Visual Traffic Jam Analysis
Based on Trajectory Data

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Introduction

• Many cities are suffering from traffic jams

Beijing   Melbourne   Atlanta
Introduction

- Current traffic jam monitoring technologies

Real time road condition from Google Map

Introduction

- Complexities of traffic jams
  - Road conditions change with time
  - Different roads have different congestion patterns
  - Congestions propagate along the road network
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Related Work

- Traffic Modeling
  - Outlier tree [Liu et al. 2011]
  - Probabilistic Graph Model [Piatkowski et al. 2012]
    - Study the propagation of traffic outlier events between regions
    - powerful but complex
Related Work

• Traffic Event Visualization

[Andrienko et al. 2011] Incident Cluster Explorer

Individual events extraction

[Pack et al. 2011] Individual events filtering

Data Description

• Beijing taxi GPS data (from DataTang.com)
  • Size: 34.5 GB
  • #Taxi: 28,519
    (7% of total traffic flow volume)
  • #Sampling point: 379,107,927
  • Time range: 24 days
    (Mar.2nd~25th, 2009, missing 18th)
  • Sampling interval: 30 seconds
    (60% data missing)
Data Description

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    (Mar. 2nd~25th, 2009, missing 18th)
  - Sampling interval: 30 seconds
    (60% data missing)
- Beijing road network (from OpenStreetMap)
  - Size: 40.9 MB
  - 169,171 nodes and 35,422 ways

Overview

- GPS Trajectories
- Preprocessing (based on a traffic jam data model)
- Traffic Jams
- Visual exploration (based on a visual interface)
- Traffic Jam Knowledge
Overview

- GPS Trajectories
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Design Requirements

- Traffic jam data model
  - Complete
    - Include location, time, speed
  - Structured
    - Study propagations of traffic jams
  - Road Bound
    - Traffic jams happen on roads

- Visual interface
  - Informative
    - Show location, time, speed, propagation path
  - Multilevel
    - Explore from city level to road segment level
  - Filter Enabled
    - Select and study a subset of propagations
Overview

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- Traffic Jam Knowledge
Preprocessing

Input data
- Raw Taxi GPS Data
- Raw Road Network

Traffic jam data
- Road Speed Data
- Traffic Jam Event Data
- Traffic Jam Propagation Graphs

Preprocessing

Input data
- Raw Taxi GPS Data
- Raw Road Network

Traffic jam data

2009/03/02 12:00:00

Speed (km/h)

- N/A

Traffic Jam Visual Analysis
Preprocessing

Input data

Raw Taxi GPS Data

Raw Road Network

GPS Data Cleaning

Cleaned GPS Data

Road Network Cleaning

Cleaned Road Network

Map Matching

GPS Trajectories Matched to the Road Network
Preprocessing

Input data

Raw Taxi GPS Data  Raw Road Network

Cleaned GPS Data  Cleaned Road Network

GPS Trajectories Matched to the Road Network

Road Speed Calculation

Road Speed Data

Road speed: for each road at each time bin (10 min)

<table>
<thead>
<tr>
<th>Time</th>
<th>Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:10 am</td>
<td>50</td>
</tr>
<tr>
<td>9:20 am</td>
<td>45</td>
</tr>
<tr>
<td>9:30 am</td>
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Preprocessing

Input data

Raw Taxi GPS Data  Raw Road Network

Cleaned GPS Data  Cleaned Road Network

GPS Trajectories Matched to the Road Network

Traffic Speed Data

Traffic jam events: road, start/end time bin

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Traffic Jam Event Data
Preprocessing

Input data
Raw Taxi GPS Data
Raw Road Network
Cleaned GPS Data
Cleaned Road Network
GPS Trajectories Matched to the Road Network
Road Speed Data
Traffic Jam Event Data
Propagation Graph Construction
Traffic Jam Propagation Graphs

Defining propagation based on spatial/temporal relationship:

\[ e_2 \text{ happens after } e_1 \text{, and on a road following } e_1 \]

\[
\begin{array}{c|c|c}
9:10 \text{ am} & 50 \text{ km/h} \\
9:20 \text{ am} & 45 \text{ km/h} \\
9:30 \text{ am} & 12 \text{ km/h} \\
9:40 \text{ am} & 15 \text{ km/h} \\
\hline
9:10 \text{ am} & 55 \text{ km/h} \\
9:20 \text{ am} & 10 \text{ km/h} \\
9:30 \text{ am} & 12 \text{ km/h} \\
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\end{array}
\]

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Preprocessing

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A real propagation graph:

Start points
End points

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Preprocessing

Input data
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- Raw Road Network

Traffic jam data
- Road Speed Data
- Traffic Jam Event Data
- Traffic Jam Propagation Graphs

Visual Interface

Three levels of exploration

Road Segment Level Exploration and Analysis
- Road of Interest
- One Propagation Graph
- Propagation Graphs of Interest

Propagation Graph Level Exploration
- Spatial Density
- Time and Size Distribution
- Topological Clustering

Propagation Graph List
- Spatial Filter
- Temporal & Size Filter
- Topological Filter

Dynamic Query
Visual Interface: City Level

- Graph list view: show propagation graphs as icons

Time range
Spatial path: color for congestion time on each road
Size: #events, duration, distance
Visual Interface: City Level

- Graph projection view: topological aggregation
  - All propagation graphs are grouped
  - Each group is represented by a point
  - Graphs in the same group have similar topologies
  - Distance between points represent the topological distance between graph groups
Visual Interface: Single Propagation Level

Traffic jam data

- Road Speed Data
- Traffic Jam Event Data
- Traffic Jam Propagation Graphs

One Propagation Graph

Propagation Graphs of Interest

Propagation Graph Level Exploration

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Visual Interface: Single Road Level

Traffic jam data

- Road Speed Data
- Traffic Jam Event Data
- Traffic Jam Propagation Graphs

Road of Interest

One Propagation Graph

Propagation Graphs of Interest

Road Segment Level Exploration and Analysis

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Visual Interface: Single Road Level

- Table-like pixel-based visualization

Each cell represents 10 min of a day

Each column represents 10 min

Each row represents one day

Color encodes speed

>50 km/h
40
30
20
10
0
N/A

Make non-jam cells smaller to highlight traffic jams
Case Studies

- Road level exploration
- Propagation graph exploration
- Propagation trend exploration

Case Study: Road Level Exploration

- a
- b
- c
- d
Case Study: Road Level Exploration

- Filter propagation graphs
- Observe propagation path
- Check road speed
- Check propagation time
- Watch animation
Case Study: Propagation Graph Exploration

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Case Study: Propagation Graph Exploration

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Watching Taxi Trajectory Animation
Case Study: Propagation Trend Exploration

One fixed region

Different mornings

Showing to the public

International Information Design Exhibition
09/26/2013~10/13/2013

Simplified version
Only road level exploration
Conclusion

• A visual analytic system to study traffic jams
  • An automatic process to extract traffic jams from GPS trajectories
  • A visual interface to support multilevel exploration of traffic jams

Future Work

• Improve the traffic jam data model (e.g. add prediction functions)
• Support more analysis task (e.g. spatial/temporal clustering)
• Try better visual design of propagation graphs
• Collaboration with the domain experts
Acknowledgement

- Funding:
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- Data:
  - Datatang.com
  - OpenStreetMap

- Anonymous reviewers for valuable comments

Our website:
http://vis.pku.edu.cn/trajectoryvis