Using Geotagged Photos to Study Visitors Mobility in Urban Parks during Shadow

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Abstract. The share of urban parks in a metropolitan is mostly small, nevertheless, they are one of the main attractions affecting the experience of mobility in urban cities. Since shaded areas influence active traveling, e.g., walking and cycling, the effect of shaded areas in cities is currently being investigated, specifically as temperatures continue to rise. In this study, we analyze mobility patterns of photographers by mining spatio-temporal descriptors associated with crowdsourced geotagged photos from Flickr integrated with the computation of the 3D line of sight to the sun position for shadow computation. Mining photographers' trajectories with unsupervised location clustering are used to recover knowledge about the main attractions visited in urban parks while considering shadow analysis. Such an approach can contribute to diverse city management aspects, including urban design and planning, tourism and more. Preliminary results for Central Park in Manhattan are presented, showing an original approach for the retrieval of relevant valuable information on visitors mobility patterns and hot spots identification while considering building shadows.

Keywords. Geo-tagged User Generated Content, Shadow Analysis, Unsupervised Data Clustering, Mobility Patterns

1. Introduction

Traveling in public urban parks is a different travel experience than traveling in densely built-up urban areas. Visitors travel urban parks for various reasons, e.g., tourism, scenery, sports, and recreation (Vu et al., 2016). Moreover, urban parks have a specific direct psychological effect on senior visitors. Takano et al. (2002) studied the positive psychological value effect

LBS 2019
15th Conference on Location Based Services
Vienna, 11–13 November 2019

Published in “Adjunct Proceedings of the 15th International Conference on Location Based Services (LBS 2019)”, edited by Georg Gartner and Haosheng Huang, LBS 2019, 11–13 November 2019, Vienna, Austria.

This contribution underwent double-blind peer review based on the paper. https://doi.org/10.34726/lbs2019.48

parks have on senior citizens. In addition, Ciange & Popescu (2013) showed that urban parks have attractive attributes that are sufficiently valuable for travel planning.

As temperatures continue to rise, the shadow has an effect also in parks in terms of their attractiveness to visitors. Skyscrapers are becoming more popular and common in urban environments, being developed around urban parks, such that their shadow is directly affecting the park. Investigating the effect of urban park shadow on the visitors mobility can provide insights on urban planning. User-generated geotagged data sources are increasing dramatically, and are nowadays more commonly used to share travel, tourism, as well as daily experience (Mor & Dalyot, 2018). Although only a small part of tourists is presumed to share their travel experience, which in case of mobility analysis can bias the results, current research suggests that active participation in social media is constantly expanding (Antelmi et al., 2019). Using these active trail data together with shadow analysis can provide information on main routes and attractive locations in parks during the day, which can serve as an aware solution to explore and analyze the shadow impact on visitors in urban parks, and how the existence of shadow can contribute to better urban planning.

In this research, we analyze geotagged photos from Flickr to retrieve photographers' travel trajectories and identify main clusters around attractive park locations by using an unsupervised DBSCAN clustering (Vu et al., 2016, Ester et al., 1996). This information is integrated with a shadow analysis according to the visit time (i.e., geotagged photos' captured timestamp). Accordingly, we recover knowledge regarding the correlation of mobility patterns and shadow. An experiment presents preliminary promising results in understating the visitors mobility pattern and the main attraction locations in urban parks together with understating the impact of shadow. This showcase of using updated crowdsource geotagged data shows its potential for retrieving valuable and immediate information that is otherwise hard to retrieve, which can benefit visitors to urban parks.

2. Methodology

2.1. Geo-Spatial Data

For the analysis area of Central Park in Manhattan, an accurate and detailed DSM (Digital Surface Model) of the area was used, composed of gridded raster produced by LiDAR technology in a resolution of 1 foot (approximately

0.3 meters)[1] and with 3D buildings model[2]. Geotagged photos from Flickr database were retrieved for the same area. Flickr stores geo-located and temporal metadata information about the uploaded photos and the photographers who took it. the photographers' mobility patterns are analyzed by spatio-temporal descriptors associated with their geotagged photos (Mor & Dalyot, 2018).

2.2. Shadow Analysis by Line of Sight Analytics

Shadow computation is based on two main angels that define the sun position: azimuth and elevation. The angles are computed based on spherical trigonometry using the geographic location and the timestamp of the geotagged photos. The geographic coordinates of the sun are computed artificially based on the creation of a 3D vector from the origin point of the geotagged photo to a distant point using the parameters: azimuth, elevation and slant distance (defined as 5 km). 3D vector of the line of sight (LOS) analytics is used for visibility analysis using the generated DSM (Morello & Ratti, 2008), as presented in Figure 1. The result of the relational analysis between the artificial sun position and the location of the geotagged photos provides the inference between light (visible) and shadow (invisible) points to the sun. 3D LOS computation (shadow analysis) can be time-consuming, especially for the analysis of aggregated shadow over a continuous time period (Miranda et al, 2018); accordingly, our development is a discrete solution for shadow analysis that is computed efficiently for specific time stamps of visitors mobility, considering the 3D buildings' obstruction.

2.3. Unsupervised Data Clustering: DBSCAN

Unsupervised DBSCAN data clustering is implemented to obtain main visited attractions in urban parks (Vu et al., 2016); it is used to acquire knowledge about the current state of shadow at the clusters' locations. In our approach, we use the K-nearest neighbors (KNN) (Ester et al., 1996) for predicting the optimal values for the DBSCAN. An Euclidean distance was computed for all pairs of points for a different K value, and for each cluster, we compute the 90^{th} percentile of the average distance. We extract the geotagged photos that fall inside each cluster and retrieve the photographers' information. For each cluster, we compute the percentage of photos that were

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[1] https://opendata.cityofnewyork.us/

[2] https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-nyc-3d-model-download.page

taken while that location was in a shadow. For each cluster, we calculate the statistics of shadow, and carry out a temporal seasonal analysis.

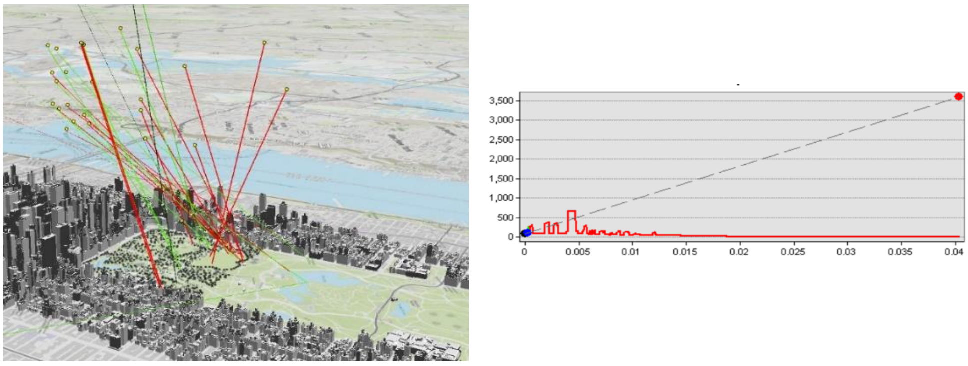


Figure 1. Left: 3D LOS analytics between geotagged photos and artificial points representing the sun (red: shadow, green: light). Right: profile visibility analysis.

3. Preliminary Results

Central Park, Manhattan, New-York, is considered as one of the most famous and visited attractions in the heart of Manhattan. This urban park is visited by residents and tourists alike and is the most visited urban park in the United States. A total number of 33,000 geotagged photos taken by 4,900 unique photographers were extracted for the region. We used photographers that took more than three photos (1,370 photographers) to allow the construction of valid visit mobility. Shadow analysis is computed for each geotagged photo independently and an aggregation process is achieved for gathering information for each photographer. Shadow analysis results are divided into two main subgroups: One main group consisting of approximately 200 visitors who are completely in the shadow, mostly at night-time, and the second main group consists of over 600 visitors that are in the sun.

150 clusters are found by using the unsupervised DBSCAN, depicted in Figure 2 (left). Exploring the DBSCAN parameters was conducted using the KNN approach and using the elbow method, as depicted in Figure 2 (right), evaluated according to the 90th percentile, indicating that the optimal values are 30 points (photos) within 30 meters. We analyzed the most popular places in Central Park that are extracted by our algorithm and are recommended on tourism websites[3]. The common visit time that people are not in shadow at different attractions in Central Park is between 12 pm to 2 pm, while the common visit time in shadow is between 4 pm to 5 pm (photos

[3] www.planetware.com/

that were captured at night-time are excluded). Analyzing over seasonally, the summer period of June to August is the less-visited season in Central Park by photographers. Usually, most people visit the main attractions during the spring season (March-June). Analyzing the shadows (%) at different clusters, depicted in Figure 3, we can see that the main attractions are usually visited not during shadow; however, when they are visited during shadow, they are likely to be at the southern attractions who are shadowed by the skyscrapers that are located south to Central Park; for example, the Pond area is 15% visited while in the shadow.

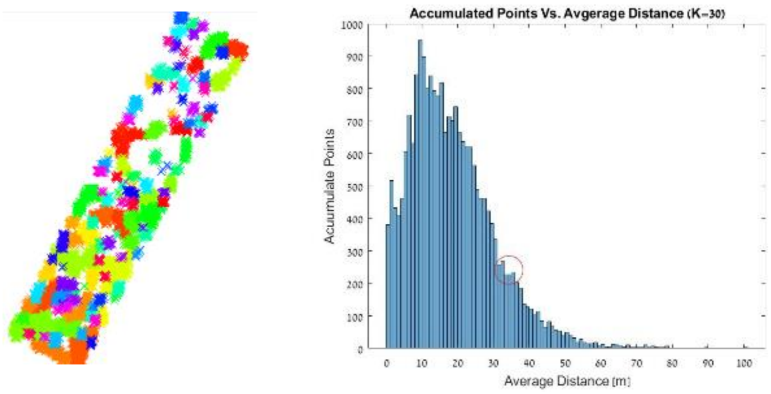
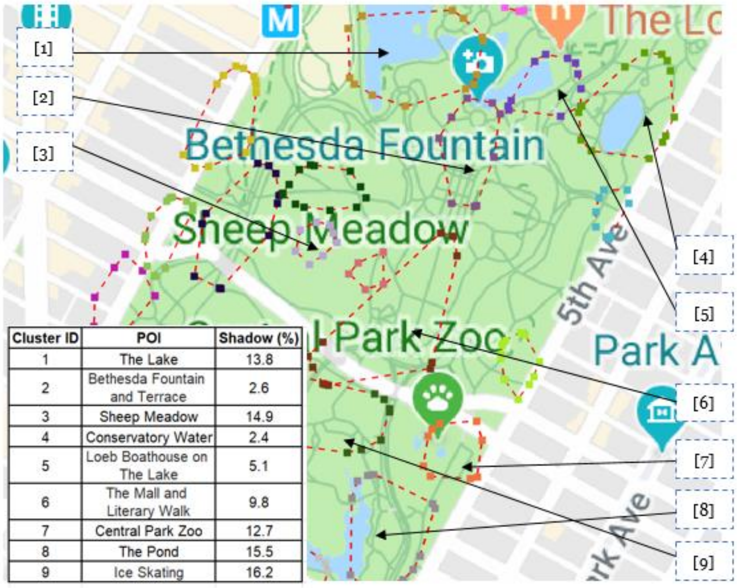


Figure 2. Left: DBSCAN clustering (each color represents a cluster). Right: KNN statistics analysis of the average distance for amount of points (red circle represents the optimal value using the elbow method).

4. Conclusions and Future Work

Experiments show very promising results in exploring and recovering visitors mobility in urban parks while considering existing building shadows by integrating user-generated crowdsourced data for analysis. We have managed to study the temporal behaviour of visitors in Central Parks' main attractions during shadow at different seasons. Integrating a more detailed and high-resolution DSM infrastructure that includes canopy would improve the visibility computation analytics, while improving our clustering implementation to retrieve better results. Future work will include deeper understanding of the visitors routing considering shadow, and to develop a recommendation system that will use shadow and additional environmental and temporal parameters to recommend route planning. We believe that development of urban parks is an important key role of development in various disciplines; urban designers and planners, city municipalities and tourism facilities could better plan the effect of urban structures on urban parks regarding the visitors mobility in attraction areas by using updated and dynamic geotagged crowdsourced data.



Cluster ID	POI	Shadow (%)
1	The Lake	13.8
2	Bethesda Fountain and Terrace	2.6
3	Sheep Meadow	14.9
4	Conservatory Water	2.4
5	Loeb Boathouse on The Lake	5.1
6	The Mall and Literary Walk	9.8
7	Central Park Zoo	12.7
8	The Pond	15.5
9	Ice Skating	16.2

Figure 3. Shadow analysis at the southern Central Park area according to different attractions (background layer: Google Maps).

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