High Performance Spatial Visualization of Traffic Data

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Overview

- Background
- Objectives
- Tasks
- Literature Search
- Traffic Data
- Traffic Model Design
- Visualization Examples
Background

- High-Performance Visualization techniques
  - Becoming crucial
  - Traffic data growing faster
  - Hard to be analyzed manually

- Performance Bottleneck
  - Large volume of traffic data
  - Limited analysis to a very small sample of data
  - Difficult to perform interactive visualization
    - Answer “What is” questions
    - Drill down to small subsets: a traffic zone, a lane, one single hour
Objectives

- Develop high performance spatial tools and techniques
  - Generate critical visualizations of traffic data
- Develop new spatial data-structures and algorithms
  - Address the performance bottlenecks
- Novel interactive visualization
  - Summary traffic maps for a variety of aggregate information
    - Annual traffic volume
    - Daily hours of congestion
  - Multi-dimensional surface visualization
    - Speed as a function of time, highway network location
  - Techniques to visualize relationships between traffic attributes (volume, occupancy) over different dimensions (Space, time)
  - A video-like visualization of traffic data for an approximate but rapid summarization of major trends
Specific Objectives

- Identify performance bottlenecks
  - Review relationships between visualization algorithms and scalability

- Organize the multidimensional traffic space into a lattice framework

- Use the lattice framework
  - Efficiently produce summary plots, including video
    - Beneficial to the traffic analyst
  - Help the identification of important nodes in the lattice
  - Each node of the lattice can potentially generate a new visualization schema
  - Identify the redundant nodes
  - Optimize algorithm generation
    - By using summary information from parent/child nodes
Tasks

- Task 1: Requirement Analysis
- Task 2: Identification of Bottleneck in Visualization
- Task 3: Develop visualization algorithms for spatially index data
- Task 4: Prototype software development
- Task 5: Report Preparation
Tasks

- **Task 1: Requirement Analysis**
  - *Identify the important visualization requirements of loop-detector data*
  - *Study the work flow of generating, revising, and re-purposing of visualizations at TMC*
  - *Query TMC researchers to understand which visual metaphors may be the most suitable for the analysis of traffic data*

- **Task 2: Identification of Bottleneck in Visualization**
  - *Start with a specific visualization, e.g. maps, towards the identification of performance bottlenecks*
  - *Identify performance bottleneck in the generations, and revision of visualizations*
    - Use “Code Profiling” and other performance measurement techniques
  - *Determine if it may be profitable to separate out the visual mining from the non-visual mining*
    - By duplicating the database
    - Potentially lead to consistency problems
  - *Leverage our work form previous project on data-archiving to reduce performance bottlenecks*
Tasks (cont.)

- Task 3: Develop visualization algorithms for spatially index data
  - *Develop spatial data-structures and algorithms*
    - Address the performance bottlenecks in generation of various visualizations
    - Take advantage of the aggregate descriptions
    - Maintain aggregate information
  - *Develop a lattice framework*
    - Each node correspond to a sup-space of the multi-dimensional conceptual space
    - Conducive to “What-if” scenarios
    - Allow integration into other high performance visual kernels
  - *Address the important of the validity of results derived from aggregate data*
    - Contradictory between aggregate data and those arrived on the base data
  - *Investigate the recent wavelet compressing techniques*

- Task 4: Prototype software development
  - Validate results via a software implementation
  - Determine if our software can be seamlessly integrated with the proposed mini-CAVE

- Task 5: Report Preparation
Literature Search

- Visualization for the specialist end user
  - *(Hill 96’)*
- Visualization for the non-expert end user
  - *(Prevedouros et. al 94’)*
- Role of GIS
  - *(Ganter et. al 94’), (Baecher et. al 96’), (Quiroga et. al 96’)*
- Higher Dimensional Visualization
  - *(Burnetti et. al 96’), (Landphair et. al 96’)*
- Combine data mining with GIS
  - *(Chase et. al 99’)*
Literature Search

- Visualization for the specialist end user
  - (Hill 96’)
    - summarizes the Traffic Flow Visualization and Control system
    - Conclude that accurate real-time visualization can aid in incident detection and management

- Visualization for the non-expert end user
  - (Prevedouros et. al 94’)
    - Develop a visualization system for non-expert end user
    - Claim that users do not need any training for understanding the displayed results

- Role of GIS
  - GIS allow for effective visualization of spatially referenced data
  - (Ganter et. al 94’) propose a prototype for visualization of dynamic traffic data
  - (Baecher et. al 96’) address the issue of rapidly integrating data in different formats into a common visualization tool
  - (Quiroga et. al 96’) integrate GPS and GIS data to study the problem of traffic congestion
Literature Search (cont.)

- Higher Dimensional Visualization
  - One limitation of current GIS: Inability to handle multi-dimensional data
  - (Burnetti et. al 96’) overview the common problems associated with the rendering of three dimensional data
  - (Landphair et. al 96’) address the issues of complexity, hardware, software, and cost associated with the visualization of transportation data

- Combine data mining with GIS
  - (Chase et. al 99’) use data mining, data warehousing, and spatial visualization techniques to discover implicit patterns and relationships embedded in the data
Traffic Data (Input)

- Detector Map in Station Level
Traffic Data (Input)

- Detector Map in Station Level
Traffic Data (Input)

• Detector-station Relationship

Detector 50
Detector 51
Station 20
Detector 52

• Basic Tables

Station Table

<table>
<thead>
<tr>
<th>Station</th>
<th>Polygon_id</th>
<th>Polygon Boundary</th>
<th>Location</th>
<th>Freeway</th>
<th>Direction</th>
<th>Zone</th>
<th>.....</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P1</td>
<td>(3,5),(4,10)...</td>
<td>26th St.</td>
<td>I-35W</td>
<td>N</td>
<td>Q4</td>
<td>......</td>
</tr>
<tr>
<td>2</td>
<td>P3</td>
<td>(5,7),(6,4),..</td>
<td>28th St.</td>
<td>I-35W</td>
<td>N</td>
<td>Q4</td>
<td>......</td>
</tr>
</tbody>
</table>

Detector Table

<table>
<thead>
<tr>
<th>Detector</th>
<th>Station</th>
<th>Time</th>
<th>Detector</th>
<th>Volume</th>
<th>Occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1997 1 12 12:30</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1997 1 12 12:50</td>
<td>2</td>
<td>60</td>
<td>12</td>
</tr>
</tbody>
</table>

Value Table
Data-flow and main modules in our system

Map

Clean, load

Data Warehouse

Raw data
5-minute Detector volume & occupancy

Cube

Query result

Data Mining and Knowledge Discovery (e.g. visualization)

Clustering Classification Association Rules

Pattern Map Graphic Trend
- (i) Video
- (ii) Per-Freeway - Time map
- (iii) Freeway - Network map (fixed time)
- (iv) Attribute - Time plot (fixed space)
Design Schema

- **A Star Schema**

- **A Snowflake Schema**
Concept Hierarchies for Dimensions

- Time dimension

  Time dimensions
  
  Year
  
  Season
  
  Month  Week
  
  Date
  
  Hour
  
  Minute

- Space dimension

  Space dimension
  
  County  Freeway  Region
  
  Freeway+ Direction
  
  Station
  
  Detector
Visualization Example (0) Video Display

- Phenomenon of interest
  - Average Volume
  - Date: 1997 January 15 Wednesday 16:05PM
Visualization Example (0) Video Display

- Phenomenon of interest
  - Average Occupancy
  - Date: 1997 January 15 Wednesday 16:00PM
Visualization Example (I) I-35W North Bound

- Phenomenon of interest for I-35W North Bound
  - Clusters of similar stations

- Per-freeway - Time map
  - Data(average volume) map for I-35W North Bound
Visualization Example (I) I-35W North Bound

- Freeway - Network map
- K-means clustering using volume data

I-35W North Bound on 1/13 1997
Visualization Example (I) I-35W North Bound

- Attribute - Time map
- Average volume within each cluster

I-35W North Bound on 1/13/1997 using K-means clustering
Visualization Example (II) I-35W South Bound

- Phenomenon of interest for I-35W South Bound
  - Clusters of similar stations

- Per-freeway - Time map
Visualization Example (II) I-35W South Bound

- Freeway - Network map
- K-means clustering using volume data
- I-35W South Bound on 1/13 1997
Visualization Examples (II) I-35W South Bound

- Attribute - Time map

I-35W South Bound on 1/13/1997 using K-means clustering
Visualization Example (III)

- Phenomenon of interest
  - Bottlenecks in TMC data

- Bottleneck Stations from MNDOT
Visualization Example (III)

- Phenomenon of interest
  - *Bottlenecks in TMC data*

- Decision Tree

```
Volume during 6:10-6:15PM
  <=152       >152
    No         Occupancy during 11:25-11:30AM
      <=19    >19
    Volume during 11:30-11:35AM
      <=4     >4
       Yes     No
          (Bottleneck)   (Bottleneck)
```
Visualization Example (IV)

- Phenomenon of interest
  - *Outliers/Exceptions detection*
  - *Data inconsistent with the reminder of data*

- I-35W North Bound

![Average Traffic Volume(Time v.s. Station)](image)
Visualization Example (IV)

- Phenomenon of interest
  - Outliers/Exceptions detection
  - Data inconsistent with the reminder of data

- I-35W South Bound