Traffic Visualization
Applying Information Visualization Techniques to Enhance Traffic Planning

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Abstract: In this paper, we present a space-time visualization to provide city's decision-makers the ability to analyse and uncover important "city events" in an understandable manner for city planning activities. An interactive Web mashup visualization is presented that integrates several visualization techniques to give a rapid overview of traffic data. We illustrate our approach as a case study for traffic visualization systems, using datasets from the city of Oulu that can be extended to other city planning activities. We also report the feedback of real users (traffic management employees, traffic police officers, city planners) to support our arguments.

1 INTRODUCTION

Transportation systems can now be accessed by mobile, desktop or web applications. As more data becomes available, there is a need for more data-driven transportation systems (Zhang et al., 2011) especially to improve traffic data analysis, evaluation for traffic quality determination (Wang, 2005; Ehmke et al., 2010) and to evaluate congestion (Bacon et al., 2011). Our work leverages previous research on the integration, analysis and visualization of traffic data within geographic information systems (GIS) (Claramunt et al., 2000; Shekhar et al., 2002) using spatial and temporal dimensions to provide user specified aggregation levels (Song and Miller, 2012). These approaches have used one or more visualization techniques including line charts, maps or images (Zhang et al., 2011), but have limited interactivity and static levels of aggregation.

Mashups have been used to represent geospatial data and can be suited for exploratory visualizations (Wood et al., 2007). We have adopted the mashup approach by combining three specific toolkits to build our mashup as a web application using classic visualization techniques. Cluster visualization have been used to enhance traditional calendar visualizations (Van Wijk and Van Selow, 1999) and a combination of time-series visualizations has been used for understanding spatiotemporal hotspots using multiple geospatiotemporal data (Maciejewski et al., 2010). However, classical visualizations are more suitable for decision-makers that have not training or experience regarding advanced visualization techniques. We provide a solution that can support a rapid overview using dynamic levels of aggregation of temporal and spatial data to explore and compare traffic events. In this paper, we introduce our case study based on an Oulu traffic dataset to create an interactive space-time visualization. We describe our proposed methods and tools and a preliminary evaluation based on interviews to a group of Oulu decision-makers. Finally, we conclude and present our future work.

2 CASE STUDY

Our primary aim is to provide a mashup visualization using a combination of data mining, visualization techniques and Web-based tools to help decision-makers in their exploration of traffic data.

Requirements. To explore historical traffic data, decision-makers need to *navigate data with respect to time and space*. They must be able to understand local traffic state from different time periods, such as during rush hours or special events and an overview

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of a certain time period, *e.g.*, a week or a day, for a specific region of the city. The *visualization must be interactive and flexible* to enable users to dynamically refine the view of the dataset focusing on the problem they are trying to understand, while hiding the less useful information. Finally, the atomic visualization elements of the mashup must be synchronized to help the user to isolate useful information.

Oulu Case Study. The Oulu city traffic allows us to demonstrate the feasibility of our space-time interactive visualization mashup using the Oulu traffic dataset. We illustrate its potential, using a dataset with a minute resolution of traffic data collected over a one month period (May 26^{th}, 2011 to June 21^{st}, 2011). This dataset is composed of approximately 600,000 traffic records in total, for all of the intersections with traffic lights (77 traffic intersections) and detector lane-locations in intersections (4-32 lane in each intersection). Our current implementation uses traffic counter data hence it displays traffic volume in terms of number of vehicles in a given time frame. Interviewing some decision-makers of the city of Oulu, we outlined the following use cases:
Traffic planning: re-programming of traffic lights. With the *current system* (see Section 4) users have to export history data for a given intersection. They have to import data to Excel to calculate statistics. Hence, they calculate new optimal timing and re-program specific traffic lights - 20 traffic lights at a time.
Police: movement of units in the field. Mid summer is one of the major holidays in Finland when people are leaving the cities and travel to the countryside. Based on their experience, police historically knows when, how and to where people are leaving the city and supply police units to specific places when it is needed. However, if their guess fails, a re-placement of units has to be done, which is time consuming.

In Section 4, we explain in detail the current system used in Oulu and the decision-makers' evaluation of the current implementation.

3 DESIGN APPROACH

We propose a system architecture (see Figure 1) that provides the aforementioned interactive visualization mashup. The high-level architecture is composed of two components, the Data Miner and Web Mashup Front-end.
Input Data. To get the input data for our Data Miner, it was necessary to clean, pre-process and rearrange the Oulu dataset according to the needed visualization input.

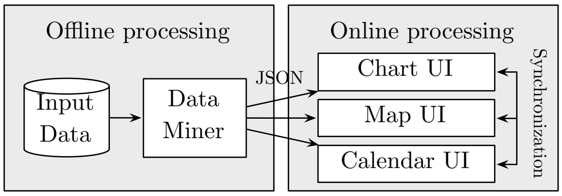

Figure 1: System architecture.

Data Miner. We sorted the input data for each intersection considering time and intersection id. Then, we generated JSON files from the raw Input Data of the original dataset as output to be imported from the web user interface.
Web Mashup Front-end. Our design follows Shneiderman's visual information seeking mantra (Shneiderman, 1996), "overview first then details on demand". Considering the related work in Section 1, our aim is to provide an accessible overview with dynamic levels of aggregation of temporal and spatial information. Thus, we combined three different visualization techniques using UI web-based components, based on the idea to support decision-makers with classic visualizations that can be easy to use and the author's experience.

- *Chart UI.* It facilitates analysis and exploration of traffic variations flow for all intersections, a specific intersection or selected regions. Our Chart UI was implemented using Highstock API (http://www.highcharts.com/products/highstock), a JavaScript library to visualize timeline Charts.
- *Map UI.* Each intersection is placed in the Oulu city map using circles. The color of each circle indicates the traffic volume on that intersection for a specific period of time. Our Map UI uses the Google Maps API and its color scheme.
- *Calendar UI.* We additionally integrate a calendar view to illustrate the traffic variation flow using the calendar cells and a color scale per day. We used D3.js (http://d3js.org/), a JavaScript library for visualizations.

Preliminary Visualization. Figure 2 shows the visualization traffic described above using the three main components. First, the Chart UI (Figure 2a) visualizes the total traffic volume in terms of number of vehicles with respect to time from 26^{th} May to June 21^{st}, 2011. A grey background is used to represent missing data from the original dataset. Second, the Map UI (Figure 2b) shows a spatial representation of the average volume of traffic with respect to intersections during a specific period of time. Third, the Calendar UI (Figure 2c) shows the mean traffic volume in which each day is colored according to the number

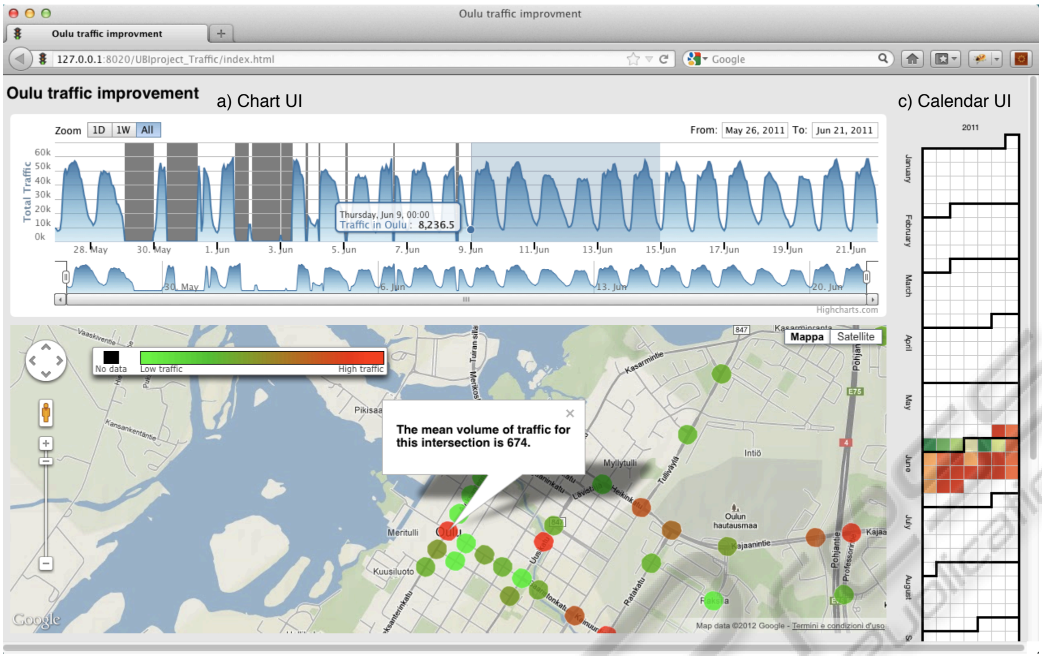

Figure 2: Traffic flow visualization combining: a) chart; b) map; and c) calendar visualizations.

of vehicles. These components are synchronized and provide the following functionalities:

Meta Overview. It is presented using three different visualizations of spatial and temporal traffic data.

Zoom. Due to the size of our dataset, we restricted different levels of aggregation on our Chart UI: per day (1D), per week (1W) and all data. A spatial zoom is provided by the Map UI.

Interactive Filtering. Users may wish to focus on a specific intersection, specific time or specific period of time (see Figure 2). They can select a specific point/region in the Chart UI that will update both Chart and Map UI. Selecting a marker (circle) in the Map UI will update the selection in the Chart UI adding the area related to the intersection as an additional line to facilitate users' interpretation.

Details on Demand. Users can get details regarding the amount of traffic of a specific intersection or time represented as a marker by selecting it from either the Chart or Map UI.

4 RESULTS AND COMPARISON

To validate the decision-makers' requirements we visited the Oulu traffic control center. They showed us the system they currently use. Then, we showed them our mashup for a preliminary evaluation.

The *current system* summarize historical data us-

Figure 3: Representaton of the current system in Oulu.

ing traffic reports but neither graphical nor statistical representations are available, except for a black/white map as the one shown in Figure 3, which is a representation of their system – we were not allowed to take pictures. Each point on the map represents an intersection, the color of each intersection only refers to its location. Hence, no visual information about the traffic intensity is provided. They must use a repetitive manual process to get intersection historical data: *(i)* select one intersection from their system, *(ii)* select the properties they are interested in, *(iii)* select time/data, *(iv)* export data as a table, *(v)* import data into a spreadsheet (*i.e.*, Excel), and *(vi)* generate graphs using the spreadsheet program. They must repeat all the above steps if other intersection information is needed. The interviews brought three specific user groups to our attention. The *traffic management employees* that have to export data to Excel and do manual processing to generate statistics regarding traffic data. A lot of effort is needed and a system that enables graphical and real-time statistical analysis of traffic data is desired. The *traffic police officers* are interested in a real-time calculation of the traffic because this can help them to place units ahead where the masses are moving. Finally, the *city planners* consider traffic estimation as valuable information for city designs.

During our *preliminary evaluation*, we got feedback from our interviewees. They were enthusiastic about our tool like and they had even requested similar improvements for their tools. They provided improvement ideas for our visualization. For instance, the *traffic management employees* suggested that our tool could be combined with the Oulu statistical models to estimate traffic data. The *traffic police officers* could combine the information provided by our tool with their accident database to get more insights about traffic consequences. For the *traffic city planner*, it is important to combine road traffic and pedestrian data in real-time. This provides the opportunity to offer optimal places for companies to set their outlets based on the pedestrian traffic around the city.

5 CONCLUSIONS

We described our case study for a space-time visualization of traffic data in the city of Oulu. We presented our exploratory visualization design by building a Web mashup, applying several visualization techniques and validating it with three Oulu different decision-makers. We argue that a proper combination of different visualization techniques that consider multiple data dimensions, and an interactive synchronization between space-time visualizations are suitable for traffic planning activities. This can support data analysis and evaluation of traffic data to reveal trends about interesting traffic events. In future work, we will address some limitations that affect our current implementation: *(i)* it needs to be combined with city statistical models that adjusts traffic capacity per road to support estimation of traffic data, *(ii)* it currently refers only to traffic data but, according to decision-makers' needs, it can be easily extended to pedestrian information, and *(iii)* real-time data is needed to support real-time decision-making activities.

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