Virtual reconstruction of urban environments from historical photographs through Image Based Animations (IBA). The Plaza de la Virgen de Valencia around 1870

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Abstract. *The recreation of the historical environment of emblematic urban spaces in our cities through interactive technologies, allows to extend their knowledge among the interested users while contributing to its assessment. When the documentary bases are photographs it is possible to carefully model the recorded elements using photogrammetry techniques based on 3D primitives, so that by means of an immersive navigation limited to certain points of view, an appearance of acceptable tridimensionality is obtained, where only isolated images of dispersed frames are available. The virtual recreation can be completed increasing its realistic appearance through its edition with animations of objects (for example, carriages) and characters, texts, musical setting, etc. The results can be presented in formats such as video or navigation through virtual reality helmets. From a selection of the first historical photographs of the Plaza de la Virgen, that we have obtained searching in several documentary sources, our multidisciplinary team is interested in a reliable, realistic and pleasant presentation of the urban environment of one of the most representative places in the city of Valencia, whose spatial configuration has changed significantly over the years.*

Keywords: Virtual reconstruction, historical urban environment, image based animations

Photomodeling fron geometric primitives

Image Based Animations use photomodeling with geometric primitives for partial 3D recreation of a scene, starting from a 2D image as a photograph, a painting or a vintage engraving. This mode of photogrammetry starts from the use of spatial geometric forms, simple to treat mathematically, to achieve the convergence of the model, and has been successfully tested in well-defined models, as the architecturals.

In the photogrammetric field, interest in these formal patterns is based on theoretical studies on specific aspects, such as those carried out by Lang and Schickler (1993) concerning to semi-automatic systems, Lin et al. (1994) assuming the buildings as parametrized blocks (boxes), or Bergevin and Levine (1993) about the relation of 3D objects and their two-dimensional images, to name only a few. Other more general approaches are due to Braun et al. (1995), who put together a general photogrammetric project strategy, or El-Hakim (2002), which incorporates these recognition techniques into a broader automation strategy for architectural reconstruction projects. An interesting precedent in the field of computer applications

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has been I-MAGE (Image Processing and Measurement Assisted by GEometrical primitive), presented by ARPENTEUR (Architectural PhotogrammEtry Network Tool for EdUcation and Research), one of the first software photogrammetric packages on line.

The convergence of the model starts from the consideration of certain formal categories for an extraction of metadata of interest. For this purpose, a limited series of three-dimensional solids, such as cubes, pyramids, wedges, etc., are used, so that, when they are "nailed" to the vertices of a 2D object, this allows their three-dimensional reconstruction. The constraints of these geometric primitives play a double role. On the one hand they verify determining conditions in the orientation procedure of the frames, which can also include the calibration of the cameras, with sufficient data. On the other hand, they allow us to approximate the formation of the photogrammetric model, that is, the position, rotations and dimensions of objects, through homological correspondences, in the manner of the classical constructions of projective geometry. "The algorithm uses the edges that are marked on the photos to solve these parameters and rarely do you have to concern them with." (PhotoModeler Shape-based Projects Manual).

As for the requests of each form, the number of variables depends of their internal geometry. In the case of a box, the parametrization algorithm requires a total of 9 data: 6 corresponding to its location (3 translations and 3 rotations), combined with the own transformation parameters (length, width and height), whereas a truncated wedge, for example, needs ten parameters (because it has two widths compared to the box's one width parameter). In the early stages, many of the parameters are considered free, so that in the more general case, an extreme adjustment occurs (at an unknown scale, in a system defined by the base form and with a single camera without distortion), which is being improved by adding new shapes and new cameras.

The cast of 3D primitives available is a basic feature in order to the versatility of the procedure. Computer applications offer a collection of basic shapes such as box, pyramid,

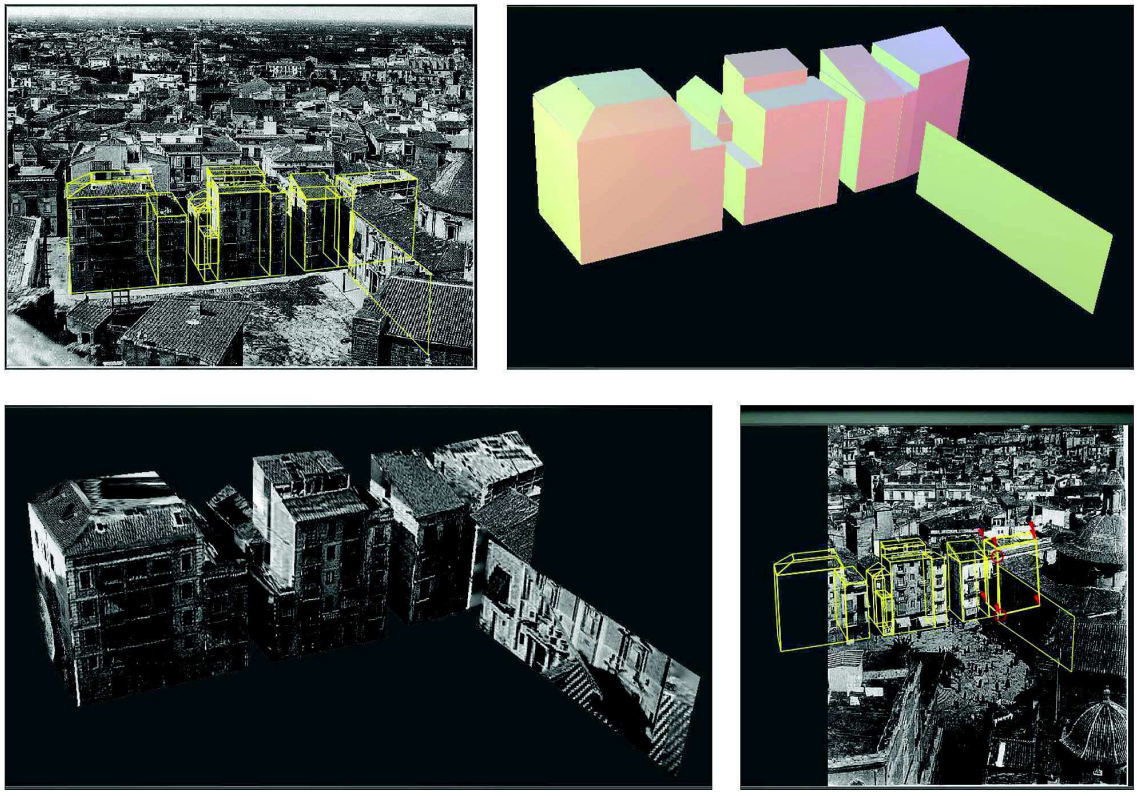

Figure 1.
Photogrammetric model

Figure 2.
Original images

cylinder, or covers (with 2 or 4 waters), useful for camera adjustment and modeling (exterior orientation). The possibility of working with cameras without previous calibration allows to incorporate frames or also cuts of them, even from different cameras, and thus to quickly model buildings and urban environments from several image sources, registered with different points of view and levels of detail. Since, the project will be more reliable, from the metric point of view, and more complete at the documentary level, if two or more overlapping images are available.

In the evaluation phase, other primitives, generally 2.5 D type, complement the previous ones. These are generally editable contour functions, that is, they allow the incorporation of new vertices, such as extrudable polylines, or polygons that determine surfaces and planes visible only from the interior of the scene. It is possible also to complete the scene with standard linear or surface elements.

The use of the three-dimensional vocabulary is complemented by a series of syntactic rules that solve the relative location of some forms with others.

That is, when adding a new primitive to the project, its positional relation must be defined with respect to any previous one, since this information is necessary to produce its orientation by bundle adjustment, as can be deduced from the strictly geometric point of view. The most basic rules in this respect are concentric (defining the Tx and Ty translations), stack (stacked on the previous form defining Tz), and align (defining the Rx, Ry and Rz spins), as well as their additions.

These instruments, along with many other features, such as the possibility of duplicating objects, welding vertices, or adding new objects on the inside face, etc., allow solving most of the difficulties that occur in projects of this type. Both, the quality of the modeling, as well as of the mapping of phototextures, increases with a greater number of converging shots available in each project.

Reconstruction of the scene and camera movement

A Photo Based Animation with geometric recreation is the result of a set of photogrammetric and editing techniques, which allow to obtain a three-dimensional approach of a model with insufficient information available for a complete digital restitution.

It starts by recognizing the proper geometry of the photographic image or engraving, in order to implement a photogrammetric restitution by means of the commented 3D primitives technique.

In this way it is possible to solve both the inner orientation parameters of the cameras, and the 3D interpretation of the motifs that are considered appropriate.

Then, it is a question of integrating the 2D image together with the partial restitution, relocating and scaling it according to the elements of external orientation obtained directly from the frame.

For this purpose, principles of projective geometry, based on the homological relations between the real figure, its plane to plane decomposition, and the consequent 2D

projections, result important.

Once the modeling is embedded into its own visual pyramid, that is, the set of radiations associated with each orientation, a Photo Based Animation offers a dynamic but limited vision of the spatial perception of the scene.

To do this, all parameters of the immersive camera to be created are set. Basically, a movement of the position (new projection), together with a displacement of the target, producing a straightening of some of the orientations (new section of the projective beam), and if appropriate, also adjusting the FoV to enhance the final illusion effect.

The project consists, therefore, of some three-dimensional elements restored, on the one hand, and on the other, of the original photographic background.

The first, once adjusted within its real position, are those that lead the spatial appearance, while the latter add realistic details. For this, it is necessary to animate a small camera movement, which shows new planes of the 3D model.

At the same time, observing the 2D background of the initial photographic image from another angle, inevitably produces a small discrepancy between its position in the "re-photographed" image and the true one, which would correspond to a complete real model.

The same must be delimited so that it is not very pronounced, thus determining the limit of the sequence imposed by this interesting hybrid configuration.

The transformation of the Plaza de la Virgen of Valencia around 1870

In a broad outline, around 1870 occurred two important changes in the formal configuration of the Plaza, which led to the loss of the previous medieval period balance: the renovation of the private buildings on the north and west fronts, and the demolition of the town hall in 1859, after a fire, and the subsequent decision to landscaping this space next to the old Audiencia (today Palau de la Generalitat). The new private properties of the northern and western fronts damaged the environmental quality of the Plaza, as can be seen in the photographs of that time, because their formal characteristics were not adequate: poor material quality and excessive height in relation to the Cathedral and the Basilica. The two photos that we present of the north front (courtesy of José Huguet archive), along with our dynamic reconstruction of the scene, emphasize it. To this purpose, we have integrated in them a partial 3D modeling of this front, adding an alpha channel to make transparent the original image area occupied by it, since it has been placed in the back of each photo to avoid overlaps. In the videos that we have attached, we present a limited movement of the parameters of the recovered cameras, in order to create a small animated sequence. They have been filtered and trimmed to improve their realistic appearance. Also some characters have been added.

Links to the videos

Image 1: https://1drv.ms/u/s!AjJBFl_kTMn7q2Qjc1VP1MwyoHbp

Image 2: https://1drv.ms/v/s!AjJBFl_kTMn7q2joRrLvJ4kQPfTH

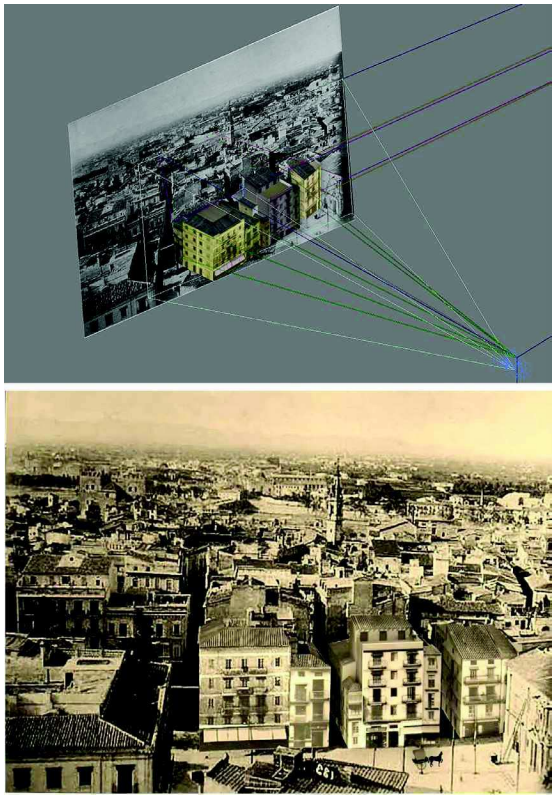

Figure 3.
Photo 1. Frame 1

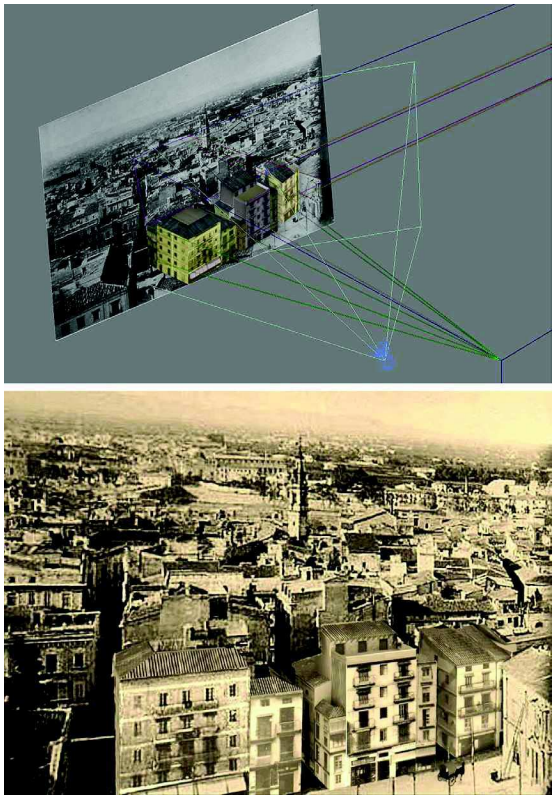

Figure 4.
Photo 1. Frame 440

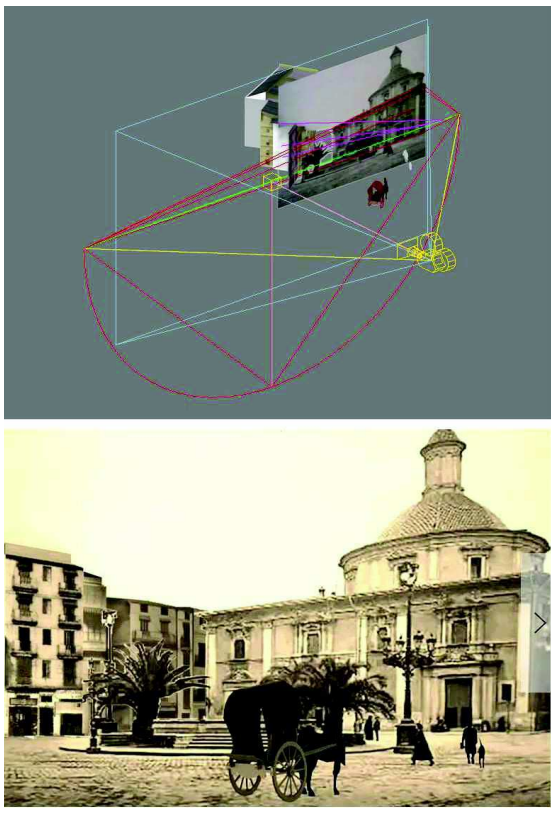

Figure 5.
Photo 2. Frame 1

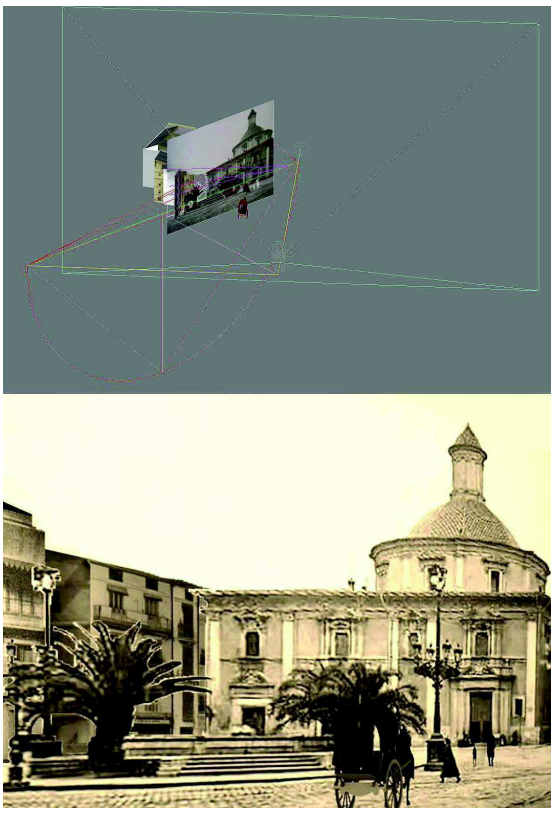

Figure 6.
Photo 2. Frame 440

Conclusion

Unlike the usual techniques of photo animation, with "2D TO 3D" appearance (for instance Constantini A. 2016, or SAB 2015), Image Based Animation is characterized by the modeling of some elements of the scene, so the result is a hybrid 2D / 3D model. When this reconstruction starts from photogrammetric techniques with parametrized 3D primitives, its metric reliability is proved.

Thus, a more realistic visualization of the scene is possible, taking advantage of all the original details that are not restored, along with the three-dimensional view of the others, which brings more expressiveness, when only incomplete information such as photographs, pictorial images or engravings, is available.

These models, edited as videos or by means of formats for immersive navigation, can contribute to bring people the knowledge of historical scenes, doing it in a dynamic way, overcoming the habitual static vision of the original images.

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