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A DIRECT METHOD FOR MEASUREMENT OF COORDINATES OF A THREE DIMENSIONAL TEST FIELD

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For an extensive use of non-metric cameras in photogrammetry , an easy, practical and inexpensive method for construction of a test-field is needed.

In this paper a direct method for coordinate measurement of a three - dimensional test-field is presented.The method is very rapid,practical , easy and can be of a high precision.

Une methode pour la mesure directe des coordonnees d'un objet-teste tridi - mensionnel

Pour l'utilisation plus generale des cameras non-metriques afin des travaux metriques, il faut chercher des methodes simples et pratiques pour la construction d'un objet-teste.

Dans cet article une methode est presentee pour la mesure directe des coordonnees d'un objet-teste tridimensionnel. La methode est facile,pratique et elle peut etre d'une precision assez elevee.

Eine direkte Metode fur Koordinaten-Brechnung von einen dreidimesionnalen Test Field

Fur generale benutzung von nicht photogrammetriche Kamera,ist eine bil-lige,einfache und praktische Metode notwendig.

In diesem vorliegenden Artikel ist eine direkte Metode fur Koordinaten bestimmung des Test Field erwahnt. Diese Metode ist einfach,praktisch und schnell. Sie kann sehr grosse genauigkeit haben.

INTRODUCTION

The most active areas of non-topographic application of photogrammetry has been in architecture and in biomedical sciences.

During last decade however close range photogrammetry has undergone - significant changes in most its systems and concepts. And its potential as a flexible tool for rapid,non-contact spatial measurements in numerous engi-neering and scientific disciplines is considerably increased.

The experiences in last several years indicate that this powerful tech-nic can be both practically and economically feasible,for industrial measure-ments and inspection tasks.

What is then the reason that for a century the photogrammetry was not largely spread outside the surveying and mapping community? The reason can be found in the fact that the inner orientation parameters of a camera change with object distance and with the lens field.

In contrast to aerial photogrammetry , in which the object is too far from the camera, for close range photogrammetry the object distance is finite (up to 300 m ,according Karara). Thus it is impossible to have a metric - camêra for all object distance ranges; and special methods of calibration , tailored to the specific requirements,are needed.

In spite of the wide variety of available metric cameras and their permanant increasing versatility and adaptability, there are still numerous - special applications for which no suitable metric camera exists. the rather high heterogenity in requirements and conditions of various special applications is the main origin of this insufficiency. Therefore the use of non-metric camera and camera calibration problems have assumed increasingly - more importance.

The non-metric cameras are of low cost and largely available. But the user of non-metric camera has to calibrate the camera by himself; and for a general use of these cameras inexpensive and practical methods of camera calibration are needed.

On the other hand the use of the analogue equipments is limited by their optical and mechanical constraints , the lens distorsion is large and unstable ; therefore the analogue data reduction of the picture is not possible.

During the last decade both non-metric camera calibration and data reduction problems are solved through advanced analytical procedures.

As in the non-metric cameras the calibration parameters often do not retain their values, in " on the job " camera calibration procedures the calibration is combined with object photography, and the same exposures are used for both camera calibration and data reduction. In these methods the interior orientation parameters are all introduced as additional unknowns into the solution fo exterior orientation.

D.L.T.(direct linear transformation) is an " on the job " method developed by the University of Illinois. It is a direct linear relationship - between comparator coordinates and object space coordinates. It is moreover a direct solution and it does not involve initial approximation nor partial derivation.

In general however, the procedure consist of exposing photographs of an array of targets , whose X,Y and Z coordinates are precisely known.
The inner orientation parameters will be then calculated on the basis of the image coordinates and the object coordinates of the targets.

It is therefoe evident that the use of non-metric camera has nothing to do with accuracies or other characteristics, and the precision obtained depends on two following factors:

- efficiency of the analytical computer program,used for data reduction , for which there is no restriction
- the accuracy of the test field

It is thereby concluded that for a practical and extensive use of non-metric cameras the easy , practical and inexpensive methods are needed for test field costruction

Several methods are actually used for coordinate determination of a test field;the followings are some examples:

- geodetic methods are used in differenc forms for both two dimensional and three dimensional controls.These methods are generally expensive , difficult and time consumming
- in the self calibration methods a stable camera is needed
- a more sophisticated three dimmensional test field is used by Dohler
- Malhotra's method for geodetic determination of object space control is based on construction of two or more real or pseudo-images of the test area

A direct three dimensional coordinates measuring method, devised by the author is described in the following.

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1 - Principle

The picture scale being about 1:10 or smaller , for an error of ±5 micrometer on the image, the minimum permissible error on the object will be ±0.05 mm.

It is generally very difficult and time consumming to achieve such an accuracy by conventional methods,moreover some computations are needed.

By present method the X,Y and Z coordinates of object points are directly measured and no additional computation is needed. The method is easy, rapid, practical and it can be of a high precision.

2- Test field configuration

In the experimental test , a small scale pyramid was choosen as object (FIG 1). As the use of the non-metric camera by D.L.T. method had been in purpose, the test field is incorporated on the object surface.
The control points are randomly choosen all over the object surface, so

that they could suitably characterize the topographic formation of the object or more exactly the object surface relative depth distribution in the picture field.

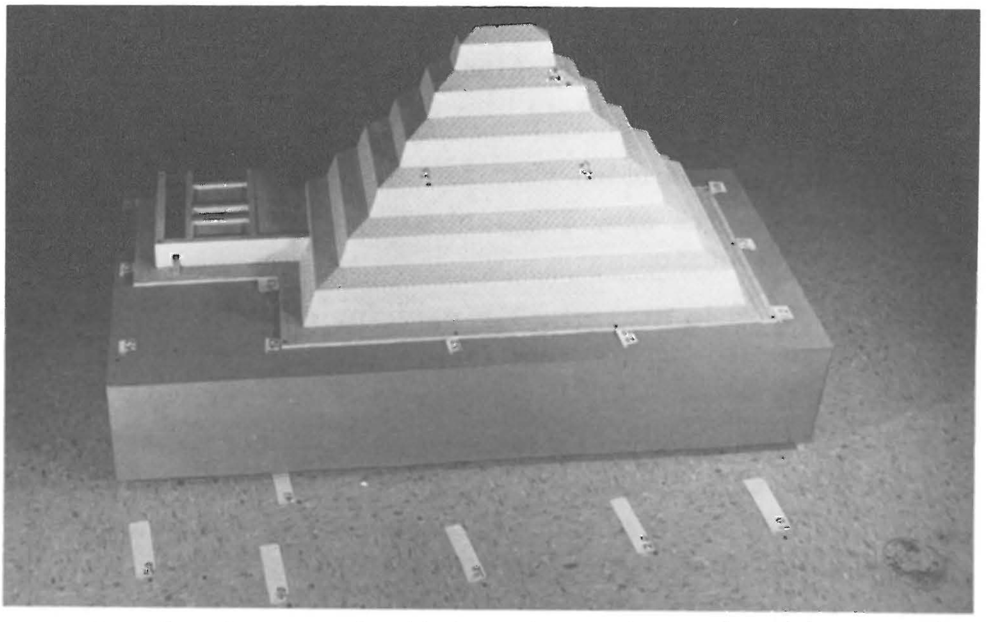

FIG 1- the test field incorporated on the object surface

3 - Measuring equipment

Since a three dimensional test field has been in purpose, two types ofmeasuring equipments are used:

3.1- for X and Y coordinates; the combination of instruments were as follow:

3.1.1 - acoordinatograph under which the object had been fixed (for easy handling and precise reading or punching the coordinatograph of a Wild A7 Plotter is used).

3.1.2 - a video-camera mounted on the coordinatograph as plotting device and a display for pointing control.

3.2 -for Z coordinate; a precision levelling of the test field is performed by using a cathetometer and a staff (a light bar , with a horizontal - fine line mark on it).

4 - Measuring requirements

The following conditions are required for measurements:

4.1- for X and Y coordinates; the following conditions should be satisfied by suitably precise spirit level and necessary adjustments:

4.1.1- horizontality of coordinatograph

4.1.2- verticality of video-camera optical axis

4.1.3- straightness of coordinatograph's rails

4.2- for Z coordinate; the verticality of the levelling staff should be checked by a spirit level.

5- Accuracy analysis

For a precise test field costruction ,the measurement error should be carefully studied and the accuracy requirements of the equipments be investigated:

5.1- the X (and Y) coordinate error; the most important origins of the error in these measurements are the followings:

5.1.1- parallax; the video-camera used for this experiment was not equiped with a reticle ,and a cross mark on the camera lens surface is used for pointing. Therefore the existance of the parallax error in the observations had been inevitable. This error ,however ,can be completely eliminated (a reticle may be considered by manufacturer)

5.1.2- video-camera collimation (non-verticality of camera optical axis); the verticality of the video-camera axis can be controlled by a spirit level, and for this purpose the video-camera may be precalibrated.

By video-camera calibration ,Cx and Cy,the angular components of camera collimation on XOZ and YOZ planes,may be limited to the precision of the used spirit level.

In a perfectly parallel translation of video-camera the effect of camera collimation on X (and Y) coordinate of point i will have two components:

5.1.2.1- costant component;

$$Ec = Dm.C$$

(C is used for Cx and Cy)

Ec has the same value for all of object points and its effect is nothing than an object translation movement.

5.1.2.2- variable component;

$$Ei = (Di - Dm)\ C = Hi\ C$$

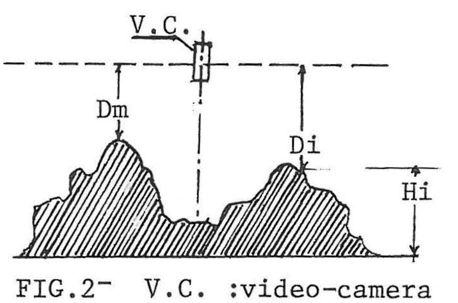

FIG.2- V.C. :video-camera
Di : V.C. to object point vertical distance
Dm:Di for object highest point
Hi:object point relative depth

Ei depends on the point's relative depth. As exemple with a precision of 12 seconds of v deo-camera's spirit level and maximum object relative depth of 50 cm, the maximum value of Ei will be about o.o3 milimeter

Due to lacking of a reticled and calibrated video-camera,in this experiment,a 0.05 mm for Ei had been inevitable.

5.1.3- Non adjustment of coordinatograph; this deviation also can be divided in two components:

5.1.3.1- general component,presented by non-horizontality of coordinatograph plane; since the video-camera axis verticality is independently controlled, the general component has no effect on Ei and the -

maximum variation of Ec also, even for 10 degree coordinatograph slope is insignificant.
The very most important error due to the general component is affected by coordinatograph scales' slope, which is about 0.005mm on X (or Y) coordinate for a coordinatograph X (or Y) scale slope of 10 minutes and will increase with the square of this angle (for small slopes).
As a result for horizontality control of the coordinatograph a circular spirit level will be satisfactory.

5.1.3.2- local component- this deviation is the result of non straightness of coordinatograph's rails. Causing the local deviations of video-camera optical axis, the effect of this local component will be a random error, for which the computation can be concluded from section 5.1.2

For elimination of local component error the coordinatograph rails must be checked and adjusted.
In this experiment the local deviation raised to ±10 seconds, causing an error of ±0.025mm in X (and Y) coordinate.

5.1.4- Pointing error; the targets may be of 1 or 2mm diameter, white circle in black. In absence of parallax the the error of pointing can be limited to ±0.01mm. In the experiment however, because of parallax the mean pointing error had been about ±0.05mm.

5.2-Levelling error; the most important error in object levelling are the followings:

5.2.1- non verticality of the staff; for 15 minutes of staff deviation - and 75cm maximum staff height, the maximum levelling error will be smaller than 0.01mm and a circular spirit level is then satisfactory for the staff verticality control.

5.2.2- other factors affecting the Z coordinate measurement is the shape of staff lower end point, and the surface slope at targetted points, which should be carefully taken in consideration.

6- Conclusion

The presented method seems to be very simple, rapid and can be applied for construction of a test field integrated on the object surface as an independent and permanent test field. It can be of a high precision and no additional computation is needed.

In exception of the cathetometer the rest of equipments are parts of photogrammetric workshop and the method will be considerably economical , specially when a number of special suitable works are waiting.

To get a high precision the following considerations are required:

- more care should be taken for X and Y coordinates measuring equipment, as the relative object depth increases,
- To obtain Z precision the control points should be choosen on the

smaller slope of the surface .

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