Spatial Association of Geotagged Photos with Scenic Locations

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Abstract
Web 2.0 provides a continuously growing source of volunteered geospatial information through numerous interactive Web applications. It complements geographic information that can be extracted from traditional sources, such as Earth imagery. This paper analyses for a sample of scenic routes whether footprints of geotagged photos posted on Web 2.0 are more frequently found along scenic routes than along their corresponding fastest routes. If the footprint frequency is higher for scenic routes, locations and street segments within close distance to footprints can be assumed to contribute to route scenery, and therefore be utilized as an additional data source within software based trip planners for the computation of scenic routes.

1 Introduction
The development of Web 2.0 allows the Web community to interact with each other, provide information to central sites, and thus become a significant source of information. More and more Web 2.0 platforms use geographic information as a key factor in their information, which lead to the term Geospatial Web (SCHARL & TOCHTERMANN 2007). Especially the development of the Global Positioning System (GPS) and its integration into cell phones, photo cameras, and other mobile devices has made it easy even for non professionals to measure latitude and longitude and to share geotagged information with the Web community. Such collection of spatial information which is built in a collective effort from voluntary Web 2.0 users has been coined Volunteered Geographic Information (VGI) (GOODCHILD 2007). Well known examples of Web 2.0 applications are Wikimapia¹, where users provide descriptions of places of interest to them, or OpenStreetMap² (OSM) which builds a public-domain street map of the whole world. Other applications allow to map favorite locations through geotagged photos, e.g., flickr³, or Panoramio⁴, or to map favorite routes, e.g., RouteYou⁵.

This paper focuses on volunteered geotagged photos and examines whether the location of photo footprints is generally associated with scenic portions of a street network. Knowledge about scenic segments is of importance for computer assisted trip planning since route scenery and attractiveness have been identified as prominent route selection criteria besides travel time, simplicity, and safety (HOCHMAIR 2004; HOCHMAIR 2008). A series of earlier

¹ http://wikimapia.org
² http://www.openstreetmap.org
³ http://www.flickr.com
⁴ http://www.panoramio.com
⁵ http://www.routeyou.com
empirical studies identified parameters for landscape scenery (APPLETON 1975; STEINITZ 1990; BISHOP & HULSE 1994; BISHOP 2003) which can be used in a GIS to predict the scenery for given locations using viewshed analysis. 3D models allow for a more detailed approach to automated analysis of views, including human depth-variation preferences (BISHOP et al. 2000), or modeling the impact of nearby objects, such as transmission towers (GROSS 1991). However, these approaches require detailed spatial information, such as existing vegetation at fore and middle ground, and complex algorithms for information extraction, e.g. to identify folded landscapes (STEINITZ 1990). As opposed to this, geotagged images are readily available and can be downloaded from Web 2.0 sources using APIs.

Although it is intuitive that volunteered geotagged photos are preferably taken along scenic street segments, this assumption has not been empirically tested so far. Thus the following working hypothesis is formulated: Geotagged photos on Web 2.0 applications are found more frequently along scenic routes than along fastest routes. This hypothesis will be tested for Panoramio photos. Using the concept of proof by contradiction, a null-hypothesis can be formulated which states that the number of panoramio photos found along scenic and fastest routes is equal, or that it is even higher for fastest routes. To describe the number of photos along a route, we use a measure called linear footprint density. It is obtained by creating a buffer around the route, followed by counting the number of photo footprints within that buffer, and by dividing this number by the route length. The linear footprint density captures therefore the number of photos per route length unit.

2 Potential Web 2.0 Data Sources Related to Route Scenery

Testing the hypothesis requires two data sets: a set of scenic and corresponding fastest routes, and a set of volunteered geotagged photos associated with these routes.

2.1 Point Data

Two types of geotagged point data provided through Web 2.0 sources can be distinguished:

1) Point data that are added in a collaborative effort to map the whole world, where points represent primarily the location of physical objects, such as parks, buildings, view points, or sea ports. Examples are the categories shop or hotel in OSM and Wikimapia.

2) Point data that are based on personal experiences, such as mapping one’s favorite locations, visited places, or footprints of photos taken. These points do not necessarily map a physical object. Examples are stopovers in travel diaries, such as in mapvivo\(^6\), or footprints of photos in flickr or Panoramio.

With respect to scenery, the first group of points has the advantage of being assigned to a more or less pre-defined set of categories when uploaded by the Web user. This categorization allows to filter feature classes when downloading scenic points from these portals and building the database for scenic route planning. The disadvantage with this type

\(^6\)http://mapvivo.com
of point data, and in general with all types of data that aim to provide a map like depiction of the world, is that subjective relevance, i.e., the perceived scenery associated with such features, is not reflected in the map. This is because even attractive features and locations, such as a nice viewpoint, are only mapped once. Whereas OSM and Wikimapia in general host this kind of spatial data, Wikimapia provides a point feature class “interesting place” which partially relates to scenery. It could express some subjective preference of Web users for a place since more than one feature can be pinned onto a single location. However, points in this feature class are scarce. For example, only three features are found in the Port of Miami area (Fig. 1a). Visualizing OSM point data that could be considered related to scenery gives a similar picture. Fig. 1b shows OSM point data from categories “tourism”, “historic”, and “leisure”, which includes parks, museums, and theaters, among others. The problem of point scarcity with reference to identification of scenic route segments remains.

![Fig. 1: Points from category “interesting place” on Wikimapia (circled) (a), and points from categories tourism, leisure, and history in OSM (b)](image)

Footprints from geotagged flickr and Panoramio photos are used as examples for the second type of point data. Both flickr and Panoramio allow uploading geotagged pictures as well as manually georeferencing of photos on a basemap. Whereas the flickr Website provides also access to images that are not geo-referenced, Panoramio is more of a geolocation-oriented Website where all published images are geo-referenced.

Flickr allows to share geotagged photographs taken both outdoors and indoors. It is apparent that only the outdoor photos can be potentially utilized to determine route scenery. Flickr users can assign uploaded photos to one or several groups to more clearly specify their content. Searching groups for photos provides more accurate and complete search results than utilizing photo tags, because many users do not annotate their photos, or they use the same tags for all their photos uploaded. To assess the density of available flickr photos for a given geographic area, the flickr API was used to download photos from 27 scenery related groups, including “scenicwater”, “scenery”, “scenic-outdoors”, “scenicareas”, “landscape”, “worldlandscape”, “mountain_water”, “heights”, or “world”. Flickr photos are stored with an accuracy value between 1 and 16, where world level is 1, city is 11, and level 16 is considered to be accurate at the street level. The map in Fig. 2 visualizes flickr footprints that reveal somewhat reliable accuracies, i.e., levels between 14-16.
In Panoramio, photos are organized exclusively through tags, not through groups. All Panoramio photos are showing outdoor scenes which makes them potentially associated with scenery. No accuracy information is provided at this point, therefore all footprints are used for this study. Fig. 2 shows footprints for Panoramio (small dots) and flickr (large dots) in the Port of Miami area. When compared to Fig. 1 it can be seen that the point density for both data sources is higher than for OSM or Wikimapia data. Panoramio’s point density is higher than the point density for the 27 flickr groups (even when mapping all accuracy levels 1-16 in flickr). Because of this we expect more discernible results for Panoramio photos. Therefore the focus of point analysis in this study will be on Panoramio photos although a similar study could be repeated for flickr photos.

![Map of Panoramio and flickr points in Miami](image)

**Fig. 2:** Points from Panoramio and 27 flickr groups in the Port of Miami area

### 2.2 Scenic Routes

Various Web 2.0 sites allow registered users to upload waypoints of their favorite routes. For this study 32 user suggested motorcycle routes for Florida, Germany and Austria were downloaded from the EveryTrail\(^7\) portal. Although the downloaded routes are not explicitly labeled scenic, the descriptions for some of the routes and the fact that they generally avoid highways suggests that they pass through a nice landscape or urban environment, respectively. In addition, nine favored on-street bicycle routes were downloaded for Florida from the GPSies\(^8\) portal. These bicycle routes were relatively short, so that none of the corresponding fastest route counterparts were running on a highway segment. All together a total of 41 routes were used for the analysis.

Planning a route between two locations involves the optimization of various criteria, such as travel time, travel comfort, and scenery, among others. Since in most cases available route alternatives perform differently on a given criterion, the traveler needs to weigh the

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\(^7\) [http://www.everytrail.com/]

\(^8\) [http://www.gpsies.com]
importance of each criterion, depending on the trip purpose (Bovy & Stern 1990). If a route chosen deviates from the shortest or fastest route, this means that the benefits of the alternative routes, such as increased travel safety or better scenery, are higher than the cost associated with the longer travel distance or time. Since volunteered photos taken along a chosen route primarily reflect landscape, we can assume that a linear footprint density along alternative routes can be attributed to route scenery, thus indicating more scenic routes. We use fastest routes, computed from Google maps directions\(^9\), as reference routes where route origin and destination are adapted from downloaded scenic routes. For the comparison of geotagged photos, only non-overlapping portions between scenic routes and their fastest routes were considered. Tab. 1 summarizes the lengths of the 41 downloaded scenic and computed fastest routes after removal of route overlaps. It further shows how much longer (in %) scenic routes are in comparison to their corresponding fastest routes.

**Tab. 1:** Characteristics of used route set. Route lengths are given in km.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Location</th>
<th>Number</th>
<th>Mean Distance</th>
<th>Median Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scenic</td>
<td>Fast</td>
</tr>
<tr>
<td><strong>Motorbike</strong></td>
<td><strong>Florida</strong></td>
<td>16</td>
<td>205.7</td>
<td>165.0</td>
</tr>
<tr>
<td></td>
<td><strong>Germany</strong></td>
<td>12</td>
<td>137.0</td>
<td>97.6</td>
</tr>
<tr>
<td></td>
<td><strong>Austria</strong></td>
<td>4</td>
<td>184.8</td>
<td>150.6</td>
</tr>
<tr>
<td></td>
<td><strong>All routes</strong></td>
<td>32</td>
<td>177.3</td>
<td>137.9</td>
</tr>
<tr>
<td><strong>Bicycle</strong></td>
<td><strong>Florida</strong></td>
<td>9</td>
<td>24.4</td>
<td>20.5</td>
</tr>
</tbody>
</table>

3 Panoramio Footprints along Shortest and Alternative Routes

This section introduces two methods for counting Panoramio footprints within route buffers, i.e., the base method and the filter method.

3.1 Base Method

Since footprints of geotagged photos do not exactly overlay with route geometries, a buffer distance around routes needs to be defined. The buffer distance accounts for the fact that georeferencing methods for photos, i.e., GPS or using a basemap, have some inaccuracies. It also expresses the fact that a scene captured by the photographer may be similarly attractive some distance away from the location where it was taken. The latter distance will depend on the local surroundings, such as building heights, canopy, or topography, but in general we assume that the scenery changes slower in less densely built areas than in high density housing areas. To simplify terminology in the remainder of the paper we refer to the first type of areas as “rural environments”, and to the second type as “urban environments”, although, strictly said, lower housing and street densities can also occur within urban boundaries, e.g. around parks or lakes. We use street density as a proxy variable for housing density. To assess the street density along the analyzed routes, the 82 scenic and fastest routes were overlaid with a 500m x 500m square grid. Then the street density was computed within each grid as total street length in the grid divided by 25,000. Visual inspection of these density values along with satellite images suggests that a density threshold of 6,200 is appropriate to separate higher density from lower density housing.

\(^9\)http://maps.google.com
areas. For route segments above the 6,200 threshold a route buffer of 100m, and for route segments below this threshold a 300m buffer was assumed to be appropriate. In addition to this, the working hypothesis was also tested with a constant 100m buffer. Fig. 3 visualizes these concepts. The thick line denotes the route, the shaded area is the route buffer, and dots show the footprints of Panoramio photos. In Fig. 3a a constant buffer size is used. In Fig. 3b the numbers in the grid cells indicate the street density, based on which the buffer distance varies between 100m and 300m.

Fig. 3: Base method applied on 100m buffer (a) and combined 100m/300m buffer (b)

The point counts per route km, i.e., the linear point density, were compared between buffers around the scenic and fastest routes for all 41 route pairs described in Tab. 1. Since linear point densities were not normally distributed, a non-parametric test was used. For the 100m buffer (Fig. 3a) results show that the linear point density associated with scenic routes (Mdn=0.553) is significantly higher than for fastest routes (Mdn=0.391) (Wilcoxon Signed Rank, N=41, Z=3.842, p=<0.001, 2-tailed). Results also reveal that for the combined 100m/300m buffer approach (compare Fig. 3b) the linear point density associated with scenic routes (Mdn=1.058) is significantly higher than for fastest routes (Mdn=0.738) (Wilcoxon Signed Rank, N=41, Z=3.738, p=<0.001, 2-tailed).

3.2 Filter Method

Whereas the previous results support the hypothesis in this paper, the association of Panoramio photos with scenic routes compared to fastest routes can still be improved. Casual comparison of Panoramio footprints with the photo content and photo tags leads to some observations relating to scenery. It appears that some users upload photos showing their home or work place which is unrelated to scenery. Such pictures show, for example, a house owner’s garden. Other pictures appear to show some random content, such as gas stations or fast food restaurants, which were probably taken to test the photo camera or GPS device. On more frequented roads, particularly highways, more pictures of such random content appear to be taken as well, which includes photos of other cars, traffic signs, or the sky. To more precisely separate scenic photos from irrelevant photos, a simple rule can be applied. Since information provided by two users is more reliable than information from just a single user, it is suggest to retain only a footprint if it is within a given distance from the footprint of a photo provided by a different Web user. The buffer distances from Fig. 3 can be used as a distance thresholds.
Fig. 4 gives an example of the proposed filter method. Labels next to footprints show the username of the person who uploaded a photo. A buffer distance is assigned to each footprint, depending on the street density (Fig. 4a). 100m buffers are in black, and 300m buffers in gray. The two point clusters in the middle left and the lower right area contain photos from at least two different users. That is, each footprint is within at least one circle associated with a second photo footprint that was uploaded from a different user. As opposed to this, the two footprints on the upper left are not contained by any other circle. Therefore they are removed within the filter process, whereas all other footprints are retained (Fig. 4b).

![Fig. 4: Distance thresholds for footprints (a), and result of filter process (b)](image)

The hypothesis of this paper was also tested on footprints modified by the filter method using a constant 100m buffer radius and the combined 100m/300m buffer radius. For the 100m buffer the linear point density associated with scenic routes (Mdn=0.220) was found to be significantly higher than for fastest routes (Mdn=0.084) (Wilcoxon Signed Rank, N=41, Z= 4.235, p=<0.001, 2-tailed). Also for the combined 100m/300m buffer approach the linear point density associated with scenic routes (Mdn=0.547) was significantly higher than for fastest routes (Mdn=0.258) (Wilcoxon Signed Rank, N=41, Z= 4.412, p=<0.001, 2-tailed).

### 3.3 Comparison of Methods

Further it was tested whether observed differences in linear point density between scenic and fastest route increase if the filter method is used instead of the base method. For a route pair consisting of a scenic and a fastest route, the normalized difference measure $m$ can be computed as $m=(d_s-d_f)/(d_s+d_f)$, where $d$ stands for the linear point density of the scenic ($d_s$) and fastest route ($d_f$), respectively. If $d_s=d_f=0$, then $m=0$ by definition. A higher $m$ thus means a higher difference in linear point density between scenic and fastest route. The $m$ values of all 41 route pairs were compared for the base and the filter method using a constant 100m buffer and a combined 100m/300m buffer. With the constant 100m buffer $m$ was significantly higher for the filter method (Mdn=0.504) than for the base method (Mdn=0.201) (Wilcoxon Signed Rank, N=41, Z=3.428, p=0.001, 2-tailed). Also for the
combined 100m/300m buffer approach \( m \) was significantly higher for the filter method (Mdn=0.329) than for the base method (Mdn=0.182) (Wilcoxon Signed Rank, \( N=41 \), \( Z=3.092 \), \( p=0.002 \), 2-tailed). This indicates that the filter method provides a better distinction between scenic and fastest routes based on Panoramio photo footprints.

Tab. 2 summarizes the results of the various empirical tests. Values in the two \( d \) columns show that for both buffer types and point selection methods the linear point density is higher for scenic than for fastest routes, which supports the hypothesis of this paper. Values in the \( m \) column show that the relative difference between the number of points associated with scenic and fastest routes is higher for the filter method than for the base method. This means that the distinction between scenic and fastest routes based on Panoramio footprints is more accurate when applying the filter method.

**Tab. 2: Results for tests of hypothesis**

<table>
<thead>
<tr>
<th>Buffer distance</th>
<th>Method</th>
<th>( d ) (Mdn)</th>
<th>( Z )</th>
<th>( p )</th>
<th>( m ) (Mdn)</th>
<th>( Z )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>100m</td>
<td>Base</td>
<td>0.553</td>
<td>3.842</td>
<td>(&lt;.001)</td>
<td>0.201</td>
<td>3.428</td>
<td>(&lt;.001)</td>
</tr>
<tr>
<td>100m</td>
<td>Filter</td>
<td>0.220</td>
<td>4.235</td>
<td>(&lt;.001)</td>
<td>0.504</td>
<td>100m/300m</td>
<td>Base</td>
</tr>
<tr>
<td>100m/300m</td>
<td>Filter</td>
<td>0.547</td>
<td>4.412</td>
<td>(&lt;.001)</td>
<td>0.329</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5 illustrates the patterns numerically described in Tab. 2. The two highlighted routes in Fig. 5a and b show part of one of the 41 route pairs used for hypothesis testing. The route labeled “Scenic” runs along a scenic river and partially within a national park in Austria (Nationalpark Gesäuse). The route labeled “Fast” runs along a highway (Pyhrnautobahn). Dots along routes indicate the location of Panoramio footprints when using the combined 100m/300m buffer distance. Fig. 5a uses the base method, whereas Fig. 5b shows the footprints that are retained after the filter method.

**Fig. 5:** Panoramio footprints within 100m/300m before (a) and after (b) the filter method

Reflecting the value pattern in the \( d \) columns in Tab. 2, the linear point density of footprints is higher for the scenic than for the fast route both in Fig. 5a and b. With the base method (Fig. 5a) this difference is less obvious than for the filter method. The latter removes most of the isolated footprints along the highway while preserving many footprints along the scenic route. Thus the difference between scenic and fast route regarding footprints is more evident with the filter method, which is reflected by the higher \( m \) values associated with the filter method in Tab. 2.
4 Discussion

The results of this empirical study reveal that geotagged Panoramio photos show a higher spatial association with user posted routes on Web 2.0 when compared to fastest routes. This is indicative of street segments near Panoramio photo footprints exhibiting some sort of scenery. In areas with an abundance of geotagged photos, such as in Fig. 5, the footprints could be readily utilized as a data source to plan a scenic route when applying a corresponding algorithm. This approach can be applied in all geographic regions where a sufficient number of photo footprints is available. A more centralized approach is provided through various organizations and initiatives, such as the National Scenic Byways Program in the United States\textsuperscript{10}, which, after a thorough collaborative screening process, assign a scenic label to selected routes in their administrative boundaries. In the latter approach the coverage is somewhat coarser, generally limited to selected linear routes, and neglecting scenic local streets beside the labeled routes. In geographic regions with scarce geotagged photos, the photo footprints will not be so helpful in planning a scenic route. Such regions may, for example, be relatively homogeneous without any remarkable scenery. Or the area is secluded and therefore less frequently visited. In either case, some general proxy criteria, such as avoidance of highways or industrial zones, or preference for nearness to water bodies (lakes, rivers) may be used for the automated computation of scenic routes instead (HOCHMAIR & FU 2009).

Various topics for future work can be identified. One task is to analyze how footprints of geotagged photographs overlap with scenic landscapes as defined by criteria identified in literature (APPLETON 1975; STEINITZ 1990; BISHOP & HULSE 1994; BISHOP 2003). A significant overlap would facilitate an automated identification of scenic street segments with a more parsimonious set of landscape/topographic/landcover variables when used in combination with photo footprints. The filter method introduced improves matching results with scenic routes significantly. Nevertheless, further refinement of this strategy will help to remove undesired footprints not associated with scenery, such as clusters of photo footprints around railway stations. Another topic to be addressed is the accuracy of geospatial data contributed by individual Web users (GOODCHILD 2008), more specifically, the distance between the location where a photograph was taken and its mapped position. This will help to determine whether, for example, a 100m buffer distance is meaningful to count footprints along a route.

Whereas this research found that geotagged images are an additional potential data source to identify street segments of relative scenery in a given area, future work also needs to address the question of which algorithm for the computation of scenic routes is appropriate given the location of geotagged images alone, or in combination of different data, respectively. Two general approaches are commonly used. Given scenic points along the street network an algorithm that maximizes the number of such points along a route while minimizing the path length could be applied, e.g., using integer programming methods or genetic algorithms (CURRENT et al. 1985). Alternatively, if scenery is an attribute of route segments, modified edge weights within a single-criterion shortest path algorithm could be utilized (HOCHMAIR & NAVRATIL 2008).

\textsuperscript{10} http://www.byways.org
References