

Digital Cartography at the Denver Service Center

Editor's Note: In the May issue of *Park Science* Maury Nyquist introduced readers to the Natural Resources Information System (NRIS) that he and his colleague, Harvey Fleet, are building at the Denver Service Center. In response to requests for additional details Dr. Fleet has provided the following description of his activity in digital cartographic information management, work that forms an integral half of the NRIS. Fleet is Chief, Branch of Science, at the Denver Service Center.

By Harvey Fleet

I have long been convinced of the immense value of maps as communicators of information. They are the only medium I know that at once conveys both spatial (= geographic) and thematic (= substantive) information. To the investigator interested in relationships and synthesis, their immense utility is severely hampered, however, by their static nature: the data they contain are neither manipulable, analyzable, nor synthesizable; they may not be readily available or reproducible; and they are almost never easy to revise (with more current or correct information), particularly where propagation of the revised data is desired. The techniques—or more properly, the **technology**—of digital cartography and digital cartographic information management overcome these deficiencies, although I would be the first to acknowledge that they introduce a new, unique set of their own. But as I will describe here, these shortcomings are being overcome.

Digital cartography is not new to the Park Service. Activities during the '70s involved efforts in the Great Smokies, Yosemite, Delaware Water Gap, and John D. Rockefeller Parkway to build and use digital cartographic data bases. For a variety of reasons I described in a paper in the *Proceedings of the Second*

Conference of Research in National Parks these efforts were not very successful. My own work started about three years ago when I learned of the system and capabilities being developed by the U.S. Fish and Wildlife Service's Western Energy and Land Use Team (WELUT) in Fort Collins, Colorado. Since the early '70s WELUT has had a full-scale commitment (as has the Forest Service and Bureau of Land Management) to the development and utilization of contemporary techniques for managing and analyzing information. It is principally these techniques that I have adopted and adapted for use as part of the NRIS.

Digital Cartography Not Remote Sensing

Digital cartography is **not** remote sensing. As in the bassoon and oboe, both of which use double reeds, there is a familial relationship, but each produces quite different results (sounds) from the other. Similarly, remote sensing and digital cartography both handle digital data, but, like the bassoon and the oboe, each produces quite different results: remote sensing **gathers** information, while digital cartography **manages** and **manipulates** it (and not all—or any—of it necessarily from remotely sensed sources). Although both deal with digital data, remote sensing handles digital **multi-spectral** data; digital cartography handles digital **cartographic** data. In the NRIS we are attempting to exploit the common blood between these two technologies.

I conceive of digital cartography as consisting of three distinct but essential components: data entry, data analysis and management, and production of output.

Each component has its own hardware and software requirements. The old tools and techniques, with

which so many people are comfortable, have very little place in digital cartography. Felt tip pens, drafting tools, lettering sets, and writing implements are out; CRT's (cathode ray tubes),* digitizing tablets, computers, computer program (= software), disc and tape storage devices, and plotters are in. Before a functioning digital cartographic information management system can be established, the front end commitment is heavy: each of the three components—entry, analysis and management, and output—must be carefully and accurately installed. Failure of any one will cause failure of all.

Data Entry Capability

Our data entry capability consists of Talos and Tektronix digitizing tablets, a Tektronix 4054 Graphics Display Computer, and MAPDRAW, a sophisticated package for compiling line segments, or "arcs," into finished mapfiles. (An arc is a node-to-node line.) The digitizing tablets transform the mapped information into digital form, lists of X,Y points in an X,Y plane. Using homemade software, we capture these data on the tape cartridge in the 4054 and then ship them over to a powerful mainframe machine (a CDC CYBER 730) that we timeshare at the Bureau of Reclamation.

After an appropriate format transformation we use MAPDRAW to compile each line segment, or arc, one by one, into meaningful polygons or lines. The resulting "draft" mapfile is checked for digitizing errors and corrected. The finished mapfile is then ready for analysis.

"How long does this process take?" The task time is dependent on the complexity of the map to be digitized. The number of line segments, or arcs, determines the labor involved. The relationship is curvilinear or even logarithmic: as the number of arcs to be digitized goes up, the time-to-digitize each arc also increases. The following rule-of-thumb can serve as a general guide to the total time required for this process: 30 to 40 seconds of digitizing per arc for a map containing several hundred arcs to 2 to 3 minutes per arc for a map containing several thousands of arcs.

Other Data Input Considerations.

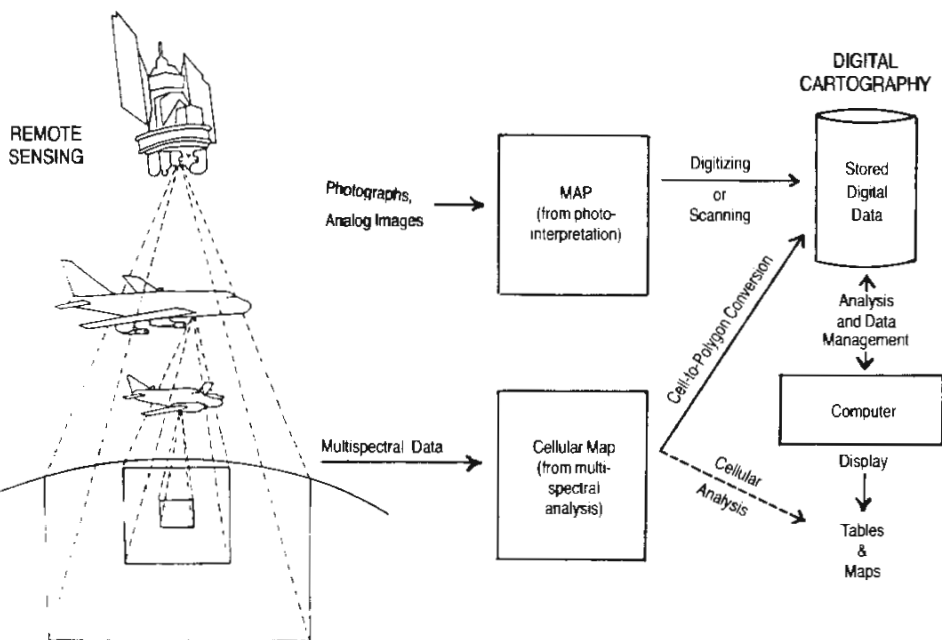
No single issue in the whole of the process of digital cartographic information management is more important than quality of the data base. Should the data be inaccurate, imprecise, misregistered, inadequate in resolution, or simply irrelevant to the questions at hand, the entire process will fail. Investigators will quickly discard a system which yields unfruitful results.

So no effort must be spared in deciding which data themes to enter into the system, the precise content of those themes, the resolution of the data elements, the digital data density desired, the organization of themes into mapfiles, subjects, and categories, and the geographic registration of the map components, if any. The computer is utterly indifferent to deficiencies in any of these items, and, unlike a human analyst or draftsman, will not make "adjustments" for deviations in registration, duplication of data, or data voids. Beware: what you put in is what you get out!

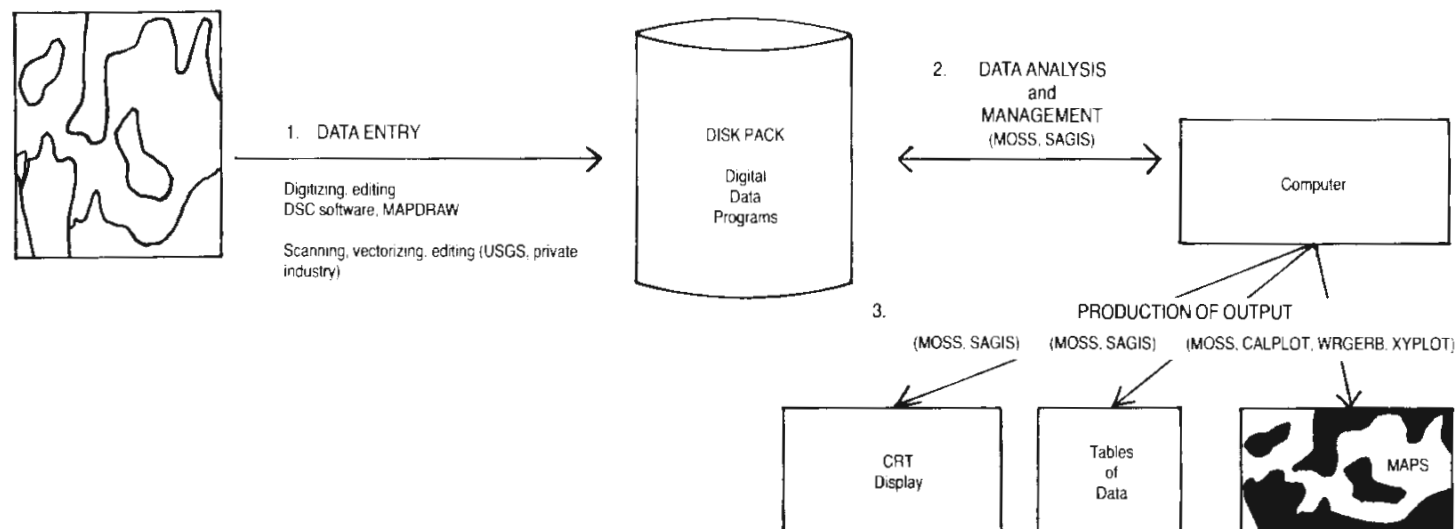
Analysis Described

Having built the mapfile, the investigator can begin to use it to answer questions and discover relationships. The questions one can ask and the answers one can obtain depend on three critical factors: the

REMOTE SENSING GATHERS INFORMATION, DIGITAL CARTOGRAPHY MANAGES, ANALYZES AND DISPLAYS IT



THE THREE PRINCIPAL COMPONENTS OF DIGITAL CARTOGRAPHY



quality of the data base (as discussed above), the capability of the software used in analyzing it, and the capabilities of the hardware on which the software will run. In Denver we have two very powerful, analytical software packages available. They are MOSS (Map Overlay and Statistical System) and SAGIS (Systems Application Group Information System). Important capabilities of these systems include: displaying plots on the graphics screen; shading plots; merging maps; overlaying polygon sets (i.e., finding polygon intersections); performing proximity searches; generating buffers around lines, points, or polygons; finding contiguous edges; calculating distances and lengths of lines; windowing and blowing up; compositing (arithmetic and logical); searching by size criteria; polygon-to-cell conversion; calculating areas and other statistics; generating a contour map from a grid surface; and locating UTM coordinates of any point on the display screen.

Feel free to write or phone me for a complete list of capabilities. MOSS and SAGIS are products of the Fish and Wildlife Service's WELUT group and are still under development. I estimate the packages represent between \$1 and \$2 million dollars worth of effort.

Like many of you, I am aware of the many powerful geographic information systems in addition to MOSS and SAGIS. Why did we choose these? Because: (1) acquiring them involved no front-end expenditures (up to tens of thousands of dollars; the packages are in the public domain); (2) the systems are operating on hardware accessible to us (a Control Data Corporation CYBER-730, operated by the Bureau of Reclamation); and (3) they work.

MOSS and SAGIS are Polygonal.

One more important point: MOSS and SAGIS, unlike many packages for analyzing geographic information, can perform their analyses on polygons or lines, not just on cells. The chief benefit of this method is precision: calculations are performed on data sets that most faithfully conform to reality. A line will be a line, a polygon a polygon, rather than an approximate collection of like cells. Of course, one must pay the price for such power. Compared to cellular computations, the calculations for polygonal data are more complex, require more computer processing, and, if one is time-

sharing, they cost more. The benefits of this method, however, make the price well worth paying.

Output Hardware.

Of course, all these good things going on in the machine are of no use unless one can view the results. The workhorse of the output end is the graphics display screen — in our case either a Tektronix 4054 Graphics Desktop Computer or a Tektronix 4014 Graphics Display Terminal. These relatively large-screen monochrome devices (19" diagonal) have very high resolution display screens (4096 x 4096 addressable points). For complex cartographic data, this resolution is essential. Any Plot-10 compatible device can be driven by MOSS or SAGIS.

Instructions are issued from the keyboard of the 4054 or 4014 to the host computer, and results (various kinds of plots, with shading and labeling, if desired) are drawn on the screen for inspection. A working copy of the screen contents can be made, if desired.

For more formal purposes, we have three available plotters: a Tektronix, a Xynetics, and a Gerber. We are just now bringing our own Tektronix into full production as our primary plotting device. We are using it to produce high quality plots of the material generated by MOSS and SAGIS. Various line thicknesses, line styles, and ink colors, coupled with the 4054's capability to store MOSS plots off-line, yields enormous flexibility in the scale, style, format, and content of maps. The Tektronix is restricted to a plotting surface no larger than 22.75 in. x 17.5 in. (one USGS quad sheet), so for larger plots we either piece together the smaller sections or use the Xynetics or Gerber flatbed plotters.

The Xynetics is compatible with SAGIS mapfiles; so far we have used this device only for proofing MAPDRAW mapfiles (MAPDRAW is a SAGIS package).

The Gerber plotter is operated by the USGS's Rocky Mountain Mapping Center. This very high speed, high precision machine produces plots up to almost five feet wide by ten feet long! Using our own conversion software, we drive it with output from MOSS.

Its principal use for us now is producing single-piece plots of large maps. In the future we would like to use it to produce, with its light pen or scribing point capabilities, color separation plates for four-color

printing. For now we are concentrating on exploiting the full range of capabilities of our Tektronix plotter, which is much cheaper and easier for us to run.

Exciting Developments.

Several exciting developments have recently appeared on our horizon. We are exploring the possibilities of automated digitizing with the Geological Survey. Using an elaborate, and expensive, instrument (originally designed for scanning wallpaper designs), the Survey will try digitizing some of our maps as part of its research program into this technique. If we can use the Survey's software for automatically compiling the digitized arcs into polygons, the technique will eliminate perhaps as much as 80 percent of the time and expense of our current data entry procedure.

Also, NASA is loaning us use of a Varian minicomputer system, principally for multispectral analysis. Putting MOSS up on this machine, if possible, would eliminate our complete dependence on the CYBER mainframe for digital cartography. In addition, if we are able to blend its ELAS software (for classifying and manipulating multispectral data) with MOSS's polygonal capabilities, we could have one of the most powerful packages for collecting, managing, analyzing, and displaying geographic information in the nation. This will not be an easy task, and we do not expect immediate success.

Lastly, I am attempting to wire a very powerful interactive graphics library into MOSS (and, possibly, SAGIS). This revision should vastly expand the capabilities of our Tektronix plotter.

We are just beginning to show applications of the capabilities I have described. For most, if not all of you, this is what it's all about — and rightfully so. The Park Service has no place for technology for technology's sake alone. Unless these tools can be shown to help us manage our resources better, we do not need them.

Developing this program has been an immensely challenging, frustrating, exhausting, and rewarding activity, and it is with great excitement that I look forward to harnessing for management the tremendous potential of this technology.

*CRT's = TV viewing screens.