A Raster Approach to Topographic Map Revision

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ABSTRACT: With the approaching completion of the U.S. Geological Survey's 1:24,000-scale mapping program for the conterminous United States, map revision becomes a primary activity. Experimental techniques for map revision are being developed which require digitizing both map and photographic sources in a raster format, rectifying the resulting data to a common coordinate system, simultaneously displaying the digital map and photographic data, performing visual change detection, and manually updating the digital map data with an on-screen digitizing procedure. Updated image and line map output are generated from the raster data using a film-write device. Map revision performed completely in the raster domain achieves geometric accuracies sufficient to meet National Map Accuracy Standards at the 1:24,000 scale from 7 m pixel data and 1:100,000 scale from 28.5 m pixel data. Approximately 80 percent of the transportation and hydrography features are updated at the 1:24,000 scale from the 7 m pixel raster data.

INTRODUCTION

By the end of 1984, over 47,000 standard 1:24,000-scale 7.5-minute topographic maps covering over 85 percent of the contiguous United States and Hawaii had been published by the U.S. Geological Survey (USGS). Because coverage of the United States will be complete by 1991, maintenance of the 1:24,000-scale map series is now a primary goal of the National Mapping Program of the USGS, requiring the allocation of significant manpower and resources. The objective of this paper is to explore the potential for using a digital raster data base analogous to a geographic information system to support topographic map revision (Figure 1).

Map revision involves two distinct operations: (1) change detection and (2) map update. Conventional methods for map revision require registration of the map to be revised with new photo source material to detect changes by visual techniques. Once noted, these changes are manually delineated on the original map graphic or overlays and used to update the map (Speiss, 1982). For digital map revision techniques to be successful, they must replicate these change detection and update operations.

Most investigations of digital techniques for map revision have used vector data (Besenicar, 1978; Masry and McLaren, 1979). However, an alternative solution in which digitized map data in raster format are combined with digital image source material is worthy of consideration (Rastatter, 1975; Usery, 1985). Recent advancements in digital image processing, raster processing of cartographic data, and computer technology indicate this alternative has excellent potential for map revision (Welch, 1982; Benjamin and Gaydos, 1984; Fegeas and Pearsall, 1984).

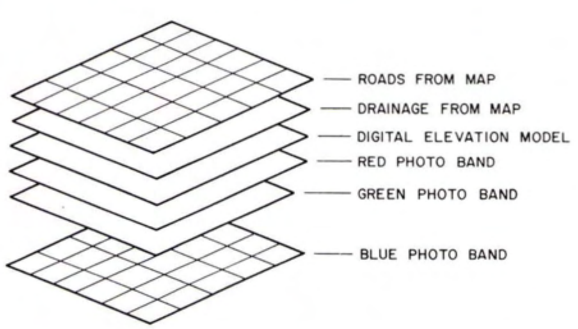

FIG. 1. A geographic information system (GIS) for map revision using several layers of raster data.

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Several studies have demonstrated the capability of meeting selected topographic map compilation and revision requirements with satellite imagery and digital data such as that collected by the Système Probatoire d'Observation de la Terre (SPOT) (Ducher, 1982; Welch, 1985; Gugan, 1987). This paper details results of revising test areas from three 1:24,000-scale maps and one 1:100,000-scale map using digital image processing techniques including digitization, rectification, image enhancement, and feature extraction.

PROCEDURES

Three test areas were selected in north Georgia corresponding to portions of the Blue Ridge, Athens West, and Tiger 1:24,000-scale topographic quadrangles (Figure 2). Data available for these test areas included maps of 1:24,000 and 1:100,000 scale; map separates for cultural, vegetation, hydrographic, and hypsographic features depicted on the 1:24,000-scale quadrangles; National High Altitude Program (NHAP) color infrared photographs at 1:58,000 scale; USGS digital elevation models (DEMs); and Landsat-4 Thematic Mapper (TM) CCT-PTs.

In order to perform revision using raster data, it was necessary to convert the maps and photographs to digital format. For the Blue Ridge test area, the map separates include the black plate of transportation and other cultural features, the blue plate of hydrographic features, the green plate of vegetation features, and the purple plate of manually revised features. These were digitized at a 7-m pixel ground resolution using a Nippon Electric Corporation (NEC) VC1-B305 charged-coupled device video camera and a frame-grabber attached to an Earth Resources Data Analysis System (ERDAS) 2400 image processing system. The map separates were pin registered and digitized with the video digitizer which samples the field of view of the camera lens into 512 by 480 pixels. Digitization of the separates was performed in segments with approximately 10 percent overlap between segments to acquire data over the entire 6.8 by 6.8 km test site (Figure 3).

Pre-selected ground control points (GCPs) were located within each segment such that several points were positioned in the overlap area. Each segment could then be rectified indepen-

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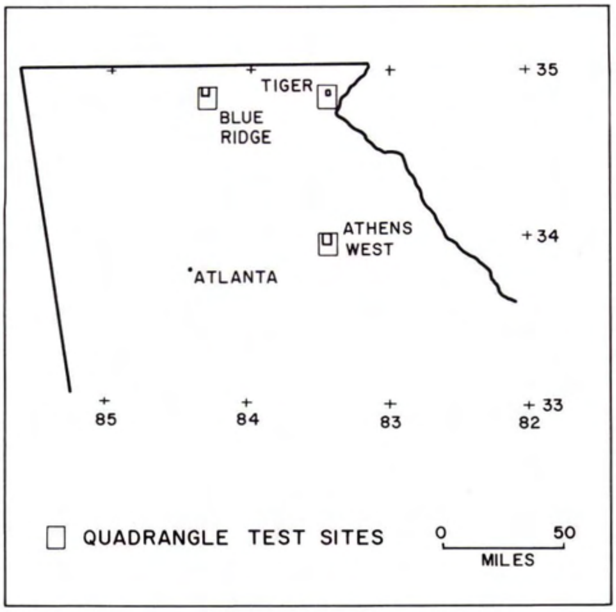

FIG. 2. North Georgia study sites selected to develop and test topographic map revision techniques from digital data.

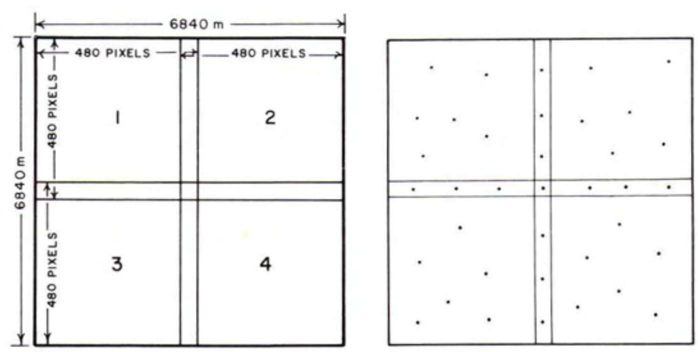

FIG. 3. Map segments shown in (a) were digitally mosaicked using control point distributions similar to that shown in (b).

dently and the GCPs in the overlap area would insure that segments could be mosaicked together to form a single digital image. Rectification with GCPs using polynomials is a widely accepted technique for correcting the geometry of satellite digital images (Wong, 1985; Bernstein, 1976; Welch and Usery, 1984). In this study these methods were sufficient to achieve better than one pixel root-mean-square planimetric (x,y) vector errors ($RMSE_{xy}$) for all test areas (Table 1). The errors shown in Table 1 permit revision meeting National Map Accuracy Standards (NMAS) at the 1:24,000 scale for datasets with 7.125-m pixels or smaller. Datasets with pixel sizes between 7.125 and 28.5 m were of sufficient accuracy to support revision at the 1:100,000 scale.

The separates were digitized with a pixel size of approximately 7 m. Because features such as roads are indicated on the separates as 12–m widths, 7–m pixels should be of sufficient resolution to capture that information. However, the actual symbols of roads on the separates are two parallel casings, each with a width of only 0.076 mm, representing 1.8 m in ground units. Because of this fine detail, the 7–m pixel size is insufficient to capture the required information.

The separates are high contrast negatives and can be digitized as binary images. This type of digitization requires a resolution

TABLE 1. GEOMETRIC ACCURACY OF DIGITAL MAP AND IMAGE DATA

Study Area	Data Source		Rectified Pixel Size(m)	$RMSE_{xy}$ (m)*	Largest Scale (NMAS)
Athens	1:24k**	map	7.125	± 4.6	1:15k
Blue Ridge	1:24k	map	7.125	5.4	1:18k
Tiger	1:24k	map	3.5625	3.6	1:12k
Athens	1:100k	map	28.5	13.1	1:44k
Athens	1:80k	photo	14.25	14.0	1:47k
Blue Ridge	1:58k	photo	7.125	5.3	1:18k
Tiger	1:58k	photo	7.125	4.9	1:17k
Athens	TM		28.5	18.2	1:61k
Tiger	TM		28.5	24.3	1:81k

*Computed from withheld points
**k = 1,000

on the order of 0.5 to 1.0 m to capture the fine detail of the map data. Because a video signal only carries information for approximately 512 by 512 pixels, a pixel size of one metre would require excessive numbers of segments to be digitized to acquire a large enough area to reflect revision needs.

An alternative to binary digitizing of the map separates is to sacrifice spatial resolution and digitize larger areas with increased information content. Each segment of the separates can be digitized with eight bits per pixel, yielding a gray-level image instead of the binary data. The effect of this higher radiometric resolution is to represent the edge pixels on roads and other features as intermediate gray level values while the black areas yield low values near zero and the clear areas yield high values near 255. This digitizing procedure was implemented on the Blue Ridge test area.

For the Tiger and Athens West areas a method was used which required extraction of the road and railroad, hydrography, and revision information from the map separates and drafting these features on white mylar in black ink with symbolized line widths proportional to the actual mapped feature widths. The Tiger pin registered mylar separates were then digitized at 3.5–m pixels and resampled to 7–m pixels to correspond with the other datasets. The Athens West data were extracted from a 1:100,000–scale map and digitized to approximately 28.5 pixels for revision with the TM data (Plate 1).

The color infrared photographs for the Blue Ridge and Tiger sites were digitized by Eikonix Corporation using their 78/99 linear array camera. The 23– by 23–cm NHAP photographs were digitized with a total of 2,048 by 2,048 pixels, yielding a pixel resolution of approximately 7 m in ground units. This resolution represents a compromise between the area of coverage for the test sites (approximately 6.8 km by 6.8 km) and the volume of data that can be processed in a reasonable time on the Digital Equipment Corporation (DEC) PDP 11/24 minicomputer which is the host for the ERDAS 2400 image processing system used on the project. Although digitizing of the color infrared photographs at a pixel size of 7 m degrades their resolution by 3 to 4×, this pixel resolution is still significantly better than that of current or planned satellite remote sensing systems which will ultimately provide the source data for digital revision.

CHANGE DETECTION AND DATABASE UPDATE

The use of a raster database with a digital image processing system offers an excellent mechanism for map revision. Each image or map database layer, such as those shown in Table 2, can be displayed with eight bits per pixel, providing 256 color intensities for each of the red, green, and blue color memories.

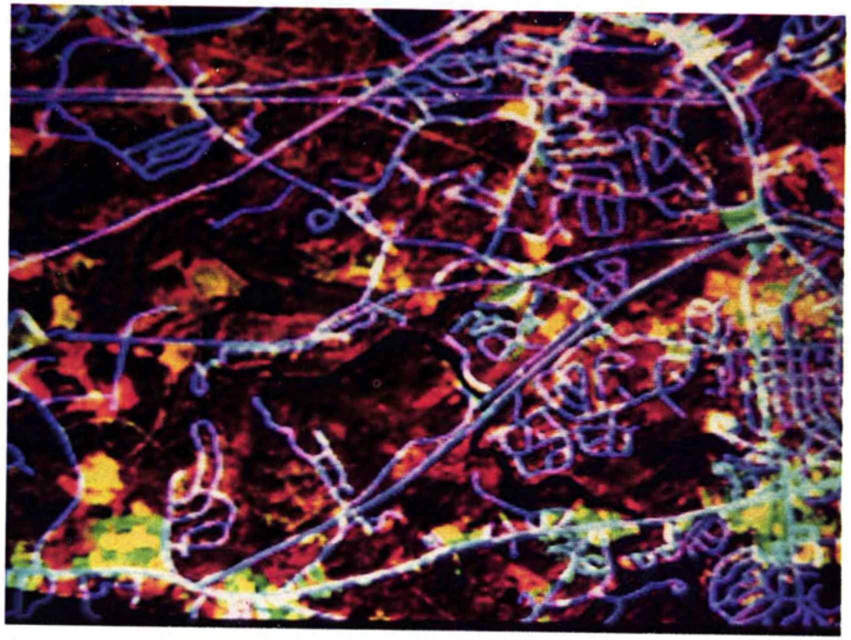

PLATE 1. Digitized 1:100,000–scale transportation data displayed as the blue band with TM bands 4 and 3 in red and green, respectively. Pixel size is 28.5 m.

PLATE 2. Changes from the original map data to the current photographic data are easily detected by visual methods. The photographic red and green bands are shown in the red and green color memories while the map data are shown in the blue color memory.

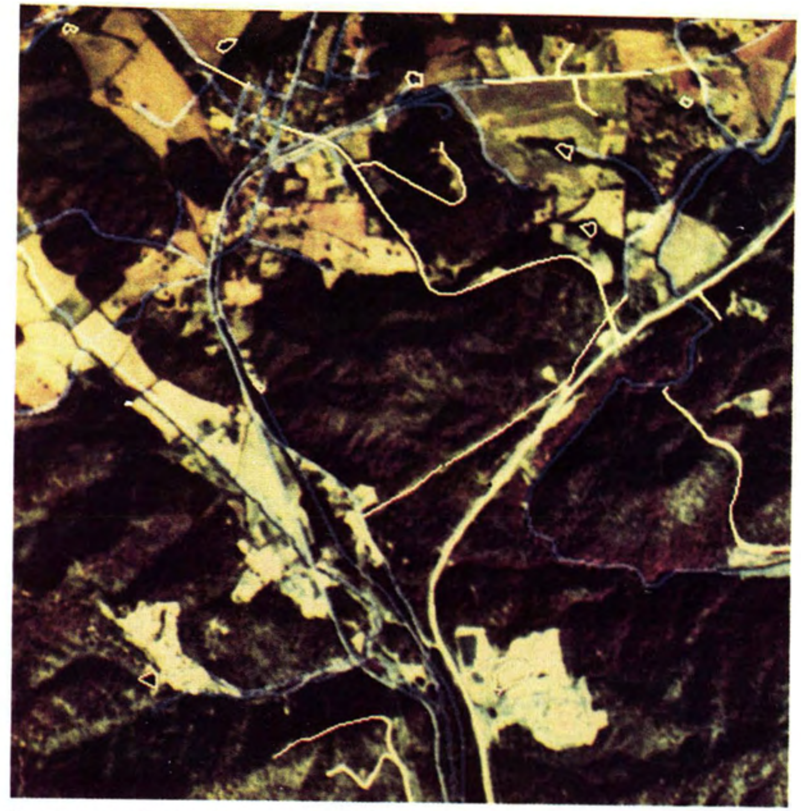

PLATE 3. Revised image map of the Tiger test area. Photo red, green, and blue image bands are shown. Original map data have been combined with the blue band while the revised data were combined with all three bands and thus appear white in the image map.

TABLE 2. DATABASE FOR BLUE RIDGE

Dataset Description	Pixel Size (m)	Number of Overlays	Overlay Number	Data Source*
TM/DEM	28.5	8	1	TM - Band 1
			2	TM - Band 2
			3	TM - Band 3
			4	TM - Band 4
			5	TM - Band 5
			6	TM - Band 6
			7	TM - Band 7
			8	DEM
Digitized Photo	7.125	3	1	Photo - Red
			2	Photo - Green
			3	Photo - Blue
Digitized Map	7.125	5	1	24k map - roads
			2	24k map - buildings
			3	24k map - drains
			4	24k map - vegetation
			5	24k map - revision
DEM	28.5	1	1	DEM 8-bit
	28.5	1	1	DEM 16-bit
	7.125	1	1	DEM 16-bit

*k=1,000

In Plate 2, for example, map overlays and image bands are combined for change detection.

An alternative display method was implemented to represent the map data as a binary graphic displayed in combination with the digitized photo or TM data. In this display method three image bands are represented using eight bits per pixel for each of the red, green, and blue color memories. An additional bit per pixel may be used as a graphics overlay to register the map data to the displayed image bands. This type of display requires reducing the map data to binary digital images with the resulting degradation discussed previously. These methods can be used to display the datasets to different degrees of effectiveness to perform change detection through visual analysis (Plate 2).

Because the visual detection of changes was so readily observed, an interactive method to record those changes can be used. The method requires tracing features with an interactive device such as a joystick, mouse, or trackball which controls a cursor on the screen. The cursor is placed on the beginning of a new feature, a road, for example. Pressing a button on the control mechanism fixes the cursor position as one end of a rubber-band vector. Movement of the cursor is used to extend the rubber-band vector along the feature in straight segments. Pressing a second button on the control mechanism ends the segment and begins a new vector at the current cursor position. A third button can allow ending the current vector with free movement of the cursor to begin a new segment or end the tracing session. An editing feature can also be provided which allows retraction of the rubber-band vector for better placement along the feature of interest.

Deletion of features can be accomplished using a block fill mode on the image processor. A feature to be deleted can be circumscribed with a box whose position and size are controlled by the interactive device. When appropriately placed around the obsolete feature, the box is filled with a user specified value such as one equivalent to the image background, thus eliminating the feature from the display. An update of the data file from the displayed values will eliminate the feature from the digitized map data.

While the interactive digitizing procedure provides coordinates for the new features, those coordinates will be in a vector format as a result of the tracing operation. A coordinate sorting program can be used to sort first on the y coordinates then on the x coordinates and place a value of 255 in the pixel positions appearing in the vector lists. All other pixel values in the raster file can be set to zero. The resulting raster revision file will then form another layer in the database. Again, the display can be used to view the combined revision overlay with the original map data, the original image data, or any combination of overlays.

All of the test areas were revised using these methods. Table 3 illustrates the completeness of revision information attained by these techniques when compared to the conventional analog revision methods. It should be noted that the difference results from the resolution of the digital data rather than from the technique used.

REVISED MAP OUTPUT

The final step in the revision process is the generation of a revised map from the updated digital data. In this study revised image maps were desired. Consequently, the digital revision overlays for the Tiger test area were combined with the digitized photo and map data and printed on a film-write device. The combination was performed in the following manner. Photo bands for red, green, and blue were written to the output files as three separate bands. Roads and drains from the original map were written only to the blue band. The revision data were written to all three bands and thus appear as white in the revised image map (Plate 3)

CONCLUSIONS

Digital image processing offers an excellent method of performing revision of map data in raster formats. Rectification of digitized images and maps to ground control with first degree polynomials allow accuracies of better than ± 1 pixel to be achieved. For pixels with dimensions of 7 m or less, these accuracies are sufficient to support map revision at 1:24,000 scale. For pixels with dimensions between 7 m and 30 m, the accuracies are sufficient to support 1:100,000–scale map revision. Completeness of map revision information is a direct function of resolution or pixel size. In this investigation, approximately 80 percent of the features shown on 1:24,000–scale maps could be revised using data with pixel dimensions of 7 m.

The problems encountered in this investigation were primarily a result of data resolution. Remote sensing systems, such as SPOT, can provide data with resolutions approximating those used in this study. SPOT will produce these data in large volumes and on a worldwide basis, thus facilitating revision of small scale maps. Higher resolution systems generating data with pixel dimensions of 5 m or smaller can provide the capability to revise larger scale maps such as the USGS 1:24,000–scale series. Although data volumes for such systems are currently a deterrent to using high resolution raster data for map revision tasks, the advent of high speed image processing workstations equipped with optical disks can make this process effective for

TABLE 3. COMPLETENESS OF REVISION OF 1:24,000-SCALE TOPOGRAPHIC MAPS

Test Area	Percent Completeness
Blue Ridge	
roads	88
drainage	100*
Tiger	
roads	76
drainage	100*

*Drainage changes included man-made lakes created since the map was published. Although all new lakes were identified, the coarse resolution of the data prevented accurate delineation of the areal boundaries.

production revision operations. The extension of this research to partially or fully automated methods for map revision are logical goals.

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