Towards an Advanced Spatial-Temporal Visualization System for the Metropolitan Washington D.C.

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Abstract - This paper delves on a suite of visualization approaches for exploring real-time and historical loop-detector data in the Washington Metropolitan D.C. region. To that endeavor, we have developed an effective web-based visualization system, the Advanced Interactive Traffic Visualization System (AITVS). The AITVS provides capabilities to browse the spatiotemporal dimensions hierarchy via roll-up and drill-down operations. It supports data visualization in a standard web-based environment where users can conveniently access the system via the Internet, thus facilitating the utilization of transportation information.

INTRODUCTION

The transportation network is a critical asset that affects any region's safety, economy, and natural environment. Therefore, it is paramount that a maintenance strategy for the transportation network includes real-time highway monitoring to survey the traffic flow of a highway network, detect emergent events, and analyze traffic patterns. Virginia Tech's Spatial Data Management Lab has developed the ***A***dvanced ***I***nteractive ***T***raffic ***V***isualization ***S***ystem (AITVS) that provides *real-time* highway monitoring capabilities via a suite of novel and comprehensive analytical visualization components.

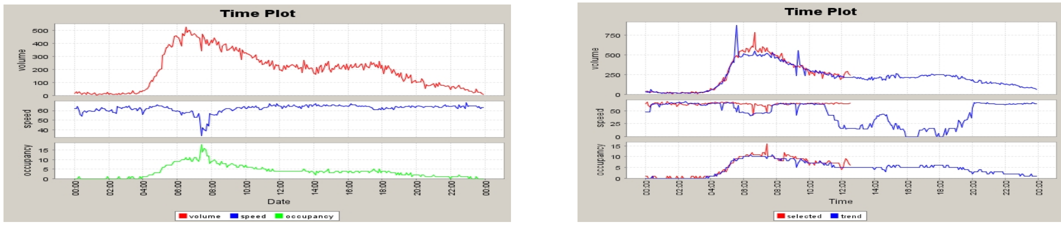
AITVS is a web-based multiple view application, which is defined as a system that uses two or more distinct views to support the investigation of a single conceptual entity. Multiple views can provide utility in terms of minimizing some of the cognitive overhead engendered by a single, complex view of data. The system presents information in various formats to observe and analyze traffic trends. In the underlying data structure, the traffic information has been modeled as a spatial data warehouse to facilitate the use of a query engine for on-line analytical processing and visualizations. A caching engine is employed on top of the database to reduce user response times required for real-time monitoring.

The AITVS provides six 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.

AITVS VISUALIZATION

Time Plot (current and predicted traffic behaviors)

In Figure 1, 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 I-66 eastbound traffic on Tuesday Nov 2nd, 2004 on station 121 where I-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 date duration. Figure 1(b) shows identical value types for its XY-axes as Figure 1(a) 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) and invokes statistical methods to extrapolate the predicted behavior. For Figure 1(b), the user is able to select their choice of highway station node and the span of historical data used for the prediction



(a) **(b)**

Figure 1. Shows speed, volume, and occupancy of a particular station for a specified period of time of day

Date Plot

Figure 2 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 visualization component, the highway station node, date duration, and time can be dynamically selected by the user.

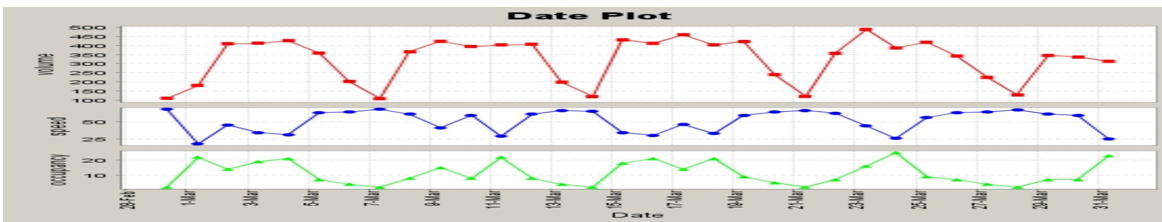


Figure 2. Shows speed, volume, and occupancy of a particular station for a specified date range

Highway Station Plot

Figure 3 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).

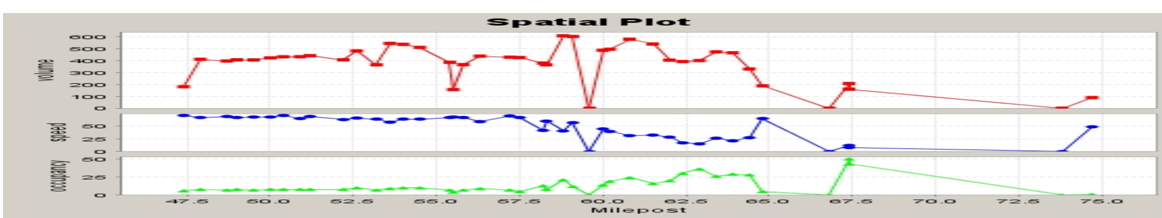
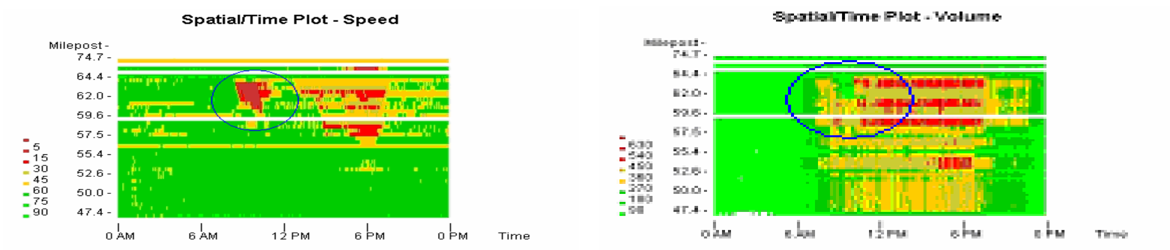


Figure 3. Shows speed, volume, and occupancy of a particular station for a specified set of highway station nodes

Highway Stations vs. Time Plot

Figure 4 corresponds to the **Highway stations vs. Time of Date**. In Figure 4(a), 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 4(b) shows the volume for the same traffic data and we observe that the volume corresponding to the triangle in Figure 4(a) 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.

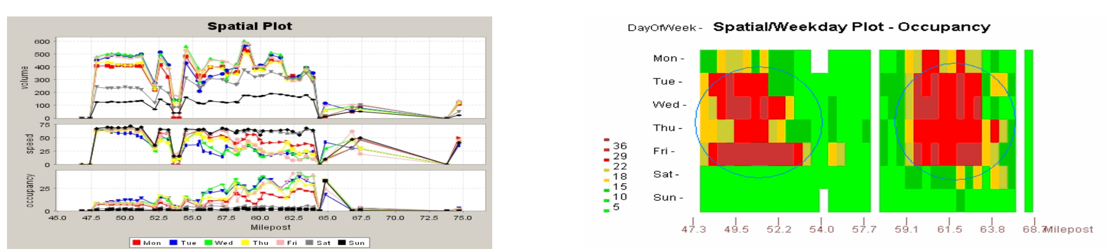


(a) **(b)**

Figure 4. Shows speed, volume, and occupancy of a set of station nodes for a specified time of day. Figure above only depicts 'speed' and 'volume'.

Highway Stations vs. Day of Week Plot

Figure 5 corresponds to the **Highway Stations vs. Date of week**. In Figure 5(a), 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 5(b) 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 represent occupancy values. Figure 5(b) provides a much clearer representation of the traffic trend as compared to Figure 5(a) 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 5(a)) plot may find more utility than the XY-plot (Figure 5(b)). 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.

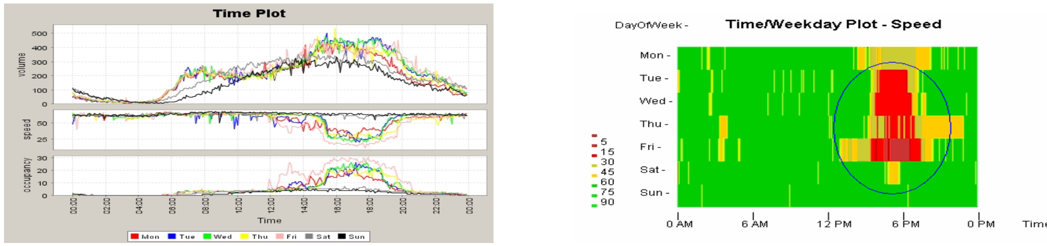


(a) **(b)**

Figure 5. Shows speed, volume, and occupancy of a set of station nodes for a specified time of day

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 for an average Friday on Feb 2005, afternoon rush hour begins early at 2PM. For both visualization components, users may select the highway station node and aggregate date range.



(a) **(b)**

Figure 6. Shows speed, volume, and occupancy of all days in the week for each time of day

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. 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.