AN EVALUATION OF A MICROPROCESSOR BASED REMOTE IMAGE PROCESSING SYSTEM FOR ANALYSIS AND DISPLAY OF CARTOGRAPHIC DATA

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ABSTRACT

The Earth Resources Observation Systems (EROS) Data Center has developed a prototype Remote Image Processing System (RIPS) which utilizes off-the-shelf microprocessor technology and a color raster refresh display. Although it was designed primarily for low cost interactive image analysis, the system is being evaluated for use in cartographic analysis and display tasks.

Similarities and differences between RIPS-type raster refresh display systems, and minicomputer-driven graphics terminals which are commonly used to display cartographic data were investigated. It was determined that many traditional differences have been eliminated because (a) new cartographic analysis systems are often configured with raster refresh displays, and (b) image analysis systems have been programmed to accept and display cartographic data.

In order to evaluate the applicability of RIPS for cartographic analysis tasks, representative spatial analysis algorithms were performed on RIPS and compared to a minicomputer with a graphics display. Tests included routines for point-in-polygon matching, line drawing or rasterization, spatial filtering, and image classification. Results indicate that many functions that have traditionally been relegated to larger machines can now be efficiently performed by microprocessor systems.

Based on the results of these tests, optional RIPS configurations were defined for increasing spatial resolution (at the expense of spectral resolution), and for substituting faster winchester type disk drives for lower cost floppy disks. Future versions of RIPS may also incorporate a coordinate digitizer and an electrostatic plotter.

INTRODUCTION

The EROS Data Center has developed a prototype microprocessor system for conducting interactive image analysis tasks using a color raster refresh display. Over the last two years, system software and applications demonstration programs have been written and tested on the microprocessor.

Based on this experience, it was determined that the system was capable of performing selected spatial analysis tasks which utilize cartographic data as input or which result in cartographic output. It was decided to test the system by performing various cartographic analysis and display tasks, and to compare its performance with other systems which are in operational use at the EROS Data Center.

THE RIPS PROJECT

Since 1974, EROS's Data Analysis Laboratory has been used extensively for training and cooperative demonstration project work. Although many users have conducted successful pilot projects, some were unable to make operational use of digital techniques because (a) image processing systems typically cost over $500,000, and (b) interactive processing requires a resource analyst with field experience as well as digital processing skills. High costs dictated a centralized facility, but the need for extensive user/system interaction made it necessary to locate the system near the project study area.

A microprocessor system was envisioned which would be able to display a "full color" raster image with resolution suitable for detailed analysis. It would also allow the user to perform interactive tasks on-site, via an image display and a terminal (Waltz and Wagner, 1981).

The prototype system was based on a Z80 microprocessor (a common 8-bit CPU), an S100 Bus (for ease of interface to peripherals), a 256 x 240 x 12-bit color display (4 bits each of red, green, and blue, or 8 bits of black and white), and an RS232C type terminal. A list of these "off-the-shelf" components is available (Wagner, 1981).

Design goals stressed simplicity and low cost, and included the following:

(a) The system was to communicate with a host computer system (including image transfers) at 1200 baud using a standard telephone line (Wagner, 1981).

(b) The system was to be programmable on-site, and would have sufficient file handling and display utility routines to allow applications programs to be easily written.

(c) The system would be capable of displaying continuous color (4096 colors) to support display of raw and enhanced digital multispectral scanner imagery such as digital Landsat data.

When the first system was built, it became clear that any microprocessor capable of creating a minimal (but adequate) display was also capable of much more. Programs which could be run on the RIPS also had the advantage of a dedicated processor, and avoided the telephone line bottleneck (Note: If supported by a host computer, RIPS itself is not limited to 1200 baud. The purpose of this limitation was to utilize readily available telephone lines and equipment and to place importance on data compression and efficient image handling protocol.)

EROS has built three RIPS stations to date, and has a procurement pending for six to twelve more (the additional six are options which may be exercised by EROS or by other Department of Interior agencies). In addition to supporting project work, the RIPS will also be used in a digital classroom planned for EROS's training courses. The RIPS stations will be relatively portable with the ability to be packed as three separate units for transport (Figure 1). The pending procurement is based on a functional

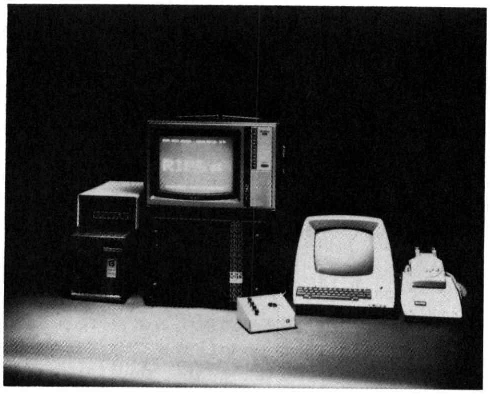


Figure 1. The RIPS System

specification, and is being competitively bid in the hope that private sector involvement will be stimulated to create further efficiencies through repackaging, optimization, and extension of the basic design.

One of the most significant contributions of the RIPS design project has been the development of a simple but elegant protocol for handling image data over standard telephone lines (Nady, 1981). Also, a prototype applications software system, for typical image processing functions which are used for analysis of remotely sensed data, has been developed to demonstrate and test the RIPS (Holm, 1981).

Comparison of RIPS With Traditional Cartographic Display Devices

Several technological advances have occurred in recent years which have improved raster refresh displays and lowered costs dramatically. For example, RAM memories are commonly employed in newer cartographic displays to allow for fast access, selective erase, and hardware zoom and roam features.

Most cartographic display terminals are configured with relatively high resolution (512^2 or 1024^2), corresponding to the address space available in the older technology storage tubes. As most color CRT's are not capable of resolving more than about 600 discrete samples per scan, a special, expensive CRT is needed to properly appreciate 1024^2 resolution.

RIPS, on the other hand, is presently limited to a 256 x 256 display with the spatial restriction stemming not so much from the cost of additional RAM, but rather from the time penalty incurred when transferring a 512^2 image over a standard telephone line. For example, a 512^2 image takes four times longer to transfer, and provides only a marginal improvement in the visual display. Image compression techniques can improve on the transfer time, but do not eliminate this problem.

The RIPS has an extended 12-bit spectral resolution (4096 colors) compared to from one to four bits resolution (up to 16 colors) in typical cartographic displays. This difference is important, and should be considered in selecting the best system for a given set of applications. For example, a high resolution monochomatic display is best for displaying intricate line work, while RIPS might be preferred for displaying line work superimposed on a continuous raster image such as topography, aeromagnetics, or a multispectral scanner image (for example, Landsat MSS or TM).

1) Display of Vector Data

RIPS was designed as a display device for a regular grid of data, so a program was written to demonstrate its capability to convert cartographic line work to a raster and then display it. The test consisted of displaying the line work superimposed on a false color composite background image (Figure 2). The lines were

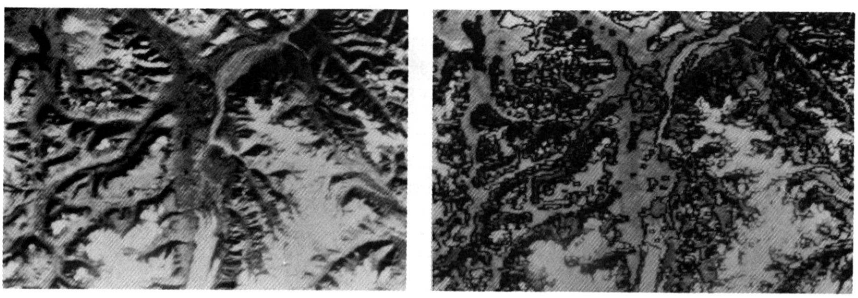


Figure 2. Landsat MSS display (left). Line drawing (right) superimposed on display.

extracted from a Landsat image using an unsupervised spatial/spectral clustering algorithm (Jenson and Bryant, 1981) and converted to topologically structured edges (Nichols, 1981). RIPS was then used to (a) read the coordinate pairs from disk, (b) convert the coordinates to screen relative locations, and (c) rasterize (draw a line) between each point pair. The minicomputer system utilized a standard terminal control system (TCS) to draw vectors on a storage CRT (Figure 2).

Surprisingly, RIPS was able to rasterize and display the lines over seven times faster than the minicomputer could draw them on a storage CRT, because the minicomputer output was limited by a 2400 baud terminal port (which is a typical limitation on a general purpose machine and was the fastest terminal port supported by the system).

2) Spatial Filtering

Spatial filtering was tested to demonstrate the potential for processing local spatial operators (for example, topographic slopes from terrain elevation, spatial diversity or texture from Landsat data, or first and second derivatives from gridded geophysical data). A general purpose convolution filter algorithm is currently implemented which was determined to be the functional equivalent to these more specialized examples.

The convolution test is a test of the computational horsepower of the RIPS, as it requires nine multiplies, nine adds, and one divide for each of the 61,440 pixels.

In this case, the RIPS shows itself to be adequate for a 3 x 3 neighborhood operation on relatively small areas. The run time for this program was 110 seconds, which is tolerable for most interactive analysis tasks. In comparison, an IDIMS (HP3000) system processed the same area in 72 seconds. For larger areas however, (larger than 256 x 240 pixels), a larger system would be clearly advantageous. With a special purpose array processor, the IDIMS execution time was reduced to 11 seconds. The need for such a processor may be justified for very large images (for example, an MSS scene of 3548 x 2983 pixels, or an RBV image of 5322^2 pixels), or when fast iteration or execution turnaround is needed as in real time parameter adjustment. The output from RIPS (Figure 3) is functionally identical to the IDIMS output.

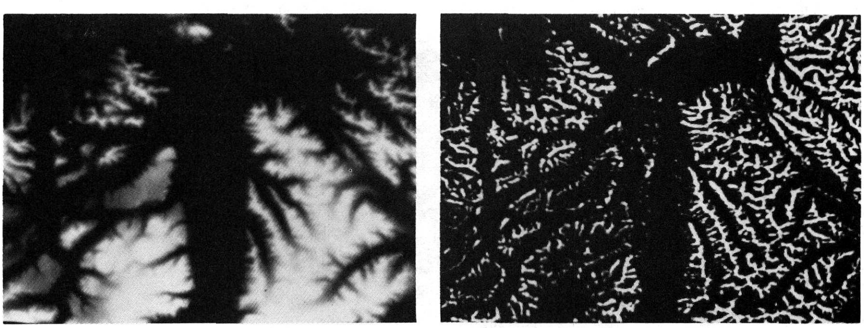


Figure 3. Digital Elevation Model display (left). Convolution filter (Laplacian) applied to elevation (right).

3) Point in Polygon

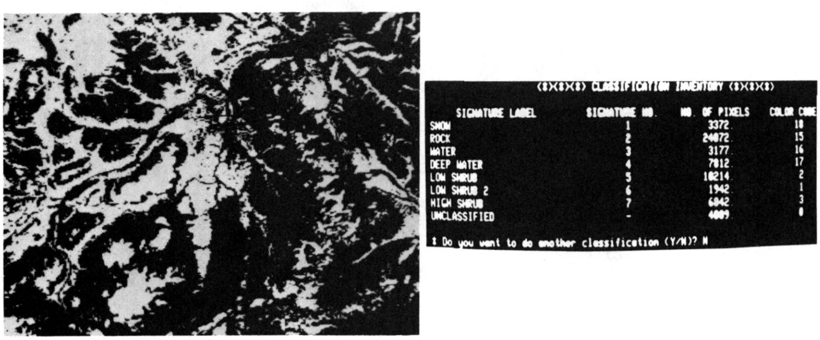
In addition to display of vector data, certain calculations are performed regularly on point, line, and polygon data. The point-in-polygon algorithm is such a function, and is used in connection with polygon overlay operations and other tests for containment. While the RIPS might not be appropriate for a generalized polygon overlay, it is concievable that other containment tests will be needed. For example, a point-in-polygon test can be used to validate the mathematical centroid as an interior point for purposes of labeling plotted polygons.

This is a simple test of the CPU's ability to perform integer arithmetic and logical tests. RIPS is slower than its minicomputer counterpart, but adequate for all but large data base overlay tasks.

4) Image Classification

Image classification is not generally considered to be a cartographic analysis task, but is discussed in this paper because (a) classification is the means for converting radiometric values to information classes which can be used to generate choropleth maps, and (b) the classifier which is employed on RIPS is optimized for a microprocessor and illustrates some fundamental differences in approach. In this test, the minicomputer uses a maximum likelihood classifier algorithm which requires calculation of a quadratic equation for all possible classes of each pixel. For a large study area, or a large number of potential classes, this calculation is potentially quite slow. Classification is one of the more challenging of image processing problems, and can require the use of a bigger (and faster) machine or parallel computing. Alternatively, a simpler decision rule can be employed.

On RIPS, a classifier was implemented based on a minimum (transformed) distance to the means decision rule (Holm, 1981). The execution time of 598 seconds was comparable to the maximum likelihood classifier on a much larger and faster CPU (528 seconds). The RIPS was able to classify an image (Figure 4) in a



<*X*X*> CLASSIFICATION INVENTORY <*X*X*>

SIGNATURE LABEL	SIGNATURE NO.	NO. OF PIXELS	COLOR CODE
SNOW	1	3372.	18
ROCK	2	24072.	15
WATER	3	3177.	16
DEEP WATER	4	7812.	17
LOW SHRUB	5	10214.	2
LOW SHRUB 2	6	1942.	1
HIGH SHRUB	7	6042.	3
UNCLASSIFIED	-	4009.	0

* Do you want to do another classification (Y/N)? N

Figure 4. Multispectral classification result (Suits classifier).

reasonable time because the Holm implementation of the Suits decision rule can be performed using integer arithmetic and is optimized for the RIPS.

Results have not been checked for accuracy, but a qualitative comparison indicates that this classifier has promise and that further applications testing is appropriate.

5) Zone Search

Some applications require that distance to points, lines, or areas be calculated. In image processing, this function can be computationally expensive, since distances would be calculated between every pixel and all the feature(s) being tested. A large computer (B6700) implementation of this algorithm has been used at EROS for this purpose. In one project, a minimum distance search was run on a (raster) road network to determine pixels within a half kilometer (approximately 17 cell) radius of a road (Miller, W. and others, 1981). A total of over 52 hours of computer time was required for a 1800 x 2200 study area!

On RIPS, several simplifying changes were made. First, rather than calculate distances for each cell, the features (points, lines, areas) are preserved as entities in the image and the searching becomes a function of the number of features rather than all the pixels with features present (Miller, S., 1981). Also, the output is changed to a binary value (in/out) rather than a calculated distance, and utilized the random access memory of the RIPS display. A 10 cell radius zone search which executed in 141 seconds is shown in Figure 5.

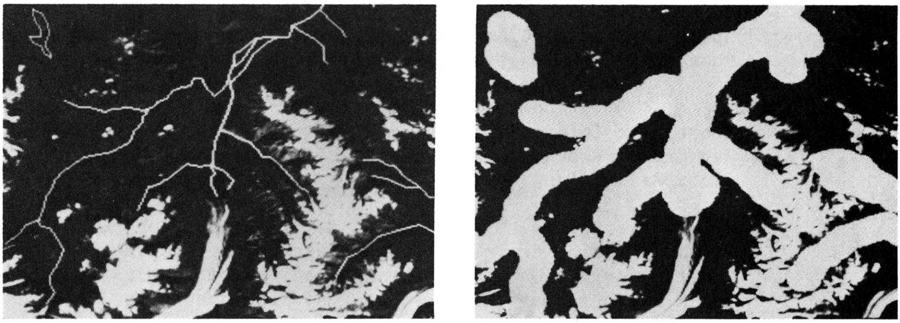


Figure 5. Surficial Hydrology network superimposed on Landsat MSS (left). Result of zone search (right) showing areas within 2.5 km radius of water.

SUMMARY AND CONCLUSIONS

Several tests run on the RIPS have shown that it is capable of performing spatial analysis tasks and displaying cartographic data. On the basis of these tests and others which have been performed as proofs-of-concept, development in several areas is anticipated. EROS and other RIPS cooperators will be developing applications software and extending the hardware to include a) a coordinate digitizer input capability, b) a vidicon scanner input, and c) a major software upgrade with extended image size and format handling, program-to-program communication, and vector handling primatives.

Also, under consideration are the addition of a 16-bit microprocessor, winchester disks (which are faster and have a larger storage capacity), and configuration of a 512^2 display for selected applications.

RIPS has been linked to two host computers to date, and it will likely be linked to two more machines in the near future. As software is written to utilize this lower cost technology, it is anticipated that many RIPS and RIPS-like systems will be custom tailored for image processing, cartographic entry and output, spatial analysis, and teaching applications.

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