ON THE ACCURACY OF NON-TOPOGRAPHIC PLOTTING

Juha Jaakkola
Finnish Geodetic Institute
Finland
Commission V

1. Abstract

In the plotting of non-topographic models, the photography, equipment, and control point information greatly vary from case to case. Also when using analytical plotters for graphical plotting, it is possible in the orientation of models to exactly treat expanded object control (geodetic observations, constraints caused by the object geometry, and orientation parameters) and to take into account the accuracy of control point coordinates and interior orientation. This all has been in wide use in photogrammetric point densification measurements. The effect of these factors in single model plotting will be studied using the law of error propagation.

2. Introduction

The increasing amount of analytical plotters and pertinent software (FUCHS 1982) have made the use of these instruments realistic for close range applications with direct graphical output. The combination of digital model orientation and analog output brings the advantages of both methods. In the orientation of models, several features, which were possible only in fully digital systems, can now be strictly integrated into graphical plotting.

The most important advantages of this development are:

- Increasing accuracy. All control information, which is very versatile, can be treated strictly, and allocated there where it is most effective. Modelling of error sources is possible.
- Increasing economy. Control measurements can be optimized in accordance with accuracy demands and ease of field work.
- Versatility. It is possible to plot non-metric images and photos taken with unusual dispositions.

Due to the flexibility of these methods, the estimation of accuracy and its distribution, which is important when planning photography, is more difficult than when using analog methods. Also the accuracy requirements change from case to case, and can be different for each coordinate. This problem can be reasonably solved only using theoretical studies of accuracy. The author has developed a computer program, which calculates mean errors of plotted points using the law of error propagation.

3. Principle

For strict treatment of all available data, model orientation must be calculated using the bundle method. In order to simulate real plotting only those observations, which would be used also in practical measurements, are included in this phase. The mean errors of the object points are then calculated point by point using formulas for three dimensional intersection. The whole variance-covariance matrix of intersected points can be calculated in this phase. It must be stressed that modelling of all errors is not possible, and the mean errors are only estimations of absolute values. Nevertheless, the changes in accuracy, due to the changes in different factors, are more reliable.

In model orientation the observation equations, which have been derived only partially from real observations, have been divided into three groups. These groups are the unknown parameters, real observations, and constraints (fictitious observations).

3.1 Unknown parameters

All unknown parameters can be treated as directly observed quantities. For some orientation parameters this is also very realistic. In close range applications it is usual that the accuracy of control point coordinates is not high enough, and these must be included in the adjustment as directly observed unknowns.

In model orientation, the geodetic and photogrammetric information for the determination of additional parameters (interior orientation and distortion) is often insufficient. Also the geometry of the model is sometimes improper for this purpose. In practical model measurements only the parameters of interior orientation can be used as unknowns. Their weights must be considered carefully with respect to model geometry.

3.2 Real observations

Analytical model orientation can be performed as a combined adjustment of observed photocoordinates and geodetic observations. This guarantees the best results with respect to accuracy and economy.

3.3 Fictitious observations

This group of observations is mathematically identical with the previous group. These observations are in reality constraints, which have been defined through the object geometry. They are usually based on a subjective estimation of the fullfilment of these constraints in the object itself. This judgement will be realised in the weights of these observations. The amount of possible constraints in close range applications is almost unlimited.

The fictitious observations of differences between corresponding orientation parameters follow a slightly different logic. . When using stereometric cameras, some parameters of exterior orientation are the same, within the accuracy of the assembly, for both cameras. Also when the photos of a model have been taken using a single camera, it is possible to separate the systematic and random errors of the parameters of interior orientation.

4. Weighting

Because all unknowns and constraints will be treated as observations, it is necessary to give them proper weights. This is quite problematic because there are different types of observations, most weights are very hypothetical (constraints), and the stability of the system requires weighting different from that implied by the a priori accuracy of the "observations" (e.g. interior orientation).

Incorrect weighting leads to reduced accuracy, that should be taken into consideration. The effect of this kind of errors can be calculated using the following formula (GOTTHARDT 1962).

$$Q_{xx} = (A^T\bar{P}A)^{-1} A^T\bar{P}Q\bar{P}A (A^T\bar{P}A)^{-1}$$

where: Q_{xx} = Weight coefficient matrix of unknowns x

A = Coefficient matrix of the observation equations

P = Weight matrix = Q^{-1}

$\bar{P}$ = Incorrect weight matrix

5. Examples

As an example of the possibilities of the program and of the effect of some factors on the accuracy, the following case will be described. A photo pair taken with a levelled stereometric camera (SMK120 by Zeiss/ Oberkochen, c = 60 mm, b = 120 mm, plate format = 90 mm * 120 mm) using horizontal axes of photography will serve as photographic data . The distance of photography was 5 - 24 m, giving a scale of 1:83 - 1:400 and a base-to-distance ratio of 1:4.2 - 1:20. The area photographed was a horizontal parallellogram, which lay 1.3 m below the level of projection centers. In case A, which has been used as a reference case, a XYZ control point was situated in each corner of the parallellogram and one point in the middle of the farthest side. (See Figure 1.). Additional information is given in Table 1.

Photo coordinates (x,y)	± 0.005 mm
Control point coordinates (X,Y,Z)	± 10 mm
Interior orientation (c,x_o,y_o)	± 0.01 mm

Table 1. Mean errors of the "observations".

Case A shows the well known large variation of errors in the X and Y coordinates if the base-to-distance ratio is small and varies much. The Z coordinates are very accurate because all points lie almost in the photo horizon.

Case B. In this case the errors of interior orientation have been estimated to be too good. The real accuracy is ± 0.02 mm.

In the X coordinate, this error can be compensated quite well, except in the corners in the background. In the Y coordinate, the compensation is poor, and the largest changes in accuracy are > 10 %. Changes in Z are meaningless.

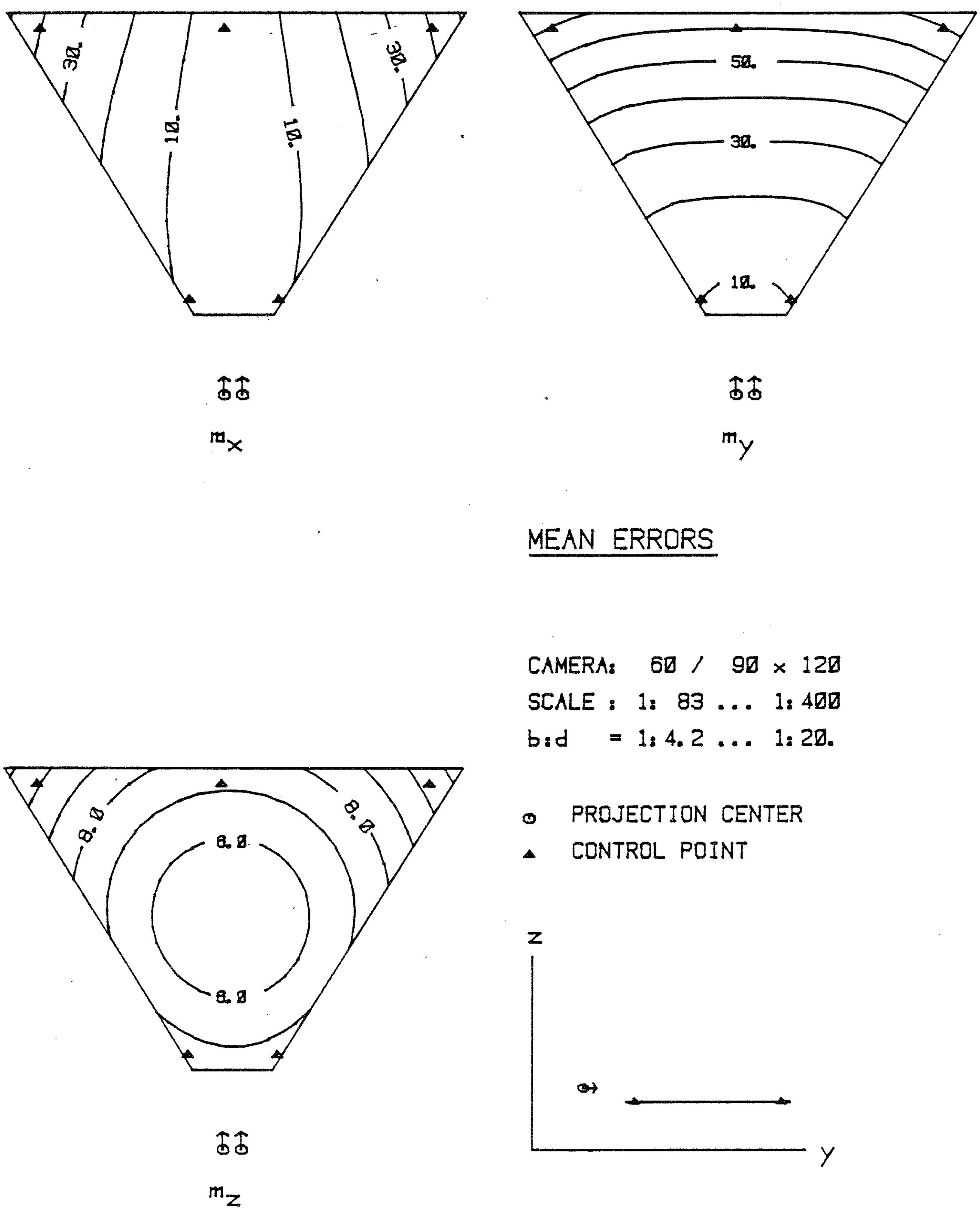

Fig. 1. Mean errors in case A.

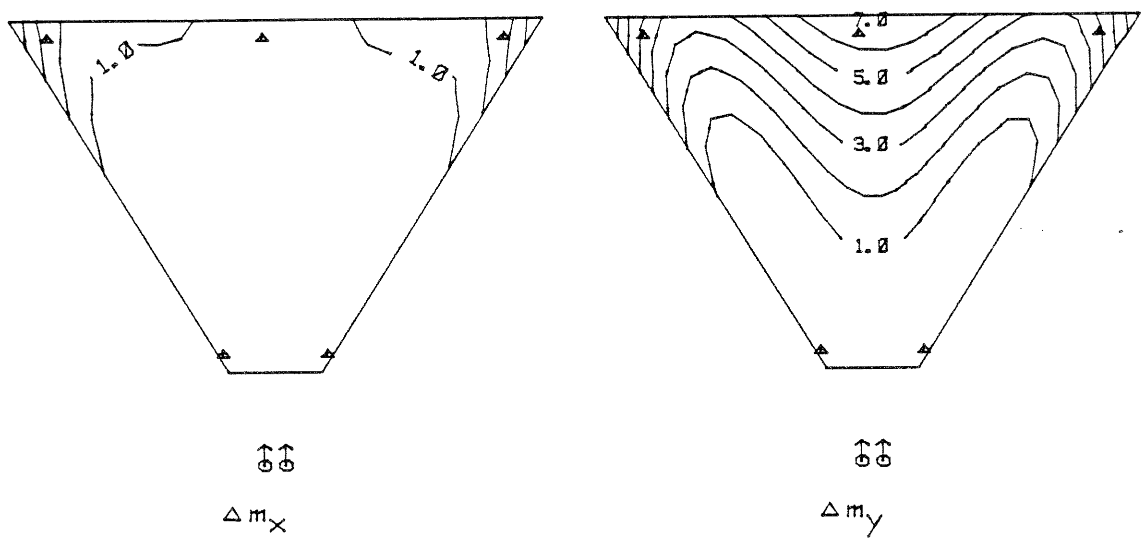

Fig. 2. Differences of m_x and m_y between cases A and B (B - A).

<u>Case C</u>. Due to the levelling of the camera, the ω and κ values are known with an accuracy of 50^{cc}. This increases the height accuracy and makes it more homogenious. The largest improvement is 62 %.

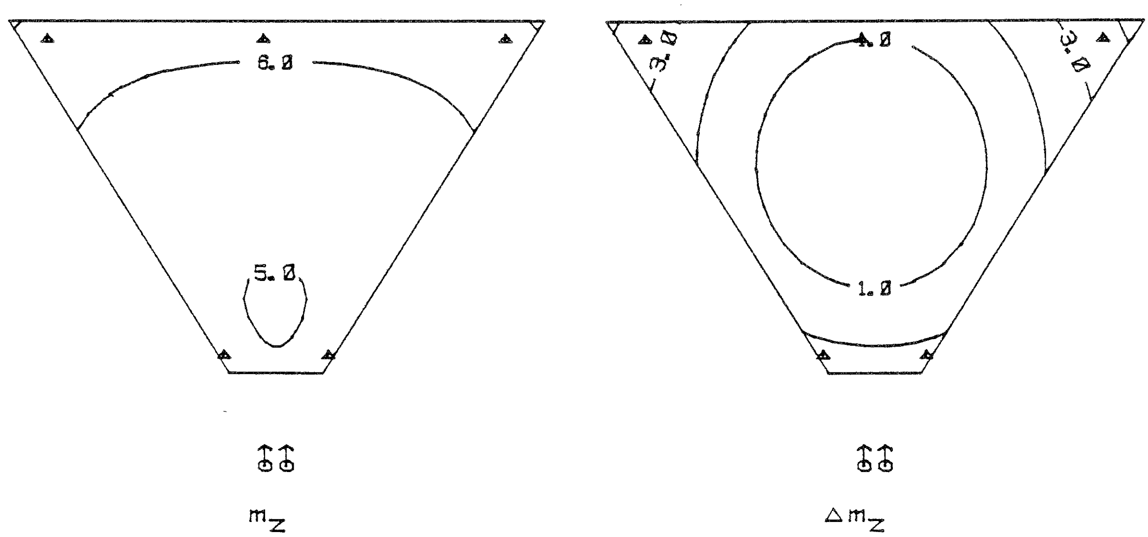

Fig. 3. m_z in case C and its improvement when compared with case A (A - C).

<u>Case D</u>. In the center of the model there are two additional control points. The accuracy increases slightly on the left and right sides of the model.

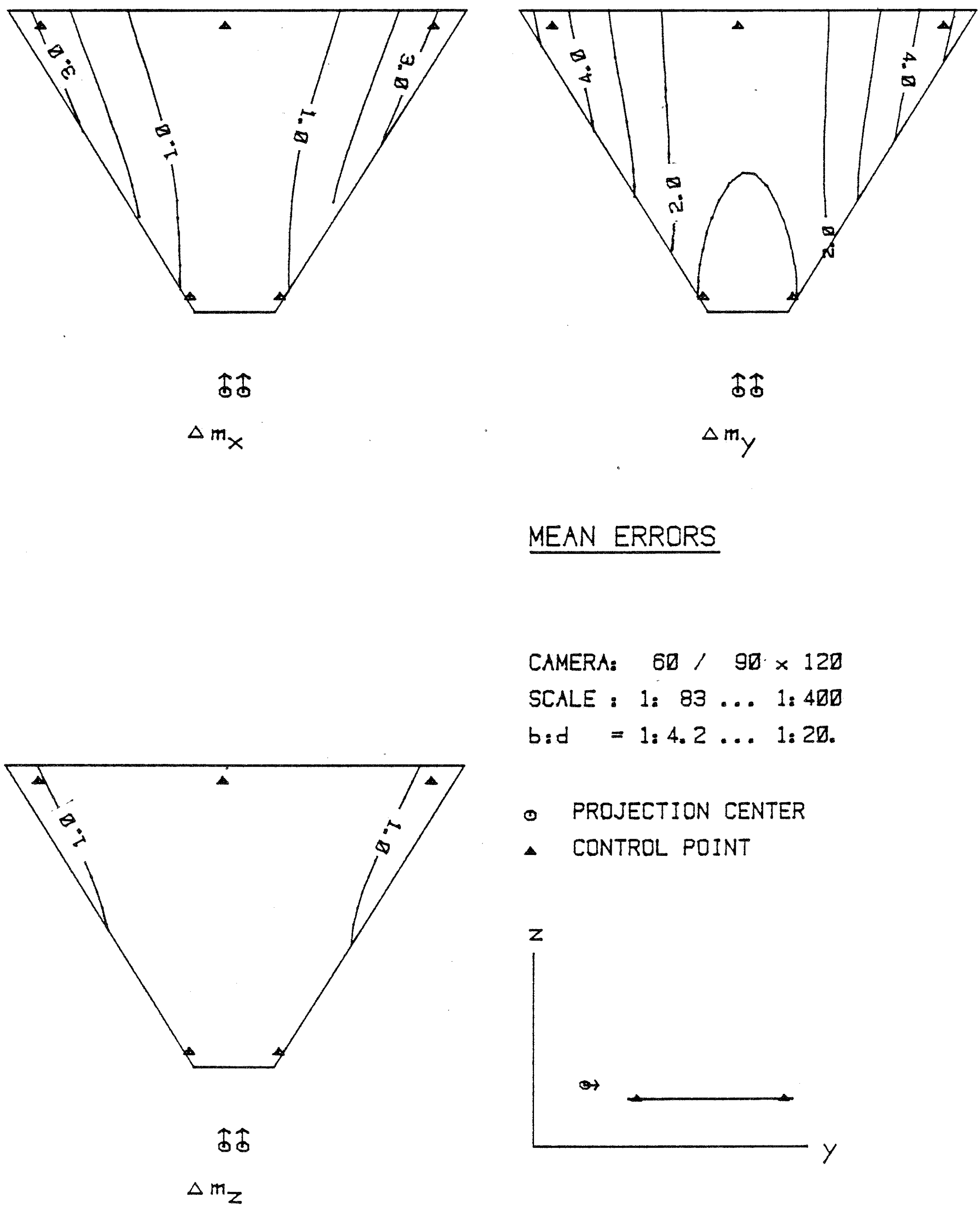

Fig. 4. Improvements of the mean errors between cases A and D (A - D).

Case E. The two additional control points are beneath the farthest two. Compared with case D, the accuracy is a little better in the background and poorer in the foreground. The results are thus more homogenious.

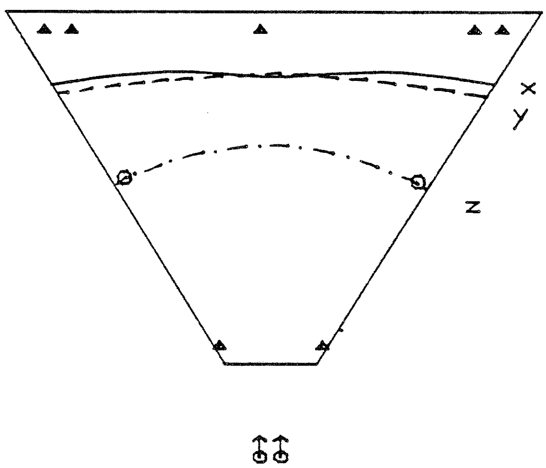

Fig. 5. The lines of equal accuracy of the X, Y and Z coordinates in cases D and E. In the background, case E gives better accuracy.

Case F. The accuracy of all five control points is ± 1 mm in all coordinates. The improvements of accuracy are relatively and absolutely largest in the foreground, which makes the model still less homogenious. In the Z coordinate, the accuracy improvements are relatively very large. This case shows that the accuracy of control points should be in good agreement with the accuracy of photogrammetric observations.

Case	X		Y		Z	
	min	max	min	max	min	max
A	5.2	52.1	7.5	80.6	5.3	11.5
B	5.4	57.2	7.6	88.7	5.4	11.8
C	5.2	52.0	7.5	80.3	5.0	7.1
D	4.6	48.2	7.1	74.9	4.6	10.3
E	4.7	47.0	7.2	72.8	4.8	9.2
F	1.0	50.6	3.6	78.8	1.4	5.4

Table 2. Minimum and maximum values of the mean errors.

6. Conclusions

The examples have shown that already quite small changes in input parameters have clear effects on the accuracy of the object coordinates. Also large variation of the mean errors in single cases prove the needs for a careful study of accuracy before performing the photography.

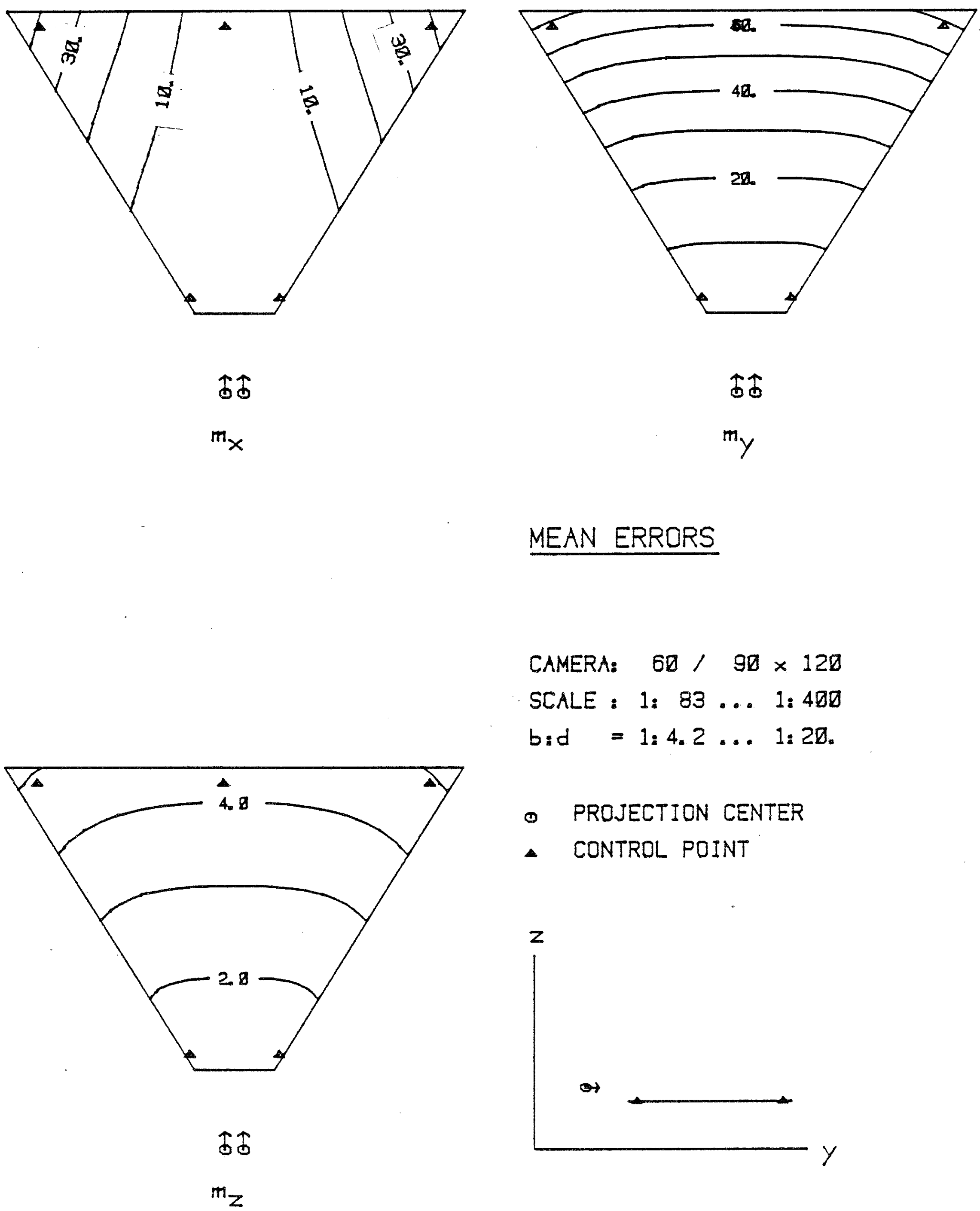

Fig. 6. Mean errors in case F.

Literature:

Fuchs H.: CRISP. A Software Package for Close Range Photogrammetry for Kern DSR-1 Analytical Stereoplotter. International Archives of Photogrammetry. Vol 24, Part V/1, York 1982.

Gotthardt E.: Die Auswirkung unrichtiger Annahmen über Gewichte und Korrelationen auf die Genauigkeit von Ausgleichungen. Zeitschrift für Vermessungswesen 1962, Heft 2.

Kager H., Krauss K.: Gemainsame Ausgleichung photogrammetrischer, geodätischer und fiktiver Beobactungen. Geowissenschaftliche Mitteilungen, Heft 8. Studienrichtung Vermessungswesen Technische Universität Wien 1976.

Wrobel B., Ellenbeck K.-H.: Terrestrisch-photogrammetrische Punktbestimmung durch Simultanausgleichung gemessener Orientierungsdaten und Bildkoordinaten in der Bündelblockausgleichungen. XII ISP Congress Helsinki 1976.