GeoVisualization of Automobile Congestion

Kirk Goldsberry
Assistant Professor of Geography
Michigan State University
kg@msu.edu
517-353-0308

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> *"The bulk of human travel is repetitive and relatively invariant in time and space. It would be unusual for humans to consult a cartographic map of an environment prior to every trip (Golledge, 2004, pg.6)."*

Automobile congestion is a large and growing problem in almost every major city in the world. In the United States, traffic delays are more frequent, more severe, and occur during more parts of the day than ever before (Shrank and Lomax, 2006). Despite the predictable nature of long-term traffic trends, day-to-day, and hour-by-hour traffic conditions remain unpredictable. In terms of spatial cognition, automobile congestion represents a gap in a driver's cognitive map. For this reason, and due to recent developments in sensor technologies, and Internet mapping, the popularity of "real-time" traffic maps is increasing. Millions of readers around the world consult traffic maps everyday in the hopes of enhancing their cognitive map and/or environmental knowledge. Within this context, traffic maps are a prominent example of applied GeoVisualization of dynamics, movement, and change. This paper discusses the conceptual and practical issues of traffic mapping.

In terms of Transportation Science, traffic maps are a component of Advanced Transportation Information Systems (ATIS), which themselves are a component of Intelligent Transportation Systems (ITS). Other examples of ATIS include, variable message signs, In-vehicle-navigation-systems, and traffic reports on radio or television. Within Geographic Information Science, traffic maps are an example of GeoVisualization. Due to traffic's dynamic spatiotemporal nature, conventional cartographic techniques fail to adequately deliver relevant traffic information to readers. Conversely, GeoVisualization methods present adequate delivery mechanisms for the delivery of "real-time" traffic conditions in cartographic form. As a result, scores of traffic maps have begun to show up online. Although traffic map applications are becoming quite popular research into their design is quite limited.

This paper includes three sections, one for each of three primary phases of traffic visualization: data collection, application development, and traffic map reading.

Data Collection:

Traffic maps require traffic data; the first phase of traffic mapping involves the collection of real-time traffic data. Recent developments in sensor technologies have facilitated an increase in traffic data collection. Most traffic data collection strategies begin with the Inductive Loop Detector (Klein, 2001). Loop detector systems are used to detect the presence or passage of motor vehicles. Common applications of ILD include traffic light triggers, parking lot access controls, and vehicle counting. The detector itself is essentially a coil of wire connected to nearby control box. A signal perpetually passes through the coil, and when a vehicle passes over, the inductance of the loop is reduced. The timing of this inductance reduction enables velocity detection. In other words, the duration a vehicle is over a detector, from the front of the vehicle to the back, is its velocity. Many city and statewide governments have employed ILD to help officials monitor vehicle passage along busy roadways.

ILD iteratively collect traffic data at fixed geographic coordinates. These geo-referenced point feature data include vehicle speed, vehicle density, and network flow measured at that location. The

ILD's collect the raw data and send it via wire line to a control box where the data are processed. The Data Processing stage involves the input of the field data measured by the road sensors. Before the raw field data can be used in a data application, or a traffic management application, they must be processed. When the sensors are ILD, raw data such as loop ID and the times each vehicle enters and leaves the loop are sent via wire line to a control box. These raw data are processed, and often aggregated, to create more refined attribute data such as vehicle passage, presence, count, occupancy, time, and flow information.

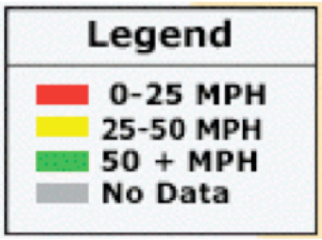
California provides a good example of how ILD are used to collect traffic data. The California Department of Transportation (CalTrans) has installed and maintains thousands of Inductive Loop Detectors (ILD) in the pavement of the California freeway system. The detectors are more common in urban areas, and non-existent in rural areas (CalTrans District 7, including Los Angeles, includes over 8,000 detectors). The data are collected and managed by The Freeway Performance Measurement System, PeMS in Berkeley, California. PeMS collects, stores, and processes this data and provides access so that engineers and other scientists can analyze the performance of the freeway system. The database is immense, and growing an approximate two gigabytes each day.

Application Design:
The second phase of traffic map design requires the design of a data application to cartographically depict the dynamic sensor data. Dozens of traffic map applications exist for locations all over the world. It is unclear when the first real-time traffic map was published online, but it is apparent that they are becoming increasingly popular. In 2007, two noteworthy events occurred. First, Google maps added traffic information to its immensely popular Internet mapping application. Users of Google maps are now able to not only route between any two addresses in the United States, they are now able to glimpse at current traffic conditions along their prospective route. Second, Apple introduced the "iPhone" and included access to real-time traffic maps as a prominent advertising point.

These current developments indicate an exciting future for traffic mapping, but it's also important to review the diverse approaches to mapping congestion as a way to inform future designs. Current maps are strikingly inconsistent, and this inconsistency is a clear indicator of a lack of design principles for online traffic mapping. Furthermore many current traffic maps violate cartographic conventions. Figure 1 summarizes some of these disagreements.

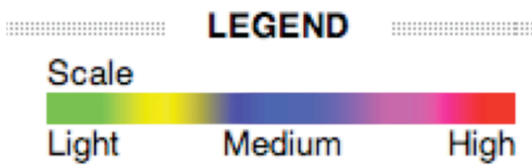
As illustrated in figure 1, traffic maps might improve if their designs adhered more closely to cartographic conventions – but other design concerns are less cartographic in nature. For example, current maps often employ sub-optimal image-based data formats resulting in large, "clunky" files that require greater amounts of bandwidth and longer download times. This is especially critical considering that a large number of readers are accessing these maps in wireless environments, which are characterized by limited and inconsistent bandwidth availability. One way to reduce the size of graphics is to employ vector data formats, such as Flash or SVG. Traffic maps must be designed in such a way that they are legible on a large array of devices including desktop computers, laptops, PDA's, in-vehicle displays, and cell phones. These devices represent both the core of ATIS communication and an important new challenge for GeoVisualization. Current image-based map displays are not scalable and therefore perform poorly on devices with diverse screen sizes, color capabilities, and pixel resolutions. Goldsberry (2007) presents a prototype traffic map for Los Angeles that depicts real-time Los Angeles conditions using Scalable Vector Graphics (SVG). The prototype proves that a new generation of vector-based real-time traffic maps can be created using SVG, a free-of-charge, and standards-based open-source format less vulnerable to proprietary influences.

Example Disagreements: Traffic Map Design versus Cartographic Principles



Representing Unipolar Statistics

Brewer (1994) advocates using a sequential scheme to represent unipolar data. "A sequential scheme can be acheived by holding hue and saturation constant, and varying lightness (Slocum, 2005, pg. 253)." Brewer (1994) and Robinson (1984) agree that lighter colors should be used for low data values, and darker colors for high data values. In the examples on the left (From TripChek's Portland map and Sigalert's Los Angeles Map), hue-based schemes are used to depict changes in a unipolar statistic.



Classed versus Unclassed

Although intensely debated, research findings from experimental cartography generally suggest classed maps are superior to unclassed maps, especially when hue or lightness are the dominant visual variables. Visually matching a map shade to a legend shade is more difficult with unclassed maps (Slocum, 2005), thus the perceptual accuracy of classed maps has advantages (Muller, 1979). Lastly, Spradlin (2000) found that individuals preferred classed maps to their unclassed counterparts. The example at the left is an unclassed, hue-based traffic map legend from Athens.

No Legend

"Legends or keys are naturally indispensable to most maps, since they provide the explanation of the various symbols used. It should be a cardinal rule of the cartographer that no symbol that is not self-explanatory should be used on a map unless it is explained in the legend (Robinson, 1978, pg. 295)." If a user of the Google traffic map to the left wanted to know exactly what yellow or red meant, that reader would out of luck. Traffic maps need to account for their readers' desires to know just how fast or slow "yellow" is.

Legend Hierarchies

The ordinal level of measurement involves a categorization of measurements plus an established order of those categories (Slocum, 2005). In the San Francisco traffic map (see legend below) four categories exist: No Congestion, Heavy, Moderate and Stop and Go. Map readers rely on legend language, and symbol design to assist in understanding the relative severity of each of these terms. This legend does not facilitate that understanding; it is unclear if "Heavy" traffic is more or less severe than "Stop and Go" traffic. Traffic maps that employ the ordinal level of measurement need to pick terminology and devise legends that create a sensible hierarchy of traffic categories.

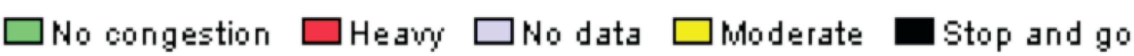


Figure 1: Example disagreements between cartographic conventions and existing real-time traffic maps.

Traffic Map Reading:

Traffic maps are essentially GeoVisualization applications that bridge the gap between the traffic database, and the map-reader. In this sense, a traffic application is a window into real-time traffic conditions. Traffic maps are a unique blend of thematic and navigational maps, and traffic map-readers perform complex wayfinding tasks by analyzing the interplay of thematic traffic symbols and the road network.

The design of traffic map applications needs to consider perceptual and cognitive issues associated with map reading. The third section of this paper exposes these issues and identifies which design variables influence the perception of traffic maps. Cartographic variables such as classification schemes, symbolization schemes, and representational forms each influence the perceptions of map-readers. This paper demonstrates how readers' perceptions of traffic severity are swayed by classification, and symbolization of traffic data.

This paper deals with dynamics of geo-localised sensor data, and specifically with geo-localised traffic data. The research investigates graphic issues of traffic mapping and how they influence perceptual issues related to traffic map reading. The findings suggest that adherence to cartographic conventions can improve the intuitiveness of traffic maps, but do not ensure optimal intuitiveness. The results demonstrate that readers' perceptions of traffic conditions are significantly swayed by design decisions made in the application design phase.

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