UC Berkeley
Working Papers

Title
Visualizing Loop Detector Data

Permalink
https://escholarship.org/uc/item/37j8b3ff

Authors
Zhang, Xiaoyan
Rice, John

Publication Date
1999-12-01

Visualizing Loop Detector Data

Xiaoyan Zhang
John Rice
University of California, Berkeley

CALIFORNIA PARTNERS FOR ADVANCED TRANSIT AND HIGHWAYS

This paper uses Postscript Type 3 fonts. Although reading in on the screen is difficult it will print out just fine.

Visualizing Loop Detector Data

Xiaoyan Zhang and John Rice

Department of Statistics, University of California at Berkeley

Abstract

Over the years, many TMCs have accumulated large loop detector datasets due to its extensive presence in existing infrastructure. However, the information in these data sets often lies dormant partly because of the lack of effective means to summarize and display the data. We present a simple visualization technique developed for loop detector data which addresses this issue. The method uses color-encoded images to visualize loop detector measurements as a function of space and time. We use examples based on a field dataset to illustrate some of its possible applications.

1   Introduction

Visualization has long played an important role in the process of understanding and interpreting large, complex data sets. In transportation practice, automatic data collection and increasing complexity of traffic networks join to produce a larger, and more complex data stream. Informative data presentation techniques are beneficial to transportation engineers, operators, researchers and the general public alike.

As a mature technology, the loop detector is widely present in existing infrastructures and is a standard data source for traffic surveillance. Many TMCs have accumulated large amounts of loop detector sets over the years. Faced with these existing/incoming large data sets, researchers are often at a loss to find relevant information or suitable subsets for their purposes. Effective means to store, organize and present the data to allow easy access and efficient usage are much in need.

In this article, we focus on using visualization technology to summarize and present loop detector data. We propose a technique suitable for visualizing large batches of loop detector data collected simultaneously from many locations along a linear stretch of roadway. The basic idea of the technique is to map each data value to a colored pixel at the corresponding position in a time-location plane and construct an image from these pixels. The color pattern of the image depicts changes in the measured quantity over time and space, thus the traffic condition.

The technique is capable of summarizing large amounts of data into interpretable images to extract useful information about prevailing traffic condition over a large span of time and space. Other phenomena, such as malfunctioning loop detector, are identifiable in these images as well. It also permits easy observation of more localized phenomena, such as shock wave propagation, by "zooming into" the region of interest. Although the technique was developed on the basis of loop detector data, it is readily applicable to other point detector measurements, simulation results or even derived quantities. It is well suited to a data fusion environment.

The idea of using color to represent traffic characteristic measurements has been used in real-time on-line traffic maps (see `http://traffic.tamu.edu` for an example). These maps are informative and easy to understand for general audiences, but they often lack enough details to permit thorough research.

Our technique is similar in spirit to contour plots and the visualizations in [1], where graphical symbols are used to encode measurement values in a time-space plane.

The rest of the article is organized as follows. Section 2 describes the visualization process in detail. We present some examples based on field data in section 3. The paper closes by discussing some possible applications and directions for future work in section 4.

2 Technique

The loop detector outputs (flow, occupancy and speed for double-trap detector) are functions of both time and space. We consider the simple 1-D situation where all detector stations on located on the same branch of the roadway network, and distances between detectors solely determine the physical layout. In this scenario, let $U(x_i, t_j)$ represent the measurement at time t_j from detector located at x_i. $U(x_i, t_j)$ may be unavailable for some (x_i, t_j) pairs. Our approach visualizes measurement values by mapping $U(x_i, t_j)$ to a colored pixel at (x_i, t_j), where the pixel color encodes data value. A color image is generated after interpolation. Color pattern of the image is the visual cue for changes in $U(x_i, t_j)$.

In most situations, the raw data are not suited to direct display. To facilitate visual pattern perception, pre-processing prior to image generation is needed. In the examples presented in section 3, we applied the following steps before visualization. The purpose of the first two steps is to reduce the effects of short-term variations which is presumably not of major interest. One or more of the steps can be adjusted or eliminated depending on the available data or the specific purpose of a certain application.

1. **Aggregation**   The data are first aggregated in time to a suitable level, i.e., each vector of loop detector data is divided into small non-overlapping time blocks and arithmetic means of each block are taken. Median could be used as well and might be

preferable if the distribution of measurements are highly skewed. This step eliminates fluctuations in data values at very high frequency to reduce the grainy effect which hinders human recognition of the prevailing pattern. On the other hand, one should be careful not to use too coarse an aggregation level to avoid missing valuable data patterns. For all later examples, the aggregation level is either 1 or 2 minutes. After this step, the data size may be reduced to a manageable level. All later procedures are performed on the aggregated data.

2. **Smoothing**   To further control the visual effects of temporary variations in detector measurements, we ran an one-dimension running median smoother of length 10 over time, which is 10 minutes of data at 1 minute aggregation.

3. **Interpolation**   Measurements are only available at detectors which are sparse and unevenly spaced. Linear interpolation along the location axis is employed to avoid abrupt color changes at detector locations. Interpolation also deals with missing data problems nicely.

The last step of the visualization process is to determine a color mapping scales. Adopting a traffic community convention, we used a Red-to-Yellow-to-Green color map where shades of red correspond to various degrees of congestion (low speed, high occupancy) and green is associated with free flow. In the gray-scale reproductions included in this paper, lighter colors means faster speeds. The pseudo-color axis for each data type was determined empirically to allow balanced usage of the entire color axis.

3   Examples

In this section we present some examples of applying our visualization technique to a field data set to demonstrate some of its possible applications. The data set used is the I-880 database collected on interstate highway I-880 near Hayward, California. The test site is roughly 6 miles long with double-trap loop detectors instrumented 1/3 miles apart on average. In addition to high-resolution (1 second) double loop detector measurements, the data set also contains an incident database and probe vehicle tracks. More details on data collection and organization of the raw data can be found in ([2]).

In most of the examples, the quantity being visualized is the speed estimated by double-trap loop detectors. Identical color mapping schemes were used for comparable images. From experiences gained with the I-880 data set, we find that images based on occupancies (not shown) exhibit quite similar patterns as those on speeds. The vertical axis displays space. Please keep in mind that the traffic goes upward.

3.1 Malfunctioning loop detectors

Identifying malfunctioning detectors is an important task. Our visualization approach can serve as the first step in systematic screening of corrupted data.

Figure 1 shows double-loop speeds on a stretch of highway about 6 miles long during 5-10am. The horizontal strip at loop detector #1 spanning the whole duration of 5 hours looks abnormal. The plot for the neighboring lane #3 (shown in Figure 4) does not show such a strip. Since there are no other obvious causes of this discontinuity, a maintenance check on loop #1 seems reasonable. Note that this abnormality is immediately apparent in the figure, but would be much more difficult to deduce from the raw data.

3.2 Recurrent congestion and shock wave propagation

Again looking at Figure 1, one notices a triangular-shaped slow-moving region at the bottom of the figure. This corresponds to a rush-hour breakdown that started at around 7:20am and lasted for more than an hour. The incident database indicates that there were only two short-lived incidents after 8am near loops #4 and #15. Thus it does not look like that the slow-down was caused by incidents. In fact, this is a region where heavy congestion is common during peak hours.

Figure 1 illustrates that congestion initiates from downstream but starts to dissipate from upstream. Graves and Karr mentioned in [1] that the triangular shape may be characteristic of recurrent congestion (congestion caused by excessive demand which happens frequently as opposed to incident-induced ones). From our experience with the I-880 dataset, the triangular shape is present on most of the plots with some degree of congestion. Since the majority of the data were collected during peak hours, we did not a good opportunity to observe congestion patters caused solely by incidents.

Figure 2 magnifies the region in which the slow-down was being formed. The curves in it are trajectories of probe vehicles. From the figure, we can clearly observe that a shock wave propagates upstream at a velocity around 3 mph, consistent with results in [1] The trajectories bent when they entered/left the shock wave region, showing changes in travel speed. This is an example where the technique may be used in research attending to short-term, local traffic patterns.

3.3 Incidents

One can easily identify slow-moving regions in those plots. Although one needs other information to distinguish an incident from slow-down caused by recurrent congestion, it is still a valuable visual aid, especially when used in conjunction with a historical archive of similar plots (see [4]). Composite images with highlighted incident regions can be more informative

in traffic operations or research.

Figure 3 illustrates incidents. There were several incidents reported around loop detectors #17 and #4 between 7am and 10am. The longest one started at 7:10am at #17 and persisted until about 9:10am.

When the technique is implemented in real time, it may be used to alert traffic managers of on-going abnormal road condition to allow timely response. A comprehensive historical database is indispensable in such scenario, so that traffic managers can ascertain whether emerging slow moving regions are normal or abnormal.

3.4   Historical traffic profiles

The visualization technique provides an effective tool of building historical traffic profiles. Figure 4 shows a week of traffic. Each of the plots become more informative when viewed in context. Here Wednesday clearly stood out. Tuesday and Thursday display similar features, but Monday and Friday were different. Detector #12 looks like a bottleneck where recurrent congestion often initiated. Information like these can be useful to transportation administrators in evaluating roadway performance and in planning.

A test web site has been constructed for the I-880 dataset at the URL http://www.stat.berkeley.edu/users/fspe/. Such archives, for which this is a prototype, would be useful to traffic operators in monitoring the state of a freeway and to researchers in studying phenomena such as the formation and discharges of queues.

4   Conclusions

The visualization technique described in this article provides an effective tool for exploratory activities to gain understanding and insights of large loop detector data sets. It allows users to get a visual overview of large batches of data and promotes more effective usage of large traffic databases. Its real time version can be valuable to transportation managers for detection of changes in traffic condition to permit early intervention. Varaiya described a hypothetical transportation performance measurement system in which the technique is incorporated in [4]. We have used the technique to evaluate a travel time estimation method where we visualized estimation errors to understand its performance under different traffic conditions ([5]). It may also be used as a measure of integrity check of microscopic simulation models.

Prompted by the rich literature on scientific visualization, we have a few ideas to extend our technique. Our current technique essentially uses pseudo-color axis to encode one time-space-dependent quantity. One may consider using additional axes to encode more quantities to design many new displays. One can construct a 3-D color surface with z-axis representing

flow and color encodes speed, or a 2-D color image with overlaid texture illustrating historical traffic conditions, or even a multimedia display accompanied by tones encoding traffic information of a competing route etc. However, discretion should be taken in design to avoid flooding the viewer with too much information.

A good visualization technique would still be of limited usages without a reasonable interactive interface. Some functions which should be included in such a system are: multiple datasets managing, easy manipulation of data pre-processing, interactive selection of region of interest to zoom in, easy control of color mapping scheme and options of applying image processing tools on the images. All our computations were done in Matlab, which provides a convenient environment for numerical computation and graphical display.

References

[1] Todd L. Graves, Alan F. Karr, Nagui M. Rouphail, and Piyushimita Thakuriah. Real-time prediction of incipient congestion on freeways from detector data. Technical Report 79, National Institute of Statistical Sciences.

[2] K. Petty, H. Noeimi, K. Sanwal, D. Rydzewski, A. Skabardonis, P. Varaiya, and H. Al-Deek. The freeway service patrol evaluation project: Database support programs, and accessibility. *Transportation Research, Part C: Emerging Technologies*, 4(3), 1996.

[3] Karl F. Petty, Peter Bickel, Michael Ostland, John Rice, Frederic Schoenberg, Jiming Jiang, and Ya'acov Ritov. Accurate estimation of travel times from single-loop detectors. *Transportation Research: Section A*, 32(1):1–17, 1998.

[4] Pravin Varaiya. How to measure transportaion system performance? URL link to the paper can be found at `http://www.path.berkeley.edu/~varaiya/`, November 1997.

[5] Xiaoyan Zhang, John Rice, and Peter Bickel. Empirical comparison of travel time estimation methods. working paper, July 1999.
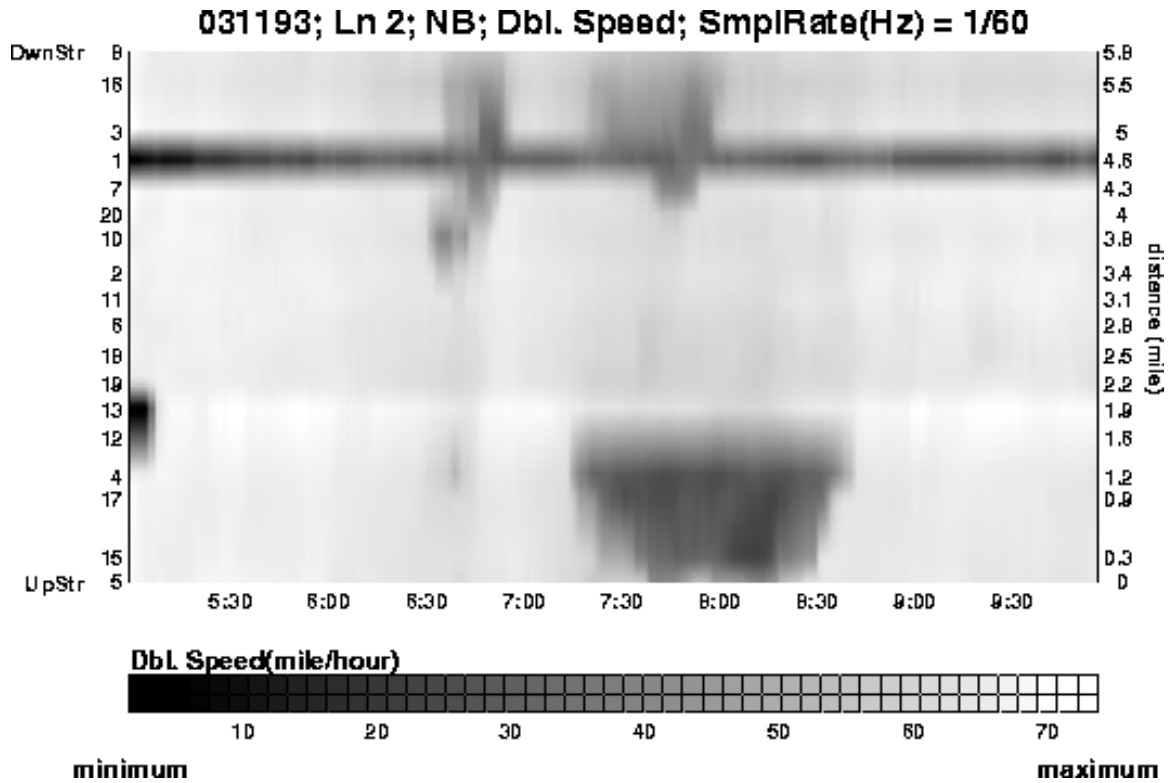
Figure 1: Malfunctioning Detector. The data was double-trap speeds for north-bound traffic in lane 2 (second leftmost lane in a four-lane highway). The raw data was aggregated to 1 minute (SmplRate = 1/60 Hz). Labels on the left are detector numbers, on the right are distances from the first detector. The top half of the color bar at the bottom shows the color mapping axis. Text labels "minimum" and "maximum" illustrate extreme values of the processed data.

Figure 2: Shock wave propagation and probe vehicle tracks. See caption of Figure 1 for details. Note that the time span is roughly 7 : 10 to 7 : 46, while all other plots cover 5 − 10AM.

8

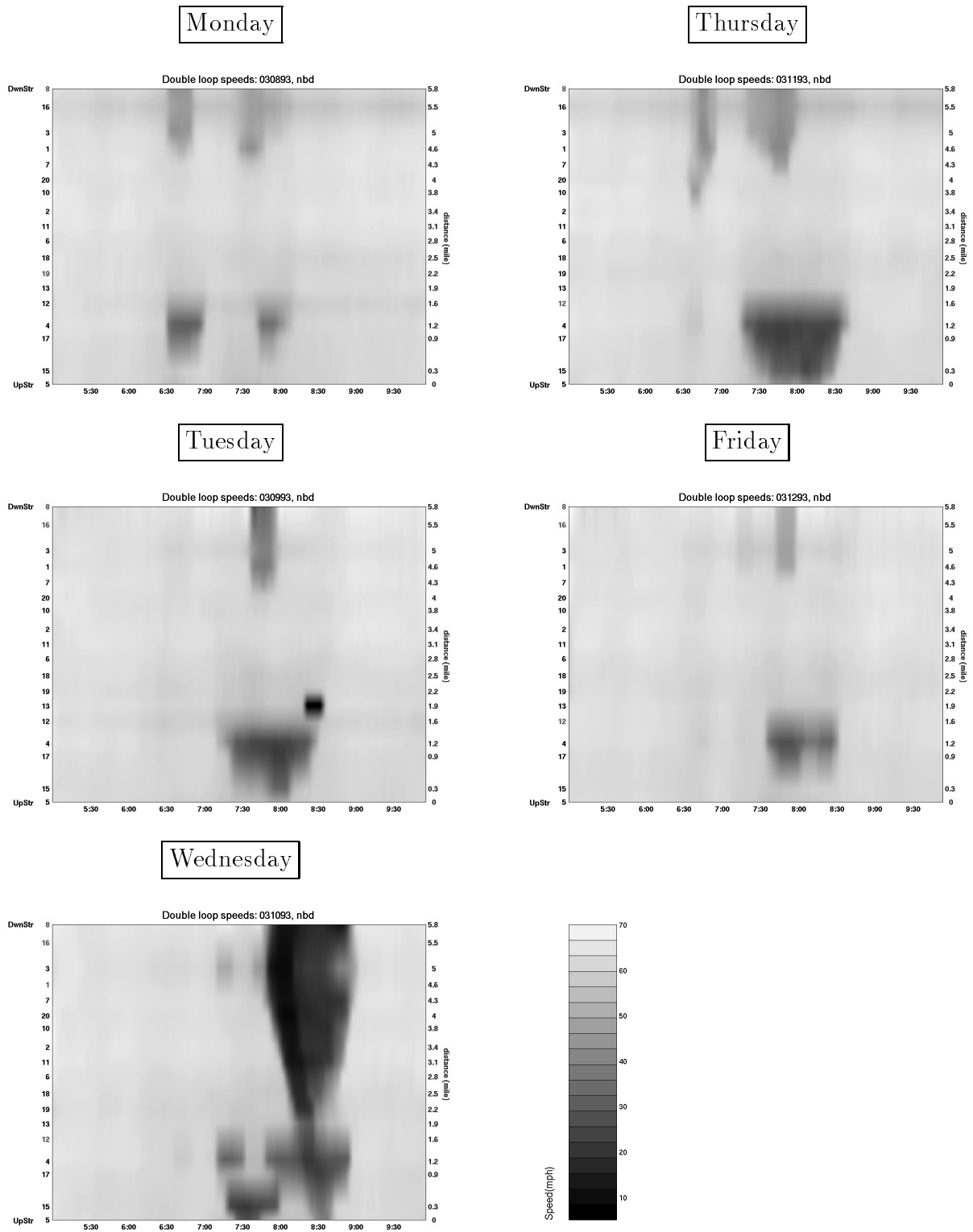Figure 3: Incidents. See caption for Figure 1 for detail.

9

Figure 4: One week of plots. Thursday is also shown in Figure 1 and Figure 2. See caption for Figure 1 for detail.