INTERACTIVE MODELLING BY PROJECTION OF ORIENTED SPHERICAL PANORAMA – AD DEIR, PETRA, JORDAN

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ABSTRACT

Multi-image panoramas are normally used extensively for virtual tours and documentation of Cultural Heritage for their easiness and completeness. Moreover they have metric capabilities enabling the 3d evaluation of an object provided at least two panoramas (Fangi, 2007, 2008). The procedure already very well tested, is highly efficient and fast, although neither the orientation phase nor the plotting phase are still automatized. The photogrammetric technique is used for the survey and the three-dimensional representation of architecture; it has the same accuracy of the monoscopic multi-image low-cost systems. The advantages to use such technique turn out to be numerous: first of all the great simplification of the photogrammetric problem: every single panorama replaces many photogrammetric takings representing a complete documentation of the object, then the high speed of execution and the easiness to plot by non-expert technicians. The main limit of this approach consists on the contrary in the difficult identification of the corresponding points, which is easy in case of sharp points and corners, while it is difficult or impossible - because of the lack of stereoscopy- in case of rough and uneven surfaces, such as rocks, or rough blocks, like in archaeology, or curved walls.
To try to solve this problem the proposed procedure has been tested, consisting in the interactive 3d editing of the model obtained from the plotted original wire-frame, (this last limited to the suitable points only), by means of the projection of the oriented panoramas in 3d max® environment, which is possible because the orientation of any panorama is known, say the 3 coordinates of the projection centre, and the 3 rotation angles. The Cad allows to edit the model points and surfaces, until they fit on the image projection. The study case is the Ad-Deir temple in Petra, Jordan, where some stones of tender consistency are eroded and have completely irregular shape. The vector plotting was limited to few points, the only easily identifiable. From the wire-frame a surface model has been set up. This model has been edited, completed by the back projection of the three panoramas used for the plotting. The image projection was also applied as texture to the surfaces, leading to a satisfactory result.

1. THE MULTI-IMAGE SPHERICAL PANORAMA PHOTOGRAMMETRY

A series of digital images are taken from the same point of view to cover 360°. The image are stuck using a commercial software and projected on a sphere. The sphere is then mapped in a plane, with the so-called longitude-latitude projection or equirectangular projection. The issue is a digital image called spherical panorama, the width large twice the height. From the image coordinates one can derive the direction angles, horizontal and vertical from the centre O of the sphere to the object point P. Since the main axis of the sphere is not exactly vertical, two correction angles $d\alpha x$, $d\alpha y$, around the two horizontal axes X and Y must be estimated and applied. The collinearity equations [4] can be written, the intersection of projective lines supplies the 3d coordinates X, Y, Z of the object point P. For further details see (Fangi, 2007, 2, 3, 4).

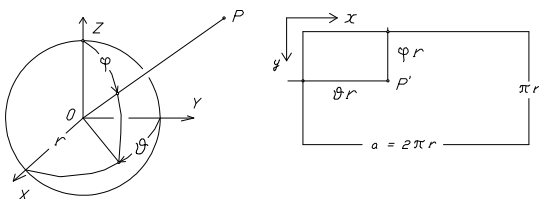$$x = r.\theta \quad e \quad y = r.\varphi \qquad [1]$$

Known the width a of the panorama, the radius r of the sphere can be derived

$$r = a / 2\pi \qquad [2]$$

The horizontal and vertical directions are:

$$\theta = x/r \quad \varphi = y/r \qquad [3]$$

The collinearity equations are:

$$x = r \cdot \left(\theta_0 + atg \frac{(X - X_0) + d\alpha_z (Y - Y_0) - d\alpha_y (Z - Z_0)}{-d\alpha_z (X - X_0) + (Y - Y_0) + d\alpha_x (Z - Z_0)} \right) \qquad [4]$$

$$y = r \cdot a\cos \frac{d\alpha_y (X - X_0) - d\alpha_x (Y - Y_0) + (Z - Z_0)}{\sqrt{(X - X_0)^2 + (Y - Y_0)^2 + (Z - Z_0)^2}}$$

being X, Y, Z the arbitrary point terrain coordinates and $X0, Y0, Z0$ those of the projection centre O, $d\alpha x$, $d\alpha y$, the two correction angles, $\theta_0,$ the horizontal zero bearing.

The coplanarity condition is useful to estimate the relative position of a pano with respect to another one, and then to be able to produce 3D model coordinates by eqns. [4] with the estimated five r.o. parameters:

$$g = x'^T V x'' = 0 \qquad [5]$$

$$[x' \quad y' \quad z'] R'^T \begin{bmatrix} 0 & -bz & by \\ bz & 0 & -bx \\ -by & bx & 0 \end{bmatrix} R'' \begin{bmatrix} x'' \\ y'' \\ z'' \end{bmatrix} = 0 \qquad [6]$$
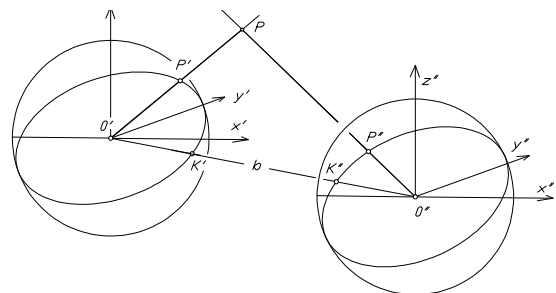
Figure 1 – The latitude-longitude projection.

Figure 2 – The coplanarity of two spherical panoramas

being *bx*, *by*, *bz* the components of the base *b*, *x'*, *y'*, *z'* , *x"*, *y"*, *z"* the coordinates of the image points *P'* and *P'* lying in the two spheres, easily derived from the radius r and the two direction angles θ and φ. As in traditional photogrammetry, 5 couples of points are enough for the R.O., but normally at least 10 couples are observed.

2. THE STUDY-CASE: Al-DEIR IN PETRA, JORDAN

The Monastery (Al Deir), Petra, is a Unesco World Heritage Site, Jordan, Middle East (figure 3). Petra is the superb rocky city discovered in 1812 by the Swiss E. Burckhard. The Monastery is the largest monument in Petra. The Deir received this name from the cave that is known as the Hermit's Cell. No one knows where this name comes from, and it could only come into use after the middle Ages. It is said to be the most meaningful and noticeable monument of the Nabatean architecture [9].

The Deir monument is about 40 meters wide and it is carved deeply into the mountain, made of honey-coloured sandstone. The door itself is 8 meters high (8.20m), leading to a wide interior chamber. In front of the monument, there is a large levelled area, and it seems to have been used for great congregations of crowds.

3. THE SURVEY

During a tourist tour in may 2008, the A. took three panoramas, from left side, right side and from a central position (figures 3, 4). Any panorama, formed with PTGui 7 software, has size 36354 x 18157 pixels. The used camera was a Lumix FZ50 Panasonic 10mb image resolution and estimated focal length was 11.69 mm, corresponding to 50mm of the traditional 35mm camera.

The orientation was performed with relative orientation procedure. Taking the two exterior panos as base, the left and the right ones, a model was formed, using eqns. [6] and [4]. Than the model has been rotated to make *x* axis parallel to the facade. Only one distance was possible to measure with a Disto® distantiometer, the high of the entrance door (8.20 m) thus allowing the scaling of the model. With the model points got in such a manner, also the central panorama has been oriented by resection. The final values of the orientation parameters has been obtained by block bundle adjustment with eqns. [4].

Obviously this project cannot be regarded as a real survey, due to its limitation and incompleteness, but only as a small test about the suitability of the panoramic photogrammetry for metric documentation of such monuments.

Table 1 – The orientation parameters of the tree panorama

N	X(m)	Y(m)	Z(m)	$\Theta_{0(g)}$	$D\alpha x$	$d\alpha y$
1	88.719	52.042	27.698	338.660	-.255	.1889
2	139.299	44.938	25.910	238.351	-.309	-.163
3	117.591	41.776	26.049	327.424	.2610	.0377

Figure 3. Portion of the left panorama (n.1) of the Deir temple. The panoramas were completed at 360° on site, but they have been cut to the only interesting part to reduce their memory occupation
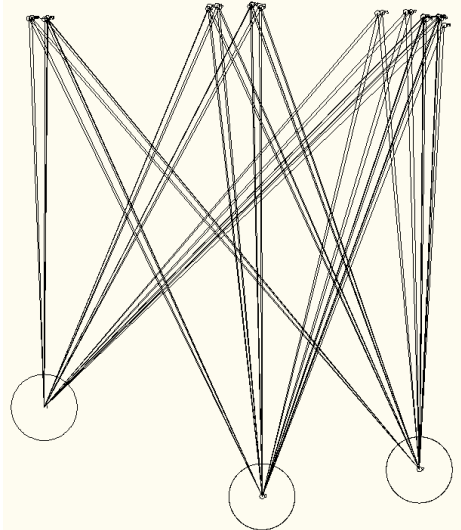
Figure 4 . Plan of the three panorama and the collimations for the relative orientation
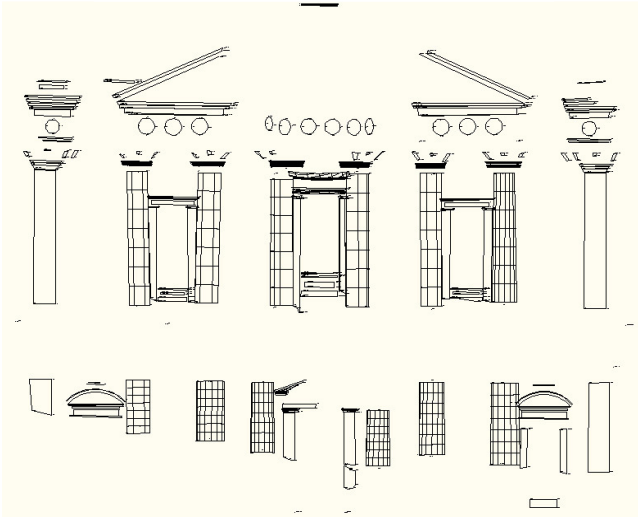

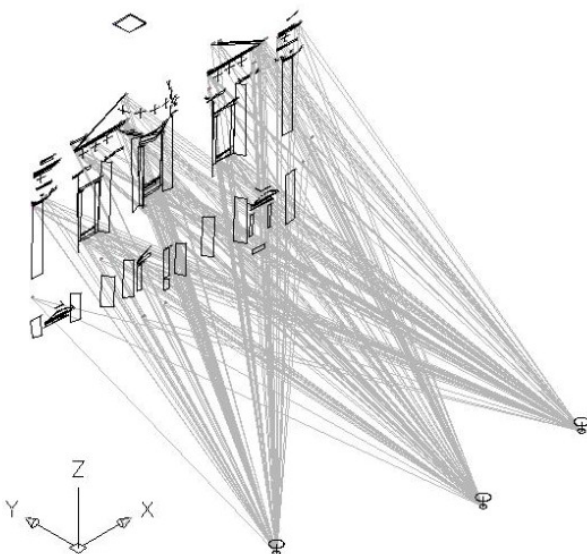Figure 5 – The wire-frame of the temple (by E.Ministri)

Figure 6 . – The block of the bundles of the three panos

4. THE INTERACTIVE MODELLING

The surface is very irregular eroded and rough due to the weather action on a very tender rock, (sandstone). The plotted wire-frame (figure 5, 6) is limited therefore to the only identifiable points that are few in comparison to the whole of the monument, because of the lack of stereoscopy. The whole lower part and the deepest parts are completely missing. Then to complete the evaluation, the following procedure has been applied. The wire frame has been imported in 3D Studio Max® 9 environment, including the projective straight lines, and the station points, as in fig. 4. The next step has been to pass from the lines of the wire-frame model to the surfaces of the model, although approximate in the beginning. The three panos have been applied to the three spheres, centred in the three stations points, in their correct position, derived from the orientation parameters.
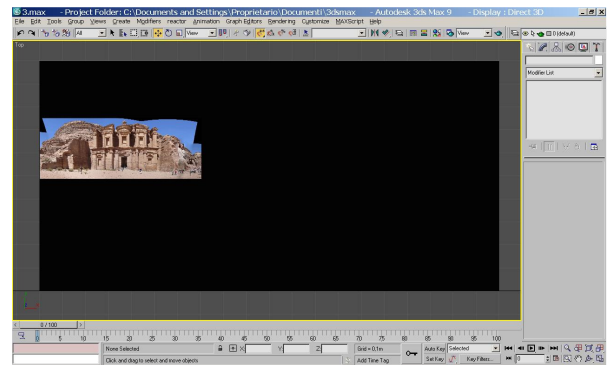

Figure 7 – The insertion of the panorama in the map of the sphere. The panorama is only a portion of 360° because of easiness to use, otherwise it would be too huge to handle

In figures 7 and 8 the insertion is reported of a panorama in the sphere. The pano, originally covering 360°, has been cut to the only interesting zone to reduce the memory occupation, but its position in the sphere is known after the orientation. The software works in a very similar manner of an analogue optical plotter, running by optical projection of the images, in this case the panoramas (figure 9).
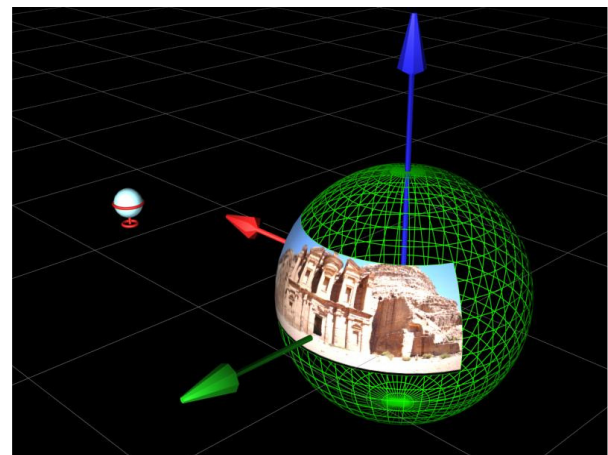

Figure 8 – The application of the oriented panorama over the sphere

Due to the capabilities of the software, the panos are projected from the projection centres over the model surfaces,

allowing editing and modifying them up to the satisfactory fitting of the projected panoramas from all the directions. The object is modelled in small simple surfaces, like planes, cylinders, etc. There are tools in the software able to edit points and surfaces. For instance, it is possible to modify in real time the diameter of a column at the base and at the top, until the column fits in its projection.
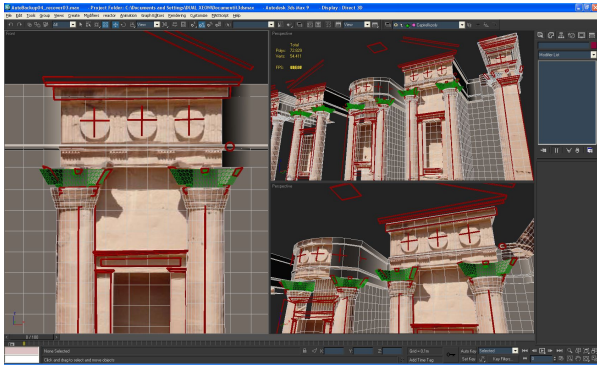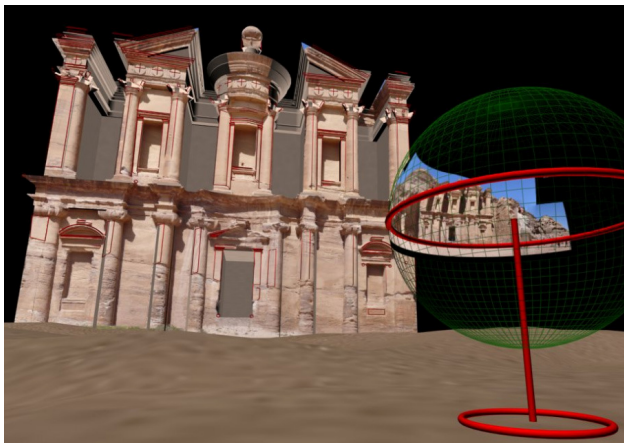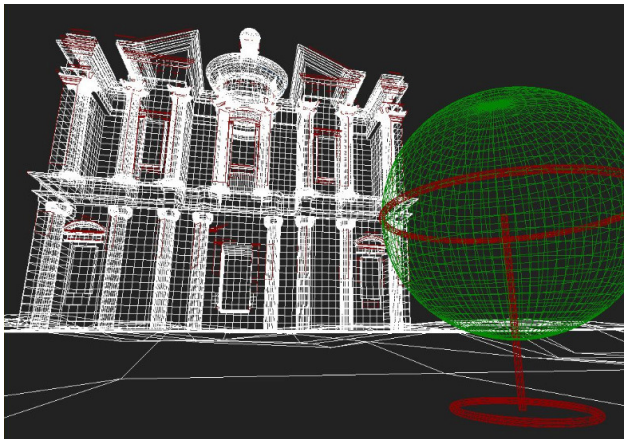

Figure 9 – The working space of 3D Studio Max®

Figures 10, 11 - The model surfaces and the projection of the panorama from the sphere. With the red lines the original wire-frame got by plotting in monoscopic mode

This performance could be defined as interactive photomodelling by projection of the oriented multi-image spherical panoramas.
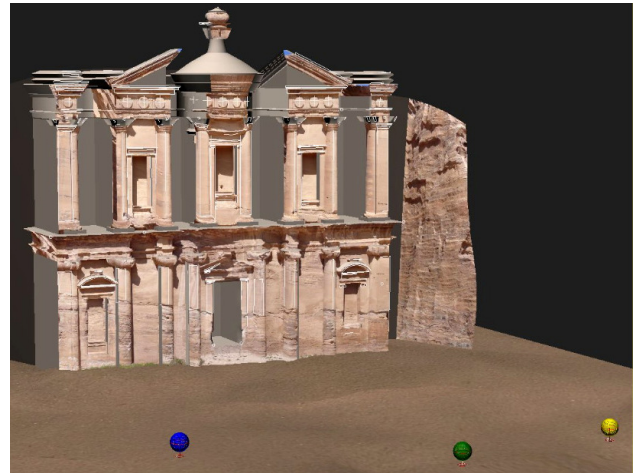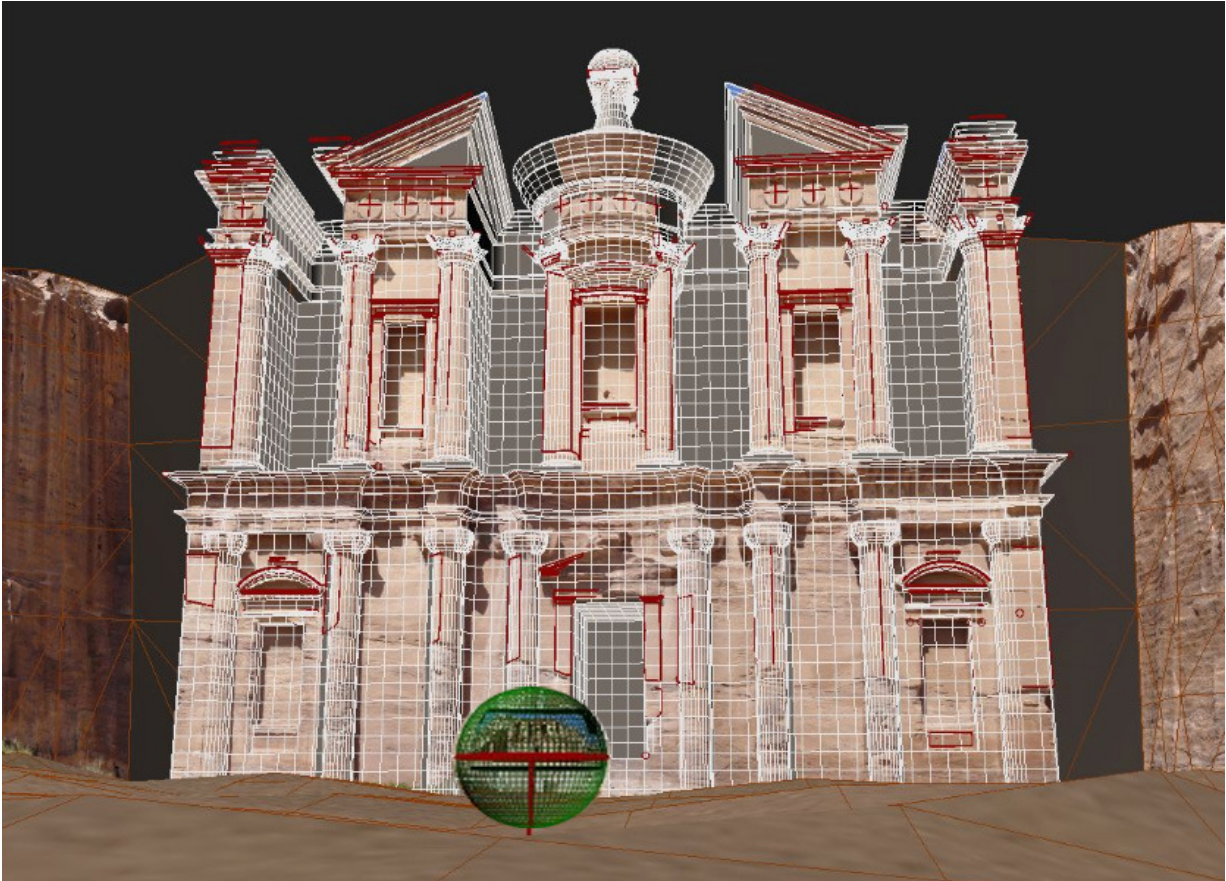

Figure 12 - The final result of the projection for the three panoramas

Still large areas of the monuments are not covered by the panos, because of the depth inside the mountain. To cover the whole surface, much more photographic images would be needed. On the contrary, in the zones well served, the result of the photomodelling looks good (figures 12 and 14).

Figures 13, 14 - Comparison of the surfaces and the textured model. There are large areas with scarse or no information at all.

5. CONCLUSIONS

The present project cannot be regarded as a real survey but only as a small test about the capabilities of the spherical photogrammetry. Very many are the advantages of the spherical panoramas:

- The high speed of the execution of the survey
- The completeness of the documentation, the pano having 360° fov
- The simplification of the photogrammetric problem, the inner orientation is skipped
- The inexpensiveness of the hardware, limited to a digital camera, and a tripod

The main limit of the system is that only the identifiable points can be plotted, because of the lack of stereoscopy. To overcome this difficulty the described procedure has been successfully experimented.

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