EDGE-BASED IMAGE REGISTRATION

Thomas C. Henderson
Institut National de Recherche en Informatique
et en Automatique (INRIA)
Domaine de Voluceau - Rocquencourt
B.P. 105, 78153 Le Chesnay, France

Ernst Triendl and Rudolf Winter
Deutsche Forschungs- und Versuchsanstalt
für Luft- und Raumfahrt (DFVLR)
8031 Wessling, W. Germany

INTRODUCTION

The standard method for geometric registration of images consists of selecting control points in the two images and computing the correlation maximum of small subimages containing the control points. Our goal is to achieve a model-guided correlation of control points for the analysis of multi-temporal and multi-source data. The direct correlation of control areas for registration will be supplimented by comparison of descriptions of elementary objects, e.g., drawn lines, borders and edges whose positions are known with subpixel accuracy. With the help of such model-guided correlation, images of various types, e.g., photographs and drawings, can be registered.

Within the framework of the DIBIAS system (the DFVLR image processing system), the goals attained so far include:
- model development:
(1) an optimizing edge detector has been analyzed for suitability within a registration system as a basis for edge modeling,
(2) an algorithm has been developed for edge comparisons based on the edge descriptions provided by the edge detector, and
(3) the Hough shape transform model has been incorporated;
- software development:
(1) the supporting software frame, i.e;, a basic image processing system (called DIBIAS), has been developed,
(2) a registration system exists which allows linear or quadratic transforms and nearest neighbor resampling,
(3) the normalized cross-correlation is available for both gray level images and edge descriptor images,
(4) the edge detection modules produce edge descriptions with subpixel accuracy, and
(5) modules exist for defining and detecting shapes composed of edge elements.

Geometric registration is a three-step process consisting of control point correspondence, equation determination and resampling (see Pratt [1] for an introduction to image registration). The last two steps have rather standard implementation in our system (module GEOKOR), with provision for either linear or quadratic transformation equations and with nearest neighbor resampling. Our work has focused on the control point correspondence problem.

Control point selection (module SELECT) involves choosing pairs of corresponding points in the two images to be registered. This can be done interactively, i.e., the user specifies point pairs, or by means of an automatic matching operation performed between the image and templates in a control point data base (e.g., pixel arrays and shape models). The matching operation can be performed by one of several standard techniques including normalized cross-correlation, FFT cross-correlation or sequential similarity detection.

An area under active research is the use of edges and shapes in images for geometric registration. Andrus investigated the use of binary edge maps for image registration [2]; Wong and Hall [3] describe how edges can be used to register optical and radar imagery. Svedlow et al [4] compared the use of several similarity measures on edge features for image registration and concluded that edge extraction contributed significantly to the success of their image registration system.

The major flaw in all of these edge-based registration approaches is that only the appearance of the edge or the likelihood of the edge is compared between images. A more complete approach is to actually compare the edges themselves at a symbolic level. For example, Price and Reddy [5] use this approach in a general purpose change detection system, but the registration takes place at the level of objects in the images and not at the pixel level.

We present a method for describing edge elements of an image to subpixel accuracy,a measure of similarity for comparing two edge images, and finally, a model for representing and recognizing shapes based on these edge elements. The corresponding software exists for all these techniques and is available as separate modules within the image processing system at DFVLR.

EDGE DETECTION

The optimizing edge detector developed by Triendl [6] is used to produce a complete description of each edge element in the image; that is, each pixel has a triple (PHI,RAD,COR) associated with it, where PHI is the edge orientation, RAD is the shortest distance from the center of the pixel to the edge, and COR is the edge correlation value or likelihood (rather than just a likelihood). Consider the two channel LANDSAT image shown in Figure 1.

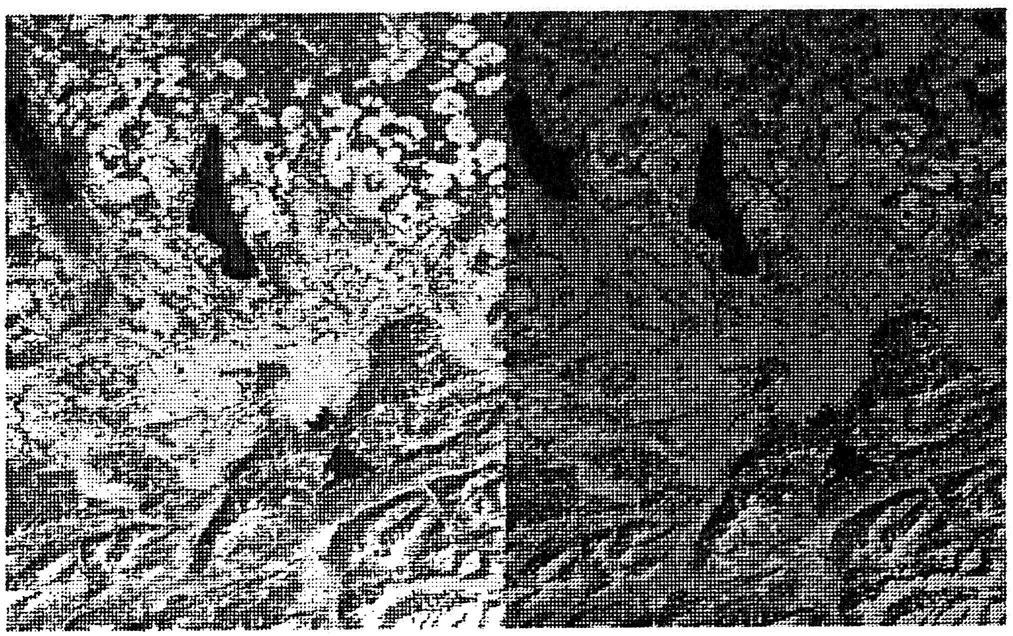

Figure 1. Two channel LANDSAT image of size 1000x810 pixels.

Given a k-channel image as input, the module EDGING produces a 3k-channel output image, 3 channels of output per input channel. These three channels contain the (PHI,RAD,COR) descriptor for each pixel in the channel. Figure 2 shows the 6-channel output for a part of the LANDSAT image (called LANDSAT hereafter).

Usually, one does not care to see the edge triple image, but rather an edge appearance image. The module EDGOUT produces such an image. Moreover, since the edge descriptors are at subpixel accuracy, the edge appearance image can be shown at any resolution. Figures 3 and 4 show the edges of LANDSAT at resolutions 0.5 and 0.2 of a pixel.

Two modules exist for grouping edge responses across channels and spatially. The first of these is EDGGRP which is the basic edge grouping operation and is performed across channels. Each spatial location in the image has (possibly) several edge descriptors

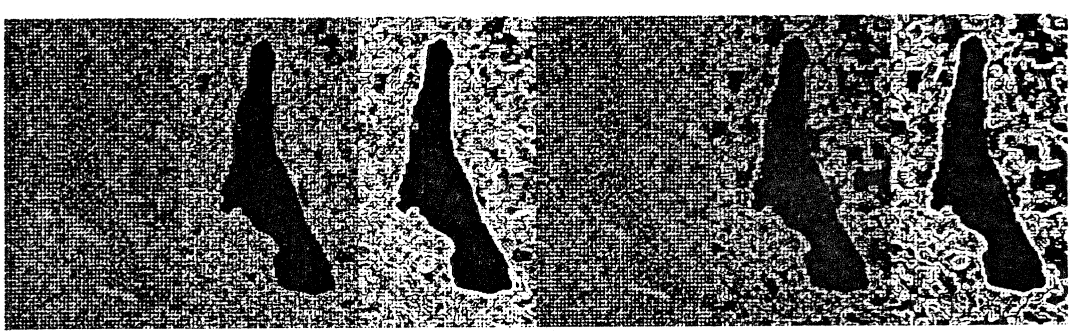

Figure 2. Edge descriptors for LANDSAT.

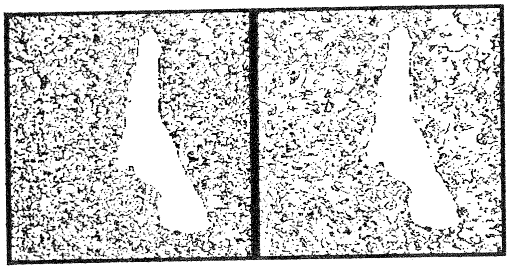

Figure 3. LANDSAT (Scale 0.5)

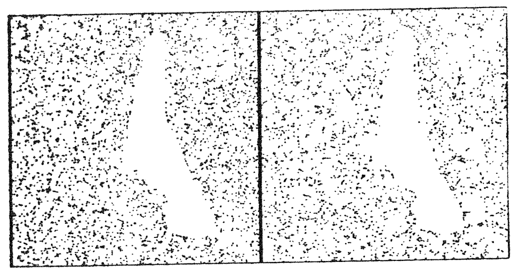

Figure 4. LANDSAT (Scale 0.2)

associated with it (from the different channels in the original image). If the PHI and RAD elements of two descriptors are close enough, and their COR values high enough, then the two are grouped into one edge descriptor with the more likely edge more heavily weighted. EDGGRP produces up to two distinct edge descriptors for each spatial location, and the more likely edge is in channels one to three. Once the edges have been channel grouped, they can be grouped spatially. This step is performed by EDGSPG and results in more compact and continuous edges. At each spatial location of the image, an n by n window of edge descriptors is grouped to produce an edge descriptor at the pixel in question. The grouping operation proceeds similarly to the channel grouping. Figures 5 and 6 show the result of channel grouping and spatial grouping, respectively, on LANDSAT.

EDGE SIMILARITY MEASURES

The module KORREL produces a pixel-wise correlation on either gray level images or edge images. For gray level images, the normalized cross-correlation is computed. However, for edge images, an

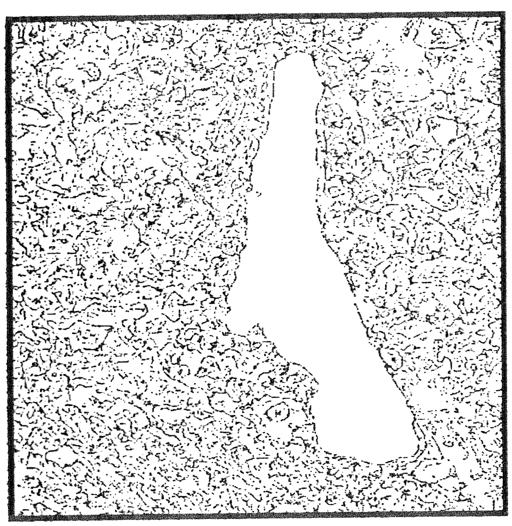

Figure 5. Channel grouping.

Figure 6. Spatial grouping.

alternative method has been developed. Let w be the window of the search area to be correlated with t, the template of size m by n. The correlation coefficient of the window is computed as the average of the pixel similarity responses. This pixel similarity response is a function of three values which measure the similarity of the orientations, radii and edge qualities. Given A, B and C, the orientation, radius and edge quality similarity values (e.g., the absolute values of the differences of the triples at two pixels), the pixel similarity response is equal to $w_1*A+w_2*B+w_3*C$, where the w_i's weight the contribution of each coefficient. The weighting values of $w_1=0.75$, $w_2=0.20$ and $w_3=0.05$ give good results and reflect the fact that angle is the most important criterion, radius next and edge quality the least important.

SHAPE-BASED IMAGE REGISTRATION

When the images to be registered do not provide sufficient information to use conventional registration methods, e.g., the difference in scale of the images is unkown, or an image is too inaccurate, for example, hand drawn, then shape information can be extracted and used to make the correspondence between images.

The position-invariant Hough shape transform (see Davis and Yam [7]) is used to recognize shapes in satellite images. The technique was originally used for object tracking, but has been installed in our registration system as a shape detector. Two modules exist which define and detect shapes. These two modules are called MAKEMU and GEOMUS and use the edge triples from EDGING as shape elements. Figure 7 shows the edge elements of LANDSAT

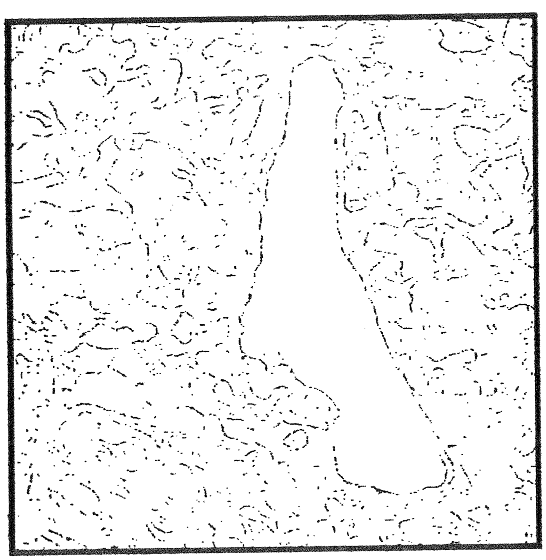

Figure 7. Shape elements for LANDSAT.

produced with these modules. These edge elements are those whose likelihoods are very high (above 86 percent) and thus should always be produced by the edge detector.

CONCLUSION

The component modules of a comprehensive image registration system have been described. This system provides, in addition to the standard interactive and gray level correlation techniques, the means for using edge elements at individual pixels or assembled into shapes for control point selection and to solve the control point correspondence problem. The application of these modules to a LANDSAT image has been shown. A detailed discussion of these techniques and a registration experiment are given in Henderson et al [8].

ACKNOWLEDGEMENTS

We would like to thank the members of the DIBIAS group at DFVLR for their support. This research was funded in part by the Deutsche Forschungsgemeinschaft.

REFERENCES

1. Pratt, W. (1978) Digital Image Processing, John Wiley and Sons, New York, pp. 551-567.
2. Andrus, J., C. Campbell and R. Jayroe (1975) "Digital Image Registration Method Using Boundary Maps," IEEE Trans. on Comp. Vol. C-19, Sept., pp. 935-940.
3. Wong, R. and E. Hall (1979) "Performance Comparison of Scene Matching Techniques," IEEE Trans. on Pattern Anal. Mach. Intel. Vol. PAMI-1, no. 3, July, pp. 325-330.
4. Svedlow, M., C. McGillem and P. Anuta (1978) "Image Registration: Similarity Measure and Preprocessing Method Comparisons," IEEE Trans. on Aero. and Elec. Systems, Vol. AES-14, no. 1, pp. 141-149.
5. Price, K. and R. Reddy (1979) "Matching Segments of Images," IEEE Trans. on Pattern Anal. Mach. Intel., Vol. PAMI-1, no. 1, pp. 110-116.
6. Triendl, E. (1978) "How to Get the Edge into the Map," Proc. Inter. Joint Conf. on Patt. Recog., Japan, pp. 946-950.
7. Davis, L. and S. Yam (1980) "A Generalized Hough-like Transformation for Shape Recognition," U. of Texas, TR-134, Feb.
8. Henderson, T., E. Triendl and R. Winter (1980) "Model-Guided Geometric Registration," DFVLR Tech. Report NE-NT-D-80-36, Sept.