Merging Multiresolution SPOT HRV and Landsat TM Data

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INTRODUCTION

PROCEDURES for merging multisensor and multiresolution satellite data in digital formats to create composite images of enhanced interpretability have been discussed by Welch (1984) and Chavez (1984). With the successful launch of SPOT-1 in February, 1986, and the acquisition of 20-m resolution multispectral and 10-m resolution panchromatic images with the High Resolution Visible (HRV) solid state line array cameras, attention has focused on the possibilities for using digital image processing techniques to sharpen the multispectral image by integrating or merging it with the panchromatic band (Welch, 1985). Similarly, there is considerable interest in merging the SPOT-1 10-m panchromatic band with Landsat-4 and -5 Thematic Mapper (TM) images of 28.5-m pixel resolution to create multisensor, multiresolution, multispectral, and multitemporal composite image products that can be effectively analyzed by visual interpretation. This brief documents methodologies that have proved successful and provides examples of composite images that demonstrate the improvements in interpretability achieved by merging image data sets of high and low resolution.

LANDSAT-5 AND SPOT-1 DATA SETS

In order to evaluate merged multiresolution data sets, it is desirable to utilize imagery of an urban area where the rendition of buildings, land parcels, edges, and other high frequency detail can be used for comparative assessments of image quality (Welch, 1982). Consequently, a 5-km by 5-km test site located in the city of Atlanta, Georgia and recorded by the Landsat-5 TM on 4 April 1985 and by the SPOT HRV on 4 May 1986 was selected for this study (Figures 1 to 3, Table 1).

The Landsat-5 TM data were available in computer compatible tape (CCT-pt) formats, and had been resampled to 28.5-m pixel resolution and corrected for radiometric and geometric distortions by the Thematic Mapper Image Processing System (TIPS). Earlier studies have shown the Landsat-5 TM data to be of exceptionally good geometric fidelity (Borgeson *et al.*, 1985; Welch *et al.*, 1985).

The SPOT data were recorded with the HRV camera pointing 17 degrees off-axis, resulting in effective instantaneous fields-of-view of about 11 m and 22 m for the panchromatic and multispectral modes, respectively. These data were processed at Level 1B by SPOT Image Corporation to yield an equivalent vertical image resampled to nominal pixel dimensions of 10 m (panchromatic) and 20 m (multispectral). However, as is the case for all SPOT-1 images, the multispectral and panchromatic data are not co-registered. Registration must be undertaken by the user if a merged image product is required.

A 512 by 512 pixel subset of the SPOT-1 10-m panchromatic data was selected as the reference image to which the SPOT-1 and Landsat-5 TM multispectral images could be registered. A screen-sized subarea of this reference image is presented in Figure 3. Urban details, including roads, buildings, and parks, are easily identified.

REGISTRATION AND DISPLAY PROCEDURES

A general procedure for creating data sets that will be in register involves the following steps: (1) determination of the image coordinates of control points common to all data sets; (2) computation of the unknown coefficients for a first degree polynomial equation required to register the multispectral images to the panchromatic reference image; and (3) resampling of the multispectral data sets to 10-m resolution using parametric cubic interpolation techniques to avoid blocky image structures (Schowengerdt *et al.*, 1984). These steps were employed to create resampled 512 by 512 image data files of 10-m resolution for the SPOT-1 multispectral bands (bands 1 to 3) and the six visible, near-infrared, and short wavelength infrared TM bands (bands 1 to 5 and 7).

Registration accuracy was evaluated at withheld test points, and yielded root-mean-square error (RMSE) values of approximately ± 7 m and ± 14 m for the SPOT-1 and TM multispectral images, respectively. These values are equivalent to ± 0.4 data pixel for the SPOT-1 and ± 0.5 data pixel for the Landsat-5 image subsets, and indicate the excellent geometric integrity of the satellite image data. Errors of this magnitude are not apparent in the composite images (Figures 4 to 6).

Once a layered set of images is stored on disk, the digital numbers (DN) associated with the various multispectral images may be combined or merged with those for the panchromatic reference image using techniques previously discussed by Saint and Weill (1984), Cliche *et al.*, (1985), and Chavez (1986). These methods may be summarized in the two following equations:

$$M_i' = a_i * (M_i * P)^{1/2} + b_i \quad (1)$$

$$M_i' = a_i * (w_1 M_i + w_2 P) + b_i \quad (2)$$

where M_i' is the DN for a pixel in the ith band of the merged image; M_i is the DN for the corresponding pixel of the ith multispectral image; P is the DN for the corresponding panchromatic reference image pixel; w_1 and w_2 are weighting factors; and a_i and b_i are scaling factors to place the resulting DN within the dynamic range (0,255). By using either of these algorithms, the panchromatic image DNs are merged or integrated with the DNs for the resampled multispectral images to create sharpened images that can be contrast-stretched using histogram equalization or similar digital image enhancement techniques. The sharpened, contrast-stretched images may then be displayed as a red-green-blue false color composite on the CRT display of the image processing system or written to film for hardcopy products.

The above algorithms were applied with reasonable success in merging both the SPOT-1 and Landsat TM multispectral data with the SPOT-1 10-m panchromatic reference image. However, images of superior contrast and spectral discrimination were achieved using a third method based on the intensity-hue-saturation (IHS) color transformation procedures documented by Haydn *et al.* (1982). This technique was recently employed by Hallada (ASPRS, 1986) to merge Landsat and SPOT images of

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0099-1112/87/5303–301$02.25/0

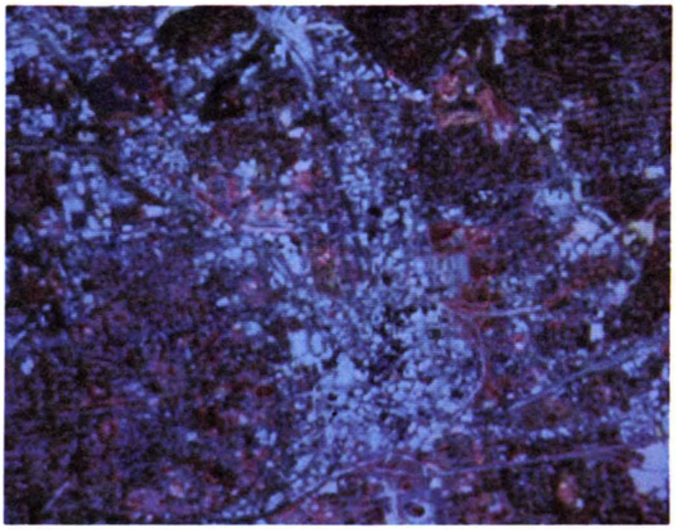

FIG. 1. False color Landsat-5 TM image of Atlanta, Georgia recorded in April 1985 (band 2 = blue, band 3 = green, band 4 = red). Image pixel size is 28.5 m.

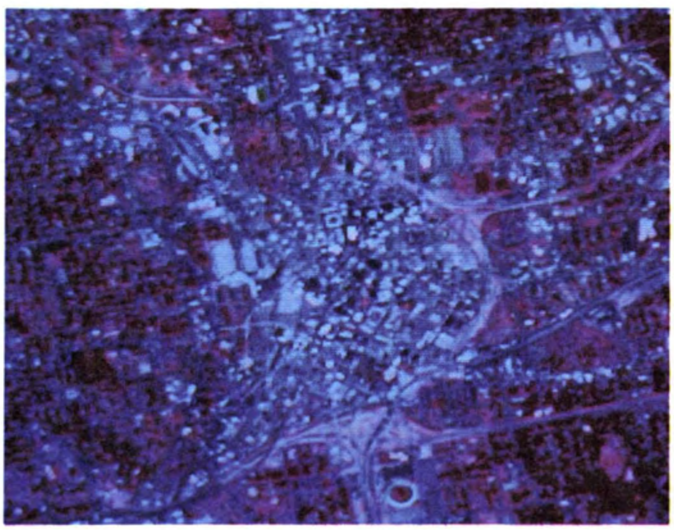

FIG. 2. False color SPOT-1 image of Atlanta, Georgia recorded in May 1986 (band XS1 = blue, band XS2 = green, band XS3 = red). Image pixel size is 20 m.

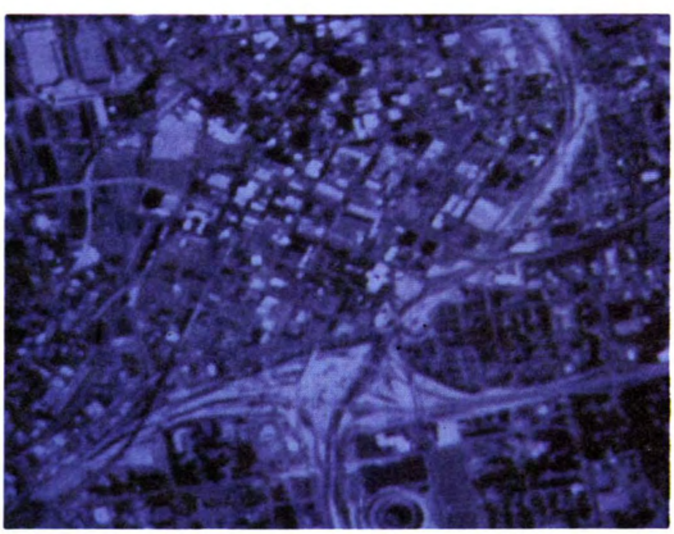

FIG. 3. SPOT-1 panchromatic reference image of Atlanta, Georgia. At 10-m resolution, only one-fourth the area of Figure 2 is displayed.

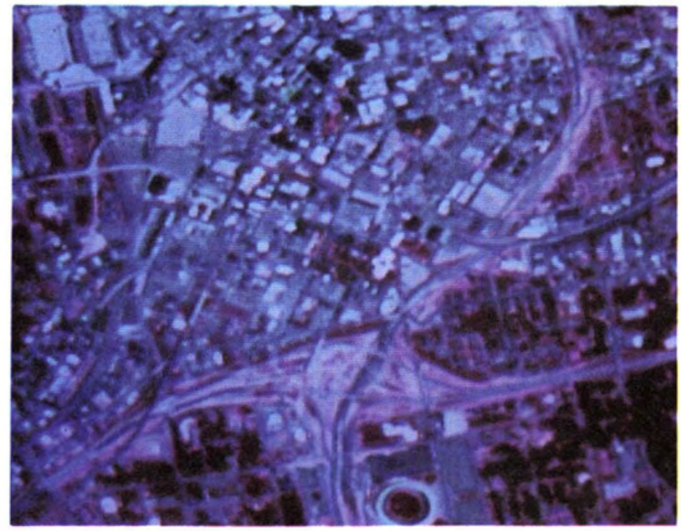

FIG. 4. False color composite image of the merged multiresolution SPOT-1 panchromatic and multispectral bands. Image pixel size is 10 m. The spatial and spectral resolution properties of the SPOT-1 data are retained in the merged image.

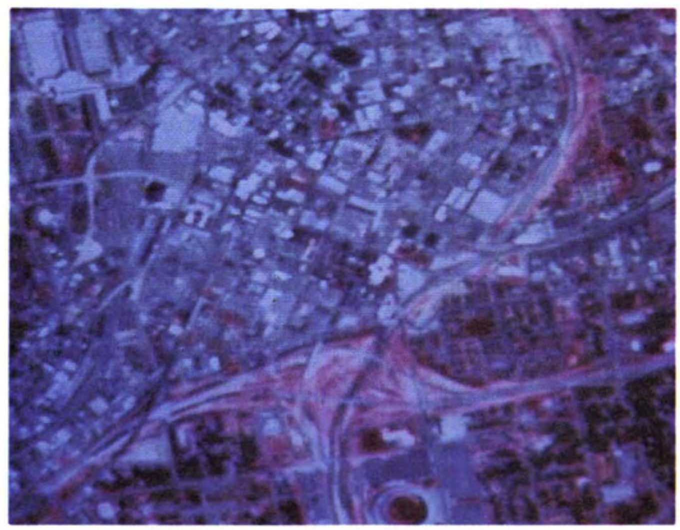

FIG. 5. False color composite image of the Landsat-5 TM, bands 2, 3, and 4, and the SPOT-1 panchromatic band. Image pixel size is 10 m. The interpretability of this multisensor, multiresolution, multispectral, multitemporal image is comparable to the merged SPOT-1 image in Figure 4.

FIG. 6. False color composite image of the Landsat-5 TM infrared bands (bands 4, 5, and 7) and the SPOT-1 panchromatic band. Image pixel size is 10 m. This merged image display indicates that the SPOT-1 panchromatic band can be successfully used to enhance the interpretability of the Landsat TM infrared bands.

TABLE 1. CHARACTERISTICS OF THE SPOT-1 AND LANDSAT-5 IMAGE DATA BASE

Sensor	Recording Date (WRS-Coordinates)	Band	Wavelength Interval (μm)	Pixel (m)
SPOT-1 HRV	05/04/86	P	0.50–0.75	10
	(K611J282)	XS1	0.50–0.59	20
		XS2	0.61–0.68	20
		XS3	0.79–0.89	20
Landsat-5 TM	04/04/85	1	0.45–0.52	28.5
	(P19R37)	2	0.52–0.62	28.5
		3	0.63–0.69	28.5
		4	0.76–0.90	28.5
		5	1.55–1.75	28.5
		7	2.08–2.35	28.5

the Chernobyl reactor site for the cover of the October 1986 issue of *Photogrammetric Engineering and Remote Sensing*.

With the IHS method, three selected bands of the registered SPOT HRV and Landsat TM multispectral data are first transformed into the IHS domain. The SPOT panchromatic reference image DNs are then substituted for the DNs of the intensity component, and the data are transformed back to the red-green-blue (RGB) color domain. The resulting composite SPOT and SPOT-TM images shown in Figures 4 to 6 are of similar spatial resolution to the panchromatic reference image, yet provide excellent spectral discrimination of natural and cultural features in the urban environment.

CONCLUSION

Striking improvements in the quality of SPOT-1 and Landsat-5 TM multispectral images of 20-m and 28.5-m pixel resolution can be realized by using an IHS algorithm to merge the individual multispectral bands with a SPOT-1 panchromatic reference image of 10-m resolution. The resulting false color composites have spatial resolution properties similar to those of the reference panchromatic image, yet retain the spectral discrimination qualities of the original multispectral data set. Thus, it is entirely feasible to establish layered digital image data bases from which either true or false color multisensor, multiresolution, multitemporal images of enhanced quality can be generated by digital image processing techniques. Such products will prove useful to scientists seeking to maximize the amount of information extracted from satellite image data, to photogrammetrists faced with the revision of outdated maps of developing countries, and to cartographers involved in the preparation of image maps of optimum quality.

ACKNOWLEDGMENTS

SPOT image data are copyrighted ((c) 1986) by the Centre National d'Etudes Spatiales, Toulouse, France, and distributed in the United States by SPOT Image Corporation, Reston, Virginia.

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