Visualizing Mobile Phone Usage for Exploratory Analysis: A case study of Portugal

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Abstract
This paper presents a visualization tool for mobile phone usage analysis. Data of mobile phone usage from Portugal is used for demonstration. The visualization runs on two modes: Flow and Intensity. Flow mode displays a 3D animation of mobile phone usage, showing the communication flows between municipalities. Intensity mode displays a 3D animation of the intensity level (amount of mobile phone usage) per cellular tower aggregated every 30 minutes. The tool also allows the user to interact with it by not only selecting different modes of display, but also visualizing data of any selected municipality. The visualization gives an overview of the dynamic communication flows, which helps describe mobile phone usage characteristics and social behavior. It can also be useful for telecom operators for better informed planning and management, as well as for urban planners and researchers for exploratory behavioral analysis.

Author Keywords
Data visualization; urban flow; mobile usage

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

Introduction

The advance in information and communication technologies enables easy collection of data of telecommunication such as mobile phone, SMS, and Internet usage, that can be useful and beneficial to telecom operators in service improvement through customer behavior analysis. With fast growing urbanization, these telecom data become even more useful not only to the telecom operators but also to urban planners in understanding communication patterns that reflects social behavior of inhabitants, and can even convey mobility information for travel behavior analysis [1]. Exploratory data visualization is an important tool for analysis and modeling that can provide the first-hand information of emerging trends and patterns of citizen behavior.

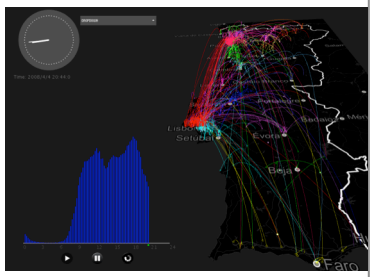
Related work

Mobile phone data (communication logs) is being collected by telecom operators for billing purposes. By mining this mobile phone data carefully, it reveals many interesting social behavior [1][2] and mobility patterns [3][4] that helps us better understand human behavior at a large-scale, which collectively forms community and city behaviors. With these new insights into the city behaviors, more informed decisions and management for urban planning and transport engineering can be achieved. Phithakkitnukoon et al. [1] reveals interesting interplay between sociality and mobility, by mining longitudinal mobile phone data. Mobile phone data was also analyzed to study the effect of the weather on people's sociality [2]. Not only the communication logs but also location traces of mobile phone data has been used to understand people's mobility, as Demissie et al. [3] shows how to use mobile phone data to infer about travel demands with an application in public transport development in a developing country. Song et al. [4] mined mobile phone location data to find the universal law of human mobility. What seems to be missing in the literature is a visualization tool that can help provide the first-hand information of emerging trends and patterns, which may lead to a more in-depth analysis.

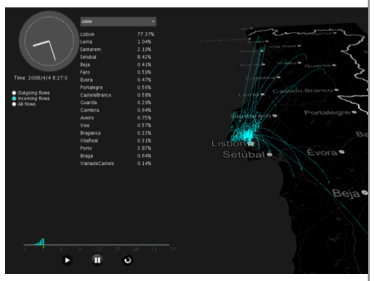
We were inspired by a couple of interesting projects. The first one was the *Borderline* project by MIT Senseable City Lab [5] that shows a visualization of communication flows across the United Kingdom. We were attracted by the 3D animation and the curvature lines representing the call connection. Another project was the Beijing SMS EVE by Orange Labs and VIZMIND [6]. We were inspired by the way of visualizing SMS data using firework-like effect. So, we wanted to extended on these visualizations to include the user interaction feature that allows the user to control the displayed components. Visualization of mobile phone usage is useful for preliminary analysis as it helps researchers seeing emerging trends and patterns that may lead to formulating interesting research questions. So, in this work we develop an interactive visualization with features that are useful for analysis such as ability to choose to observe communication flows for any specific municipality and displays the call flow percentages between selected municipalities.

Visualization

As for the demonstration, this visualization tool uses mobile phone data collected from Portugal. It provides multiple perspectives of the data and has two modes of visualization. The first mode is Flow, which displays a 3D animation of call flows between municipalities and allows the user to choose any particular municipality to



(a)



(b)

Figure 1: A snapshot of Flow mode: (a) Default flow mode screen, (b) Selected municipality flows.

be displayed, including call flow percentages between municipalities. The second mode is Intensity, which displays a 3D animation of intensity level or the amount of mobile phone usage per cellular tower, including a graph that presents municipality-wise information. Our tool was developed with Processing Development Environment (PDE)[1].

Data Description

Our data is a Call Detail Record (CDR) that includes both communication logs and locations of the connected cellular towers. The location (latitude and longitude) of the nearest cellular tower was recorded whenever call was made or received (i.e., cellular network connection was established). Our data includes a total of 1.3 million mobile phone users and 6,509 cellular towers across 308 municipalities of Portugal. The data only comprises of voice call information; timestamp, caller's ID, callee's ID, call duration, caller's connected cell tower ID, and callee's connected cell tower ID. The data does not contain information relating to text messages (SMS) or data usage (Internet).

Data Pre-processing

In this procedure, we pre-processed the aforementioned data by combining, grouping, and rearranging our data to prepare input data for our visualization tool. For flow mode, we extracted all incoming and outgoing calls information for each cellular tower. We then computed the percentages of these incoming and outgoing calls per municipality. Timestamp and municipality information were considered for regrouping the flow data. For intensity mode, we prepared the data that contains the amount of mobile phone calls per cellular tower. The amount of calls is aggregated for every 30 minutes.

Visualization Modes

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

FLOW MODE

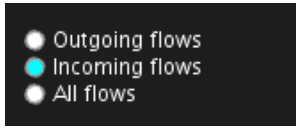
The Flow mode displays a 3D animation of mobile phone usage between originating cellular tower and receiving cellular tower on the Portugal map. A snapshot of the flow mode is shown in Figure 1a. The communication flows are represented with curvature lines connecting between the originating and receiving towers. Different colors are used for different municipality flows, so that makes it easy for the user to distinguish the municipality-wise flows. The visualization also allows the user to choose to view flows associated with any particular municipality. Moreover, it provides the simultaneous call percentages at given time between the selected municipality and other connected ones, as well as allows the user to choose to view just outgoing calls or incoming calls or both. For demonstration, this visualization shows an animation of 24 hours, with a graph showing amount of calls hourly throughout the day and time (displayed with analog clock graphic). A snapshot of the flow mode with the only selected outgoing calls is shown in Fig. 1b.

INTENSITY MODE

The Intensity mode visualizes the amount of calls per cellular tower, aggregated over 30 minutes. Color vertical cylinders are used to represent the intensity level – the taller the cylinder, the higher the intensity. A snapshot of the intensity mode is shown in Fig. 2. For demonstration, the visualization covers the time period of one week. A graph located at the bottom left of the screen shows the

[1] https://processing.org

(a)



(b)

(c)

Figure 3: GUI: (a) Drop-down list of municipalities, (b) Types of flow button, (c) Display control buttons.

total call intensity hourly, while a vertical bar chart (left side of the screen) shows the call intensity of individual municipalities, separated by different colors that also match the cylinder colors on the map.

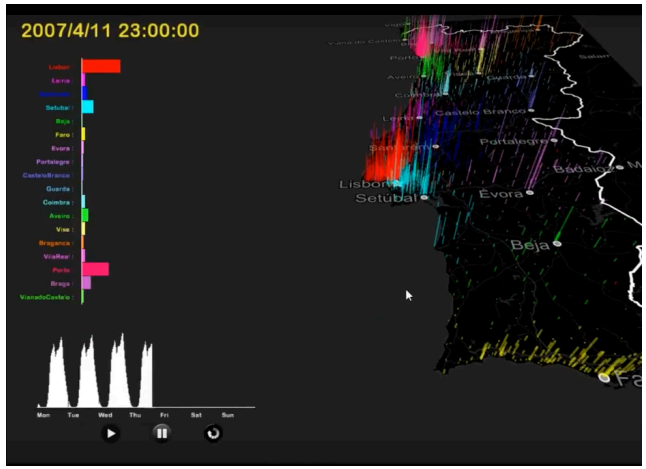


Figure 2: Intensity mode

INTERACTION

Keyboard and mouse inputs are important tools for controlling the visualization. Users are able to interact with the tool, such as zoom-in, zoom-out, change of viewpoint, and select to visualize the data of any particular municipality.

GUI

In the Flow mode, the user can select to display the data of any particular municipality by using a dropdown menu on the top-left of the screen (Fig. 3a). User can also choose to display just outgoing flows or incoming flows, or all flows for the selected municipality, using the button on the left on the screen (Fig. 3b). Moreover, user can control the animation using Play, Pause, and Restart buttons that are located in the bottom left of the screen (Fig. 3c).

Demo

For demonstration, a video clip showing how our developed visualization tool works is available at https://youtu.be/NbQp7OMT6nE.

User Experience

A user experience study was conducted to get the feedbacks from the real users. Since the tool was developed for potential users who are in the telecom area. So, we recruited subjects who are working or associating with the telecom industry, such as telecom engineers, researchers, and developers. We based our survey study on the theory of four element of user experience [7]. We recruited 50 subjects; 32 males and 18 females. There were 23 subjects who are 21-30 years old, 23 subjects who are 31-40 years old and four subjects who are 41-50 years old. 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 5.28, 5.42 for being easy to use, 5.44 for being easy to start using and 5.38 for being fun and engaging (Fig. 6).

If separated by gender (Fig. 7), female on average gave a higher scale than male subjects for all statements. So we can interpret this result that female users were more attracted to the tool than male users. For example, some comments from female users are "*This program is so beautiful*" and "*It's so easy to use*". When the result is separated by age (Fig. 8), on average the users who are in the age group of 41-50

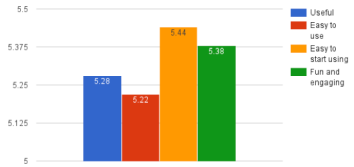


Figure 6: Overall result

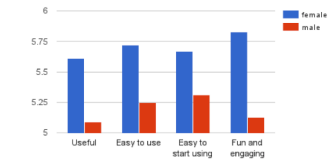


Figure 7: Result separated by gender

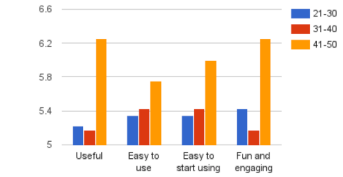


Figure 8: Result separated by age

years old gave a higher score than other age ranges. This can be interpreted that the users with more experience in telecom industry see more benefit and potential useful applications of the tool. For example, some comments from male users in the 41-50 years old age group is "*The tool is quite useful and it is easy to understand*". The tool seems to be not so attractive to user age range of 21-40 years old. For example, some comments from a male user in 21-30 age group is "*It's difficult to use*" and from a female user in age group of 31-40 years old is "*It isn't clear enough to understand what's going on*". In summary, based on the questionnaire results and feedback comments from the subjects, our tool was mostly found to be easy to start using. Nonetheless, the results also suggest that we need to improve the easy-to-use aspect of our visualization tool.

Conclusion

In this work, we developed a visualization tool that displays the flow and intensify of mobile phone usage. Mobile phone data (CDR) collected from Portugal was used for demonstration. The tool allows users to view a particular municipality data, and displays simultaneous percentages of communications between municipalities. Moreover, the user can adjust the view of display through the mouse and keyboard. We believe that our tool is useful and beneficial to telecom operators and also for urban planners and researchers as it can facilitate exploratory analysis of mobile phone data that helps in observing emerging trends and patterns, which may lead to further more in-depth analysis or forming interesting research questions concerning mobile phone customer characteristics or citizen behaviors.

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