RECENT ADVANCES IN GIS PROCESSING TECHNIQUES USING COLOR GRAPHICS & MINICOMPUTER TECHNOLOGY

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A. Introduction

Advances in the collection of geographic information have resulted in the requirement for more sophisticated processing techniques. Specific technological improvements have been made in the areas of: automated cartography, digital remote sensing, color graphics and digital processing. These advances have given impetus to a HRB-Singer independent research and development effort to exploit these areas for purposes of developing system specification for an image processing and analysis facility (IPAF). A multi-year effort has been planned. This paper addresses the salient features of efforts to date and presents a functional description of a prototype geographic information system (GIS).

The prototype system being developed combines machine-readable representations of thematic maps and remote sensor data with cartographic display software and remote sensor data analysis routines, and with applications oriented analysis software for decision making/ planning utilization. This prototype is an attempt to merge information contained in a multitude of thematic maps and remote sensor media into a coherent data base and from this data base to extract (via digital analysis techniques) information not present in any particular input.

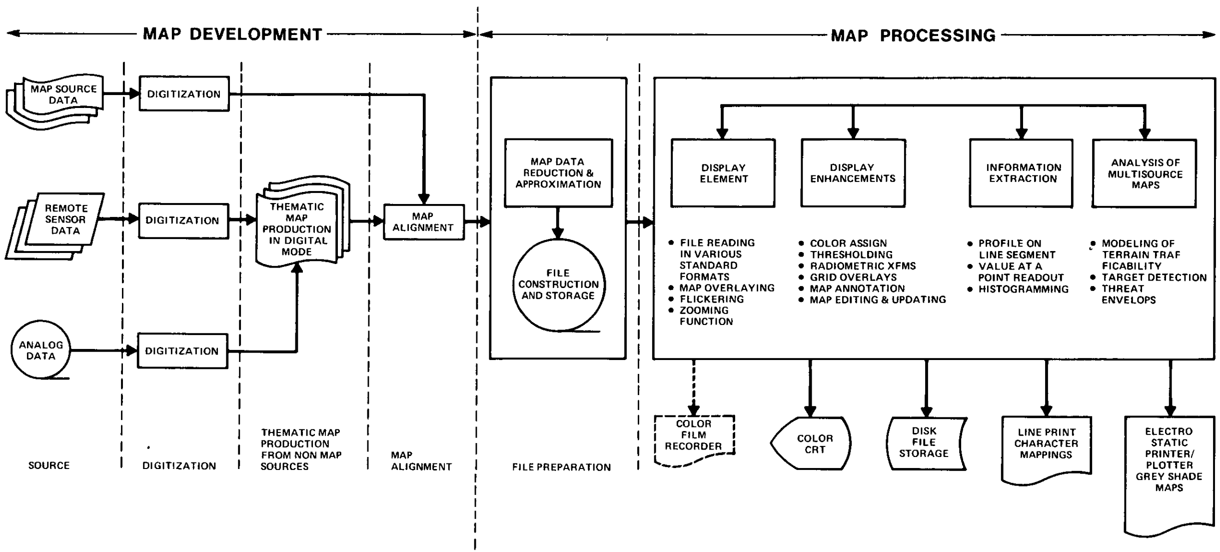
This prototype system is attempting to address a number of problems in the handling of large volumes of map data. A number of data reduction techniques are being explored, e.g., two dimensional surface approximations and the use of polygon storage techniques. This paper will later address the trade-offs between display speed, accuracy, and storage. The polygon storage mode requires less storage and preserves accuracy reasonably well. The existing prototype system hardware configuration is one to two orders of magnitude slower at construction of polygon based displays vis-a-vis raster displays. In addition to exploring the trade-offs involved in data handling, the use of color is being exploited. Color has the impact of adding another dimension to cartographic displays and greatly augments display flexibility, but the use of color introduces questions of user perception of color in mapping. The alignment and rescaling of multiple map bases onto a standard base for analysis presents a computation problem in the 32K of the host's memory. The use of relative ground control points and least squares polynomial curve fitting is being examined as a possible solution to the alignment and rescaling problem. It is our expectation that the resolution of these, and other problems will result in a IPAD which presents the user with an extremely powerful analysis and decision making tool, all in a compact computing environment.

B. <u>The Prototype GIS Processing System</u>

The present in house capability for exploiting geographic information is centered about a DEC PDP-11/45 processor and a I^2S model 70 image analysis terminal. On/Off line storage is facilitated via RP-03 MHD disk, RK-05 disk cartridge, and 7 or 9 track magnetic tape. Present hard-copy output is limited to either line printer/plotter which is useful for grayshade image output (limited to 16 level at present).

Functionally, the prototype system can best be described as is illustrated in Figure 1. This overview describes the system from the top level as being map development or map processing based. There are four phases of map development, these are: source, digitization, thematic maps, and map alignment. The source

FIGURE 1- FUNCTIONAL DIAGRAM OF THE PROTOTYPE GEOGRAPHIC INFORMATION SYSTEM



media forming input to the system is raw map data, remote sensed data or analog tape data originating from some line scan system. A digitization phase is included to transform analog input to a digital format. At present, digitization is tedious since the appropriate capital equipment has yet to be procured. The third phase of map development is termed thematic map production. Thematic maps represent an invaluable input source for use in generating graphic overlays. This capability will be described in more detail later on. The final phase of map development, map alignment, addresses the very real issue of registering multisource geographic information. The second major function of the prototype system is that of map processing. Here it is assumed that the final phase of map development has resulted in a file entry in the data base. In certain cases, a map product will be reduced via a suitable approximation technique. This will also be the subject of a later discussion in this paper. Map processing, for purposes of this effort, is grouped into one of four categories. These are: a display element; display enhancement; information extraction; and analysis of multisource maps. These features are enabled via analyst interaction with the I^2S model 70 electronics and color CONRAC monitor which permit processing of 512x512 arrays of 8 bit data. The display element permits: the retrieval and subsequent display of various data formats; map overlaying; flickering and roam, to name but a few features. Display enhancement features include routines to change color assignments; threshold images; alter images radiometrically; overlay with grid registration points; annotate map; or edit and update. Another major attribute of map processing is termed statistical information extraction. Routines to assess the spatial content of the image or map are provided. These include techniques to profile amplitude of a user selected line segment; to obtain digital amplitude readouts of a user defined target or target region, etc. A histogram capability is provided to accomplish the latter. The analysis segment is tailored to special applications in the military and nonmilitary sectors. Terrain trafficability, target detection, and threat modelling have been identified as special applications for this prototype GIS, based upon a series of potential customer contracts.

In general, the application for the GIS steers the type of input and output media the GIS will need and create.

The prototype system includes, at present, input sources of two types: traditional base maps and remotely sensed photogrammetric material. The remotely sensed data includes both satellite multi-spectral scanner and return beam vidicon outputs. Data from traditional base maps include elevation, soils, highway networks, and hydrogeologic characteristics. Intermediate level processing products are computed from input data, e.g., land-use maps from remotely sensed data and gradient maps derived from elevation data. Outputs from the prototype system include new maps generated by fusion of the intermediate and primary map sources, maps of the occurrence of user specified features, decision making/planning aids and application oriented thematic maps, e.g., isochrones of travel time for a particular vehicles specifications given a set of weather, congestion, and time of day parameters.

C. The Role of Interactive Display in Computer Based Geographical Information Systems

The importance of the interactive capability in the prototype system can not be understated. Present capabilities include the ability to interactively overlay, sum, difference, transform, make nominal comparisons, histogram, profile, and zoom. These constitute prerequisites to more sophisticated modelling. Modelling and/or decision making from the analysis of multiple map bases can be enhanced by the execution time introduction of dynamic data, e.g., climatological parameters or other rapidly changing variables. If one were interested in terrain trafficability modelling, the static map based information would not be sufficient for decision making and/or planning purposes. Terrain trafficability is a function of both slow-changing or static variables (for which base maps can be made) and rapidly changing variables (for which no base map will exist). One parameter of such a terrain trafficability model, soil bearing capacity, is a function of soils information and local weather conditions for which no apriori map exists. In addition to the upgrade in modelling flexibility, the interactive capability permits the user to update base map information when changes have been observed. The flexibility of interactive display manipulation of static and dynamic data is a very desirable element in the prototype system and augments the information extraction and analytic capabilities inherent in the system.

D. GIS Data Base Limitations

There are a number of problems associated with the implementation of multi-source geographic information in a minicomputer environment: however, the large volume of data, limitations of display size, and hardware transfer speed limitations seem to be the most significant. Imagery products and related map data sets tend to be described quantitatively as constituting megabits of information. It is a small wonder that minicomputer implementation in conjunction with GIS is lagging. Given that small scale systems architecture reduces the flexibility of large data set handling, the question might be raised rather justifiably then why adapt such technology to this problem. There are solutions, namely mathematical modelling. A variety of approximation techniques serve as useful data reduction devices. The trend seems to favor the use of polynomial approximation where coefficients and degree of fit are key design parameters. There are, of course, a set of conflicting system objectives which need to be reconciled prior to the utilization of such techniques. For the purpose of our effort, the following have been established:

(1) maximize restoration while minimizing information loss
(2) minimize storage requirements (i.e., maximize degree of reduction)
(3) minimize computation and display execution times.

Obviously, these aspirations are conflicting and tradeoffs become necessary, since the best solution to (1) involves no approximation while (2) requires some approximation. We have established a few design criteria which incorporate relative degrees of attainment for all three goals.

The polynomial approach provides the capability to approximate all elevations within a square of terrain via a low-order mathematical function. Given that the input map is represented by 512 x 512 8 bit values and there exist conflicting design parameters, the search for an optimal solution focuses in on the degree of partitioning of the matrix and the manner of sampling. (i.e., whether we under sample or not.) Table 1 summarizes the partition sizes, number polynomials needed per partition size, and the storage requirements. As an example, if we were to partition the

n, (nxn)	#POLYNOMIALS	# COEFFICIENTS FOR Kth ORDER POLYNOMIAL (K=1,2,3...6)					
		1st ORDER	2nd ORDER	3rd ORDER	4th ORDER	5th ORDER	6th ORDER
1	262,144	U	U	U	U	U	U
2	65,536	192K	U	U	U	U	U
4	16,384	48K	96K	160K	240K	U	U
8	4,096	12K	24K	40K	60K	84K	112K
16	1,024	3K	6K	10K	15K	21K	28K
32	256	768	15K	2.5K	3.8K	5.4K	7.2K
64	64	192	384	640	960	1.3K	1.8K
128	16	48	96	160	240	336	488
256	4	12	24	40	60	84	112

TABLE 1: COEFFICIENT STORAGE AS A FUNCTION OF POLYNOMIAL ORDER & SAMPLING INTERVAL
(NOTE: U = UNDEFINED FOR PARTITION SIZE ''n'')

input space into a set of 8 x 8 submatrices, we would need to store off 4096 polynomials and 40 K coefficients, assuming a third order fit. That is to say, $\frac{(P+1)(P+2)}{2}$ coefficients per polynomial. The derivation of coefficient values can be accomplished by trend surface analysis wherein all the values of the submatrix are used to define the coefficient set. An alternate approach is to select candidate points within the submatrix according to some sampling scheme. This obviously produces a larger residual error than does trend surface but has the advantage of not being quite so compute bound. Our efforts to date suggest that a random sampling scheme for selection of points and a submatrix size of 8 x 8, using a 3rd order fit, provides a good tradeoff between execution time, storage and residual error measured against observed values. Work continues in this area and our results are still not conclusive.

E. Concluding Observations

Future plans call for the acquisition of a digitizer and array processor to finalize the system implementation for the IPAF at HRB-Singer's interactive computer facility. A conversion over to the VAX 11/780 processor will also be accomplished to permit remote usage and take advantage of the 32 bit work size and virtual memory of that machine.

The array processor will be used to download the data reduction algorithms from the PDP-11/45 initially and the VAX 11/780 later. Future endeavors also call for the development of special purpose software applications packages for both military and non-military interest areas.