2014 IEEE Pacific Visualization Symposium

Traffic Origins: A Simple Visualization Technique to Support Traffic Incident Analysis

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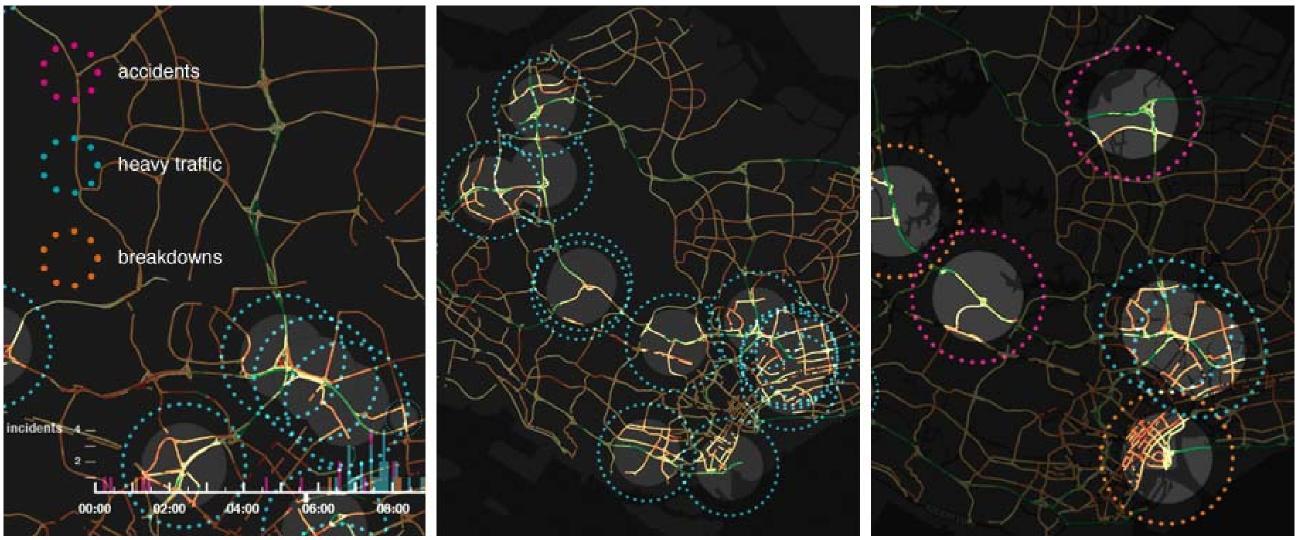

Figure 1: Traffic incidents highlighted using the Traffic Origins approach. When an incident occurs, its location is marked by an expanding circle that reveals traffic conditions in the immediate vicinity.

ABSTRACT

Traffic incidents such as road accidents and vehicle breakdowns are a major source of travel uncertainty and delay, but the mechanism by which they cause heavy traffic is not fully understood. Traffic management controllers are tasked with routing repair and clean up crews to clear the incident and often have to do so under time pressure and with imperfect information. To aid their decision making and help them understand how past incidents affected traffic, we propose *Traffic Origins*, a simple method to visualize the impact road incidents have on congestion. Just before a traffic incident occurs, we mark the incident location with an expanding circle to uncover the underlying traffic flow map and when it ends, the circle recedes. This not only directs attention to upcoming events, but also allows us to observe the impact traffic incidents have on vehicle flow in the immediate vicinity and the cascading effect multiple incidents can have on a road network. We illustrate this technique using road incident and traffic flow data from Singapore.

Index Terms: Software [H.1.2]: User/Machine Systems—Human factors Software [H.5.2]: Computer Graphics—Graphical User Interfaces (GUI)

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1 INTRODUCTION

The sheer volume of data associated with traffic incident management makes it hard to isolate the impact that traffic accidents and vehicle breakdowns have on congestion. Zhang [14] showed that the effects such incidents have are highly non linear and difficult to predict largely because multiple incidents often occur sequentially due to queue backups. This problem is of significant importance to city traffic management controllers, who are responsible for routing repair and clean up crews in real time to clear the incident and members of the public, who want to know how such disruptions affect their daily commute. In this paper, we present *Traffic Origins* (Figure 1), a simple visualization technique that highlights the effects of traffic incidents on congestion. We apply our methods to historical incident and traffic data and discuss the advantages and limitations of our technique. As a proof of concept, we demonstrate our approach at a data visualization exhibition in Singapore.

2 RELATED WORK

Research interest in traffic congestion and mitigation has surged in recent years due to the wide availability of data collected by traffic management centers as part of daily operations. These centers gather detailed records of road conditions and traffic incidents so as to effectively monitor the real time performance of highways and arterial roads. Analysts at these centers are particularly interested in understanding how traffic incidents cause congestion, but lack the visualization and analysis tools to do so [13].

978-1-4799-2873-6/14 $31.00 © 2014 IEEE
DOI 10.1109/PacificVis.2014.35

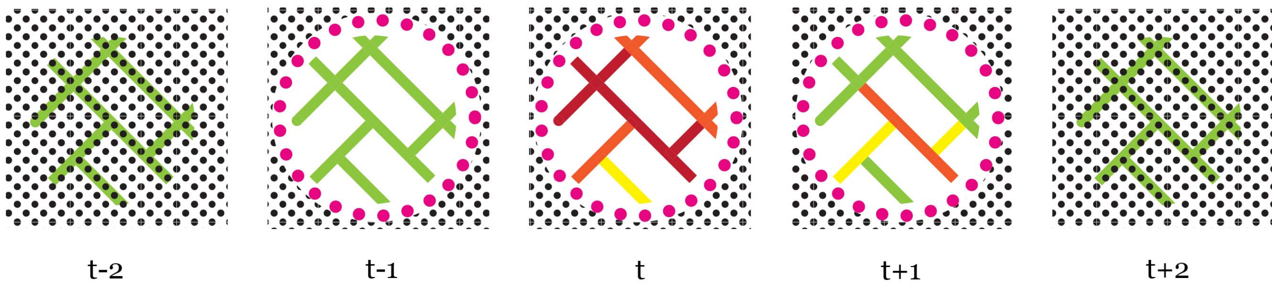

Figure 2: Figure showing the sequence of events used to draw attention to road incidents. At time $t-2$, the road network remains occluded. At $t-1$, an expanding circle uncovers the underlying congestion free road network. At time interval t the road incident occurs and causes congestion in its immediate vicinity. The circle remain open until time $t+1$ (just after the road incident ends) and closes at $t+2$. This allows users to see the before and after effects of the road incident.

2.1 Traffic Incident Prediction and Analysis

Previous work in traffic incident prediction and analysis have emphasized using machine learning techniques to predict the severity of traffic incidents. Miller [7] developed a practical system for predicting the cost and impact of highway incidents using classification models trained on road sensor data and police reports while [3] used regression trees to establish an empirical relationship between traffic accidents, road conditions and environmental factors. Where traffic incident visualization was the focus as in [10], the goal was to design visual analytics tools to recognize causal relationships and trends in traffic incident data, not to visually link specific traffic incidents with subsequent congestion.

2.2 Real Time Traffic Monitoring

Several mobile apps notify end users of service disruptions and visualize traffic conditions in real time. Google [11] was one of the first companies to aggregate data from several sources such as road sensors, car and taxi fleets to provide real time transit and traffic information to users. Average vehicle speed is visualized in simple ways and overlaid on Google Maps. Waze [1] crowd sources anonymous speed, hazard and road incident information from its community of 50 million users to provide personalized travel advisory services and location based advertising. Both these commercial services aim to provide real time information to users to aid trip planning and decision making. In contrast, *Traffic Origins* is designed to enable traffic management controllers to combine historical traffic and road incident data to observe how incident induced traffic congestion propagates throughout the road network. Unlike the above mentioned apps which provide traffic information at a specific point in time, our methods promote a visual overview of event sequences by overlaying time varying road incident and traffic flow data on a map of the road network. This allows expert users to perform meaningful event sequence analysis, identify anomalies and gain insight into how congestion arises.

3 Interaction Technique

Traffic Origins is designed to let expert users (traffic management controllers in a high stress and challenging work environment) visualize the spatial and temporal aspects of traffic incidents and their impact on congestion in a visually intuitive and compelling way. When applied to historical data and used in an after-action review setting, our visualization must allow them to quickly grasp the effectiveness of actions taken in response to past traffic incidents. Therefore, we had to make a tradeoff between showing detailed statistics and analysis for each incident and visualizing the overall effect these incidents have on network performance. The visualization shows time-varying traffic flow and road incident data simultaneously on an interactive map of Singapore. A 50% opacity mask is applied uniformly to the entire map to mute the color of major road segments (red for heavy traffic, green for fast moving traffic) so that the user's attention is fixed on the road incidents. Just before a road incident occurs, an expanding circle at the location of the road incident clears the mask, thereby allowing the user to see how traffic behaves in the immediate vicinity of the incident. Details of the incident are visually encoded into the circle. Pink circles indicate accidents, blue circles show reports of heavy traffic, and orange circles signal vehicle breakdowns. The duration of the incident (an indication of severity) is proportional to the amount of time the circle stays open. Because the circle remains open until just after the incident ends, users can compare traffic conditions before and after the incident occurred.

To allow users to casually explore the Singapore traffic map and examine incidents in greater detail, users can use a touchpad to zoom and pan the map to areas of interest. We promote a minimalistic visual style that lets users focus on traffic incidents and road conditions by using custom map tiles that ignore urban form while preserving the physical landscape of Singapore. Our map is implemented using the Unfolding map library for Processing [9].

Finally, we provide an overview of the day's activity by including a timeline that uses a stacked bar graph to show how the number and type of incidents varies over time. Stacked bar graphs are well suited for this task [8] because they visually aggregate the three incident types (accidents, heavy traffic and breakdowns) by both color and time. The visualization supports two modes. In exhibition mode, the visualization loops from 12:00 AM to 11:59 PM over a period of two minutes while in analysis mode, the user can adjust a slider to replay incidents and rewind or fast forward in time.

3.1 Visualizing Road Speeds

Road speed information collected by Singapore Land Transport Authority's (LTA) network of loop detectors is visualized in *Traffic Origins* through a simple mapping of color to speed (red for heavy traffic, green for fast moving traffic) and drawn as individual road segments on the Singapore road network. One drawback of this approach is that when animated, the visualization appears jerky because road speeds change quickly due to the start/stop nature of congestion. To smooth the data, we averaged road speeds at 15 minute intervals. Instead of rendering the color of the road segments directly, we linearly interpolated them so that the transition between each interval appears smooth.

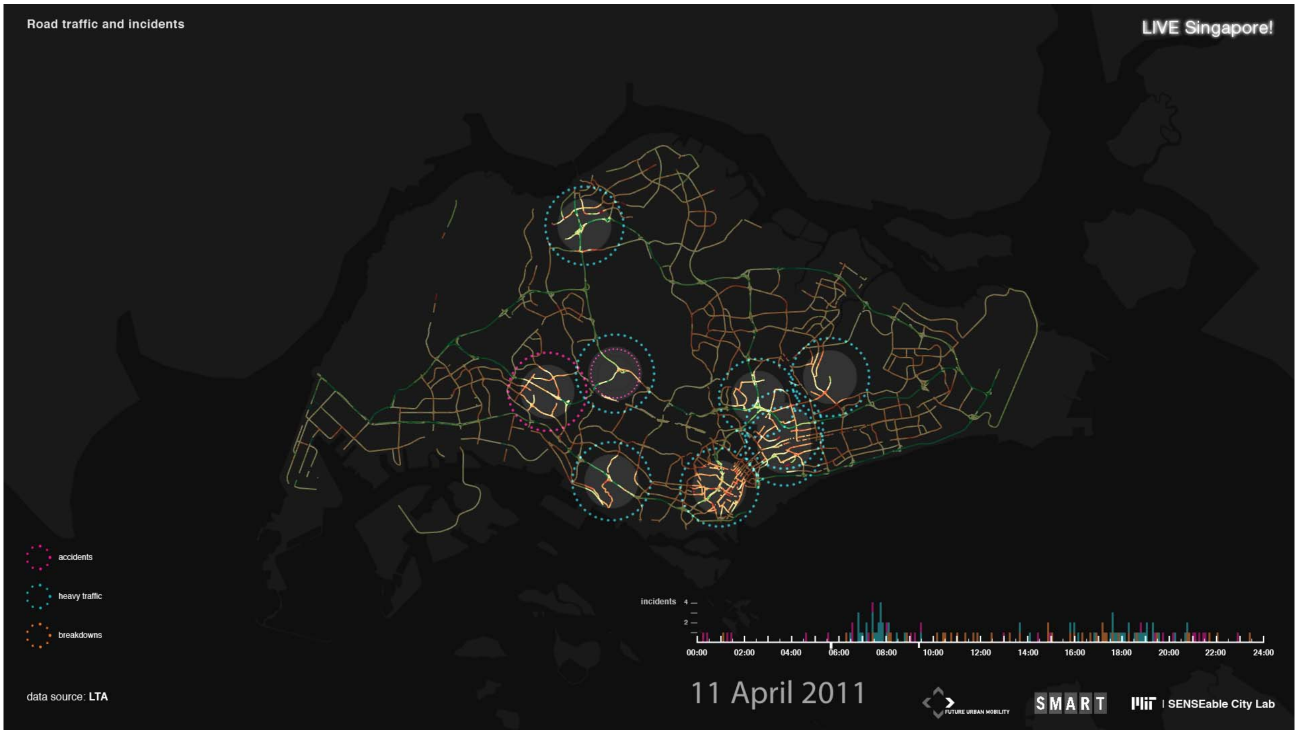

Figure 3: User interface for the Traffic Origins road speed + traffic incident visualization

3.2 Highlighting Road Incidents

Commercial mapping software typically draws attention to road incidents by placing a marker at the incident's location. While this is useful for navigation, it is less useful for analysis because it does not focus the user's attention on the impact that these incidents have on traffic in the immediate vicinity before and after the incident happens.

In *Traffic Origins*, we use the *Focus + Context* metaphor described in [4] and [6] to draw attention to traffic incidents. Our visualization starts with a map of the road network covered by a translucent dark "fog" at time $(t-2)$. 15 minutes $(t-1)$ before a traffic incident occurs, we draw *focus* by uncovering the underlying traffic flow map at the incident's location with a growing circle. The incident is then displayed in the *context* of ensuing congestion by keeping the circle open for the duration of the incident (t). The circle stays open $(t+1)$ for another 15 minutes so that users can observe traffic returning to normal. This approach is illustrated in Figure 2.

3.3 Limitations

The chief limitation to our approach is that it highlights correlations between traffic incidents and congestion, even when there is none. Incident induced congestion is complex and still poorly understood, and in several cases there was no observable congestion after an incident. This is probably because the severity of congestion depends on several factors (such as weather, traffic conditions, type of vehicle involved etc) that are not captured by the data, and it is entirely possible that traffic flow remains smooth despite an incident occurring. By drawing attention to the immediate vicinity of a traffic incident even if it did not result in congestion, our visualization approach leaves the user to make his own conclusions.

3.4 Implementation

Traffic Origins was developed in Java using the free and open source Processing [12] programming language. Designed to run on a notebook computer with full HD resolution (1920x1080 px), our visualization runs smoothly at 60 frames per second.

4 Case Study

As a proof of concept, we showed our visualization (Figure 3) at an exhibition of urban mobility in Singapore. This exhibition was part of the LIVE Singapore project, an interdisciplinary, multi-year effort to combine and disseminate various urban data sets to provide citizens visual and tangible access to information on their city [5]. Our goal was to reach out to the academic community, expert users from the LTA planning and operations department as well as private citizens to get feedback and informally observe how they interacted with the visualization.

4.1 Dataset

We used two sources of data: one month (April 2011) of loop detector data for the entire road network (12,500 loop detectors in 1,300 intersections) in Singapore and traffic incident data from the same period. Each loop detector record gives the number and speed of cars that pass over each loop detector during a 15-minute time slot while the traffic incident data contained a record of the type (accident, heavy traffic or breakdown), location (latitude and longitude) as well as the start and end times of the incident.

4.2 Design Goals

From a design perspective, our objectives were twofold. Firstly, we aimed to create an engaging visualization that used an attractive visual language to make traffic and congestion data accessible, enjoyable and easily understood by traffic management controllers, transportation experts and LTA officials. This group would already be very familiar with congestion patterns in Singapore and we wanted to get feedback and start a dialogue with them in a casual setting away from the traffic management center, to see if they could gain new insights through our visualization.

Secondly, we wanted *Traffic Origins* to be used in a walk-up-and-use setting that encourages members of the public to walk over and casually explore the data. To this end, we designed our visualization to support casual exploration by allowing users to interact with the data via a touch pad while the Singapore road network is displayed on a high resolution screen. With the growing popularity of GPS and map apps, people are used to the idea of mapping traffic congestion in order to avoid traffic jams and find the fastest route. However, what they typically see when they open a map app is a snapshot of traffic at a particular point in time. In contrast, *Traffic Origins* lets users get a sense of how congestion builds in response to specific traffic incidents.

4.3 Discussion

The notion that attractive visualizations improve understanding and data interpretation is worth exploring. It has been shown that aesthetically pleasing visualizations are more effective [2], which is why *Traffic Origins* emphasizes aesthetics and simplicity, both in visual form and user experience. Although simple, our visualization method was intuitive enough to be understood by both expert users and laymen, which, as an unexpected side effect, enabled us to communicate the difficult and complex daily tasks faced by traffic management controllers to the public. Feedback from participants at the exhibition highlighted the importance of aesthetics in drawing their attention and encouraging them to explore the visualization further.

On a macro level, *Traffic Origins* allowed us to observe how traffic incidents vary over the course of a single day. Heavy traffic incidents are predictable clustered around the morning and evening peak hours, accidents in the early morning and late evening and vehicle breakdowns are evenly distributed over the work day.

On a micro level, our visualization gave us the opportunity to observe the visual relationship between traffic incidents and resulting congestion. It was not uncommon to see road segments turn from green to red and back to green again as road incidents occurred and were subsequently cleared by clean up crews dispatched by the LTA's traffic management center. Occasionally, a series of unrelated traffic incidents in the Central Business District would cascade and lead to grid lock, particularly during the morning peak period. Interestingly when accidents and breakdowns happened on a highway, traffic often slowed down in both directions which suggests that drivers in the opposite lane slowed down to look at the incident.

5 Conclusion and Future Work

The main contribution of this paper is a visualization technique to highlight the impact that traffic incidents have on congestion. We draw attention to a road incident through the use of an expanding circle that reveals the state of the road network in the immediate vicinity of the incident, thereby enabling users to see the before and after effects of the incident. A proof of concept demonstration at a public exhibition showed that our visualization method was aesthetically pleasing and understandable by both transportation experts and members of the public.

Overall, our work received significant interest all around. Officials from the LTA were interested in using our visualization to highlight the efficiency of their clean up crews (most incidents were cleared within 20 minutes or less) and in the longer term, better respond to traffic incidents and design a more robust and fault tolerant road network. Researchers were keen to use our methods to quantify the impact of traffic accidents for use in data driven simulation models as well as a tool to visually display simulation results. We are actively pursuing both avenues of future work.

Acknowledgments

Support for this research has been provided by the Future Urban Mobility project of the Singapore-MIT Alliance for Research and Technology (SMART), SMART Innovation Center Explorer Grant No. 015824-119 and Innovation Grant No. ING13057-ICT. Data and expert feedback provided by the Singapore Land Transport Authority. We are grateful for this support.

References

[1] Waze - outsmarting traffic together.

[2] N. Cawthon and A. V. Moere. The effect of aesthetic on the usability of data visualization. In *Information Visualization, 2007. IV'07. 11th International Conference*, pages 637–648. IEEE, 2007.

[3] L.-Y. Chang and W.-C. Chen. Data mining of tree-based models to analyze freeway accident frequency. *Journal of Safety Research*, 36(4):365–375, 2005.

[4] A. Cockburn, A. Karlson, and B. B. Bederson. A review of overview+ detail, zooming, and focus+ context interfaces. *ACM Computing Surveys (CSUR)*, 41(1):2, 2008.

[5] K. Kloeckl, O. Senn, G. Di Lorenzo, and C. Ratti. Live singapore!-an urban platform for real-time data to program the city. *Computers in Urban Planning and Urban Management, CUPUM*, 4, 2011.

[6] R. Krüger, D. Thom, M. Wörner, H. Bosch, and T. Ertl. Trajectorylenses–a set-based filtering and exploration technique for long-term trajectory data. In *Computer Graphics Forum*, volume 32, pages 451–460. Wiley Online Library, 2013.

[7] M. Miller and C. Gupta. Mining traffic incidents to forecast impact. In *Proceedings of the ACM SIGKDD International Workshop on Urban Computing*, pages 33–40. ACM, 2012.

[8] W. Müller and H. Schumann. Visualization methods for time-dependent data-an overview. In *Simulation Conference, 2003. Proceedings of the 2003 Winter*, volume 1, pages 737–745. IEEE, 2003.

[9] T. Nagel, J. Klerkx, A. V. Moere, and E. Duval. Unfolding–a library for interactive maps. In *Human Factors in Computing and Informatics*, pages 497–513. Springer, 2013.

[10] M. L. Pack, K. Wongsuphasawat, M. VanDaniker, and D. Filippova. Ice–visual analytics for transportation incident datasets. In *Information Reuse & Integration, 2009. IRI'09. IEEE International Conference on*, pages 200–205. IEEE, 2009.

[11] E. Ratliff. How google maps is changing the way we see the world. *Whole Earth*, 1(5):5, 2007.

[12] C. Reas and B. Fry. *Processing: a programming handbook for visual designers and artists*, volume 6812. Mit Press, 2007.

[13] M. VanDaniker. Visualizing real-time and archived traffic incident data. In *Information Reuse & Integration, 2009. IRI'09. IEEE International Conference on*, pages 206–211. IEEE, 2009.

[14] H. Zhang and A. J. Khattak. Analysis of cascading incident event durations on urban freeways. *Transportation Research Record: Journal of the Transportation Research Board*, 2178(1):30–39, 2010.