AITVS: Advanced Interactive Traffic Visualization System

http://spatial.nvc.cs.vt.edu/traffic/
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1 Introduction

Transportation and the highway network are the backbone or critical elements in the total public infrastructure system. As such, most serious examinations of an emergency response plan or activity will include the road transportation system as one of its most pivotal elements of consideration. However, demand for road travel continues to expand as population increases (particularly in the metropolitan areas) while new constructions have not kept pace. According to the Federal Highway Administration, it is forecasted that the volume of freight movement alone is to nearly double by 2020 [4]. Congestion and looming gridlock crises seriously threaten any region's mobility, safety and economic vitality. A crucial component in addressing these concerns is the development of specific technologies to monitor, model, and optimize traffic flow. We have developed the ***A***dvanced ***I***nteractive ***T***raffic ***V***isualization ***S***ystem (AITVS), a web based traffic visualization system, to help mitigate these very concerns by providing novel and comprehensive visualization components to analyze and monitor traffic conditions.

Existing transportation visualization system applications exhibit some useful but limited tools for in-depth exploration and study of traffic data. The visualization models offered by existing systems only provide tools that highlight *current* traffic condition (based on average speed, volume, and occupancy) with the exception of PORTAL which gives an added ability to perform some primitive historical graph plots. Hence, the current set of traffic visualization systems are only appropriate for use with travelers and commuters and do not provide the critical instruments for comprehensive study and research as necessitated by traffic engineers, policy makers, and researchers.

Portland Transportation Archive Listing (PORTAL) [1], Houston TranStar [2], and University of Washington Intelligent Transportation System (UW-ITS) [3] provide a small subset of the visualization components for both real-time and historical visual data modeling. Table 1 shows a summary of visualization features offered by the current intelligent transportation systems (ITS) and AITVS. PORTAL, Houston TranStar, and UW-ITS are able to achieve short user-response times that are on par with our AITVS (1-5 seconds for an average graph query), but does not provide the range of visualization modules as rendered by AITVS. Our AITVS mitigates the shortcomings of the existing systems by providing a rich set of the multidimensional visual components combined with quick user-response times to produce a comprehensive and high-performing traffic visualization system. It is through the combination of various database techniques and the delegation of some of the visual data processing to the application layer that we are able to achieve fast user-response times of 1-5 seconds for each graph query.

Table 1: ITS feature comparison

ITS	Visualization Features
PORTAL	http://portal.its.pdx.edu/ Volume x Time plot, Speed x Time plot, Occupancy x Time plot, Vehicle miles, Travel times, Delay times, road maps with statistical overlay
Houston TranStar	http://traffic.houstontranstar.org Speed x Time plot, road maps with statistical overlay
UW-ITS	http://www.its.washington.edu Road maps with statistical overlay
AITVS	http://spatial.nvc.cs.vt.edu/traffic Volume x Time plot, Speed x Time plot, Occupancy x Time plot, Volume x Date plot, Speed x Date plot, Occupancy x Date plot, Volume x Station plot, Speed x Station plot, Occupancy x Station plot, Date x Day of Week plot, Station x Date plot, Station x Day of Week plot, Time x Day of week plot, Malfunction detectors, Prediction plots, extended range historical plots, roadmap with selectable station nodes

2 AITVS – Advance Interactive Traffic Visualization System

In general, the subjects of analysis in a multidimensional data model are a set of numeric measures. Each of the numeric measures is determined by a set of dimensions. In a traffic data, for example, the measures are speed, volume, and occupancy, with time and space being its dimensions. Dimensions are hierarchical by nature. For example, the time dimensions can be grouped into ‘Week’, ‘Month’, ‘Season’, or ‘Year’, which form a lattice structure indicating a partial order on the dimensions. Similarly, the space dimensions can be grouped into ‘Station’, ‘County’, ‘Freeway’, or ‘Region’. Given the dimensions and hierarchy, the measures can be aggregated into different combinations. For example, for a particular highway and a chosen month, the weekly traffic volumes can be analyzed. The concept of data cube is the engine behind AITVS. A data cube is used to generate the union of a set of alphanumeric summary tables corresponding to a given hierarchy. Based on this concept, AITVS organizes the album of generated visualization using a given hierarchy to support browsing via roll-up, drill-down, and other operations on aggregation hierarchy.

The AITVS was developed as the work of Virginia Tech’s Spatial Data Management Group. AITVS is a multiple view system, which has been defined as a system that uses two or more distinct views to support the investigation of a single conceptual entity. Multiple views can provide utility in terms of minimizing some of the cognitive overhead engendered by a single, complex view of data. The system presents information in various formats to observe and analyze traffic trends. In the underlying data structure, the spatial information has been modeled as a spatial data warehouse to facilitate the use of a query engine for the on-line analytical processing used in the visualization component. AITVS updates its traffic data once every minute upon receiving real-time data from the loop detectors, but can be adjusted to aggregates of any specified time value. Currently, it is set to update on a 5 minute interval.

AITVS architecture follows a three-tier structure. It integrates the visualization engine, the web server, and the database server. The three components together provide a web-based visualization system. The data cube engine is developed with Java and runs under any J2EE compatible web server. AITVS generates on-the-fly JPEG images and HTML in order to furnish the web interface. We have developed a dedicated service running at the backend to process real-time raw traffic data and to store the data into the database. The overall user response time of the system is from one to five seconds. Historic data is stored in the databases and can be accessed by the users at any time. The simple web-based interface provides users with easy access to the system.

The AITVS provides seven distinct visualization components that comprehensively cover the various performance metrics of a roadway system. The visualizations are as follows: Time Plot, Date Plot, Highway Station Plot, Highway Stations vs. Time Plot, Highway Stations vs. Day of the Week Plot, and Time vs. Day of Week Plot. Section 3 illustrates the details of each of visualization components.

3 Demonstration

We will demonstrate seven sets of visualization modules as described above. Table 2 provides a summary and some jpeg figures generated by AITVS for each visualization component.

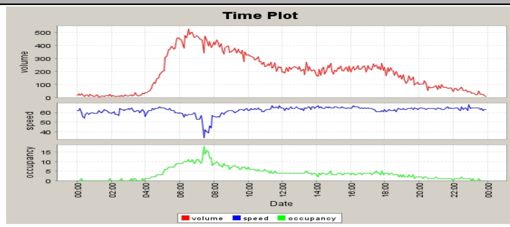
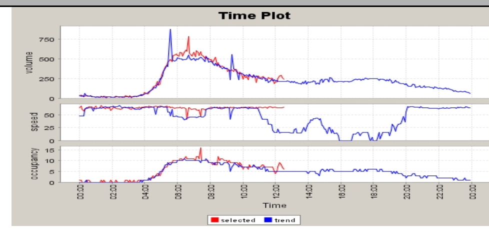
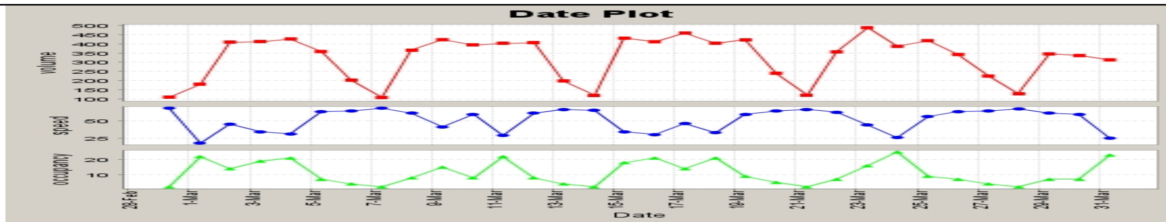
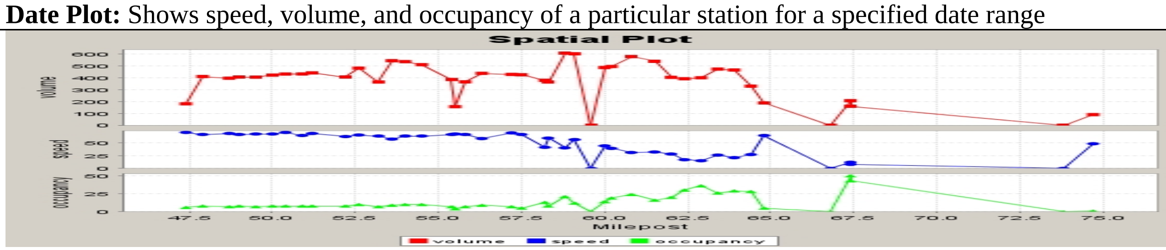
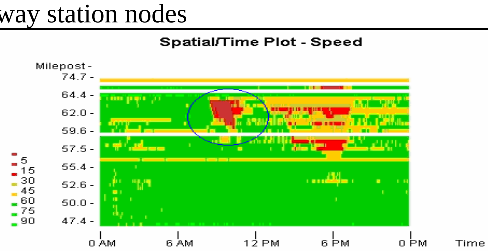
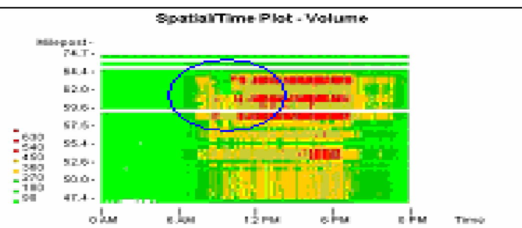
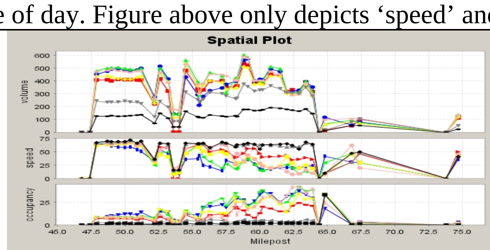
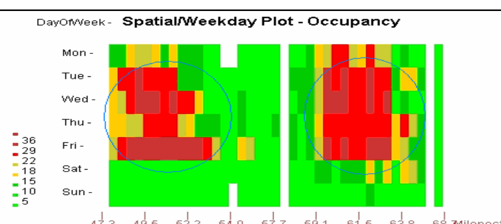
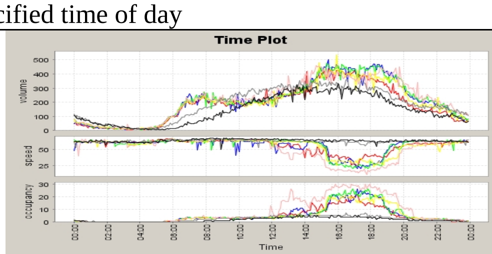
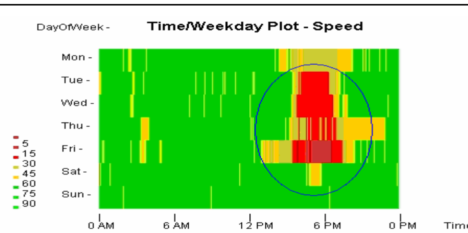
3.1 Time Plot (current and predicted traffic behaviors)

Row A corresponds to the **Time of Date**. In Figure A(i), the X-axis represents the time intervals, 00:00 to 24:00, and the Y-axis shows volume, speed, and occupancy respectively from top to bottom. The graph plot represents the eastbound traffic on Tuesday Nov 2nd, 2004 on station 121 where Interstate-66 crosses route 28 at milepost 53.2. This graph shows a strong morning rushing hour pattern between 5AM to 11AM; where volume is greater than 300 vehicles every five minutes and speed is lower than average. The user adjustable attributes are the highway station nodes and the range of date. Figure A(ii) shows identical value types for its XY-axes as Figure A(i) but exemplifies not only the current traffic trend (red), but also provides the predicted traffic behavior (blue) for Wednesday Jun 29th, 2005. AITVS calculates the prediction model based on a user-specified time length (e.g. 4,5,6.. weeks) data input and invokes statistical methods to extrapolate the predicted behavior. For Figure A(ii), the user is able to select their choice of highway station node, the exact date to plot, and the span of historical data used for the prediction.

3.2 Date Plot

Row B corresponds to the **Date of Week/Month**. The X-axis represents days and the Y-axis shows volume, speed, and occupancy respectively from top to bottom. The figure shows the I-66 eastbound traffic at 8:30AM for each day of March 2004 on station 121 where I-66 crosses route 28 at milepost 53.2. This plot shows a strong weekly pattern that the traffic volume of Saturday and Sunday is extremely lower than the one of Monday to Friday. It is also noticed that as volume and occupancy decreases, speed increases which reflects another traffic behavior pattern. For this

Table 2: AITVS visualization components

Row	Figure and description
A	 **A(i)**  **A(ii)** **Time Plot:** Shows speed, volume, and occupancy of a particular station for a specified period of time of day
B	 **Date Plot:** Shows speed, volume, and occupancy of a particular station for a specified date range
C	 **Highway Station Plot:** Shows speed, volume, and occupancy of a particular station for a specified set of highway station nodes
D	 **D(i)**  **D(ii)** **Highway stations vs. Time Plot:** Shows speed, volume, and occupancy of a set of station nodes for a specified time of day. Figure above only depicts 'speed' and 'volume'.
E	 **E(i)**  **E(ii)** **Highway Stations vs. Day of Week Plot**: Shows speed, volume, and occupancy of a set of station nodes for a specified time of day
F	 **F(i)**  **F(ii)** **Time of Day vs. Day of Week Plot**: Shows speed, volume, and occupancy of all days in the week for each time of day

visualization component, the highway station node, date duration, and time can be dynamically selected by the user.

3.3 Highway Station Plot

Row C corresponds to the **Highway Stations**. In this figure, the X-axis shows the consecutive mileposts within the route and the Y-axis denotes the volume, speed, and occupancy respectively. The graph represents the I-66 eastbound traffic at 8:30AM on Tuesday Oct 26th, 2004. Between milepost 58 and 59, the occupancy is relatively higher and speed is lower than average. The stations at milepost around 60 and after milepost 65 were malfunctioning with zero volume, speed and occupancy. The user-adjustable criterions for this component are date, time, highway, and traffic direction (i.e., east or west bound).

3.4 Highway Stations vs. Time Plot

Row D corresponds to the **Highway stations vs. Time of Date**. In Figure D(i), the X-axis denotes the time, the Y-axis shows the milepost, and the colors represent the speed values (e.g., red=5mph and green=60mph). Each row of the graph corresponds to the traffic speed of one station on the selected date. This figure depicts the I-66 eastbound traffic on Saturday Nov 6th, 2004. Notice that in the morning during 9:30AM to 10:15AM traffic congestion occurred for a span of 45 minutes, an unusual event for the regular commuters. We recognize a distinct incident pattern, an upside-down triangle. Figure D(ii) shows the volume for the same traffic data and we observe that the volume corresponding to the triangle in Figure D(i) is abnormally low. This thusly supports the presence of a traffic incidence. The user adjustable properties for this component are date, highway and traffic direction.

3.5 Highway Stations vs. Day of Week Plot

Row E corresponds to the **Highway Stations vs. Date of week**. In Figure E(i), the X-axis depicts the mileposts along the route and the Y-axis shows volume, speed, and occupancy respectively. The graph represents a series plot of all days of a week for Feb 2005 at 6PM where each line represents each average day of the week. From this superimposed plot, we observe that weekdays show strong traffic activity as compared to the weekends. Figure E(ii) shows the same traffic data, but represented as a variant model. The X-axis shows the milepost, Y-axis denotes the days of the week, and the colors as occupancy values. Figure E(ii) provides a much clearer representation of the traffic trend as compared to Figure E(i) since it is much easier to delineate the change in traffic metric value through the change of colors. Depending on the subject of analysis, the series (Figure E(i)) plot may find more utility than the XY-plot (Figure E(ii)). AITVS offers these various modes of visualizations to accommodate for different analysis requirements. For both visualization components, the date range, time, highway, and traffic direction are user-adjustable.

3.6 Time of Day vs. Day of Week Plot

Row F corresponds to the **Time of Day vs. Day of Week Plot**. In Figure F(i), the X-axis indicates the time and the Y-axis shows volume, speed, and occupancy respectively. This graph amalgamates values for each day of the week for Feb 2005. Again, here we see strong afternoon (4-6PM) rush hour commute during the weekdays as indicated by the large hump and valleys on the series graph. Figure F(ii) depicts the identical traffic data, with the X-axis as time, Y-axis as the days of the week, and the colors as speed values. Here, the red region at around 4-6PM indicates afternoon rush hour which corresponds to the humps mentioned above in Figure F(i). The graph also indicates that on Friday, afternoon rush hour begins early, at 2PM. For both visualization components, users may select the highway station node and date range.

4 Discussion

The concepts of visualization have proven to be highly useful for identifying patterns in large spatial data sets. AITVS is an attempt to develop these techniques and apply them to analyze traffic data. These interactive visualization techniques make the knowledge discovery process much less burdensome, and thus facilitate the usage of the transportation data. In addition to visualization, data mining techniques can be employed for data analysis and filtration. One such technique is the identification of outliers, which plays an important role in automatically recognizing abnormal situations and emergency congestions. The prototype developed for the AITVS system now provides an analysis in 2D, an effort is currently underway to develop 3D representation. Future adaptations of this work will address issues in supporting adaptive user interfaces based on users' expertise and requirements.

5 References

[1] Bertini, R.L., Byrd, A. and Yin, T. *Implementing the ITS Archived Data User Service in Portland, Oregon.* in *Proceedings of the IEEE 7th Annual Conference on Intelligent Transportation Systems* , Washington , D.C., 2004 http://portal.its.pdx.edu/

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[4] U.S. Department of Transportation: Federal Highway Administration, *Congestion Mitigation*. 2005. http://www.fhwa.dot.gov/