Visual Traffic Jam Analysis based on Trajectory Data

Zuchao Wang\(^1\), Min Lu\(^1\), Xiaoru Yuan\(^1, 2\), Junping Zhang\(^3\), Huub van de Wetering\(^4\)

1) Key Laboratory of Machine Perception (MOE), and School of EECS, Peking University
2) Center for Computational Science and Engineering, Peking University
3) Key Laboratory of Intelligent Information Processing, and School of Computer Science, Fudan University
4) Department of Mathematics and Computer Science, Technische Universiteit Eindhoven

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Introduction

- Traffic jam is a critical problem in big cities
Introduction

- We are able to monitor traffic jams nowadays
Introduction

• Understanding the traffic jams remains a challenge due to their complexities
  – Road condition change with time
  – Different roads have different congestion patterns
  – Congestions propagate in the road network

We develop a visual analytics system to study these complexities

为了理解这些复杂因素，我们设计了一个可视分析系统
Related Works

- Traffic modeling

We hope to study the traffic jams on the roads

Outlier tree
[Liu et al. 2011]

We hope to summarize historic traffic jams with simple model

Probabilistic Graph Model
[Piatkowski et al. 2012]
Related Works

- Traffic event visualization

We hope to visualize the relationship of traffic events

[Andrienko et al. 2011]

Incident Cluster Explorer
[Pack et al. 2011]
Design Requirement

• Traffic jam data model 交通拥堵数据模型
  – Complete: include location, time, speed
  – Structured: study propagation of jams
  – Road bound

• Visual interface 可视分析界面
  – Informative: show location, time, speed, propagation path, size of propagation
  – Multilevel: support from city level to road level
  – Filterable
Data Description

- Beijing taxi GPS data
Data Description

- Beijing taxi GPS data
  - Size: 34.5GB
  - Taxi number: 28,519
  - Sampling point number: 379,107,927
  - Time range: 2009/03/02~25 (24 days, but 03/18 data is missing)
  - Sampling rate: 30 seconds per point (but 60% data missing)
- Beijing road network (from OpenStreetMap)
  - Size: 40.9 MB
  - 169,171 nodes and 35,422 ways
Preprocessing

Input data

- Raw taxi GPS Data
- Raw Road Network

Road Speed Data

Traffic Jam Event Data

Traffic Jam Propagation Graphs

Traffic jam data
Preprocessing

- Raw taxi GPS Data
- Raw Road Network
Preprocessing: Data Cleaning

数据清理
Preprocessing: Map Matching

路网绑定
Preprocessing: Road Speed Calculation

道路速度计算

Road speed: for each road at each time bin

```
...... ... 
9:10 am 50 km/h 
9:20 am 45 km/h 
9:30 am 12 km/h 
9:40 am 15 km/h 
...... ... 
```

```
...... ... 
9:10 am 55 km/h 
9:20 am 10 km/h 
9:30 am 12 km/h 
9:40 am 45 km/h 
...... ... 
```
Preprocessing: Traffic Jam Detection

Traffic jam events: road, start/end time bin

<table>
<thead>
<tr>
<th>Time</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:10 am</td>
<td>50 km/h</td>
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Diagram showing the preprocessing steps for traffic jam detection, including raw data cleaning and road network processing.
Preprocessing: Propagation Graph Construction

Defining propagation based on spatial/temporal relationship:

- $e_0$ happens before $e_1$, and on a dWay following $e_1$

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Visual Interface

- 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
- Propagation Graph Level Exploration
- Propagation Graph List

- Spatial Density
- Time and Size Distribution
- Topological Clustering

- Spatial Filter
- Temporal & Size Filter
- Topological Filter

Dynamic Query
Visual Interface: City Level

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

Propagation Graphs of Interest

Propagation Graph List
Visual Interface: City Level

- Graph list view
Visual Interface: City Level

- Graph list view: icon design

![Diagram showing Visual Interface](image)

- **Time range**: 03/13 17:00 - 19:50
- **Spatial path**: color for congestion time on each dWay
- **Size**: #events, duration, distance
Visual Interface: Single Graph Level

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

One Propagation Graph

Propagation Graphs of Interest

Propagation Graph Level Exploration
Visual Interface: Single Graph Level

- Flow graph
Visual Interface: Single Road Level

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
Visual Interface: Single Road Level

- Table like pixel based visualization

Time of a day: 144 columns (each for a 10min)

Days: 24 rows (each for one day)

Each cell represents one time bin

Color encode speed
Visual Interface: Single Road Level

- Table like pixel based visualization

Make non-jam cells smaller to highlight jam events
Case Study

• Road level exploration and analysis
• Visual propagation graph analysis
• Congestion propagation pattern exploration
Case Study: Road Level Exploration and Analysis

- Different road congestion patterns
### Case Study: propagation graph analysis

- **Spatial temporal information of one propagation**

<table>
<thead>
<tr>
<th>Spatial path</th>
<th>Temporal delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>D ↓ G</td>
<td></td>
</tr>
<tr>
<td>E ↓ H</td>
<td></td>
</tr>
<tr>
<td>L ↓ I ↓ J ↓ K</td>
<td>Large delay</td>
</tr>
<tr>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time (00:00 - 21:00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
</tr>
<tr>
<td>03:00</td>
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<tr>
<td>06:00</td>
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<tr>
<td>09:00</td>
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<tr>
<td>12:00</td>
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<tr>
<td>15:00</td>
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<tr>
<td>18:00</td>
</tr>
<tr>
<td>21:00</td>
</tr>
</tbody>
</table>

2009-03-21
Case Study: Propagation Pattern Exploration

- Propagation graphs for one region in the morning of different days
Conclusions

• Present a process to automatically extract traffic jam data
• Design a visual analysis system to explore the traffic jams and their propagations
• Use our system to study a real taxi GPS dataset
Future Works

- Improving the traffic jam model (e.g. with Probabilistic Graph Model)
- Support more analysis task
- Try better visual design of propagation graphs
- Make a formal evaluation
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  – OpenStreetMap

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http://vis.pku.edu.cn