Seeing Double

New generation of map image-processing systems integrates raster and vector technologies

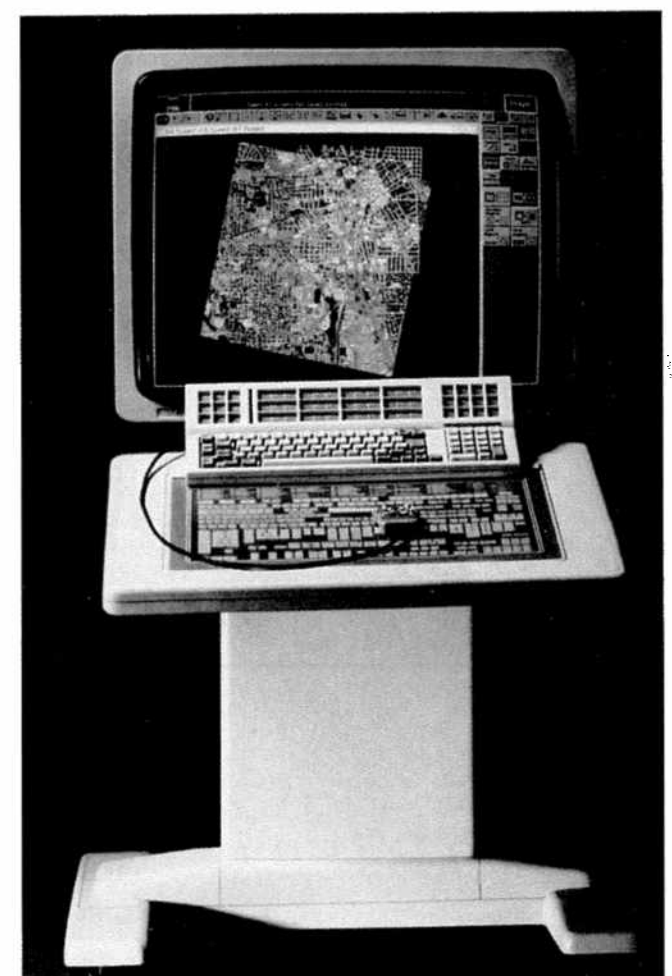
By Michael L. Sena

The newest wave of computer-aided mapping and geographic information systems (GISes) will soon begin shipping in volume. And when they do, mapmakers will see double; that is, they'll be seeing both raster data and vector representations of geographic databases on the same display screen. This results in a faster, more accurate data-capture method and improved functionality over the traditional system architecture, which is focused on processing one type of data (raster *or* vector).

In the past, map producers had to choose either a raster or vector system when automating their production processes, and many opted to purchase one of each: a raster system to manage and analyze remotely sensed data or orthophoto images, scan existing maps, and plot printer-ready films; and a vector system to digitize points, polygons, and lines, enter text, assign database attributes, and analyze spatial relationships.

Now, many established vendors of raster GISes have added vector capabilities to their systems, and vice versa. These Raster-Vector/Map Image-Processing (RV/MIP) systems offer many advantages over single-function systems.

First, the cost of preparing detailed databases on these systems is low. This results from using powerful hardware that is less expensive than the mainframes and minicomputers required previously; integrating off-the-shelf, industry-standard software; and adding to the supply of digital databases, such as the US Geological Survey's (USGS) Digital Line Graph files or Etak's street map files.



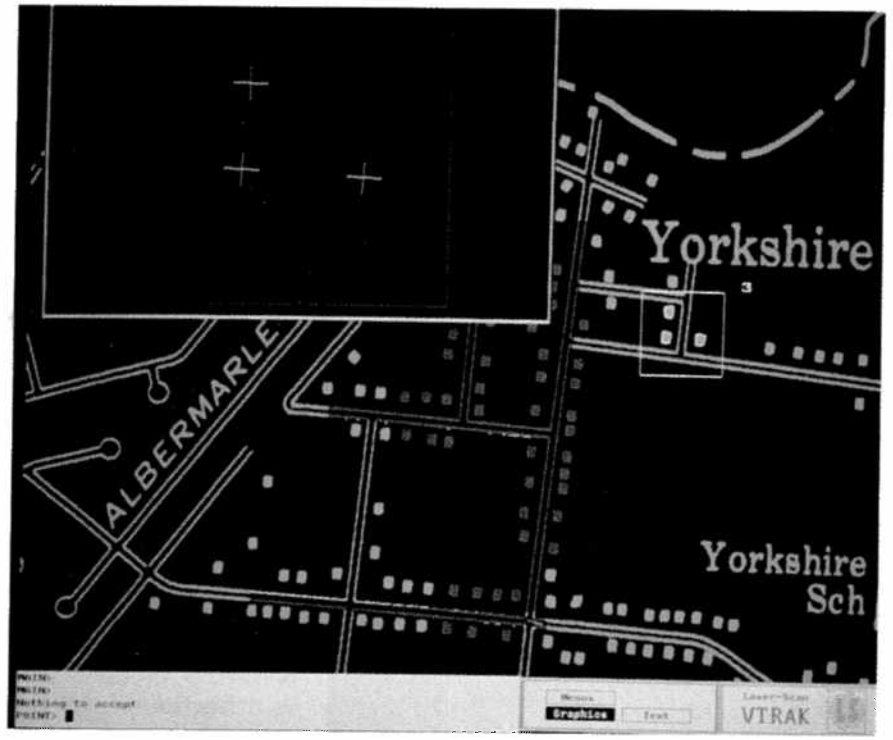
Intergraph's Interpro 27-inch color workstation displays almost an entire USGS quad sheet at 1-to-1 scale.

These systems also provide greater accuracy and precision because they use as source material up-to-date aerial photography and satellite imagery instead of existing, manually produced maps.

Finally, because their hardware platforms and software are optimized to process large data sets, RV/MIPS produce maps in a fraction of the time required by single-function systems. On-screen digitizing capabilities and specially designed screen icons and menus also help increase speed, and the use of imagery reduces the time spent researching sources and compiling digitizing base materials.

For centuries, mapmakers have searched for better, faster, and less-expensive ways to represent and model the curved, 3D world on a flat, 2D surface. While graphics systems offer the only available means to create such a model, until now they've been unable to satisfy more than two of three main objectives—high quality (accuracy and precision), low price, and large quantity (expansive area of coverage)—at one time on any given project. Achieving high quality over large areas is expensive, achieving high quality inexpensively only allows you to map small areas, and mapping large areas inexpensively sacrifices quality.

One reason for this is that mapmakers have relied on existing, manually produced maps and map compilations as source material for



The green portion of this image represents a scanned USGS 1:24,000 quad sheet, and the red represents what has already been converted to vector data. The close-up window shows the center points and orientation of three buildings that have been recognized as oriented symbols. (Courtesy Laser-Scan Labs.)

digital conversion, and these maps are usually inaccurate and incomplete. For example, a large number of map documents covers each country in the world; the US alone has 55,000 USGS 1:24,000 Topographic Series map sheets, each containing a fraction of the feature data required to make a complete model. While these maps display roads and generalized land cover, hydrography, and other features, they do not contain, for example, parcel boundaries and underground utilities.

Also, if you collected all available maps with all features for any area, you'd probably find they

Michael L. Sena is president of Matrix Consultants (Boston).

MAPPING

were created at varying scales and inconsistent levels of geographic precision—in fact, some areas have been mapped in detail, and others haven't been mapped at all.

The most accurate sources of land-based features are up-to-date orthophoto maps and Landsat Thematic Mapper (TM) and SPOT Panchromatic, or Multispectral Scanner (MSS), images. While MSS images have a digital spot size or ground equivalent of 80 meters (too coarse to observe roads and buildings in detail), Landsat TM images, with a pixel equivalent of 30 meters, are useful for viewing areas at map scales of up to one inch to a mile. And SPOT I provides wide area coverage at a level of detail high enough to let mapmakers begin to distinguish roads and buildings.

But highly accurate data alone does not make a consistent and accurate map. The major impediment to widespread use of remotely sensed data combined with vector mapping and GIS technology has been a lack of properly designed hardware and application-specific software.

While map image-processing systems introduced over 10 years ago were powerful, they were mainly used to perform visual analysis and Boolean operations and to produce enhanced prints of remotely sensed data. They weren't considered useful for detailed database production, and they weren't successfully applied to cartographic and film production applications.

For example, Scitex (Bedford, MA) has been combining raster and vector images on the display screen for almost 10 years. Users of the Scitex Response 280 Cartographic System have been able to scan existing maps in color with the system's Super Scanner and open window masks and linework in black and white with the system's ELP Laser Scanner. The R280 also lets users import vector data in SIF, Gerber, DXF, or other XY-coordinate formats and convert the data into virtual map images (pictures of what the map will look like when printed) in raster form. Using the raster image as a backdrop, users can then display and edit vector coordinates and connecting lines. Raster data can also be converted to R280 format and overlayed with vector data (both can be interactively edited), and rasterized vector data and scanned and remotely sensed data can be combined and plotted as screened, printer-ready films in sizes up to 1-by-1.7 meters.

When Scitex introduced these possibilities, the system and its functions were considered unique and powerful. Some functions, such as virtual map symbolization and the ability to plot screened film, still exceed the capabilities available on any other system. Nevertheless, the R280 has always had limitations, and Scitex has done little to build on its early lead.

For instance, the R280 can display only 12 colors from 256 in a 312-by-256-pixel resolution. Furthermore, the Super Scanner (no longer in production) can recognize only 12 colors at a single pass, and vector editing consists of rudimentary commands. The R280's CPU is an HP 1000 mini with 64K of

RV/MIPS—What's Available Now

Several mapping/GIS vendors have recently provided mapmakers with RV/MIP systems:

- Intergraph's (Huntsville, AL) TIGRIS (Topologically Integrated Geographic and Resource Information System) Imager is a multispectral image-processing system that combines in a single data set topologically structured vector data and raster image data. Users can reference, manipulate, edit, and analyze the data on a single standard Intergraph 240, 340, or 360 workstation.
- U.S. Mapping Co.'s (Stone Mountain, GA) '386-based Image Mapper uses Intergraph's MicroStation software as the vector base, Media Cybernetics' Dr. Halo for raster editing, and a proprietary package for image processing, coregistration of raster and vector images, and output. Image Mapper transfers raster and vector data to either vector systems or raster output systems such as the R280.
- Erdas (Atlanta, GA) and ESRI (Redlands, CA) teamed up to produce the Erdas-Arc/Info Link. Available for workstations and PCs, the Link lets users display Arc/Info coverages over Erdas color digital images. Erdas image-processing functions extend the Link's capabilities to include integrated map/image display, a common coordinate system, vector/raster conversion, edge enhancement and smoothing, and orthophoto map generation.
- Terra-Mar Resource Information Services Inc. (Mountain View, CA) integrates raster and vector mapping on a single, low-cost workstation. Atlas* Draw and Atlas*Graphics from Strategic Locations Planning Inc. are incorporated into the system for interactive digitizing. Images can be output via low-res color or high-res laser plotters.
- Datarepro's (Stockholm, Sweden) RV/MIP system is designed for map publishing, database creation, and output. Autocad is used for vector input and editing. Datarepro built a user interface around Autocad for feature classification selection and coding. Vector data is sent to a Scitex system for rasterization and plotting.
- Laser-Scan Labs' (Reston, VA) Lasertrak is an operator-controlled, automatic line-following digitizer that converts scanned raster data into vector format, literally before the user's eyes. The new VTrak system puts the same functionality of the more expensive Lasertrak on a DEC Vaxstation.

While all these systems use a raster image from a scanned map, orthophoto, or remotely sensed data as a backdrop for on-screen digitizing, Laser-Scan's VTrak combines automatic line following of a scanned feature with periodic user intervention.

VTrak accepts scanned data from a variety of scanners. The user identifies the feature classification to be digitized and moves the tracking point to lock on the feature; VTrak then automatically digitizes the feature until it encounters another feature class, waiting for the operator to give it further instructions. The recorded vector data is topologically structured on-the-fly. As yet, VTrak does not address the problem of text recognition.

Both the Erdas-Arc/Info Link and TIGRIS provide tools for change detection and database updating. Erdas-Arc/Info is a hybrid of two vendors' systems: Erdas, which displays raster images, manipulates images for change detection, performs statistical analyses, and enhances certain features for editing; and Arc/Info, which digitizes over the raster image or displays previously digitized data on the image. On the workstation version, both packages can be active in their own window, and users can switch between them. On the PC version, the user exits one program and enters the other. In either case, the image remains displayed.

TIGRIS is impressive. It runs on Intergraph's Interpro workstation line, which was redesigned to provide a platform for raster/vector image processing. Intergraph integrates geometry, attribute data, and topology by building all TIGRIS subsystems on one platform with a consistent user interface and a single data structure.

Targeting Cartographers

Both Datarepro and U.S. Mapping Co. target cartographers with their products; U.S. Mapping's Image Mapper is also well-suited to large-scale facilities mapping conversion. Both systems take advantage of Scitex raster processing and plotting, and both use PC-based vector input and editing.

The main difference between them is that Datarepro rasterizes a scanned image on the PC. The software converts the digitized points and lines into correct line widths and specifications and turns the data into a virtual map image. Vector centerline data is sent to Scitex via SIF, and the data is rerasterized and plotted. This reduces or eliminates editing time on the Scitex and allows files to be transferred and plotted in batch mode.

Image Mapper converts the vector image to raster format using Intergraph's MicroStation commands but sends the rasterized image to Scitex as a Scitex Type 30 file (a raster pattern file that can be displayed, edited, and plotted on the ELP laser plotter). This means that what you see on the Image Mapper workstation is what you will get on the plotted Scitex film, with no vector data transfer, no need to establish line, text, and symbol font libraries in Scitex, and no time-consuming, vector-to-raster execution on the Scitex system. Currently, the only drawback to using Image Mapper as a Scitex workstation is its inability to define complex line patterns and intersection priorities on MicroStation, similar to what Scitex and Datarepro can do. If Intergraph or U.S. Mapping overcome this, map publishers will finally have a powerful alternative to the Scitex edit station. —*MS* memory, so all operations are executed from and to the system's disk, which is limited to 300M of on-line storage.

When the R280 was developed, the technology for capturing, storing, and manipulating large raster data sets was new. Only recently has the technology become available at a price that governmental and commercial users can afford.

John Dykstra, Intergraph's (Huntsville, AL) expert on map image processing, says that a system architecture focused on processing one type of data (raster or vector) does a relatively poor job of processing the other—vector manipulations perform a relatively large number of calculations on a small amount of data, while raster manipulations usually perform a relatively small number of calculations on large volumes of data.

A USGS Digital Line Graph file imported into Arc/Info is overlayed on a SPOT image processed by Erdas. The digitized vector data doesn't align with the actual location of the roadway—Arc/Info software is used to correct the alignment.

The link has been missing between vector-based GISes and systems designed for rapid spatial and spectral processing of raster data, and it's this missing link that the new generation of RV/MIP systems provides by truly integrating raster and vector technologies.

Integrated RV/MIPS must meet the following requirements:

• High Data Storage: A single SPOT scene measures 60-by-60 km when acquired from a vertical angle and usually requires one 6250- or two 1600bpi computer-compatible tapes for storage; the volume of data in a panchromatic scene varies from 36M to 104M; a three-band multispectral scene varies in volume from 27M to 78M; and a Landsat TM image contains up to 300M of data, while a highly detailed vector representation of a similar area at the same scale requires between 2M and 5M of space. For these reasons, the ability to store large amounts of data is crucial.

• Screen Display and Resolution: In raster image-processing applications, the more graphics bit planes and the higher the screen resolution, the better the results. To fully exploit the visual and analytical potential of remotely sensed data, eight bits per spectral band, or a total of 24 bits for RGB, is desirable (this provides a palette of 16.7 million colors). A resolution of at least 1024 by 1024 is also desirable.

In applications such as road design, mapmakers can draw vector graphics over a raster image of the road either destructively or non-destructively. Destructive graphics steal pixels from the raster image, substituting their colors for those of the raster image. This means that the vector graphics have the same number of bit planes available for color selection as do the raster images.

If the application calls for dragging or rubber-banding vector graphics, the vector graphics must be drawn non-destructively. In this case, a bit plane is stolen from the raster imagery, thereby reducing the number of available colors for displaying both the raster and vector images.

• Application-Specific Software: An RV/MIP system must allow for such functions as radiometric calibration (atmospheric corrections, sun angle normalization, and slope/aspect correction); geometric preprocessing (map projection changes and image-to-image registration); image enhancements; interactive graphics capabilities; and image input and output.

High-quality output is important in mapping applications, and it is in this area that most systems require further development. While satellite and orthophoto imagery may be treated as continuous-tone, converting the data from RGB to CMYK, assigning line symbols and screen values for vector graphics, and combining the data in one set of high-quality film plots hasn't yet been perfected.

Up to now, the end users with the deepest pockets and the most to gain have pushed for development of RV/MIPS. For example, the oil and gas exploration industries have looked to remote imaging systems to achieve a competitive edge, and low prices and deregulation have increased pressures to accurately and quickly identify natural resources. Government mapping projects world-wide have also been a major source of funding for new systems.

A Strong Future

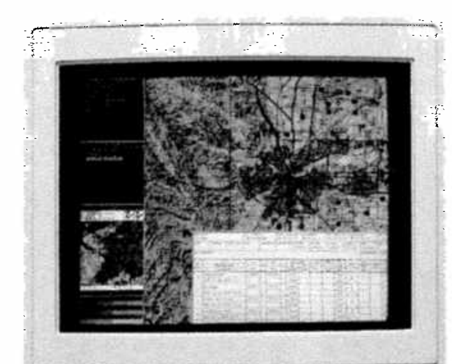
While big business and government have been pushing the hardware and software side, exploding consumer demand for digital databases has prompted better and faster methods for producing accurate and precise maps. PC mapping products have popularized digital cartographic and geographic databases, and consumer electronic products such as in-vehicle navigation systems and "in-the-home" trip planning systems will dramatically increase demand.

Because most major mapping system vendors have already added some form of RV/MIP capability to their products, chances are RV/MIP capabilities will be standard in all future products. Other industries, such as desktop and color electronic publishing, electronics and mechanical design, finite-element analysis, and medical imaging, also require the increased functionality RV/MIP systems offer.

Also, new satellite imagery will soon be available: The European Space Agency's ERS-1 remote-sensing satellite will provide excellent ocean imagery; J-ERS-1, the Japanese Earth Resources Satellite, will have 25-meter-equivalent pixel size and a Landsat-type imager; and the Earth Observing System (EOS) to be launched aboard the US Space Station is promised to be a huge technological advance.

The next generation of mapping/GISes has arrived, and mapmakers will be seeing double. I think they'll like what they see. *CGW*

VITec's Application Development Environment enables quick and easy creation of programs such as this flight planning application which integrates image, graphics and text. This entire program was written in less than four weeks.



VITec's complete environment includes 2-D virtual memory management, interface to scanners and printers, and device and resolution independence.