From the suggestion of viewing to the understanding of photography:

A case study on rephotography

Pedro M. CABEZOS-BERNAL[1] | Paolo FORMAGLINI[2] | Filippo GIANSANTI[2]

[1] Universitat Politècnica de València, Spain | [2] Laboratorio Fotografico Architettura LFA, Università degli Studi di Firenze, Italy

Abstract: The ways to connect the historical heritage with the contemporary town have included, in the last years, various graphical solutions, most of all based on historical photography and sometimes even on painted views, which were carried out by artists from the past. The aim of this article is to define a proper easy-to-use procedure to match the point of view of a historical photography with a new one, in order to accurately compare the previous state with the reality of our time. An analysis of the existing solutions for this kind of image production will be carried out to check their alignment with the needs of the research. A significant attention will be given to the study of perspective rules as they are the basis of the whole process. The development of the procedures that will be proposed comes from the belief that a correct interpretation of the photographic language and techniques are the basis of a correct processing. It can be done not only by using software solutions, but also by employing classical shooting strategies, for example, using technical cameras or tilt and shift lenses reinterpreting the construction of the picture and its composition, as well as the correct use of the photographic device. Some application examples will be also included to illustrate the accuracy of the results and to bring back details from the past that will be compared with the current state, in order to preserve the historical memory of many monuments from the past.

Keywords: photogrammetry, rephotography, perspective, historical images, photography

Introduction

Rephotography is an act of photographing the same place or the same object in different times. Why to speak about rephotography nowadays? Without any doubt this subject is being used in various application fields more and more.

Opposed to the general belief, this fact is certainly not recent, as rephotography has been used with scientific rigorousness since the 19th century, with a vast application in the range of ecological and geological studies. On this subject, the most interesting studies were those of Paganini (1880), Deville (1889), Finsterwalder (1890). Those studies were centered on taking precise measures by triangulation of various points from photographic documents, in order to track the alterations produced in the ecological systems.

The development of this discipline grew and grew during the whole 20th century up to the introduction of digital photography. According to this new form of photography, new needs has come to the surface: on one side, it is necessary to adapt previous techniques to the digital means, on the other side, new techniques must be developed to fit better the new instruments and to support expending requests in every field.

Rephotography is invading the panorama of image with different purposes. The expansion at all levels of digital image and the relative easiness of use, has led to the expansion of re-photography in many fields that are not necessarily “scientific”, which may also be considered due to their vast potentiality. Popularization of web contents, tourist promotions or systems of virtual museums are increasingly using this type of technology, sometimes with both technical and communicative mediocre results.
Re-photography is also being used in various scientific research. In this case a rough result is not admissible and so many researchers have been trying to give adequate answers and thoughts to these scientific requirements.
Therefore, our goal is to gather together various hypotheses proposed until now through studies like those by Soonmin Bae or Francesco Remondino and provide a solid base to begin with a quick development of proper applications to make a correct usage of rephotography dynamic and within everyone's reach.

The state of rephotography today

As previously said, rephotography is an act of repeating the picture of the same subject in two different time points; but what is necessary to obtain a correct rephotography?
Schematically, necessary is a correct point of view to recreate the same conditions of the original snapshot.
In approaching correct characterization of the original snapshot’s viewpoint there are some difficulties.
First of all, it is important to take into consideration distortions caused by the lens of camera; these can be divided into two types: geometrical distortions (radial and tangential) and chromatic aberrations.
Radial distortion is a type of aberration causing straight lines to appear curved in the picture. It is caused by the misalignment of rays of light when crossing the group of lenses composing the entire lens.
In the case where straight lines (referring to the middle of the picture) appear like concave curves, the radial distortion is so called “barrel distortion”. When those straight lines generate convex curves the radial distortion is so called “pincushion distortion”.
There are many mathematical algorithms to correct these distortions (fig. 1). Thanks to technical development of the digital photographic devices, we are able to use RAW images. These are images in which only the data of the digital sensor is recorded and it is not processed by the internal software of the photo camera. Naturally, this is not possible to perform with an analogue camera. By using photographic processing software, we can efficiently correct all the distortions in the post-processing phase. There are available lots of software to correct radial distortion as Agisoft PTLens or Adobe CameraRaw in Photoshop or Lightroom. Indirectly, we can use an open source stitching software like Hugin to correct the radial distortions, which uses the following equation to correct the radial distortion:

$$r_o = a*r_c^4 + b*r_c^3 + c*r_c^2 + d*r_c$$

with r_o as initial distance from the centre of distortion to the P point (vector OP)
r_c as distance from the centre of the distortion and the P’ point (vector OP’)
The factors *a*, *b* and *c* are parameters to determine, while the factor *d* is determined by the expression:
$d = 1-a-b-c$

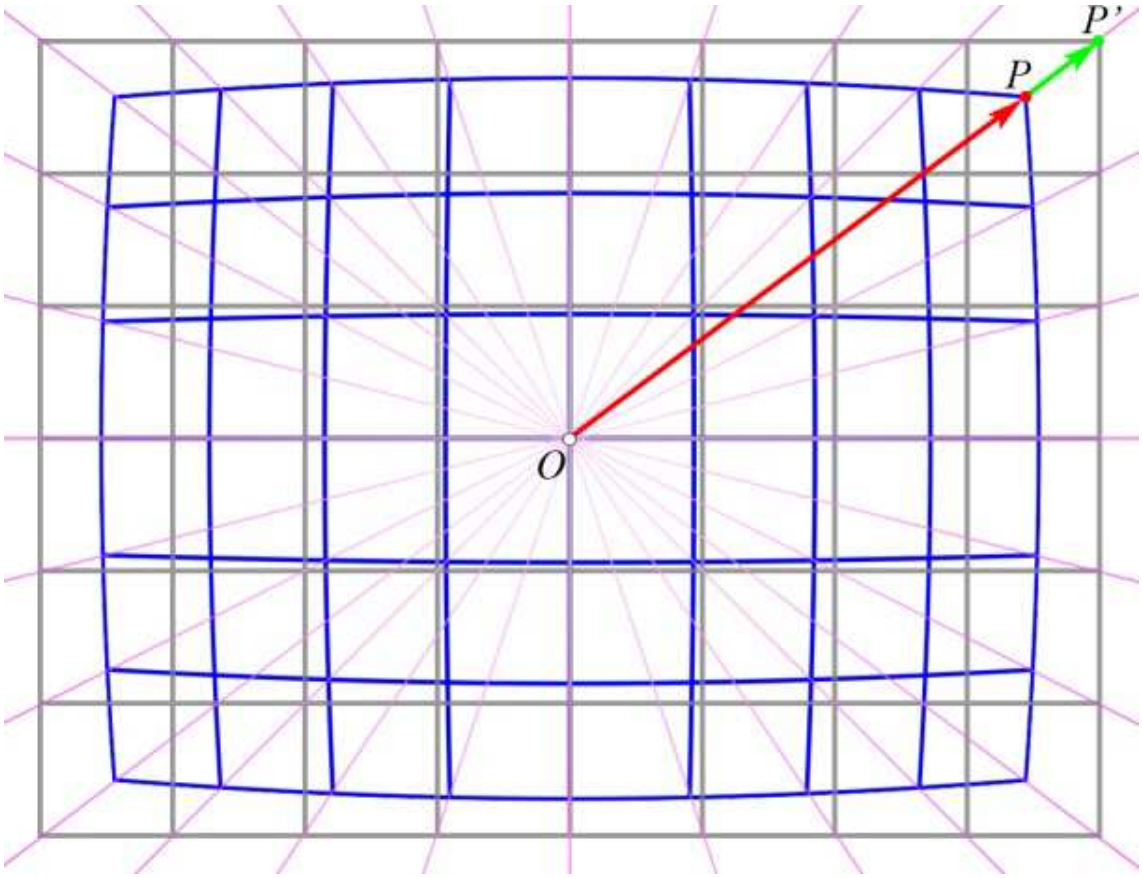

Fig. 1 – Radial distortion correction (Pedro M. Cabezos-Bernal)

By proceeding with geometrical distortions, it is also relevant to mention the tangential distortion.
It is produced by the lens misalignments during construction phase, causing a shift of centers of the lenses from the main optical axis. Tangential distortion generates a compound deviation from radial and tangential component at the same time, being the latter orthogonal to the first component. However, in modern lenses this defect is negligible.
Chromatic aberrations are another defects causing red, blue, green, cyan, magenta or yellow halos, which are more noticeable in high contrast zones. They are caused by the different refraction index of the lens, according to the wave length of light passing through the lens. Also in this case, eliminating this defect can be easily done by retouching software like Adobe Photoshop or Gimp.
Once we have corrected the distortions produced by the lens, next step is to find the main elements of the projection, since we can equate a distortion-free photography with a perspective projection. At first, we have to determine if the plane of projection of the photography (focal plane) was vertical or oblique, as this differentiates the way we obtain the point of view.
We will discuss below the different strategies to do a geometric restitution about the point of view of a photography, depending on the position of the focal plane regarding the scene elements. [*CABEZOS-BERNAL & CISNEROS-VIVÓ, 2013]*

Vertical projection plane

The geometrical foundation of a vertical projection plane perspective is shown in fig. 2, where a cube is projected on a vertical plane, showing the point of view (PV), vertical projection plane (PC), principal point (PP), horizon line (LH), and the existing relationship between the vanishing points, the viewpoint and the edges of the cube.

If the photography has not been cropped, we can assume that the principal point is placed in the centre of image. Therefore, the viewpoint will be on the line that is orthogonal to the projection plane, crossing its centre.

The horizon line may or may not be horizontal, depending on rotation of the camera over the optical axis.

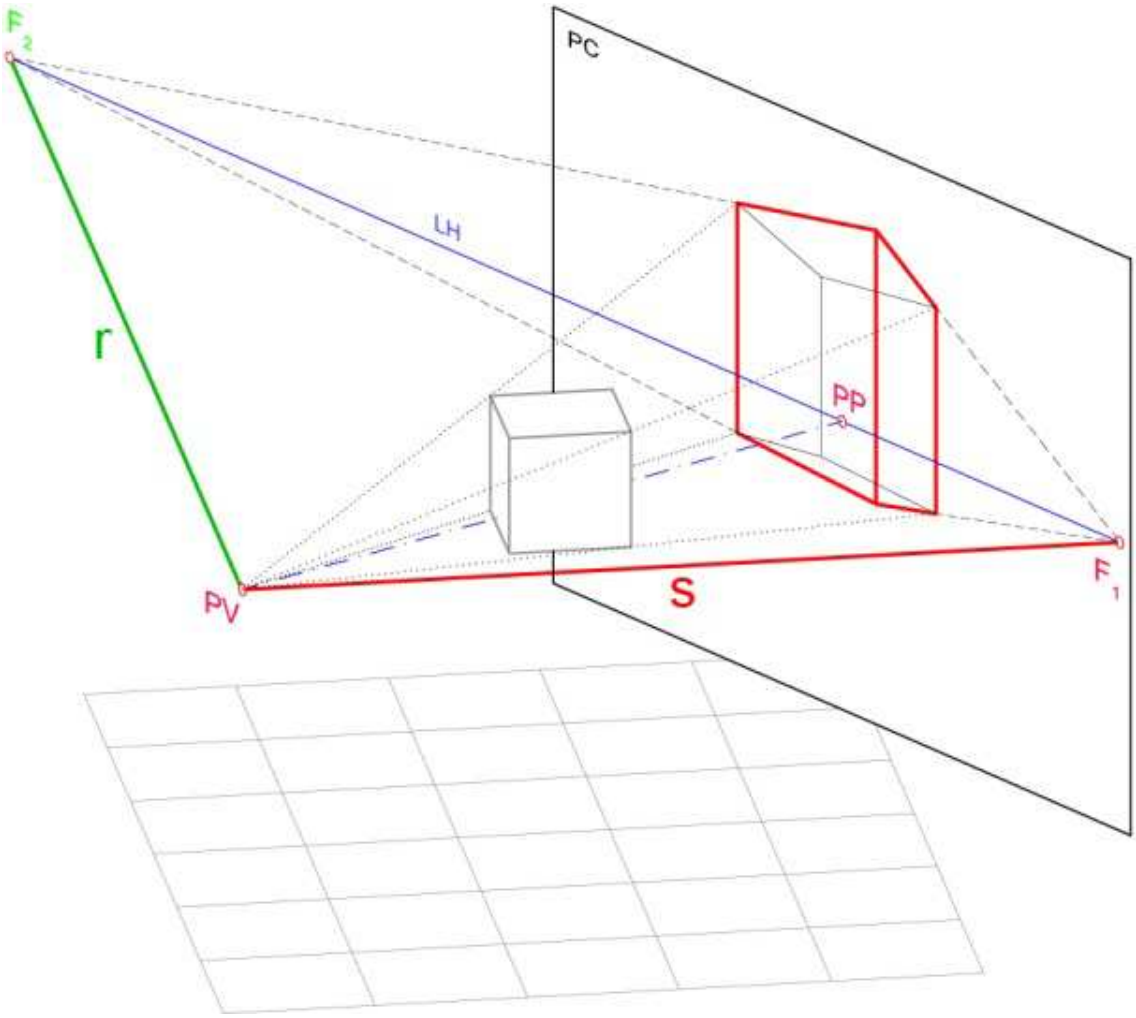

Fig. 2 – Perspective projection of a cube on a vertical surface (Pedro M. Cabezos-Bernal)

In order to obtain the point of view of the photo we need to find vanishing points at least of two horizontal directions of the subject and calculate angle between those lines. Point of view will be reached by tracing a new line with the same angle launching from the line of horizon, as shown on the fig. 3. As the vanishing points of horizontal directions of the scene are located on the horizon line and in this case the principal point is on the horizon line, it is necessary to determine only one vanishing point to define the horizon line. In case of a cropped photography it would be necessary to add more vanishing points, as the location of the principal

point will be unknown. At the end if we draw an arc of which center is (PP) and the radius is the line in-between vanishing point and PP then we can be sure the point of view is inside this arc. To discover the exact position of the point of view PV we need to find another point of view above the horizon line and read the angle between this new point of view and the horizontal line.

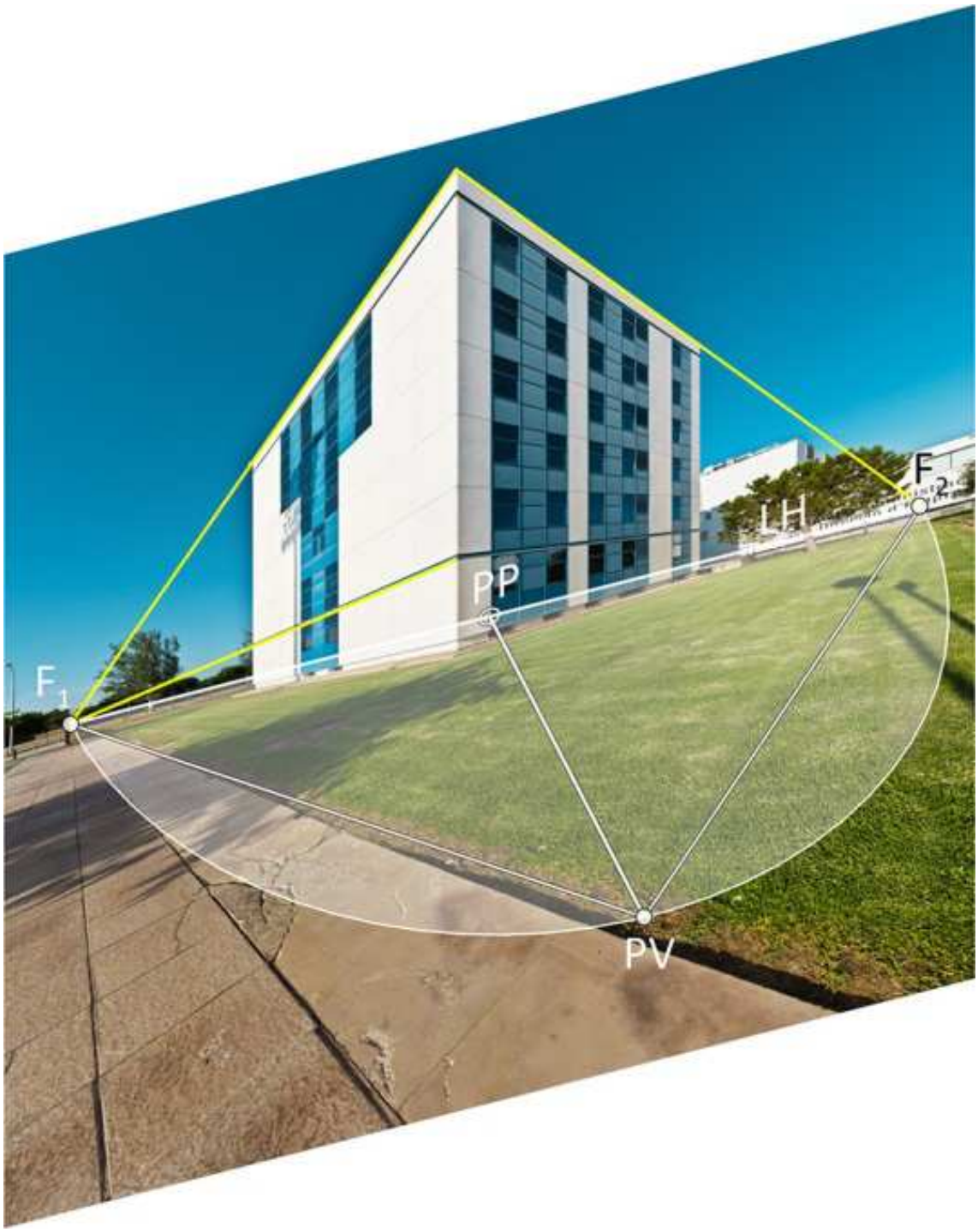

Fig. 3 – Perspective projection of a cube on a vertical surface (Pedro M. Cabezos-Bernal)

Oblique projection plane

Fig. 4 shows an example of perspective projection of a cube on an oblique plane. In this case, we can see the relationship between vanishing points of the edges of the cube, forming the triangle with vertexes F1, F2 and F3, which is the base of a pyramid whose vertex is the point of view PV, being the lines r, s, y and t, parallel to the edges of the cube. In this case the point of view is defined by the trihedron which can be obtained from three vanishing points of orthogonal directions, or from only two vanishing points of two orthogonal directions, if the principal point of the perspective is known (centre of the photography if it has not been cropped) (fig. 5).

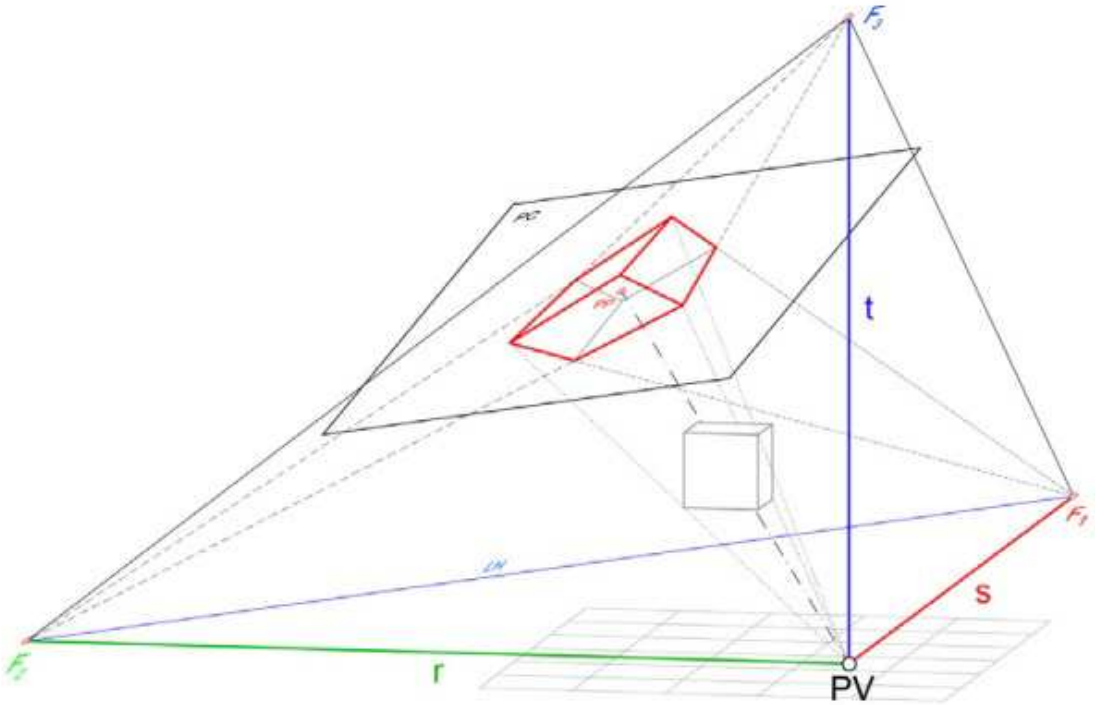

Fig. 4 – Perspective projection of a cube on a oblique plane (Pedro M. Cabezos-Bernal)

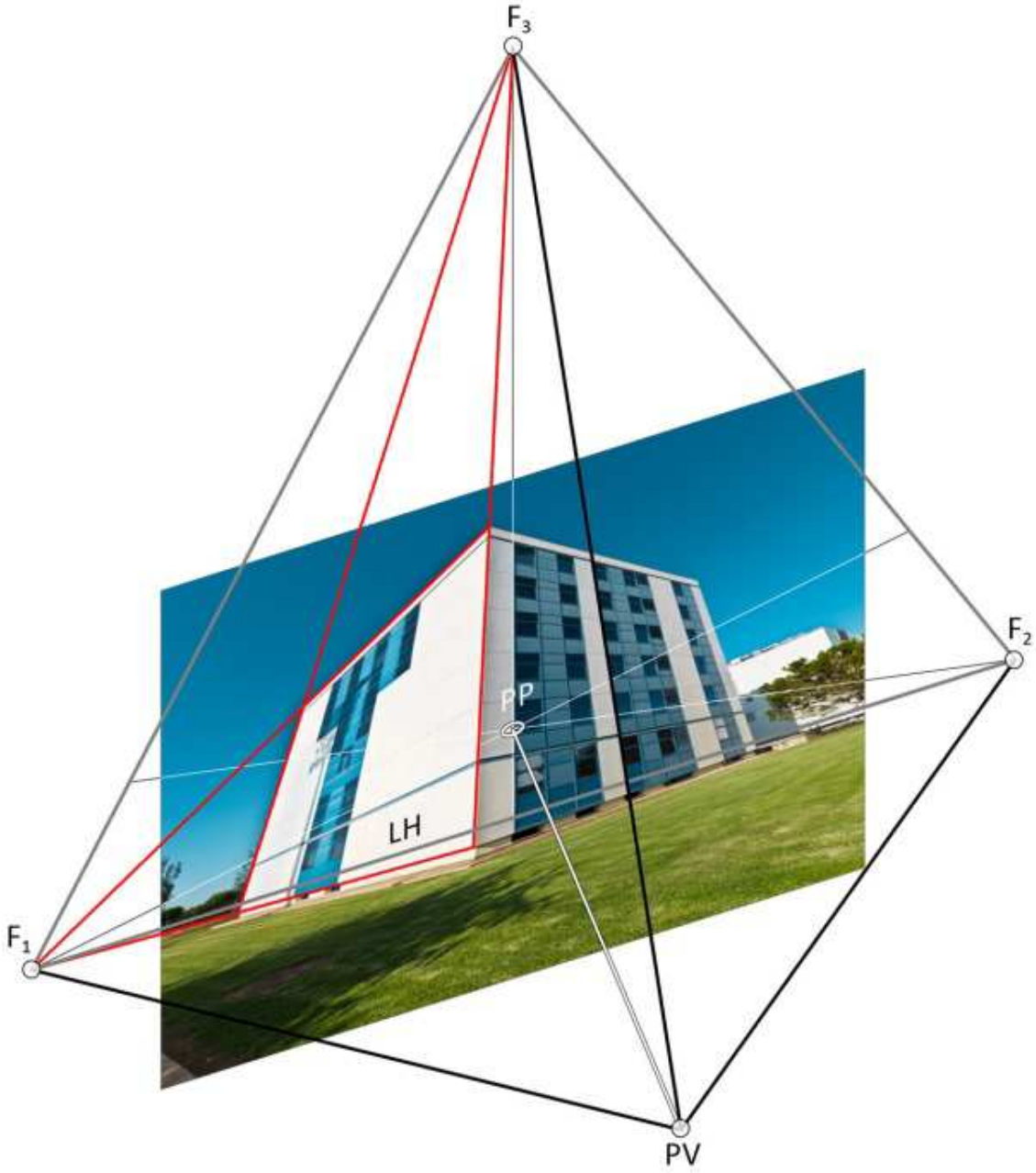

Fig. 5 – Trihedron obtained from three vanishing points (Pedro M. Cabezos-Bernal)

Recreating the shooting conditions

Once we have corrected the lens distortions and obtained the point of view by geometric restitution, we will be able to recreate the same conditions of the original shot. We only need a measure from the scene to scale properly the geometric scheme in order to place it onto a plan to locate the point of view on it. Fig. 6 shows an application example where a rephotography of “Torres de Serranos” in Valencia has been carried out applying the exposed geometrical methods in order to restitute and locate, on a plan, the point of view of the original photography, which was taken in 1857 by Joseph Carpentier and published by the French editor of stereoscopic views Alexis Gaudin.

Fig. 6 – Rephotography of “Torres del Serranos” in Valencia taken in 1857 by J.Carpenter (Pedro M. Cabezos-Bernal, February 2016)

In the last years, some researchers have developed various types of methods to recreate the original conditions of the snapshot by digital interpolation, as in the works by Bae (2010) and Remondino (2012, 2014), which have brought excellent results, but they’ve produced some questions connected to the fact that they work on the digital or digitalized picture to apply, by means of interpolations, the distortions created by the original device. Advantages of this type of approach are surely the extreme versatility and the excellent functioning as the original pictures get gradually closer to the contemporary time. However, the older the photograph is, the more difficult is to digitally correct the various optical aspects originated by the historical photo device. In the same way the re-enactment of depth of field and the distortion correction can be difficult in photographs taken using tilt and shift lenses, such as many photographs from the 18th up to beginning of 20th century.

Generally, the main problem, when working with historical photographs is to simulate the depth of field, the focus of device and the correction of the vertical lines obtained through the shift of the lens.
Therefore, an alternative approach to the problem, instead of edit digitally can be to re-photograph using the original ancient instruments, creating a “real rephotography” instead of a “digital rephotography”. To do so, we need to increase our research on photographic equipments in order to recognize accuracy of the model that has taken the original photo. To this purpose, we are still working (probably it will be done at the begin of 2017) on an online web system that can interact rapidly with historical archives and give us access to the equipment inherent to a concrete historical period. Regarding Italian territory, it could be enough to connect with Alinari Archives in Florence, or Vasari Archive in Rome. Furthermore, users of this system can upload their personal historical photos, which will be available to any researcher. Through this platform we could discover and identify the exact time and place of photographs if subjects were photographed together with a specific equipment. A clear example are some pictures taken during war periods that clearly shows the photographer and his cameras.
Once the equipment has been identified, the network should work as a database with a search engine to find identical or similar machines.
Possibilities of this network will be increased in the future, since the proliferation of digital media as a starting point for rephotography is inevitable.

Discussion

The exposed methodology supposes an improvement in order to correct the lens distortions and to accurately restitute the point of view of photographs from the past, which is compulsory in rephotography.
The geometrical restitution avoids using topographic instruments to obtain coordinates of points from the scene as in the case of a classical photogrammetric orientation process and eludes also employing specific photogrammetric software, as the whole workflow can be done using a CAD tool, like Autodesk AutoCAD or 3D Studio Max.
As an alternative to digital process of rephotograpy, a rephotograpy using ancient cameras it is also possible for those who have possibilities to use these kind of classical equipment. In this case the website that will be developed by authors, will help researchers to identify this footage and to share photographic material, as well as to work as a search gate to get access to the main Italian photographic archives.

Conclusions

The illustrated work has the purpose to shed light on the state of rephotography today.
In the first part, we spoke about the current conditions of rephotography, the demonstration of meaning and technologies that are available today and the geometric solutions to avoid problems that this technique involves and requires.
At the end, we illustrated a web-based idea how to have an easier and more profitable individuations of optical-photographic parameters that characterize historical photos.

However, rephotography is still an unexplored large field with many opportunities for improvement. The purpose is to bring useful suggestions about discussion of relevant topics. We are aware of expansive possibility of a current theme which is still not probed enough.

Bibliography

CABEZOS-BERNAL, Pedro & CISNEROS-VIVÓ, Juan (2013), Photogrammetric 2D/3D restitution of architectural elements and the integration of virtual models with his photographed real environment, using CAD, freeware software and conventional cameras, DisegnareCon vol.12, October 2013

CABEZOS-BERNAL, Pedro & CISNEROS-VIVÓ, Juan (2012), Fotogrametría con cámaras digitales convencionales y software libre, EGA, 17(20), pp. 88-99.

COMPUTATIONAL REPHOTOGRAPHY- Soonmin Bae, Aseem Agarwala, Fredo Durand- ACM transactions on Graphics, Vol.29, No. 3, Article 24, Publication date: June 2010

FERRER MUÑOZ, José Luis (1981). La perspectiva en las artes y en las técnicas, UPV, Valencia.

GRUEN, A., (2012). Development and status of image matching in photogrammetry. Photogrammetric Record, 27(137), 36-57.

HIRSCHMUELLER, H., (2008). Stereo processing by semi-global matching and mutual information. IEEE Transactions on Pattern Analysis and Machine Intelligence, 30: 328-341.

MAESTRE LÓPEZ-SALAZAR, Ramón (2003), T.D.: Perspectiva cónica y fotografía: Análisis aplicado al levantamiento de planos de arquitectura,Valencia.

REMONDINO F., DEL PIZZO S., KERSTEN T., TROISI S., (2012). Low-cost and open-source solutions for automated image orientation – A critical overview. Lecture Notes in Computer Science, 7616: 40-54

REMONDINO F., RUPNIK E, NEX F., (2014). Automated processing of oblique imagery. GIM International, Vol. 28(2): 16-19.

RODRIGUEZ-NAVARRO, Pablo (2012), Automated Digital Photogrammetry versus the systems based on active 3D sensors. La Fotogrametría Digital Automatizada frente a los sistemas basados en sensores 3D activos, in EGA, 17(20), pp. 100-111

VILLANUEVA BARTRINA, Lluis (1996), Perspectiva lineal. Su relación con la fotografía, UPC, Barcelona.

Imprint:
Proceedings of the 20th International Conference on Cultural Heritage and New Technologies 2015 (CHNT 20, 2015)
Vienna 2016
http://www.chnt.at/proceedings-chnt-20/
ISBN 978-3-200-04698-6
Editor/Publisher**:** Museen der Stadt Wien – Stadtarchäologie
Editorial Team: Wolfgang Börner, Susanne Uhlirz