TransitTrace: Route Planning using Ambient Displays

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ABSTRACT

Every day, travelers use Public Transport Systems to reach their destinations. Public Transport Authorities generally use passive wayfinding devices, including ambient displays, to provide useful information for travelers, such as the number of vehicles in the vicinity of a stop and their estimated times of arrival. However, due to both the complexity of the transport networks and the lack of sophistication in the design of these displays, the information provided by these devices is limited. We present *TransitTrace*, a visualization that exploits interaction-free ambient displays to provide travelers with more detailed information and ultimately to help them to navigate the city using a Public Transport System. Specifically, the proposed design makes use of a novel animation strategy to aid travelers in route planning tasks. In this paper, we describe details about the system and visualization design of *TransitTrace*, as well as its initial implementation using transportation data provided by the City of Chicago.

Categories and Subject Descriptors

H.2.8 [**Database Applications**]: Spatial databases and GIS; H.5.1 [**Multimedia Information Systems**]: Animations

Keywords

Public Transport Systems, Geotemporal Visualization, Ambient Displays

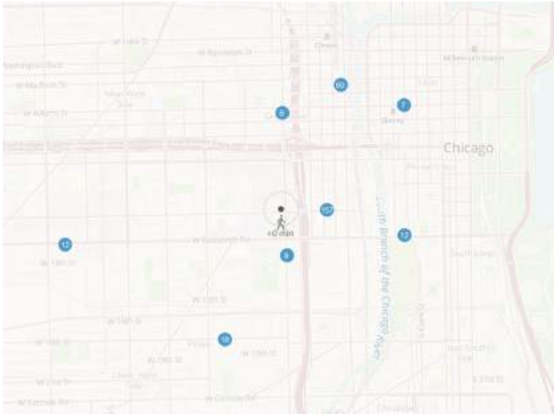
1. INTRODUCTION

Public Transport Systems (hereafter, PTS) are a primary infrastructure of a city. Improving the accessibility and usability of PTS is one of the major concerns of urban planners and city administrations. Effective usage of PTS can lead to economical, environmental, and social benefits, and creates more sustainable cities [12]. Millions of commuters use PTS on a daily basis for getting to and from work; a city's tourism industry also relies on PTS to encourage visitors to explore a range of urban attractions. PTS are inherently complex and travelers can make use of different navigation tools to help plan their trips. A study conducted by the Israeli Ministry of Transport identified system legibility as one of the greatest barriers to the more widespread of use PTS [19], indicating that new visualization approaches could enhance PTS.

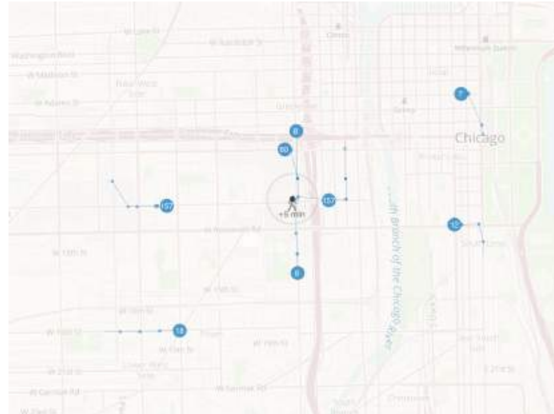
SIGSPATIAL'15, November 03-06, 2015, Bellevue, WA, USA.
© 2015 ACM. ISBN 978-1-4503-3967-41511...$15.00
DOI: http://dx.doi.org/10.1145/2820783.2820857

We introduce a novel visualization technique that makes use of animated PTS trajectories in order to enable multiple users to plan routes simultaneously via ambient displays. Our project has been inspired by the Chicago Transit Authority's web-based slideshow, "DIY Transit Info Display" [2]. This initiative encourages owners of commercial services to feature displays that provide helpful information for the customers. These ambient displays could be placed in publicly viewable areas throughout the city, such as at malls, museums, universities, and outside workplaces. For this reason our visualization is explicitly *not* interactive, making it more difficult to enable route planning and presenting an interesting visualization challenge. The only assumption that we make is that the user is interested in catching transports that pass within the immediate vicinity of the ambient display location close to the time he or she is watching the visualization. We also have no knowledge about the destination of the user, and therefore we visualize routes to *all* of the reachable destinations from the nearest transportation stops. This constraint holds also because the visualization needs to serve multiple users at the same time. Moreover, we aim at letting the user freely plan his or her journey based on the availability of nearby rides; therefore we want to visualize all the possible alternatives available to reach a particular destination. Finally, we aim at arousing users' curiosity and helping them to become more aware of the overall structure and availability of transit systems routes throughout the city. We present our visualization system, *TransitTrace*, using Chicago Transit Authority (CTA) data to explore route planning in the City of Chicago. CTA currently has 126 bus routes and 8 trains routes, and is one of the most complex PTS in the world [1].

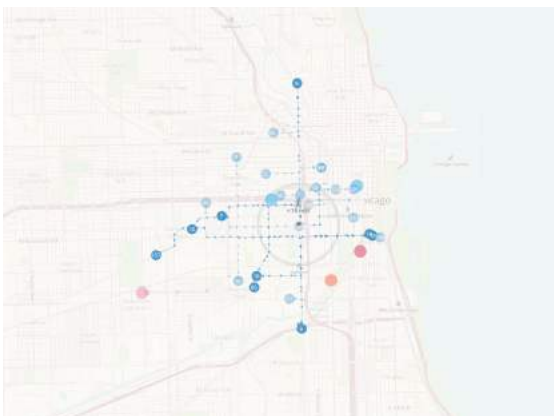
Understanding movement patterns is an important research topic in visual analytics, and a wide variety of tools that assist in analyzing movement data have been developed in recent years. This topic is also closely related to PTS visualization, which necessarily involves representing moving vehicles. Andrienko et al. [4] list three visualization categories for movement data: *direction depiction*, *summariza-*



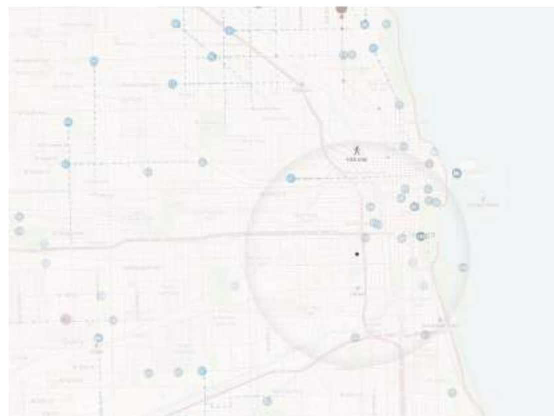
(a) State 1: The animation shows begins by showing the current position of all vehicles that will be arriving in the users' vicinity within a given window of time.



(b) State 2: The animation animates slowly, showing the progression of vehicles moving toward the user.



(c) State 3: The animation zooms out as needed to show vehicles and the traces of their routes as they move away from the users' position. Colored dots appear indicating available transfers to subway lines. A widening circle centered around the current location indicates how far a user could walk in the same amount of time.



(d) State 4: The animation freezes briefly to show the position of each vehicle (and any vehicles that can be accessed via a transfer) after one hour. The animation then reverses so that the user can "trace back" the vehicle closest to a particular destination and determine which vehicle to board and what transfers are necessary.

Figure 1: The figures show the different steps of the animation, centered around a particular location in Chicago where the ambient display is installed. When the animation reaches State 4, it plays in reverse until it returns to State 1, at which point the animation repeats, updated with new, realtime data.

tion and *pattern extraction*. Zhong et al. [20] and Goncalves et al. [10] describe common techniques that are used to visualize movement data which include *static maps*, *space-time cubes*, *animated maps*, and *small multiples*. Work by Nguyen et al. [14] addresses the problem of representing the temporal information on the routes, namely, visually representing the different trips that occur in the day along the same route. They propose using a space-time cube in which two of the three axes represent the spatial information and the third axis provides the temporal information. Animation techniques can be effective in visualizing movement data. For example, *TRAVIC* [5] is a visualization tool that features animated maps, although the movements are mostly based on static schedule data. A recent project by Nagel and Groß, *Shangai Metro Flow* [13], encourages users to reflect on overall urban patterns using a visually appealing animation. Visual aesthetics is especially important to consider when the visualization is targeted for the general public [6]. More generally, Forbes et al. [8] explore how visualizations of dynamic data can make use of animation, and more recent papers examine the use of motion in different visualization contexts [7, 9, 18]. Janetzko et al. [11] combine multiple techniques to show movement data from different perspectives. Their work applies trajectory abstraction on a map and provides a simplified graph visualization with coherent topology. They also make use of a small-multiple technique to show changes in the movement of observed subjects. *Flow Maps* [17] are a common visual encoding for geospatial movement data between different geographic regions, but may lead to visual clutter when used to visualize large geotemporal datasets.

2. SYSTEM OVERVIEW

Today many transit authorities offer an API for developers providing transit schedules and real-time information such as delays or service temporal unavailability. The most common format for these data is the General Transit Feed Specification, or GTFS [3], widely adopted by many transport authorities world-wide. Our system is currently built on GTFS, but could also be extended to other data formats; *TransitTrace* visualizes the public transportation of Chicago using the freely available GTFS data provided by the Chicago Transit Authority. Chicago has a highly complex transportation network that makes it infeasible to use GTFS data directly on the client side, and thus some server side preprocessing is required. For this reason we deploy a server to provide a RESTful service that the client visualization uses to request the data as needed for the current view. In our visualization, we want to obtain a live map with realtime animations that simulate each vehicles' position, and we also want to show their estimated future positions. For this reason we have implemented a look-ahead interface in which the client periodically requests transit information for a certain time interval. Each request specifies: a circular bounding region that represents the area nearby the ambient display location; a time interval used to retrieve trips based on time; a maximum number of transfers within the same journey; the maximum distance of transfer stops; and the maximum waiting time for transfers. Based on these parameters, the server selects only the trips within the specified bounding box and all of the trips that connect to these trips. We filter out any transfer that is not relevant for the user, such as those that occur before the trip reaches the immediate vicinity of the user location area. In our implementation, we define a transfer as occurring when the "trace" of two vehicles cross paths, but only when one vehicle has at least one stop that is sufficiently close (both temporally and spatially) to a stop made by the other vehicle.

3. VISUAL DESIGN

We designed *TransitTrace* to visualize a high number of transit routes on an overview map. An initial analysis of the CTA data set revealed that there can be more than 1,000 vehicles in service at a given time. We know however that it is not relevant to show all the trips that are in service, nonetheless the number of relevant routes could still be quite hight. Since the visualization is meant to be installed on non-interactive ambient displays and to serve multiple users at the same time, we cannot readily adhere to one of the canonical visual design guidelines, that is, providing an overview first, and only then providing further details on demand [15]. *TransitTrace* was created to address these issues.[1] Transports— buses and subway trains— are visually represented as colored circular markers that leave a trail, or "trace," as they move on the map. We assign all buses with the same blue color and assign each train with a color that identifies the line it runs on (this color is available in the CTA dataset). Moreover, to emphasize the transportation mode, train markers are bigger than bus markers. In the case of buses, we also display their route number on top of their circular marker. We also use color and transparency to differentiate distant, difficult-to-access transports from those that are in the close vicinity of a stop. The animation of the traces that the transports leave behind is the main visual component of the visualization. We use these traces to overcome the difficultly of tracking an object over time and remembering where it has been previously. Traces disclose vehicle paths, also enabling the user to see the vehicle directions. To reduce the visual clutter we designed traces so that they gradually fade out, and we display only the parts of transport path that are relevant to the traveler. This dramatically reduces the amount of overlapping between different vehicle traces leading to a more clear and concise representation. Each vehicle trace is long enough to intersect with the traces of vehicles that connect to it. This helps to highlight possible transfers to other vehicles. Stations are visually represented as small circular markers that appear as the vehicle markers pass by. Currently, it is not viable to display the name of the stations since in some situations there are too many labels to display at the same time. This limitation is due to the nature of the installation, which requires any text to be of an easily readable size, and also due to our goal of striking a balance between functionality and aesthetic appeal [16]. Nonetheless, showing the stations' position still provides a valuable information, enabling the user to locate reachable destinations and to estimate how far those destinations are from the station. Future work will explore different methods to provide textual indicators when needed.

A challenge of this project is supporting complex route planning tasks without the use of any interactions that would enable the specification of complex queries for individual users. We thus designed our visualization using an animation technique that makes route planning viable even when the circumstances precludes interaction. Our animation dynamically shows vehicle movements forward and backwards in time. This enables users to see which vehicles pass by the desired destination as the animation plays forward, and then lets them follow the vehicles back toward the origin as the animation plays in reverse. This "spring" animation is reminiscent of the behavior of a spring as it compresses and releases. The animation begins by displaying the current vehicles' positions, showing the traveler where nearby transports are located relative to his or her position. The visualization then gradually animates, providing a prediction of where the vehicles will be over the next hour, allowing the user to understand how the vehicles will move and to detect whether or not any of these vehicles will lead to a desired destination. When the animation reaches the end of the observation period, it reverses course, rewinding to the newly updated vehicle positions. It is this last rewinding step that makes the animation effective for route planning. While the animation plays forward the user can of course look for vehicles that stop by his or her destination, but by the end of the animation it can be difficult to remember where these vehicles originally came from, especially if there a number of transfers are required. The reverse animation lets the user *trace back* the transports to their origin, allowing the user to successfully reconstruct the sequence of vehicles from the destination toward the origin, and ultimately to see which vehicle he or she should first board, and where the closest station to board that vehicle is. Fig. 1 shows an overview of the different stages of the animation.

[1] A video demonstrating the functionality of *TransitTrace* can be found at https://vimeo.com/132205854.

In the initial state, the animation progresses slowly to give sufficient time for the user see which vehicles are in his or her current vicinity. After this initial state, the animation progressively speeds up in order to reduce the amount of time required to show the whole observation period; for the same reason, the animation is asymmetric, and runs backward faster that it does when it runs forward. This is because in the reverse animation the user already knows which individual vehicle he or she needs to track.

We have designed a series of informal user studies using realtime City of Chicago transportation data to evaluate how successful our visualization system is at enabling route planning tasks. While these studies show that users, after a short explanation, are able to use our visualization effectively and moreover that they find our approach enjoyable to use, further work is necessary to find appropriate timing and visual encoding parameters that are most effective with the widest range of travelers, such as the speed of the animation, the length of the the visual traces, and the use of text to provide meaningful contextual clues.

4. CONCLUSION AND FUTURE WORK

This paper introduces *TransitTrace*, a web-based visualization that enables users to navigate Public Transport Systems using ambient displays. Our visual technique combines trajectory visualization with animation to overcome the limitations that arise from the unavailability of interaction on ambient public displays; we show that it is possible to effectively enable real-time route planning on a dynamic overview map even without any user interaction. Moreover, our visualization can also be used by multiple users at once; initial evaluation has shown that multiple users are simultaneously able to use our visualization to plan their routes effectively. We are currently working with public transport agencies in Chicago and in Milan to test *TransitTrace* in real-world situations.

5. ACKNOWLEDGMENTS

This work is funded in part by NSF CMMI award #1402918.

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