A Tool for Exploratory Visualization of Bus Mobility and Ridership: A case study of Lisbon, Portugal

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Abstract
This paper presents a visualization tool for bus mobility and ridership. Data of bus usage from Lisbon, Portugal is used as a case study. The tool runs on two modes; mobility and ridership. The mobility mode displays an animation of bus movement in the city with varying number of riders of each bus stop throughout the day. In the ridership mode, the user can observe the varying number of riders (bus usage) in different areas of the city. The tool also allows the user to interact with the tool by not only selecting different modes of display (mobility and bus ridership), but also changing 2D-3D views, visualizing specific bus lines and stations, and viewing weather conditions. The visualization gives an overview of the dynamic urban flow. This also helps describe bus usage behavior, and it can be useful for urban planning and transport engineering to manage the flow in the city.

Author Keywords
Data visualization; urban mobility; bus usage.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI)

Introduction

Globally, more people live in urban areas than in rural areas, with 54 percent of the world's population residing in urban areas in 2014. In 1950, 30 percent of the world's population was urban, and by 2050, 66 per cent of the world's population is projected to be urban [1]. Government and private organizations should pay attention to smart urban growth, because the city has high population density usually get problems and challenges in public transportation and urban planning. A large number of countries collect data of public transportation such as buses and taxis. These data can be used to benefit design and/or decision for urban management and development. One of the most important issues today is urban transportation. At this time the power of big data can synthesize and analyze data, that prepares us for smart urban growth and for city to transform to smart city. Exploratory data visualization is an important step for analysis and modeling of emerging trends and patterns of citizen behavior in public transport usage.

Related Work

Intelligent transportation is one of the most important elements of the smart city. Analyzing the patterns of public transport usage helps better understand user or citizen behavior, and hence lead to more informed design and planning that meet the real demands and needs. Bhattacharya et al. [2] built a predictive model for predicting bus usage while aiming at an adaptive public transport system that adaptively dispatches buses to meet varying user demands. Foell et al. [3] mine individual bus rider patterns for predicting next-day transport usage, which is useful for design of personalized travel information systems. Visualization of bus usage thus becomes very important for preliminary analysis as it helps researchers seeing emerging trends and patterns that may lead to formulating interesting research questions. Our visualization tool was inspired by other previous projects. One of those projects is the Shanghai Metro Flow by Nagel and Groß [4]. We were inspired by the way different elements of public transport are visualized. So, in this work we develop a more interactive visualization with features that are useful for analysis such as ability to select specific bus line, bus stop, and to display weather events, as well as an option for 2D and 3D views.

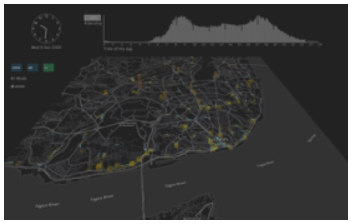
Visualization

As for demonstration, this visualization tool uses a bus data collected from Lisbon, Portugal. It provides multiple perspectives of the data and has two modes of interactive visualization. The first mode is Mobility, which displays an animation of the bus mobility and varying number of riders of each bus stop, including weather events. The second mode is Ridership, which displays an animation of ridership (number of people getting on the bus) in different areas in the city. It was developed with Processing Development Environment (PDE)[1].

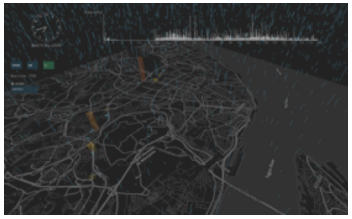
Data Description

Our dataset contains one-week (9-15 Dec 2009) bus information from a bus operator in Lisbon. The dataset has two parts, first is a bus probe data and the other is a ticketing data. The bus probe data contains bus route information, i.e., arrival time at bus stop and bus location. The ticketing data contains the information on the amount of passengers getting on the bus at different bus stop locations.

[1] https://processing.org



(a)



(b)

(c)

Figure 1: Three visualization scenes of Mobility mode: (a) Mobility mode, (b) rain event with a selected bus line, and (c) fog event with a selected bus station.

BUS PROBE DATA

The bus probe dataset contains information of bus route in the city of Lisbon during the period of one week, with 2,104 bus stops and 96 bus lines. We considered the context of the bus with its bus ID, bus stop ID, arrival times at bus stops, and bus stop locations (latitude, longitude).

TICKETING DATA

The second part of the dataset is about travel card usage. Data was collected on bus, after passenger used travel card to board, so the card ID was recorded along with a timestamp and bus specific information such as vehicle ID and bus line ID.

WEATHER DATA

Events of weather condition, such as rain and fog, were extracted from a publicly available weather data source, Weather Underground [5].

Data Pre-processing

In this procedure, we pre-processed the aforementioned data (probe and ticketing data). We combined and arranged the data so that we were able to match all passengers' boarding times recorded in the ticketing dataset to a specific bus arrival time present in the bus probe dataset, and generated an output data file that we further used in our visualization part.

Visualization modes

Our tool consists of two visualization modes, each providing different aspect of the bus usage.

MOBILITY MODE

The Mobility mode displays an animation of bus mobility and varying number of riders of each bus stop (a snapshot is shown in Figure 1a) on the Lisbon map. The visualization also allows the user to select to view a particular bus line and station. For demonstration, this visualization shows an animation of 24 hours, with a graph showing amount of users and clock display. Under different weather conditions, our tool shows, for example, bus mobility in a rainy (Figure 1b) and foggy conditions (Figure 1c). We use a light blue cylinder to visualize each bus, while color intensity of boxes rising up and down with different heights reflect the amount of users at different bus stops throughout the day.

RIDERSHIP MODE

The Ridership mode visualizes the amount of users (every half hour) getting on buses in different areas in the city, which was divided into cells, as shown in Figure 2. For demonstration, the visualization covers the time period of one week. Graph (on the top) shows quantity of all passengers in the city. Color intensity along with the height of the bar on the map are used to display the user density, ranging from yellow (low) to red (high).

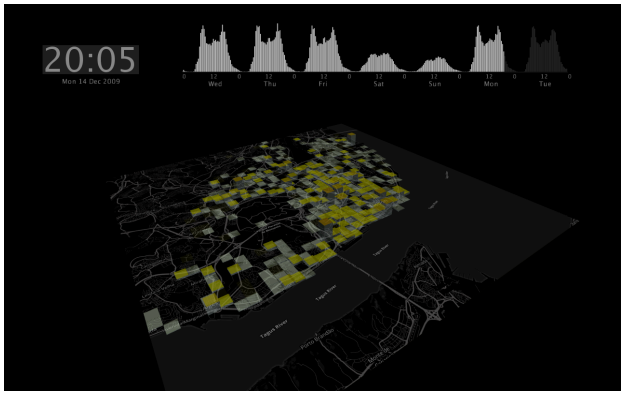


Figure 2: Ridership mode

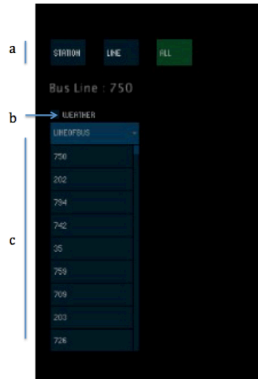


Figure 3: Mobility mode's GUI, a) bus line and station selection button, b) weather condition button, c) drop-down list of bus lines and stations.

Interaction

Mouse and Keyboard inputs are important tools for controlling the visualization. User are able to interact with the tool, such as rotate camera view, zoom in and out.

GUI

In the Mobility mode, user can select to display particular bus line and station using the button on the left of the screen (Figure 3a). User can also choose the line of bus or a number of stations using a drop-down menu (Figure 3c). Moreover, the tool has the Weather button (Figure 3b) for the user to select to view the weather event.

Clock and Graph

The graph indicates quantity of passengers. Two types of graphs are available. First is the overall graph that shows the total number of users in the city throughout the day (Figure 4a). The other is a graph that shows the number of users at a selected bus station (Figure 4b). About the clock, in Mobility mode, an analog clock is used while a digital clock is used in the Ridership mode.

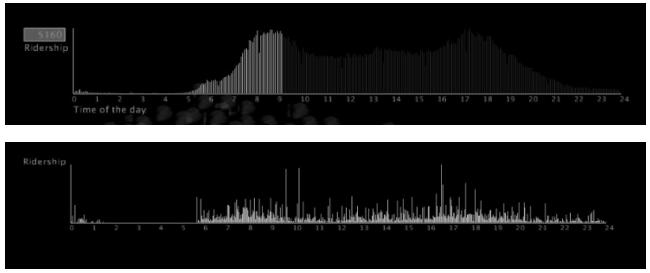


Figure 4: (a) Overall graph, (b) Individual station graph.

Demo

For demonstration purposes, a video clip showing how our developed visualization tool works is available at https://youtu.be/b7MrUHDYSKs.

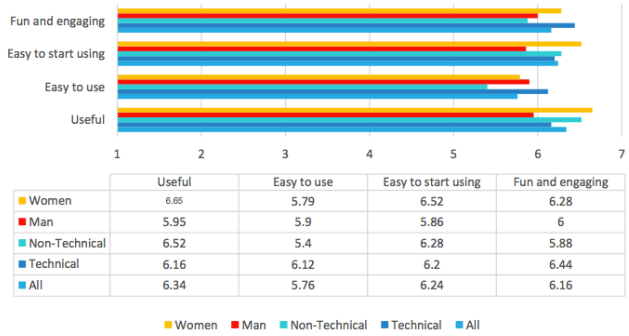
User Experience

We conducted a user experience study to get the first feedbacks from the real users. We based our survey study on the theory of four elements of user experience [6]. We recruited 50 subjects; 21 males and 29 females. They were 25 non-technical and 25 technical background users. We asked each subject to use the tool and afterwards answer a 1-to-7 Disagree-Agree response scale questionnaire with four statements: It is useful; It is easy to use; It is easy to start using; It is fun and engaging. Overall, the average scale for being useful is 6.34, 5.76 for being easy to use, 6.16 for being easy to start using, and 6.24 for being fun and engaging. (Figure 5).

If separated by gender, female on average gave a higher scale than male subjects for being useful, easy to start using, and fun and engaging, while male gave higher scale than female for being easy to use. So we can interpret this result that female users were more pleased with the artistic aspects than male users. For example, some comments from female users are "*The graphic is very nice*" and "*The information is useful, and the interface is attractive*". On the other hand, men were satisfied with the tool being easy to use. Moreover, the satisfaction was slightly different based on background knowledge in technology. Being fun-engaging and easy to use were rated higher from technical students. For example, non-technical users commented that "*The system may not be easy for people with limited knowledge in computer technology*

to interact with the system". This may suggest that our tool may be slightly more difficult to use for users who have limited experience in using software GUI.

In summary, based on the questionnaire results and feedback comments from the subjects, our tool was mostly found to be enjoyable and easy to understand. Nonetheless, the results also suggest that we need to improve the easy-to-use aspect of our visualization.



	Useful	Easy to use	Easy to start using	Fun and engaging
Women	6.65	5.79	6.52	6.28
Man	5.95	5.9	5.86	6
Non-Technical	6.52	5.4	6.28	5.88
Technical	6.16	6.12	6.2	6.44
All	6.34	5.76	6.24	6.16

Women Man Non-Technical Technical All

Figure 5: Questionnaire results

Conclusion

In this preliminary work, we developed a visualization tool that presents the flow of buses and level of ridership in the city. Bus usage information from Lisbon, Portugal is used for demonstration. The tool allows user to adjust the view of display through the mouse and keyboard. Moreover, the tool GUI also allows the user to view a particular bus line and station, as well as weather conditions. We believe that our developed tool is useful as it provides an overview of bus usage behavioral patterns for researchers and designers for conducting further in-depth analysis or making critical decisions, to see emerging trends and patterns or even formulating interesting research questions.

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