CLOSE RANGE ORTHOIMAGE USING A LOW COST DIGITAL CAMCORDER

E. Tsiligiris[a], M. Papakosta[a], C. Ioannidis[b], A. Georgopoulos[c]

[a] Surveying Engineer, Post-graduate Student, National Technical University of Athens – tsili@hol.gr
[b] Ass. Prof., Lab. of Photogrammetry, National Technical University of Athens – cioannid@survey.nyua.gr
[c] Prof., Lab. of Photogrammetry, National Technical University of Athens, Greece - drag@central.ntua.gr

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ABSTRACT:

Video recording and digital photogrammetry are usual techniques to achieve monument morphological and metric documentation respectively. An all at once approach provides significant cost and time saving, especially when dealing with complicated objects, which demand multiple photography for their full coverage. Based on this consideration, this paper examines the possibilities of using a low cost digital camcorder to supply imagery in order to create large-scale orthoimages of a site with adequate geometric accuracy and radiometric quality, through the usual photogrammetric procedures. The first step of this research is the calibration of the camcorder at an appropriate test field applying a bundle adjustment. Then, an application took place on one side of the *Gate of Adrianos* monument. Still images were captured through a DV card. The manual generation of a DSM and the creation of orthoimages derived from different initial still images took place in a SSK Z/I Imaging digital photogrammetric workstation. A comparison of the achieved accuracy, completeness and cost of this method's products with the conventional orthophotos of the monument, which were derived from photos taken with photogrammetric cameras, was made. Finally, limitations of the specific camcorder's use, for the geometric documentation of the monuments, are also described.

1. INTRODUCTION

During the last years digital photogrammetry became a very useful tool not only for site recording but especially for architectural geometric documentation. Many applications exist in the relevant literature, in which metric or semi-metric analogue cameras and non-metric digital cameras are used. Video is an other alternative tool for the documentation of monuments, in various levels, starting from simple digital image recording up to the 3D extraction of metric information. Videometry has developed significantly since 1990 mainly in the field of industrial applications or for the monitoring of dynamic phenomena (Tournas, 2003), and in the field of architectural applications as well. The video capabilities for the recording and visualizing both real and computer generated scenes or the readily available output of every CAD, photogrammetric or visualization tool or even the production of geo-referenced 3D video (Sechidis et al, 2001), show that it is a powerful and promising tool for archaeological applications. Moreover, the development of the Mini–DV and Micro MV–Network technology is more than rapid making the digital camcorder to be a low cost solution.

According to the above it was decided that a test should be performed. The main aim was to investigate the capability of digital amateur videos for providing usual photogrammetric products, such as an orthoimage. The application of this work was carried out on the east side of the *Gate of Adrianos* monument, considering as main theme of the camcorder's orthoimage, part of a column capital. This monument was built in the 2nd century by the Roman emperor *Adrianos* at the entrance of the ancient city of Athens. This impressive construction measures approximately 14 m in breadth and 17 m in height. It consists of two parts. A lower one which presents a majestic arch - the main city gate- and an upper part, which is lighter, ornamented with pillars. Today it is located at

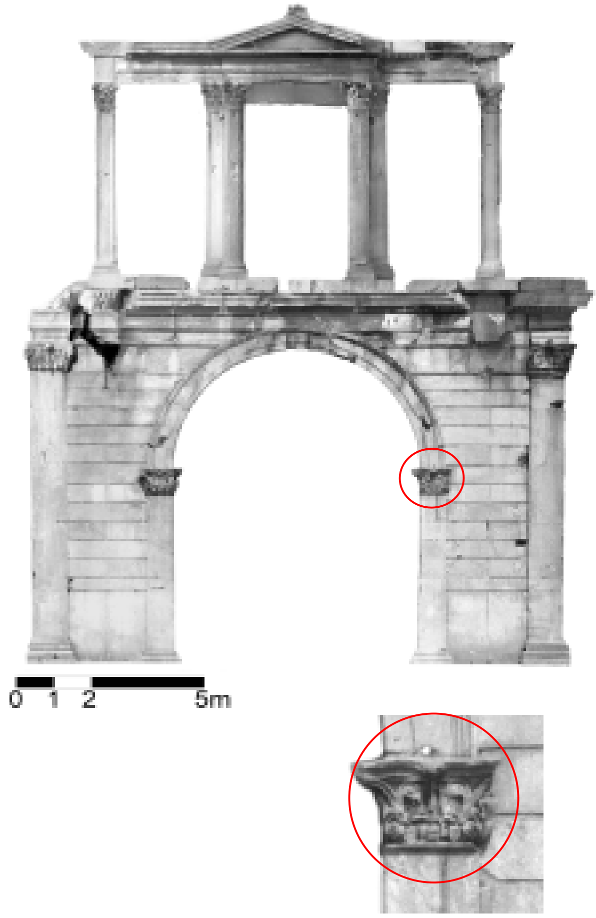


Figure 1. Grayscale Orthoimage of the east side of Gate of Adrianos and an ortho-detail of the specific column capital

the centre of the modern city.

Grayscale orthoimages of both sides of the whole monument were previously generated by the Laboratory of Photogrammetry of the School of Rural and Surveying Engineering of NTUA, during a research programme funded by the Hellenic Ministry of Culture (Figure 1). The images had been acquired using metric cameras such as UMK 13x18, P31, and Rolleiflex 6006.

For the application needs in this paper, a detailed close range video recording of the eastern side of the Gate of Adrianos was made. Finally only a small part of this side was selected for editing, testing and production of an ortho-photomosaic. That part is a column capital, shown magnified on the lower part of Figure 1 (inside the red circle).

The comparison of the orthoimages coming from the two different image sources, metric cameras and digital camcorder, and the evaluation of geometrical accuracy and radiometric quality will be examined.

2. THE DIGITAL CAMCORDER

For the application purposes a Sony DCR-TRV140E (Figure 2) supporting the Digital8 standard was used. It is one of the cheapest digital camcorders in the market. The connection with the computer is achieved through the DV-OUT port supporting the IEEE 1394 protocol. The effective part of the ¼″ CCD provides more or less 350K actual pixels. The focal length varies from 3.6 mm to 72 mm according to the manufacturer's specifications. The zoom has no fixed positions but a continuous range and it is manually controlled. Thus it is almost impossible to achieve a known and repeatedly steady focal length. Hence it was determined that the lens should be fully retracted in order to have the focal length at its shortest length. The focus was fixed manually at infinity. A Pinnacle Studio video card was used in order to create captured clips in AVI format from the camcorder. The captured videos and the grabbed still frames were created by using Adobe Premiere.

The video speed e.g. the frame rate was 25 fps and the average data rate 4,28 MB/sec.

Figure 2. Sony DCR-TRV140E

The file type of the still images is uncompressed TIFF. The quantity of 350K pixels is inadequate and leads to an a priori poor quality. Although the video card provides -during the frame grabbing process- an image size of 720x576 pixels, part of the original image is cropped out. Thus the size of all the images of the present work is 706x550 pixels. The image loss of 2% and 4.5% at horizontal and vertical direction respectively is significant not only for the coverage of the recorded object but also for the overestimation of the computed focal length. The change of image's aspect ratio from 1.25 to 1.28 should also be considered.

3. CALIBRATION OF THE CAMCORDER

The low image resolution in combination with the usual needs of archaeological applications demand the achievement of maximum accuracy possible from the photogrammetric procedures, thus the accurate determination of inner orientation parameters, i.e. principal distance, principal point coordinates, radial and possibly tangential distortion parameters. For the calibration of the particular camcorder, video images of a three dimensional testfield were taken. The testfield was placed in a room at the School of Rural and Surveying Engineering of NTUA, and its dimensions are 6x6x3 m^3 area, consisting of targets which are attached to a metallic board and on 8 digit columns (Figure 3). The coordinates of the targets had been calculated by topographic intersections of high accuracy, better than 3mm. The testfield was video recorded from several distances varying from 1m to 5m, and from different angles. The result was a great number of different scale images with and without overlap, with and without convergence.

The influence of the radial distortion is more than obvious, looking at the curved appearance of the vertical columns (see Figure 3). It was expected, since a wide-angle lens was used. (Devernay et al, 2001; Karras et al, 2001).Twelve images were chosen and most of the visible targets were measured with pixel accuracy. Initially the images were inserted in AutoCAD© environment, and the image coordinates of the targets were measured. Through an affine transformation the measured coordinates in 'screen' units were transformed in pixel units. Some of the distant targets appeared fuzzy and they were rejected. (Figure 4).

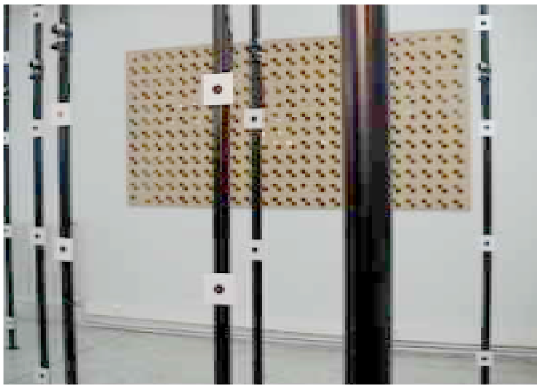


Figure 3. Still image of the testfield

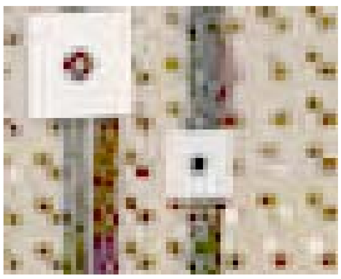


Figure 4. Detail of distant targets

The determination of camera calibration parameters was made simultaneously with the calculation of the exterior orientation elements of each image in a bundle adjustment solution. An inhouse developed application, named CCDINT (Tournas et al, 2001) was used. The calculation of the approximate values of the unknown parameters is made by the software using the Direct Linear Transformation (DLT). After the bundle adjustment the final results for the focal length and the principal point's location were (in pixels):

$c = 951$, $\sigma_c = \pm 32.3$

$x_o = -9.2$, $\sigma_{xo} = \pm 77.5$

$y_o = 0.8$, $\sigma_{yo} = \pm 86.7$

As it comes from the results of the adjustment, the stability of the digital camcorder is very poor. The variability of the estimated parameters is higher than expected. The main reason for the large standard deviations of the above parameters is the low accuracy of the image coordinates measurements due to poor image quality (Lerma et al, 2002). The pixel size can be estimated by comparing the focal length in pixels and in mm, equal to 3.8 μm. The first two coefficients of the radial distortion were also computed :

$k_1 = 0.006$, $k_2 = -1.028\ 10^{-9}$

The estimated radial distortion was not used to produce new corrected digital images. Instead it was inserted in the photogrammetric procedure, as parameters of the interior orientation of the images. Although a wide-angle lens was used, the tangential distortion was neglected.

4. APPLICATION

4.1 Field work

For the video recording of the façade of the Gate of Adrianos, the experience derived from the editing of the testfield images was taken into consideration, according which:

- object details that lie longer than 3m away from the camera are not clearly shown
- point coordinates could be measured with low accuracy.

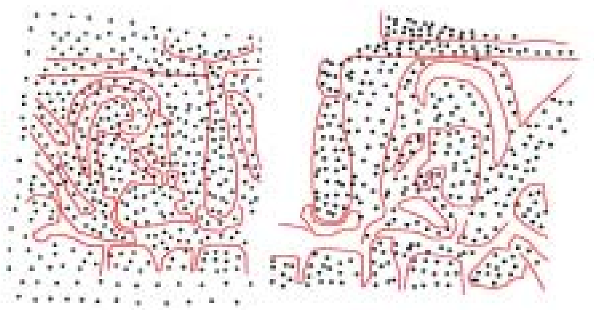
The dimensions of the column capital are 1m width x 0.6m height and it lies approximately 5m from the ground level. In order to approach it and for the video recording, too, an especially stable metallic scaffolding was used, which is built around the whole façade of the monument for the purposes of a conservation project of the Hellenic Ministry of Culture. The scaffolding had in total 7 horizontal levels of a width of 2m approximately, in contact with the monument. The particular column capital lied almost in the middle of the interval between two levels.

The video recording was made following a predefined path, almost parallel to the object's surface, along the scaffolding level. The distance between the camcorder and the object was not greater than 1.5 m in order to overcome the low resolution of the still images and to be able to distinguish architectural details. The movement of the camcorder had to be slow, so that "fuzzy" images could be avoided. The area of coverage was rather narrow, thus a sequence of stereo frames had to be created. The base of the sequential still images was approximately 0.20 m. Thus the B/H ratio was approximately 1:8.

Figure 5. Initial still frame of the central part of the column capital

4.2 Orthoimage Creation

Three sequential approx. 70% overlapping still images, covering part of the column capital and establishing two stereomodels, were chosen to generate an orthoimage. All the usual photogrammetric procedure was accomplished through the SSK Z/I Imaging digital photogrammetric workstation. Since the pixel size was not quite known, but computed, it was preferred to treat the digital camcorder as an analogue camera. Interior orientation consisted of collimating the corners of the cropped (output from the Adope Premier) images. Natural detail control points were already available with an accuracy better than 1 cm. The interior orientation had no significant errors, not greater than 2 μm. The relative orientation was also easy to be solved. The remained y-parallax was 3 μm. The stereoscopic vision was good, and the sense of object's depth was clear. Unfortunately, triangulation of the three images could not be solved. Hence the exterior orientation was computed for each model separately. Therefore distinct medium–density DTMs were created manually for each model. The given output pixel size of the orthoimages was set at 1 mm (Ioannidis et al, 2001).



Model a Model b

Figure 6. Dgn files of the area of interest

Figure 7. Orthoimage at a scale of 1:10

4.3 Accuracy Evaluation

The geometry of the orthoimage was examined not only through the location and the relative distances of the control points, but also in comparison with the already mentioned grayscale orthoimage of the whole eastern side of the Gate of Adrianos. The accuracy of this orthoimage, as it was checked through field measured control points scattered all over the surface of the facade, was better than 0.8 mm.

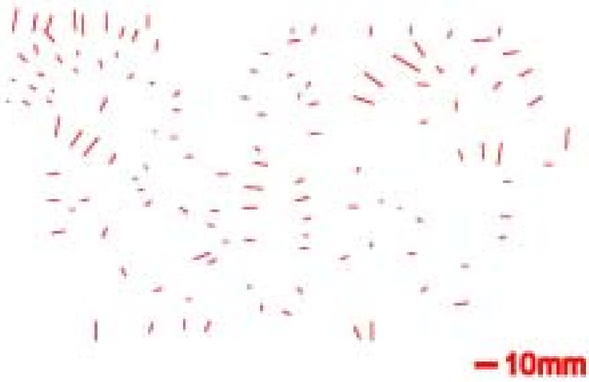


Figure 8. Residuals

A number of 126 distinctive check points on the surface of the object in both orthoimages were measured. None of the residuals was greater than 12 mm and the RMS was equal to 8 mm. Thus, the end-product covers the accuracy needs of a mean –scale orthoimage (1:20) but it is rather inadequate for large scale orthoimages (e.g. 1:5 or 1:10). The radiometric appearance is also unfavourable at large scales, due to low resolution, which makes the appearance of the pixels rather disturbing. Nevertheless, the radiometric histogram of luminosity and the RGB channels is normal (Figure 9).

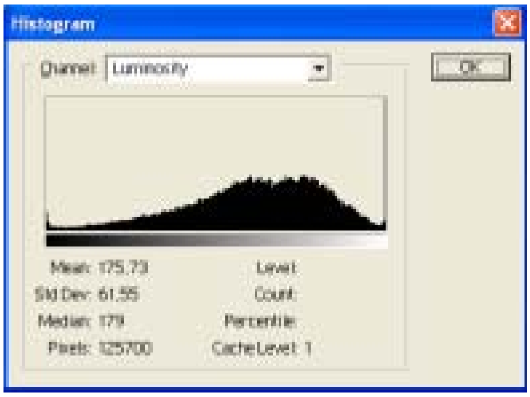


Figure 9. Histogram of luminosity

5. CONCLUSIONS

The experience and the results, obtained from the present work show that it is rather early to accept the camcorders as the main image source for high accuracy photogrammetric procedures and for long-distance objects. The need for higher image resolution was obvious at all stages of the photogrammetric procedure: the invalidity of the results of calibration, the sensibility of the parameters of absolute orientation when using different control point selection or measurement, and the problems occurred during the matching. Nevertheless these devices can be -in geometric and radiometric way- sufficiently reliable for low accuracy photogrammetric projects or simple archaeological documentation. Moreover, the development of the digital camcorders foretells that in the near future significant developments will appear. Already, videos with sensors Advanced HAD CCD with resolution higher than 2 Mpixel are available, with market prices cheaper than 2,000-2,500 Euros. So, we can expect better results for the final vector or raster photogrammetric products by using a cheap solution for image acquisition.

In the cases that there is not enough budget for detailed geometric recording of complicated monuments, the video recording consists a very good solution for documentation purposes. It is a cost effective and quick alternative, which has no demands for special knowledge or preparation for stereoscopic recording of the objects. In addition, when the necessary budget is found or if a damage of the monument will happen due to any natural of human intervention, the recorded images can be used for metric purposes.

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