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Map Revision and Computer-Assisted Interpretation with the KARTOFLEX from JENA

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ABSTRACT

Paper print photographs and diapositives such as aerial photographs, orthophotos, visualized scanner images, or maps can be superimposed by a map in the KARTOPLEX from JENA and viewed through a highly efficient optical system. Various combinations of the three input channels are possible. In the simplest case of application a free-hand transfer of image elements into the map is made after scale adjustment.

An extended version of the KARTOPLEX with digitizer in the map plane and built-in microcomputer serves for computer-assisted interpretation (count function, calculation of line lengths and areas.)

Additionally, accuracy is considerably increased via feedback to the optical system through polynomial transformation.

INTRODUCTION

Utilization of the earth's resources by the growing world population increasingly changes the surface of our planet. Recording of these changes is absolutely necessary for future-oriented planning and supervision. Relevant information is now gained with sensor systems using air or space vehicles as carrier platforms. Image material of highly different quality is produced by visualized scanner recordings or by taking photographs with cameras. The superposition of these pictures with existing maps is a basic principle of visual interpretation for transferring changes very quickly into the map (map revision) or creating thematic maps (image interpretation).

VIEWING SYSTEM

For these tasks the floor-based KARTOPLEX machine (Fig. 1) was developed in Jena, which allows the viewing of images and maps with efficient optical systems. An optical switching facility offers many variants of observation and superimposition. The map is positioned directly before the operator on a table designed for transmitted light and incident light. Via a zoom system with a magnification range of 0.8 ... 4x the map is projected into the eyepieces. The almost vertical photo carriages accommodate image formats of up to 30 x 30 cm² (12" x 12"). They can be moved in x', y' and px' by freelace motion or by fine drives. Slow-motion drives are also available for py', x', and y'. They allow the optimum fitting of image details to map points and the mutual orientation of the images for stereoscopic viewing and the superposition of several channels. Photos are observed with zoom systems operating in the magnification range of 2.4 ... 12x, so that scale adjustments between image and map are possible in the range from 0.6 to 15X. For colour mixture bandpass filters can be attached to all lenses. The controllable image illumination allows of being used for both incident light and transmitted light.
Apart from the points, lines and areas are essential elements of a map. Therefore, the microcomputer contains programs, which fulfil the functions of a curvimeter and planimeter, with the acquisition of the coordinates by single point recording (straight-line elements) or also in prespecified time intervals (curviform elements) being possible (Fig. 4). After input of the map scale the calculated line lengths or areas are for simple entries into the map indicated on a display line and output via a serial interface. The digitizing system is fitted with holders for scribing tool or pencil and with various measuring marks. The measuring marks or the scriber points, respectively, are projected into the images, so that also new points, lines or areas can be measured.

Accuracy investigations with grid copies under synthetic image conditions have shown that in dependence on the viewing magnification the mean coordinate in the map (magnification 0.8 ... 4x) is less than \( \pm 0.16 \) mm ... \( \pm 0.06 \) mm (\( \pm 0.05 \) ... \( \pm 0.02 \) mm in the image plane). The resulting mean distance errors lie between \( \pm 0.22 \) ... \( \pm 0.09 \) mm at the scale of the map.

The accuracy of areal determination can likewise be stated, when the reference area is square, i.e., when the sides are entered into calculation with the same weight. Fig. 5 shows the achievable relative accuracy in the areal determination in dependence on the size of the squares and the viewing magnification.

The input of the scale factor allows an increase in accuracy under consideration of paper shrinkage and the indication in m (or feet) or ha (or acres).

This computer-assisted interpretation is for numerous applications (cadastre, forestry, mapping of land use, etc.) of particular importance due to the achievable high accuracy.

POLYNOMIAL TRANSFORMATION

The accuracy of the measurement of new points is additionally increased by the feedback between microcomputer and optical system. In the extended version the front lens of the map zooming system can be displaced in a plane parallel to the map plane in each coordinate direction by \( \pm 10 \) mm. In this way, the mirrored map is shifted relative to the images. Shifting is performed automatically by small stepping motors, which are controlled by a correction program. The correction program is based on a polynomial transformation. The degree of the correction polynomial depends on the number of the control points identified and measured in image and map in the visual field.
Of the great number of positions of the optical switching facility the following cases are particularly important for application:

- Stereoscopic observation of the images with imagery of a map by projecting it into an eyepiece.
- Binocular observation of an image with the superimposed image of both eyepieces.
- Binocular observation of the two images with attached bandpass filters and imagery of the map by projecting it into both eyepieces.

For improving the image interpretation the projected map image can be masked out. Interpretation results are entered into the map with a pencil or a scribbling tool; a prerequisite however is that after scale adjustment by means of the zoom system the map is shifted so as to achieve an optimum agreement between image and map. The two zoom systems for image observation are coupled by a slipping clutch, so that the observation magnification for both images can be changed jointly or also separately.

Both, the LMK Aerial Camera System (9" film) as well as the MRF 6 and MGR 4 Multispectral Cameras (70 mm film) from Jena are provided with forward motion compensation (FMC), by which a particularly high resolution is achieved. For photographs taken with the MRF 6 under space conditions with stable orbit parameters and magnification of the small-format images (55 x 81 mm²) will prove to be expedient. With magnifications of 2.4 and 4.6 times the PPA Automatic Enlarger produces image formats of 13 x 19 cm² and 25 x 37 cm², which are especially favourable for the application in the KARTOPEX.

For example, at a flying altitude of 250 km sets of multispectral photographs of 6 channels are obtained at the scale of 1 : 2 000 000, which after PPA premagnification can be superimposed in the KARTOPEX with maps of the scales 1 : 100 000 and 1 : 50 000.

POINTS, LINES, AREAS

The KARTOPEX is produced in the simple form described above and in an extended version. The latter includes a digitizing system in the map plane (Fig. 2) with a measuring area of 30 x 30 cm² and a resolution of the linear encoders of 0.03 mm. The digitizer is connected via a counter with the input of a built-in microcomputer (Fig. 3). Map coordinates are collected either point by point via a recording button or a foot switch or automatically in selectable time intervals. Via an operating keyboard a 6-digit point number can be entered, which with each recording is increased by one increment. If this point number starts with the figures 99, the manual input of coordinates of the map grid or of other control points is additionally provided.
3, 4 or 5 control points can be selected in a configuration which according to Fig. 6 is required to be as favourable as possible. After the measurement of the points with the digitizer the parameters of the correction polynomial in the orientation program are calculated and the stepping motors adjust the front lens of the map zooming system in such a way that in all control points the map is brought to coincidence with the image.

In the region between the control points a significant increase in accuracy is achieved. The application of this orientation program does not require any photogrammetric basic knowledge. Even for images without central perspective (visualized scanner images) it yields very good results.

The PROM-stored program library of the built-in microcomputer is in addition completed by special test programs.

**Figures**

**Fig. 1** KARTOFLLEX (extended version)

**Fig. 2** Digitizer and optical transformation system

**Fig. 3** Schematic diagram of KARTOFLLEX (extended version)

**Fig. 4** Operating modes of KARTOFLLEX (extended version)

**Fig. 5** Relative accuracy of areal determination with the digitizing system of the KARTOFLLEX

**Fig. 6** Control point configuration in the field of view and transformation formula
Fig. 3: Schematic diagram of KARTOFLEX (extended version)
<table>
<thead>
<tr>
<th>MODE</th>
<th>Point by Point</th>
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<th>Output</th>
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**Fig. 4: Operating modes of KARTOFLEX (extended version)**

**Fig. 5: Relative accuracy of areal determination with the digitizing system of the KARTOFLEX**
Fig. 6: Control point configuration in the field of view and transformation formula

\[ x = a_0 + a_1 x + a_2 y + a_3 xy + a_4 y^2 \]
\[ y = b_0 + b_1 x + b_2 y + b_3 xy + b_4 x^2 \]