Dipl.-Ing.
Torsten Kludas
Jenoptik Carl Zeiss Jena GmbH
Application Photogrammetry

XIV. INTERNATIONAL CIPA SYMPOSIUM
2.-5. Oktober 1991
DELPHI , Greece

T E B I A S

- terrestrial single model evaluation with the analytical stereoplotter DICOMAT

1. The DICOMAT - System

Features

DICOMAT is a powerful analytical stereoplotter for all photogrammetric applications. The use of special transformation equations and an optimum distribution of intelligence between the measuring instrument and the operator computer ensure a maximum of flexibility and versatility.
This analytical plotter system consists of a mechanical measuring instrument with control panel, control electronics, operator computer including peripherals and the user software required for the individual applications.
Because of his universal real-time algorithm and a very high measuring accuracy (≤ ± 2 µm) the DICOMAT is able to work in a wide range of application fields.

Main applications

The DICOMAT - system works for plotting of metric photographs, detailed metric photographs, amateur photographs, visualized scanner scenes of any focus for data collection in the fields of aerophotogrammetry and terrestrial photogrammetry.
The plotting in non-planar systems of coordinates is a special property for working in architecture or industrial photogrammetry with the DICOMAT - system.
The especialy real-time algorithm - developed by **MARK** in 1987 - provides DICOMAT with universal characteristics so that the range of application can easily be expanded.

DICOMAT's real-time algorithm

In contrast to other well-known analytical plotting machines the collinearity equation of central perspective is not used in the DICOMAT, but the general image equation

$$x' = f_1(x,y,z) \qquad y' = f_2(x,y,z) \tag{1}$$

which is developed by the theorem of **TAYLOR**.
According to the theorem of Taylor each function being (r+1)-times continuously differentiable can be developed in the environment of a point $P_o(x_o,y_o,z_o)$ to:

$$\begin{vmatrix} x' \\ y' \end{vmatrix} = \begin{vmatrix} f_1(x_o,y_o,z_o) \\ f_2(x_o,y_o,z_o) \end{vmatrix} + \mathbf{F_x dx} + \tfrac{1}{2}\mathbf{dx^T F_{xx} dx} \tag{2}$$

$\mathbf{F_x}$ and $\mathbf{F_{xx}}$ are the matrices of the partial derivatives.

If the evaluation is not be made in the coordinate system (x,y,z), but in a coordinate system (x,y,z), for which the following relations holds true

$$\mathbf{x} = \begin{vmatrix} x \\ y \\ z \end{vmatrix} = \begin{vmatrix} u(\bar{x},\bar{y},\bar{z}) \\ v(\bar{x},\bar{y},\bar{z}) \\ w(\bar{x},\bar{y},\bar{z}) \end{vmatrix} \tag{3}$$

Taylors formula must be rewritten as follows:

$$x' = x_o' + \mathbf{F_{\bar{x}} d\bar{x}} + \tfrac{1}{2}\mathbf{dx^T F_{\bar{x}\bar{x}} d\bar{x}} \tag{4}$$

If systematic errors are still contained in the images, the final image coordinates must then calculated by

$$x_k' = g(x',y') \tag{5}$$

By application of Taylor's formula follows:

$$x_k' = x_{ko}' + \mathbf{G_{\bar{x}} d\bar{x}} + \tfrac{1}{2}\mathbf{dx^T G_{\bar{x}\bar{x}} d\bar{x}} \tag{6}$$

Now this formula can be used for the especial mathematical model of taking process as like the central perspective or the evaluation of scanner scenes.
The central perspective, for example, is discribed with the known collinearity equations

$$\begin{vmatrix} x' \\ y' \\ -c_k \end{vmatrix} = \frac{1}{\lambda} \mathbf{A^T} \begin{vmatrix} x - x_{o1} \\ y - y_{o1} \\ z - z_{o1} \end{vmatrix} \tag{7}$$

This equations will be treated by the theorem of Taylor in the way before, now Taylors formula must be rewritten as follows:

$$\begin{vmatrix} x' \\ y' \end{vmatrix} = \begin{vmatrix} x_o' \\ y_o' \end{vmatrix} + \begin{vmatrix} \alpha & 0 \\ 0 & \beta \end{vmatrix} \left[\begin{vmatrix} \mathbf{K_1} \\ \mathbf{K_2} \end{vmatrix} \mathbf{d\bar{x}} + \tfrac{1}{2}\mathbf{d\bar{x}^T} \begin{vmatrix} \mathbf{R_1} \\ \mathbf{R_2} \end{vmatrix} \mathbf{d\bar{x}} \right] \tag{8}$$

This is the DICOMAT's real-time formula with the matrices of the partial derivatives

$$\begin{aligned} \mathbf{K_1} &= \mathbf{G_{1x} \cdot F_{1x} U_{\bar{x}}} & \mathbf{R_1} &= \mathbf{G_{1x} \cdot F_{1x} U_{\bar{x}\bar{x}}} + \mathbf{G_{1x^{\cdot}x^{\cdot}}} \\ \mathbf{K_2} &= \mathbf{G_{2x} \cdot F_{2x} U_{\bar{x}}} & \mathbf{R_2} &= \mathbf{G_{2x} \cdot F_{2x} U_{\bar{x}\bar{x}}} + \mathbf{G_{2x^{\cdot}x^{\cdot}}} \end{aligned} \tag{9}$$

$$\mathbf{d\bar{x}} = \begin{vmatrix} d\bar{x} \\ d\bar{y} \\ d\bar{z} \end{vmatrix} ,$$

$$\alpha,\beta = f(\mathbf{A},\ \mathbf{U_{\bar{x}}},\ x,\ y,\ z)\ . \tag{10}$$

The DICOMAT works in the following way:

The object space is subdivided into spatial segments.
The elements $d\bar{x}, d\bar{y}, d\bar{z}$ are given by the operator over the input elements (handwheels, footdisk) in the real-time formula. All the other elements (xo', yo', $\mathbf{K_1}$, $\mathbf{K_2}$, $\mathbf{R_1}$, $\mathbf{R_2}$, α, β) are computed by the host computer with special transformation subroutines. This elements are computed and stored for each segment. The transition from one segment to a neighbouring segment is always associated with a change of the entire parameter set.

The total transformation is split into three catenated partial transformations

$$\begin{aligned} \mathbf{x} &= U(\bar{\mathbf{x}}) \\ \mathbf{x}' &= F(\mathbf{x}) \\ \mathbf{x_k}' &= G(\mathbf{x}') \end{aligned} \tag{11}$$

We call this the U-, F-, and G-Transformation.

U-Transformation: to transform into another object coordinate system, like
- earth curvature, refraction
- cylinder or spherical coordinate systems
- special map projections
- multimedia photogrammetry

F-Transformation: to restore the mathematical model of the photographic process, like
- central perspective
- scanners

G-Transformation: to correct systematic device and image errors, like
- film deformations
- distortion
- instrument errors

2. The TEBIAS - Software

Description of TEBIAS

TEBIAS is one of the program packages for data acquisition in the DICOMAT - application software.
The program is used for terrestrial single- and double-image elevation to restitute survey photographs and photographs of unknown interior orientation.
The TEBIAS program package is structured as follows:

Data management

MANCA
Management of terrestrial **ca**mera data
to serve the build-up and management of terrestrial survey and photographic camera parameters.

MANPD
Management of terrestrial **p**roject **d**ata
serves the build-up and management of projects to be processed with the possibility to restitude both single and double images as well as to employ different cameras.

MANOP
Management of **op**erator data
to define the personal operator data in working with the DICOMAT input elements (handwheels, footdisk) for direction, rotation and transmission.

MANGEO
Management of **geo**detic data
to form files for every project containing data of geodetic observations made in an object space, like for
- geodetic (control) points
- projection centres
- distances, coordinate differences, directions
- base components

Orientation

STATUS
to define the status of the actual model with parameters like project name, camera number or overlap area for examples.

INNOR
to establish the functional relation of interior orientation and instrument coordinates by measuring fiducial marks or margical points of picture gates, respectivly.

EXOR
to serve the selection of problem-specific programs for the exterior orientation:

LINTRA
permits photos taken by photographic cameras to be restitude the interior orientation of which is not known, or approximately known (11-parameter-**lin**ear **tra**nsformation).

RESEC
is based on the functional model of spatial **resec**tion the use of which requires knowledge of interior orientation data.

RELOR
is used to ascertain the **relative orientation** elements of a stereopair of known interior orientation after bridging.
There are two algorithms possible to select:
(1) Independent photo pairs (algorithm by **HINSKEN**)
(2) Conjunction of successive photographs (algorithm by **SCHUT**)

ABSOR
serves the ascertainment of the **absolute orientation** elements of a stereopair after relative orientation.
There are two methods foreseeing:
(1) Absolute orientation by the help of the geometry of planar objects (house fronts for example)
Minimum: one distance made for geodetic observations
(2) Spatial similarity transformation with control points
Minimum: three control points for geodetic observations

BUNDLE
to improve the results from the absolute orientation by the help of additional observations in a bundle adjustment

REGEN
to **regenerate** the stereomodel with all known orientation parameters by computation of the transformation parameters. By the help of this program it´s possible to use the universal algorithm of the DICOMAT with all advantages to transform into other planar or non-planar coordinate systems, as like
- cylindrical coordinate systems
- spherical coordinate systems
- planar coordinate systems of an house front
- underwater coordinate systems

Calibration

The calibration process for determination of the camera´s (survey or photographic camera) interior orientation data based on the functional model of the bundle method.
The **CALIBR** programm (**Calibration** of cameras) is used to identify the geodetic observations made and to calculate the approximate values of the unknown quantities to be determined. Included in this operation is the reduction of the directions measured in the object space to the camera projection centre.