Shadows analysis and viewshed georeferencing for dating of historical photographs

New possibilities for chronology studies of lost built heritage

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Introduction

In recent years, the possibility of recovering from historical photography information on the past condition of buildings and infrastructures that have disappeared, has gained momentum among studies of the built heritage. This potential is more noticeable in the case of buildings that have undergone modifications over time, where photography could be used to reconstruct the history of modifications. However, despite this potential, the information on the date of capture, stored with each photograph by the respective archives and repositories, presents a series of inconsistencies in practice. Inexistence of the original data, attribution of inaccurate or very long periods, and confusion with the date of entry into the archive would be the main obstacles. As a result, the information contained in the images cannot be used to know the temporal sequence in the history of modifications, and the possibility of taking advantage of the latent potential in the photograph is lost.

The problem of dating historical photographs, and the relevance for their use in built heritage studies, has so far received little attention. As a way of moving away from simplistic approaches to dating from archival science, which infer an estimated time range based on the presence of known objects in the image (i.e. buildings of known years), it is of particular interest to establish a way of exploiting information about the shadows that objects cast, as these are known to evidence a specific and measurable position of the sun. While recent advances have proved satisfactory in exploiting the correlation between shadow analysis and some geometrical aspects, such as optical metadata in image sets, or camera position obtained by GPS, new methods require to be defined for the case of historical photography, where those parameters are not known and where different photographs often show different states of the studied object.

Methods

The present study then focuses on addressing such a problem based on long known fundamental principles of shadow analysis and astronomical formulas. Assuming a vertical surface of known height, and the measurement of the corresponding shadow it casts on a horizontal surface, it would

be possible to infer the day of the year (DoY) if the time of day (ToD) is known, or the ToD if the DoY is known. Moreover, knowing the geographic orientation of the scene, it would be possible to obtain both data simultaneously.

To access these possibilities, and following the ever-present suggestion of deploying all this information through a virtual reconstruction, the notion of using a three-dimensional format to represent the visual information contained in the photographs is explored. To this end, the proposed method attempts to obtain these crucial data (volumetry and orientation) by photogrammetric means, projecting the image information on the recovered geometry -visible from the camera's cone of vision- of known dimensions and geographical orientation.

The proposed processing method is based on the following workflow (Fig. 1). In a first step, the local camera position and orientation are obtained using vanishing points (Guillou et al., 2000), while recovering the volumetry by auxiliary parallelepipeds (Tan, Sullivan and Baker, 1995). In a second step, the scene is globally located and oriented using known control points in the image by resection (Bruschke et al., 2017). In the third step, the image is projected onto the geometry, canceling the perspective distortion and obtaining the actual magnitudes (Suazo, 2020). Then, in the fourth step, the values associated with the length of the gnomon (object casting the shadow) are collected, as well as the length and azimuthal angle of the shadow projected horizontally. Finally, in the fifth step the recovered values feed the dating equation, mainly based on available astronomical formulas (Fitzpatrick, 2008).

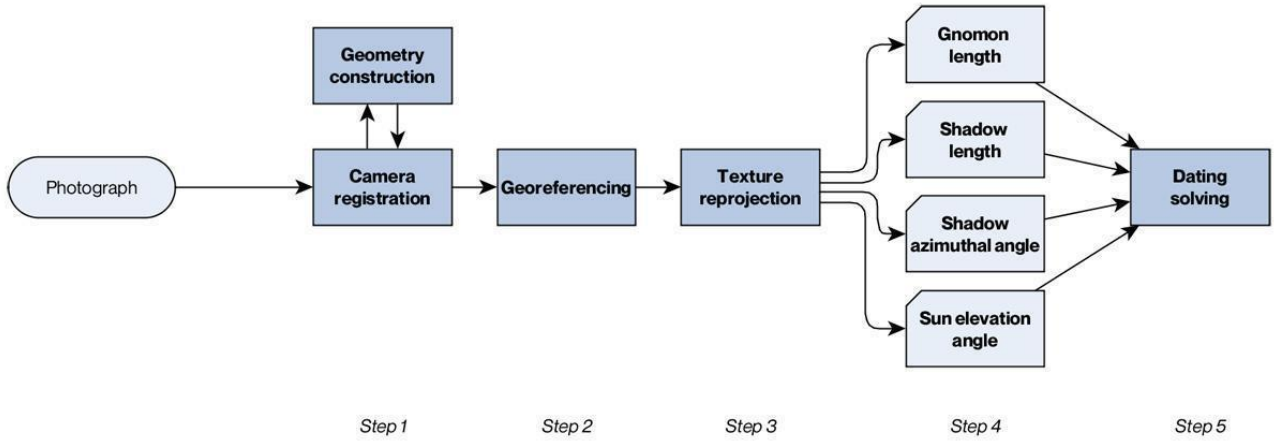

Fig. 1. Proposed workflow and processing steps (© Antonio Suazo).

For purposes of evaluation, the proposed system has been applied to a case study, the construction process of the Civic District in Santiago, Chile -which took almost a decade to complete- and the reconstruction of its chronology from a set of historical photographs, without known dating, collected from different archives and digitized repositories. From the first set of selected images, a subset that met the aforementioned requirements was used: the presence of identifiable straight and parallel converging lines (for camera registration); at least three control points with known geographical coordinates (for georeferencing); and under illumination with direct sunlight, with accurate and defined shadows, where at least one gnomon of known vertical geometry (or reconstructable by photogrammetric means) cast a shadow with a straight side on a horizontal surface (for dating calculation).

Results

The results are shown following the proposed workflow. From a total of 83 collected photographs attributable to the period, 48 were pre-selected where the urban complex being studied is depicted. Of these, in 36 it was possible to identify in the image the requirements to perform the camera registration, georeferencing, and dating calculation based on shadows. Thus, the complete set of 36 images were processed and their ToD and DoY solutions were obtained (Fig. 2). In each case, the two possible dates closest to the inferred solar altitude and azimuth values were stored.

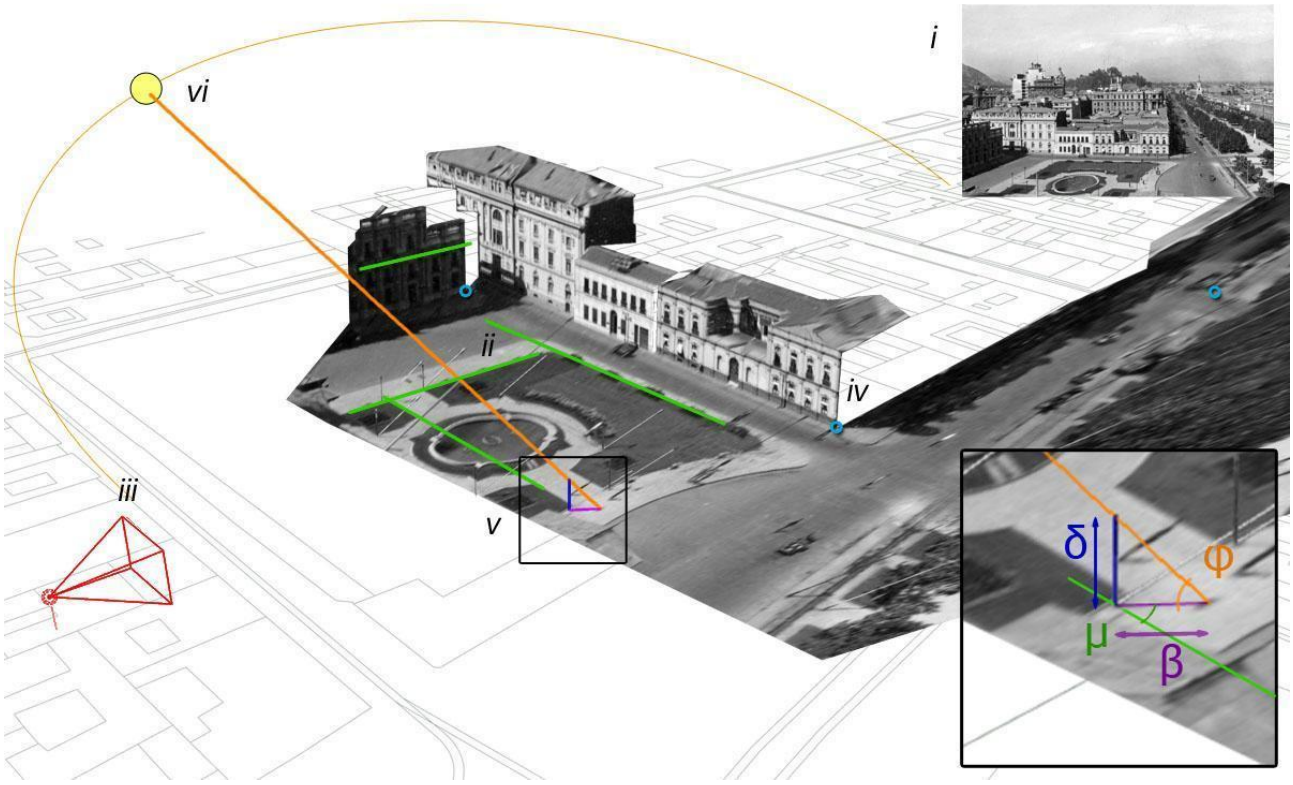

Fig. 2. Processing example in detail. Starting from the original photograph (i), in-image detected parallel lines (ii) were used to obtain camera position and orientation (iii), further georeferenced with the aid of control points (iv). This was used to generate basic scene geometry, including the chosen element to act as gnomon (v), allowing to recover the four main measures (black square): gnomon length(δ), shadow length (β), sun elevation angle (φ), and shadow azimuthal angle (μ), to feed with them the astronomical formula, ultimately obtaining values of Time of Day and Day of Year (vi). (© Antonio Suazo).

Conclusions

The main results obtained with the application of the processing in the case study are shown below:

- For all photographs processed, it was possible to obtain the values of i) ToD and ii) DoY. This was possible not only for photographic material (positives and negatives), but also for other indirect media such as photographic postcards and images included in advertising posters.

- Regarding the error rate, it was established that, although it is mostly related to the quality of the first step of alignment and global registration of each camera, in general the successive steps of the proposed workflow do not contribute with significant errors, and none of them is greater than, for

example, the variations produced by the geometric distortion of the lens, already studied in the literature.

- As a way to address the integrity of the image, it is suggested to carry out at least three measurements on shadows, located at different points of the photograph, in case of eventual alterations or manipulations to the visual information.

- Concerning the dating solution itself, there are two instances of evaluation. First, linked to obtaining ToD and DoY values, the proposed procedure generates consistent and replicable dating results, exceeding initial expectations. Secondly, the determination of an absolute year remains an open issue, as it is difficult to establish a result solely from the astronomical formula used (the variation in the angle of the sun turned out to be even smaller than the margin of error, so the value alone is negligible).

- Even so, ToD and DoY values obtained do provide additional information not previously available, which can be used to delimit the presumed year, in combination with other sources and conventional methods (i.e. by spotting events and or buildings depicted in the image associated with known ToD and DoY).

In summary, through the study, it was possible to formulate, design a workflow and apply in a case study, a procedure to date historical photographs and thus determine a date of capture. Having temporal capture data is very relevant to considering the documentary dimension of the historical photograph, and becomes a central issue for spot findings based on the information contained in it. This highlights the relevance of having modern methods to perform this dating, which is added to the methods already practiced for the recovery of the metadata associated with them, and to the study of built and missing heritage, especially with interest in the evolution and chronology of their interventions.

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Conflict of Interests Disclosure

No potential competing interest was reported by the authors.

Author Contributions

Antonio Suazo: Investigation, Methodology, Software, Writing – original draft

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