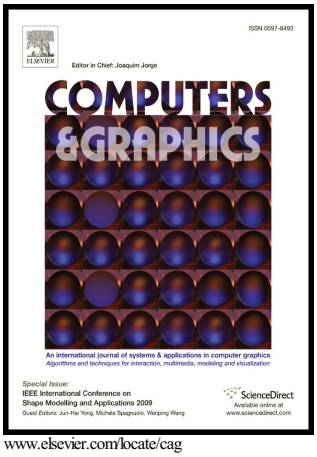

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Visual Analysis of Bike-Sharing Systems

Guilherme N. Oliveira[a], Jose L. Sotomayor[a], Rafael P. Torchelsen[b], Cláudio T. Silva[c], João L. D. Comba[a,*]

[a]*Instituto de Informática - UFRGS, Brazil*
[b]*CDTec - UFPel, Brazil*
[c]*New York University, USA*

Abstract

Bike-sharing systems are a popular mode of public transportation, increasing in number and size around the world. Public bike-sharing systems attend to the needs of a large number of commuters while synchronizing to the rhythm of big cities. To better understand the usage of such systems, we introduce an interactive visualization system to explore the dynamics of public bike-sharing systems by profiling its historical dataset. By coordinating a pixel-oriented timeline with a map, and introducing a scheme of partial reordering of time series, our design supports the identification of several patterns in temporal and spatial domains. We take New York City's bike-sharing program, Citi Bike, as a use case and implement a prototype to show changes in the system over a period of ten months, ranking stations by different properties, using any time interval in daily and monthly timelines. Different analyses are presented to validate the visualization system as a useful operational tool, that can support the staff of bike-sharing programs of big cities in the exploration of such large datasets, in order to understand the commuting dynamics to overcome management problems and provide a better service to commuters.

Keywords: Bike-sharing systems, visual analytics.

1. Introduction

Public bike-sharing systems (BSSs) are services of increasing popularity, with many instances running around the world. The system is based on a set of stations located at several spots around the town with bikes available for rent. Commuters can take a bike out of any station, ride it for a limited period and then return it to any station. One problem with this usage scheme is that the operational staff has little control over the distribution of resources (bikes) as commuters are always moving them around. This control ensures that the stations do not get full or empty (an event called *outage*), thus users can get a bike from any station and also leave a bike at any station. Station rebalancing is used to prevent outages. Trucks are used to move bikes from different locations, which raises questions about how to choose the best route that minimizes gas consumption and time. Also, trucks are subject to traffic conditions and popular stations might need to be rebalanced more often than others.

Citi Bike of New York City is an example of a bike-sharing system. It was deployed in May of 2013 and is the largest bike-sharing system in the United States, officially serving 6,000 bikes through 330 stations with a total of more than 11,000 docks [1]. Rebalancing efforts in Balancing Bike-Sharing Systems are usually done during the night when the usage frequency is minimal (or there is no service at all). Citi Bike NYC's rebalancing operations are performed during daytime to handle the intense commuting behavior. The recording of the information about each station throughout time (station states) can serve as an indicator of unbalanced stations, as well as circulation habits in the city. The analysis of usage data may lead to strategies for improving rebalancing procedures, plan upgrades in the infrastructure, and help commuters better use the program. Previous work with such data analysis, usually focuses on simple scenarios, like small time windows, few variables, only trips or only balance data. In this work, we provide an exploratory view of bike-sharing usage data to understand its underlying dynamics. We provide sample analysis of such data, that could be of use to the operational staff of bike-sharing systems trying to improve the quality of service to commuters. The data is comprised of the station states (number of bikes and free slots available) recorded at periodic time intervals, as well as commuter's trip information (origin and destination station and timestamps). Figure 1 shows one of the visual designs proposed to inspect station state data.

The main contributions introduced in this work for the analysis of this data can be summarized as follows:

- encoding of the system usage data in pixel-oriented visualization designs that help understand the dynamics of station states and trip circulation patterns;
- visual designs that support flexible partial reordering of the pixel-oriented representation using an interactive brush that selects time intervals and station groups;
- several analysis scenarios conducted on real data from Citi Bike illustrate the capabilities of the proposed solutions to reveal relevant spatial and temporal patterns.

*Corresponding author.
Email address: comba@inf.ufrgs.br (João L. D. Comba)