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Visualization of Orientations of Spatial Historical Photographs

J. Bruschke[1], F. Niebling[1], and M. Wacker[2]

[1]Human-Computer Interaction, Universität Würzburg, Germany
[2]University of Applied Sciences Dresden, Germany

Abstract

Historical imagery are an important basis for research in Digital Humanities (DH). Especially art and architectural historians rely on historical photographs that are provided by online media repositories. In general, querying those image repositories is based on metadata. Unfortunately, these are often incomplete, imprecise, or wrong, impeding the search process. Using photogrammetric methods to spatialize the historical imagery, keyword-based search is enhanced by time- and location-dependent browsing methods within a four-dimensional model. The interactive, spatial presentation and exploration of these images opens up new potentials to answer research questions related to art and architectural historical science. One important aspect of the work presented here is to provide visualization methods that present statistical information about image positions, and in particular camera orientations. In addition to heat maps, we present adaptations of methods from flow field visualization to enable the exploration of camera orientations in large numbers of photographic images.

CCS Concepts

•Human-centered computing $\rightarrow$ ***Visualization techniques; •Information systems*** $\rightarrow$ *Spatial-temporal systems; Digital libraries and archives;*

1. Introduction

Historical photographs contain high density of information and are of great importance as sources in humanities, in particular in art and architectural historic research. A substantial number of institutions archive historical images of architecture in urban areas and make them available to scholars and the general public through online platforms. Working with digitized, historical image collection requires good expertise in handling metadata. Contrariwise, the exploitation of depicted objects by using keywords and filter is rather inefficient and can be inexpedient [BB11, Kam12]. On the basis of a detailed study of various online repositories as well as structured interviews of users in close collaboration with art historians, desiderata of different target groups could be identified and user requirements derived [FKBM17, FMKB18].

On the basis of these user requirements, we are creating a research platform that supports the exploitation of extensive, historical imagery with spatial relationships. Hence, keyword-based search is only a complementary aspect, while sources and their spatial context are put in the foreground. Our concept is based on relaying the spatial and temporal orientation of photographs, so that the topographic position within a city represents an access point to the corresponding sources. Spatial search can enhance the process of finding images, especially those where users have little knowledge about the depicted object, or only a vague idea of what they are looking for.

In addition to location-based search, interaction and visualization methods are provided that enable and support the answering of art and architectural historical research questions. Use cases provided by historians require visualization methods that are beyond the state of the art. For example, one research question is: From which side have buildings been photographed preferably? Traditional methods for statistical visualizations of image distributions that are currently employed are location-based, i.e. heat maps showing color-coded quantities, but do not consider the orientation of images.

In this work, we present approaches towards a statistical visualization of orientation of photographs, employing methods adapted from the field of scientific visualization, especially concerning the visualization of flow fields.

2. Related work

Very few online platforms focusing on historical images implement interactive 2D maps, e.g. HistoryPin or PhillyHistory. They are utilizing *Google Maps* or *OpenStreetMap* as 2D map providers. Thus, the map material used to present contextual information only displays the contemporary building situation. Besides, these applications are designed for non-expert use.

Snavely et al. [SSS06] use photogrammetric methods, in particular *Structure-from-Motion* (SfM), to automatically orientate an extensive, unstructured collection of photographs relative to each other to make it searchable within 3D space. They primarily use

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Figure 1: *Spatialized images and model within 4D browser*

contemporary images that are retrieved from Internet sources and feature a comparably high image quality.

Schindler & Dellaert [SD10] extend this approach towards historical images, for images not only to be oriented spatially, but also temporally, allowing for transformations in the cityscape to be detected. From this, they derive a historical 3D city model that facilitates orientation within the former cityscape, by mapping the complete building situation. This enables a more detailed understanding of the distribution and orientation of images and the situation of the photographer within the context of the surrounding buildings [SD12].

Methods for statistical presentation of images which are currently used, e.g. texture-based heat maps [LBH14] as well as point-based visualizations [HGJ*15], consider only the photograph's position. Concerning the use case presented here, a major drawback of these methods is that depending on their orientation, images taken from the same spot can show very different objects. An aggregation of positions with color-coded densities thus loses orientation of images which is of high interest for historical science research. Methods used in vector field and flow visualization [LHD*04, LKJ*05] can serve as a basis for the visualization of distribution of orientation.

3. A research platform for spatial, historical photographs

The current web-browser based prototype of our research environment enables users to search for images spatially, temporally and by keywords [BNM*17]. Next to a results list known from conventional web-frontends to image databases, the spatialized images contained in the search results are presented within a 3D viewport, which shows additional 3D models of buildings for context (cf. Figure 1).

By interaction with the 3D scene, e.g. selecting buildings or defining an area, the images in the result set are filtered, so only those images that show the building or are within the area are remaining. On image selection, an additional view displays extended metadata information and an image viewer enabling a more detailed inspection of the image. Two images can also be compared to each other in another view. Users can take the position of the photographer and blend between photograph and 3D model by selecting images.

The sample dataset is still rather small and includes historical images and 3D model of the inner city of Dresden. The images have been primarily spatialized manually. Methods to automatically orientate historical photographs and generate historic 3D models using SfM are currently researched [MSH*18].

4. Visualization of orientations

For a single image, the orientation and camera frustum is represented by a pyramid, which is shown when hovering the image in the 3D viewport of our prototype. According to our evaluation of expert user needs, an important information is the distribution of those orientations and the question, from which side a building has been preferably photographed. In computer graphics, normal maps can be used to encode orientation. Unfortunately, they are not intuitive to evaluate, especially by users unfamiliar with these techniques.

For this purpose, we develop visualization methods that encode orientation and can be easily understood by domain experts. Since the exploration of orientation in unstructured data has been a key feature of flow field visualization, we try to evaluate how those methods can be adapted to our use cases. Although height is sometimes important to see a single image in its spatial context, the vi-

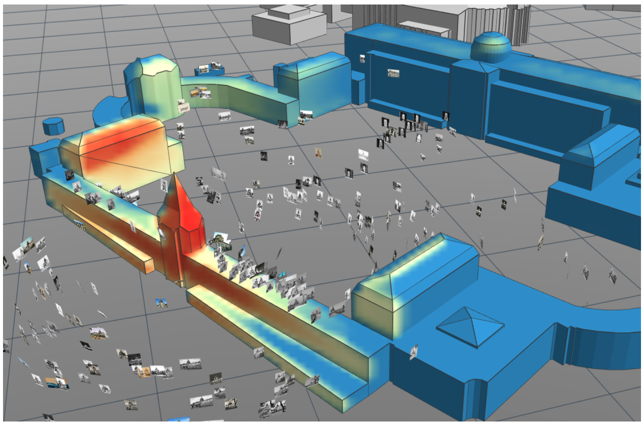

Figure 2: *Heat map on building's surface*

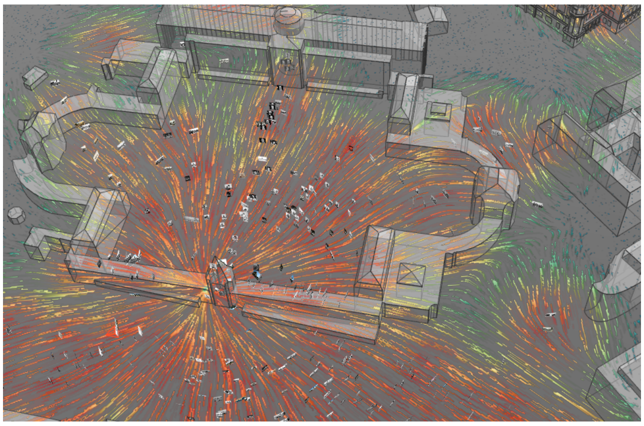

Figure 3: *Animated particles computed on the GPU for visualization of orientation*

sualizations will only consider two dimensions for reasons of simplicity.

4.1. Heat maps

A first visualization method for statistical aggregation of images is a conventional heat map that shows the distribution of image positions. So, high concentrations of images can be quickly identified. This simple visualization also serves as a reference for the development and evaluation of further advanced methods.

Extending the idea of heat maps, one approach is to apply a heat map on the building's surface to visualize how many images depict certain parts of the object (cf. Figure 2). For this purpose, new texture coordinates are computed for the 3D object representing the building depending on the user's view. Along the newly generated texture grid, sample uv coordinates are transformed to world positions. The number of images containing each sample point, respecting camera frustum of the image as well as occlusion by other buildings contained in the 3D model, can then be determined. Although this method does not directly show orientations of images, it can help to determine which parts of a building are frequently depicted in photographs.

4.2. Glyph-based vector field visualization

In addition to statistical aggregation of image positions using heat maps, we provide a glyph-based visualization of aggregated image orientations using a vector field generated from image positions and orientations. Vectors in the vector field are derived along a regular grid by averaging and normalizing the direction vectors of cameras used to take photos within a certain user-defined radius. These vectors are then represented by glyphs, i.e. arrows or wedges. For each sample point, additional parameters can be retrieved and used as quantifier to the length of a vector or for additional encodings, such as e.g. color. Those parameters can be:

- number of images contributing to the sample point,
- average distance of images to sample point in relation to radius,
- distance of sample point position to nearest image in relation to radius,
- average direction vectors, so images pointing in diverse directions result in a lower weighting.

Initially, sample points were computed along a regular grid for reasons of simplicity. Hence, the glyphs looked very regular and not really dynamic. Adding some random offset to the sample point positions produces a jittered grid resulting in a more comfortable look of the visualization.

4.3. Particle-based flow animation

Towards a more dynamic approach for the exploration of flow fields representing camera orientations, we employ animated particle visualizations [Aga17]. The derived vector field is encoded as a normal map used to animate particles on the GPU (cf. Figure 3). Color and speed of the particles are set according to the length of the vector. A vector of high magnitude yields in faster speed of particles. The dynamic particle flow indicates the various directions.

A common method that is used in the field of flow visualization is *Line Integral Convolution* (LIC). Static LIC is, however, only partially conducive in our case, as direction of flow is not or not directly visible. LIC can also be oriented and animated [WGP97] resulting in a visual impression similar to very dense particle-based animation. This algorithm can also be efficiently computed on GPU even for unstructured datasets [NBS14].

4.4. Discussion

These first approaches that have been implemented until now still need extensive evaluation regarding their usability and understandability by user tests. But even if these visualization methods have not been evaluated in detail, some shortcomings could already be revealed.

A topological analysis of the camera positions and orientations is not included yet. In contrast to vector fields in flow visualizations, camera positions can be close to each other or even identical, with cameras pointing in very different directions, violating basic assumption of vector field visualization. By just averaging the directions, cameras that point in the opposite direction as the majority basically get eliminated. Hence, how the vector field is computed still needs to be optimized.

As architecture is the focus of our interest, filtering and weighing according to depicted objects is advantageous. Some situations, however, prove to be difficult. While most images are taken from outside and facing towards the building, images taken in e.g. courtyards can point in any direction from anywhere in the yard. Given those situations and our relatively small sample dataset, common scenarios have to be generated by the employment of dummy photographs and orientations. The presented methods then need to be evaluated according to their usability.

5. Conclusions and future work

We have presented further developments of our browser-based environment for the research of historical photographies in a spatial context. We introduced various methods towards statistical visualization of images upon this basis. Distribution of the orientation of images is an important information for historians according to our requirements analysis. As there are currently no visualization methods available that tackle this concern, new methods need to be developed or existing methods need to be adopted from other fields. Towards this goal, we presented adaptations of methods used in flow field visualization to convey statistical aggregation of image orientation. An extensive evaluation of these visualization and interaction methods towards usability and understandability are still to be performed.

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