Visual Traffic Jam Analysis Based on Trajectory Data

Zuchao Wang, Min Lu, Xiaoru Yuan, Peking University
Junping Zhang, Fudan University
Huub van de Wetering, Technische Universiteit Eindhoven

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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A visual analytic system to help people study these complexities

Related Work

- Traffic Modeling

Outlier tree
[Liu et al. 2011]

Study the propagation of traffic outlier events between regions

Probabilistic Graph Model
[Piatkowski et al. 2012]

powerful but complex
Related Work

• Traffic Event Visualization

[Andrienko et al. 2011] Incident Cluster Explorer

[Pack et al. 2011] Individual events extraction

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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  - Time range: 24 days (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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- Traffic Jam Knowledge

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
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Preprocessing

Input data
- Raw Taxi GPS Data
- Raw Road Network

Road Speed Data

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

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Preprocessing

Input data
- Raw Taxi GPS Data
- Raw Road Network

Traffic jam data

2009/03/02 12:00:00

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Preprocessing

Input data:
- Raw Taxi GPS Data
- Raw Road Network

Steps:
1. GPS Data Cleaning
2. Map Matching (GPS trajectories matched to the Road Network)
3. Road Network Cleaning
4. Cleaned GPS Data
5. Cleaned 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 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 events: road, start/end time bin

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

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

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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
- Road Speed Data
- Traffic Jam Event Data

Defining propagation based on spatial/temporal relationship:

\[ \begin{array}{c|c|c|c}
    \text{Time} & \text{Speed} & \text{Location} \\
    \hline
    9:10 \text{ am} & 50 \text{ km/h} & \text{a} \\
    9:20 \text{ am} & 45 \text{ km/h} & \text{a} \\
    9:30 \text{ am} & 12 \text{ km/h} & \text{a} \\
    9:40 \text{ am} & 15 \text{ km/h} & \text{a} \\
    \text{...} & \text{...} & \text{...} \\
    \hline
    9:20 \text{ am} & 10 \text{ km/h} & \text{b} \\
    9:30 \text{ am} & 12 \text{ km/h} & \text{b} \\
    9:40 \text{ am} & 45 \text{ km/h} & \text{b} \\
    \text{...} & \text{...} & \text{...} \\
\end{array} \]

\( e_2 \) happens after \( e_1 \), and on a road following \( e_1 \)

Traffic Jam Event Data

Propagation Graph Construction

Traffic Jam Propagation Graphs

A real propagation graph:
Preprocessing

Input data
- Raw Taxi GPS Data
- Raw Road Network

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

Input Taxi GPS Trajectories

Visual Interface

Three levels of exploration

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

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

   420 Graphs

   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

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
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

Visual Interface: Single Road Level

- Table-like pixel-based visualization

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
Case Study: Road Level Exploration

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- f
- g

Case Study: Propagation Graph Exploration

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

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Major start point

Major end points

Case Study: Propagation Graph Exploration

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Case Study: Propagation Graph Exploration

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Watching Taxi Trajectory Animation

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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
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  • OpenStreetMap

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