</tr>
<tr>
<td>Node6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100m</td>
<td>0</td>
<td>0</td>
<td>......</td>
</tr>
</tbody>
</table>
Overview

- Introduction
- **Approach Overview**
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- Results

GeoLife Dataset
Features for each pair of connected nodes:

- average of the speeds
- standard deviation of the speeds
- the confidence of the Geolife trajectory data matching the openstreetmap data

GeoLife Dataset

<table>
<thead>
<tr>
<th>track_id</th>
<th>Node5</th>
<th>Node9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track 1 of user 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Track 45 of user 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Track 6 of user 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Track 3 of user 120</td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>track_id</th>
<th>ave_speed</th>
<th>var_speed</th>
<th>confidence of map matching</th>
<th>Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>track_id =1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>track_id =2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>track_id =3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>track_id =4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Features of {node5, node9}
Map matching

GeoLife Dataset

OpenStreetMap (OSM)

One segment

node i
node i+1
node i+2
...

dist0
dist1
dist2
.....

ave_dist

confidence of map matching

The corresponding segment

node j
node j+1
node j+2
...

ave_dist

confidence of map matching
Variables:

- ave_s: average of speeds
- re: road evaluation

Variables:

- var_s: variance of speeds
- re: road evaluation

Variables:

- ave_dist: map matching
- re: road evaluation

\[
p_n(\text{ave}_s|\text{re}) = e^{-\frac{(\text{ave}_s - 50)^2}{2\sigma^2}}
\]

\[
p_n(\text{var}_s|\text{re}) = \alpha^{\text{var}_s}
\]

\[
p_n(\text{ave}_\text{dist}|\text{re}) = \beta^{\text{ave}_\text{dist}}
\]
Bayesian theory:

\[ p_n(re|ave_s_n) = \gamma * p_n(ave_s_n|re)p_{n-1}(re) \]

\[ p_n(re|var_s_n) = \gamma * p_n(var_s_n|re)p_{n-1}(re) \]

\[ p_n(re|ave_dist_n) = \gamma * p_n(ave_dist_n|re)p_{n-1}(re) \]

\[ p_n(re) = \lambda_1 * p_n(re|ave_dist_n) + \lambda_2 * p_n(re|var_s_n) + \lambda_3 * p_n(re|ave_s_n) \]

<table>
<thead>
<tr>
<th>track_id</th>
<th>prob(re)</th>
<th>Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>track_id =1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>track_id =2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>track_id =3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>track_id =4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

corr(road condition, humidity)
• Introduction

• **Approach Overview**
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• Results
• Road evaluation and the impactor of Precipitation are used to adjust the distance between each pair of connected nodes
• Calculate the shortest route using the connectivity matrix and new distance matrix
• Introduction
• Approach Overview
  – Intersections detection
  – Features extraction
  – Route planning
• Results
intersections
Connectivity matrix
Road evaluation

OpenStreetMap osm file

- **bad**
- **good**
Weather impactor

OpenStreetMap osm file

correlation
- low
- high
Route planner (traditional method)
Route planner (our method)
THANKS FOR YOUR ATTENTION! QUESTIONS?