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

Chang-Tien Lu, *Virginia Tech, VA, USA*
Arnold P. Boedihardjo, *Virginia Tech, VA, USA*
Jinping Zheng, *Virginia Tech, VA, USA*

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.

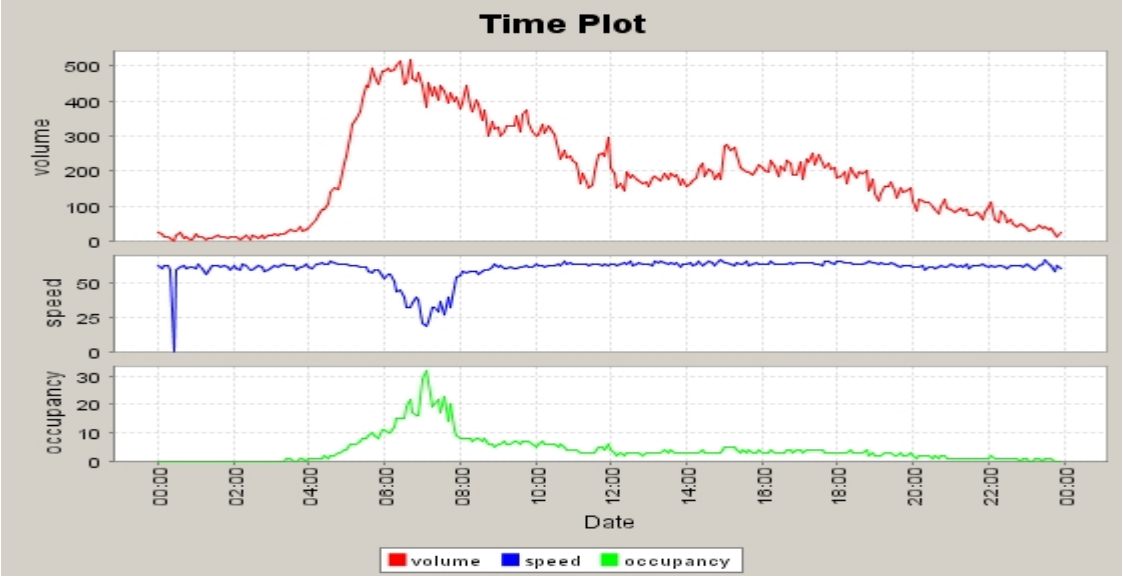
AITVS is a web-based multiple view application, which is defined as a system that uses two or more distinct views to support the investigation of a single conceptual entity. Multiple views can provide utility in terms of minimizing some of the cognitive overhead engendered by a single, complex view of 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. The following section illustrates the details of each of visualization components.

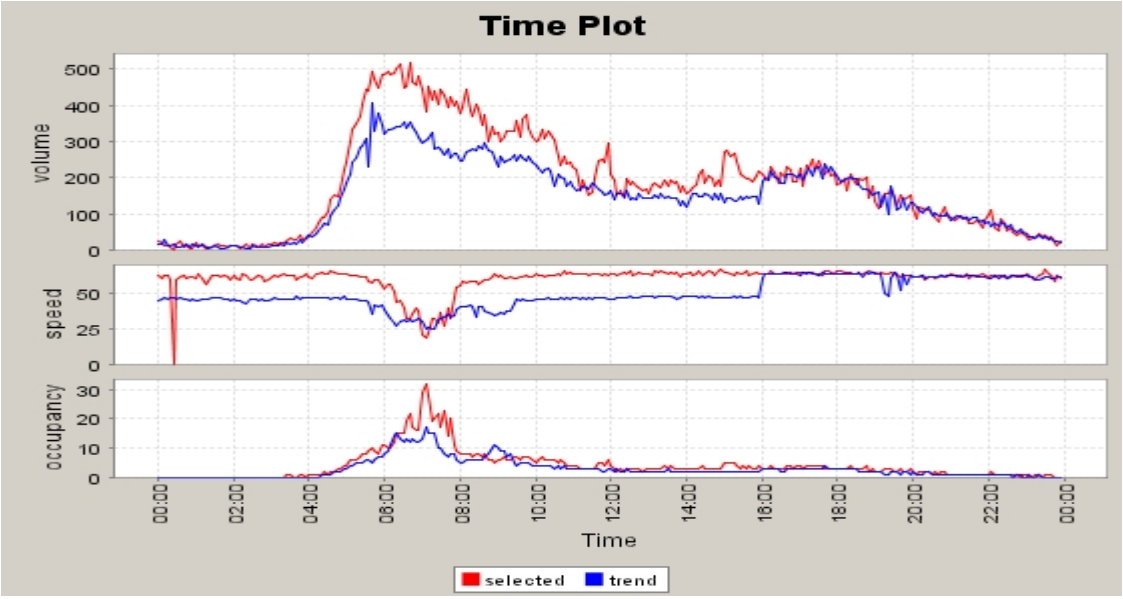
AITVS VISUALIZATION

Time Plot (current and predicted traffic behaviors)

In Figure 1, the X-axis represents the time of day, 00:00 to 24:00, and the Y-axis shows the traffic volume, speed, and occupancy. The graph plot represents the I-66 eastbound traffic on 9/19/2006 on station 121. This graph shows the morning rushing hour pattern between 6AM to 10AM, where volume is greater than 300 vehicles every five minutes and speed is below 30 mph (I66 speed limit is 55 mph). Figure 1(b) shows the same traffic (in red) and provides traffic trend as average of the past 4 weeks (in blue).



(a) Observed traffic condition at station 121 on 9/19/2006.



(b) Observed traffic (red) and trends (blue) at station 121 on 9/19/2006.

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

Date Plot

Figure 2 shows the I-66 eastbound traffic at 8:30AM for each day of January 2006 at station 271. From this plot we can observe the higher flow traffic pattern on the weekdays as compared to the weekends. Other patterns that are observable are the positive correlation between volume and occupancy and their negative correlation to speed.

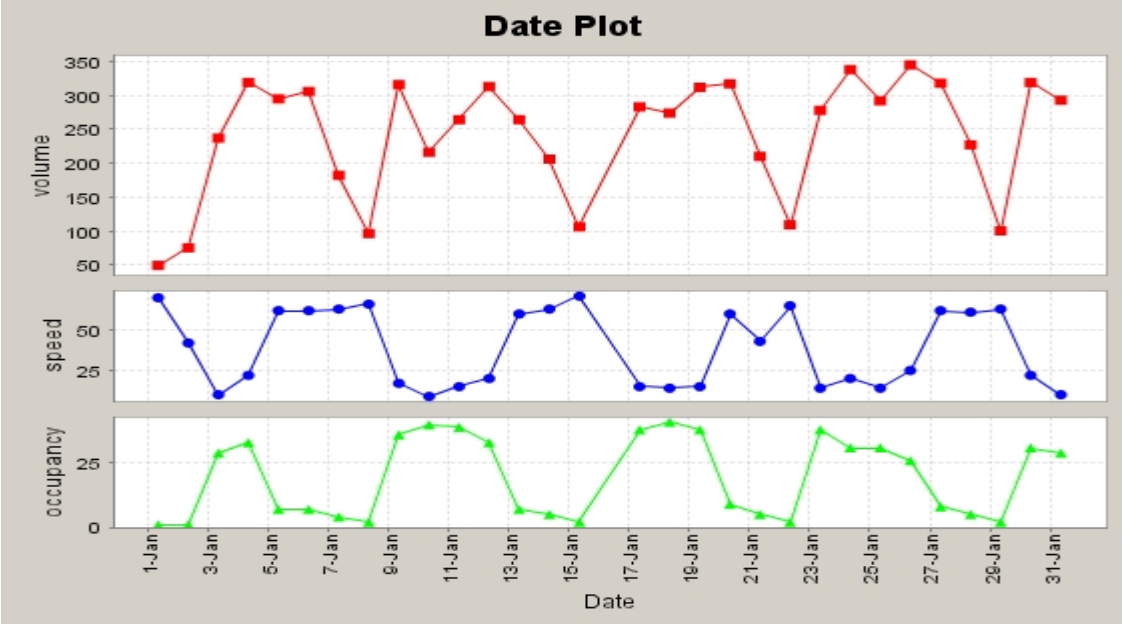


Figure 2. Shows speed, volume, and occupancy of station 271 from 1/1/2006 – 1/31/2006.

Highway Station Plot

Figure 3 corresponds to all highway stations on I66 east bound. The X-axis denotes all mileposts. This figure shows the traffic at 8:30AM on 10/16/2006. Using this graph we can observe the traffic characteristics of a specific region of the highway and compare its behavior against its neighbors. In a similar token, we can get a glimpse of the overall performance of the entire highway. The zero-valued stations denote malfunctioning station detectors. These values can be filtered by the AITVS to only show the functioning stations.

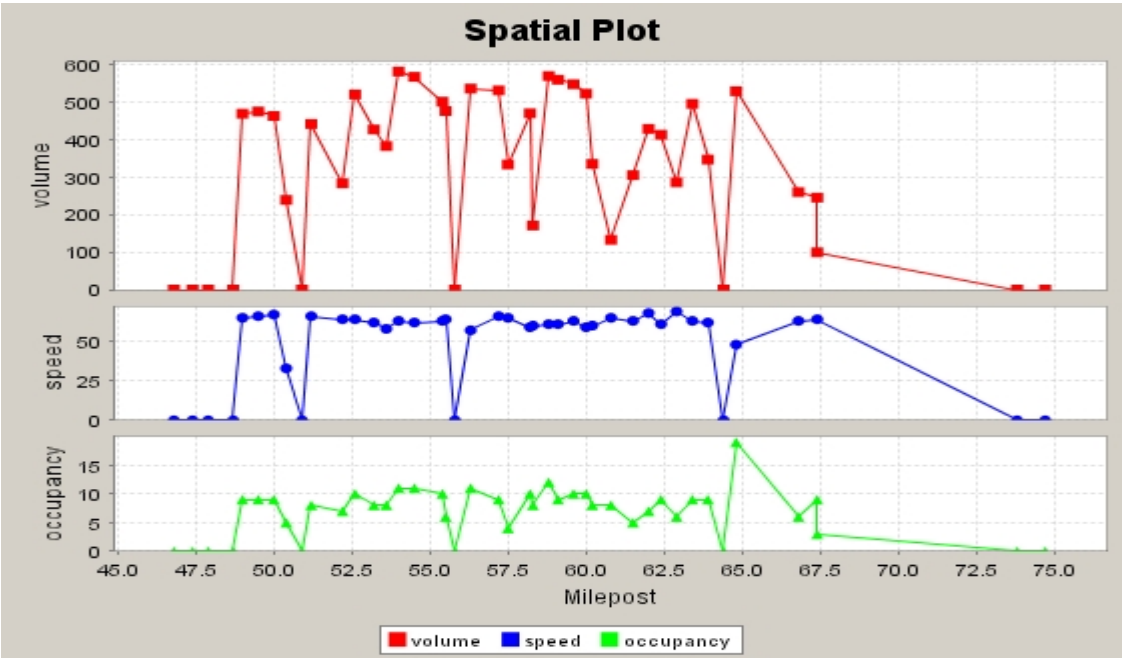
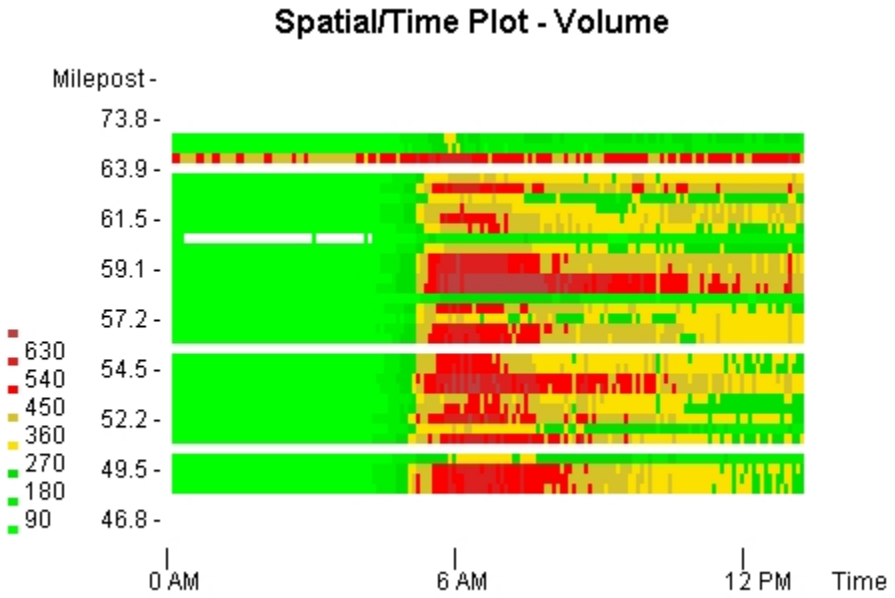


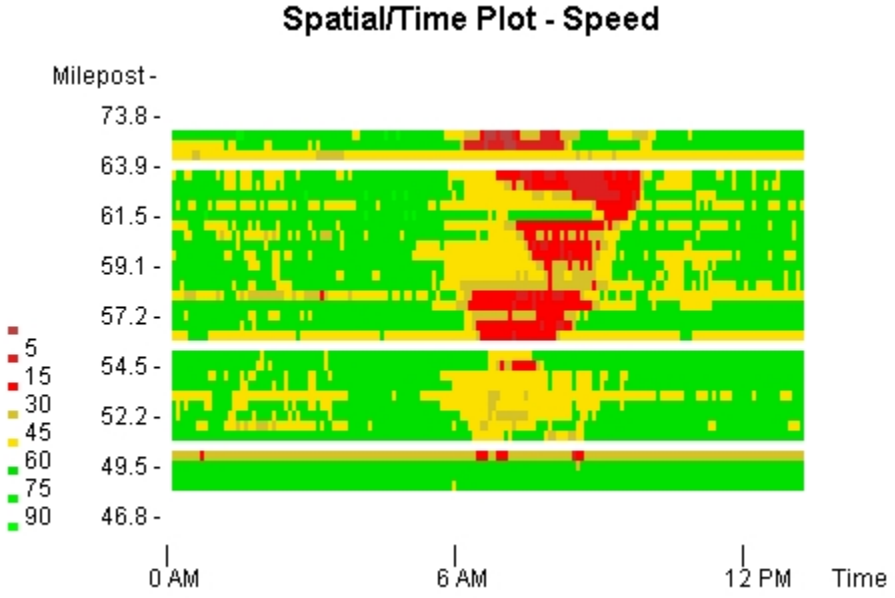
Figure 3. Shows speed, volume, and occupancy of I-66 Eastbound on 10/16/2006.

Highway Stations vs. Time Plot

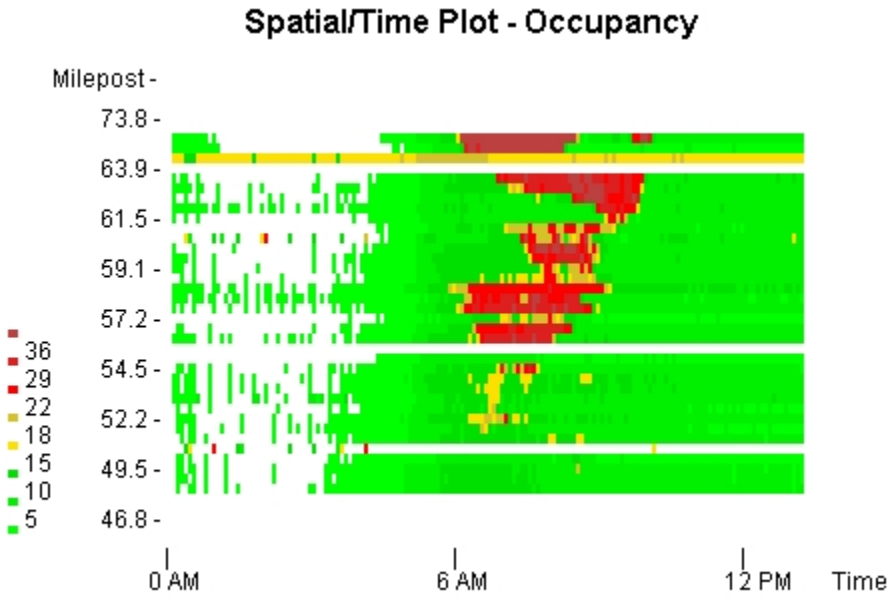
In Figure 4, the X-axis is the time, the Y-axis is the highway milepost, and the colors indicate the volume/speed/occupancy values. This figure is essentially a 3D graph of Figure 3 with the addition of time dimension and representing the Z-values (traffic metrics) as different colors. This graph representation is most comparable to an elevation map. Using this visualization, one can easily observe patterns such as the morning rush hour shown as the "red" regions. For example, Figure 4(b) predominantly shows red areas from 6AM-10AM from mileposts 54.5 to 73.8, which indicates morning rush hour traffic speed of approximately 20 mph.



(a) Colored volume plot of I66 Eastbound on 10/16/2006.



(b) Colored speed plot of I66 Eastbound on 10/16/2006.

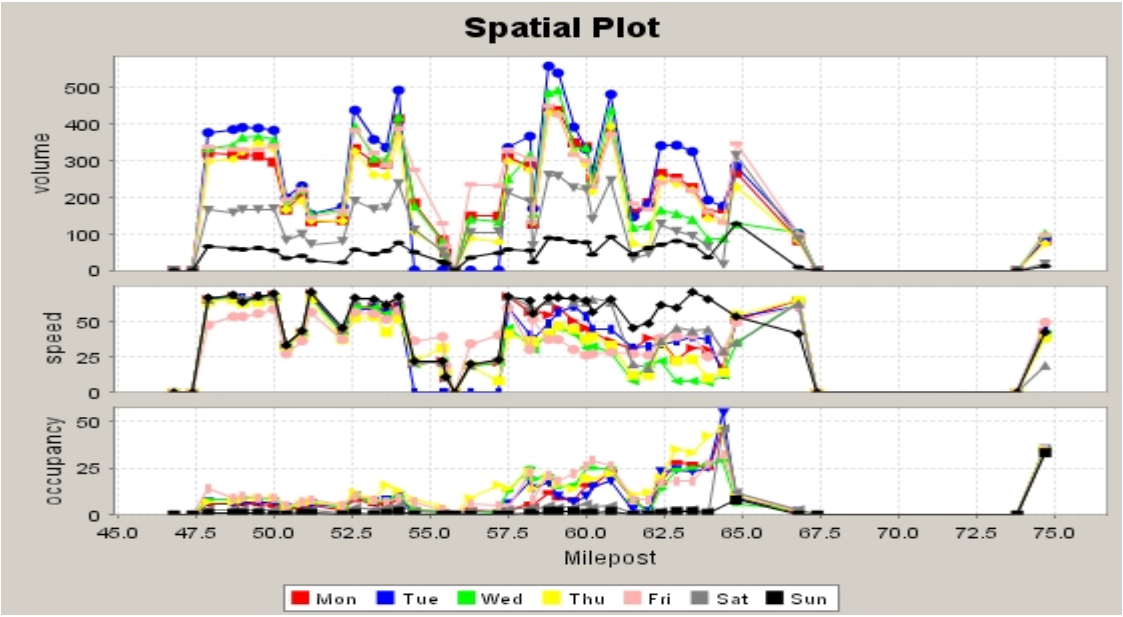


(c) Colored occupancy plot of I66 Eastbound on 10/16/2006.

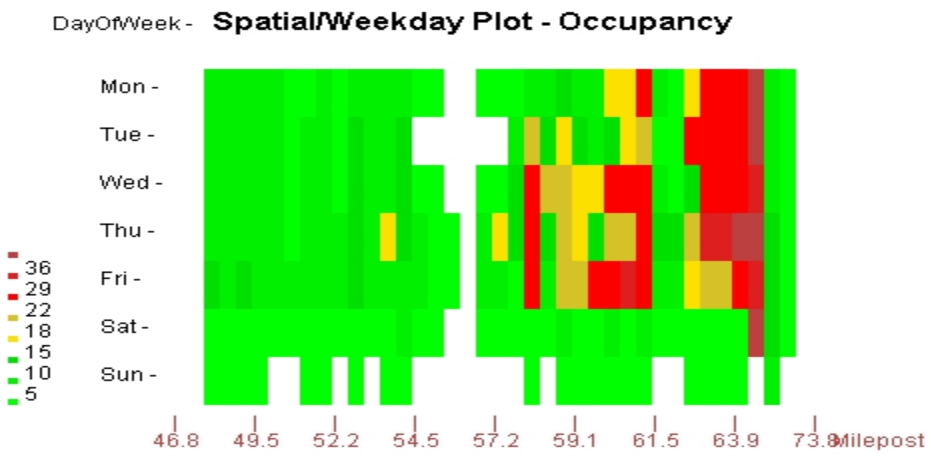
Figure 4. Shows speed, volume, and occupancy of I66 Eastbound for the day of 10/16/2006.

Highway Stations vs. Day of Week Plot

Figure 5(a) represents plots of the daily patterns of December 2005 at 8:30AM. This superimposition allows comparison of traffic behaviors for different temporal specification of the same spatial region. Alternatively, the series graph can be individually represented as colored based graphs shown in Figure 5(b).



(a) Traffic on I66 Eastbound from 12/1/2005-12/28/2005 at 8:30AM.



(b) Occupancy on I66 Eastbound from 12/1/2005-12/28/2005 at 8:30AM.

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

In Figure 6, the X-axis is time. This plot shows the traffic of station 121 from 2/1/2006 to 2/7/2006. From this graph, we can see the morning rush hour shown by the peak convergence at around 6AM to 10AM. However, notice that the pattern is only seen during the weekdays while the weekend traffics are relatively low during the morning period.

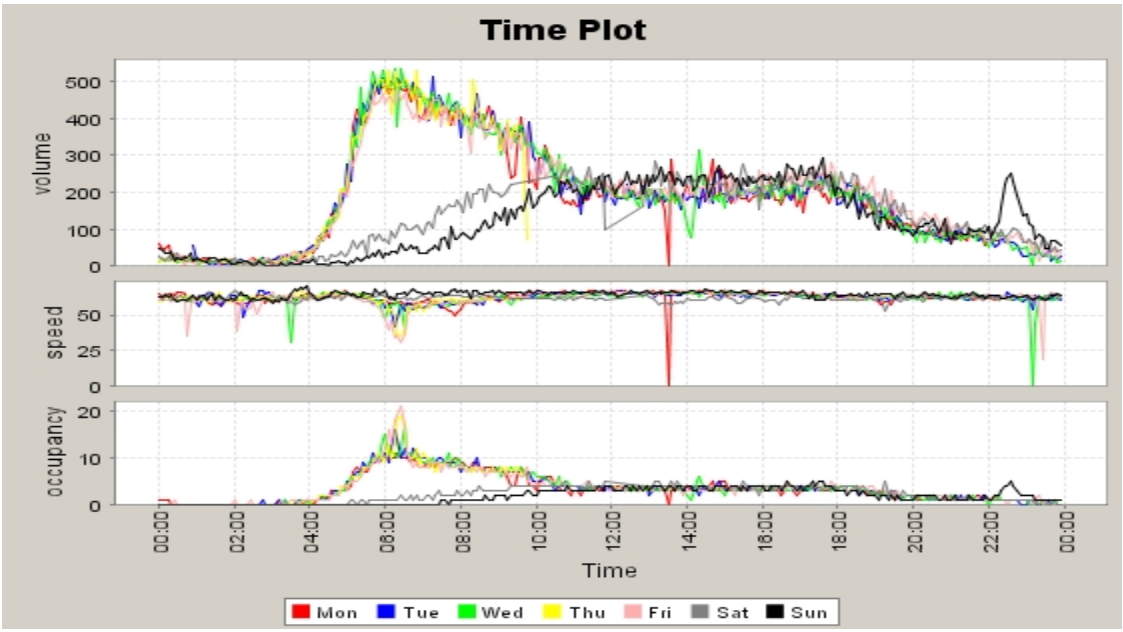


Figure 6. Shows speed, volume, and occupancy of all days in the week for station 121 for 2/1/2006-2/7/2006.

Conclusion and Future Work

Visualization aids in the analysis and discovery processes of large data sets. AITVS provides a rich set of visualization tools which allows for both macro and micro level investigations. Future work of this project includes integration of adaptive user and 3D interfaces, data mining components (e.g., automatic incident detection), and traffic simulations.