MOVING INTERACTIVE THEMATIC MAPPING
FROM MAINFRAME TO MINI:

Some Design Possibilities and Development Experience

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1. Introduction

The analysis, interpretation and assimilation of
geographically referenced data often requires that it
be presented in the form of maps and other graphic
displays. CARTE is a thematic mapping program which
produces annotated chloropleth, line or point-symbol
displays of socio-economic, energy, or other data on a
variety of interactive terminals or hardcopy plotters.

CARTE is designed primarily for interactive use and
provides both simplicity for the novice and a wide
range of options for the advanced user. Script or
command files provide a convenient facility for setting
defaults and other parameters from a monitor program as
well as providing for non-interactive operation. CARTE
has the ability to write a script which will reproduce
the current map display. This frees the interactive
user to concentrate on the map design without concern
for keeping track of the commands issued, and also
allows him to produce a series of similar maps with a
common layout.

The goal of CARTE is to provide thematic maps to a
broad user community. This software is a part of SEEDIS

(Socio-Economic-Environmental-Demographic   Information
System)   [1],   a   broadly-based   set   of data bases and
software which includes 100 million data   items   and   a
wide variety of analytic and display tools.

We   know   that displays such as CARTE are indispensable
to our users and we feel that as the state of   the   art
is   advanced   it will become possible and economical to
supply the general public with these kinds   of   graphic
displays.   This   will allow citizens to participate in
decision-making with the same access to data that   only
a few lucky administrators now have.

2. Software Organization

SEEDIS,   including   CARTE,   has   been under development
since 1972 (see [2]   for   an   overview   of   an   earlier
version   of   CARTE),   but   the   recent acquisition of a
Digital   Equipment   VAX-11/780   prompted   us   to   do   a
complete   redesign.   An   overview   of   CARTE   program
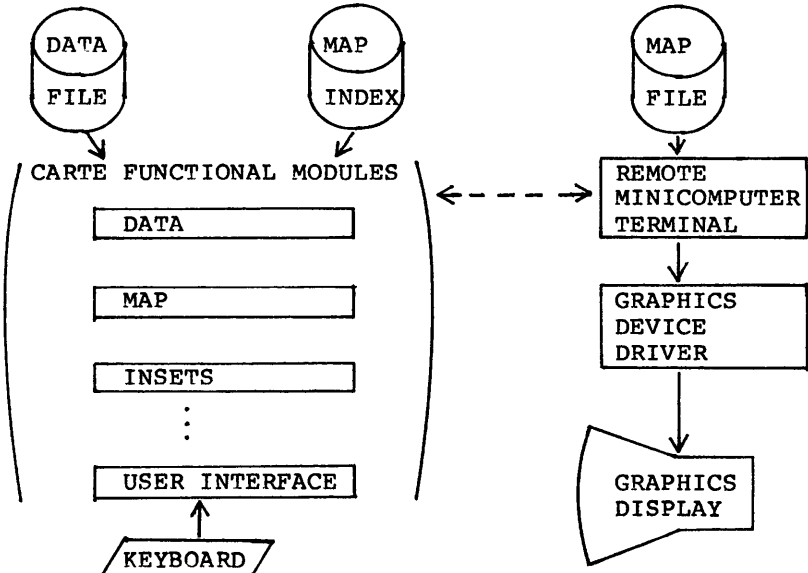structure is given in Figure 1.

Figure 1.   CARTE Functional Overview

As shown, input comes from   three   sources: geographic
base   (map)   file,   thematic   data   file   and   user

directives. Both map and data files for use in CARTE
are prepared by other modules in the SEEDIS system. Map
files are organized by polygon, with each record
containing an array of geocodes as well as a list of
boundary points. No other topological information is
maintained in the map file. Data files are also keyed
using geocodes, so that map records and data records
may be presented in any order.

Output from CARTE is mainly in the form of maps, but it
can also display tables and histograms of data items
for exploratory purposes. Another form of output is
the script file, by which a user can save and recall
the design of a map. The script file is in the form of
CARTE directives, so that it may be modified with a
text editor and reprocessed in CARTE to produce a
corrected map design.

3. Using Intelligent Terminals

To support the possible use of intelligent terminals in
map-making we have divided CARTE conceptually into two
parts: host- and (potentially) terminal-resident. The
philosophy behind the division is this: Basic graphic
display functions must be performed by the terminal,
while manipulation of items from a large data base can
only be done by the host. For rapid response, the map
itself is stored at the terminal. In order to make a
map, certain information must be passed from the host
to the terminal. The exact division between the parts
was chosen to minimize the amount of this information.

With the separation of control and graphics generation,
CARTE can use a unique graphics portion for each
graphics device. This allows wide variations in
strategy for controlling these devices. Even the map
files can be different for differing terminals, since
they are unique to each terminal. With raster devices,
we would expect to store the image in raster form and
manipulate the color look-up table to achieve the
desired display [3]. This approach promises extremely
fast graphic generation for many types of maps.

The terminal functions include the geographic base file
interface plus routines to display symbolism and
annotation. The remainder of the program (about 90% of
the code), is the host portion. It includes the
control program, data base interface and user input
analysis and semantic routines. The host computer does

not access the map file directly, but instead uses a map index (essentially the geocode portion of the geographic base file) to correlate the data and map.

To make a map, the terminal first receives from the host a list describing the types of symbolism desired. A symbolism description denotes whether polygon outlines and labels are to be drawn as well as the type of area fill (crosshatch, solid color, etc.). Furthermore, the description contains a list of graphic attributes such as vector color, line style and character size. These attributes are identified mnemonically so that they can be passed directly to the device driver without further processing by the terminal. Since graphic attributes can be applied to annotation as well as to the display of polygons, we have introduced the term "display style" to denote this wider use of symbolism.

In addition to the style definitions, the terminal receives the name of the map file, the limits of the geographic area to be displayed and the area of the screen to contain the display. To produce the map, the terminal receives a vector giving for each geoarea, the index of the corresponding display style. Finally, the terminal receives graphic primitive instructions for drawing any necessary annotation.

4. User Interface

Like many other large software systems, CARTE employs a centralized user interface. Our particular implementation somewhat resembles GPIS [4], which is used in GIMMS. Our design goals were: flexibility, ability to prompt the user, and ease of use not only from the user's standpoint but from the implementor's as well.

A typical CARTE command begins with a keyword or verb, and continues with one or more parameter lists. Within a list, parameters are separated by commas, and the lists themselves are separated by spaces. Each call on the scanner processes one list, so that the applications program can perform any necessary intermediate semantic processing. A command can be implicitly continued to more than one line by terminating the previous line with a comma, equals-sign or (within an expression) an operator.

Parameters are commonly of the form "keyword=value", though a value alone may appear in selected cases where no ambiguity results. The following is a typical example:

    TITLE   1   STRING="text", XY=(.3,.3), MODE=CENTER

which specifies a text string, centered about the screen coordinates (.3,.3). As evidenced, parameters can have several kinds of values, including numbers, expressions, character strings, or other keywords. Since the XY parameter specifies a graphic location, its value could have been input by positioning a graphic cursor. However, only locators can be input in this way.

The user interface incorporates three settable prompting modes: "beginner", "familiar" and "expert". In all three modes, the user may enter a command as in the example above. If the prompt mode is "expert", no prompting is done; default values are supplied for omitted parameters. In "beginner" mode, the system prompts for all omitted parameters; the user may still decline to enter a value for any of them. "Familiar" mode is a hybrid of the other two; there is no prompting unless the user requests it by omitting parameters from the command line. The prompts themselves are very simple: a keyword followed by one or two words describing the type of value desired. We are considering the possibility of incorporating the on-line help information, which is organized by command and parameter, into the prompts. Below is a sample dialog in "beginner" mode (user inputs are in lowercase):

                title
                INDEX?
                1
                STRING? (Character string)
                "text"
                XY? (Coordinates)
                (.3,.3)
                MODE? (LEFT, RIGHT, or CENTER)
                center

5. Use of VAX/VMS System Features

In moving CARTE to the VAX, we have been able to take advantage of some special features offered by this

machine. One such feature is virtual memory. With virtual memory program organization is simplified since there is no need for explicit overlays. Dynamic paging ensures that main memory is occupied only by program segments which are actually being used. CARTE also allocates virtual memory itself when convenient. This enabled us to remove explicit limits, for example, on the number of geographic areas and on the number of points per polygon which can be plotted.

Another, important feature used in CARTE is the condition handling facility. CARTE uses the condition handling facility to process all abnormal conditions, including user input errors and user interrupts. When a signaled condition is too serious for execution to continue, program flow is unwound to the main control program, which reads the next user command. Thus, the user can continue after any error, even coding errors provided he avoids the failing module. We believe this to be very important in an interactive system.

6. Unresolved Issues

A number of issues have been left unresolved by our conversion. Among these are:

o Base map organization.
  Map files represent each polygon as a list of points and do not store any higher level topological information. While this structure makes assembling of polygon outlines very efficient, there are some drawbacks. For example, interior boundaries are drawn twice.

o Terminal hardware dependencies.
  CARTE does not make use of information about graphics terminal characteristics. For example, it would be nice to know the possible character sizes in order to place the default title and legend; or, it would be nice to use the output resolution in order to optimize polygon outlining and shading.

o Base map preparation.
  CARTE can only operate with one base map at a time and does no cartographic processing. If the user wishes to combine two maps, or otherwise edit the map file, a separate processing step is necessary.

7. Conclusions

In the six months CARTE has been operational on the VAX, it has been used to prepare over 150 maps for presentation, plus an uncounted number for experimental or exploratory purposes. These included:

   o A series of maps of energetics data for the U.S. by state and Federal Region IX by county.

   o A series of maps of air quality statistics and cancer mortality data for the Populations at Risk to Air Pollution project.

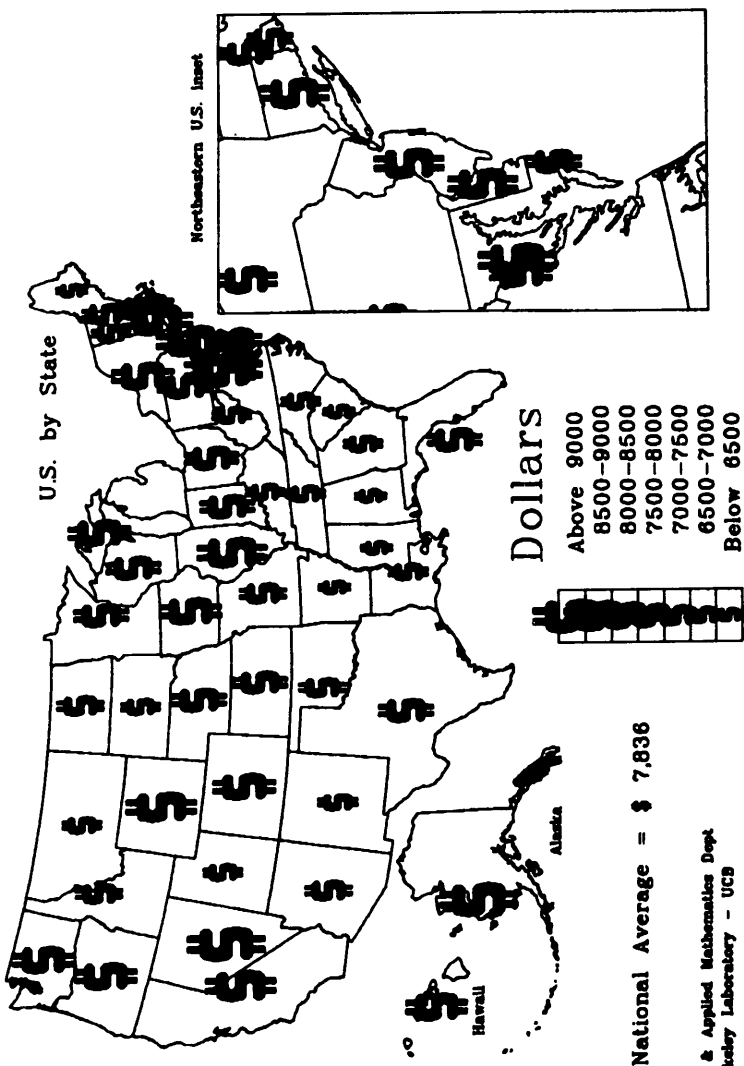   o Other maps dealing with economic and demographic data (Figure 2).

Our users are more than pleased with the rapidity and quality with which maps can be composed and produced. They believe, as we do, that such graphical displays can be a great aid in developing and presenting new knowledge.

References

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2. Wood, P.M. "Interactive display of polygonal data", First International Advanced Study Symposium on Topographical Data Structures for Geographic Information Systems, G.H. Dutton (Ed.), Harvard University Laboratory for Computer Graphics and Spatial Analysis, Cambridge, Mass., October 1977.

3. Dalton, J., Billingsley, J., Quann, J., and Bracken, P., "Interactive Color Map Displays of Domestic Information," Sixth Annual Conference on Computer Graphics and Interactive Techniques (SIGGRAPH '79), Chicago, Illinois, August, 1979.

4. Waugh, T. "A parameter-driven language for use in application systems," First International Advanced Study Symposium on Topological Data Structures for Geographic Information Systems, G.H. Dutton (Ed.), Harvard University Laboratory for Computer Graphics and Spatial Analysis, Cambridge, Mass., October 1977.

Figure 2.

Per Capita Income – 1978

Source – Estimates, Bureau of Economic Analysis

U.S. by State

Northeastern U.S. inset

Dollars

Above 9000
8500–9000
8000–8500
7500–8000
7000–7500
6500–7000
Below 6500

Alaska

Hawaii

National Average = $ 7,836

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