

## PC-BASED 3D IMAGE MEASURING STATION WITH DIGITAL CAMERA AN EXAMPLE OF ITS ACTUAL APPLICATION ON A HISTORICAL RUIN

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### Commission V

KEYWORDS: Three-dimensional Measurement, Digital Camera, Calibration, Non-Metric, Close Range, Historical Ruin

#### ABSTRACT:

We have developed a new inexpensive PC-based photogrammetry system, by which we can accomplish rapidly in real time all the measurement and analysis, including photographing, 3D measurement, plotting, ortho-image creation etc. We have just started to sell in Japan.

We can do this on the actual survey site, using simply an ordinary digital camera and a lap top computer. And if necessary, we can confirm or measure afterwards the resulted images in great detail and precision with a 3D display.

As an example of its actual application, we experimented our system on Parthenon in Athens. We took its pictures by a digital camera loaded with a calibrated zoom lens (i.e. the lens for which camera-parameter has already been pre-installed in computer), visualized it in 3 dimensions and produced the final plan.

The result was quite satisfactory. The system also proved itself to be very useful for us to cooperate with the architects (or the person in charge of National Cultural Heritage Preservation, for example), exchanging information and making decision as to the object extent or various other points of importance on the very site itself.

With this system we could also obtain a very positive result in 3D measurement of a wall relief or a statue in ruins or excavations.

### 1. INTRODUCTION

In our data process and preservation of, for example, cultural heritage, formerly we always had to bring the films and all the digital data gathered on the survey site back to the research office for analysis. Therefore, we had many problems; for example, 1) the produced image was processed by an analyst in the office with no idea of what the object actually looked like, and 2) the produced image was not sufficiently scientifically compatible. Besides, it took much time.

To solve the problem, we have developed a new PC-based photogrammetry system, by which we can accomplish plotting as well as ortho-image creation in real time on the survey site.

The 3D visualization of the object thus obtained helps the surveyors' judgment, speeds up the work and serves as an effective presentation material.

How this system (PC-based 3D Image Measuring Station) operates will be explained below with its actual application to the measurement of ruins.

### 2. PC-BASED 3D IMAGE MEASURING STATION

#### 2.1 System structure

The basic structure consists of PC and its software.

If we use a laptop PC, we can take a picture, measure the object and make final result demonstration all on the very site.

Furthermore, we can use 3D display which visualizes the object in 3 dimensions and enables us to confirm the actual state of the object and the measuring results as well as to make the detailed measurement and plotting. For 3D display, we can use micro-pole system or dual polarizing monitor system which is now used. (Otani, Ito, Kochi and others 2000)

In the "micro-pole system" the 3D visualization is realized by placing on the liquid crystal display a special film which makes polarization of 90 degree between the layers of odd and even number as in Fig 1. We can see in 3 dimensions when we look at it with polarized glasses. As we do not need any special electric circuit, the cost is low. The liquid crystal display from 15 inches to 30 inches is available for this system.

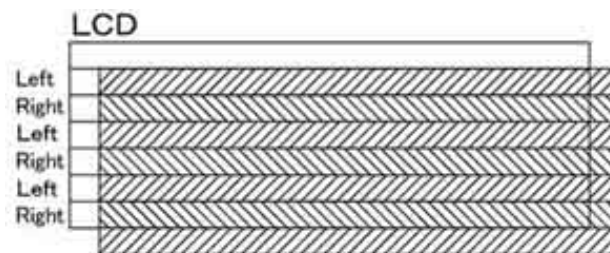


Figure 1. Micro-Pole

The Fig.2 shows this system consisted of a digital camera, a laptop PC, a 30 inches micro-pole 3D display.



Figure 2. PC-based 3D Image Measuring Station

## 2.2 Function of Image 3D Image Measuring Station

Fig.3 shows the functions and measuring flow of this system. The Image-Measuring Station (PI-3000) is capable of performing all the measuring processes: such as photographing, 3D measuring/plotting, ortho-image creation, 3D model creation, and data outputting. It can measure an object in two stereo-pair images out of one single picture. It can also measure by taking two or more pictures or by taking picture from all around. It can also link with TS. After taking in the data of the digital image, it can make single photo orientation, relative orientation, bundle-adjustment, and linkage with TS data.

The function of 3D measuring and plotting includes creation of rectification image, semi-automatic 3D plotting and editing, automatic DTM measuring, TIN producing and editing. As the outcome of all these functions we have ortho-bird's view image, contour lines, cross-section image, 3D model image and digital data outputting. Plus we have GIS interface.

Again, as a custom-made system, we have also automatic measuring system with stereo-camera, volume measuring system, of soil for example, as well as ruins measuring system.

With PI-3000 we can input the picture taken by a digital camera into PC, and we can go even so far as to make orientation, plotting and measuring. All these works can be done easily and rapidly by semi-automatic or automatic way. Of course, we can bring the data obtained on the site to other place for analysis. The followings are some of the features of this system.

### 2.2.1 Photographing

If the camera has the calibrated zoom, we can take the picture from the proper photo-position and focal distance. Once the focal distance is determined, take necessary number of pictures on that fixed spot. To increase the accuracy get the object in full screen or enlarge the image to be photographed in two or more pictures.

### 2.2.2 Orientation

We have two kinds of orientation: manual and semi-automatic mode. For relative orientation we put two stereo-pair pictures on the screen and mark the corresponding points by mouse. For the orientation by semi-automatic mode, we put several targets (each with white mark on black ground or black mark on white ground) on the object. And by simply pointing at the approximate area of the each target, we can obtain immediately its exact centroid. The Fig.4 shows how the centroid is found by approximate aiming of the cursor. The point of intersection of two lines is the exact centroid automatically determined.

With this mode, anybody can easily obtain exactly the same orientation. And as we use the bundle-adjustment for orientation, we can easily connect more than two images. Orientation



Figure 4. Orientation

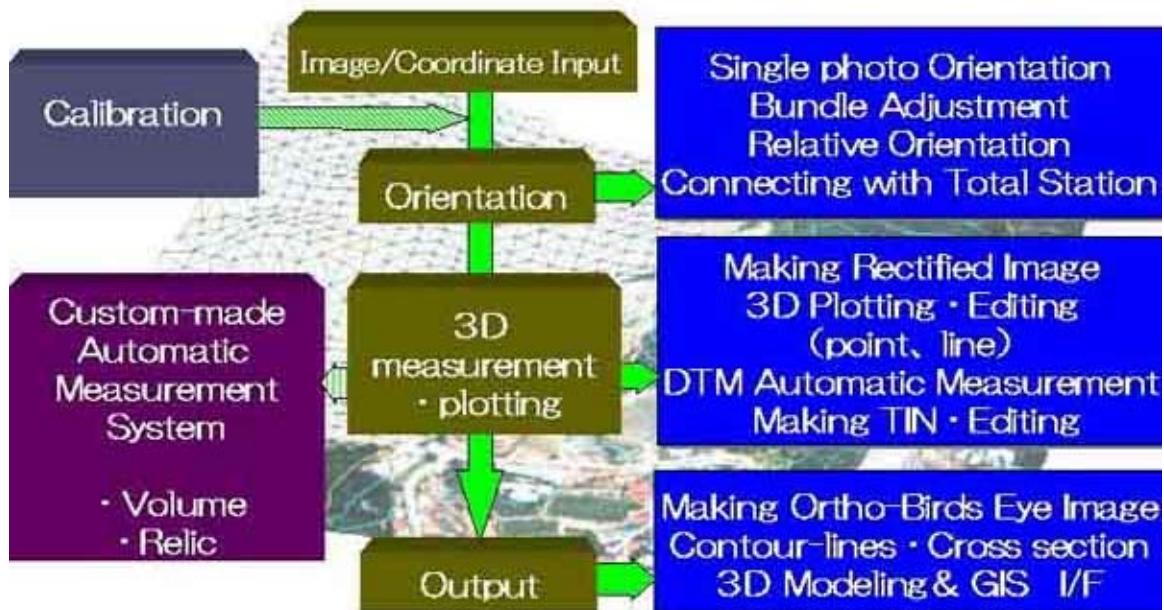


Figure 3. Function of 3D Image Measuring Station

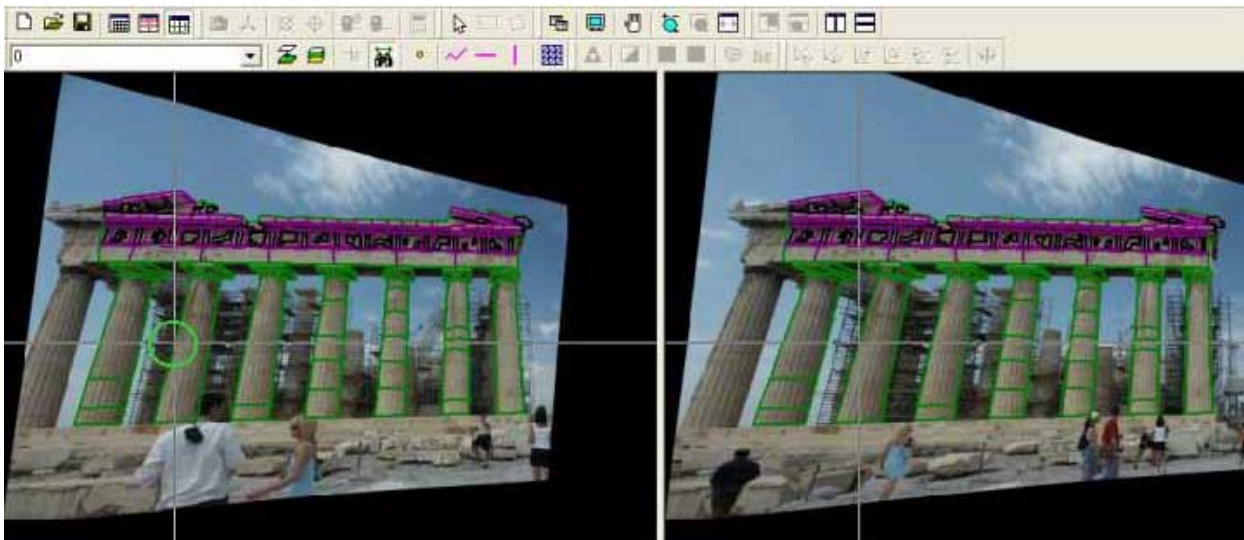


Figure 5. 3D plotting

### 2.2.3 3D measuring and plotting

For 3D measuring and plotting we have semi-automatic and automatic (Automatic DTM) mode. In the automatic mode, we get right and left rectified images on the PC screen. In the semi-automatic mode, if we trace where we wish to plot or to measure on the left image, the corresponding points are automatically calculated on the right picture. If the corresponding points are truly corresponding, they will be shown in green circle, if not, in red (Fig. 5).

In case of red, we can adjust by turning the dial on the mouse. Therefore, the manual measuring is also possible by using this function. By this function anybody can make 3D measuring and plotting. The rectified images shown on the right and left can be visualized in 3 dimensions and measured and plotted on 3D display.

And for automatic DTM measuring, we simply have to input the measuring extent or area. It is also possible to measure by adding the data of plotted points obtained by semi-automatic or manual measuring.

## 3. ZOOM LENS CALIBRATION

Most of the digital camera on the market now have zoom function and auto-focus function. And if we use them, many of the problems of photographing are eliminated.

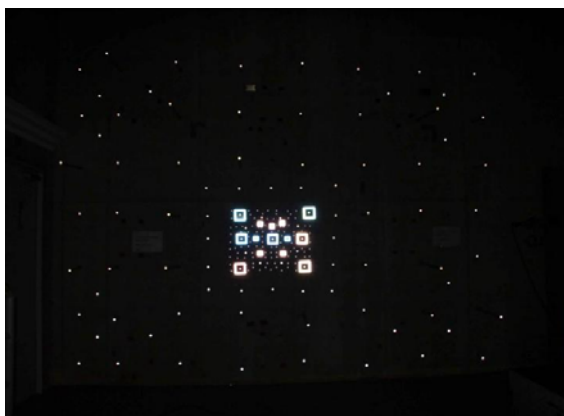


Figure 6. Calibration-field

We no longer have to concern about the size or brightness of the object, for example. Therefore, we have already developed the calibration for zoom lens (Noma, Otani, Kochi and others 2002.).

Furthermore, we have now developed 3D field for new calibration of zoom lens. With this new device we are now able to make highly accurate and fully automatic measurement even with wide angle lens or telephoto lens by merely taking a picture.

The Fig. 6 shows the 3D calibration field we have recently developed. In the center (within the brightened square) there are 100 retro-reflective target points placed in 3 dimensions for telephoto and out side of the central square there are also 100 target points for wide angle photographing. We simply have to take a picture with the camera aiming at the center to obtain the necessary and sufficient targets for both telephoto and wide angle. With this field and with the digital camera, Minolta Dimage7, we succeeded to obtain the accuracy of 1/4,000(zoom lens). This camera has 5 million pixels with focal length 7.2mm~50.8mm (equivalent to 28~200mm in 35mm format)

## 4. MEASURING AND 3D MODELLING BY PI-3000

### 4.1.1 3D Measuring and Plotting of Parthenon:

We took the picture of Parthenon by Minolta Dimage7 and measured and plotted with PI-3000. These three pictures, as you can see, were freely taken from an ordinary angle.

The distance from the object was about 24m. The photographing length between the right and left cameras was 6.6m. The focal distance was wide angle of 7.56mm.

Under this condition the resolution capability of one pixel is about 1 cm on 2D plane.



Figure 7. Photographing of Parthenon (east elevation)

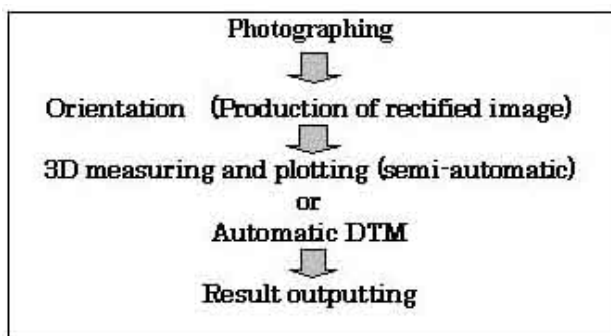


Figure 8. Operation flow chart

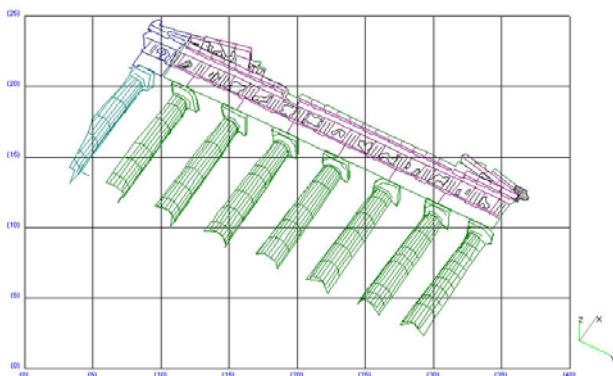


Figure 9. 3D Plotting of Parthenon

On these three pictures we made 3D plotting by the semi-automatic mode of PI-3000 and made automatic measuring as well. Its operation flow chart is shown in Fig 8.

To measure irregular surface we use automatic DTM measurement, but if we simply wish to produce a plan, it is not necessary to use it. The time we spent for this operation was within working hours of a day. What is thus plotted in 3D can be observed from all directions. The Fig. 9 shows the bird's view image plotted in 3D.

To verify the result we made 2D CAD (Fig.10) out of the actual surveyed image of Parthenon which had been made before. The picture plotted in 3D by PI-3000 was not surveyed at the time of photographing. Therefore, we took about 20 basic points out of the actually surveyed image as absolute coordinates, added them to the picture plotted in 3D by PI-3000, made ortho-image out of it and then superposed this ortho-image on the 2D CAD (Fig.11).

The resulted accuracy was  $\pm 1$  pixel =  $\pm 1$ cm.

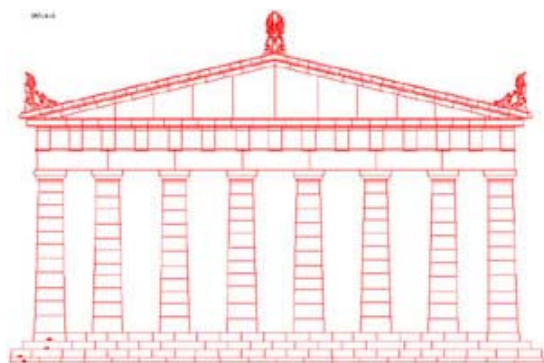


Figure 10. CAD image

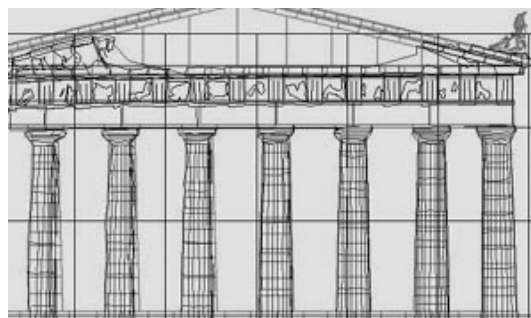


Figure 11. Superposing of Images

#### 4.2 3D Modelling of wall relief and statue

We also made 3D modelling of a wall relief (Hydriaphoroi) and a statue (Peplophoros) at the Acropolis Museum in Greece. We used the same Dimage7. For photographing we did nothing special but took the pictures from a random position. We took two pictures of the relief.

On the relief pictures of right and left we simply marked 9 points for orientation as in Fig 12, and made automatic measuring.

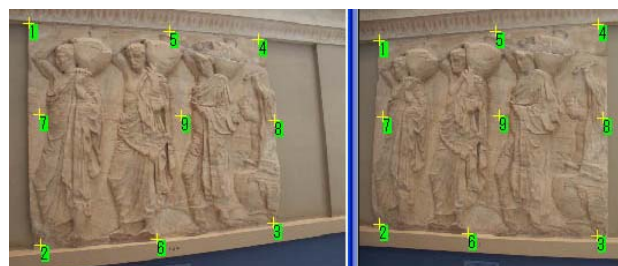


Figure 12. Orientation (Hydriaphoroi)

We made this 3D modelling very easily and in a short time. As the automatic measurement takes only a few second, the modelling of the whole picture was finished in less than 10 minutes.

Fig 13 is the image obtained by rendering from the measured result and by adding contour lines.

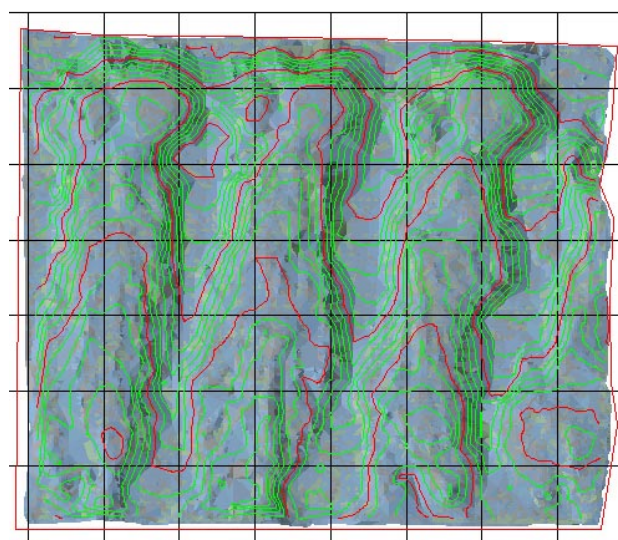


Figure 13. After Rendering and Contour lining



Figure 14. Bird's View Image (VXL Format)

Fig 14 is the bird's view after the same data were translated into VXL format. VXL is a format which is very light and easily obtainable. We can see from the result how the relief is successfully 3D modelled in great details.

We took three pictures of the statue (Peplophoros).

Fig 15 shows three photographs of the statue.

Fig 16 shows its bird's view and Fig 17 is the contour lines.



Figure 15. Photographs of statue (Peplophoros)



Figure 16. Bird's view

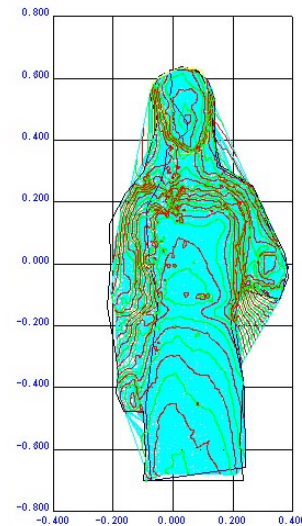


Figure 17. Contour lines

## 5. CONCLUSION

We were able to arrive at a very positive and satisfactory result in measuring technique with our newly developed PC-based photogrammetry system and an ordinary digital camera with calibrated zoom lens. With this system we took the pictures in an ordinary and simple way and successfully made accurate 3D measurement, plotting and modelling out of them. Besides, with a laptop PC on the survey site we could immediately confirm the data, eliminate photographing errors or oversights, acquire the necessary data while checking the essential points in details and analyze the final results in precision. Thus we could greatly simplify our work and economize our time. And we found that the 3D visualization of the object and the site would also serve as a valuable tool for effective and convincing presentation for a related project.

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