ORTHOIMAGE GENERATION IN A GIS ENVIRONMENT

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ABSTRACT

An orthoimage is the most practical format for utilizing digital images for map revision and resource mapping. Accordingly, orthoimage generation has been implemented in a geographic information system. This module includes the ground control point selection, image transformation, and mosaicking procedures. Both the functional design and the algorithm selection issues are discussed. The utilization of digital orthoimages for map revision is illustrated on an example.

KEY WORDS: Orthoimage, Rectification, Mosaicking, Map revision, Document scanners, GIS.

1. INTRODUCTION

With the advent of digital, soft copy, photogrammetry, interest in orthoimages is rapidly increasing. An orthoimage is a very versatile product. It can serve as a general purpose digital base map, like its hard-copy predecessor, the orthophoto map. A companion or backdrop to a digital line map and a base for resource inventories are other useful applications. In fact, the inventory information itself can be derived directly from an orthoimage by visual interpretation or digital image analysis. Map revision is another potential use.

Digital orthoimage formation is based on the same theory of differential rectification as its hard-copy counterpart. There are, however, variations in the production environment. There are several high precision, dedicated hardware/software installations in existence. Systems such as PRI2SM from International Imaging Systems (Boniface, 1992), the image station module MGE from Integraph and the USGS system described in Skalet, et al. (1992), clearly belong to this category. Software packages, which utilize general purpose computers for orthoimage production, are also available. ORTHOMAP from Galileo Siscan and the ERDAS Digital Orthomodule are notable examples. Each production environment has its pros and cons.

The dedicated, stand-alone systems employ high resolution precision scanners for analogue to digital conversion and generate high quality products which meet class "A" map accuracy standards. The generation of digital elevation models by digital image correction may also be part of the process. Needless to say that such installations are expensive and only affordable by large organizations. Markets for such high precision products are presently limited. There is, however, a demand for less expensive, medium precision digital orthoimages in the resource mapping field.

One alternative for satisfying this need is to use a geographic information systems (GIS) workstation for the production and storage of digital orthoimages. GISs are becoming the norm for storing resource inventories and digital base mapsand a multi-function GIS would serve the needs of small and medium size organizations well. The Computer Aided Resource Information System with Raster Image Extension (CARI/RIX) is such a facility.

CARIS is a GIS marketed by Universal Systems Ltd. of Fredericton, N.B., Canada, while RIX was developed at the University of New Brunswick [Derenyi, 1991]. RIX supports the superimposition of vector data on a raster image backdrop, on-screen digitization, image classification, analytical photogrammetric operations and a variety of image processing and geometric registration tasks in interactive and batch mode.

2. THE PRODUCTION PROCESS

The discussion of orthoimage production in CARIS/RIX is limited to the use of aerial photographs, although the capability exists for handling satellite data as well. The main steps of the process are:
- analogue to digital conversion of the photograph in a scanner digitizer,
- ground control point (GCP) acquisition,
- interior and exterior orientation of the photographs,
- differential rectification and resampling and
- mosaicking.

2.1 The Scanning Process

The objective was to devise a low cost scheme which suits the needs of resource mapping and map revision. Therefore, a desk-top document scanner was chosen for the digitization. In recent years, significant improvements were made by manufacturers in the performance of these scanners. Although these low cost models are primarily intended for desk-top publishing, Drummond and Rosma (1989) proved their potential for cartographic applications. Document scanners typically have a 300 to 400 dots per inch (0.085 to 0.061 mm) geometric resolution, eight bits per pixel (256 gray levels) radiometric resolution and a scanning surface of 8.5 by 14 inches (216 by 355 mm). Unfortunately this surface is slightly narrower than the 230 mm standard size of aerial photographs and one of the fiducial marks and a narrow strip of the photo may be lost in the digitization. Scanners with 11 by 17 inches (279 by 432 mm) digitizing surface are, however, readily available at somewhat higher cost.

Data output from most scanners is in TIFF format while the Integrated Pixel Value (IPV) format is used for raster image files in CARIS. The program REFOTIFF (REFOrmating from and to TIFF) handles this incompatibility.

2.2 GCP Selection

Depending on the circumstances, the exterior orientation elements of photographs can be obtained from a previous block adjustment or provided by an onboard inertial navigation sensor. These data are then stored in a sensor parameter file for direct access by the differential rectification program. If this is not the case, then GCPs are needed to compute the sensor parameters. The PICKGCPs module serves the GCP acquisition.

When well-defined points or targets with known ground coordinates appear in the image, the coordinates can be measured using the on-screen digitizing routine of CARIS. These values are then stored in a coordinate file with the corresponding ground coordinates. In the absence of known ground coordinates, the operator can manually select GCP locations in a digital map and the corresponding image which are simultaneously displayed in separate windows.

The operator can check the residual error of the GCPs by performing a projective or polynomial transformation of specified degree and reject those which are unacceptable. A global index based on "t" distribution is provided for gross-error detection. It has been realized that inexperienced users often encounter problems in the subsequent exterior orientation computation caused by insufficient number or distribution of the GCPs. In order to provide users with information on the geometric strength of the control configuration, the I-1 norm condition number of the system inversion is provided. This can then be checked against a predefined tolerance of the condition number.

2.3 Exterior Orientation

For frame camera photographs the space resection program CALCAMP (CALCulate CAMera Parameters), based on the collinearity equations, are used to calculate the exterior orientation parameters. A residual error analysis is also included in the space resection module. Both the condition number and the global index for gross-error detection are provided. Usually the evaluation of the result of a space resection with check points is performed in image space. That is, the known object space coordinates of the check points are transformed into image space, and compared with the measured image space coordinates. It has been found that the reverse is also desirable, because a comparison in terms of object space coordinates is more meaningful for the user. This reprojection must of course incorporate the known elevation of individual check points. The CHCKPHOT (CHeCK PHOTographic sensor parameters) module is designed for the evaluation of space resection.

2.4 Differential Rectification

The formation of the orthoimage essentially means a pixel-by-pixel reprojection from image onto plane area elements set at the terrain elevation of each particular pixel. The radiometric or gray-scale value of each new pixel is then determined.

There are two approaches to construct the transformed image. One is the output-oriented or indirect approach, and the other input-oriented or direct approach. In the indirect method, the object coordinates of each output pixel are defined first, then transformed into the original image coordinate (input) system by the collinearity equations. A resampling is then performed to obtain the grayscale value from the original image at these image coordinate locations.

The second method works in the opposite way, in two stages. In the first stage, for each pixel in the original image, the corresponding coordinates in the output image coordinate system are computed and the grayscale value is carried with this new pair of coordinates. In the second

stage, an interpolation is performed to get the grayscale value for each pixel in the output image. This is called the direct method, because the grayscale value of the original image pixels is directly transformed. In CARIS/RIX the output-oriented or indirect approach is employed.

The computation requirement can be reduced by adopting an anchor point scheme. This means that not all pixels in the original image are transformed, but only the selected anchor points (Mueller and Sauleda, 1988; Mayr and Heopke, 1988). This scheme also assumes that each cell formed by anchor points consists of a surface which can be modeled in the interpolation procedure.

Another computation saving scheme is to reduce the number of multiplications in the transformation procedure. Due to the incremental nature of the raster image structure, a significant portion of multiplication in the transformation process can be substituted with a simple addition.

2.5 Mosaicking

Two or more individual orthoimages can be assembled, to form a single continuous coverage of an area, by a program called JOINIMAGE. It is based on the algorithm published by Hummer-Miller (1989). This scheme has the advantage that images can be joined along any seam line, including a convoluted one, as long as the line does not intersect itself. The seam line is specified by operator selected points on the screen. Seam points can also be specified in the map coordinate system. The user also has to declare which of the two images are retrieved in the overlap area. It is assumed that the two images to be joined are in the same coordinate system. The image is processed line-by-line, thus the memory requirement is low and large images can easily be handled.

3. EXPERIMENT

The digital orthoimage formation scheme in CARIS/RIX was tested in a map revision experiment. The test material included a 1: 50 000 scale digital map sheet of the Canadian National Topographic System (NTS) series and a 1: 10 000 scale digital map sheet of the New Brunswick Geographical Information Corporation (NBGIC). To facilitate the evaluation of the results, various features were deleted in a copy of each map file to stimulate an out-of-date map. These features were then re-established from the same black and white aerial photographs used for the original map compilation. The photo scale was 1: 40 000 and 1: 35 000 respectively.

The digital images were obtained by scanning the paper prints in a Hewlett-Packard ScanJet Plus document scanner at 300 dots per inch (118 dots per cm) which resulted in a 85 µm pixel size at image scale. The corresponding pixel size on the ground was 3.4 m and 3.0 m in the two photographs respectively. The radiometric values were recorded in 256 gray level. Road intersections and other well-defined features were selected in the screen display of the digital maps as control for the space resection.

Both maps cover the City of Fredericton and vicinity. The downtown area, which spreads along the shore of the St. John River, is essentially flat ground at an elevation near sea level. There from the terrain has a steady incline and reaches an elevation of 130 m at the city limit.

Change detection was performed visually on the screen in a merged map and image display. The new features were then traced in the image by freehand cursor control and digitized. The features mapped included: highways, major thorough-fares, residential streets, river shoreline, power transmission

line, racetrack, highway bridge, buildings and edge of forest. All features were digitized in point mode. Roads were digitized along the centre line.

The newly digitized features were then combined with the original map and the position of the features in the original map were used as the reference to ascertain the accuracy of the revision process. Point features were tested by forming the coordinate differences. Line features were subdivided into sections at well defined breakpoints. Thereafter, X, Y coordinates were generated at equal intervals along the original and newly digitized path of the features. The deviations at corresponding point pairs were then computed.

A total of 977 points of well defined features were tested in the 1: 50 000 scale map. The root mean square error (RMSE) of the position of the newly digitized features was 1.5 m. At none of the points did the difference exceed 25 m, which was the limit set by the map accuracy standards at the 90% confidence level. The REMSE of the 1369 feature points tested in the 1:10 000 orthoimage was 0.8 m and only 3% of the points exceeded the 5 m limit set for the 90% error.

The above results are most satisfactory. The map accuracy standards are satisfied and the RMSE of digitization in both orthoimages has a subpixel accuracy. At the scale of the aerial photographs used to form the orthoimages the RMSEs correspond to 0.037 mm and 0.023 mm respectively. The magnitude of these values is in the range of the measuring accuracy attainable in second order photogrammetric plotters.

4. CONCLUSIONS

All phases of the digital orthoimage generation developed at UNB are performed in a GIS environment, which has been equipped with both vector graphics and raster image handling capability. This scheme is especially attractive for resource mapping and map revision since the orthoimages can be formed on as needed bases. GCPs, needed for the geometric transformation, can be selected interactively in the same environment, in a symultaneous dispay of a map and image. In the map revision experiment conducted with digital orthoimages, a low cost document scanner was employed to digitize the photographs. Nevertheless, the map accuracy standards were fully satisfied, which indicates, that the low-cost digital orthoimage production schem presented here has a definite merit. More experiments are, however, needed to evaluate the full potential of this scheme and to refine the methodology.

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