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*

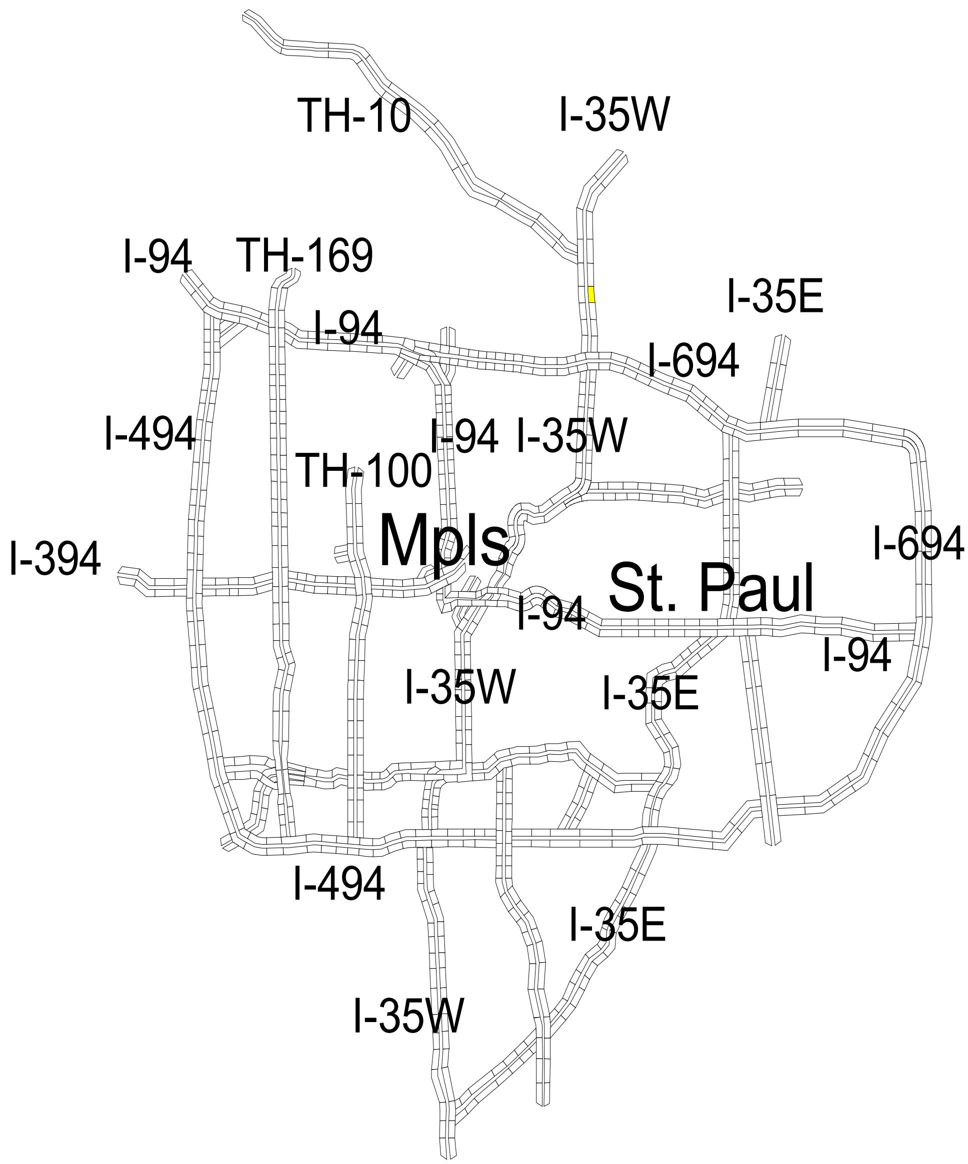
Literature Search (cont.)

- 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*

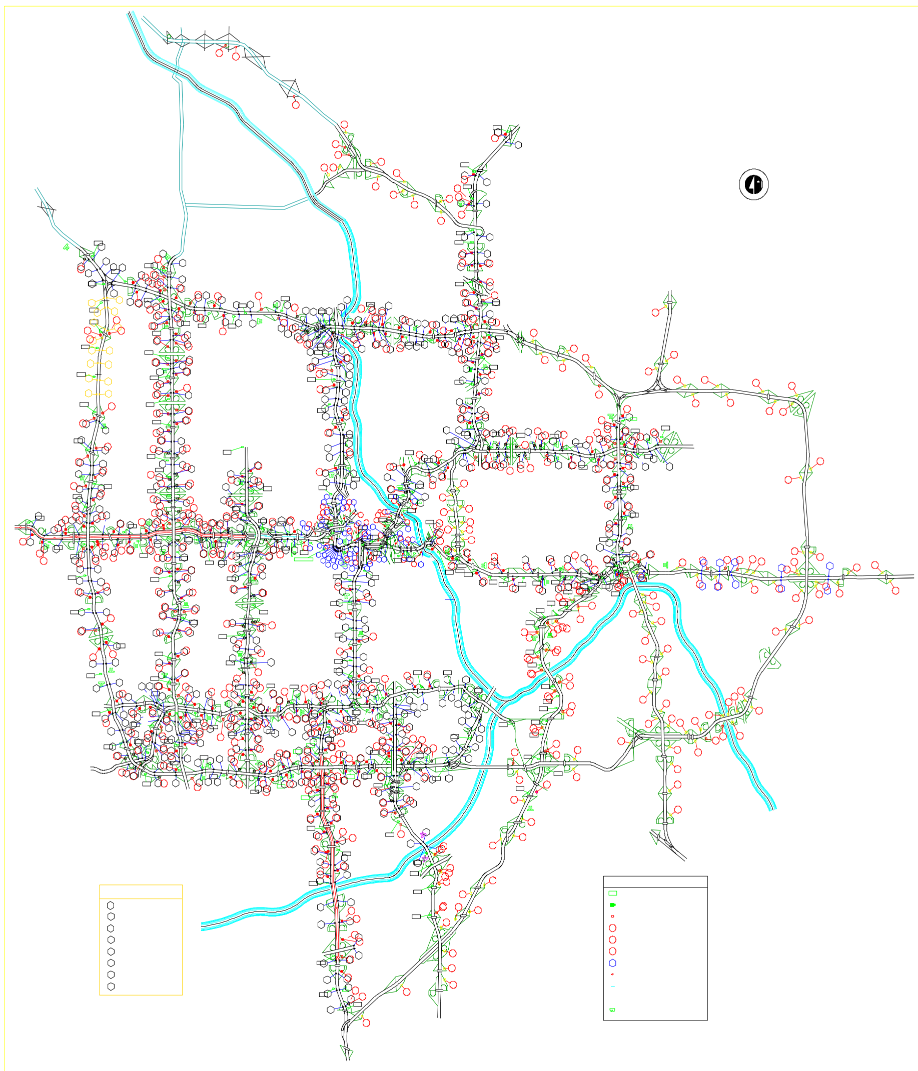
Traffic Data(Input)

- Detector Map in Station Level



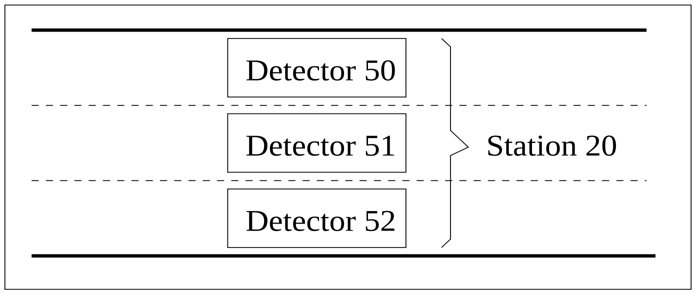
Traffic Data(Input)

- Detector Map in Station Level



Traffic Data(Input)

- Detector-station Relationship



- Basic Tables

Station Table

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

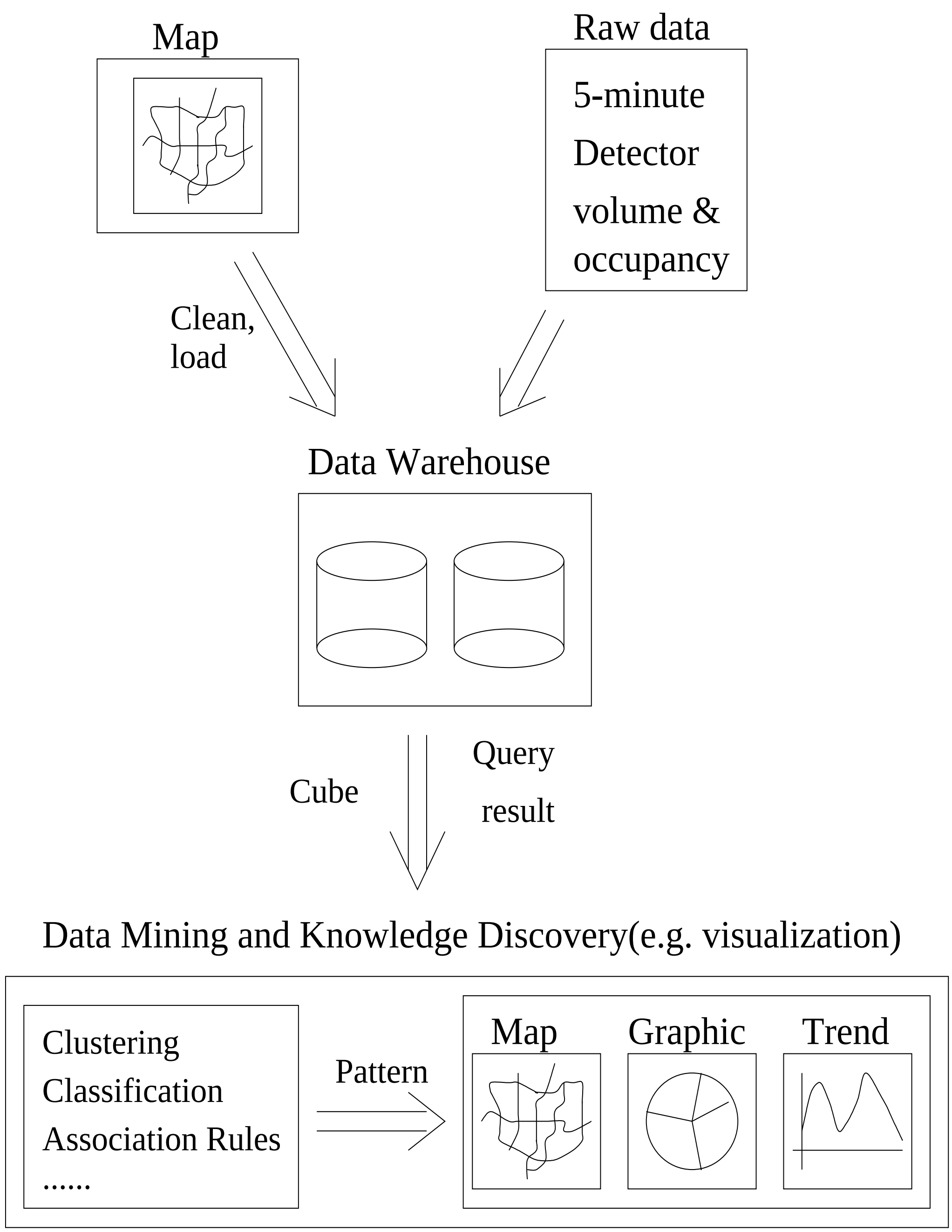
Detector Table

Detector	Station
1	1
2	1
....	

Value Table

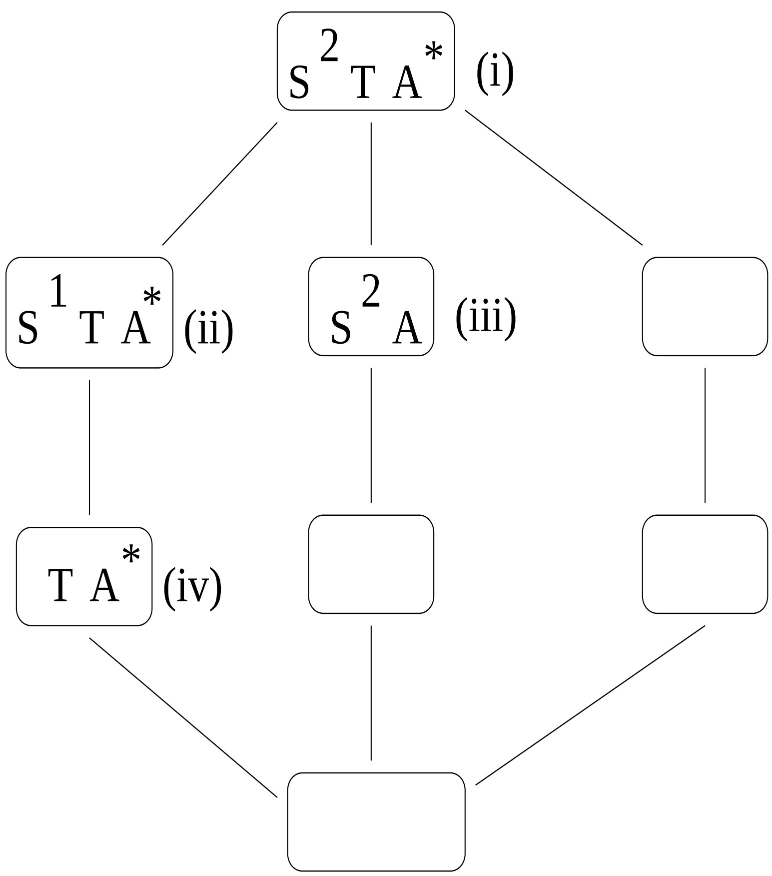
Time	Detector	Volume	Occupancy
1997 1 12 12:30	1	50	3
1997 1 12 12:50	2	60	12
....			

Data-flow and main modules in our system



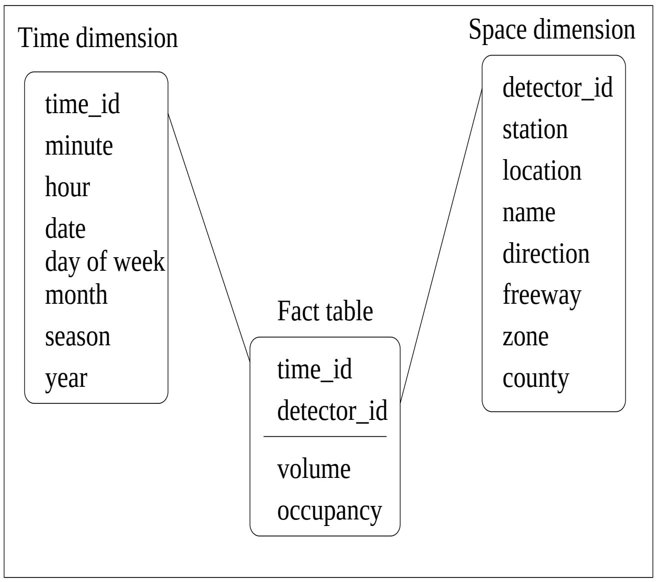
Dimension Lattice

- (i)Video
- (ii)Per-Freeway - Time map
- (iii)Freeway - Network map (fixed time)
- (iv)Attribute - Time plot (fixed space)

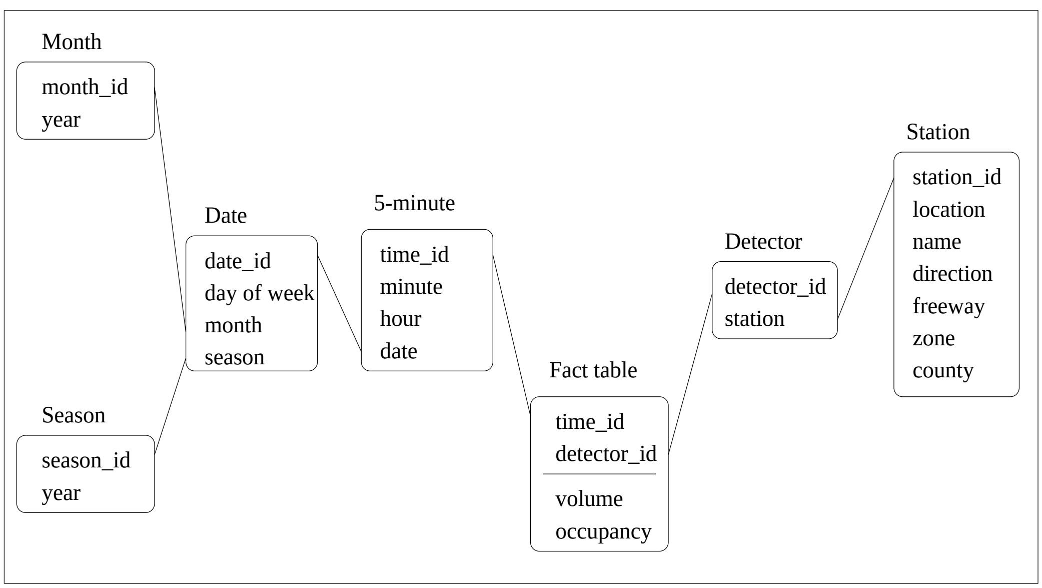


Design Schema

- A Star Schema



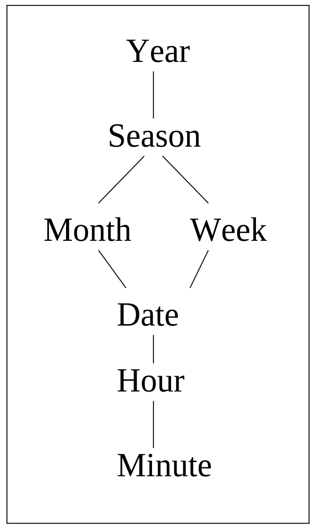
- A Snowflake Schema



Concept Hierarchies for Dimensions

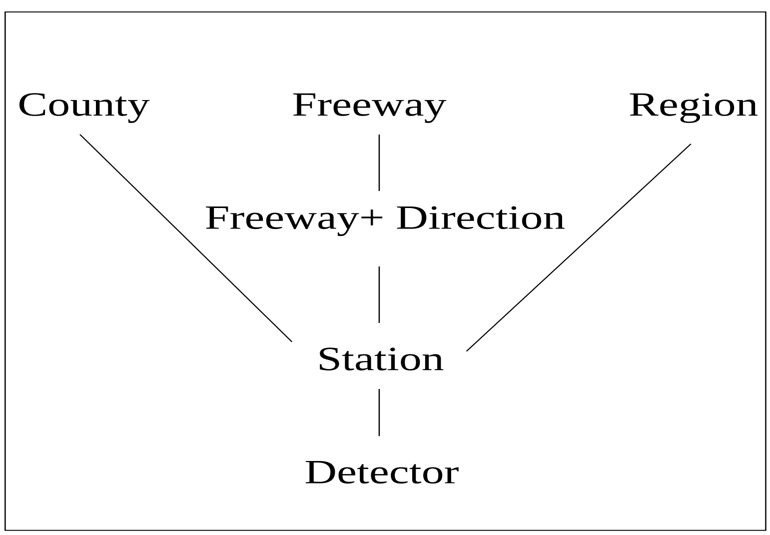
- Time dimension

Time dimensions



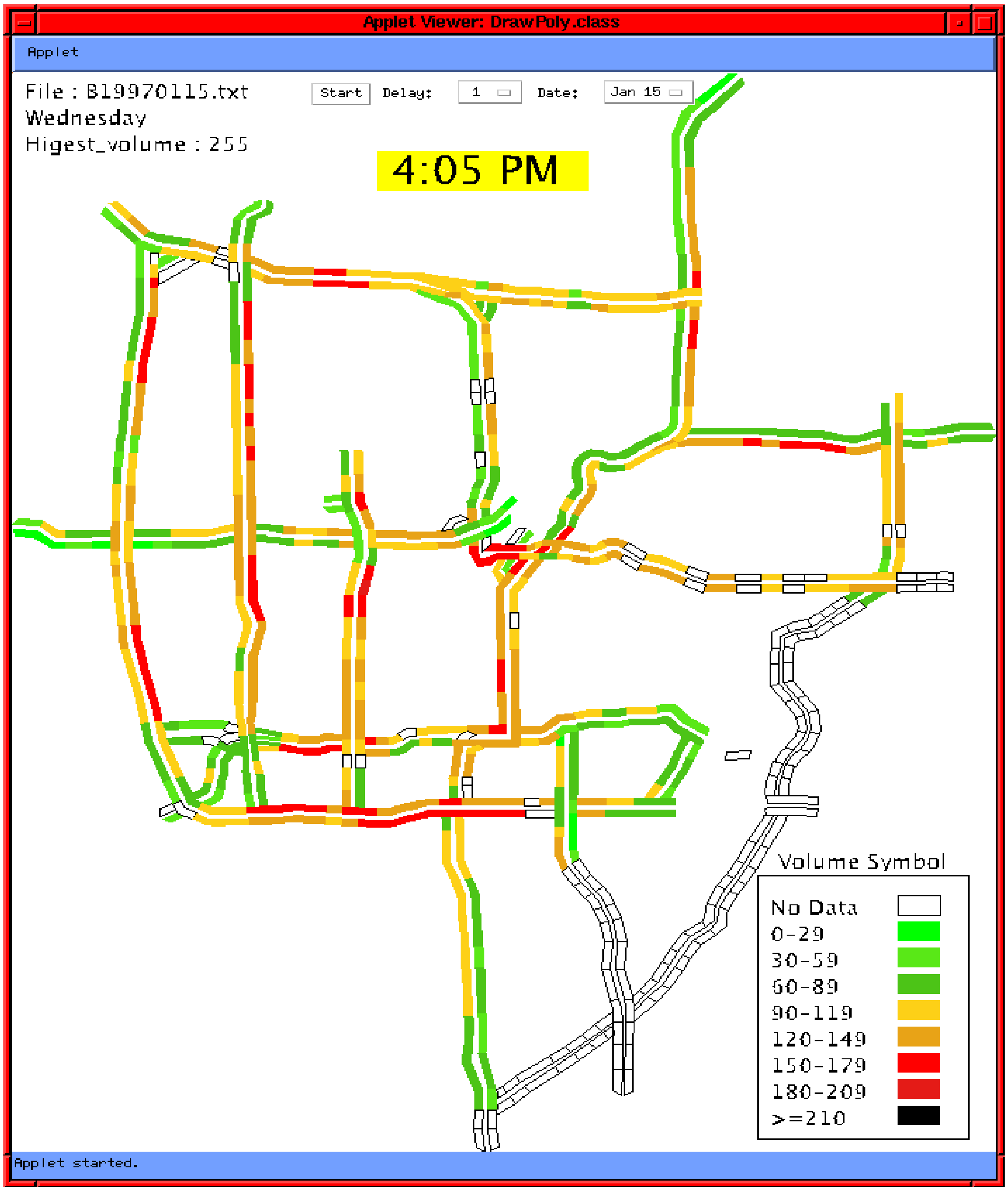
- Space dimension

Space dimension



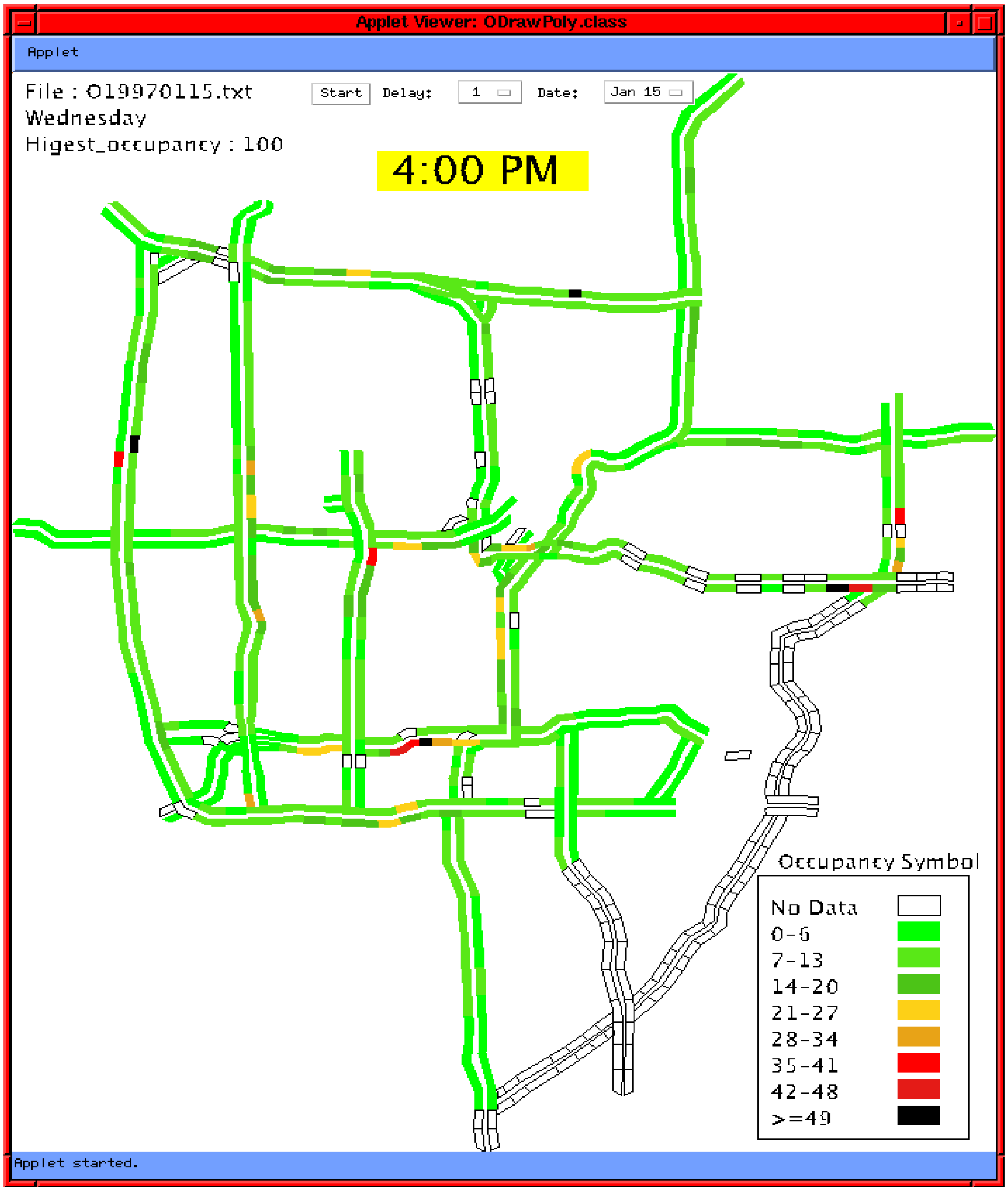
Visualization Example (0) Video Display

- Phenomenon of interest
  - *Average Volume*
  - *Date: 1997 January 15 Wednesday 16:05PM*



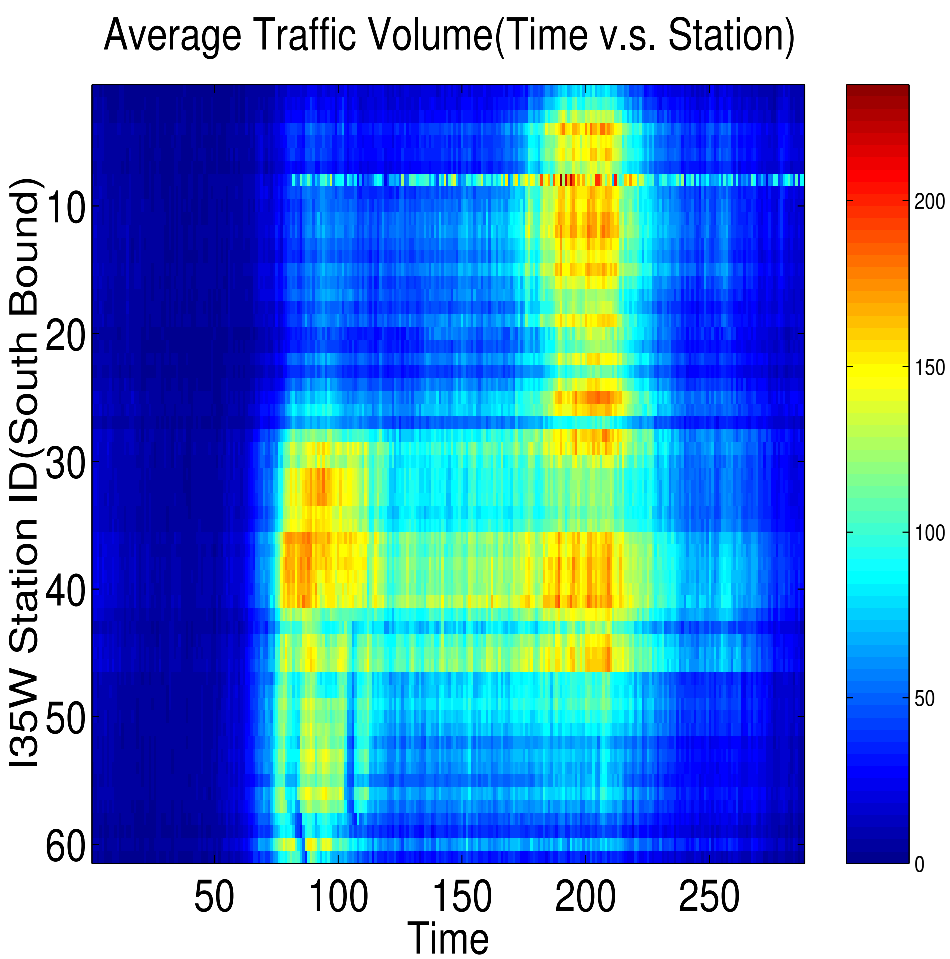
Visualization Example (0) Video Display

- Phenomenon of interest
  - *Average Occupancy*
  - *Date: 1997 January 15 Wednesday 16:00PM*



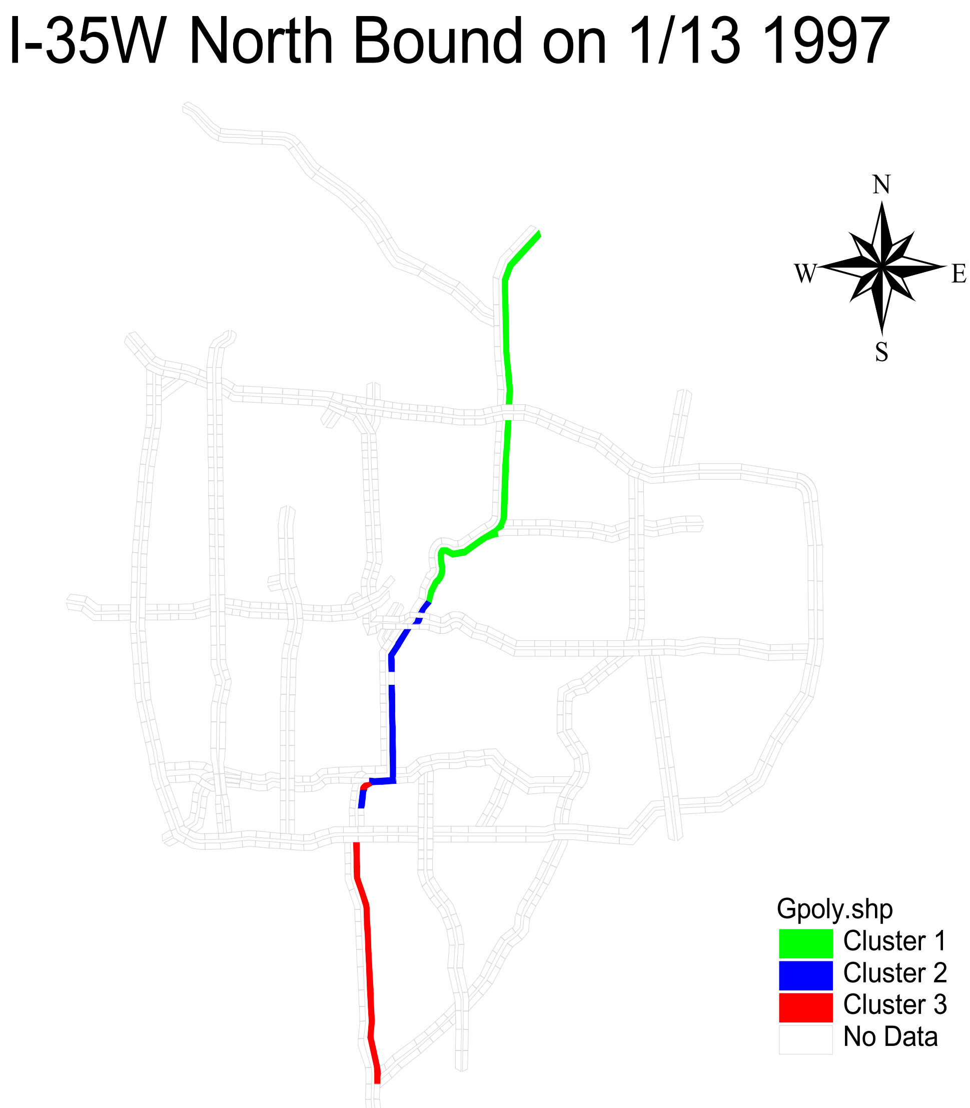
Visualization Example (I) I-35W North Bound)

- 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*



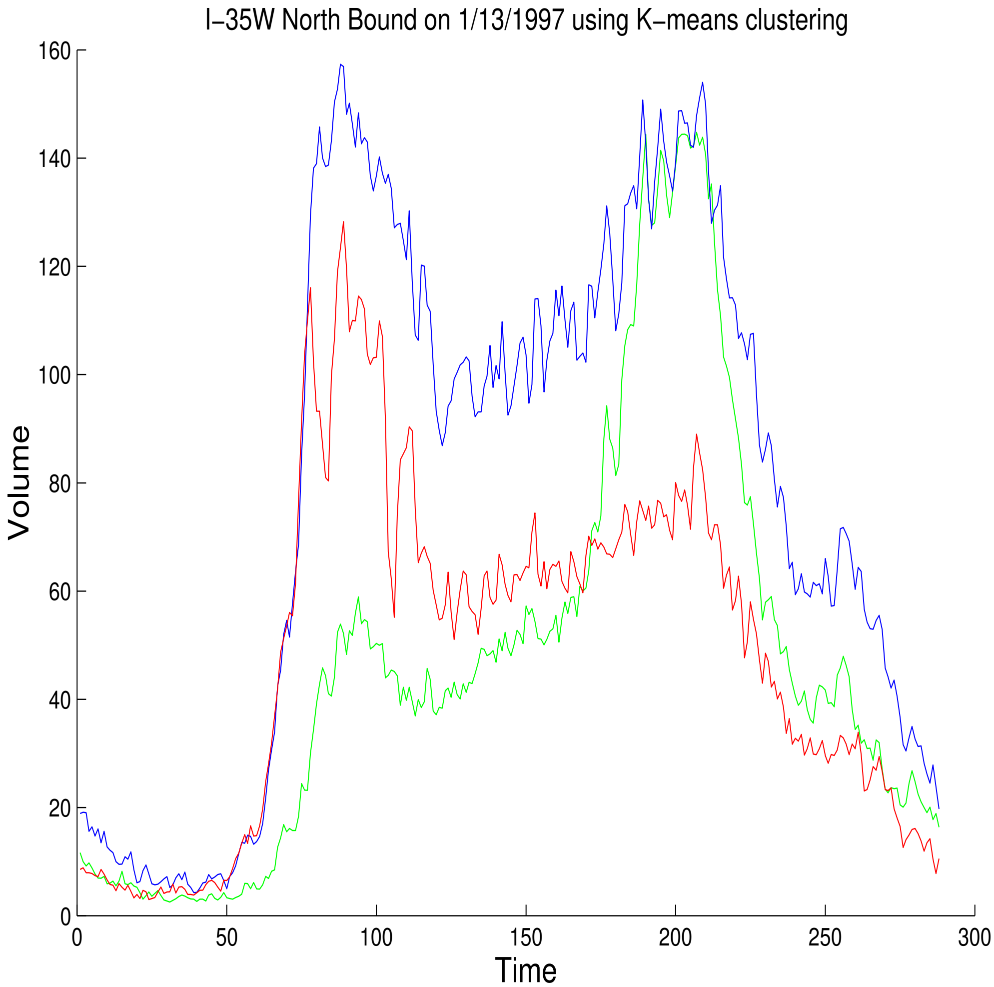
Visualization Example (I) I-35W North Bound)

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



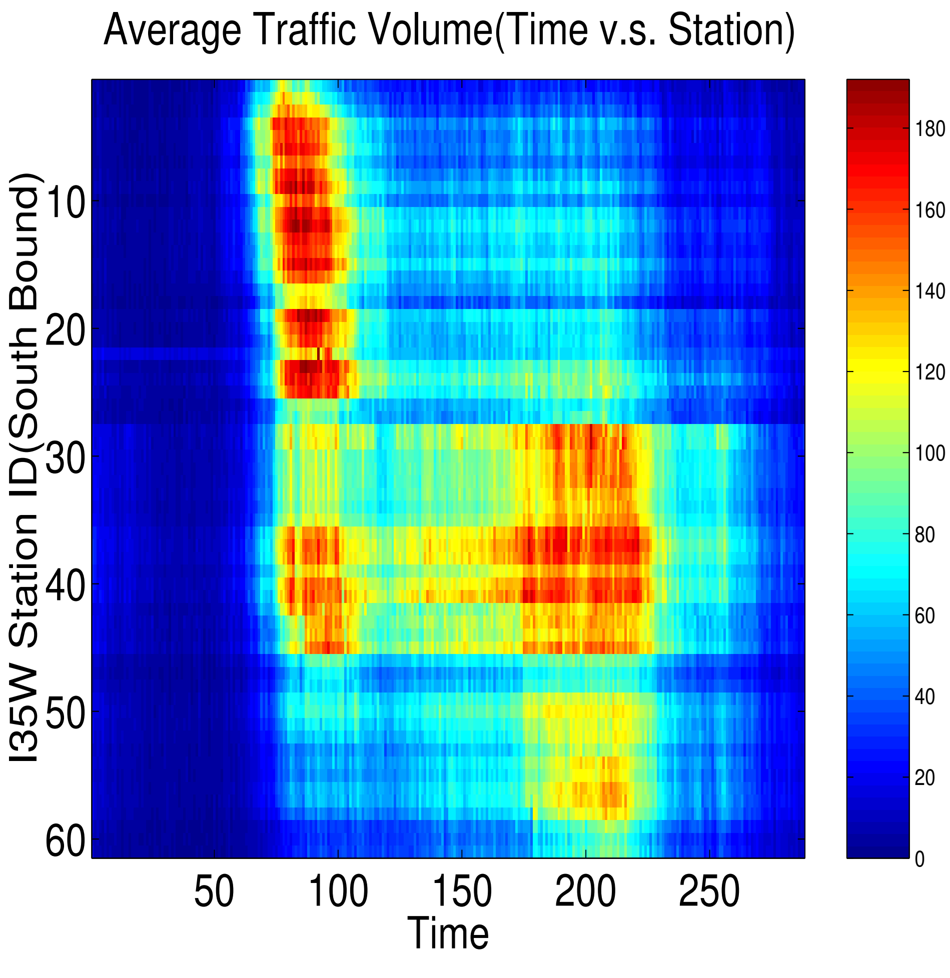
Visualization Example (I) I-35W North Bound)

- Attribute - Time map
- Average volume within each cluster

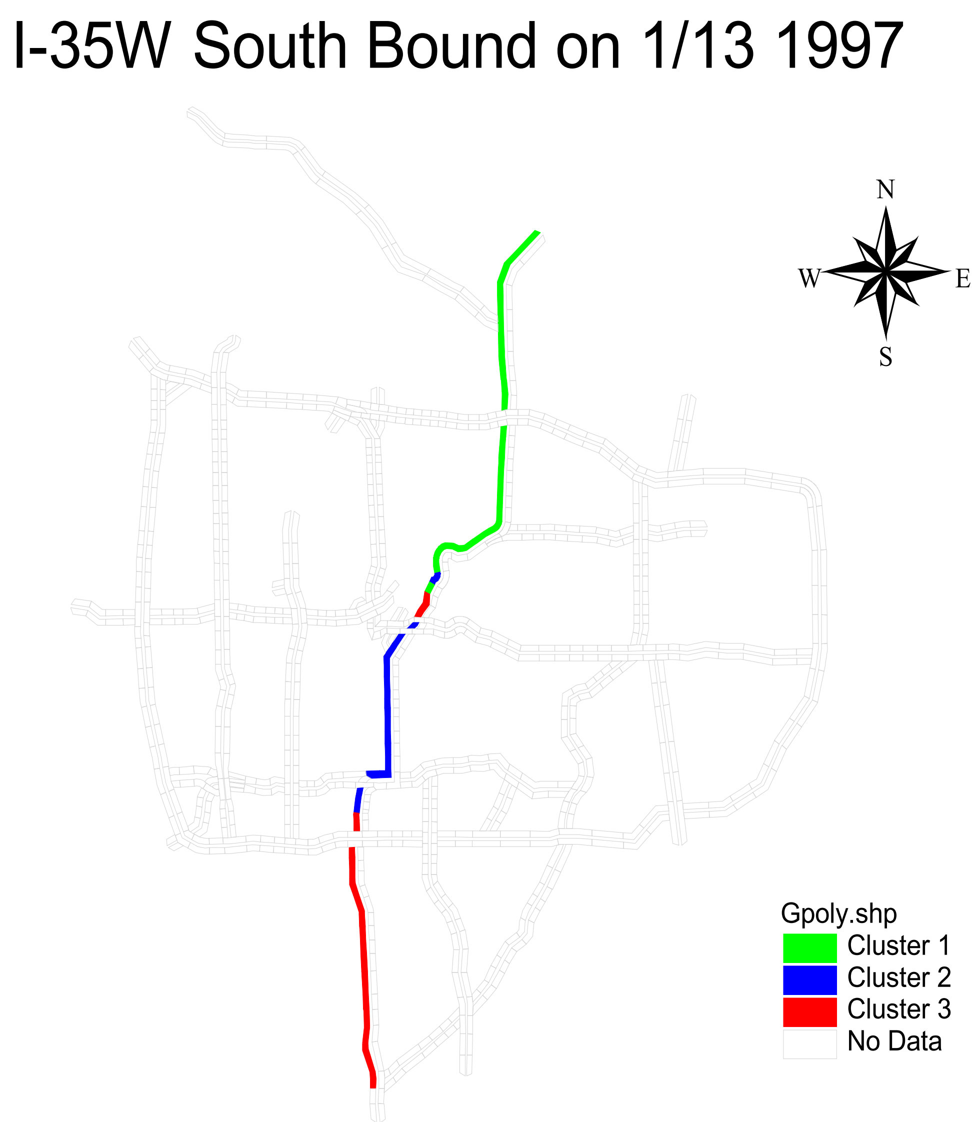


Visualization Example (II) I-35W South Bound)

- Phenomenon of interest for I-35W South Bound
  - *Clusters of similar stations*
- Per-freeway - Time map

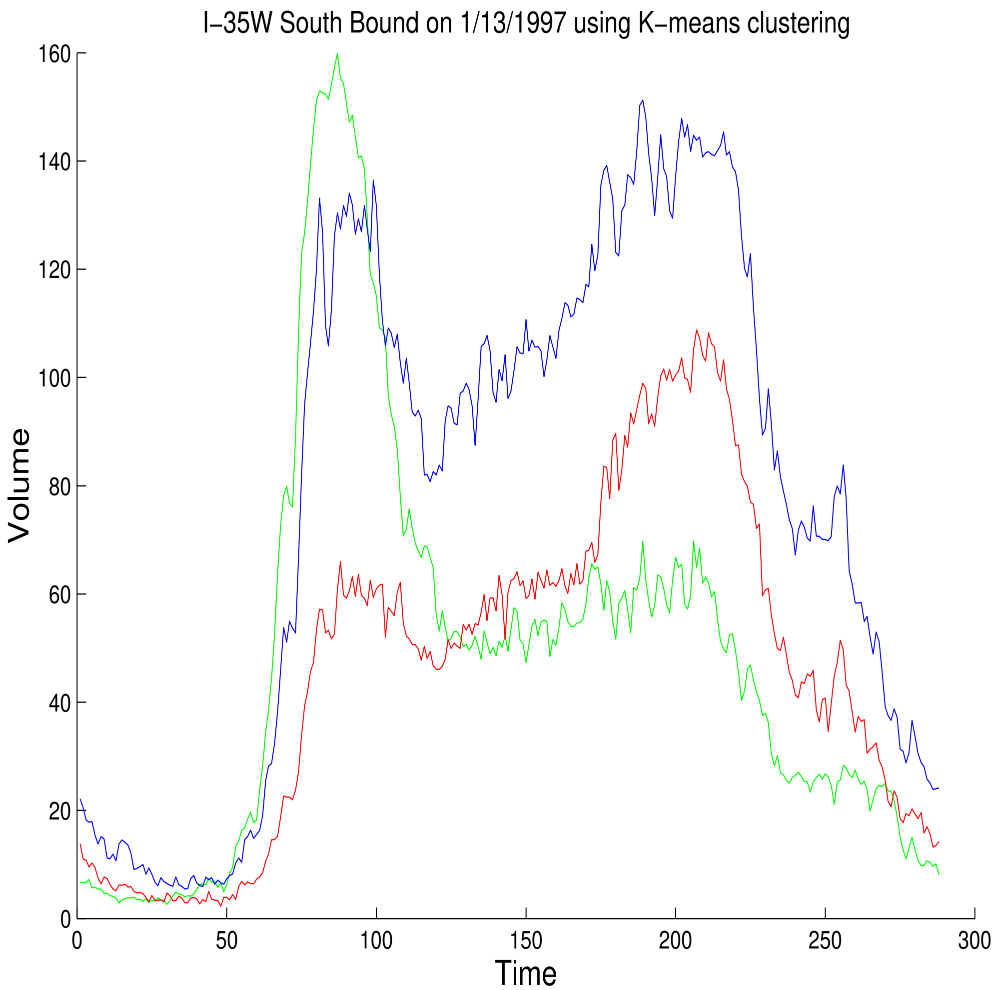


Visualization Example (II) I-35W South Bound)

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

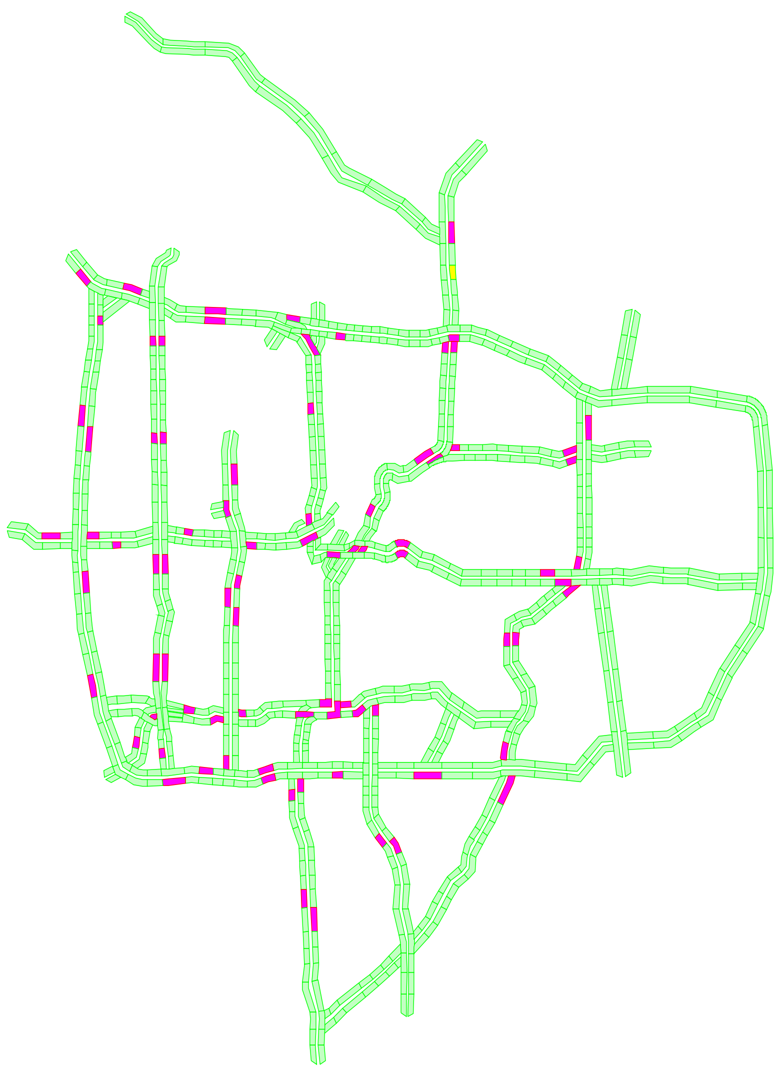
Visualization Examples (II) I-35W South Bound)

- Attribute - Time map



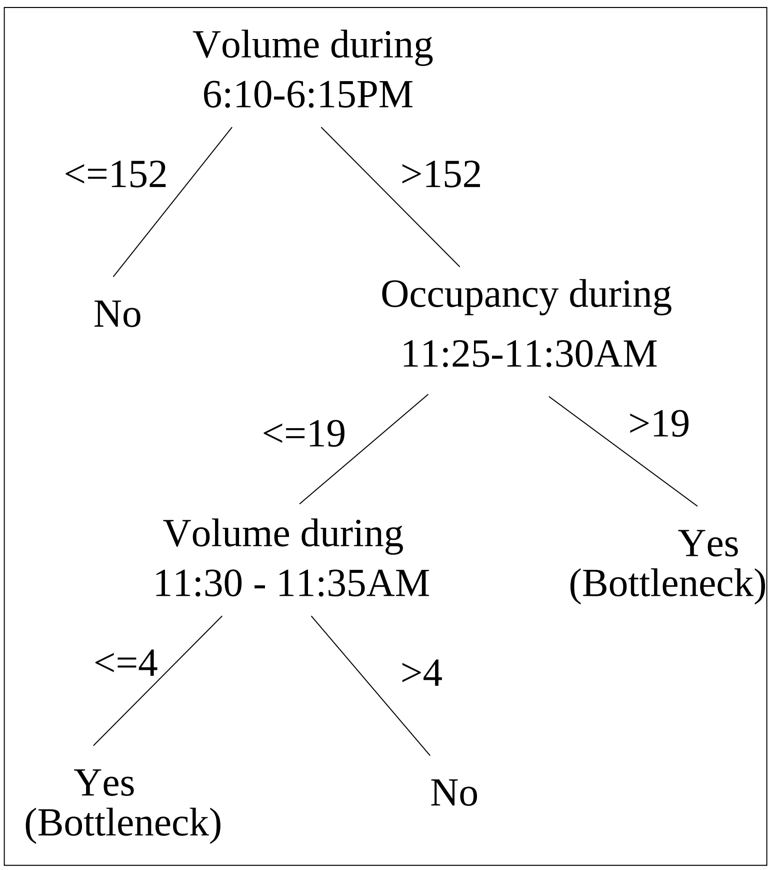
Visualization Example (III)

- Phenomenon of interest
  - *Bottlenecks in TMC data*
- Bottleneck Stations from MNDOT



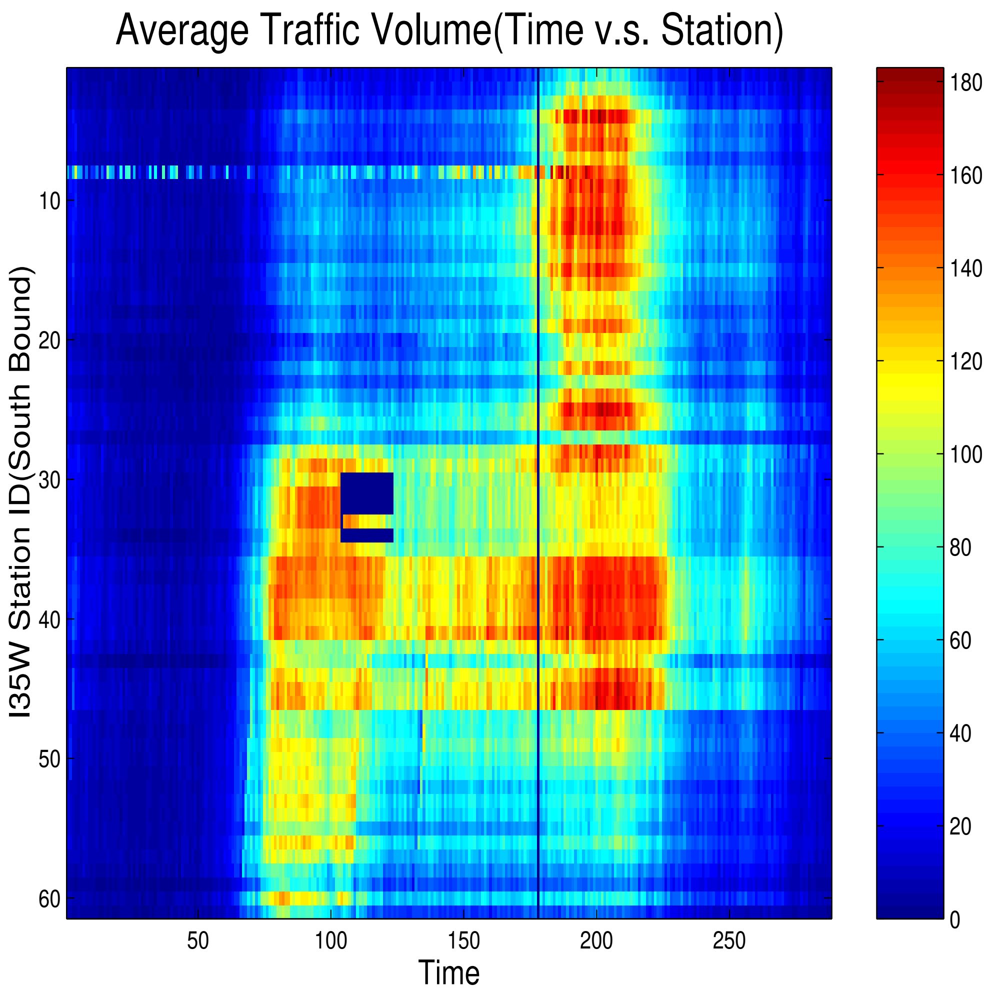
Visualization Example (III)

- Phenomenon of interest
  - *Bottlenecks in TMC data*
- Decision Tree



Visualization Example (IV)

- Phenomenon of interest
  - *Outliers/Exceptions detection*
  - *Data inconsistent with the reminder of data*
- I-35W North Bound



Visualization Example (IV)

- Phenomenon of interest
  - *Outliers/Exceptions detection*
  - *Data inconsistent with the reminder of data*
- I-35W South Bound