Kachkaev, A. & Wood, J. (2013). Crowd-sourced Photographic Content for Urban Recreational Route Planning. Paper presented at the University Transport Study Group UK Annual Conference, 2 - 4 Jan 2013, Oxford, UK.

Crowd-sourced Photographic Content for Urban Recreational Route Planning

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Abstract

Routing services are able to provide travel directions for users of all modes of transport. Most of them are focusing on functional journeys (i.e. journeys linking given origin and destination with minimum cost) while paying less attention to recreational trips, in particular leisure walks in an urban context. These walks are additionally predefined by time or distance and as their purpose is the process of walking itself, the attractiveness of areas that are passed by can be an important factor in route selection. This factor is hard to be formalised and requires a reliable source of information, covering the entire street network. Previous research shows that crowd-sourced data available from photo-sharing services has a potential for being a measure of space attractiveness, thus becoming a base for a routing system that suggests leisure walks, and ongoing PhD research aims to build such system.

This paper demonstrates findings on four investigated data sources (Flickr, Panoramio, Picasa and Geograph) in Central London and discusses the requirements to the algorithm that is going to be implemented in the second half of this PhD research. Visual analytics was chosen as a method for understanding and comparing obtained datasets that contain hundreds of thousands records. Interactive software was developed to find a number of problems, as well as to estimate the suitability of the sources in general. It was concluded that Picasa and Geograph have problems making them less suitable for further research while Panoramio and Flickr require filtering to remove photographs that do not contribute to understanding of local attractiveness. Based on this analysis a number of filtering methods were proposed in order to improve the quality of datasets and thus provide a more reliable measure to support urban recreational routing.

1 Introduction

In recent years the government and local authorities have taken a number of initiatives that aim to encourage walking in the UK. They mainly include making street infrastructure more suitable for pedestrians (MVA Consultency, 2010; Department for Transport, 2011) improving navigation by providing more information using maps and signs (Transport for London, 2012; Woodhouse, 2012) and also promoting walking as physical activity and part of healthy lifestyle (Ramblers' Association, 2012; Walk4Life, 2012; WalkEngland, 2012; WalkLondon, 2012). A number of routing services (e.g. *Walkit*[1], *TfL journey planner*[2], *Google Maps*[3], Mapquest[4], etc.) help pedestrians getting turn-by-turn directions for their journeys before making trips, thus also encouraging more people to walk more. Most of the services are designed for finding directions between given points with minimum cost (time and distance), thereby supporting walking for transportation purpose *functional* walking).

[1] http://walkit.com/
[2] http://journeyplanner.tfl.gov.uk/
[3] http://maps.google.com/
[4] http://mapquest.com/

Meanwhile, route planning for *recreational leisure* walking is not presented in these services with minor exceptions (Walkit, 2012) despite being rather popular, especially among tourists (Ramblers' Association, 2010). There are some existing online projects that are suggesting manually prepared walks (e.g. Discovering Britain[1]), but despite the high quality of such trips their variety is formed by moderators or users and thus is limited.

Unlike functional walking, recreational walking implies a more complex combination of factors that form selection of a particular route, many of which are having psychological nature and relate to human perception of space (Davies et al., 2012). One of the most hard-to-formalize factors that a person can be considering when planning a walk is the attractiveness of areas that appear on their way. A reliable way of formalising this factor and its embedding into a pedestrian routing system could be found useful by millions of people planning leisure walks all over the world.

There is a significant difference between recreational walks in rural in urban areas. While rural footways are in many cases designed for recreational walking, urban street network in general has a functional nature, thus potentially making the automation of choosing attractive paths in cities a more complex task. Previous research of data available from various sources of user-generated content show that photo-sharing services can potentially form a reliable measure of popularity and attractiveness of space, for instance, data from some photographic services has already been successfully used for detection of landmarks and generation of tourist trips for visiting the most popular places in a particular area (Dykes et al., 2008; Andrienko et al., 2009; Baeza-Yates, 2009; Kisilevich et al., 2010; Purves, R. et al., 2011; Adrienko et al., 2012). These studies demonstrated the existence of patterns in spatial and temporal distributions of photographs shared by Internet users on Flickr and Panoramio and have proved the ability of such datasets to locate popular and attractive places in cities.

A number of projects have also tried to link photographic data with tourist trip planning. For example, Kurashima et al. (2012) propose a travel route recommendation method that makes use of the photographers' histories as held by Flickr. Recommendations are performed based on a photographer behaviour model developed by the authors, which estimates the probability of a photographer visiting a landmark. Lu et al. (2010) from Microsoft in their project called Photo2Trip also analysed Flickr user photo streams and proposed travel route planning system based on them. Using location and temporal information discovered from geotagged photographs, the system that was developed could provide a customised trip plan for a tourist, i.e. popular destinations to visit, visiting order of these destinations, the time arrangement in each destination, and the typical travel path within each destination. Similar research is done by Okuyama, K. and Yanai, K. (2010) and De Choudhury et al. (2010) at Yahoo.

However, the nature of leisure walks is different. A walk is a continuous movement in space, with no long stops such as visiting a museum. Time that is spent for a walk has linear dependence from distance and pace (speed) that are defined by a user. A problem of finding a path that does not exceed given distance or time while maximising profit (in this case − attractiveness of places that are passed by) is known as orienteering problem with time windows. It is hard to be approximated efficiently and the solution is usually approached with meta-heuristics algorithms such as genetic algorithms or ant colony optimization.

During the process of literature review, it was observed that the importance of photographic data analysis in the related projects is underestimated. Despite the fact that photographic datasets can contain photographs taken both during the day and over night, indoors and outdoors, during events, etc., can be placed incorrectly or be just human portraits, very little attention is paid by researchers to data filtering. For instance, Okuyama, K. & Yanai, K. only exclude all the pairs of the photos whose geotag locations are exactly identical but whose taken time are different by more than five minutes and De Choudhury et al. filter out photographs with time taken equal to time uploaded and those that are having no tags

[1] http://www.discoveringbritain.org/

related to locations where they are placed. However, no attention is paid to analysis of contents of photographs and such metainformation as EXIF data, which can be useful for applying more advanced filtering techniques and can result cleaner initial dataset, thus improve the work of the algorithm. Apart from all, is also necessary to understand whether photographic data can form a sufficient standalone measure for weighting in a routing system and if there any important aspects of attractiveness of recreational walks that cannot be covered by this type of data.

Ongoing PhD research is attempting to develop methodology for assessing user-generated geotagged photographic datasets for the purpose of their usage for planning leisure walks in urban areas and also to propose a routing algorithm that will be suggesting scenic routes for pedestrians based on this data. Such an objective implies two tasks: (1) selection of sources of input data, their analysis and filtering and (2) adoption of existing routing algorithms or design of a new approach. The work is focusing on routing in urban areas for being richer on photographic data (De Choudhury et al., 2010).

This paper demonstrates findings on four investigated data sources, proposes filtering methods that should be applied on the datasets and discusses the requirements to the algorithm that is going to be implemented in the second half of the PhD research.

2 Selection of data sources and data collection

Related projects described above are using Flickr, Panoramio or a combination of both as the source of the measure of place attractiveness. It the ongoing research it was also decided to consider these two photo-sharing websites as well as two other services gathering user-generated photographic data: Picasa Web Albums[1] and Geograph[2]. 'Picasa Web Albums' was chosen for it's high popularity and similarity to Flickr, and Geograph — for its resemblance with Panoramio.

It was decided to test the methodology and perform the case study in Central London, thus limit the considered area with the following bounding box: *North: 51.56, East: 0.02, South: 51.46, West: -0.21*, which approximately covers Travel Zones 1 and 2.

In order to collect photo metadata, a crawling framework was developed using Java and Processing. Being universal and scalable, it was adopted to work with APIs of 3 photo services: Flickr, Panoramio and Picasa. Data retrieval from Geograph was performed by downloading dumps of the original database from the official website and converting the data into a standardized format.

3 Data analysis and filtering

User-generated photographic sets selected as potential data sources must be analysed and filtered before being used as an input in a developing routing algorithm. The reason and importance of the analysis is caused by the observation that not all georeferenced photographs uploaded by users describe urban environment and can be used as a measure of attractiveness of surrounding space. Thus, it is necessary to exclude some types of the photographs before passing the datasets into the routing system, i.e. apply filtering. Depending on a purpose of a photo-sharing website and its rules the percentage of items that are not suitable for evaluating attractiveness of the environment can vary as well as the nature of their unsuitability. Accuracy of geographical references is also an important question (Zielstra and Hochmair, 2012).

It was decided to do the analysis of each candidate photographic dataset by performing the following steps:

1. Detection of problems and anomalies in spatial distribution on photographs
2. Qualitative analysis of entries in the dataset

[1] http://picasaweb.google.com/
[2] http://wwwwww.geograph.org.uk/

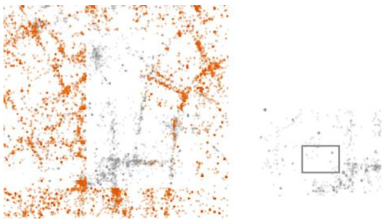
3. Data filtering. By applying a set of filtering methods on a photographic dataset, each item (photograph) is marked as accepted (i.e. the one that can be used as a measure of attractiveness of surrounding space) or rejected.
4. Data filtering verification. At this stage it is determined whether applied filtering is successful and the dataset can be used as an input for the algorithm. Steps 2, 3 and 4 can be repeated in necessary.

3.1 Spatiotemporal visual analytics

Visual analytics was chosen as a method for performing the first step. It is a multi-disciplinary approach that combines computational techniques and human judgment to “detect the expected and discover the unexpected from massive and dynamic information streams and databases” (Thomas and Cook, 2006). By means visual representations and interaction, visual analytics software tool can help finding patterns and anomalies, and thus 1) on an early stage determine if a dataset is unsuitable for the research, 2) discover potential pitfalls that a chosen source may contain. For these purposes another Java software tool was developed. The application allows browsing the data interactively, changing its visual representation and seeing related statistics. The interface of this tool is presented in Figure 1:

Figure 1: Interface of the developed visual analytics tool for dataset assessment

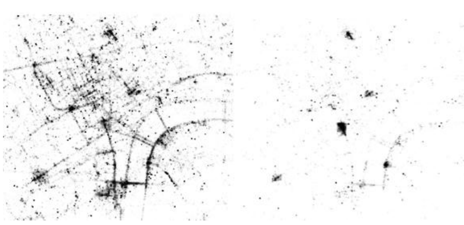
Four key anomalies were discovered in spatial distribution of photographs by means of visual analytics (Figure 1):



a

b

c



d

Figure 1: Problems found in datasets with visual analytics software tool: *a:* issues with Picasa API; *b:* locations containing large amounts of misplaced photographs, *c:* corrupt photo coordinates at 0˚ longitude; *d*: different Flickr API results depending on selection of crawling method

More details on these anomalies can be found in a recently published paper presented at the IEEE conference on Information Visualization available at http://openaccess.city.ac.uk/1320/.

Consideration of temporal distribution of photographs reveals that the datasets are influenced by public events that cause changes in user activity, however, the amount of this influence is different. As expected, the biggest impact has Flickr being a photo-sharing website used for general purpose. Panoramio and Geograph demonstrate having less numbers of days with peaks in user activity because the items are being moderated upon upload and event-related photographs are usually not accepted. Some of the events can be clearly observed on a time histogram, an example of which is shown in Figure 2:

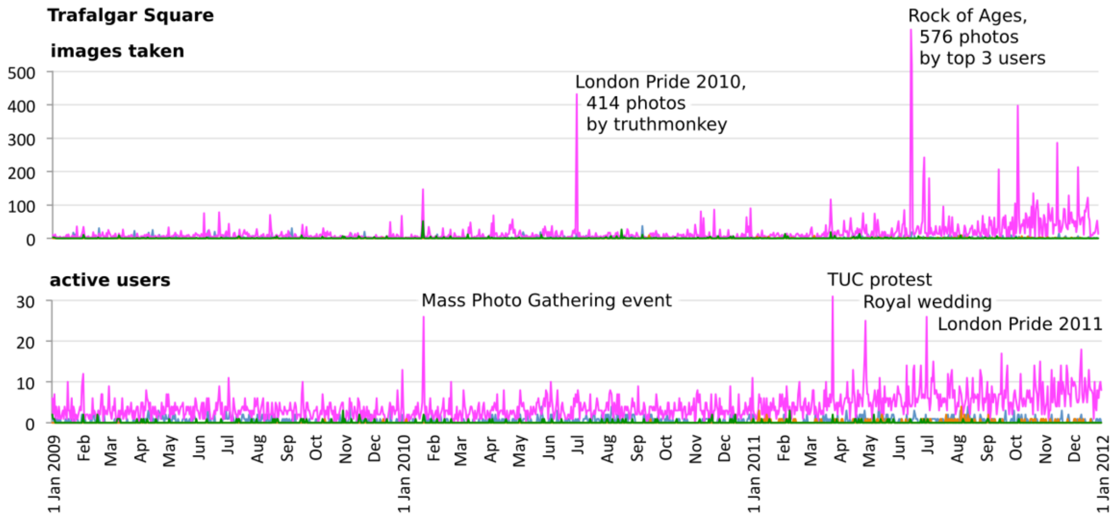


Figure 2: Temporal distribution of photographs collected from ●Flickr, ●Panoramio, ●Picasa and ●Geograph taken around Trafalgar Square (North: 51.51, East: 0.126, South: 51.505, West: -0.13); *Below:* aggregation of frequency by unique users

As it is seen above, the peaks in the histogram with numbers of images taken at certain date do not repeat themselves on the second graph showing numbers of unique photographers. In some cases individual users are sharing vast amounts of photographs that form more than 95% of all items geotagged in a given area at a certain date. Reflecting a single personal view on the surroundings, these bundles of photographs should be having less value in the weighting system of the routing algorithm than the same number of items contributed by different users. Exclusion of the peaks can be done by clustering images of the same object/event (Quack et al., 2008; Andrienko et al., 2009) and removing the items belonging to corresponding groups. After the weights of edges in the routing graph are calculated, it will be necessary to compensate them by increasing values proportionally to the number of excluded days at affected locations.

Despite that visual analytics gives a lot of hints on improving the quality of input data for the routing algorithm, looking only at the spatiotemporal distribution of photographs is not enough as the images contribute to the measure of space attractiveness differently. For instance, some photographs can be taken indoors, be human portraits, be taken during events or over night (Figure 4). The latter type of items is not wanted in the input of the routing algorithm either, because the places that are attractive over night are not necessary attractive during the day.

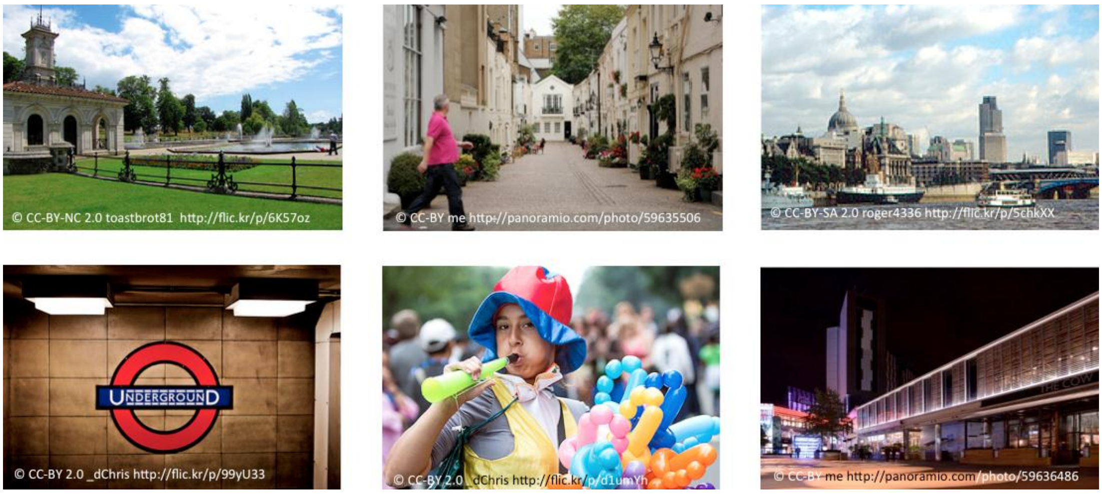


Figure 4: Examples of photographs found in collected photographic datasets. *Top:* items that render surrounding area attractive; *bottom:* items that need to be excluded from the datasets before calculating weights in the routing graph (indoor photography, human portraits and items taken during events, night photography)

Thus, a more careful look at photo metadata is required. In this research it was decided to consider camera settings that are available for more than 80% of photographs on Flickr and Panoramio including ISO, aperture and shutter speed. Combination of these parameters gives the value of luminance (the amount of light that was there when the photograph was taken): the more light there is when the photograph is being taken, the more is the probability that it is not the case of dealing with indoors or night photograph. Visualization of luminance (Figure 3) reveals quite interesting patterns:

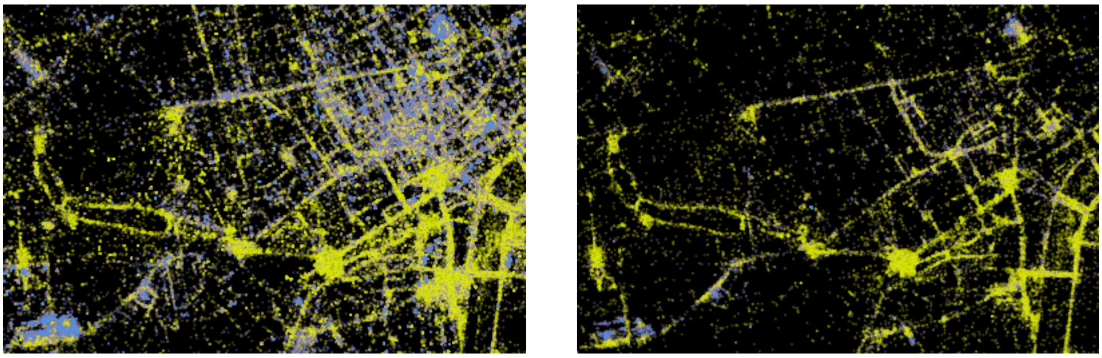


Figure 3: Average luminance of photographs on Flickr *(left)* and right Panoramio *(right)*

Despite that the image on the left looks brighter in general (this is because Flickr dataset contains 8.2 times more photographs than Panoramio one), it is clearly seen that there are more lilac coloured areas in it, which means that more places in this dataset are dominated by indoor or night photography. The most vivid examples in the shown fragment include National Museums (bottom-left) and Soho (top-right). For obvious reasons, the museums themselves cannot be chosen as places for walks, the same as the experience of walking in Soho during the day cannot not be the same as overnight. Thus, the analysis of distribution of photo location is not enough and additional filtering is required.

Low value of luminance may be not the only reason why a photograph should be excluded from a dataset before its usage in the weighting system of the routing algorithm. Human perception of space this has a very complex nature, which means that a set of hypotheses on ways of improving the representativeness of the datasets by means of filtering must be supported by human opinion. Thus, in order to refine the filtering process it was decided to perform manual assessment of a sample of photographs by running an online survey.

3.2 Manual assessment of a sample of photographs

Visual analytics of the locations of photographs and manual browsing of collected content demonstrated that filtering using only spatial or temporal distribution is not enough for obtaining a reliable dataset for the routing system, and additional analysis and filtering is required. The observations made during the first stage of data analysis together with the list of rules used by moderators of Panoramio (Panoramio, 2012) helped to develop a set of criteria a photograph must satisfy to be a candidate measure of space attractiveness. It was decided that a photograph that is a suitable input for the proposed routing algorithm:

- must be taken outdoors,
- must be taken during the day,
- must not be taken during an event,
- must be reasonably accurately georeferenced,
- must not have human faces (except passers'-by), or other moving objects as the main subject.

Percentages of photographs that do not satisfy these criteria can be different in various datasets due to diverse purposes of photo sharing services they were originally contributed to. This fact can influence the reliability of any dataset even if it contains a large amount of images. In order to determine the percentage of photographs being unsuitable for a pedestrian routing algorithm in selected data sources it was decided to conduct an online survey and involve a number of participants to answer a set of yes/no questions about individual photographs from a subset of collected photographs.

The following questions were included in the survey:

1. **Is the image a real photograph?** In case if it is not, the following questions are skipped.
2. **Is it a photograph of something outdoors?** The photographs taken under a roof, i.e. museums, cafes, or any other buildings are not suitable and must be excluded.
3. **At what time of the day is the photograph taken?** This question implies 3 possible answers: day, twilight, night. It can both estimate the amount of the night photography, which is unwanted and also help to determine if timestamp can be a reliable measure for photo filtering time can be incorrectly set on a camera or a wrong timezone can be used.
4. **Is it a photograph of something temporary?** The photographs that are taken during special events are unwanted because they can result incorrect weights in the routing algorithm.
5. **Are people the main subject of the photograph?** Human portraits and (photographs with one or several humans being a main subject) are not helping to describe the environment and are out of the scope of research interest.
6. **Could the photograph be taken by a pedestrian?** This question is needed to make sure that the percentage of photographs taken not from street level is reasonably low.
7. **Does the photograph suggest this is a nice place to walk?** A participant is asked to give a general conclusion about the photograph being a good measure of attractiveness of surrounding space in their opinion.

Due to some technical and legal peculiarities related to image content retrieval and display it was impossible to use existing frameworks for online survey such as SurveyMonkey[1], LimeSurvey[2], etc. and a new software web application was developed from scratch using Symfony2 PHP framework[3]. The source code of the tool was published under a free license[4] and can be downloaded from https://github.com/kachkaev/photoassessment. The interface of the survey is shown in Figure 4 (see next page).

[1] http://wwwwww.surveymonkey.com/
[2] http://wwwwww.limesurvey.org/
[3] http://symfony.com/
[4] MIT http://opensource.org/licenses/MIT

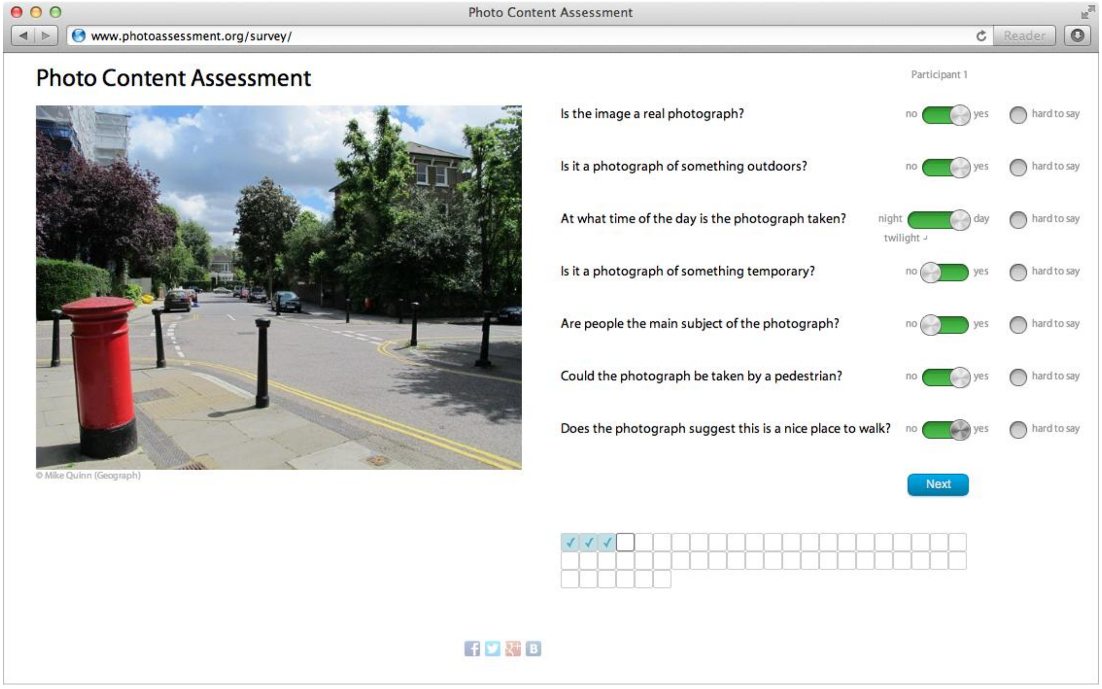


Figure 4: Interface of photo content assessment online survey available at www.photoassessment.org

The website landing page (not shown above) contains the description of the project and the instructions. After reading them, the participants press “Start” button and appear on a page that shows a photograph and related questions. By moving the sliders on the right hand side using mouse or keyboard a participant give their answers and once ready he or she presses “Next”, see the next photograph and the process repeats. Because in some cases it may be hard to give an exact answer, each question is supplemented with a “hard to say” option. The questions have logical dependencies and a number of them turns off in some cases. For example, if a user states that the photograph is taken indoors, questions 3, 4, 6 and 7 become unavailable and can be skipped. This saves participants’ time and avoids confusion.

A user is free to close the website at anytime he or she wants to and go back to continue photo content assessment afterwards. The registration is not needed, however the website remembers each participant and restores the state of the survey once he or she is back. The order of photographs is random (except the first “test” item), but once the queue is formed it remains the same for each participant. Initially it consists of 50 photographs but gets extended every time a user gives all answers. Thus, time spent purely depends on personal engagement.

At the time of submission of this paper the questionnaire was waiting for an approval from City University Research Ethics committee. The results of the survey will be demonstrated during the conference and in further publications.

3.3 Proposed metadata-based filtering methods

A set of data filtering techniques was proposed to be applied for each dataset depending on the results of a survey. This will involve:

- **Filtering based on photo timestamp** In case if it is concluded that timestamp of items in a dataset is a reliable parameter, it will be possible to filter out photographs taken over night based on it’s value.
- **Filtering based on tags, title and description** If a strong correlation is found during between photo contents and their suitability, attached textual information will be used for filtering.

- **Filtering based on EXIF data** It will be attempted to use camera settings (values of ISO, exposure, aperture and flash) to exclude photographs taken over night and indoors from a dataset if this information is available.
- **Filtering based on photo content** If the results of the survey show that there is a strong correlation between the presence of people on photographs and the ability of photographs to measure attractiveness of the area where they are taken, it will be attempted to remove photographs containing faces by applying image processing.

Selection of methods and their order for each dataset will be determined after obtaining results of manual classification of samples of photographs. There is a probability that some of the methods will be not necessary due to a very small percentage of photographs not matching a particular criterion. On the other hand, some methods in a number of other cases may be useless if necessary photo metadata is missing or unreliable. In all cases, the results of manual photo content assessment will become a useful feedback during the filtering process. As the result, cleaner and more representative datasets will form an input of the routing algorithm.

4 Requirements of a Pedestrian Routing System

Usually routing (or path finding) is based on one of the algorithms that solve the *single-source shortest path problem*, for instance Dijkstra's algorithm, Bellman–Ford algorithm, Floyd's algorithm, etc. (McHugh, 1990). In general case street network is represented by a static graph

$$G = (V, E)$$

where V is a set of vertices (road intersections) and E is a set of edges of the graph (road segments). Every path can be presented as

$$P = v_1 \to v_2 \to ... \to v_k$$

and is characterised by its weight

$$\omega(P) = \sum_{i=1}^{k-1} \omega(v_i, v_{i+1})$$

where $\omega(v_i, v_{i+1})$ is the cost of travel between nodes v_i and v_{i+1}. The value of the cost is non-negative. Distance and travel time are the simplest examples of such weights: the more expensive it is to take a certain road segment, the less likely it will be included into the most optimal path.

In most cases the goal of a routing algorithm is to find the shortest route (i.e. the path having the smallest overall weight) $P'(u, v)$ such as

$$\omega(P'(u, v)) = \sigma(u, v) = min\{\omega(P) : P \text{ from } u \text{ to } v\}$$

$\sigma(u, v)$ is the minimum cost of travel from *u* to *v*.

In some applications the graph can be directed with $\omega(v_i, v_{i+1}) \neq \omega(v_{i+1}, v_i)$, but in case of pedestrian routing the weights are equal in both direction. This is due to the nature of the subject: walking is not affected by traffic congestion or other factors that can change the weight of an edge based on the direction except the case when slopes of road segments are considered.

If the weight of an edge is a combination of several factors, the problem of path finding can be still transformed into a standard SP problem.
The mathematical model of the developing system is different: With a given set of photographs Φ, each road segment *e* is characterised by travel cost and attractiveness *A*. *C* is a function of edge lengths (*C*:*L*→*E*) and *A* is the function of distribution of photographs (*A*:Φ→*E*). Thus, the objective of the algorithm is to find an attractive route *P'* by given *v* (origin node), *u* (destination node), and user-defined time *t* so that

$$P' = P(u, v)$$
$$A(P') = max\{A(P) : P \text{ from } u \text{ to } v\}$$

$$\frac{|t - C(P')|}{C(P')} < \varepsilon$$

where ε is the time accuracy of the algorithm).

Because of the limitation set to time factor (cost criterion) it is hard to combine it with the measure of attractiveness (benefit criterion) and convert the model into a standard SP problem (Hochmair and Navratil, 2008). Therefore it was decided to try a heuristic approach to problem solving and use ant-colony algorithm (Jain et al., 2010) or genetic algorithm (Pahlavani et al., 2006) for route generation. Such types of algorithms are taken into account when it is hard to formalise the process of problem solving or in case if the solution is computation-intensive. It is planned to focus on the development of the algorithm after photo-content analysis when more will be know about the input data.

Interaction between a system and a user should be made via its interface in the following way:

1. A user selects starting point, destination, their expected average pace and time he/she wants to spend for a walk.
2. The system finds the shortest possible path and compares user-specified time with minimum time required to walk from origin to destination. In case of a circular route this step is omitted. If user-specified time is less than minimum possible time, the system suggests to enter a different value.
3. The system computes and suggests one or several alternative paths that can be walked within defined time and contain as more attractive segments as possible. The paths are presented visually in order to help a user to select the most preferable path.
4. A user looks at the configuration of the suggested paths, chooses one of them or changes the parameters of the query (goes to step 1).

5 Conclusions and Future Work

This paper discusses potential use of crowd-sourced geotagged photography as a source of measure of street attractiveness and its application in a pedestrian routing system suggesting leisure walks. The work demonstrates findings on four investigated data sources (Flickr, Panoramio, Picasa and Geograph) in Central London and lists the requirements to the algorithm that is going to be implemented in the second half of ongoing PhD research. It is shown that visual analytics being used for data analysis reveals a number of problems in the datasets and helps to propose filtering methods that can refine the accuracy of the algorithm. In order to adjust and verify filtering it is proposed to conduct manual assessment of a sample photographs by means of an online survey. After this stage is complete, the research will move to the second phase involving the implementation of the algorithm. It is planned to report on the progress in the next year's UTSG conference

References

Adrienko, G., Adrienko, N., Mladenov, M., Mock, M., Politz, C., 2012. Identifying Place Histories from Activity Traces with an Eye to Parameter Impact. IEEE Transactions on Visualization and Computer Graphics 18, 675–688.

Andrienko, G., Andrienko, N., Bak, P., Kisilevich, S., Keim, D., 2009. Analysis of community-contributed space-and time-referenced data (example of panoramio photos), in: Proceedings of the 17th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems. pp. 540–541.

Antoniou, V., Morley, J., Haklay, M., 2010. Web 2.0 geotagged photos: Assessing the spatial dimension of the phenomenon. Geomatica 64, 99–110.

Baeza-Yates, R., 2009. User generated content: how good is it?, in: Proceedings of the 3rd Workshop on Information Credibility on the Web. pp. 1–2.

Davies, N.J., Lumsdon, L.M., Weston, R., 2012. Developing Recreational Trails: Motivations for Recreational Walking. Tourism Planning & Development 9, 77–88.

De Choudhury, M., Feldman, M., Amer-Yahia, S., Golbandi, N., Lempel, R., Yu, C., 2010. Constructing travel itineraries from tagged geo-temporal breadcrumbs, in: Proceedings of the 19th International Conference on World Wide Web. pp. 1083–1084.

Department for Transport, 2011. Local Transport Note 1/11: Shared Space [www document]. URL http://assets.dft.gov.uk/publications/ltn-01-11/ltn-1-11.pdf

Dykes, J., Purves, R., Edwardes, A., Wood, J., 2008. Exploring volunteered geographic information to describe place: visualization of the “Geograph British Isles” collection, in: Proceedings of the GIS Research UK 16th Annual Conference GISRUK. pp. 256–267.

Hochmair, H., Navratil, G., 2008. Computation of Scenic Routes in Street Networks. Geospatial Crossroads@ GI_Forum 8, 124–133.

Jain, S., Seufert, S., Bedathur, S., 2010. Antourage: mining distance-constrained trips from flickr. ACM Press, p. 1121.

Kisilevich, S., Mansmann, F., Bak, P., Keim, D., Tchaikin, A., 2010. Where Would You Go on Your Next Vacation? A Framework for Visual Exploration of Attractive Places. IEEE, pp. 21–26.

Kurashima, T., Iwata, T., Irie, G., Fujimura, K., 2012. Travel route recommendation using geotagged photos. Knowledge and Information Systems.

Lu, X., Wang, C., Yang, J.-M., Pang, Y., Zhang, L., 2010. Photo2Trip: generating travel routes from geo-tagged photos for trip planning. ACM Press, p. 143.

McHugh, J.A., 1990. Algorithmic graph theory. Prentice Hall.

MVA Consultency, 2010. Shared Space: Operational Assessment.

Okuyama, K., Yanai, K., 2010. A Travel Planning System Based on Travel Trajectories Extracted from a Large Number of Geotagged Photos on the Web.

Pahlavani, P., Samadzadegan, F., Delavar, M.R., 2006. A GIS-Based Approach for Urban Multi-criteria Quasi Optimized Route Guidance by Considering Unspecified Site Satisfaction, in: Raubal, M., Miller, H.J., Frank, A.U., Goodchild, M.F. (Eds.), Geographic Information Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 287–303.

Panoramio, 2012. Photo acceptance policy [www document]. URL http://www.panoramio.com/help/acceptance_policy/

Purves, R., Edwardes, A., Wood, J., 2011. Describing place through user generated content. First Monday 16.

Quack, T., Leibe, B., Van Gool, L., 2008. World-scale mining of objects and events from community photo collections, in: Proceedings of the 2008 International Conference on Content-based Image and Video Retrieval. pp. 47–56.

Ramblers’ Association, 2010. Walking facts and figures 2: Participation in walking.

Ramblers’ Association, 2012. Walking for Health - Health walks, walking clubs, walking exercise [www document]. URL http://www.walkingforhealth.org.uk/

Thomas, J.J., Cook, K.A., 2006. A visual analytics agenda. IEEE Computer Graphics and Applications 26, 10–13.

Transport for London, 2012. Legible London [www document]. URL http://www.tfl.gov.uk/microsites/legible-london/

Walk4Life, 2012. Welcome to Walk4Life [www document]. URL http://www.walk4life.info/

WalkEngland, 2012. Welcome to Walk England [www document]. URL http://www.walkengland.org.uk/

Walkit, 2012. FAQ – Frequently Asked Questions [www document]. URL http://walkit.com/faq/

WalkLondon, 2012. Walk London [www document]. URL http://walklondon.org.uk/

Woodhouse, 2012. Legible Brighton [www document]. URL http://www.woodhouse.co.uk/brighton.html

Zielstra, D., Hochmair, H., 2012. Positional Accuracy of Flickr and Panoramio Images in Europe.