

PHOTOTIMA: VISUAL EXPLORATION OF PHOTOS WITH SPATIOTEMPORAL REFERENCES

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Abstract: Nowadays, photos associated with spatiotemporal references are available widely on computers as well as on the Internet. There exist several tools for the exploration of photos with regard to their geographical and/or temporal structures. However, communicating spatial and temporal contents of photos remains a challenging task. In this paper, we follow Peuquet's triad framework in visually combining space, time, and descriptive contents of photos to deal with that task. We address the visual exploration of spatiotemporal photos to be communicated by an integrated design of different abstraction levels in space, time, and image displaying. The tool PhotoTima is introduced for the exploration of Flickr photos in connection with their timestamps, geo-coordinates, and user-generated tags.

1 INTRODUCTION

Today, photos are created, stored, and shared widely on smart devices, computers, and on the Internet. An interesting issue about those photos is that many of them are referenced with geographical coordinates and timestamps (i.e., places and times that the photos were taken or uploaded). Time and geo-space therefore can be seen as interesting aspects for the exploration and analysis of photos. Nonetheless, due to the fact that many photos are stored in folders or collections regarding user-defined topics or events, they are typically presented in a straightforward manner of slide-show or grid-based view tools. This is a convenient way for the exploration of photos. However, it is not feasible for the analysis or examination of spatiotemporal dependencies. For example, in the case that users want to see how their photos are geographically distributed, it is much more intuitive when the photos are displayed on geographical maps (as seen on e.g., Google Panoramio - www.panoramio.com). Generally speaking, by visually combining photos with their referenced features of geo-space, time, and other aspects, we could better understand and be able to analyze contents of the photos.

In (Peuquet, 1994), Peuquet indicates that when examining spatiotemporal data, one can get not only thematic contents of the data, but also insights with patterns, information, and knowledge from their inter-related spatiotemporal combinations. She shows that

with a triplet of time (*when*), space (*where*), and content (*what*) of any spatiotemporal data, one can come up with three general combinatory situations: *what + when* \rightarrow *where*, *what + where* \rightarrow *when*, and *when + where* \rightarrow *what*. In the area of visualization, those situations are reviewed by Andrienko, Andrienko, and Gatalsky for numerical and statistical spatiotemporal data (Andrienko et al., 2003). In this work, we further concentrate on the visual exploration of spatiotemporal photos. In that regard, we would have the following contextual situations:

S1: *What + when* \rightarrow *where*: Suppose that users browse specific photos (*what*) with specific timestamps (*when*), and want to know *where* on the earth those photos exist. It would be useful if there are visual hints to show photos with patterns in time so that users can conveniently browse for photos of interest over geospace. This can be considered as an extension compared to the well-known Google Panoramio (as time-referenced searching has not been provided in that tool).

S2: *What + where* \rightarrow *when*: Another situation, suppose that users are interested in photos with specific thematic contents (*what*) on a geographical map (*where*). In other saying, the photos exist and the places are given. Because those photos were taken and distributed over time, exploring their history (*when*) is another interesting task.

S3: *When + where* \rightarrow *what*: Finally, suppose that users are interested in some selected time points

or patterns (*when*) in association with geo-space (*where*), and they want to examine relevant photos of interest (*what*). This would also be helpful to provide means to highlight those photos to users.

Though the three above situations are somewhat interrelated, developers can come up with very specific designs for specific purposes (see Section 2). However, most of existing techniques do not explicitly support a comprehensive exploration of photos with regard to all three aspects: *time*, *space*, and *descriptive contents* of photos. Therefore, we investigate an approach that simultaneously addresses the three aspects by an appropriate interplay of showing different levels of abstractions and by allowing the browsing and detailing information with regard to those three data aspects.

Our basic design consists of two parts: a tags view and a map representation. The tags view looks like a parallel coordinates view, each coordinate displays a time-referenced tag set (to support S1). The map display shows photo data through sunburst icons or thumbnails on geographical maps, allowing interactive browsing for photos with timestamps on geo-space (S2 & S3). In doing so, instead of just showing photos through maps and a simple tag cloud (e.g., as in Google Panoramio), our visualization design supports users to find tag patterns, time patterns, and photos of interest (satisfying situations S1-S3). For this purpose, we provide the tool PhotoTima for the exploration of Flickr photos displayed with Google Maps.

This paper is organized as follows. In Section 2, related work concerning the visualization of photos with a focus on techniques dealing with time and geo-space is given. Section 3 presents the general view on our visualization design. Section 4 specifically describes the time-referenced parallel tag clouds view. Section 5 presents how sunburst icons and photo thumbnails are visualized on geographical maps. Section 6 presents the implementation and application of PhotoTima using Flickr and Google Maps APIs. And Section 7 concludes the paper.

2 RELATED WORK

This section presents related work about photo visualization techniques with regard to the exploration of the *what*, the *when*, and the *where* of photos.

2.1 Imagery Photo Exploration

Presenting photos (and images, in general) has been considered from the first days of GUI designs. Thus, there are now many developments in presenting and

visualizing photos on screens. There are two main trends corresponding to the tasks that photos are explored: browsing or searching. Browsing means that users navigate with visual hints to interplay and enjoy the photos. Searching means that users provide visual queries and the systems respond with the photos. In any case, goal of a photo visualization technique is to support users to get information from the photos. In this context, such information can be specified by the *what*, the *where*, and the *when* of the photos.

A very popular photo visualization technique is showing photos for browsing in forms of slide-shows or grid-based views, where users are assisted to easily find photos in collections. Windows Photo Viewer and Google Picasa (picasa.google.com) are examples of this approach. Users scroll a view or navigate forth and back a photo list to examine each photo. The main goal of those applications is to show imagery photos (the *what*), while their geo-references (the *where*) and time-references (the *when*) are just specifically supplemented if needed. One can get that information from the descriptive title (if existing) or the detailed properties of each photo. In general, they are the very loose situations of *what* (+ slightly *where* / *when*) \rightarrow *what* and *what* \rightarrow *what* (+ slightly *where* / *when*).

There are also many other specific designs. Porta in (Porta, 2006) developed some particular forms to arrange photos as “cylinder”, “rotor”, “tornado”, or other views. Bederson created a hierarchical visualization structure that highlights the relations of photos in collections (Bederson, 2001). In PhotoLand (Ryu et al., 2010), Ryu, Chung, and Cho suggested another way to arrange photos on screen: the photos similar to each other (with pre-defined content criteria) are placed close together to form spatial clusters, and the clusters are in turn forming a land-based presentation. By doing so, they showed that users can more flexibly find photos of interest compared to traditional grid-based views.

To interact with those visualizations, users can select an area of interest, change a zooming level (typically for a set of photos), and navigate through the photoset (i.e., interactive browsing). A photo can be shown in a separated view, highlighted with visual attributes (e.g., size, border color), magnified to be distinguishable with other photos (e.g., through a fisheye presentation (Liu et al., 2004)), or linked with other descriptive data (e.g., in (Kristensson et al., 2008), a tag cloud is used where each tag in the cloud can be connected with a slide-show collection of photos).

So far, we have seen techniques for the visual exploration of photos in form of *what* \rightarrow *what*. In the next subsection, we will see how time and geo-space

are combined for other situations, which are *when* → *what*, *where* → *what*, and vice versa.

2.2 Photo Visualization with Time and Geo-Space

We first consider the *time* aspect. Yahoo! Taglines (Dubinko et al., 2006) is an example for the visual exploration of Flickr photos, where users are supported to select linear time points in a timeline slider, and then relevant photos are presented on screen. Huynh et al., in another way, used not only the timeline but also a set of graphical charts to connect photo thumbnails with time (Huynh et al., 2005). Photohelix (Hilliges et al., 2007), with spiral-based time visualization, is another example for visualizing photos linking with time. Those are techniques that present a general kind of *when* → *what* (or *what* → *when*) representation.

To present photos with regard to their *geo*-dependencies, geographical maps are usually used. Commercial tools currently provided on the Internet such as Google Panoramio, Flickr Map (www.flickr.com/map), or iMapFlickr (imapflickr.com) are typical applications for the exploration of photos based on geographical maps. Those applications support showing photos as thumbnails (Google Panoramio, iMapFlickr) or placemarks (Flickr Map) on the maps. A list of photos is optionally connected with the map on a separated view for referencing. Those tools support the task of browsing photos over *geo*-space, while temporal dependencies of the photos are neglected. In other words, those tools express the situations of *what* → *where* and *where* → *what*.

WWMX (Toyama et al., 2003) can be seen as one of the first known applications that support well the visual exploration of photos connecting with both *geo*-space and time. It is a multiple-views design, with a view representing the geographical map, a view supporting time selection (dots with weights on a timeline presentation), and a view that shows an explored photo linking with a list of thumbnails. Users can select a dot which represents a set of photos on geographical map, and the list of thumbnails, each linked with a timeline view, is updated. However, visual patterns or analytical information from spatiotemporal photos are not considered. This leads to recent research in visual analysis and exploration of spatiotemporally referenced photos, such as those in (Gomi and Itoh, 2010) or (Peca et al., 2011).

In conclusion, although there are useful and well-established techniques for the exploration of photos in space and/or time, many techniques focus only on

one or two aspects rather than supporting the whole triplet of *space*, *time*, and *thematic contents* of photos; or they need investigations for the visual exploration of photos through more analytical patterns. In that regard, we follow Peuquet's triad framework in visually combining the triplet for the examination of spatiotemporally referenced photos.

3 GENERAL DESIGN ISSUES

This section presents general design considerations that will be addressed in detail in Section 4 and 5. The considerations are twofold with regard to (1) the presentation of the three aspects of photo data, and (2) the communication of insights in terms of combining the different photo aspects.

3.1 Presentation of Photo Aspects

To support the visual exploration of photos with their spatiotemporal references, we first consider the presentation of three data aspects of photos in different abstraction levels.

In information visualization, temporal data can be represented through time plots, cyclic patterns, branch views, and so on (Aigner et al., 2008). This provides ways for users to discover temporal patterns as well as relations amongst the explored data. In this work, we visualize photo tags as time plots (see Section 4), and use cyclic patterns to indicate the number of photos on *geo*-space (see Section 5).

To present geospatial data, usually geographical maps are used because they are effective means for *geo*-data communication (as seen in cartography and geovisualization). Therefore, we will also use maps to show the spatial context of photos (see Section 5). In this regard, photo data can be visually represented on maps, linked with maps, and interactively explored as maps are zoomed and panned.

To present photo content, its image has to be displayed. We show photos both as thumbnails or full-size views as presented in Section 5. Besides, as photos are also describable through textual tags, the tags are used for the exploration of photos as well. In this work, tags are abstractly presented with various visual encodings on time plots (see Section 4).

3.2 Visual Combination and Linking

To provide further insights, the three aspects are visually combined.

For the representation of time-referenced photo content (i.e., *when* + *what*), we show numerous tag

sets, each is associated with a specific time point, to form a parallel tag clouds view (see Section 4). To present the combination of *where* + *what* or *where* + *when*, we show photo thumbnails and particular sunburst icons for time visualization on maps (see Section 5).

Those visual combinations provide ways for the examination of patterns based on two aspects. Following that, we link each visual combination with the remaining aspect to resolve the situations S1-S3 (Section 1).

For situation S1, visual patterns of tags over time in the form of parallel tags view are visually linked with their geo-references on geographical maps. In doing so, user can easily explore photos in form of *what* + *when* → *where*. To deal with situation S2 (*what* + *where* → *when*), with the selected tags from the parallel tags view, users zoom and pan on maps to find out temporal patterns of photos over space by sunburst icons. Finally, with temporal patterns of photos on maps (i.e., through sunburst icons), we support users to filter time data to get detailed photos. In this way, situation S3 (*when* + *where* → *what*) is answered.

4 VISUALIZING TAGS WITH TEMPORAL REFERENCES

In this section, we introduce our solution to cope with situation S1 (*what* + *when* → *where*), where photo tags are visualized in the context of their temporal references.

With Flickr, Google Picasa, and many web-based photo applications, photos are typically tagged with textual tags. Normally a set of photos is linked with a set of tags. In that regard, if examining photos with time references, we would have different tag sets for

different time points. This leads to the expectation for the presentation of time-referenced patterns of photos within tag sets.

To deal with tags over time, there are recent developments such as time-referenced Taggram (Nguyen et al., 2011), SparkClouds (Lee et al., 2010), or Parallel Tag Clouds (Collins et al., 2009). Each of them has advantages and disadvantages if employed for photo visualization (due to the scope of this paper, we will not discuss them in detail). In this work, we introduce the enhancements of the Parallel Tag Clouds for the visualization of time-referenced photo tags.

4.1 Time-Referenced Tag Clouds

Derived from the ideas of tag clouds and parallel coordinates plot, Parallel Tag Clouds is a technique developed for the exploration and analysis of tag clouds over axes of tags (Collins et al., 2009). This approach is applicable for the exploration of time-referenced photo tags: each axis in the parallel tag clouds shows a set of photo tags at a time point, and the whole tag cloud shows all tags over time. However, we have to enhance the basic approach to allow large volumes of tags to be examined.

Our idea is to apply a fisheye lens to focus on axes of interest and tags of interest. It means: (i) tag clouds' axes are visually abstracted in different ways to emphasize different selected time points, and (ii) tags within each axis are displayed in different sizes and positions with regard to their levels of interest.

4.1.1 Showing Axes of Interest

An axis of interest is displayed in the size that its tags are readable, while for other axes, tags are resized much smaller to fit the display screen (see Figure 1). Users are supposed to choose particular axes of interest, for example in order to compare tags over a set

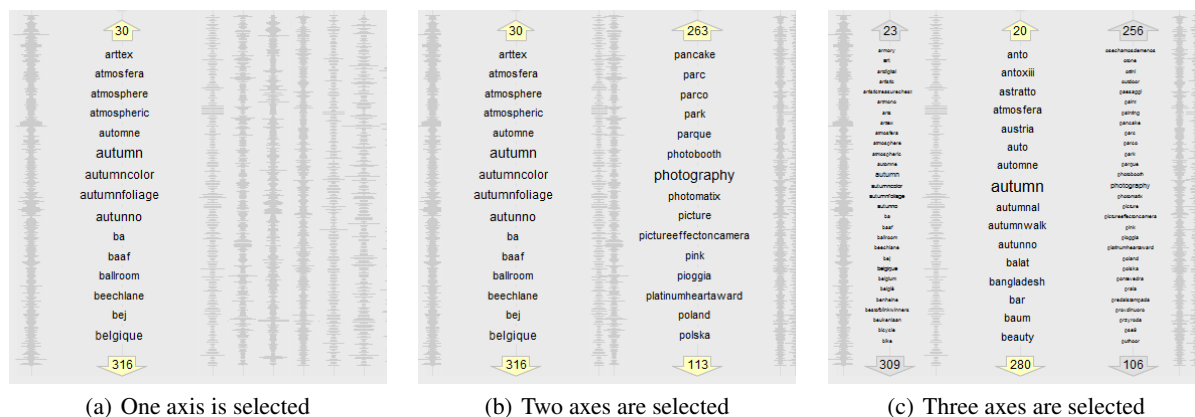


Figure 1: Parallel tag clouds with selected axes of interest and tags of interest.

of particular time points. Anyway, due to the limited display area, just a limited number of axes can be shown with tags in readable sizes (e.g., in Figure 1, we show at most three selected axes). In this regard, the axes are updated through user interactions: when users select an axis, its tags are readable and can be further examined (see Section 4.1.2); when users deselect the axis, the tags are minimized. If users select too many axes, the older axes will be marked as deselected and temporarily minimized. They will be shown again when users deselect other axes.

4.1.2 Showing Tags of Interest

The tags shown on each axis are displayed in alphabetical order for easy navigating. The heights of the tags indicate their weights (i.e., the number of related photos). Each tag can be highlighted as hovered or selected through mouse interactions. Color and background of the tags indicate their selected or hovered states. We show the hovered tags in red with pink border, while the selected tags are colorized with orange background (In Figure 2(a), tag “nature” is hovered and tags “myla” and “nederland” are selected).

Because there could be much more tags than we can show, on each selected axis just a subset of tags is displayed. Again, the idea of fisheye menu (Beder-son, 2000) is integrated. The tags in a selected range are displayed in full size (according to their weights), while those which are out of that range are minimized or removed from the axis’ view (in this case, digits at the top and bottom of the axis indicate the numbers of unshown tags). The shown tags are updated through user interactions (i.e., by scrolling or paging up and down) on that axis. We also visually link tags over axes (see Figure 2(b)). Through user interaction, tags which are identical to the examined tag on the hovered axis (i.e., tag “nature”) are highlighted with connected pink lines and red dots on other axes. The size of the dots are relative to weights of the tags

through axes. If a linked tag is out of range on another selected axis, its range is updated (in Figure 2(b), tag “nature” is shifted to the bottom of axis 4 and to the top of axis 9). Users can select or deselect tags identical to the hovered one on all axes as well (selected tags on the minimized axes are encoded in orange color). Lastly, we support filtering tags in terms of their weights. Figure 2(c) shows tags with the updated weight range of [3, 16].

In doing so, tags with different characteristics in weights, colors, and positions on parallel time plots of tag clouds are visualized to represent temporal patterns of photos (in form of *what + when*). In Section 6, we will see how this design is used for the exploration of photos on maps to satisfy situation S1.

5 VISUALIZING PHOTOS WITH SPATIAL REFERENCES

This section presents the design to cope with situations S2 (*what + where* → *when*) and S3 (*when + where* → *what*). Temporal patterns of photos are shown on maps as sunburst icons (to support situation S2), and pop-up window is used to show detailed photos for situation S3.

5.1 Photo Thumbnails and Sunburst Icons

Combining the *what* (or the *when*) with the *where* aspects of photos are carried out through different abstraction levels of photo aspects in connection with geographical maps. As thumbnails (the reduced-size versions for images representation) are typically used for recognizing and organizing photos in collections (e.g., as in the grid-based view of Google Picasa), they can be used to provide a glance view of photo

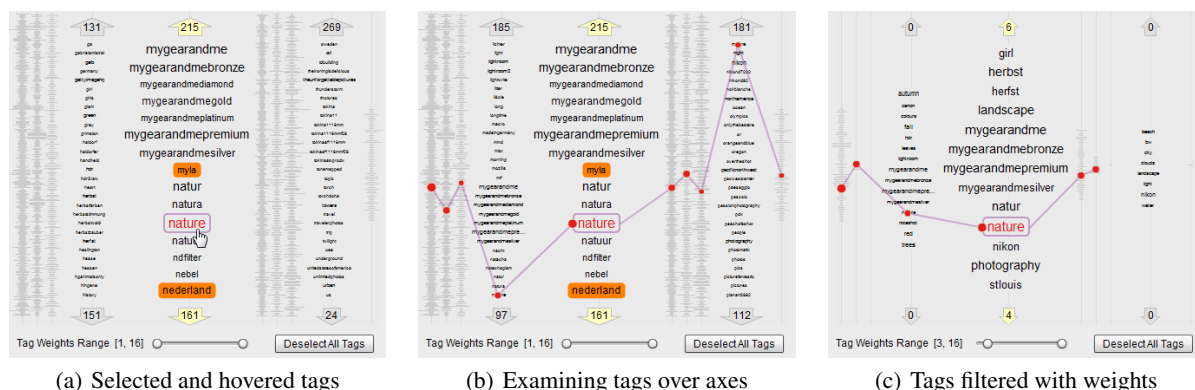


Figure 2: Presenting hovered and selected tags over axes.



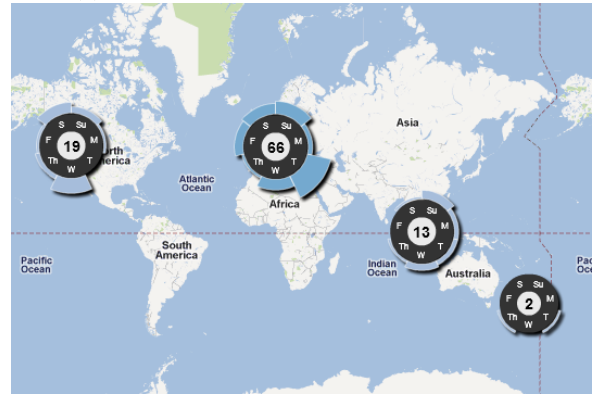
(a) showing 100 photo thumbnails on maps



(b) those thumbnails are shown in smaller sizes



(c) thumbnails for clusters (radius = 40 pixels)



(d) sunburst icons for clusters (radius = 40 pixels)

Figure 3: Showing photos as thumbnails or sunburst icons on geographical maps.

distribution over geographical maps (see Figure 3). However, if we have many photos close together, showing all thumbnails would cause perceptual problems. In Figure 3(a), when thumbnails are shown in size of 40x40 pixels, they overlap each other. If they are shown in smaller sizes (e.g., by 14x14 pixels as in Figure 3(b)), the overlapping problem reduces, but the thumbnails are too small to comprehend. Therefore, alternative visual abstractions are needed.

Firstly, we suggest to selectively show a subset of thumbnails in comprehensible sizes (i.e., 40x40 pixels). For this purpose, we cluster photos based on their geo-coordinates at each zooming level of the map. A cluster is composed of a list of photos within a local region around a centroid photo. Each centroid (and then a new cluster) is created when a photo does not fall into any existing cluster. In Figure 3(c), photos from Figure 3(a) are clustered with radius = 40 pixels. In this manner, the clusters form an orthogonal distribution of photos over geo-space. The clusters will be redistributed when the map changes its zooming level. With each cluster, we show the thumbnail for a photo of particular interest (e.g., the photo with specific tags). For clusters that contain more

than one photo, a “stack”-background is added to the thumbnail. However, since photos are not evenly distributed on maps (i.e., they are condensed at some places and sparser at other places), thumbnails with stack-background do not differentiate such information. Therefore, additional visual cues are added. For instance, numbers are added on the thumbnails to indicate how many photos are examined with that cluster (see Section 6). This design allows for the representation of *what + where* aspects.

Secondly, we further show temporal patterns of photos in form of visual icons on maps. In doing so, we can provide insights about *where + when* patterns. Within each geo-referenced cluster of photos, there could be interesting information about their temporal references. For instance, some photos co-occur at specific days in week. Thus, for each cluster of photos, we design a sunburst icon with three main parts: (1) a center circle with a number indicating the number of photos in the cluster, (2) a ring with labels for cyclic temporal patterns (we developed 3 patterns: hours-in-day, days-in-week, and months-in-year), and (3) arcs linked with the ring indicating the numbers of photos falling into the associated time slots. There,

the length and lightness of an arc represent its number of photos. Figure 3(d) illustrates our design.

In our implementation (see Section 6), photos are specifically selected for examination, we therefore colorize the arcs in orange for selected photos, and in blue to indicate the unselected ones. If an arc is too long (i.e., exceeding the space reserved for the sunburst icon), it is shortened and colorized darker (in Figure 3(d), the cluster in Europe is darker than those at the other places).

5.2 Browsing Full-Size Photos

With photo thumbnails or sunburst icons, we get the overview of photos distributed over geospace and time. However, for photo browsing, users need to see the photos in detail as well (this is a necessary task in any photo viewer tool). In that regard, we do the same as Google Panoramio in showing photos on demand. Users click on a cluster’s thumbnail or choose an arc on a sunburst icon, and a window is popped-up with detailed information about relevant photos. We show on the pop-up window: (1) title of the photo under examination, (2) its imagery content in size of max 240x240 pixels (Flickr photos’ small size), (3) links to other photos (if existing) in the cluster or the examined arc, and (4) navigator link to the source photo (e.g., the photo on Flickr website with full descriptions, comments, etc.) (see Figure 4(c)).

6 THE TOOL PHOTOTIMA

In this section, we describe the implementation and demonstrate the tool PhotoTima for the exploration of spatiotemporal Flickr photos in the context of situations S1-S3.

6.1 Implementation

We implemented a web-based visualization application in Flash, built on Adobe Flash Builder 4.5. The application PhotoTima is used for the visual exploration of spatiotemporal Flickr photos. Flickr photos are retrieved directly from Flickr servers through its APIs (www.flickr.com/services/api), while Google Maps API (code.google.com/apis/maps/documentation/flash) is employed for the manipulation of geographical maps.

The application consists of three components: a main toolbar on the top, a viewport for geographical maps on the left, and a view for time-referenced parallel tag clouds on the right (Figure 4). We allow users to toggle the tags view, select a period

of time in the view, provide some initial tags (if needed), and then load Flickr data. Through Flickr API `flickr.photos.search`, PhotoTima loads a list of photos, each contains a set of tags, a taken time, and a geographical coordinate. As Flickr photos are too numerous (e.g., in 2011, millions of photos are uploaded to Flickr everyday), by default we iteratively load 10 photos per query and refresh the interface. The photos are loaded from the most interesting ones (criterion supported by Flickr). Then, tags are grouped in various ways: per day, week, month, or year (options are provided on the tags view, e.g., “months” is selected in Figure 4). Based on the selection, tags are accumulated for relevant time points (e.g., months) and then consequently visualized on the plots of the parallel tag clouds.

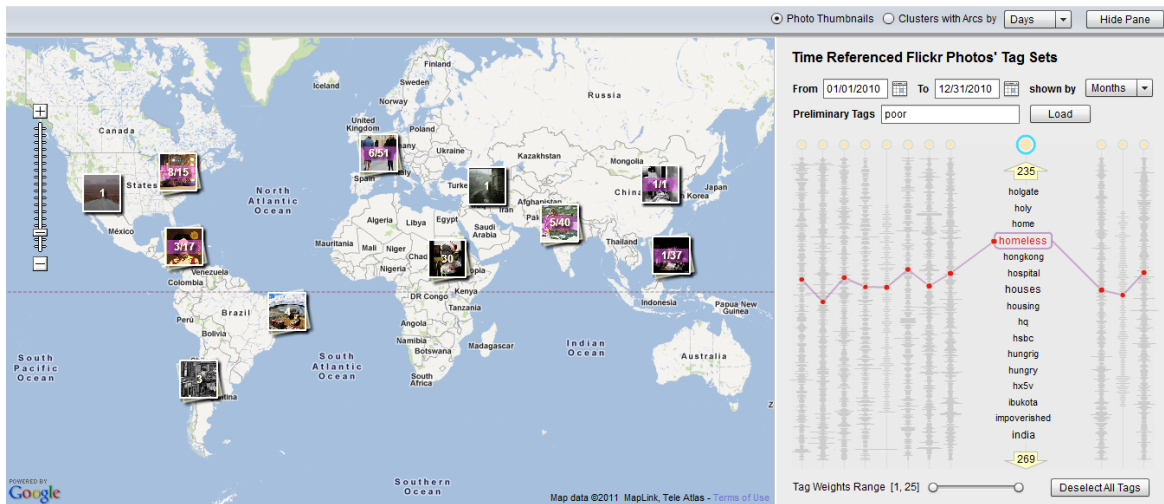
With options on the main toolbar, users choose whether to show photos as thumbnails or sunburst icons on maps. The thumbnails or sunburst icons are implemented as overlay objects added on Google Maps.

6.2 Application

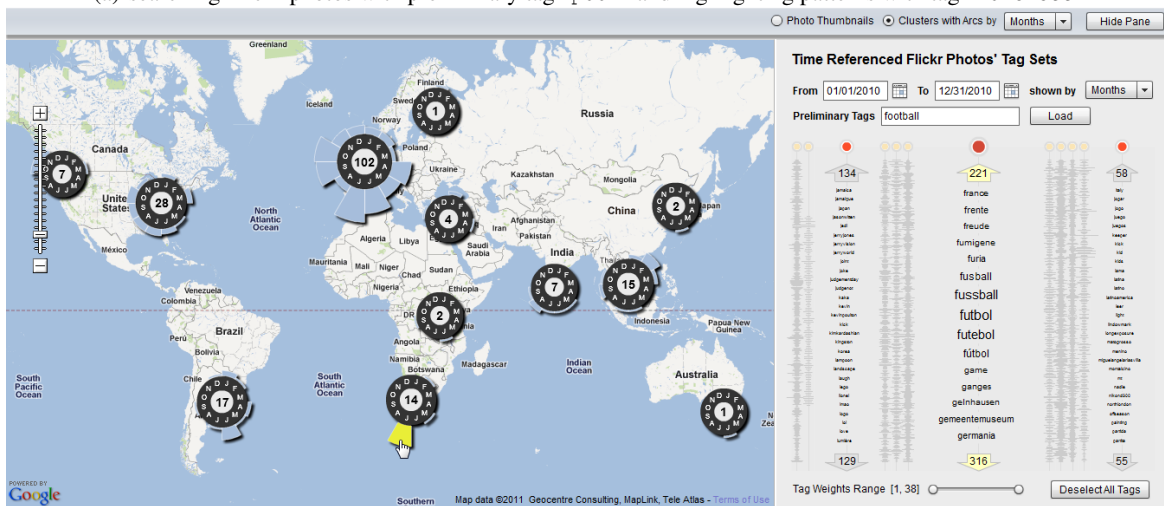
To explore Flickr photos in the context of situation S1 (*what + when* → *where*), users are supposed to specify photo tags and time points on the tags view and examine them in correlation with geographical regions of interest. To demonstrate the procedure, we loaded 200 most interesting Flickr photos taken in the year 2010 (from Jan 01 to Dec 31) in terms of the tag “poor”. The tool PhotoTima showed clusters with 51 photos (the most) in the area of Europe, then 40 in India, 37 around South East Asia, 30 in Central Africa, and 17 in Central America, while in other areas there were very few photos (15 photos in the US, and less than 5 photos on all other areas). However, when we selected an additional tag “homeless” (which is semantically related to tag “poor” - a criterion provided by Flickr) just 6 of 51, 5/40, 1/37, 0/30, and 3/17 photos were counted for those “poorest” areas, respectively, but up to 8 of 15 photos were highlighted at the area of US (numbers in pink in Figure 4(a)).

Here, users might wonder about the visual patterns. Thus, PhotoTima provides an interlinking mechanism for further exploration. For example, users can explore the sunburst icons for temporal patterns of photos on maps (situation S2: *what + where* → *when*) or click the thumbnails to see the detailed photos on maps for situation S3 (*when + where* → *what*).

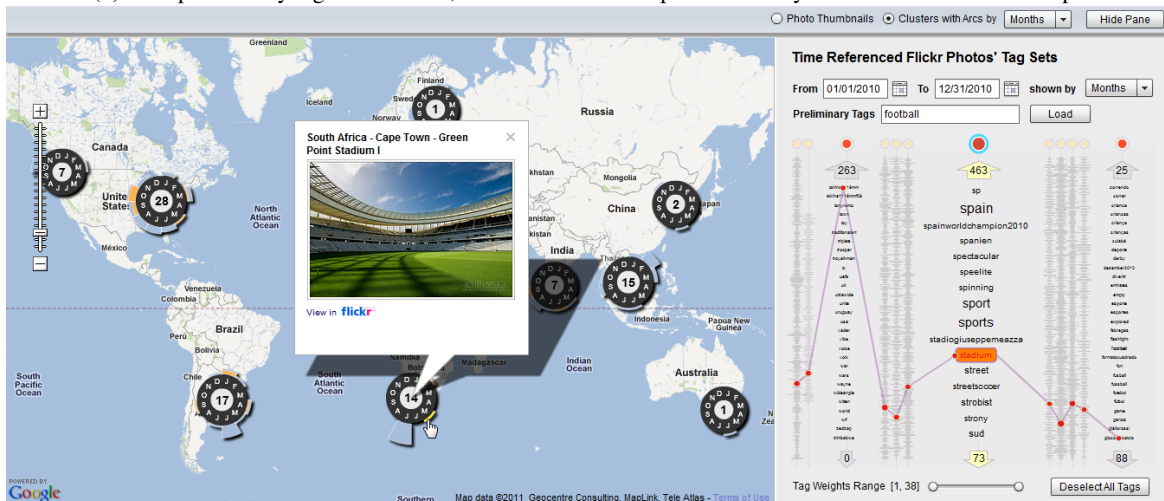
We investigated another example for 200 most interesting photos taken in 2010 with initial tag “football”. The visualization showed that there



(a) searching Flickr photos with preliminary tag “poor” and highlighting patterns with tag “homeless”



(b) with preliminary tag “football”, sunburst icons show peaks for “July” in South Africa and Europe



(c) pop-up window for detailed information of the photo tagged with “stadium” in South Africa

Figure 4: Screenshots of the tool PhotoTima.

were 102 photos in Europe, 28 around North America, 17 in South America, 15 in South East Asia, and 14 in South Africa, and so on (Figure 4(b)). What were the reasons for this distribution?

We found the answers by examining time-referenced tags of “football” photos. The visualization showed that the highest number of tags is on July (552 tags) and the fewest one is on December (142 tags). It means that Flickr users seem to consider photos taken in July most, but least in December. In that regard, we examined how photos were distributed with time pattern of months over geographical maps. As seen in Figure 4(b), almost all photos taken in December were accumulated only for the region of Europe, while the photos in July appeared as peaks in South Africa and Europe.

What was that special pattern of July? Why most of photos in South Africa (12/14 photos) appeared in July? By clicking on the sunburst piece indicating July at South Africa, the pop-up window showed photos with titles such as “World Cup 2010 South Africa: Spain v Netherlands” or “World Cup 2010 South Africa: Spain v Germany”. The answer was clear: the particular pattern about “football” photos in 2010 was about World Cup 2010 taken place in July in South Africa.

Alternatively, we examined how tag patterns in parallel tag clouds visualization could be used to help us in finding out that information. One of the related tags of the tag “football” is tag “stadium”. Interestingly, tag “stadium” appeared in all columns of the parallel tag clouds. By selecting it on all columns (i.e., for all photos), the two remaining photos (indicated by February and May) in South Africa’s sunburst icon were highlighted. Why those two photos were about stadium? Could we find any relation between those photos and the others in July? By clicking on them, e.g., the photo in May, we found out that the description was about the Green Point Stadium I in Cape Town, and when we navigated to Flickr website, we saw descriptions and comments about this stadium in its preparation for World Cup 2010 (Figure 4(c)). From that, we thought that users can also guess what the photos in July were about.

6.3 Preliminary Feedback

We conducted informal interviews to get a preliminary feedback for our tool. Six users (two visualization experts, and four users from other domains) have been invited to use PhotoTima to explore Flickr photos. We first explained the tool and the provided options (interface components, mouse options, and hot keys). Afterwards, the users applied PhotoTima to ex-

plore Flickr photos. After having used the tool, they were asked to give an informal feedback.

In general, all users gave positive feedbacks. They particularly pointed out that PhotoTima presents useful temporal patterns of Flickr photos on maps. They said that the tool is easy to use as all of them are familiar with photo thumbnails, tags, and geographical maps. In addition, they said that our tool is very comprehensible because it smoothly updates the interface.

However, although the tag clouds design was expressive, more explanations about it were requested. Besides, the users also expected the tool to be improved with additional supports: (1) providing hints so that users can select related tags of any tag, (2) showing all selected tags in a separated view as they are important information, (3) providing more hints for the photos from clusters without clicking on the icons, and (4) automatically updating photos and tags when the map-view is updated.

7 CONCLUSIONS

In this paper, we have presented an approach for the visual exploration of Flickr photos with regard to their spatiotemporal references. We addressed the visualization of complex photo data communicated through different visual encodings in space, time, and descriptive contents. Geographical maps were employed to communicate geospatial references, sunburst icons and time plots were applied for temporal patterns, and image displaying and tags were used for the presentation of thematic contents of photos.

The visual representations were linked to provide insights for spatiotemporal photos exploration. We combined *what* + *when* aspects of photos in the form of parallel tag clouds (focused tags are shown-in-context by a fisheye lens). To communicate information with regard to *where* + *what* and *where* + *when* combinations, we created thumbnails and sunburst icons on geographical maps.

By brushing-and-linking the tag clouds view and the maps view, we allowed users to explore photos with regard to all three photo aspects. In doing so, our approach can simultaneously communicate information in terms of the *what*, the *where*, and the *when* of photos, and thus supporting all situations S1-S3.

The tool PhotoTima was developed for the exploration of Flickr photos. Today, there are a lot of sites for other media sharing, such as video with Youtube - www.youtube.com, music with Last.fm - www.last.fm, and many more. Most of media sharing sites provide APIs for data access and manipulation. Thus, exploring and entertaining media with

regard to their spatial, temporal, and descriptive contents (e.g., tags) are of interest. The prototype approach of PhotoTima can absolutely be applied for the development of similar tools for other media. Anyway, how relevant a tool is depends on the APIs that a media site supports, as currently most of sharing sites provide APIs suitably for contents retrieving, instead of time and geolocation fetching (e.g., even with powerful systems such as Google Panoramio or Last.fm).

For future work, we will improve the tool PhotoTima following the issues raised from users' feedbacks. In details, we will show related tags on the parallel tag clouds, create a magic lens (Bier et al., 1993) that provides hints for the photos at the examined cluster, and update the Flickr photos and tags as the map view is changed. In addition, the tool PhotoTima will be examined in the case of using multitouch tablet computers and smartphones.

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