A method of Area of Interest and Shooting Spot Detection using Geo-tagged Photographs

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ABSTRACT

Social media sites include many photographs taken at various locations and times. As described herein, we propose a method to identify hotspots to visualize user interest using geo-tagging of photographs posted on social media sites. Hotspots are classifiable to two types based on its locations: area of interest or shooting spot. In some cases, a hotspot has relation to other hotspots. We extract and classify hotspots according to that relation based on the bias of photograph location and photograph orientation. Moreover, we classify whether an event happened or did not happen in extracted hotspots.

Categories and Subject Descriptors

H.3.5 [On-line Information Services]: Web-based services

General Terms

Algorithms

Keywords

area of interest, hotspot, photograph location, photograph orientation

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1. INTRODUCTION

Social media sites such as Flickr [1] include many photographs that people have taken. Some people might take photographs of their own interest and upload those photographs to such sites. A place at which many photographs have been taken, designated herein as hotspots, might be an interesting place for many people to visit. Analyzing such places is important for industries such as those related to tourism [2, 3].

Hotspots are classifiable to two types based on location: area of interest or shooting spot. Area of interest for people are tourist spots (e.g., Coloseum, Statue of Liberty). In such areas, many people have been taken inside or nearby. However, when people take a photograph of such an area of interest, they take the photograph at a place that is distant from the area of interest. Such places are also extracted as hotspots and are defined as shooting spots. In addition, hotspots occur because of an event that might occur. When an event such as fireworks display happens, many people take photographs related to the event. Therefore, we can classify such hotspots to four types (area of interest or shooting spot that occurred because of an event or not) based on the reasons people take photographs. To achieve this classification, we classify hotspots according to the area of interest or shooting spot using the location and orientation of photographs. In addition, we classify the cause of occurrence of the classified hotspot to an event or not using the bias of the time when the photograph was taken.

In addition, cases exist in which a hotspot has some relation to other hotspots. For example, around the Brooklyn Bridge, hotspots are extracted inside of the bridge, around the entrance of the bridge, and at distant places from the bridge. These hotspots are extracted independently, but all of them are hotspots related to the Brooklyn Bridge. We extract relations among hotspots.

Many photographs have metadata that are annotated by a camera at the time a photograph is taken. Furthermore, recent photographs taken using digital cameras or smart phones have metadata on a photograph location and orientation information. The photograph orientation presents the direction in which the photograph was taken. Particularly, photographs with a photograph-orientation feature have increased recently [4]. Using photograph orientation, it is possible to ascertain the orientation of hotspots [5]. Therefore, we aim to classify hotspots using photograph feature.

This study investigated a method using the photograph location and orientation and timestamp to discover hotspots and to classify these hotspots according to the area of interest and shooting spot, and according to whether the hotspots occurred because of an event or not. Hotspots are discovered based on the bias of photograph orientation, the positional relation of hotspots, and the density of photograph location. Moreover, we classify these hotspots according to whether hotspots are an area of interest or shooting spot. When we discover the hotspots, we must deal with the diversity of the range and shape of the area of interest.

2. RELATED WORK

Some methods have been proposed to extract geographical characteristics from the many photographs that are available on photo-sharing sites. Crandall et al. [6] presented a method to extract landmarks and hotspots using a clustering technique based on many geo-tagged photographs available on the Web. In addition, Kisilevich et al. [2] proposed a method to extract a hotspot using the density of photograph location based on the result of clustering. Sengstock et al. [3] proposed a method to extract geographical characteristics such as landmarks and coastlines based on photographic locations and tags of photographs on Flickr. The extracted geographical characteristic might reflect the interests of people. For that reason, they might be useful for marketing research and spatial analysis. Although these methods are useful to extract the area of each landmark, the results have no actual range or shape. Therefore, using those methods, it is difficult to discover a point that is focused upon by many people. Furthermore, these methods treat each hotspot as independent. However, some hotspots are related to other hotspots. Our approach extracts a relation among hotspots using the photograph location and orientation. It accurately discovers a point or range that is focused upon by people.

Photographs with a photograph orientation have become more commonly available recently. Some methods have been presented to estimate the photograph orientation, even for photographs that appear to have no photograph orientation [7, 8]. Our method specifically examines what object is photographed. However, we expect to use the estimated orientation to increase the accuracy of our method.

Some methods have been proposed to extract events from many photographs of photo-sharing sites [9, 10]. Brenner et al. [11] presented an approach to detect events and retrieval associated photographs from photograph collections. That

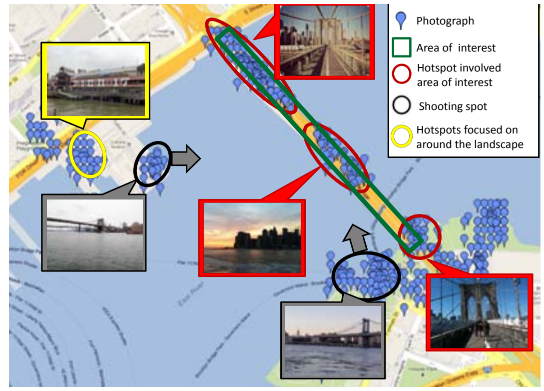


Figure 1: Examples of hotspot type.

approach extracted event location and time from photograph location and timestamp. Furthermore, that approach estimated the event name from social tags associated with the photos. Our approach does not conduct estimation from an event's name. We detected whether an event happens at a hotspot or not.

3. PROPOSED SYSTEM

We propose a method to discover and classify hotspots using photograph location, orientation, and timestamp. Additionally, we propose a method to estimate the range and shape of area of interests. We present an example of hotspots and area of interest around the "Brooklyn Bridge" in Figure 1. Figure 1 shows that hotspots are multiple cases: an area of interest, shooting an area of interest (shooting spot), and shooting around landscape. These hotspots differ among objects where photographs associated with the hotspot are focused upon. Therefore, we classify hotspots based on the photographic orientation belonging to the hotspot.

3.1 Extraction of hotspots

To identify hotspots, we specifically examine the density of photograph locations to find those where photographs are taken by many people. A place where many photographs are taken has a high probability of being a hotspot. Therefore, we discover locations with dense areas of photographs and infer them as hotspots. To do so, we use the density-based clustering algorithm DBSCAN [12] to discover the dense area as clusters. Using DBSCAN, we can extract a photograph's dense areas as a cluster. We extract a cluster, which is a set of points reached in this relation.

A cluster that is extracted using DBSCAN is an area in which photographs were taken more than in other areas. We calculated the average photograph location of the cluster. The location is a hotspot location.

3.2 Classification of hotspots

After extraction of hotspots, we classify hotspots based on the photograph orientation belonging to the hotspots. In such cases, the clusters are classified to three cases in Figure 2: $Case1$ is that in which a hotspot is included in an area of interest. $Case2$ is that in which a hotspot is focused on at a specific orientation (shooting spot). $Case3$ is that in which

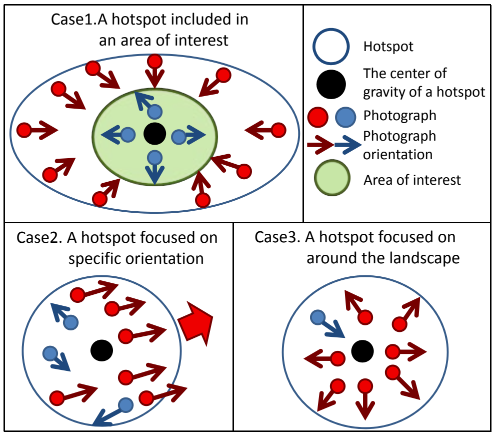


Figure 2: Classification of hotspots.

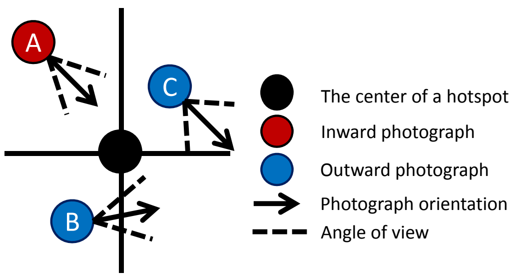


Figure 3: Inward photograph and outward photographs.

a hotspot is focused on at a position around the hotspot.

First, we describe $Case1$. In this case, interesting things exist at the center of gravity of the hotspot. Therefore, many photographs are taken at the center of gravity of the hotspot. To classify a photograph as taken at a center of gravity of the hotspot or not, we use the angle of view of a photograph. The angle of view is the angular degree of a given scene that is included in the photograph taken with a camera. The angle of view α is calculated from focal length f and the size of image sensor l as follows.

$$\alpha = 2tan^{-1}(\frac{l}{2f}) \tag{1}$$

When a hotspot exists in the angle of view, we define the photograph as taken towards the hotspot. Those photographs are defined as inward photographs (Fig. 3A). When a hotspot exists outside of the angle of view, we define the photograph as not taken towards the hotspot. Those photographs are defined as outward photographs (Figs. 3B and 3C). We calculate an orientation between the photograph location (x_1, y_1) and hotspot location (x_2, y_2).

$$\theta = tan^{-1}\frac{cosy_2 \times sin(x_2 - x_1)}{cosx_1 \times siny_2 - siny_1 \times cosy_2 \times cos(x_2 - x_1)} \tag{2}$$

We classify *inward photograph* and *outward photograph* when the shooting range of photograph from angle of view is α, and the photograph orientation is β.

$$\begin{cases} inward\,photograph & (\beta - \frac{\alpha}{2} < \theta < \beta + \frac{\alpha}{2}) \\ outward\,photograph & (otherwise) \end{cases} \tag{3}$$

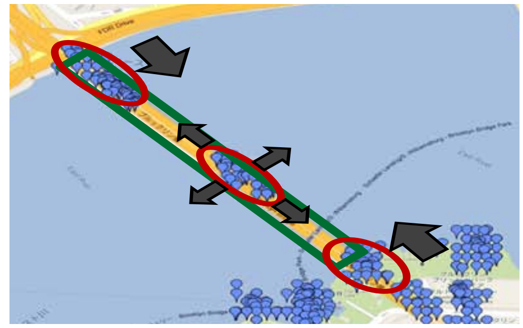


Figure 4: Example of wide area of interest.

After classification of the photographs, we count inward photographs and outward photographs concentrically from the center of the hotspot. When inward photographs are more numerous than outward photographs, we regard these hotspots as included in an area of interest and infer that the photograph is emphasized as the area of interest.

Next, we describe $Case2$. In this case, many photographs are taken with a specific orientation. Therefore, we calculate the bias of the photograph orientation based on a frequency distribution related to photograph orientation.

We divided the value of photograph orientation by 10 degrees and counted the photographs of each class. We consider that these hotspots are focused on a specific orientation if the top class includes 15 percent of the photographs belonging to hotspots.

A cluster is $Case3$ if the cluster is not $Case1$ or $Case2$.

3.3 Calculation the relevance of hotspots

There are cases when the hotspots have a relation to other hotspots. In addition, in the case of a wide area of interest such as Figure 4, multiple hotspots are extracted in the area of interest. In this case, a hotspot classified as $Case2$ or $Case3$ might be part of a wide area of interest. Therefore, we calculate the relevance of hotspots. In addition to reconstruction of hotspots based on the relevance between hotspots, we discover a wide area of interest.

In the case in which an area of interest is large, photographs are taken to various orientations near the center. However, photographs are taken to the center from the boundary. Therefore, hotspots classified as $Case3$ might be those around the center of the area of interest. Hotspots classified as $Case2$ might be those around the boundary of an area of interest. For this reason, we assume that $Case3$ means the center of the area of interest. We calculate the relevance between $Case2$ and $Case3$.

As relevance between two hotspots, we use a distance between two hotspots, an orientation of a hotspot, and density of the two hotspots. A distance between two hotspots is the distance between the centers of gravity of respective hotspots. A smaller distance between two hotspots might indicate that these hotspots are related to the same area of interest. We calculate the distance between two hotspots $dist\_ref$ from the distance between the centers of gravity of two hotspots as D.

$$dist\_ref = \frac{1}{D} \quad (4)$$

The orientation of a hotspot is the specific orientation of $Case2$. These hotspots might be related to the same area of interest if the center of gravity of a hotspot exists in the angle of view of the specific orientation. We calculate the angle of view of the specific orientation $s\alpha$.

$$s\alpha = \frac{180}{log_{10}(D)} \quad (5)$$

We calculate the orientation of a hotspot $dire\_ref$ from an orientation between two hotspots as $s\theta$ and a specific orientation as $s\beta$.

$$dire\_ref = \begin{cases} 1 & (s\beta - \frac{s\alpha}{2} < s\theta < s\beta + \frac{s\alpha}{2}) \\ 0 & (otherwise) \end{cases} \quad (6)$$

A dense relation between two hotspots reflects the density of photographs in the area between two hotspots. Many photographs might be taken around a hotspot where an area of interest and a part of the area of interest exist. However, in a hotspot such as a shooting spot, few photographs are taken in the area between two hotspots. Therefore, if many photographs are taken in the area between two hotspots, then these hotspots might be related to the same area of interest. We calculate a dense relation between two hotspots.

$$dens\_ref = \frac{num \times 100}{x} \quad (7)$$

Therein, x represents the area between two hotspots, num is the number of photographs in x.

Therefore, we calculate the relevance ref between two hotspots.

$$ref = (dist\_ref + dens\_ref) \times dire\_ref \quad (8)$$

For two hotspots, these hotspots are related to the same area of interest if $ref > 0$. In addition, if ref is higher value than a threshold, then these hotspots are regarded as a part of a wide area of interest. Therefore, we combine those hotspots into a single hotspot that contains original photographic data.

3.4 Detection of events

In many cases, hotspots exist around the interest area for many people. When an event happens and many photographs are taken in the term of events at the place, we can discover a hotspot of either area of interest or shooting spot. (Finally, we will extract the shape and range of a hotspot on the area of interest because the hotspot also occurred by an event. Therefore, we classify the hotspot as occurring by an event and the other hotspots.) To achieve this, we estimate whether an event happened in extracted hotspots using a photograph timestamp.

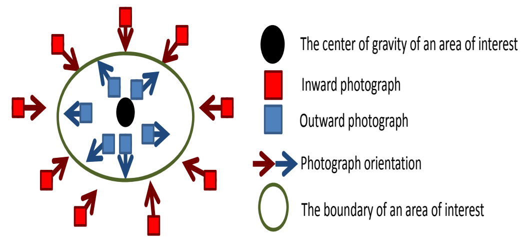


Figure 5: Estimated range of the area of interest.

When an event happens in a hotspot, the number of photographs taken on a specific day explodes compared with others. Therefore, we calculate the increase ratio of the number of photographs taken in a single day to detect events. First, we obtain photographs with photograph location belonging to the hotspot. Next, we calculate the number of photographs taken in a single day. At this time, smoothing the number of photographs, we apply a simple moving average (SMA). We calculate the nearest n days for the SMA. As described in this paper, we set $n = 7$.

Finally, we calculate a rate of increase (RI) as follows.

$$RI_M = \frac{SMA_M - SMA_{M-1}}{SMA_{M-1}} \quad (9)$$

Therein, M signifies a date. When $RI_M > 8$, we infer that an event happened in the hotspot.

3.5 Detection of area of interest

After classification and reconstruction of hotspots, we estimate the range and shape of area of interest subject to the hotspot that includes the area of interest.

3.5.1 *Estimation range of area of interest*

People take photographs both inside and outside of an area of interest. Accordingly, we estimate the range of area of interest using the rate of inward photographs and outward photographs. Figure 5 shows the photograph orientations inside and outside of an area of interest. The green circle is the boundary of the area of interest. Outside of the circle is outside of the area of interest. Inside the circle is inside of the area of interest. As shown in Figure 5, photographs taken outside (red frame) and inside (blue frame) have different features. In Figure 5, the number of outward photographs is greater than inward photographs inside of the area of interest. However, the number of inward photographs is greater than outward photographs by outside of area of interest. Therefore, a photograph that is near the center of area of interest has a high probability of being an inward photograph. In addition, a photograph that is discrete from the center of the area of interest has a high probability of being an outward photograph. The boundary of the hotspot is the change-range based on the rate of outward photographs and inward photographs.

To calculate the boundary of the area of interest, we calculate the distance between the centers of gravity of the area of interest and the photograph location in a cluster. We count inward photographs and outward photographs con-

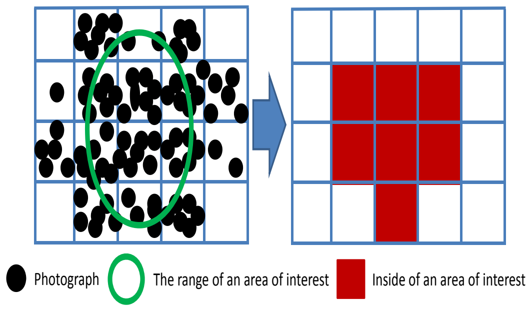


Figure 6: Estimated shape of the area of interest.

centrically from the center of the area of interest. Initially, the number of outward photographs is higher than that of inward photographs. When the points that are not outside from area of interest appear, then the number of inward photographs is greater than that of outward photographs. The points show the boundary of the area of interest in a cluster.

3.5.2 *Estimated shape of area of interest*

To ascertain more details related to the boundary, we estimate the shape of area of interest using a grid-based approach. In this process, we use not only the photographs that have a photograph orientation and photograph location, but also those photographs that have only a photograph location without a photograph orientation.

Photographs of the area of interest have been taken along the shape of the building in the area of interest. Therefore, we obtain the approximate shape of area of interest to extract a point for which the density of the photograph is high. However, when we specifically examine only the density of the photograph, we also recognize the outside of the area of interest, where many photographs have been taken. Consequently, when we specifically examine the building range, we can conduct an estimate of the shape with the inside of the area of interest. We use the estimation range in Section 3.4 to estimate the shape of the area of interest. We do not conduct these processes when the estimation range of the area of interest is 0 m.

We divided inner surfaces of the boundary into a grid as a center of the area of interest (Figure 6). As described in this paper, the grid size is 20 m. We classify the inside cells and outside cells as follows.

$$\begin{cases} cell = inside & (the\ number\ of\ photographs > 70) \\ cell = outside & (otherwise) \end{cases} \quad (10)$$

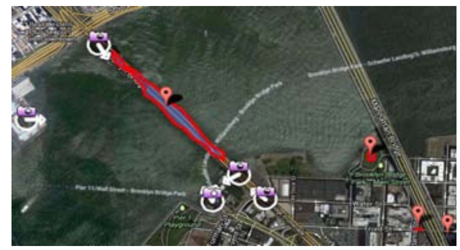
The set of cells inside the area of interest is the area of interest shape.

4. EXPERIMENT AND DISCUSSION

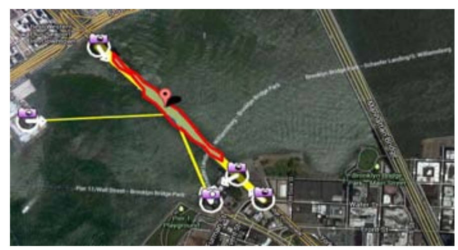
In this section, we describe the experiment using our proposed method. We describe several examples of extraction of the hotspots, relevance between hotspots, and event detection. Furthermore, we present and discuss the experimentally obtained results. We set the parameters of DBSCAN as $Eps = 0.001$ and $Num = 70$ in advance.

Table 1: Number of photographs in each query.

Query	With location	With orientation
"Brooklyn Bridge" and "Manhattan Bridge"	68,074	4,238
"Rome"	306,274	7,729
"London"	1,390,518	45,193



(a) Area of interest and shooting spots



(b) Relevance between the area of interest and shooting spots.

Figure 7: Results for the Brooklyn Bridge and Manhattan Bridge.

We describe photograph collection for experiment. We obtained photographs from photograph search results of Flickr. We use photographs taken during 1 January 2010 – 31 December 2012 Table 1 shows the query used for obtaining photographs and shows the number of results obtained. We use photographs that have Exif metadata of latitude (GPSLatitudeRef, GPSLatitude), longitude (GPSLongitudeRef, GPSLongitude), photograph orientation (GPSImgDirectionRef, GPSImgDirectionand) and Timestamp.

Tables 2, 3, and 4 show extracted clusters obtained using our proposed method for the respective queries of Table 1. "Location" shows the latitude and longitude of center of gravity of each hotspot. "Photos" shows the number of photographs in each cluster. "Category" shows the result of hotspot classification. "Spot" shows tourist attractions in the hotspot. Here, we confirmed the tourist attractions using Google Maps shown as a spot. "Relevance" shows the relevance of hotspots. The value of relevance is calculated as described in Section 3.3.

Table 2: Results of extracted hotspots of "Brooklyn Bridge" and "Manhattan Bridge"

Cluster	Location	Photos	Category	Spot	Relevance	
					Target	Value
B0	(40.705741,-73.996409)	6000	Area of interest	Brooklyn Bridge	-	-
B1	(40.704563,-73.990026)	2212	Area of interest	Park	-	-
B2	(40.702641,-73.988463)	2640	Area of interest	Park	-	-
B3	(40.707635,-73.998923)	2836	Shooting spot	Brooklyn Bridge	B0	10.923
B4	(40.704035,-73.994327)	1190	Shooting spot	Brooklyn Bridge	B0	13.254
B5	(40.703282,-73.995192)	1690	Shooting spot	Brooklyn Bridge	B0	2.188
B6	(40.704365,-73.987251)	1387	Event	-	-	-
B7	(40.705540,-74.001284)	2035	Shooting spot	Brooklyn Bridge	B0	4.361

Table 3: Result of extracted hotspots of "Rome".

Cluster	Location	Photos	Category	Spot	Relevance	
					Target	Value
R0	(41.893113,12.483439)	4648	Shooting spot	Temple of Jupiter Optimus Maximus	-	-
R1	(41.900949,12.483299)	4661	Shooting spot	Trevi Fountain	-	-
R2	(41.895085,12.484125)	5364	Area of interest	Fori Imperiali	-	-
R3	(41.902299,12.454486)	6461	Area of interest	St. Peter's Basilica	-	-
R4	(41.890313,12.491605)	26289	Area of interest & Event	Colosseum	-	-
R5	(41.906129,12.454372)	5812	Event	-	-	-
R6	(41.902489,12.457725)	4537	Shooting spot	St. Peter's Square	-	-

Figure 8: Examples of photographs depend on a variation of value of relevance.

In Figures 7, 9, 10, and 11, we present results obtained using our proposed system. The red line shows the hotspot shape. The red marker is the center of gravity of area of interest. The icons of the camera and white circle are shooting spots. White arrows indicate the orientation with which most photographs belonging to the shooting spot are taken. When a shooting spot is related an area of interest, the arrow is long. In addition, our proposed system shows the relevance between two hotspots. The yellow line is the relevance between two hotspots. The value of relevance is high if the line is thick.

Figure 7 shows results obtained using photograph search results obtained from Flickr using a query of the "Brooklyn Bridge" and "Manhattan Bridge". In Figure 7(a), the Brooklyn Bridge shape is extracted for the most part as an area of interest. In addition, a part of a park near the Manhattan Bridge is extracted. However, cluster B6 has no "Spot". The reason why these hotspots are extracted is that a personal event (i.e., private vacation trips of individual people) happened. A personal event does not reflect many users' interest. Therefore, a famous spot does not exist around cluster B6.

Here, in this result, the actual shape of the Brooklyn Bridge is not extracted (i.e., our method extracted only the bridge over the river). However, our aim is extracting the area of the user's interest, not extracting the actual shape precisely.

In Figure 7(a), Manhattan Bridge is not extracted because the photographs taken at Manhattan Bridge were fewer than the photographs taken at the Brooklyn Bridge. The image search results obtained from Flickr using the query of "Brooklyn Bridge" were 426,248. Those obtained with a photograph location were 48,032. Those with a photograph orientation were 2,917. In contrast, the image search results obtained from Flickr using a query of ”Manhattan Bridge” were 198,368; those with the photograph location were 20,042. Those with a photograph orientation were 1,321. Therefore, we consider that people have no interest in the Manhattan Bridge itself.

Near the Brooklyn Bridge, shooting spots are extracted from near the entrance of the bridge and harbor. Figure 7(b) shows the relevance between the Brooklyn Bridge and shooting spots. In Figure 7(b), shooting spots from which photographs are taken toward to the Brooklyn Bridge are extracted as a hotspot related to the Brooklyn Bridge. The ratio of photographs taken toward the Brooklyn Bridge belonging to these shooting spots is greater than 20 percent. Therefore, we consider that our system can extract shooting spots for the Brooklyn Bridge. Furthermore, the relevance of shooting spots around the bridge entrance is high because these shooting spots include a part of the Brooklyn Bridge.

Table 4: Result of extracted hotspots of "London".

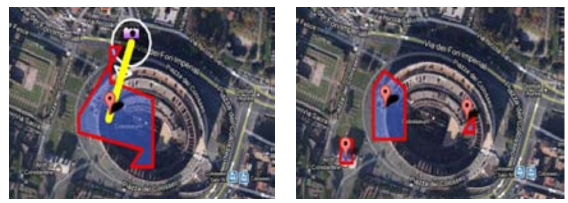
Cluster	Location	Photos	Category	Spot	Relevance	
					Target	Value
L0	(51.510182,-0.134065)	5128	Event	Station	-	-
L1	(51.513510,-0.098881)	10230	Shooting spot & Event	St Paul's Cathedral	-	-
L2	(51.503368,-0.119539)	13690	Area of interest	London Eye	L8	-
L3	(51.508059,-0.128068)	26003	Area of interest & Event	Trafalgar Square	-	-
L4	(51.508009,-0.099033)	7835	Area of interest	Tate Modern	-	-
L5	(51.506853,-0.115585)	4053	Event	Waterloo Bridge	-	-
L6	(51.505434,-0.075500)	6781	Area of interest	Tower Bridge	-	-
L7	(51.507729,-0.076388)	8163	Area of interest	Hotel	-	-
L8	(51.506405,-0.122025)	2446	Event	Hungerford Bridge	L2	3.125
L9	(51.506999,-0.127389)	48447	Area of interest & Event	Around Trafalgar Square	-	-
L10	(51.519286,-0.126808)	12757	Area of interest	The Portable Antiquities Scheme	-	-

We regard these spots as shooting spots and regard them as a part of the area of interest.

We describe the difference of photographs for relevance of hotspots in a query of "Brooklyn Bridge" and "Manhattan Bridge". Figure 8 presents some photographs taken in the hotspots described in Table 2. In target hotspot (Cluster 0 of table1), many photographs are taken inside of the area of interest. In hotspots for which value of relevance is high (Cluster 3 and 4), many photographs focused on the entrance of the area of interest. Hotspots that value of relevance as high tend to exist at the boundary of the area of interest. In hotspots for which the value of relevance is low (Cluster 5 and 7), many photographs focused on the entire area of interest. Hotspots for which the value of relevance is low tend to exist at distant places of an area of interest. This result presents relevance between hotspots and the relevance between the area of interest and shooting spot. The difference of relevance values shows what a user took.

Figure 9 shows the result around the Colosseum using image search results obtained from Flickr using a query of "Rome". In Figure 9, the DBSCAN parameters are set as $Eps = 0.0005$ and $Num = 50$. In Figure 9(a), the center of gravity of the area of interest is near the entrance of the Colosseum. Results show that the shape of the area of interest is extracted for only half of the Colosseum. The center of gravity of the area of interest is near the entrance of the Colosseum because of a bias in the interests of users. For example, at the Colosseum, more people take photographs near the entrance than at any other place. Our approach uses the density of photographs to extract an area of interest location. Therefore, the extracted location is closer to the entrance than to the center of gravity. As a result, our approach has not extracted the actual shape of the Colosseum. When many people have been taken to the Colosseum, they might tend to be taken to the outer wall of the Colosseum near the entrance. Furthermore, they might tend to take various orientations inside of the Colosseum. Therefore, interests of users specifically examine the Colosseum entrance. Consequently, our approach can extract and visualize the interests of users.

Figure 9(b) presents results obtained around the Colosseum when DBSCAN parameters are set as $Eps = 0.0003$ and $Num = 30$. In Figure 9(a), areas of interest are extracted



(a) Eps=0.0005, Num=50 (b) Eps=0.0003, Num=30

Figure 9: Results obtained for the Colosseum.

Figure 10: Results obtained around Trevi Fountain.

not only near the entrance of the Colosseum, but also on the opposite side of entrance and the Arch of Constantine. Near the entrance, many people might take photographs of the entire interior of the Colosseum toward the opposite side. Near the opposite side of the entrance, many people might take photographs of the entire interior of the Colosseum looking toward the entrance side. Therefore, in the Colosseum, people are interested not only in the areas near the entrance; they also show an interest in the opposite side of the entrance. However, shooting spots that exist in Figure 9(a) do not exist in Figure 9(a) because DBSCAN parameters have a low value: hotspots that are not dense are extracted.

As described previously, the DBSCAN parameters affect the extracted hotspots. Therefore, in our system, a user adjusts those parameters to obtain the desired result. For example, a user who wants to work with a small area of interest such as the Arch of Constantine is setting a low value of DBSCAN parameters. However, a user who wants to obtain a dense area is setting a high value. Because a user determines

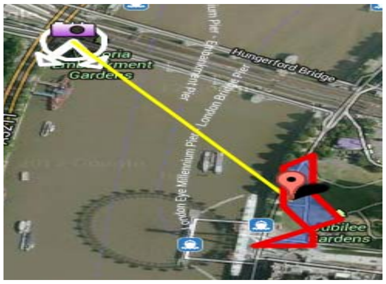


Figure 11: Result obtained around the London Eye.

Figure 12: Examples of photographs of extracted events.

DBSCAN parameters, the user obtains the intended result.

Figure 10 presents results obtained for the area around Trevi Fountain. In Figure 10, shooting spots taken of Trevi Fountain from the front of the fountain are extracted. However, an area of interest related to the shooting spot is not extracted. Our approach suffers from the bias of location in estimating the range and shape. Especially, in estimating the range of the area of interest, many photographs must be taken inside of the area. However, people cannot take photographs inside of Trevi Fountain. Therefore, our approach cannot extract Trevi Fountain as an area of interest. Additionally, using our approach, it is difficult to extract an area of interest for which is difficult to take a photograph inside an area of interest. This remains as an issue for future investigation.

We present examples of a hotspot with an event. Figure 11 presents results obtained for the area around Big Ben and the London Eye using image search results obtained from Flickr using a query of "London". In Figure 11, the relevance between the London Eye and the shooting spot are extracted. In addition, the shooting spot was examined for the event on Dec. 31, 2011. This day is New Year's Eve, when a fireworks display is held around the London Eye. Therefore, in this shooting spot, many photographs were taken of the London Eye and its fireworks (Fig. 12). Our system can extract the relation of area of interests and shooting spots with events.

5. CONCLUSION

As described in this paper, we proposed a method to extract the area of interest and shooting spot related to the area of interest using photographs with geo-tags on photo-sharing sites. Additionally, we estimated whether an event occurred in a hotspot using a photograph timestamp. To classify a hotspot into a shooting spot and an area of interest, we calculated the angle of photographs and classified inward photographs and outward photographs using photograph locations and orientation information. Furthermore, we calculated a relation of hotspots using the distance of each hotspot and the density of photographs in the areas separating hotspots. We estimated the range and shape of area of interests from the classification of results for the photographs.

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