DEVELOPING OF THE SURFACE MODELL OF HUMAN GUMS

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ABSTRACT:

Our publication discusses a special task namely the photogrammetric possibilities of working out of the surface modell of the human gums. Besides solvability our experiments embrace also accuracy investigations. The instruments used were: non-metric camera, digital camera and digitalized photos. Needed control data were supplied by a test-field built for this special purpose.

1. INTRODUCTION

The Department of Photogrammetry of the University of Budapest has been asked to do an assigned task that of making a surface modell of the human gums. This surface modell was necessary for the planning of a dental bridge of a dental prothesis by finite elements method. According to the judgement of the employer the durability of a denture planned and executed in this way will be longer. The reason for this is that the projector can take into consideration the appearing physical strengths when he puts the dental bridge into shape; it will be thicker where physical strengths will have a greater effect.

The task -in the first place for medical reasons- implies also certain accuracy conditions. It is a demand on the evolved system the easy teachability of the persons without any preliminary studies of photogrammetry. This paper is a report of the first part of the task, an investigation of its photogrammetric accomplishment adhering to the limit of error. We intended not to restraint the possibilities of the switch over to the industrial production, for we have given a lot of kinds of possible solutions (i.g. non-metric camera, still video camera, non-metric camera with a digital cameraback, posteriorly digitalized non-metric photographs) and also making known their various characteristics. The definite assembling of the joint-instrument will only take place after the observation of the employer on the experimental products.

2. PLANNING PROBLEMS

When solving the task we used the well-known methods of close-range photogrammetry. The photographs were not taken of the real object but of a hard plaster cast. These objects are produced irrespective of the photogrammetric solving. In every case these plaster casts were put into a test-field of control points and thus there were taken photographs of them. We applied two different kinds of test-fields: 1. was built precisely of three rectangular spindles on which there were stressed some millimeter-paper and on this area there were unrestricted numbers of control points for processing; 2. a test-field reminding the control points of X-ray photogrammetry of higher accuracy but of less amount. Figures 1/a and 1/b show the two different types. In the first case the additional distance measurements for controll points accuracy resulted 0,1 mm standard error of position in the second case this value

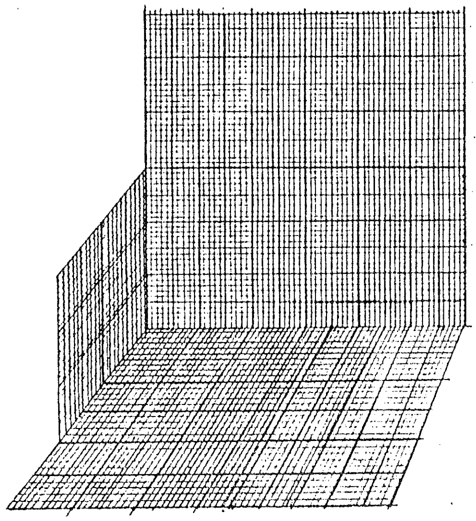

Figure 1/a: The test-field

was 0,02 mm. The accuracy values of the control point were proved by the index numbers gained from bundle adjustment. Can the control points be

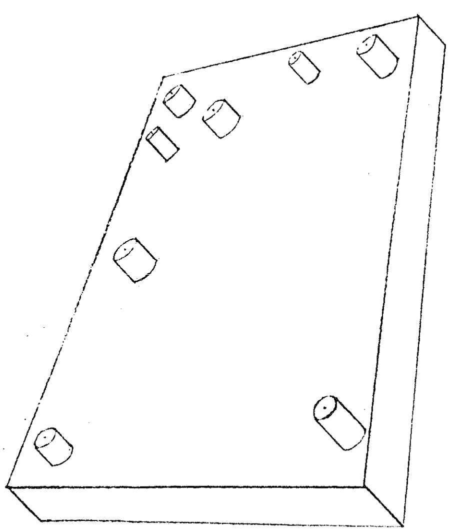

Figure 1/b: The test-field

accurate within such a geometrical lay-out our not? In order to obtain the answer we examined the effect of the error in the image space taken as a function of the principal distance and the object distance. We considered our control points accurate in case when a maximum effect would cause a lower value than 5μm in the image space. If this condition was not fulfilled during least square adjustment even control points themselves were corrected.
Concerning medical judgement deviation values below 1 mm may be corrected by the dentist, who treats the patient, so this value was considered as a maximum error and our intention was to reach the mean square error of 0,33 mm of the co-ordinate concerning surface modell.
In order to plan the accuracy of the close-range photogrammetrical network we need the index numbers characteristic of the accuracy of the image co-ordinates. If we know these values we can produce the condition equation of least square adjustment and it is possible to calculate the variance-covariance matrix previous to adjustment. If it is taken for granted that there is a network of high value of redundancy and it becomes evident from the covariance matrix previous to the adjustment that the needed accuracy is produced by the geometrical network taken it can be examined whether the omission of certain images and control points would make any modifications or not and in what proportion. At the application of the method -supposing that there is no correlation between the images- the reservation was made that from one stand-point there can be made only one photograph. This method needs a comparatively great quantity of calculation and because our task is to develope a new technology and not only a single solution of the problem, our extra-work will be refunded. Figure 2/a shows the previously made photographic geometry and the coefficient matrix belonging to it. Figure 2/b shows the

simplified solution which accomplishes the needed accuracy. This figure displayes non-metric camera arrangements providing 3μm mean square error picture co-ordinate. Naturally we admitted the method definetely only after the photo-processing of the data points brought about.

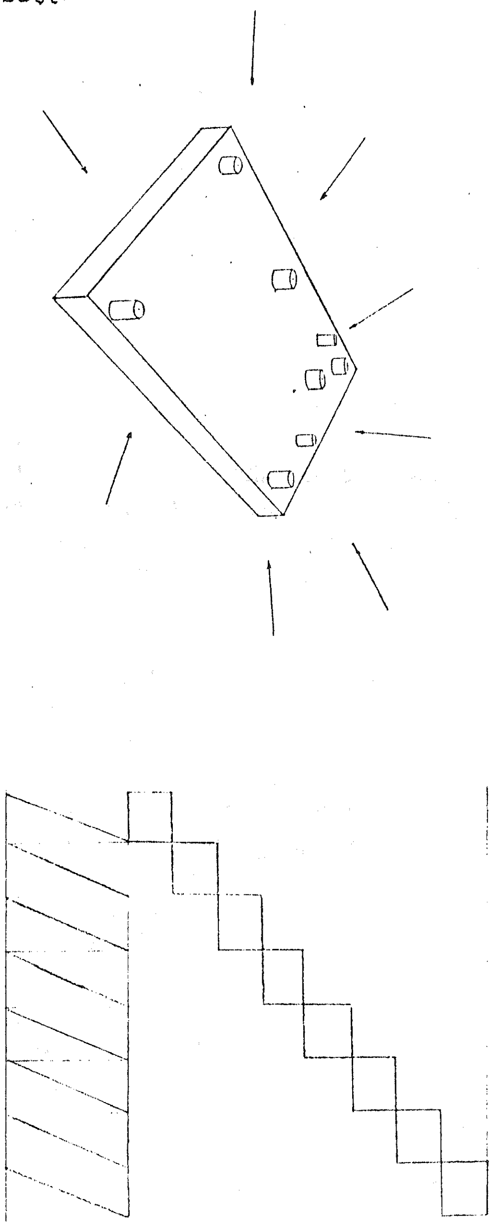

Figure 2/a: The geometry of exposure and the coefficient matrix belonging to it before accuracy planning

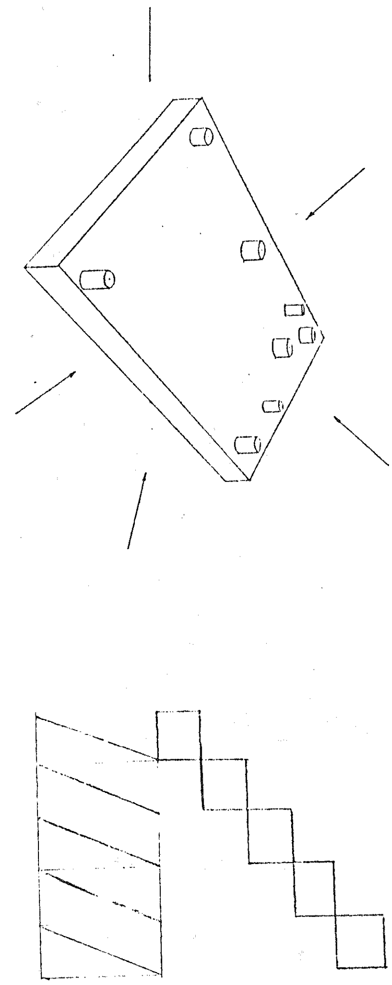

Figure 2/b: The geometry of exposure and the coefficient matrix belonging to it after accuracy planning

3. DATA ACQUISITION

Photogrammetric data gaining means that we are able to produce image co-ordinates from a -usually- unknown system of co-ordinates. Data acquisition consists of two parts: taking photos and measuring image co-ordinates. Measurement is done by means of photogrammetric instruments and in case of digital stocks at a workstation.

3.1 Photo taking

As it was mentioned above the photos taken of hard plaster cast have been made within a test network which came into being from control points. In order to avoid identification errors and to make the procedure of evaluation easier we projected a regular network of gratings on each image from a projector (photos 1., 2.). During photo taking the network of grating and the plaster cast were fixed in position ensuring the projected mark to remain on the same point of the plaster cast on every image. Photo 1. shows the arrangement of photo taking, photo 2 is an image of the object.

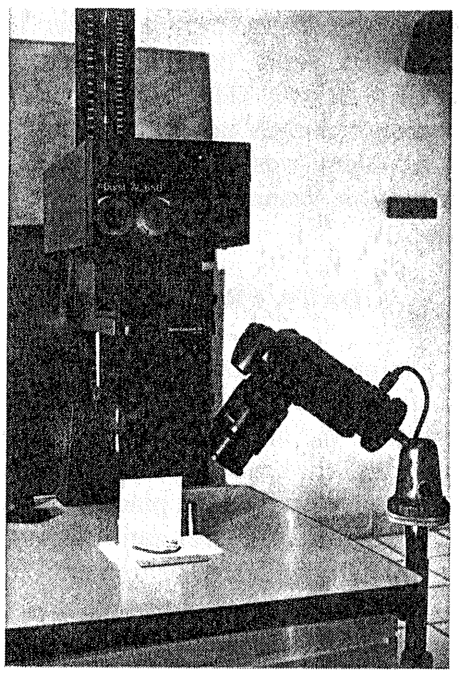

Photo 1.: Photographical arrangement with DCS 420

Applying the apriori accuracy planning methods of the multi-station close-range photogrammetric network our result was as it follows: the expected accuracy of 0,3 mm can be assured also by non-metric cameras built up for a reproduction reason if we choose an adequate high value of redundancy by the right election of the viewpoints and

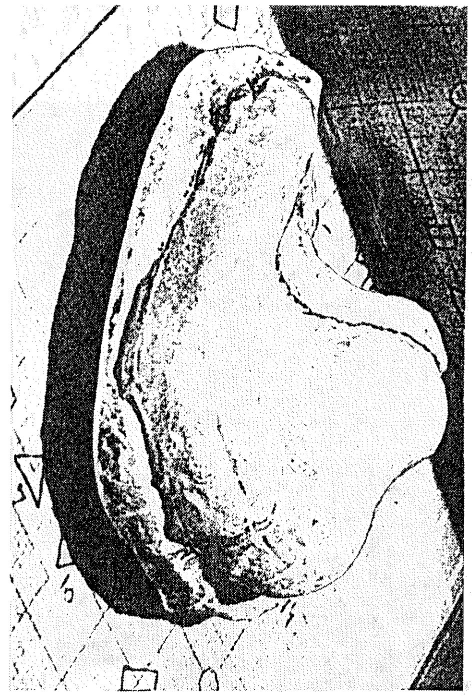

Photo 2.: The image of the plaster cast

the number of control points. The applied non-metric camera was of Nikon type developed for the reason of reproduction. We did not use complementary appliance (like a base, a ring light) because of the nature of the task. Among the applied digital intstruments the use of Kodak DCS (photo 1.) became customary in photogrammetry. At start there were a lot of literary experiences beforehand and we had some accuracy investigations which proved that by using this instrument it is possible to obtain a 1/20 pixel image co-ordinate mean square error in the image space. The use and applicability of Dicomed DDC 7520 (photo 3.) is possible only among certain limits. The main cause of this is that the camera is not really portable it was developed expecially for laboratory conditions and it contains only one row of sensors so observing the process of photo taking scrupulously it can not be taken like a central projection.

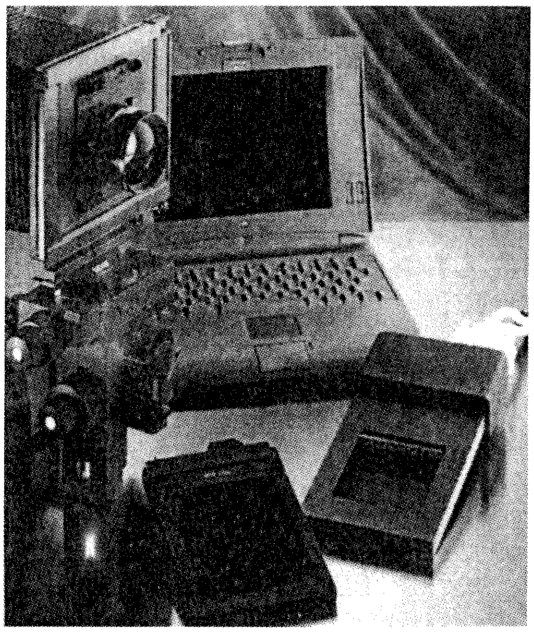

Photo 3.: Dicomed DDC 7520

Concerning its really existing disadvantages from the point view of photogrammetry it is to its great advantage that the sensor row motor impulse is refined and that is why the scanning of it is much higher than the usual values 7520x6000 image points (in contradiction to Kodak DCS 420 which has 1524x1012 image points). In case of our problem its disadvantages dont make the solution impossible for our photos has been taken under the circumstances of a laboratory and of motionless objects. The special solution of the instrument assumes that the accuracy values of the image co-ordinates are not equal along the two axes. Our admittance was proved by processing the data of a flat test-field which is parallel with one image plan that is why the accuracy of the x,y values of the image co-ordinates were characterized by different values, later.

3.2 Image evaluation

The applied technology determines the method of gaining of image co-ordinates. PK1 monocomparator was used for the analytical process of our images and contour line evaluation was made by a DSR1 analytic stereoplotter. Gaining of image co-ordinates is a demand also at digital stocks in case when the further process is analytical. The task was solved by a spatial information workstation using a general cope spatial information sofwear. During the determination of image co-ordinates firstly we had blown up the images with an accuracy below of a pixel and afterwards we made a measurement of image co-ordinates and for the precise positioning spider lines were used with control steering in several windows. The digitalization of non-metric images needs scanning and this problem was solved by a Kodak narrow film scanner.

4. DATA PROCESSING

The minimum input data of bundle adjustment are given by the image co-ordinates in the image co-ordinate system and the object space co-ordinates of the control points. In place of control point co-ordinates we can display in adjustment geodetic measurement result, too. We did not use metric cameras so we could make the previous transformation of the image co-ordinates by setting them into the negativ frame. As a consequence the co-ordinates of the principal ponit of camera were considered unknown in our calculations and in the case of digital stocks we had to prohibit the additional limitation of the images in the technological description.
As it was mentioned above we applied two different test-fields. In the first case we had several but inaccurate control points. This inaccuracy is due to the

uncertainty of the position of the three planes comparing them to each other. For this reason in the case of several points in the same plane we did not bring co-ordinates but only fictive distances into adjustment. In the second case central points marked by a cutting-off lathe on an iron cylinder plane surface produced by a surface grinder were considered control points. Their plane co-ordinates can be determined by a measuring microscope and their height values by a micrometer of a mean square error below 0,01 mm. In this case the co-ordinates of the points can be brought into adjustment like exact values.

Figure 3.: The contour lines of the upper gums

5. ANALYZATION OF THE RESULTS

As it has been clearly demonstrated, we produced image co-ordinates from each image and the adjustment was made with the same programme. The only exception was the contour line of a 3 mm contour interval of the human gums produced by an analytical plotter (figure 3.). During the computation our best results were gained by using additional parameters; the explanation of this fact is that the inner orientation were unknown and this is a demand for displaying of other parameters in this area like distortion and film motion in the formation of the funtional modell. This is true even in the case when we do not want to co-ordinate physical content to additional parameters. We put the summary of our results in a table. Every value is given in respect to the image space in order to make easier comparisons to other results; everyone was made with the same objective and in the same photographical arrangement.

	m_{pr}	μ_{pr}	μ_{po}	μ_{co} [μm]
1	3,0	23	16	20
2	2,5	19	17	19
3	2,5;3,0	22	16	23
4	3,5	25	18	24

where:

1 -Nikon film,
2 -Kodak DCS,
3 -Dicomed,
4 -Nikon dig.,
m_{pr} -is the mean square error of image co-ordinates brought into adjustment,
μ_{pr} -is the average mean square error of the object space co-ordinates previous to adjustment in the image space,
μ_{po} -is the average resultant square error of the object space co-ordinates after adjustment in the image space,
μ_{co} -is mean square error resulting from the differences between the co-ordinates of known points but which was not drawn into the determination of the parameters of adjustment and the co-ordinates gained from the photogrammetric point determination of the same points.

It can be laid down as a fact that using the methods of close-range photogrammetry it is possible to solve the task with the accuracy needed.

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