Chapter 4
Urban Activity Explorer: Visual Analytics and Planning Support Systems

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Abstract Urban Activity Explorer is a new prototype for a planning support system that uses visual analytics to understand mobile social media data. Mobile social media data are growing at an astounding rate and have been studied from a variety of perspectives. Our system consists of linked visualizations that include temporal, spatial and topical data, and is well suited for exploring multiple scenarios. It allows a wide latitude for exploration, verification and knowledge generation as a central feature of the system. For this work, we used a database of approximately 1,000,000 geolocated tweets over a two-month period in Los Angeles. Urban Activity Explorer's usage of visual analytic principles is uniquely suited to address the issues of inflexibility in data systems that led to planning support systems. We demonstrate that mobile social media can be a valuable and complementary source of information about the city.

Keywords Social media · Visual analytics · Planning support · Big data · Human activity

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1 Introduction

Urban planning professionals address a diverse range of issues from public transportation and affordable housing to environmental sustainability and economic development. Urban planners' focus on solutions and policies that improve and optimize urban systems requires an understanding of complex and dynamic urban behavior. To help support decision-making about urban issues, analysts often turn to reports and information on prior trends and patterns of human activity, including commerce, mobility and lifestyle needs. However, existing sources of information about human behavior have significant limitations. Some sources offer a broad snapshot of these complexities with large time gaps (e.g., U.S. census is conducted every 10 years, and American Community Survey estimates are published every year); others are time consuming, expensive and offer only a small sample of the intended information (e.g., questionnaires with small sample sizes and public meetings with sparse attendance), and many present temporal, topical and spatial information separately with no effective way to understand them together.

The explosive growth of social media has resulted in a huge amount of data (e.g., more than 500 million tweets/day) (Twitter Usage Statistics—Internet Live Stats 2017). This offers new opportunities to analyze human activity. Mobile devices allow people to stay connected with others while recording a user's time, location, thoughts and interests. These traces of user activity generate large datasets with great potential for understanding aggregated behavior (Ruths and Pfeffer 2014). Making sense of these large-scale datasets, however, requires the use of new techniques. Our work proposes the use of visual analytics, a field of analytical reasoning facilitated by interactive visual interfaces coupled with computational techniques. Visual analytics is a rapidly growing subfield of computer science that has evolved from information visualization and analytic reasoning with a particular focus on interaction. It has made inroads in managing cognitive load, pattern recognition and search procedures, particularly in very large data sets (Thomas and Cook 2006). A primary goal of our work is to provide planners with opportunities to manage and interpret unique, large-scale data sets such as those generated from social media.

Our research is focused on developing a Visual Analytics Systems (VAS) that presents spatial, temporal and topical information simultaneously and allows for feedback from experts in an easy-to-use web-based platform. Our system is designed to allow users to explore disparate forms and patterns of information, as opposed to a top-down system with fixed and predetermined capacities, evaluative criteria and outcomes. Our exploratory approach allows participants to gather a variety of insights about a single topic by using diverse, inter-related types of information. Previously, we conducted a survey among design and planning professionals to determine their workplace and research needs in software. This information guided the first version of our Visual Analytics Interface called the Urban Space Explorer. This interface was designed for exploration of the spatial, temporal and topical aspects of social media data as a proxy for human activity.

Following the development of our visual analytics system, we conducted a comprehensive user study of planning researchers and practitioners to gain feedback regarding the usability of our system.

This chapter focuses on our ongoing efforts to develop and improve our interface for planning professionals. The Urban Activity Explorer provides planners with a variety of tools to explore cities according to their specialized interests as well as to annotate and add knowledge back to the system. Urban Activity Explorer's new features include searching for specific terms in the dataset, focusing on a specific region and exploring topical and temporal data within that region, and annotating information in specified regions and then retrieving those annotations at a later time. These advancements contribute to our larger effort to develop an exploratory interface for planning professionals using unique, large-scale data.

We begin with a review of scholarship on social media, Planning Support Systems (PSS) and Visual Analytics Systems (VAS), and explain how these domains influence and are incorporated into our work. Next, we describe the variety of features within the interface that offer users new methods to explore large-scale data in relation to their interests. Finally, we will conclude by describing our next steps and challenges to further test and improve our research.

2 Literature Review

2.1 Social Media

The explosive growth of mobile devices and social media in the recent years has created new opportunities for people to communicate and interact as they live and move within cities. Data communicated through social media services such as Twitter, Instagram, Foursquare and Facebook, in contrast to previous data sources and methods, are continuously produced by diverse populations during the course of their everyday activities. It is this aspect of our work that can be described as predominately 'bottom up', in contrast to the many existing methods that are 'top down' (e.g., U.S. census data). These data are very rich in terms of time granularity, content, geographic information and availability. Utilizing these data sources can create new streaming (i.e., approaching real time) methods for understanding complex aspects of human activity in cities. Analyzing and utilizing these large and unstructured datasets for urban analysis has many challenges and requires new methods in computation and data analysis (Kitchin 2013).

Different methods have been created to obtain new knowledge from social media in different domains. Shakaki et al. (2010) used real time Twitter data to sense occurrences of extreme events by considering each Twitter user a 'sensor' and using various location estimation methods to find centers of earthquakes in Japan so that notifications could be sent to registered users. Topic modeling and event detection have been used by Dou et al. (2012) to sense and tell the story of Occupy

Wall Street protest events. Other notable applications of social media data include news extraction for journalistic inquiry (Diakopoulos et al. 2010), situational awareness and crisis management (MacEachren et al. 2011), and summarizing important political issues from the perspective of political institutions (Stieglitz and Dang-Xuan 2013).

Many urban scholars have utilized data derived from social media services and mobile devices to shed light on various urban phenomena. Researchers at MIT's Senseable City Lab utilized Location Based Services (LBS) data from cellphone towers to map the intensity of activity across time and space (Ratti et al. 2006). Wessel studied how social media, place and food networks interact and overlap with each other and can ultimately transform the meaning of place (Wessel 2012). Location information from social media has also been used to identify active city centers in regions (Sun et al. 2016).

These are a few examples of sophisticated analyses conducted using social media data in urban settings. However, these methods and data sources are not easily accessible to urban planners and researchers and are not yet geared towards their goals and needs.

2.2 Planning Support Systems

Urban planners have historically relied on various forms of Geographic Information Systems (GIS), urban modeling, and statistical software with the hopes of making more accurate planning and policy decisions. Klosterman traces the historical development of software used by planners from faith in large-scale urban models in the 1960s, to microprocessor-based programs in the 1980s, to the widespread availability of GIS programs in the 1990s (Klosterman 1997). He makes the case for PSS as an "*information framework that integrates the full range of current (and future) information technologies useful for planning*" (Klosterman and Pettit 2005, p. 477). More specifically, PSS are dedicated to planners' analytic, forecasting, or design tasks that fit within the workflow of planning professionals (Harris and Batty 1993). The diversity of PSS types and techniques include large-scale urban models, rule-based models, state-change models, and cellular automata models. These PSS provide planners with tools to investigate land-use change, comprehensive projections, three-dimensional visualization, and impact assessment.

We hope to build upon the work of PSS by recognizing that in order for pervasive large-scale data sets and analytic methods to benefit the planning profession, PSS must adapt to planners' specific needs and provide planners with flexible exploration among datasets. We view PSS as an opportunity to address multiple planning concerns in an intuitive manner. We developed a software tool that allows planners to interpret valuable social media data as a proxy for elements of cities integral to their tasks. By accessing publicly available social media data, we hope to expand upon the idea of Volunteered Geographic Information Systems (VGIS) and the idea of humans as social sensors (Goodchild 2007) by sensing patterns and meaning from the unstructured data streaming in the real world. We also aim to enable interpretation and collaboration between planners by allowing annotations to be shared. Finally, our system does not focus on future projections, instead seeking to understand present patterns of behavior.

2.3 Visual Analytic Systems

Interactive VAS are a form of analytical reasoning facilitated by interactive visual interfaces coupled with computational methods such as machine learning, pattern recognition and statistical analysis. Important features include the ability to deal with high-dimensional data sets, present information visually, and allow users to interact with this information thereby building knowledge and decision-making capability. Visual analytics assumes analysis is better undertaken as a symbiosis between the computational power of computers and the sense-making capacity of human users (Keim et al. 2008). These types of interfaces have been created to allow for exploration of very large datasets with a diverse range of goals. Vairoma and Wirevis are examples of VAS; Vairoma combines topical, spatial and temporal analyses of Rome in a multi-view interface to enable historians to easily navigate related articles from multiple perspectives (Cho et al. 2016); Wirevis allows for analysis of financial transaction data and uses wire tags to identify suspicious behavior (Chang et al. 2007). Current research on VAS focuses on the cognitive processes of the user and emphasizes the need for a process of user exploration starting with discovery, leading to verification and ultimately to knowledge creation (Chen et al. 2009). This approach is consistent with the underlying desire for PSS to develop systems that are responsive to users' expertise, evaluation and input.

Our system aims to use the lessons learned from advancements in VAS and PSS by iteratively learning from professional usage and getting feedback from users, as well as introducing novel big data analytics methods for understanding human behavior from social media data.

3 Urban Activity Explorer

Urban Activity Explorer evolved from research on our previous system based on feedback from planning researchers and professionals (Karduni et al. 2017). In order to utilize the richness of social media data and its potential for understanding human activities within cities, our team created a visual analytics interface by first conducting a survey of 96 urban planning and design professionals. The survey helped us to identify their main data and information needs and how social media data can be used to alleviate those needs. We then incorporated those findings within the first version of our system called Urban Space Explorer. Urban Space Explorer was a web-based multi-view interface that allowed users to explore geolocated tweet data in Los Angeles. Our system allowed the user to explore the dataset through multiple interlinked views. Interaction with each of the views would change the state of other views to allow the users to explore different spatial and temporal aspects of the dataset. The multiple views of Urban Space Explorer included: activity density, a flow of Twitter users view, a word cloud, a flow and tweet timeline, language and tweet topics.

The activity density view was created as a proxy for concentrations of different kinds of social media activity (Fig. 1(1)). The view utilized a dynamic heatmap visualization that updated based on the current scale of the map. This feature enabled the users to dynamically study densities from different scales. The timeline view showed the number of tweets per hour for a day and the word cloud highlighted the most frequent keywords. Zooming in and out on the map would update the timeline and word cloud visualization to correspond only to the observed area (Figs. 1(2) and 1(3)). Selecting a time range would consecutively show a heatmap of density for the selected time. The heatmap would also respond to a set of pre-calculated topics which were derived from the tweets using the Latent Dirichlet Allocation algorithm (Blei et al. 2003). The user could select each topic and view a heatmap, timeline, and word cloud corresponding to that specific topic (Fig. 1(6.5)).

To model the flow of users we created a new method that utilized Djistra's shortest path algorithm (Dijkstra 1959) on the street network using GISF2E (Karduni et al. 2016) to create a network from OpenStreetMap data and ArcPy to calculate the shortest paths between a series of locations for each user (see https://goo.gl/jfrdIc). The method allowed us to visualize a large number of trajectory data derived from the locations of users by calculating the shortest path between consecutive tweet points on the street network (Fig. 1(4)). Moreover, our system afforded studying a specific region as the origin or destination of tweet users by viewing the lines which flow into the region or out of the region. To complement the flow map, we created a visualization that encoded the start and end points of

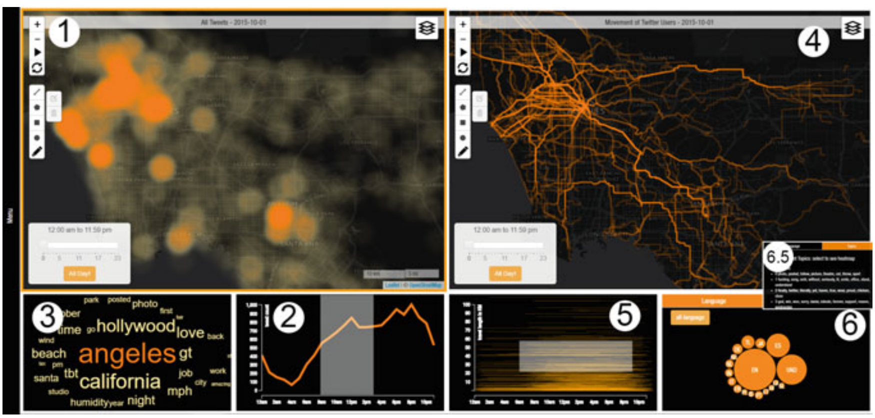

Fig. 1 Urban Space Explorer user interface

movement at the x axis and the length of travel at the y axis. This allowed users to simultaneously query time of travel as well as length of travel (Fig. 1(5)). Our system also enabled users to study the movements of Twitter users who tweeted in different languages (Fig. 1(6)). Other notable affordances of Urban Space Explorer include a time slider and animation for both flow and density, synchronized map views, changing background layers, the ability to add graphic overlaps, and a calendar to change the day of the dataset.

The development of Urban Activity Explorer as a system specifically tailored to PSS began as a follow-up to the implementation and user studies of our earlier system. We conducted a series of user studies to understand the degree of usefulness of our application and how it can be incorporated within the workflow of urban planners. Most of our study participants were interested in incorporating our interface and social media data within their tasks. However, the purely exploratory nature of Urban Space Explorer would not allow users to focus on a specific domain problem. In order to improve our system, we introduced a navigation bar with a search box that would allow users to input terms and create visualizations. User's interactions for this new feature include (Fig. 2):

A. Type a keyword in the search box and click submit.
B. View heatmap, timeline, and word cloud related to tweets containing the keyword[s].

Our users were also interested in conducting before-and-after analysis for specific events or areas to observe the reflections of a policy, design, or event through social media data. In response, we developed a tool to allow users to view tweets before and after a certain time in a specific region (Fig. 3A–D). User's interactions for this new feature are:

A. Draw a polygon on any area and click.
B. A dialog box appears with a timeline for all the tweets in that region.
C. Select a time range on the context graph, which updates the main time graph.
D. View the word cloud for that time range for a selected area.

Fig. 2 Searching for terms in Urban Activity Explorer

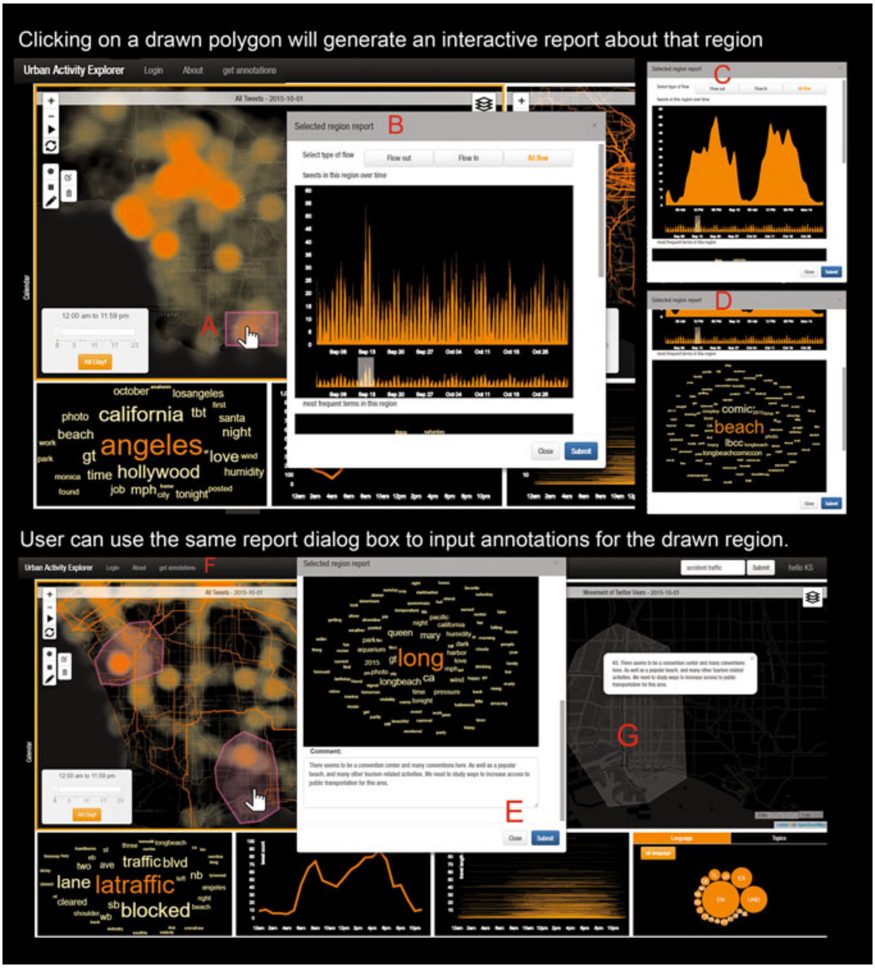

Fig. 3 Focusing on a specific region, getting reports for that region, and annotating that region

Last, the user study revealed the planners' need to save and share their knowledge and findings. Urban Activity Explorer now affords annotation, saving and sharing the results with other users (Fig. 3E–G). After logging into our system, the user can input and save annotations by:

E. Using any drawn polygon dialog box, the logged-in user can insert annotations for that specific area.
F. A logged-in user can click on the "get annotations" button on the top navigation bar and view previously annotated areas on the map.
G. Clicking on each area will reveal the annotation.

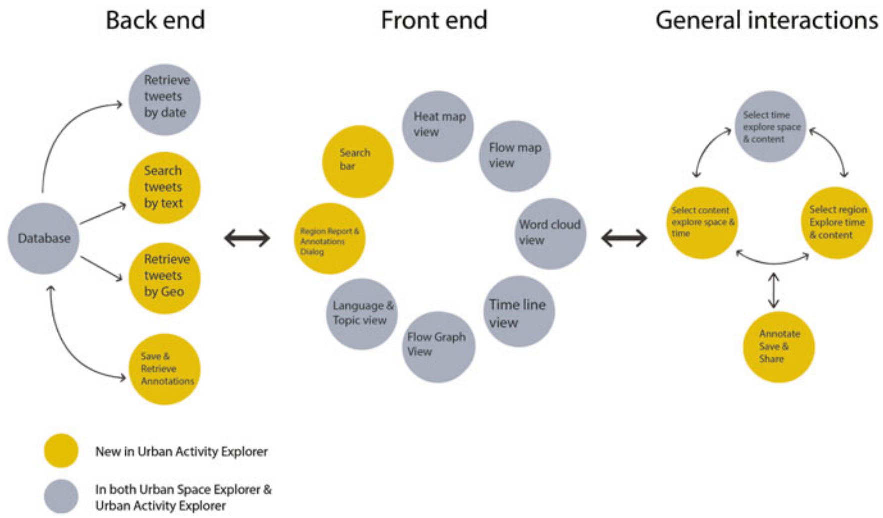

Fig. 4 General structure and interactions of Urban Activity Explorer

Aside from these new features in Urban Activity Explorer, there are modifications that were made in response to our user studies to ensure the system is as usable and intuitive as possible. These modifications include:

- the user can now visualize flow data for a desired tweet language for all of the dataset in contrast to only a single day in the previous version;
- the origin destination buttons for visualizing flows in and out of a drawn area are now moved to the report dialog created in Urban Activity Explorer; and
- all drawn layers and annotations can be toggled off and on.

In Urban Space Explorer, users had the ability to select a specific day or time, and then explore relationships between different aspects of social media data. Urban Activity Explorer adds features so that users can now select a region and explore both time and content. They can search for specific content and then explore space and time related those content. Furthermore, the user can annotate Urban Activity Explorer and retrieve their findings in the future. Figure 4 shows the general structure of our system.

4 Urban Activity Explorer and PSS

We have designed Urban Activity Explorer to study human activity by tapping into the vast potentials of social media data. Our goal is to develop an interface that serves the needs of diverse planning professionals. To illustrate the capabilities of our system, the following includes example situations that a planner may encounter, some of which are derived from our previous user studies with planners.

A city transportation manager would like to study urban areas with high traffic and frequent accidents. By searching the terms "traffic" and "accident", the user can view a geographic map of all tweets that contain those keywords. The map highlights tweets around major arterials, as well as highly dense regions. The user can explore tweet content to find major reoccurring events and activities that might cause high traffic and in consequence high accidents. Furthermore, the user can focus on each of the regions and find time ranges during which more accidents have happened. Using the annotation system, the user can save the findings and share with others.

In addition to transit related issues, other uses of our system may include identifying areas with a positive or negative response to murals and public art to allocate future funding, surveying tweets in urban areas and main streets for signs of struggling business activity to determine areas in need of reinvestment, reviewing patterns of migration across time among different cultural groups to plan for future housing development, evaluating the quality and use of open spaces and parks to efficiently allocate custodians and resources, and identifying areas with an established pedestrian realm and potential market for introducing bike share systems or locating bike paths.

We recognize that urban planning is a very diverse profession with many specialized tasks. Our system uses open source technology and can be applied to other datasets and can therefore bring the powers of a visual analytics system to many planning tasks. Our system is open source and we invite individuals or organizations to use or adapt our system with other datasets.

5 Conclusions and Future Work

We have demonstrated the unique advantages that Urban Activity Explorer offers as a PSS. First, Urban Activity Explorer is a bottom-up tool, using heterogeneous data collected by social media without pre-judging the important issues from above. While this approach can be difficult computationally, we demonstrate how the use of a sophisticated VAS can overcome these difficulties. This presents us with two important advantages over top-down systems: we can understand emergent issues that can easily be missed by goals and methods decided in advance, and the ability to obtain data already streaming in abundance can allow our system to respond quickly. While our system currently does not work with streaming data, our team is working to create a version of Urban Activity Explorer which handles streaming data from social media.

Second, social media data is unique in that it presents temporal, spatial and topical information together. This affords us the opportunity to discover linkages and meanings that are often obscured by rigid isolation of data on incompatible layers. Social media data are messy, but they are intrinsically interconnected. Our interface includes advanced data analytic methods not previously accessible to planners in a system that is easy to use and does not require advanced technical knowledge by the user. Moreover, Social media brings about some attention worthy risks including privacy of users' data and low quality and accuracy information such as fake news or bot created content. Our system only focuses on aggregations of publicly available data, hence minimizing the risks of individuals' privacy. Important future steps include further anonymization of data and utilizing automated methods to better guarantee the accuracy of the information.

Third, visual analytics offers a rich field of scholarship for understanding how human users and computational power can work together in a complementary system. The rapid development of knowledge discovery within visual analytics is particularly important to PSS, as it provides theoretical overview and practical methods for providing the kind of support that will allow the integration of meaningful computation to the complex issues facing planners.

Several important issues remain unresolved. Unlike earlier systems such as GIS, implementation of VAS systems as PSS will unlikely to be sponsored by a single government or organization. The nature of social media data is so heterogeneous that they will probably not supplant earlier systems, but will rather add an ability for exploration and nuance that can be stifled by top-down systems. Urban Activity Explorer is open source to make widespread implementation possible, but we foresee a series of systems operating in parallel rather than a single unified system.

Finally, verification of our preliminary findings will need to be done to study our assumption concerning the relationship of the available social media data to broader behavior in the city. All mobile social data sources have built-in strengths, limits and occlusions that must be explicitly considered. Our analysis of Twitter data correlating geo-located tweets (2% of the total) with all tweets must be verified to support the generalization of our spatial analysis. An ethnographic study 'in the wild' of social media users will begin soon with the goal of understanding the frequency of tweets and the relationship of tweets to face-to-face communication, spatial location, and movement. In the end, planners must understand not data alone, but humans and data together.

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