SPOT PLA Photographic Image Processing

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ABSTRACT: SPOT high resolution Panchromatic Linear Array (PLA) photographic transparencies provide interpreters with images that contain a wealth of detail. The utility of these black-and-white image products can be increased through the application of three simple but effective photographic processing techniques. The first technique produces a false color composite from a PLA transparency and two Landsat Thematic Mapper transparencies (bands 1 and 4). This hybrid approach was used to construct a high resolution diazo color infrared image and a high resolution diazo simulated normal color image. Photographic edge extraction, analogous to digital high pass filtering, was employed as the second technique to produce a transparency of PLA edges. An edge enhanced image was created by overlaying the PLA edges onto a color composite. The third technique used PLA anniversary images to construct a complementary color, high resolution, two-date composite. Areas of change occurring between the dates of the two images were displayed as one of the two complementary colors, and areas of no change appeared as a neutral gray tone. Techniques for producing and interpreting hard copies of the composites are included in the paper.

INTRODUCTION

SCENES FROM the SPOT Panchromatic Linear Array (PLA) sensor system provide image data at a relatively high spatial resolution (10m). To take advantage of the detail, analysts have usually required digital image processing facilities for combining the single channel PLA data with multiband data obtained from sensor systems such as the SPOT Multispectral Linear Array (MLA) and the Landsat Thematic Mapper (TM). An additional requirement is access to image output devices (film writers, electrostatic or ink-jet plotters, etc.) capable of handling the higher data densities of the PLA scenes. Because of these requirements some image analysts have acquired the SPOT PLA scenes in photographic form and relied on conventional interpretation and mapping techniques to extract information. This approach is often cost-effective and time-efficient, but suffers from a lack of methodology for enhancing or manipulating the images in photographic form.

This paper presents a set of three simple but effective photographic techniques for (1) compositing PLA images with images obtained from other sensor systems, (2) extracting edges from PLA images, and (3) detecting changes between PLA images. The first technique involves combining the PLA image with TM images to produce either a color infrared composite or a simulated normal color composite. Landsat TM scenes are sometimes less costly, are available for a wider spectral range, and, for some locations, are more readily available than the corresponding SPOT MLA scenes. Photographic edge enhancement is presented as the second technique. Edges, analogous to those obtained from digital high pass filtering, are extracted from a PLA image and then registered to a color composite. The third technique involves the use of two PLA images acquired at different dates. A complementary-color composite of the two scenes produces a high resolution image in which changes appear as colors and areas of no change remain as gray tones.

Photographic image products (Table 1) were obtained from the Canada Centre for Remote Sensing satellite station at Prince Albert, Saskatchewan. Full SPOT PLA images containing the city of Edmonton, Alberta at a scale of 1:500,000 were obtained as positive black-and-white transparencies; geometric corrections for the standard georeferenced products were based only on satellite system parameters. Landsat TM quarter scenes, track centered on the city of Edmonton, were obtained at a scale of 1:500,000 with the same minimal geometric corrections used to process the SPOT imagery. A Landsat TM color infrared (CIR) composite was also obtained from the Prince Albert receiving station and used as a comparative reference for the image products generated in this study. Subsets of the PLA scenes and the TM scenes are displayed in Figures 1 and 2. The area shown is the south-side of the city of Edmonton and encompasses one of the fastest growing urban regions in Canada.

TABLE 1. SATELLITE IMAGE PRODUCTS USED IN THE ANALYSES

Acquisition Date	Satellite	Sensor	Viewing Angle	Band	Cost (CDN$)
30 Aug 1986	SPOT	PLA	−4.97°	pan	930.00
2 Sep 1988	SPOT	PLA	−24.11°	pan	930.00
6 Oct 1988	Landsat	TM	nadir	1	120.00
6 Oct 1988	Landsat	TM	nadir	4	120.00
6 Oct 1988	Landsat	TM	nadir	CIR	300.00

HYBRID (PLA/TM) COMPOSITES

A color infrared composite can easily be constructed from TM images (6 Oct 88) and a PLA image (2 Sep 88). Band 1 (blue-green) and band 4 (infrared) positive TM transparencies were contact printed to yellow and cyan diazo foils. The PLA (pan) positive transparency was used to create a magenta diazo foil. Detailed descriptions of the diazo process for creating satellite image color composites can be found in Elifrits and Barr (1978) and Whitebay and Mount (1978); conventional photographic materials could also be used for compositing (Kreitzer, 1974; Romijn, 1977). Registration of the diazo foils presented no problems even with the large look angle of the PLA sensor.

A schematic showing the color code of the resulting composite is displayed in Figure 3. This composite was used as the basis for the enhancements shown in Plates 2a and 2b and appears similar to a Landsat TM color infrared composite. The slight difference in dates between the PLA image and TM images shows color shifts in the agricultural cover due to the harvesting of crops or plowing of fields. Film positives (slides) and negatives (prints) of the diazo composite were made using the copying set-up shown in Figure 4.

A variation of the above procedure can be used to create a simulated normal-color composite. In order to obtain green vegetation, cyan and yellow colors must form on the diazo foils for areas in the scene that are vegetation covered. This will occur when these areas are displayed as relatively dark tones in the corresponding image transparencies. TM band 1 (blue-green) exhibits a dark tone for vegetation, but TM band 4 shows deciduous vegetation as a light tone from the high infrared reflectance. Contact printing the TM band 4 image to produce a negative film transparency will invert this relationship.

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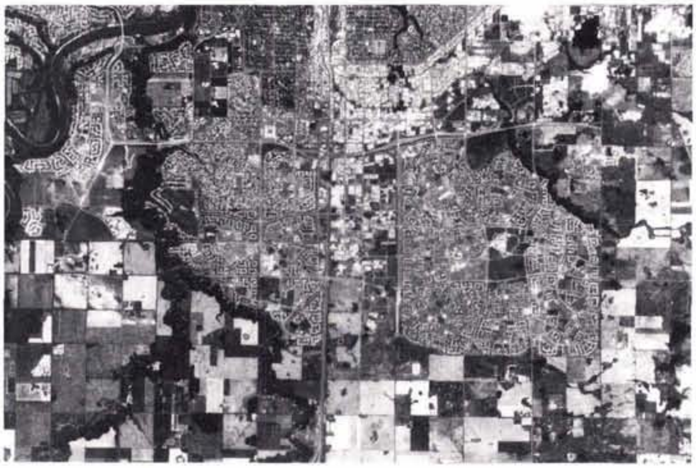
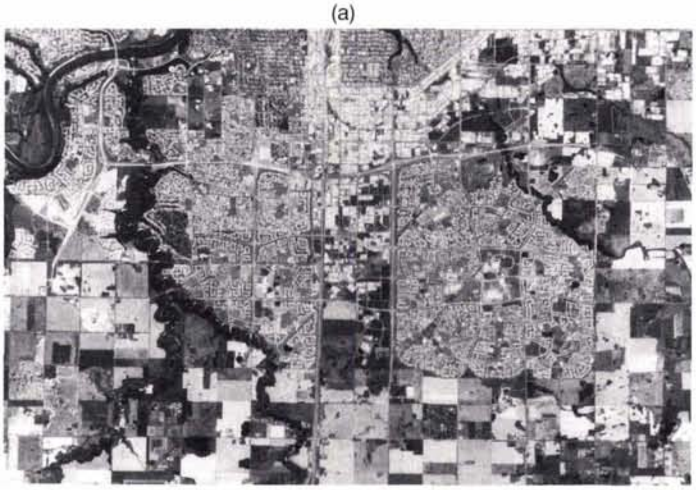
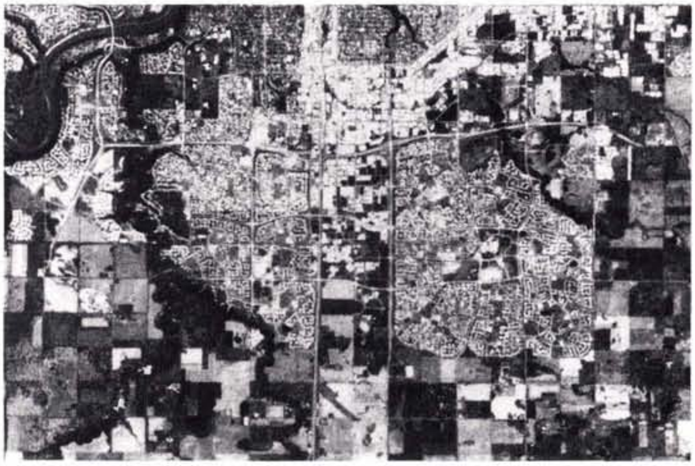


(a)



(b)

FIG. 1. Subsets of SPOT PLA imagery obtained over Edmonton, Alberta. (a) SPOT PLA image acquired 30 August 1986. © SPOT image/CNES. (b)SPOT PLA image acquired 2 September 1988. © SPOT image/CNES.



(a)

(b)

FIG. 2. Subsets of Landsat Thematic Mapper imagery obtained over Edmonton, Alberta on 6 October 1988. (a) Thematic Mapper band 1 (blue-green) image. (b) Thematic Mapper band 4 (infrared) image.

Target	red	green	blue	black	white	infrared	infrared + green	infrared + white	
+TM-4 (infrared)	cyan	cyan	cyan	cyan	cyan				Cyan diazo
+PLA (red/green)			magenta	magenta		magenta			Magenta diazo
+TM-1 (blue)	yellow	yellow	yellow	yellow			yellow		Yellow diazo
Rendition	green	green	blue	black	cyan	red	yellow	white	

FIG. 3. Color-code for the hybrid color infrared composite.

The final composite (Plate 1) was constructed from a yellow diazo foil of the TM band 1 *positive* transparency, from a cyan diazo foil of the TM band 4 *negative* transparency and from the *positive* black-and-white SPOT PLA transparency. Figure 5 shows a schematic of the simulated normal color composite and the associated color code. The principal value of this image arises from the use of the original SPOT PLA positive black-and-white transparency in the composite. This film product retains considerably more detail as a continuous tone image compared to

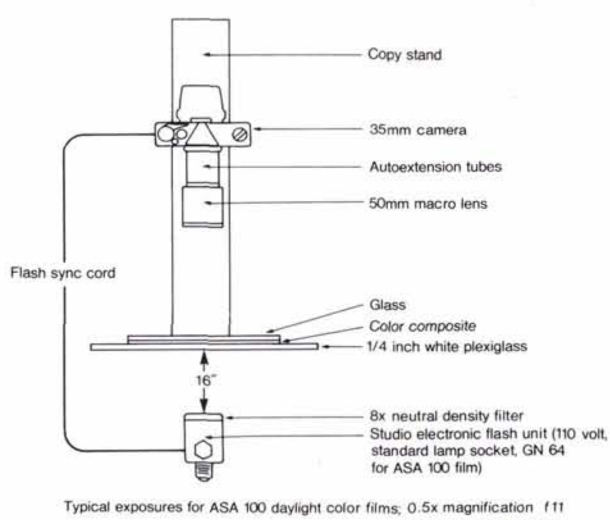


FIG. 4. Copying setup.

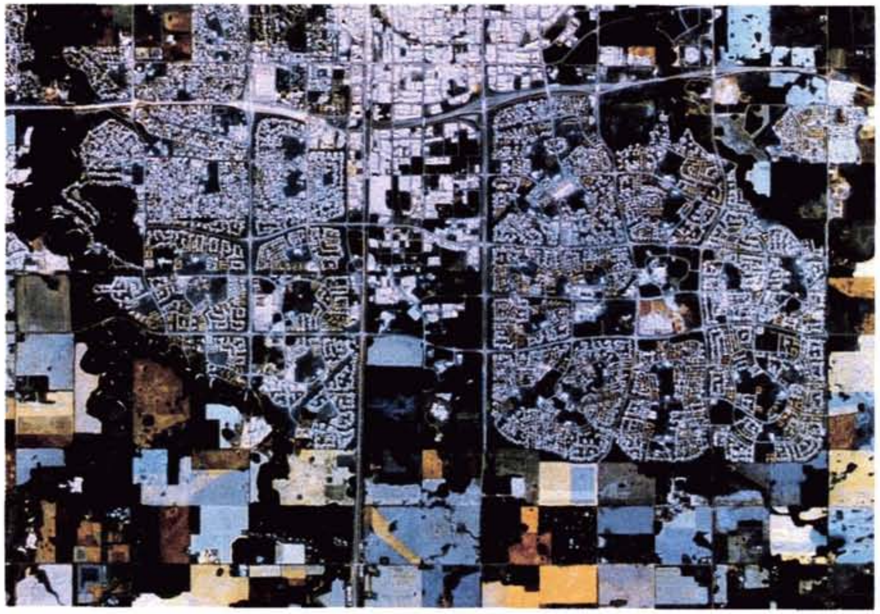
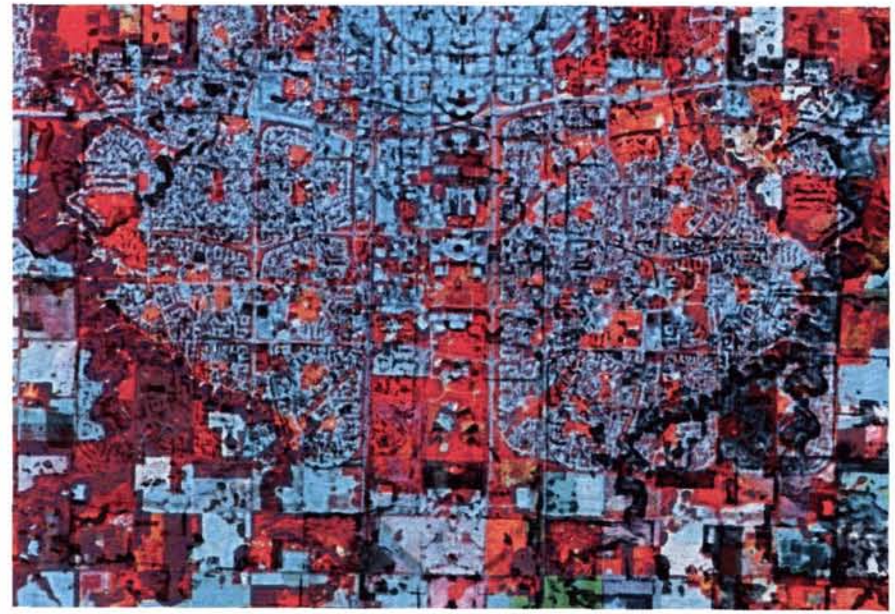


PLATE 1. Hybrid simulated normal color composite. © SPOT image/CNES.



(a)

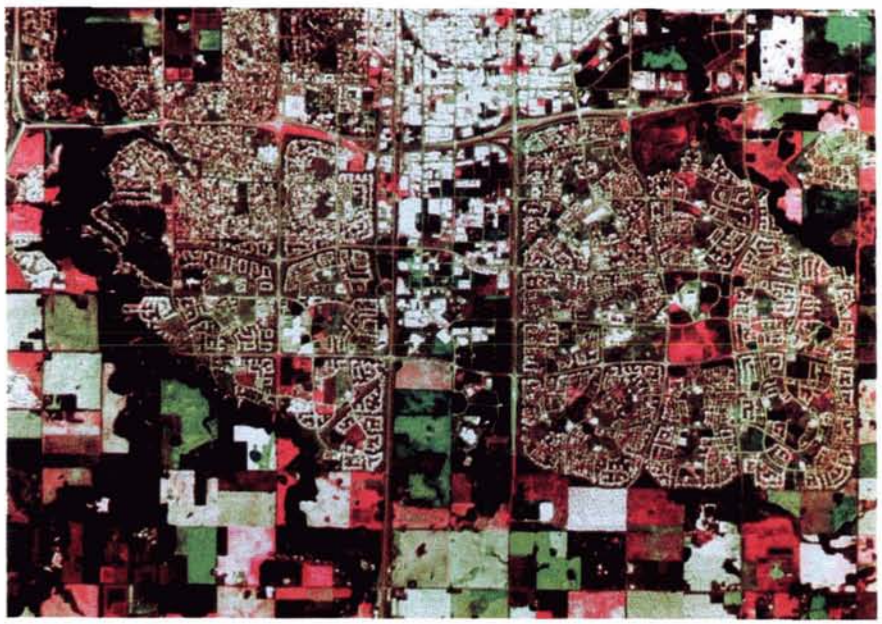
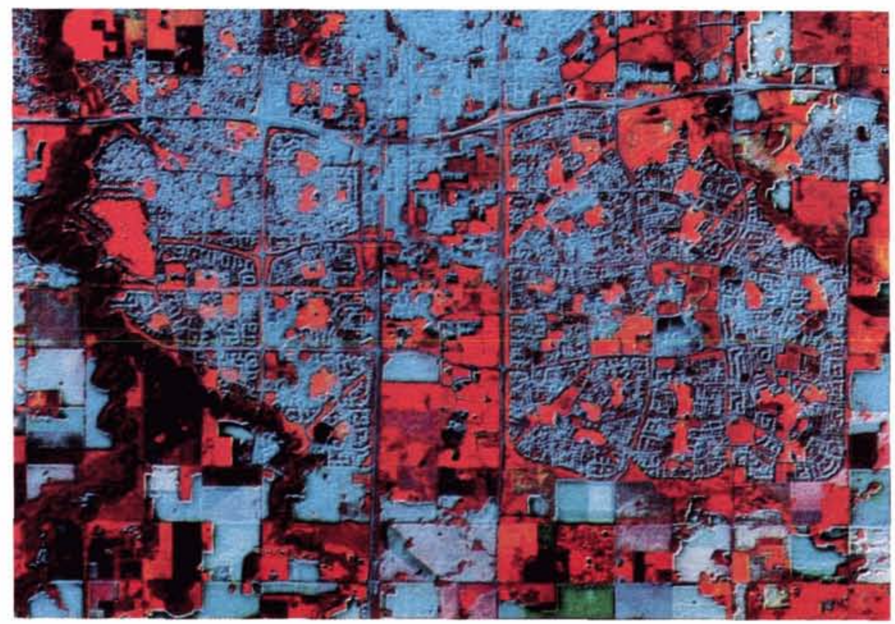


PLATE 3. Complementary-color anniversary dates change composite. See Figure 9 for the color code. © SPOT image/CNES.

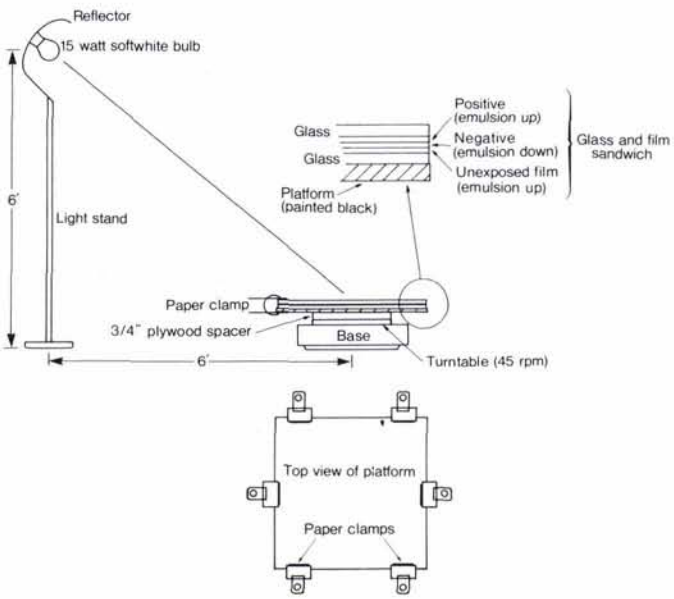


(b)

PLATE 2. Edge enhanced hybrid color infrared composites. © SPOT image/CNES. (a) Edges from positive (top) and negative (bottom) film *sandwich*. (b) Edges from negative (top) and positive (bottom) film *sandwich*.

Target	red	green	blue	black	white	infrared	infrared + green	infrared + white	
−TM-4 (infrared)						cyan	cyan	cyan	Cyan diazo
+PLA (red/green)			gray	gray		gray			
+TM-1 (blue)	yellow	yellow		yellow		yellow	yellow		Yellow diazo
Rendition	yellow	yellow	gray	brown	white	dark green	green	cyan	

FIG. 5. Color-code for the hybrid simulated normal color composite.



FILM	EXPOSURE	DEVELOPER	PROCESSING TIME (68° F)	EFFECT
Ortho Type 3	60 sec	Kodalith	31/2 min	Dense black edges
Ortho Type 3	30 sec	D-76	21/2 min	Soft muted edges

FIG. 6. Setup for photographic edge extraction.

a diazo foil. Diazo materials are inherently high contrast and are able to display only a small number of tones (Skaley, 1980).

ENHANCING EDGES

A technique for producing tone-line photographic illustrations (Eastman Kodak Co., 1973) can be used to extract edges from remote sensing images. Variations of this technique have appeared in the literature (Clarke, 1962; Mulder and Donker, 1977; Ross, 1969; Weller, 1970). The method presented here involves registering positive and negative transparencies of the same scene using the film bases as a separator between the two images (Figure 6). An unexposed sheet of film is placed beneath the registered pair of images and held in place between two pieces of glass. The glass "sandwich" is clamped to a modified record player turntable and exposed to a 45° light source while rotating at 45 rpm.

The resulting image is equivalent to the product obtained with high pass digital filtering, and the strength of the edge effect can be varied by using different films and developers. High contrast films (e.g., Kodak Ortho Type 3 or Professional Line Copy Film) processed with high contrast developers (e.g., Kodalith A and B or D-11) produce dense black edges in the final image. Continuous tone films (e.g., Kodak Professional Copy Film) and conventional developers (e.g., D-76, HC-110) produce a much softer, more muted effect.

The width of the extracted edges and the number of edges can also be controlled. The width of the edges is a function of the distance between the two registered images (base 1 + base 2) and the angular elevation of the lamp used in exposing the film sandwich (Figure 7); i.e.,

$$ew = (b_1 + b_2)/\tan \phi$$

where

ew = edge width,
b_1 = thickness of base 1,
b_2 = thickness of base 2, and
ϕ = angular elevation of exposing lamp.

The number of edges extracted depends on the order of the positive and negative image in the film sandwich. Figure 7a shows the results of placing the positive image on top of the negative image for a high reflectance linear feature such as a street in a new residential area. The edge image will show dark lines slightly displaced away from the edges of the bright feature. If the order of the positive and negative images is reversed in the film sandwich (Figure 7b) then there is the possibility of creating only a single line. When the width of the feature in the image is less than $2(b_1 + b_2)$, then only one edge will appear.

Figure 8a shows the results of exposing the September, 1988 SPOT PLA positive (top) and negative (bottom) transparencies onto Kodalith Ortho Type 3 film and developing in D-76 developer (full strength for 2½ minutes at 68°F). The image of urban edges were merged with the hybrid color infrared image by registering the film transparency with the diazo composite. A copy of the final image is displayed in Plate 2a. The edge image acts like a diffuse mask and increases the contrast of the edges in the scene. Figure 8b and Plate 2b show the edge image and the enhancement resulting from the use of a film sandwich constructed with an inverted order (negative-top and positive-bottom). This edge enhancement produces a *bas-relief* effect which emphasizes the textural components of the scene.

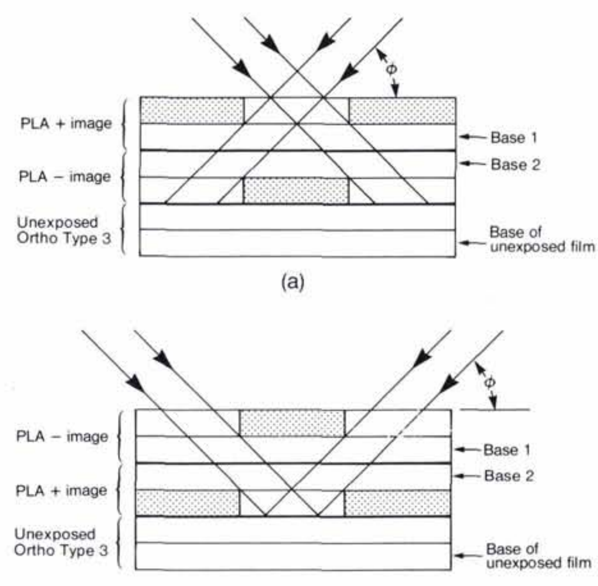


FIG. 7. Relationship between edge types and image order.

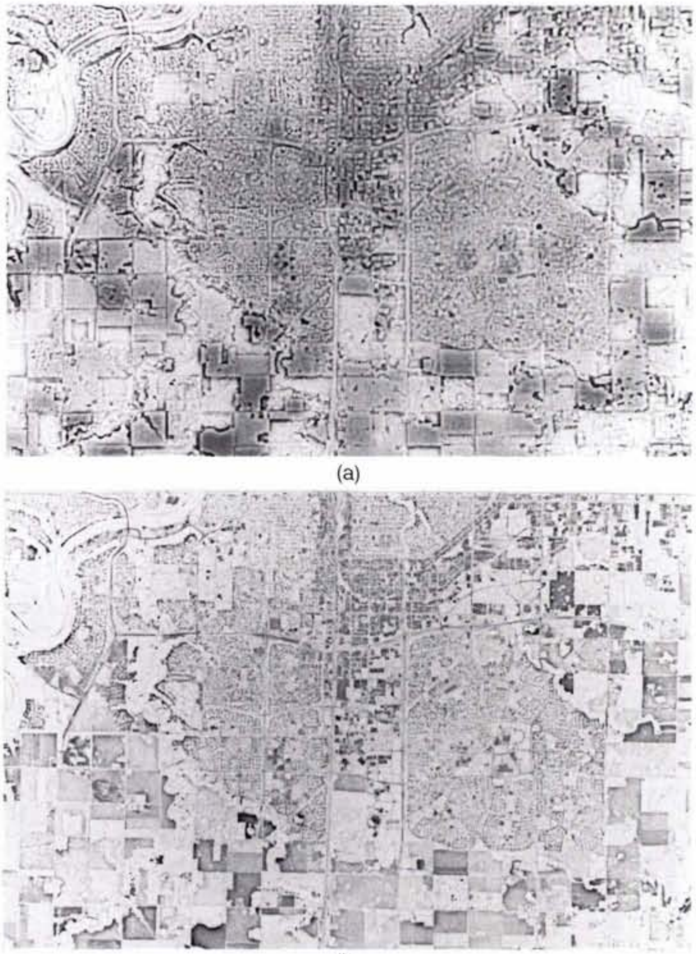


FIG. 8. SPOT PLA edge images. © SPOT image/CNES. (a) Edges from positive (top) and negative (bottom) film *sandwich*. (b) Edges from negative (top) and positive (bottom) film *sandwich*.

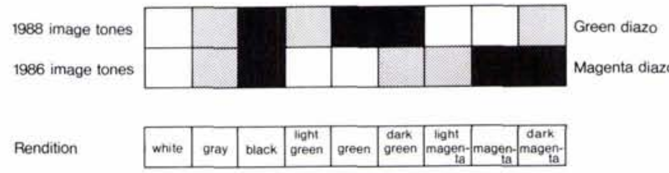


FIG. 9. Complementary color, two-date composite. The colors indicate albedo changes occurring between the dates of the two images.

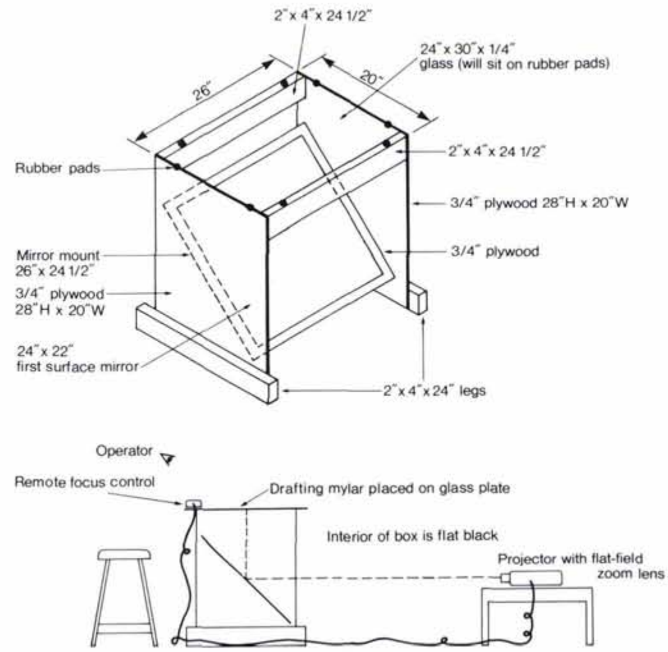


FIG. 10. Projection interpretation and mapping system.

DETECTING CHANGES

A method for constructing three-date composites using the subtractive primaries has been described previously (Eyton, 1984). The technique presented here is a modification of this earlier approach and involves the complementary color coding of two-date images. Theoretically, black-and-white positive transparencies should exhibit the same tones when obtained as anniversary images and there has been no change in the land-cover reflectance from date 1 to date 2. A color composite constructed from these two images using complementary colors should produce a black-and-white display. However, if human activities or natural events have altered the land cover between the acquisition of the first and second image, then these changes will be displayed in the composite as a shade of one of the two complementary colors.

Figure 9 shows a simple schematic of the diazo complementary color composite (Plate 3) constructed from two PLA images. Surface features that changed from a panchromatic low reflectance in 1986 to a panchromatic high reflectance in 1988 are shown in magenta. Green areas are indicative of the converse situation. A map of the annotated changes was manually drawn, while interpreting the projected image of a 35-mm slide copy of the two-date composite using the system shown in Figure 10. Slides are preferable to photographic prints for interpretation purposes because of the relatively high brightness ratio of the projected image compared to the brightness ratio of a color print.

SUMMARY

Simple but effective photographic processing techniques were used to enhance SPOT PLA images. These techniques involved (1) creating hybrid SPOT PLA and Landsat TM color composites, (2) extracting edges from a PLA image and merging them with a color composite, and (3) constructing a change detection composite from two PLA anniversary date images. In addition to the information gain resulting from each specific technique, detail from the high resolution SPOT PLA sensor was retained in each composite. The techniques should be applicable for images including a variety of cover types.

ACKNOWLEDGMENTS

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BOOK REVIEW

Measurements from Maps: Principles and Methods of Cartometry by D. H. Maling. Pergamon Press, New York; 1989. 577 p. Hardcover: $80.00 [ISBN: 008 0302904]; Paper: $36.00 [ISBN: 008 0302890].

THIS VOLUME takes as its subject the use of maps for precise measurements. It consists of a survey of methods, problems, and ideas pertaining to measurements from maps. Its scope encompasses both conceptual and methodological issues; they are presented logically and clearly, with ample references. The volume is organized into 23 chapters, each addressing a topic such as data collection, sampling, projections, inherent inaccuracies in cartographic measurements, estimation of errors, errors in areal and linear measurements, spatial sampling, fractals, stereology, deformation of paper, and map accuracy standards. I expect most readers will use this book as a reference work, but it could form a useful text for an upper level university course dedicated to examination of issues in cartographic accuracy or cartographic measurements.

Maling engages in a thorough pursuit of his topics; his work encompasses scientific literature from many nations, disciplines, and scientific traditions. In some instances the diversity of the material itself forms a statement to the unexpected complexity of ostensibly simple topics, and to the ingenuity of those who have attacked these issues. Who could have anticipated the remarkable diversity of the methods devised to evaluate errors in areal estimation? Certainly I was ignorant of many of the methods described here, but I expect that there are few among even the most expert and dedicated cartographers who have already mastered the book's content.

Some readers may question Maling's description of techniques that are antiquated in the context of digital cartography. For example, he describes in some detail the numerous manual methods for estimating distances along curved lines on maps, and in estimating areas depicted on maps. Some readers may regard his attention to such issues as misplaced enthusiasm for outmoded methodology. I defend Malings's decision on grounds of completeness, that he has documented methods that were not previously written out (at least in accessible documents), and that some of these methods can form conceptual models for more sophisticated methods. I do criticize this aspect of the book, however, to the extent that I wish he had provided comment, summary, and comparison, to provide the reader with more evaluation to accompany the excellent compilation of methods.

It is unfortunate perhaps that Maling presents this information through the vehicle of the paper map – a product that may be on the eve of its demise as the primary medium for cartographic innovation. Paper maps will be with us for many more years, but already most cartographic innovation is defined in the context of digital maps, so there has already been a shift to a new paradigm. It is, however, a mistake to dismiss this volume as anachronistic on this basis. Its content is germane in both domains, and digital cartographers are well advised to master its content, as it records lessons that will be either learned from its pages, or repeated in practice. The errors Maling describes here do not disappear in the digital format, but are only systematized to be more deeply hidden.

The perfect illustration of the difficulty and the significance of Maling's topic is his concluding chapter on maritime boundaries. Here his description focuses on the truly Byzantine methodology required to implement the diplomatic concepts of international maritime boundary law – concepts intended no doubt to embody the essence of elegant simplicity, but which can be implemented only by the most intricate methodology and a detailed knowledge of maritime charts. Here is the ultimate illustration of the practical significance of the principles and methods presented in earlier chapters.

Maling develops and presents his mathematics and statistics with, I think, appropriate detail and rigor. For the most part complete proofs are not presented, but the basic logic is given in sufficient detail to permit most readers to follow without difficulty. The reader who requires a more complete derivation will need to refer to other references, which are cited in ample number, and (as best I can determine) usually include the original or most authoritative work. Readers will appreciate the Index to Symbols, an essential aid, given the established use of so many multiple meanings for many of the symbols.

References encompass a diverse range of disciplines, perspectives, and both theoretical and applied topics. The references are mainly in English, but Maling has identified important works in other languages including Russian, German, and French. The index is adequate, but like many other scientific books, it seems to have been prepared in a mechanical manner by someone who is not really interested in the book's content. I found most items I searched for in the index, but many were listed in an awkward manner.

The book will become one of the modern cartographer's most valued references.

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