THE EVOLUTION OF RASTER PROCESSING TECHNOLOGY WITHIN THE CARTOGRAPHIC ENVIRONMENT

David A. Kolassa
Synectics Corporation
310 E. Chestnut Street
Rome, NY 13440

BIOGRAPHICAL SKETCH

Mr. Kolassa received a B.S. in Business/Public Management from the State University of New York, College of Technology in 1982. He is currently serving as a Senior Programmer for Synectics Corporation, performing evaluation research in raster data structures and raster processing technology. Prior efforts have included programming for automated cartography, automated graphic data handling, and imagery exploitation experimentation systems. He is also a member of the National Computer Graphics Association.

ABSTRACT

As we move towards a higher degree in automation and sophistication, the digital cartographic environment will place increasing demands on raster data. A sound base from which to further cartographic raster processing is the knowledge acquired from past raster R&D efforts. However, the approaches taken have not totally resolved the associated problems of raster data nor do they support effective human interaction. With this understanding, the components of a conceptual raster system aimed at overcoming the problems to support the cartographic production community is explored.

INTRODUCTION

This paper will trace the evolutionary path of raster processing within the discipline of automated cartography. The emergence and subsequent development of raster technology in the cartographic production community will be presented. This background discussion is followed by a look at the current state of raster cartography and the major obstacles that still exist. Future directions are explored through presentation of a conceptual cartographic system for current and future needs.

EMERGENCE OF RASTER PROCESSING IN CARTOGRAPHY

Early digital cartographic efforts began by paralleling the manual cartographic process. Features were digitally recorded as vectors or lineal chains in the same way a cartographer would draft them. This allowed for the natural conceptualization of digital data as features and was precipatated as a result of functions which were implemented by those trained in manual methods; and the hardware that was readily adaptable to the replication of manual methods (Pequet, 1976).

Although automation had been introduced, data capture was slow and error prone due to the necessity of human intervention. Consequently, efforts were launched to develop new methods and technologies which might offer a more productive alternative. The result was the identification of raster technology to rapidly extract digital data from analog sources. Thus, early cartographic raster processing was founded on the development of raster scanning hardware (see Figure 1).

The early sixties produced several raster scanners which were able to sample cartographic source material and digitally record the presence or absence of cartographic features. Initial applications of the output focused on map duplication purposes. Foremost was the raster digitizing of cartographic manuscripts to produce color film separations (Palermo, 1971; Clark, 1980). Data capture rates were significantly higher than manual digitizing but were offset by the expense of early scanning equipment and cumbersome editing procedures.

A major obstacle in the use of raster data for other applications was the inability to perform feature or segment manipulations on raster elements in a fashion similar to most cartographers. In an attempt to solve this problem, several efforts were made to convert raster scanned data into the familiar representation of vector chains. The raster-to-vector conversion processes typically encountered two problems: a high processing overhead and the difficulty associating attributes with newly created vector chains.

CONTINUED DEVELOPMENT

Despite the problems inherent in the use of raster data there has been a continuing trend towards raster processing in the cartographic environment. This is primarily due to the increasing demands placed upon the cartographic production community. Also contributing to the continuance of raster processing were efforts targeted to resolve the problems through either hardware or software as shown in Figure 2.

Much of the hardware advances in the past decade has revolved around the data capture issue. Raster scanners have increased in performance and resolution while declining in price since the advent of several commercial firms into the market. Other devices capturing data in a raster format are video cameras (frame grabbers) and remote satellite sensors such as Landsat. These accomplishments have served to accelerate the capture of data in a raster format.

Advances in hardware to facilitate the manipulation of raster data has also been a driving force. High resolution CRTs, raster plotters and hardcopy devices, and the use of video offer a number of options for graphic output. Array processers and mass storage devices have

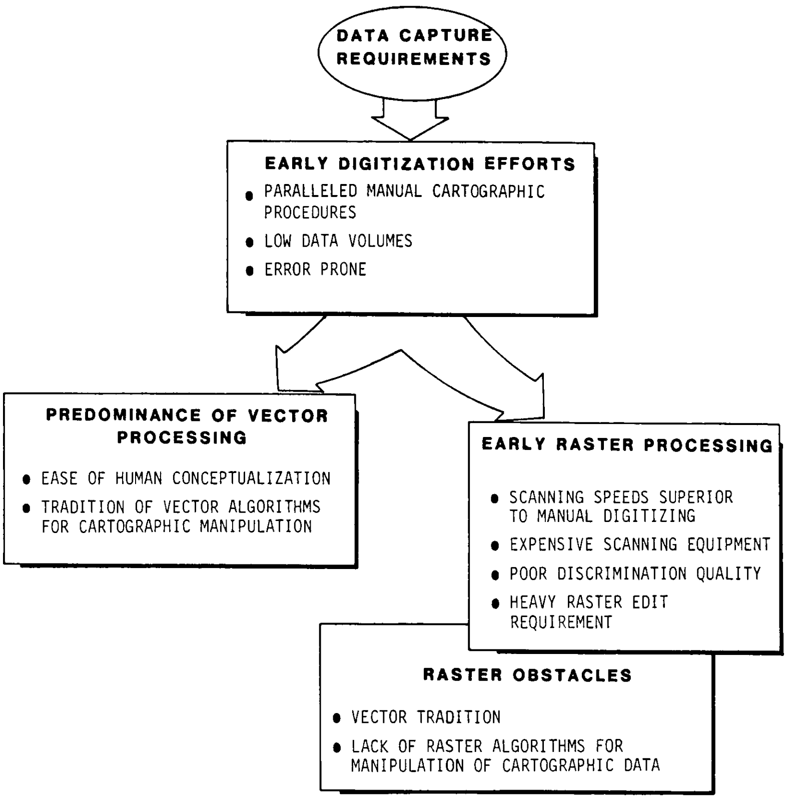

Figure 1. Early Data Capture Processes

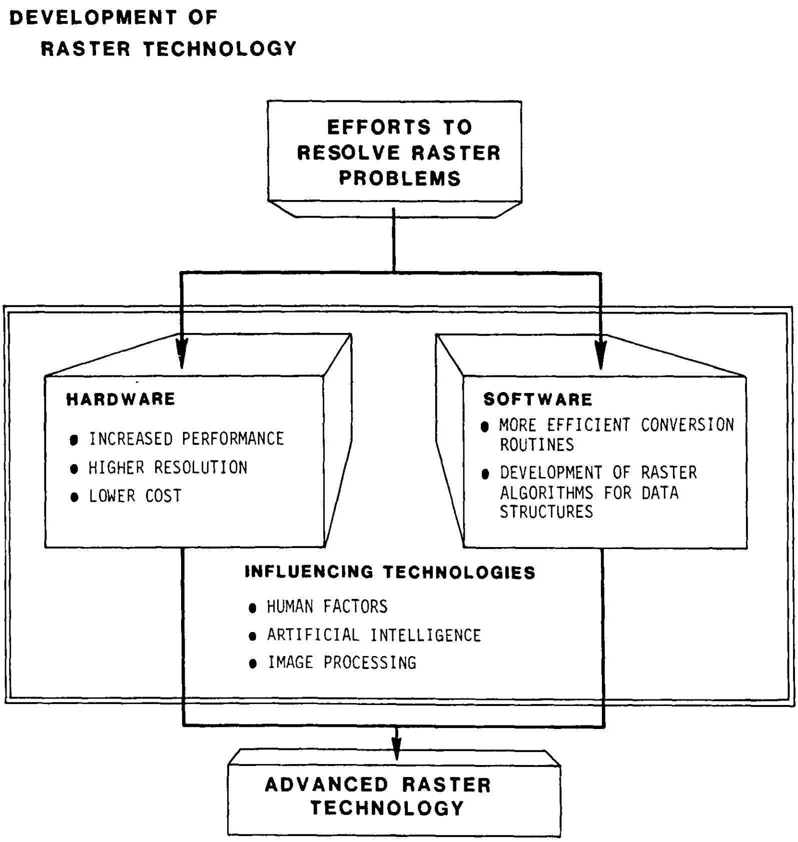

Figure 2. Development of Raster Technology

increased processing speeds and capabilities, while also exhibiting a decline in price.

In conjunction with improved hardware there has been increasing research into raster data structures and algorithms. More efficient conversions between raster and vector have been developed and implemented. The past several years has also produced interesting work in the area of data structures and algorithms which retain the data as raster elements. This approach offers a more efficient interface between the user and the data. It is perhaps this research that holds the greatest promise for the continued emergence of raster processing in the cartographic environment.

The development of raster processing has also been influenced by many other disciplines. For example, human factors engineering in relation to automated cartography has sought better human-machine interfaces to promote system efficiency and productivity. Ergonomic design considerations have been incorporated into raster devices to improve user interaction with the system. Techniques of artificial intelligence, pattern recognition, and syntactical analysis have been applied to raster cartographic feature recognition (Gilotte, 1979). Continued research which encompasses many fields will aid in solving the problems associated with raster data.

CURRENT APPROACHES

Presently, there are two distinct approaches to the utilization of raster data for cartographic purposes. The first, and most common, is seen in the raster-to-vector conversion systems. These systems usually employ a process of skeletonization to reduce lines to a single unit of width upon which line extraction and topology reconstruction is performed.

Conversion techniques insert an intermediate step prior to performing cartographic manipulations. In the compilation and revision environment where data is temporal in nature, additional processing leads to a corresponding decline in overall system productivity. While improved, the current raster-to-vector conversions still maintain some amount of processing overhead and encounter problems with attribute tagging, line coalescence in high density areas, line gaps and variable width lines, and processing times highly dependent on data resolution.

Furthermore, cartographic raster-to-vector conversion systems have primarily focused on contour and polygon type applications. This can be attributed to the specific rule sets which have been developed for these entities. More importantly, while the data is easily manipulated in vector format, its' graphical presentation to the user is foreign to its' true map symbology. As a result, the user is unable to interact with and manipulate data as it appears on the analog input source and final product.

The second approach centers around the implementation of systems where the raster format is maintained throughout the entire processing cycle. This combines the advantage of rapid data capture with quick access to the cartographic manipulation functions. However, this approach has also been stalled by problems with the manipulation of data as raster elements. Operations are usually performed on a color or pixel basis which does not afford the same flexibility as vector oriented systems.

Consider, for example, the problem of joining two features as depicted in Figure 3. Here an edit/revision to the data is required to complete the intersection of two roads. This join operation involves the identification of two features followed by the extension of a feature endpoint onto the second feature. We can easily envision the function to be performed but it is much more difficult to execute in a raster mode. Identifying a feature endpoint can be a cumbersome task where raster lines are more than one pixel in width. Other burdensome tasks are the determination of the direction to extend the endpoint and locating the connecting pixel on the second feature.

This example is further complicated in that the associated pixels represent dual cased roads. In this situation what ever is done to one side must also be applied to the other. Furthermore, when the connection is made, a deletion of pixels is required. It is problems such as this that restrict all raster systems from complete acceptance in the cartographic production environment.

FUTURE DIRECTIONS

Past efforts have laid the foundations and exposed the relevant truths for the raster processing of cartographic data. The major approaches will undoubtedly continue into the future, but more likely in specialized applications. Currently, the all raster systems appear to be the most beneficial when performing cartographic manipulations, especially compilation and revision functions. However, to overcome the related problems a new direction within the all raster approach is suggested. The knowledge base acquired from past efforts, along with an understanding of the problems and future needs, provides an ample starting point. Research at Synectics Corporation has sought to define the components of an all raster system based upon the total spectrum of available raster technology. The concept under consideration draws heavily upon the ideas set forth by Rosenfeld (1970) on connectivity, labeling, and segmentation. A brief overview of elements in this concept, as shown in Figure 4, is given in the following paragraphs.

The first step for any cartographic raster system is the capture of data. To make an all raster system as widely applicable as possible, it is beneficial to keep the data input specifications to a minimum. Therefore, the data input to Synectics' conceptual raster system is assumed to be gathered by an unintelligent scanner. This device would pass raster data to the system as a large NxM array reflecting the exact visual properties of scanned source materials.

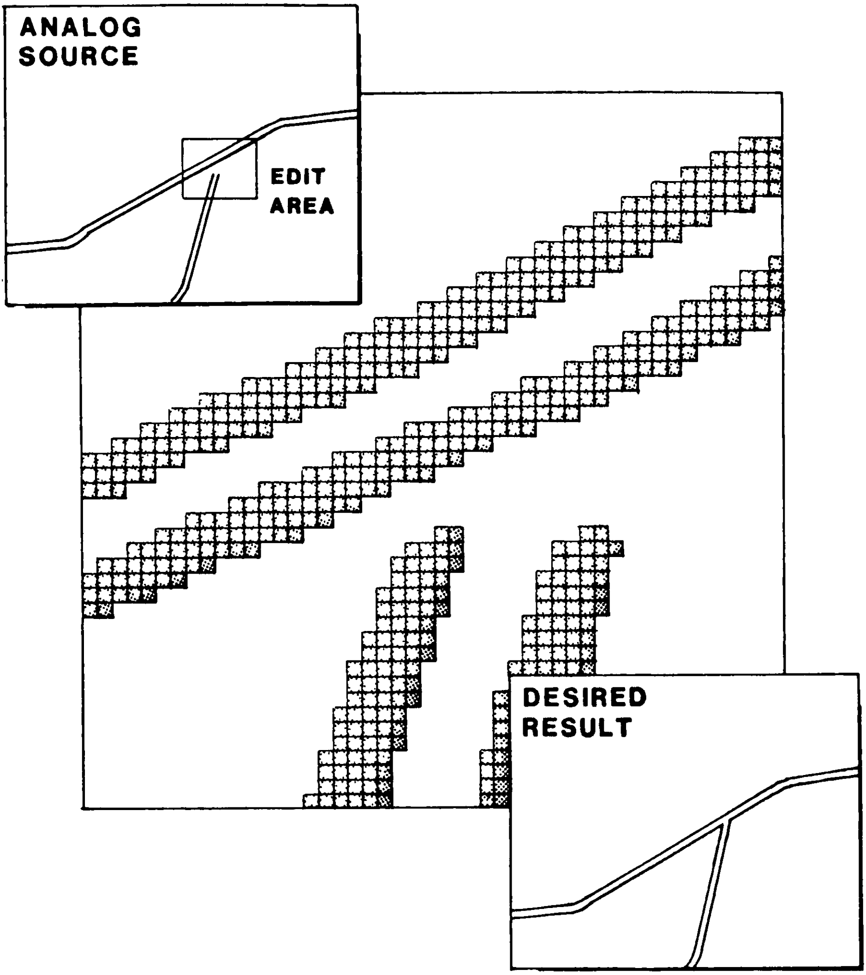

Figure 3. An Example Of Joining Two Features

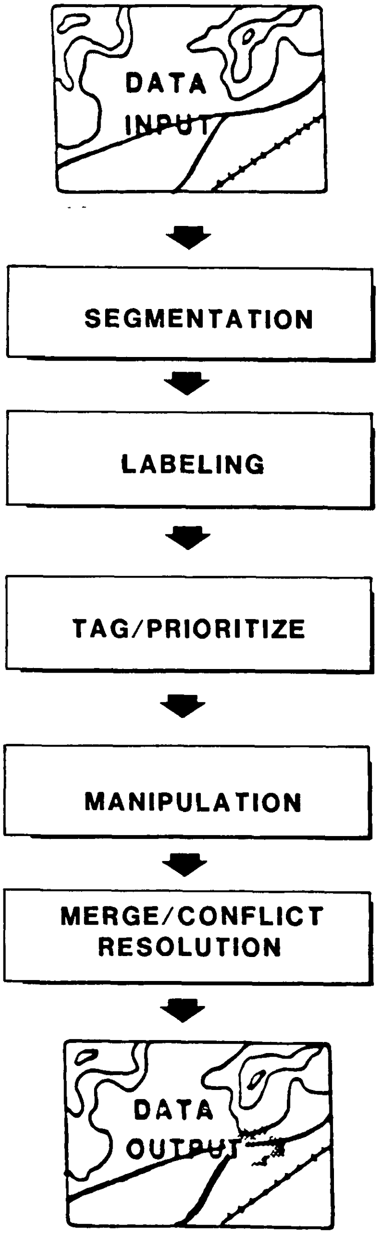

Figure 4. A Conceptual Raster System Data Flow

The next sequence of processes are required to prepare the data for the cartographic manipulation process. First, segmentation of the scanned data would form a number of subsets of pixels based upon pixel color (or gray shade) and halftone intensity. This process would result in an assignment of unique class numbers to each pixel and resolve conflicts in areas of overlays. Labeling would then be initiated to create subsets of associated pixels and assign unique identifiers to these subsets. Pixel associations would be made within similar pixel classes and among groups of pixels to form connected components. The segmented and labeled components would then undergo a tag/prioritize function to install a hierarchy among them. This ordering of components would serve to establish a priority among the cartographic entities to facilitate the cartographic manipulations.

Completing the previous tasks, the manipulation process for reviewing, correcting, and enhancing the cartographic data could easily be performed. It is this element of the conceptual raster system where the highest level of human interaction will take place. The operations included here fall into two categories: functions that act upon the data without changing data values and those which physically change the data. It is these functions which will require the greatest amount of effort in the future if we are to provide maximum human interaction.

Prior to data output, the recreation of the NxM visual array is necessary. This step would incorporate a merge/conflict resolution function to resolve conflicts among multiply defined pixels or coalescing features. The process would be able to draw upon the hierarchies established in the tab/prioritize function for some decisions while other conflicts may require operator intervention. Conceptually, this step is envisioned as merging multiple planes of data into a single plane, cleaning up any data discrepancies. This would expedite the output of raster data as either color separation lithographs or single sheets.

SUMMARY

Research over the past decade was first directed towards the design of hardware to perform data capture. Unique devices were built to scan cartographic data and convert it to a digital format. Following these efforts was a period of software development and implementation of raster based systems in direct support of the cartographic production community. As raster technology progressed, the associated problems of manipulating raster data surfaced. This spawned further research targeted to solve the problems, improve efficiency, and expand upon its capabilities.

The two predominant approaches which exist today are the raster-to-vector conversion systems and the all raster based systems. Each offers an advantage over the other but both share the common disadvantage of inadequate or cumbersome interaction between user and data. However, to fulfill the current and future requirements of the cartographic production environment, research points to the all raster approach to be the most promising. Systems development in this

direction will be able to maximize the reduction in processing overhead for increased productivity. Secondly, all raster systems will allow users to manipulate data in a form which more closely resembles the analog source and final product. In order to support these functions, more emphasis is needed on developing algorithms and data structures which permit the user to think in vector while machine operations are executed in raster. Fundamental to this development are the concepts of connectivity, labeling, and segmentation.

ACKNOWLEDGEMENTS

The work presented here was sponsored by the Rome Air Development Center under contract F30602-81-C-0279. The support of Jim Muller and the efforts of the Administrative Staff of Synectics Corporation, Rome, New York, in preparing this paper are gratefully acknowledged.

REFERENCES

Clark, R. A. 1980, Cartographic Raster Processing Programs at USAETL: ACSM.

Gilotte, M. J. 1979, Raster Processing Techniques: Griffiss Air Force Base, Rome Air Development Center.

Palermo, J. 1971, Development of Raster Data Handling Techniques at Rome Air Development Center: Air Force Systems Command.

Pequet, D. J. 1976, The Need for Raster Processing of Cartographic Data: Auto Cart III, pp. 139-147.

Rosenfeld, A. 1970, Extraction of Topological Information From Digital Images: First International Advanced Symposium on Topological Data Structures for Geographic Information Systems, Vol. 6, Spatial Algorithms: Efficiency in Theory and Practices, Harvard University.