Visualization Tool for Taxi Usage Analysis: A case study of Lisbon, Portugal

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Abstract
This paper presents a visualization tool for taxi usage analysis. Data of taxi usage from Lisbon, Portugal is used as a case study. The tool operates on two modes; Mobility and Flow. Mobility mode displays an animation of taxi movement in the city with pick-up drop-off locations, as well as statistical information about the number of total trips made, current and recent available/occupied number of taxis, and top performance taxis. Mobility mode also allows the user to select any particular taxi to be displayed individually through a drop-down menu and search bar. Flow mode gives an overview of taxi movement with an animation of origin-destination (pick-up/drop-off) hourly flows, along with statistical graph of hourly trips made. The user can choose to view any particular time duration to observe the flow. The developed tool can be useful for taxi service providers in scheduling and dispatching management, as well as urban planning and design.

Author Keywords
Data visualization; urban mobility; taxi usage.

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

Introduction

Today, taxi service is available worldwide, especially in urban areas. Taxi is a mode of public transport where passengers determine the trip, as oppose to other modes such as buses, metros, and trains where pick-up and drop-off locations are determined by fixed schedule. Taxi trips are therefore quite random as it varies with the changing demand. As such, there is a need for an efficient taxi dispatching system that allows the taxi service providers to better manage their taxis to constantly meet the demand to minimize cruising time and cost, and maximize their profit [1], as well as for the transport engineers and urban planners to better plan and design urban transportation. To address this need, we thus developed a visualization tool for exploratory analysis of taxi usage and behavior. It is aimed at providing the first-hand information for the users.

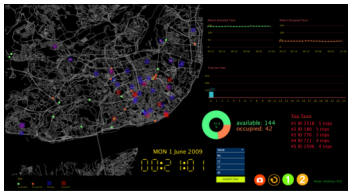
Related Work

Taxi is an essential element of urban public transportation. Trips made by taxis reflect the travel behavior of people, both citizens and visitors. As taxi trips are determined by passengers, which differ from other public transport modes such as buses, metros, and trains, analysis of taxi trips is relatively more complicated – and hence requires a sophisticated analytical tool. Recent efforts in analyzing taxi trips are largely focused on data mining and knowledge discovery. Veloso et al. [2] investigated on spatiotemporal pattern variation of taxi service and explored the relationships between pick-up and drop-off locations. To recognize social function of ubran area, Pan et al. [3] used taxi pick-up and drop-off information to classify location according to land-use. Statistically, Veloso et al. [4] explored the statistical property of taxi trip distance, which follows the Gamma distribution, and discussed taxi driving strategies. By applying the recognized patterns of taxi usage, Phithakkitnukoon et al. [5] developed a Bayesian inference-based model to predict the number of vacant taxis in different areas of the city. By combining taxi trajectory data with environmental data, Veloso et al. [6] investigated on the relationship between the level of taxi usage and flue gases' concentrations in urban area. What seems to be lacking in the literature concerning analysis of taxi data is a tool that helps with exploratory analysis – providing first-hand information, and visually allows the user to interact with the tool in order to acquire specific information – that helps lead to a more in-depth analysis. Our work has been inspired by the NYC flight-taxi visualization [7] and hubcab [8] projects, and we wanted to further convey information such as top performance taxis, pick-up/drop-off flows, and to include user-interactive features such as search bar and drop-down menu, for instance.

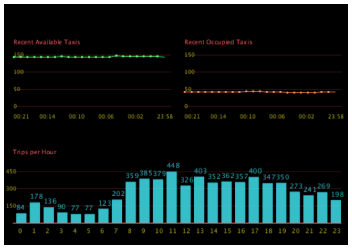
Visualization

Our visualization tool runs on two modes of interactive graphics. The first mode is Mobility, which displays an animation of the taxi movement, pick-up and drop-off locations, statistical graphs of recent taxi status and number of trips, as well as highlights top taxis according to the number of trips made. This mode gives an overview of taxi mobility as well as individual behavior and performance, which is useful for preliminary mobility analysis.

The second mode is Flow, which displays the hourly origin-destination (pick-up/drop-off) flows throughout the day, as well as AM, PM, and 3-hourly flows. This flow mode provides the first-hand information concerning origin-destination streams, which is useful for analysis of travel demand. The visualization tool



(a)



(b)

(c)

Figure 1: (a) Snapshot of the Mobility mode, (b) Graphs showing the numbers of recent available and occupied taxis (top left and right) and the bar chart shows the total number of hourly trips, (c) Pie chart (left) showing the numbers and ratio of taxi status, and top taxis chart (right).

was developed using Processing Development Environment (PDE)[1].

Data

To test out our visualization tool, we used taxi data collected in Lisbon, Portugal. Our dataset contains one-week (1-7 June 2009) taxi information. The data was provided to us by GeoTaxi company, that is one the main taxi service providers in Lisbon. The data contains timestamps and GPS location traces (latitude, longitude) of 186 taxis. It also contains the status of the taxi, whether the taxi is available or occupied. However, the number of passengers was not available. The data sampling rate varies according to the trip's nature. Samples were recorded according to the distance traveled, time elapsed, or when the state changes.

Data Pre-processing

The data was preprocessed to remove some noise (i.e., duplicates, error location records) and synchronize all taxis to be on the same timescale for our visualizations.

Visualization Modes

Our visualization consists of two modes, each providing different aspects of the taxi usage characteristics; mobility and flow.

MOBILITY

The mobility mode displays a dynamic animation of taxi mobility with the taxi status, pick-up and drop-off locations and also displays statistical graphs on a map of Lisbon. A snapshot of mobility mode is shown in Figure 1a. The visualization also allows the user to select to view any particular taxi. For demonstration, the visualization displays an animation of 24-hour taxi mobility, along with three graphs, a pie chart, and a top taxis chart. Figure 1b (top left) shows the numbers of recent available taxis, while Figure 1b (top right) shows the number of recent occupied taxis. Figure 1b (bar chart) shows the total numbers of hourly trips. A pie chart in Fig. 1c (left) shows the current numbers and ratio of taxi status (being available and occupied). Figure 1c (right) shows the top taxis chart, based on the number of trips made.

FLOW

The flow mode displays the hourly origin-destination (O-D) flows based on the pick-up and drop-off locations. Pick-up and drop-off locations were inferred according to the status of the taxi, i.e., the location where the change of status occurs; pick-up location is where the status changes from 'available' to 'occupied', and vice versa for the drop-off location. Fireballs are used to represent to the O-D flows. The visualization also shows daily flow patterns over a given week. A snapshot of the flow mode is shown in Fig. 2. The user can also choose to view AM, PM, and 3-hourly flow patterns. Additionally, it shows a bar chart of the total number of trips made hourly (Figure 3).

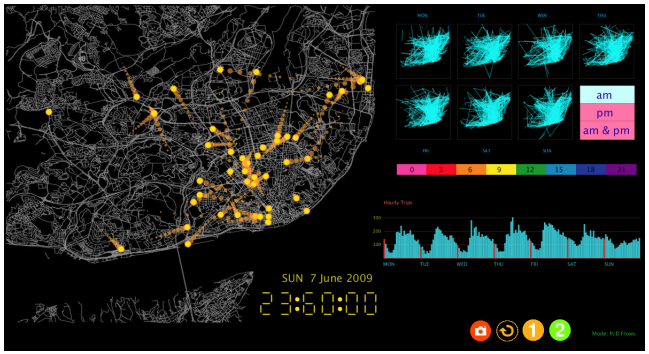
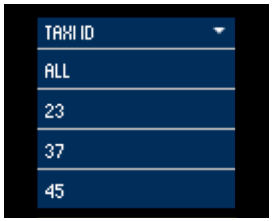


Figure 2: Snapshot of the Flow mode

1 https://processing.org



(a)

(b)

(c) (d) (e) (f)

Figure 4: (a) Drop-down menu, (b) Search bar, (c) Screen capture button, (d) Clear button, (e) Mobility mode selection button, (f) Flow mode selection button.

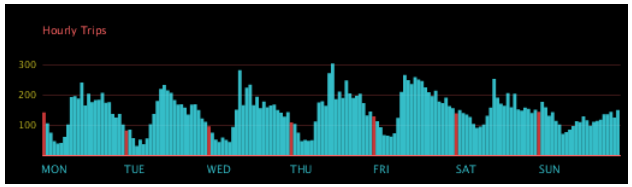


Figure 3: Bar chart showing total number of hourly trips

USER INTERACTION

Mouse and keyboard inputs are important elements for controlling the visualization and providing the user interaction. In the mobility mode, the user can select to display any particular taxi by choosing one of the taxi IDs from the taxi list (dropdown menu, Fig. 4a) or choosing from a search bar (by typing in a taxi ID, Fig. 4b). Both drop-down menu and search bar are located at the bottom right of the screen. In the flow mode, the user can choose to display the daily flow patterns over the AM or PM periods, by clicking on the vertical bar (top right of the screen). In addition, the user can also choose to observe 3-hour flows from the list of hour periods; 0AM-3AM, 3AM-6AM, 6AM-9AM, 9AM-12PM, 12PM-3PM, 3PM-6PM, 6PM-9PM, and 9PM-0AM. These different period flows are useful for analysis of O-D flow dynamism.

MAIN MENU

The main menu consists of four control buttons. The first button is the Screen-capture button (Fig. 4c) that allows the user to get a snapshot of the displayed window, saved to an image file. The second button is the Clear button (Fig. 4d) that removes all the pick-up and drop-off markers (shown in Fig. 5 where red and blue squares mark the pick-up and drop-off locations, respectively) from the screen in the mobility mode, and restarts the animation for the flow mode. Figures 4e and 4f show the mobility and flow mode selection buttons by which the user selects the preferred mode. The selection button will turn green when selected.

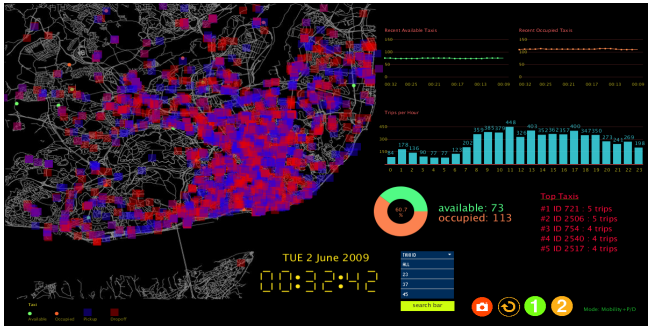


Figure 5: Pick-up and drop-off locations marked with red and blue squares, respectively.

Demo

For demonstration purposes, a video clip showing how our developed visualization tool works is available at https://youtu.be/9RU9JFhEQFs.

User Experience

To get the feedbacks from the real users, a user experience study was conducted with the users who were working in the area of transport engineering or having interest in transportation and urban planning. We designed our survey questionnaire based on the theory of four elements of user experience [10]. There were a total of 50 subjects taking part in our study, including 34 males and 16 females. They were 15 researchers, two academics and 33 students. We asked each subject to use the tool and afterwards answer a 1-to-5 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

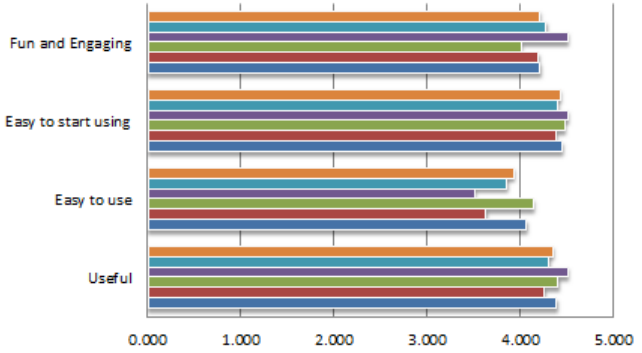
average scale for being useful is 4.34, 3.92 for being easy to use, 4.42 for being easy to start using, and 4.2 for being fun and engaging. Survey results are shown in Fig. 6.

If separated by gender, male users on average gave a higher scale than female users across all four elements. So we can interpret this result that the developed tool is more attractive to the male than female users. Some comments from female users are "*It's too difficult to understand what's going on when first I looked at it*" and "*The system needs to be more attractive*". Additionally, the satisfaction was scattered when based on occupation. Being useful, easy to start using, and fun and engaging were rated first by academics, while the element of being easy to use was ranked first by the researchers. Some comments from the academics are "*It should be tested with Thailand taxi data or other city data to perhaps see some new interesting patterns for comparison*". This may suggest that our tool is found be more attractive to people who have relatively more experience in the transport domain and see the benefits and applications of the tool such as academics and researchers than students who are just getting into the field.

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

Conclusion

In this on-going work, we developed a visualization tool for taxi data exploratory analysis that provides the first-hand information concerning the taxi mobility and flows. Taxi usage data from Lisbon, Portugal was used



	Useful	Easy to use	Easy to start using	Fun and Engaging
All	4.340	3.920	4.420	4.200
student	4.303	3.848	4.394	4.273
academic	4.5	3.5	4.5	4.5
researcher	4.400	4.133	4.467	4.000
female	4.250	3.625	4.375	4.188
male	4.382	4.059	4.441	4.206

Figure 6: Questionnaire results

for demonstration. The tool allows the user to select different modes of display and view any particular taxi and flows patterns. We believe that there are a number of stakeholders for our developed tool that include taxi service providers, transport engineers, and urban planners.

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