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# A COMPARISON BETWEEN 11-PARAMETER SOLUTION AND THE BUNDLE METHOD AT A PHOTOGRAMMETRIC CONTROL SURVEY

## ABSTRACT

The recent energy crisis forces every country to built big power plants with large cooling towers. One of these large cooling towers working on the natural draft principle was erected in North Germany. For documentation purposes also to check some specific parameters of the geometry of the entire structure high oblique terrestrial photogrammetry was employed. The coordinates of the points on the photographs taken from arbitrarily choosen camera stations were measured on a stereocomparator. The orientation and transformation into a locally defined coordinate system were performed with the rigid bundle method and also with the 11-parameter solution. In order to compare these two methods the differences of the three dimensional coordinates of all object points are determined. As a result it is shown that terrestrial photogrammetry and these two methods give efficient solutions for such precise surveys.

## INTRODUCTION

In densly populated industrial countries big power plants are nowadays more often built away from natural water recources. Large cooling towers with great dimensions are a common sight with the nuclear power plants, if there is no water for cooling purposes. A large cooling tower working on the natural draft principle was erected in Nordrhein-Westfalen (Federal Republic of Germany). This cooling tower is unique concerning the enveloping shell. It is a prestressed steel cable net structure covered with aluminium sheeting. The net is formed by triangular meshes caused by two diagonal and one meridional set of cables. The whole construction has a rotational form which is defined by 216 meridional cables. Each of these cables represent a second order parabola. The dimension of the steel ring is 141 m at the bottom and 91 m at the top in diameter. The upper ring hangs from a slender central mast, 180 m in height (Fig.1).

The parameters of the geometric shape of the whole construction and thus of all meridional curves were defined through the static calculations in the design stage. After the structure was finally erected its actual shape had to be determined before mounting the sheeting. The purpose of this control was to check whether the erected from was equal to the design.

Figure 1.

## PHOTOGRAMMETRIC SURVEY

For documenting and also to check some specific parameters of the geometry of the entire structure high oblique terrestrial photogrammetry was employed. To determine the spatial coordinates of the targets which would serve as control points for photogrammetric restitution, a precise traverse was measured around the base of the tower. The three dimensional coordinates of the travers points and of the targets were computed by a rigorous adjustment.

As the choise of the camera stations give the difficulty of overlapping the near and far sections of the net in the photographs, it was decided to choose the camera stations inside the structure. The JEOPTIK UMK 10/1813 camera was positioned on arbitrarily choosen camera stations, each position choosen wholly independent from any other with the only goal of photographing as large a section as possible (Fig.2). For further details of the photogrammetric survey, see |4|.

BOPP, KRAUSS and PREUSS restituted these photographs in order to calculate the deviations of the meridional curves from the designed shape. They calculated the spatial coordinates of the points on the mesh with a general bundle solution.

## DATA REDUCTION

KARARA and his group have introduced the method of the Direct Lineer Transformation a few years ago |1| . This method establishes a linear relationship between coordinates of image points, measured with a comparator and the corresponding object space coordinates. This linear approach for the calibration of a camera does not require fiducial marks on the photographs.

Using the advantages of the Direct Linear Transformation, BOPP and KRAUSS derived the eleven parameter solution which can also be applied to those cases where the interior orientation is known and where it should be enforced |3|.

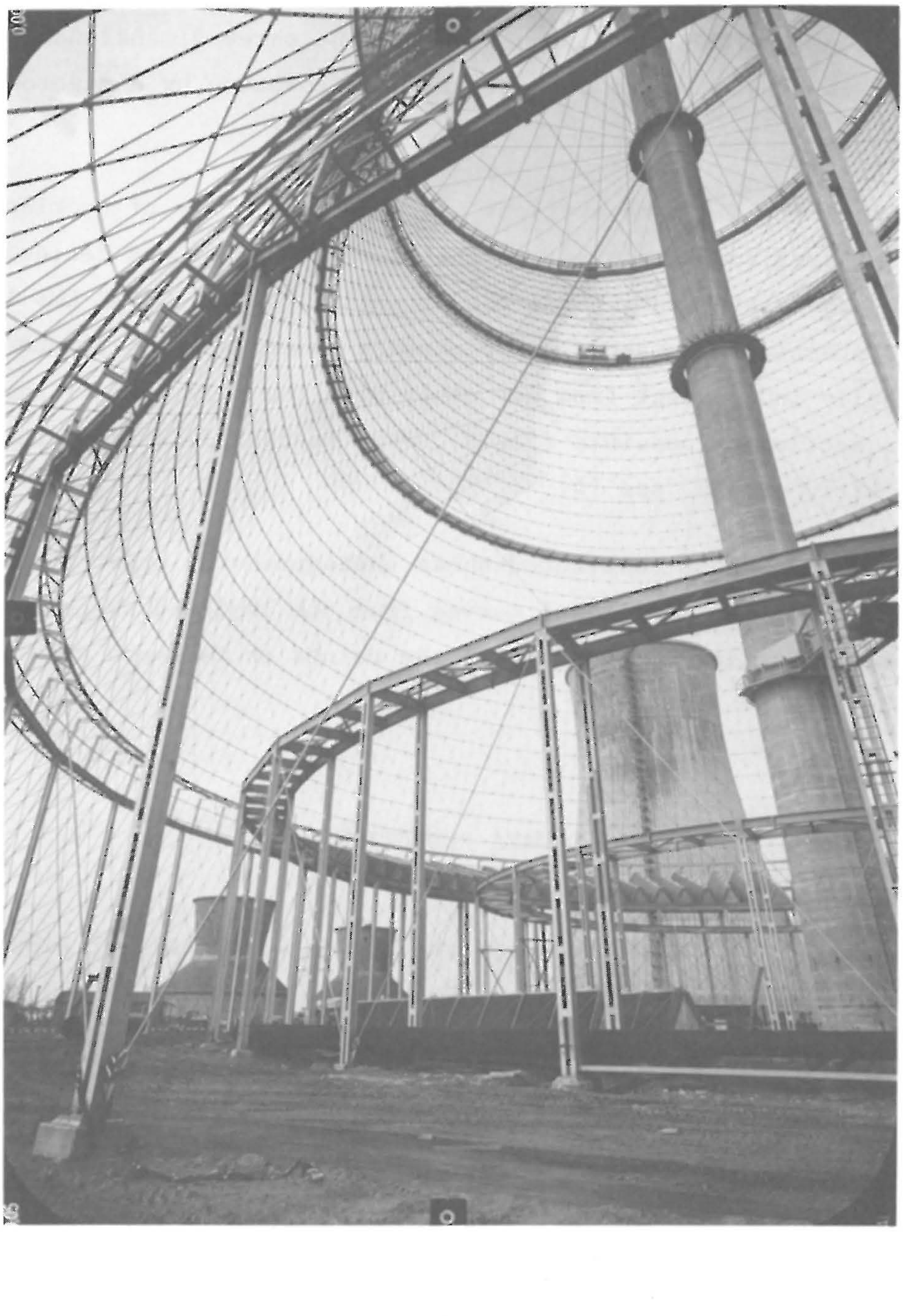

Figure 2.

ALTAN, BOPP and KRAUSS have studied the eleven parameter solution in connection with a "semi-metric" camera Hasselblad MK70 | 2 |. In contrast to this paper the differences between the rigid bundle and the eleven parameter solution are studied in connection with a "metric" camera.

The bundle solution used in this study is based on the conventional non-linear collinearity equations. In this solution, in addition to the image coordinates, the principle distance of each photo and the object space coordinates of all control points are considered as observations. Thus the orientation parameters of the bundles and the object space coordinates of all points are determined simultaneously by a least-squares adjustment with condition equations with unknown parameters and with respect to all possible correlations between the observations. In this paper only a diagonal weight matrix of the observations are considered. For the presentation of the results the differences of the coordinates of the points are determined by the mean values

$$MDX = \frac{1}{n} \Sigma |DX|$$

$$MDY = \frac{1}{n} \Sigma |DY|$$

$$MDZ = \frac{1}{n} \Sigma |DZ|$$

$$MDP = \frac{1}{n} \Sigma \sqrt{DX^2 - DY^2 - DZ^2}$$

with DX, DY, DZ differences of the coordinates, n number of points in the comparison.

The mean values, calculated from the differences of the control point coordinates determined by the bundle solution with different unit weights of the image coordinates and by the adjustment of the geodetic measurements are illustrated in Fig.3.

In the eleven parameter solution the orientation or calibration parameters of each bundle are determined in a first non-linear least-squares

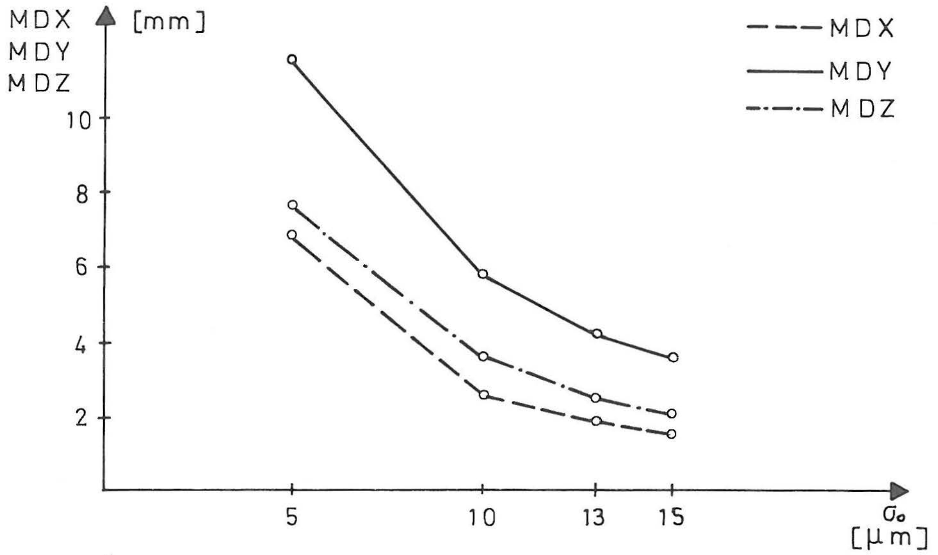


Figure 3

adjustment where the object space coordinates of the control points are regarded as constant.

The object space coordinates of all points are computed in a second non linear least-squares adjustment where the predetermined transformation parameters are constants. The concept of the eleven parameter program allows the computation of a pure orientation program if the data of the interior orientation are read as additional input.

COMPARISON OF THE RESULTS OUT OF THE BUNDLE AND THE 11-PARAMETER SOLUTION

For the comparison of the two methods the differences of the three dimensional coordinates of the object points resulting on one hand from the rigid bundle solution and on the other hand from the two step orientation respectively on-the-job calibration are determined. For the presentation of the results the mean values listed in the following table are calculated. The comparison of the results of the orientation and on-the-job calibration shows that the results of the calibration are better than the orientation. The orientation program is calculated with the camera constant given in the calibration report of the camera. The difference of this value from the determined camera constant by the on-the-job calibration is 143 μm. This can be interprated that even with the combination of a metric camera the adjustment with more parameters can give better results. Whether we use the orientation or non-the-job calibration solution the obtained maximum mean value is not more than 3 cm. For the case of on-the-job calibration this value decreases approximately to 1 cm, an mount which is aquivalent to 0.08%o of the mean object distance. This seems to be acceptable for most applications in control surveys.

| | MDX | MDY | MDZ | MDP |
|---|---|---|---|---|
| On-the-job Calibration | 15,1 | 14,7 | 11,0 | 26,7 |
| Orientation | 12,5 | 4,6 | 7,6 | 11,2 |

Table : The mean values [mm] calculated from the 11 parameter solution-bundle solution

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