DIGITAL DEVELOPMENT OF A SMALL VALENCIAN TOWER

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ABSTRACT:

Warping of images dealing with cylindrical objects through monoplotting is an efficient tool for archiving, documenting and analysing non-planar but mathematical surfaces. However, it is not usually implemented in most of the photogrammetric packages, although there are many architectural objects, monuments and buildings, as well as industrial features inadequate for orthoprojection but appropriate for development or cartographic projection.

This paper shows the background and the results of a new photogrammetric software called *DesenRec* ('*Desenvolupament i Rectificació*', Development and Rectification), ideal for full development of cylindrical shapes. A set of eight images was taken in order to test, record and mosaic the outer walls of a small tower placed in the Valencia City centre. The tower is 6 m high with a diameter of approximately 2 m. After warping each image a digital mosaic was created to plot and analyse the whole tower's shape.

1. INTRODUCTION

Terrestrial and close range photogrammetry are both much more efficient and economic than a few decades ago, mainly due to the advance of digital technology and the development of powerful processing packages. Nowadays, the use of non-metric cameras, without lack of rigorousness, opens new market photogrammetric demands. Moreover, there are more technicians interested in applying photogrammetric procedures to their field of work. This reality can be verified in specific markets such as architectural photogrammetry, archaeological photogrammetry and/or industrial photogrammetry, for instance.

The employment of digital images allows the generation of high quality raster products, adding colour and texture variables to the traditional line plottings. In the case of architectural and archaeological documentation, digital images themselves are an essential document in order to ease the study of materials and damages, interpretations and analysis of Cultural Heritage.

Projective transformation or rectification of images corresponding to planar objects is a simple technique that makes easy the documentation of walls, panels and facades. In literature can be found many related examples, and its mathematical model is well known (Lerma, 2002). Unfortunately, not all the objects are planar or can be partially considered planar. The existence of relief requires other strategies to derive the digital model before warping, e.g. stereoscopy, multi-monoscopic measurements. However, it is also possible to take another approach: the unwrapping or monoplotting of developable surfaces (Karras *et al*, 1997; Hemmleb and Wiedemann, 1997). This is particularly interesting for documenting curved surfaces and frescoes, arches, towers, chimneys, etc. Whenever parametric surfaces such as cylindrical, spherical or conical ones can be found, the development of original images is feasible.

This paper tackles the plotting of mathematical surfaces particularised to the case of cylindrical objects. In fact, a set of eight images was taken in order to test, record and mosaic the outer walls of a small Valencian tower.

2. SOFTWARE DESIGN

We have ourselves designed and developed a new photogrammetric application called *DesenRec* ('*Desenvolupament i Rectificatió*', Development and Rectification) in order to solve, on the one hand, two-dimensional transformations of planar objects, and, on the other hand, digital developments of cylindrical objects. The program is based upon monoscopic procedures and digital images. The software *DesenRec* 1.0 (Figure 1) offers the following features:

- Object oriented language program.
- Camera calibration algorithms.
- Best mathematical fitting to features or objects (planar and non-planar but continuous).
- Determination of transformation parameters between image and object.
- Gross error detection and statistical analysis.
- Digital image development and/or resampling.
- Image mosaicking.

Besides, it is not necessary to be an expert in close range photogrammetry in order to run successfully the program. Furthermore, it accepts many ways of control information based on both image and object space.

3. TEST APPLICATION

Software *DesenRec* has been tested on many emblematic monuments located at the Valencia region. The main characteristic of all of them is that they can be modelled by means of a unique mathematical expression.
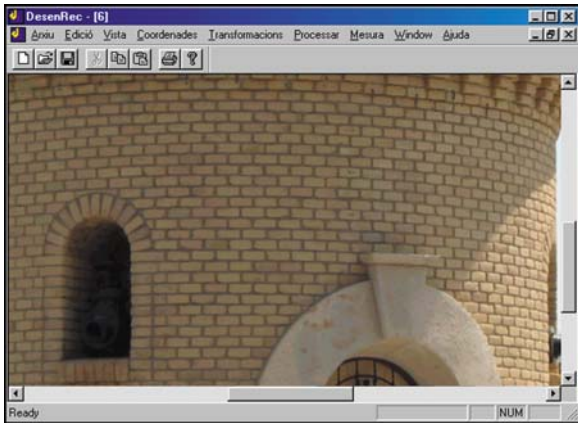
Figure 1. *DesenRec* 1.0 photogrammetric software shortcut

Herein, the monument used as target is a small cylindrical tower placed next to the old Turia riverbed (Figure 2). This tower has an approximate radius of two meters and it is about six meters in height.

Figure 2. Pictures of the small tower (front and back)

The main request was to plot the whole exterior shape of the tower up to a detailed map scale (1:50).

3.1 Preliminaries

Previous to the tower development, it was mandatory to take some pictures on the job, as well as measuring some ground control points. A total of eight digital images were taken around the tower with a CANON EOS D60 digital camera; a 15 mm principal distance was selected for this purpose. Maximum image resolution was chosen: 3.072 x 2.048 pixels.

After, some basic surveying tasks were carried out in order to determine some object points, both on the ground and on the small tower. All the ground control information was least-squares adjusted. Finally, only the points fitting the outer cylindrical shape were used to compute the best circular section of the cylinder (simplified tower). Output parameters were the centre of the cylinder as well as the radius. The whole set of parameters was determined by *DesenRec*, and there was no need to input any approximate parameters. Figure 3 shows the control points distribution used for the adjustment.
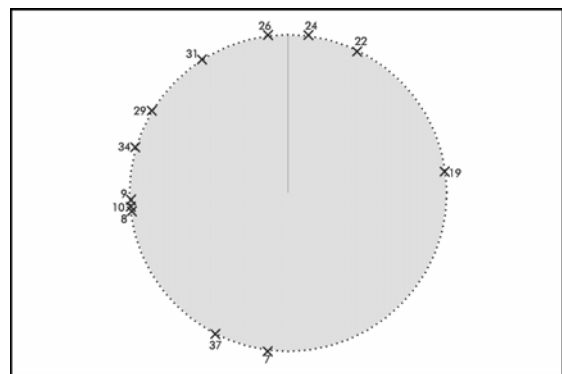

Figure 3. Top view of the outer part of the cylinder after defining the best circle passing through control points.

The mean square error of unit weight after the adjustment was only 1.2 cm. Once the cylindrical shape was established in 3D, a distortion model was computed. Thus, it was possible to analyse the monumental structural deformation (Figure 4). Contour line number 0 in Figure 4 means that there is no discrepancy between the 'real' surface and the analytical one.

From the previous data, it was inferred that the lineal development of the small tower should be 12.428 m. The height of the tower was 6.023 m. Therefore, the best fitted and developed tower surface could be easily computed.

3.2 Processing

The processing stage takes into account the photogrammetric and digital processing purposes. The first one, dealing with the determination of the interior and exterior orientation parameters to spatially relate the image to the object (Tortosa, 2003). The second one, filtering and correcting the radiometric image values, and, last but not least, allowing the image extraction of right patches from the developed images.
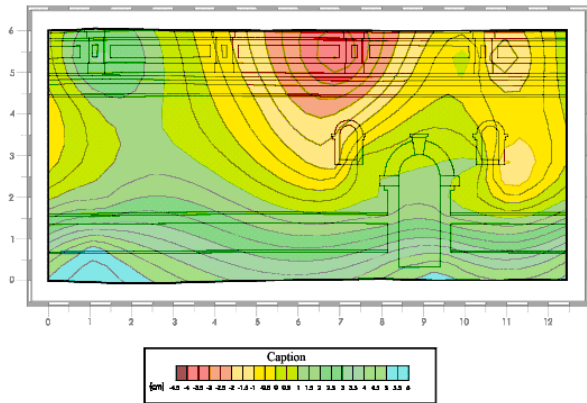
Figure 4. Error map showing discrepancies between both surfaces (real *vs.* modelled).

Furthermore, this program performs the development of both inner and outer surfaces, depending on the direction i.e. leftwards or rightwards. Figure 5 shows the result of two outer developments.

Figure 5. Set of two unwrapped images

3.3 Results

The final product was a raster digital product that shows the entire tower's exterior surface (Figure 6). The final image is obviously scaled, allowing it to be used in multiple tasks: inventories, visualisation and analyses of monument deteriorations, measurements (punctual, lineal or areal), updating of architectural information systems, plottings, thematic mapping. It is even worthy for foreseeing future conservation and restoration actions, and many multimedia purposes of our Cultural Heritage can be derived.

Besides, it was also estimated the final accuracy of the digital product in order to be sure whether or not the initial geometric requirements were fulfilled. For this purpose, many measures were computed, considering control and test points belonging to the tower. Mean discrepancies, minimum, maximum and relative errors, as well as mean square errors were computed.

Following the direction of development, i.e. the x direction, the relative error in distance was 0.16%, meanwhile in the transverse direction, i.e. the y direction, the relative error was

approximately 0.19%. Obviously, errors in both directions mean different, the former refers to the best cylindrical adjustment error; the latter depends overall on the surveying measurements.
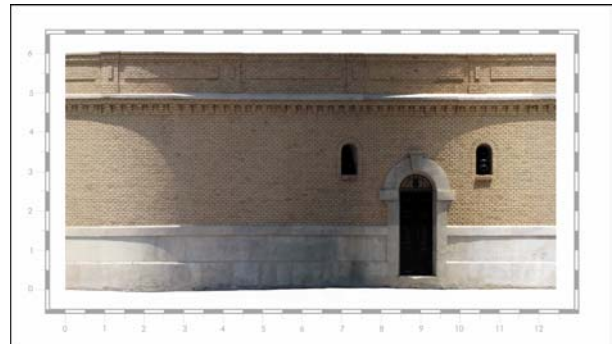

Figure 6. Mosaic of the whole exterior of the small tower

4. CONCLUSIONS

This paper has dealt the mapping of mathematical surfaces corresponding to architectural or archaeological objects, using photogrammetric unwrapping techniques.

After analysing the results, it can be estimated that the methodology of raster projection and development of mathematical surfaces is right. Furthermore, it should be considered whenever regular objects are concerned. Moreover, the availability of metric scaled images of the whole object or monument, in our case the small tower, eases the documentation, analyses, catalogue production and conservation of our Cultural Heritage. Furthermore, the visual impact and multimedia possibilities of mapping 2D and 3D objects should be emphasised.

Besides, this methodology only requires the knowledge of a small sample of control points, and conventional digital images. Thus, the combination of this monoscopic measuring technique and the employment of camera calibration procedures based on the image space make expensive the use of *DesenRec* 1.0 to similar targets. Following this way, the measurement of planar and curved objects does not depend on the digital camera used, and it solves many problems coming out in mapping exterior and interior architectural or archaeological sites or monumets. Furthermore, this technique complements and widens the way of traditional stereo or monoscopic mapping.

5. REFERENCES

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