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 especially 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

\[ x' = f_1(x,y,z) \quad y' = f_2(x,y,z) \]  \hspace{1cm} (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 \(P_0(x_0,y_0,z_0)\) to:

\[
\begin{vmatrix}
  x' \\
y'
\end{vmatrix} = \begin{vmatrix}
  f_1(x_0,y_0,z_0) \\
f_2(x_0,y_0,z_0)
\end{vmatrix} + F_{x} dx + \frac{1}{2} F_{xx} dx^2 \]  \hspace{1cm} (2)

\(F_{x}\) and \(F_{xx}\) 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

\[
\begin{vmatrix}
  x \\
y \\
z
\end{vmatrix} = \begin{vmatrix}
  u(x',y',z') \\
v(x',y',z') \\
w(x',y',z')
\end{vmatrix} \]  \hspace{1cm} (3)

Taylor’s formula must be rewritten as follows:

\[
x' = x_0 + F_{x} dx + \frac{1}{2} F_{xx} dx^2 \]  \hspace{1cm} (4)

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

\[
x_k' = g(x',y') \]  \hspace{1cm} (5)

By application of Taylor’s formula follows:

\[
x_k' = x_{k0} + G_{x} dx + \frac{1}{2} G_{xx} dx^2 \]  \hspace{1cm} (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 described with the known collinearity equations

\[
\begin{vmatrix}
  x' \\
y' \\
z'
\end{vmatrix} = \begin{vmatrix}
  1 & 0 & 0 \\
  x - x_0 \\
z - z_0
\end{vmatrix} \]  \hspace{1cm} (7)

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

\[
\begin{vmatrix}
  x' \\
y'
\end{vmatrix} = \begin{vmatrix}
  x' \\
y'
\end{vmatrix} + \begin{vmatrix}
  0 & 0 & 0 \\
  K_1 & 0 & 0 \\
  K_2 & R_1 & R_2
\end{vmatrix} dx + \frac{1}{2} \begin{vmatrix}
  0 & 0 & 0 \\
  K_1 & 0 & 0 \\
  K_2 & R_1 & R_2
\end{vmatrix} dx^2 \]  \hspace{1cm} (8)

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

\[
K_1 = G_{1x}-F_{1x}J_u \quad R_1 = G_{1x}-F_{1x}J_u + G_{1x}-x^- \]

\[
K_2 = G_{2x}-F_{2x}J_u \quad R_2 = G_{2x}-F_{2x}J_u + G_{2x}-x^- \]  \hspace{1cm} (9)
\[ \frac{dx}{dx} = \begin{bmatrix} dx \\ dy \\ dz \end{bmatrix}, \]
\[ \alpha, \beta = f(A, Ux, x, y, z). \] (10)

The DICOMAT works in the following way:

The object space is subdivided into spatial segments. The elements \( dx, dy, dz \) are given by the operator over the input elements (handwheels, footdisk) in the real-time formula. All the other elements \( (x_0', y_0', K_1, K_2, R_1, R_2, \alpha, \beta) \) 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
\[ x = U(x) \]
\[ x' = F(x) \]
\[ x'' = G(x') \] (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 ele­
vation to restitute survey photographs and photographs of unknown
interior orientation.

The TEBIAS program package is structured as follows:

Data management

MANCA
Management of terrestrial camera data

to serve the build-up and management of terrestrial survey and
photographic camera parameters.

MANPD
Management of terrestrial project data

serves the build-up and management of projects to be processed
with the possibility to restitute both single and double images
as well as to employ different cameras.

MANOP
Management of operator data

to define the personal operator data in working with the DICOMAT
input elements (handwheels, footdisk) for direction, rotation and
transmission.

MANGKO
Management of geodetic data

to form files for every project containing data of geodetic ob­
servations 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 marginal
points of picture gates, respectively.

EXOR

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

LINTRA
permits photos taken by photographic cameras to be restitute
the interior orientation of which is not known, or
approximately known (11-parameter-linear transformation).

RESSEC

is based on the functional model of spatial resection 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 HINSKJN)
2. Conjunction of successive photographs (algorithm by SCHU)

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

REGROW 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 program (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.