COMPUTER GENERATED MOSAIC OF UNDERWATER PHOTOGRAPHS
OF ANCIENT AMPHORAE, OFFSHORE THE SYRIA

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ABSTRACT

Ancient amphorae in a sunked ship were discovered 50 meters underwater, offshore the Syria, which were used as drinking water bases on ships in 12 and 13 centuries. Underwater photographs were taken to produce a computer generated mosaic, a planimetric map and color coded images.

Although the underwater survey was so hard to set up good control points and targets, an analytical photogrammetry was applied to determine the orientation parameters. A computer controlled mosaic was generated from 14 digitized underwater photographs.

Local filter and special color enhancement were applied to produce a high quality mosaic image from the original photographs of low contrast. The computer generated mosaic in digital form was used for advanced archeological studies.

INTRODUCTION

The depth of 50 meters is almost the limit where the divers can dive and work for surveying underwater objects. In order to map a number of amphorae
discovered in a sunked ship offshore the Syria, underwater photographs were
taken with control targets. As the control survey was so hard to obtain the
precise coordinates of the targets, it was rather difficult to get the good
results by the conventional photogrammetric orientation. However because the
distance survey between the targets was rather reliable, a bundle adjustment
with use of constraints for distance was used to determine the exterior
orientation parameters.

The image quality of underwater photographs was poor because of ill illumination,
low contrast, sedimeted mud over the amphorae etc., the underwater photographs
were digitized to improve the image quality by a computer. As an overall
planimetric map is more important than a topographic map for archeological
study, a computer controlled orthophoto was generated in consideration of
digital smoothing for discontinuous tones at boundaries between the neighbor
photographs in a mosaic.

UNDERWATER PHOTOGRAPHY

Underwater photographs were taken two times by the Hsselbrad MK-70 with focal
length of 60 mm, offshore the Syria.

1) October, 1985
   Altitude from the bottom: 4 meters; 6 courses; 82 photographs
   The image quality was not too bad but control grid of steel wire as shown
   in Fig.1 was not accurate for photogrammetric analysis. The total number of
   photographs were also too many for mapping. The photographs were used to survey
   the detail of individual amphora.

2) September, 1986
   Altitude from the bottom: 6 meters; 2 courses; 14 photographs
   The control targets were newly located as shown in Fig.2 but the image
   quality was not good. However the number of photographs is not too many for
   the photogrammetric analysis. Therefore the photographs were used for computer
   generated mosaic.

ORIENTATION

28 control points were located as shown in Fig.3. Distance measurement was
done by using a tape with rather good accuracy. Height measurement was done by
a hand level which will provide rather low accuracy, that is about 5cm error. Therefore the bundle adjustment with constraint for distance which has been developed by Murai Laboratory was applied. The standard deviation of residuals on the films was 270 micrometers, equivalent to 2.7 cmm error on the ground. Considering the 50 meters depth underwater and the difficulty of surveying, the result was not too bad for archeorological study.

COMPUTER GENERATED DIGITAL MOSAIC

The flow of producing a computer mosaic is as follows.

1) A/D conversion

Three time enlarged photographs were digitized by a drum scanner with a pixel size of 0.1mm, that is equivalent to 4mm at the bottom of the sea.

2) Exterior orientation

The exterior orientation parameters were determined with the bundle adjustment as mentioned above.

3) Digital orthophoto projection

The digital photographic data of 14 photographs were projected digitally onto an ortho-reference plane for the subsequent mosaic generation.

4) Digital mosaic generation

Deletion of discontinuous tones between the neighbor photographs and contrast enhancement were carried out. A mosaic was generated by computer at the scale of 1/20 on a film.

Fig. 4 shows the size of digital mosaic consisted of 3984 pixels and 2324 lines.

Because the sea bottom was very flat, each photograph was projected onto a datum under the assumption that a local area with respect to a photograph should be flat. The datum was taken constant except photo no. 109.

Fig. 5 shows a part of original image and digitally enhanced image after local filtering. Fig. 6 shows the computer generated mosaic from 14 underwater photographs and Fig. 7 shows a line draw plan of amphorae.

THREE DIMENSIONAL MEASUREMENT OF AMPHORAE

An overall distribution of amphorae can be studied with a computer generated mosaic, which was very useful for archeorological study. However, the exact size and three dimensional shape are also very important. Th larger scale of
underwater photographs taken in 1985 with altitude of 4 meters from the bottom were used for the detail measurement. A part of the sea bottom with several amphorae was measured its digital elevation using an analytical plotter.

Fig. 8 shows a bird eye view of amphorae.

CONCLUSION

Digital image processing in connection with photogrammetry was very useful to generate a computer enhanced mosaic. The computer generated mosaic and the line draw plan could provide archeorologists with very useful information. Even though the control survey was not good, the method developed in this study could show practically available results.

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PRESENTED PAPER

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Fig. 1 Underwater Photograph with Control Grid (taken in October, 1985)
Fig. 2  Underwater Photograph with Control Targets
( taken in September, 1986 )
Fig. 3 Flight Course and Location of Control Points

Fig. 4 Size of Digital Mosaic
Fig. 5 Original Image and Digitally Enhanced Image
Fig. 7 Plan of Excavation of Syrian Antiquities
Fig. 8 Contour Lines at 5cm Interval and its Bird Eye View