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Photomaps from Non-Conventional Imagery

Infrared and radar imagery were rectified using the Gestalt Photomapper.

ABSTRACT: *Several applications require the maintenance of the wealth of information present in different types of imagery, e.g., radar, infrared, side-scan sonar. The imagery must first, however, be rectified in order to eliminate distortions introduced by the geometric characteristics of the sensor and changes in its exterior orientation. Rectification of such imagery was carried out successfully by using the Gestalt Photomapper. Rectification of infrared and radar imagery are described here as examples. The method can be used with other types of imagery such as side-scan sonar and ERTS imagery.*

INTRODUCTION

A SUBSTANTIAL AMOUNT of the imagery used in remote sensing is produced by unconventional sensors such as line scanners, radar systems, side-scan sonars. The geometric fidelity of these images is reduced by distortions introduced by the imaging system and by changes in its attitude and position. Under these circumstances, quantitative information, such as the shape, size, relative position and orientation of objects, cannot be determined very reliably. Furthermore, difficulties arise when data of the same scene obtained by various kinds of sensors must be correlated and brought to a common map base.

Three main steps are involved to eliminate or reduce these distortions:

- The distortions are expressed mathematically in terms of image coordinates or object coordinates. In defining such expressions, control information and/or information about the attitude and position of the sensor are used. Polynomial transformation, least squares interpolation techniques, or the application of the collinearity condition are suggested for modelling the distortions when geodetic control is available.
- The parameters of the correction function are determined.
- The corrections are applied to the imagery in one of three possible ways:

(a) Point-by-point application, which is a fully analytical approach.
(b) In a continuous mode, while producing a graphical plot of the imagery.
(c) Rectification of the imagery and the production of photomap.

Clearly, the last approach is the most satisfactory, because it preserves the pictorial presentation and the original information content of the imagery. There are a few, one-of-a-kind instruments available to perform such a task, such as the USAETL Orthographic Radar Restitutor of the NASA Data Processing Facility (NDPF) designed to restitute the ERTS imagery[1]. However, all are very expensive and generally inaccessible to the majority of the remote sensing community.

Therefore, a method was developed at the University of New Brunswick for the rectification of these imageries on instruments available and used for the production of conventional orthophotos. The method was first tested on the OP/C orthoprinter of the Analytical Plotter AP/C. The results were presented by Masry and Gibbons[2]. The orthophotoprinter used showed some limitations in the case of rectification of imagery; one of these was the need for a variable magnification within the area of the slit.

The limitations are overcome with the Gestalt Photomapper, an instrument used in the production of orthophotos and contours from aerial photographs. As we shall see, the instrument is quite suitable for the rectification of other types of imagery. The aim of developing methods for the rectification of imagery by using instrumentation designed and built for the production of orthophotos, rather than developing a specially designed instrument, is obviously economical.

The Gestalt Photomapper

To introduce the method of rectification, a brief description of the instrument is in order. Figure 1 shows a block diagram of the different components of the instrument. Some of the components, such as the correlator, are used only in the production of orthophotos. The functions of the components are described here with the rectification of imagery in mind.

The imagery strip to be rectified is placed on either one of the input stage carriages. Each carriage can move in two directions under computer control. The scanning raster is formed by a cathode ray tube situated below each carriage and focused onto the plane of the image by an optical system. The

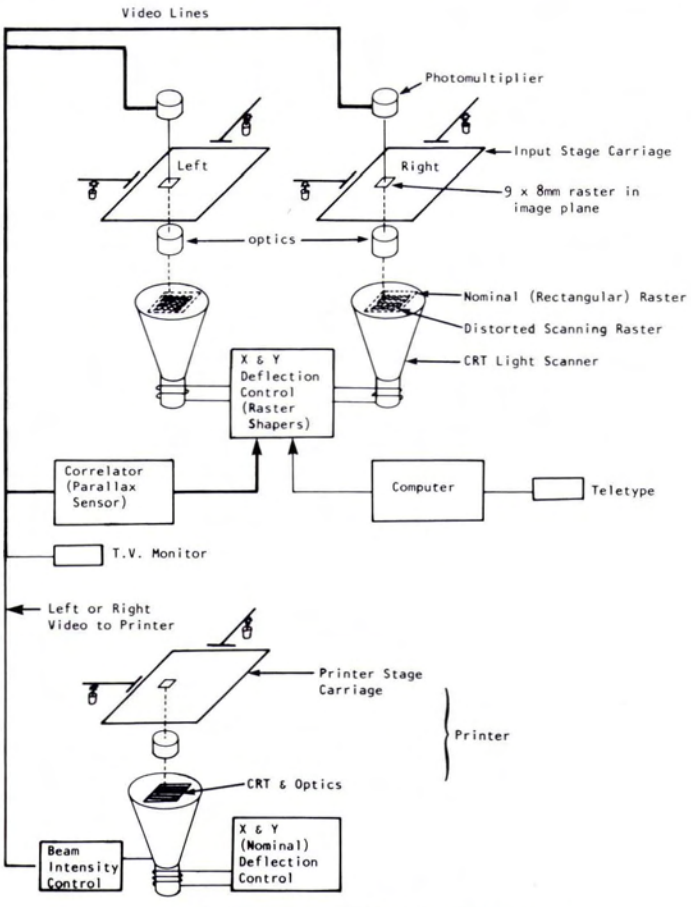

FIG. 1. Block diagram of Gestalt Photomapper.

shape and size of this raster is computer controlled to scan an area of approximately 9 mm-by-8 mm of the image at a time. The intensity of the light which passes through the image is sensed by a photomultiplier and the signal thus generated is used to control the intensity of the beam of the CRT used for the printing process. The X- and Y-deflections of this CRT is such that the "distorted" area of the imagery scanned is displayed without distortion to fill up an area of exactly 9 mm-by-8 mm. An optical system is then used to project an image of the CRT onto the plane of a photographic film. The film rests on a stage carriage which can move in two directions, also under computer control. A hexagonally shaped mask causes the area printed to be of the same shape.

Method of Rectification

The imagery strip to be rectified is placed on one of the stage carriages. The coordinates of registration marks, if any, and of the image points for which ground coordinates are available are measured and the coefficients of the correction function selected are computed in the control computer of the instrument. Information about the exterior orientation of the sensor can also be taken into consideration by expressing the effect of these on the geometry of the image as a function of the measured image coordinates that are then used to define a correction function. The rectification process then begins. The instrument operates in a patch-by-patch mode. That is, the stage carriages are stationary during the scanning and printing of each 9 mm-by-8 mm area. The correction function is utilized in forming the scanning raster within each area as explained below. The stage carriages proceed to the next area of the imagery. The movement of the carriages is in Y-direction with an incremental step over in X-direction when the Y-limit is reached, as shown in Figure 2. Rectification proceeds until the whole strip is corrected.

The dimensions of the strip to be rectified are limited only by the range of travel on the stage carriages. In the present model, these are about 23 cm in each direction, a distance suitable for dealing with aerial photographs. Once the measurements of image coordinates are carried out, the rectification is completely automatic. It takes about five minutes to print a rectified strip of 10 cm-by-23 cm.

Application of the correction function to the scanning raster is carried out as follows: Suppose that F_1 and F_2 are the correction functions which give the measured image coordinates as a function of the corrected image coordinates. Expressed mathematically,

$$x = F_1(X, Y)$$

and

$$y = F_2(X, Y),$$

where x, y are measured image coordinates and X, Y are the corrected image coordinates.

The Taylor's expansion of these functions about X_o, Y_o has the form

$$x = F_1(X_o, Y_o) + \left(\frac{\partial F_1}{\partial X}\right)_o \Delta X + \left(\frac{\partial F_1}{\partial Y}\right)_o \Delta Y + \text{higher order terms}$$

and

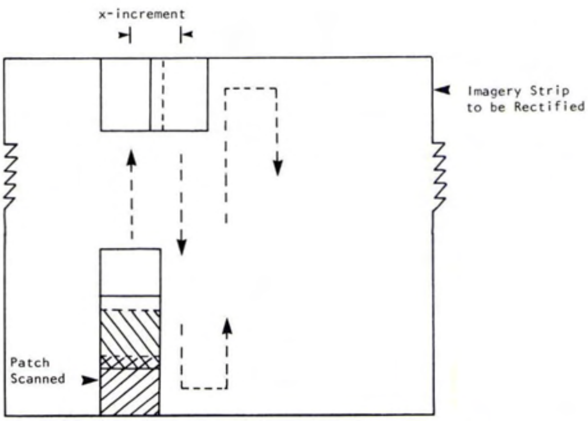

Fig. 2. Movement of the stage carriages is in Y-direction with an increment in X-direction at the limits of Y-motion.

$$y = F_2(X_o, Y_o) + \left(\frac{\partial F_2}{\partial X}\right)_o \Delta X + \left(\frac{\partial F_2}{\partial Y}\right)_o \Delta Y + \text{higher order terms}$$

where X_o, Y_o give the center of the patch. If ΔX, ΔY are sufficiently small, the higher order terms can be neglected and the first derivatives are utilized in shaping the scanning raster as follows:

$\left(\frac{\partial F_1}{\partial X}\right)_o$ gives the x-scale

$\left(\frac{\partial F_1}{\partial Y}\right)_o$ gives the x-skew

$\left(\frac{\partial F_2}{\partial Y}\right)_o$ gives the y-scale

$\left(\frac{\partial F_2}{\partial Y}\right)_o$ gives the y-skew

The size and shape of the input scanning raster is altered according to the first derivatives above. In other words, the area of imagery scanned may be different from 9 mm-by-8 mm. The scanned area is "painted" onto a fixed area of the printing CRT.

Testing of the Method

The method was tested by using infrared line scanner and side-looking radar imagery. Figures 3 and 4 show a sample of the infrared imagery before and after rectification. The patch pattern was deliberately emphasized in the rectified imagery in order to demonstrate its shape. The rectified imagery shows obvious decrease in the quasi-panoramic distortion described by Masry and Gibbons[2]. (Compare, for example, detail A before and after rectification.) The elimination of this distortion was the principal aim of the rectification and therefore the functions F_1 and F_2 assumed in the rectification were of the form

Fig. 3. Sample infrared imagery rectified. Notice the elimination of the distortion in detail A.

Fig. 4. Rectified sample infrared imagery. Patch pattern was deliberately emphasized. (See Figure 3.)

$$x = X$$
$$y = Y - \frac{Y^3}{3f^2} + \frac{Y^5}{5f^5} - \frac{Y^7}{7f^6}$$

where f is a constant dependent on the internal geometry of the scanner.

Rectification of radar imagery was carried out using polynomial correct functions of the form

$$x = B_1 + B_2X + B_3Y + B_4XY + B_5X^2 + B_6Y^2 + B_7X^2Y + B_8Y^2X + B_{10}Y^3$$

and

$$y = C_1 + C_2X + C_3Y + C_4XY + C_5X^2 + C_6Y^2 + C_7Y^3 + C_8Y^5 + C_9Y^7.$$

The coefficients of the polynomials were evaluated by using ground control points as described by Derenyi[3]. There was negligible reduction in the resolution of the rectified imagery when compared with the input imagery.

Work is now progressing to rectify other types of imagery and photography such as side-scan sonar, ERTS imagery, etc.

Conclusions

By using the Gestalt Photomapper, an instrument used commercially in the production of orthophotos, a method for the rectification of infrared and radar imagery was developed and successfully tested. In general, the method is suitable for the rectification of any type of imagery where distortion can be expressed mathematically as a continuous function and eliminates the need for specially designed instruments.

Acknowledgment

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