Usage of map symbolism in commonly-used computer mapping software packages

Wan Chʻen

The University of Montana
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The Usage of Map Symbolism in Commonly-Used
Computer Mapping Software Packages

by

Wan Chen

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[Signatures]
Chairman, Board of Examiners

Dean, Graduate School

Date

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The Usage of Map Symbolism in Commonly-Used Computer Mapping Software Packages (85 pp.)

Advisor: Dr. Paul B. Wilson

The purpose of this thesis is to explore the extent to which computer mapping software packages accomplish map symbolization of traditional manual mapmaking. To do that, the author first traced the history of cartography and the role of symbolization in traditional mapping. Different types of symbols at four levels of measurement were explained. The advantages and disadvantages of computer mapping were also discussed.

After reviewing the use of symbols in cartography, a mail survey was conducted. Samples of commonly seen nominal, ordinal, ratio, and interval symbols were included and respondents were asked to identify the kinds of symbols their particular packages were capable of handling. Respondents were mapping professionals adequately familiar with all the programs. Altogether eight programs commonly used in the northwest Rocky Mountain region were selected for the present study.

Results of the survey indicate that although mapping programs offer a variety of symbols in their libraries and have great abilities to allow users to create, or import symbols from external sources, they can not accomplish the goal of traditional mapping perfectly. Among the eight programs, some are more powerful in handling symbols than others. For example, ARC/INFO is far ahead of all the others in this respect. Nevertheless, because different packages were developed for various practical purposes, they seemed to be adequate for their respective uses; e.g. SURFER is more appropriate for mapping contouring maps. As symbols are important in enhancing geographic communication, findings in this study suggest that users of computer mapping programs should not expect software to substitute for manual mapping at present and should look for programs that fit their purposes. In the meantime, software producers should be aware of the challenges ahead in improving their products' symbolization capabilities. The study is meaningful in that it is the first attempt to look at this neglected aspect of computer cartography.
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Special thanks go to my parents and my husband, whose encouragement and support has been very important while I was in graduate school.

I also wish to dedicate this thesis to my favorite canine friend, Feifei, who has brought so much fun and luck to me.
CHAPTER 1
INTRODUCTION

Traditional Cartography and the Development of Computer Cartography

Throughout most of the history of cartography, mapping has been done manually. In early times, maps drafted by hand were the finished maps. Later the invention of the printing revolutionized mapping and made it possible for maps to be reproduced for use by the masses.

Traditionally, mapmakers used a variety of tools and media to produce desired maps. They used wooden styluses, brushes, and quill pens to draw maps on clay tablets, papyrus, vellum, paper, etc. Pen-and-ink drafting and negative scribbling are two primary ways of drawing conventional maps. Today, many maps are still being produced with manual techniques.¹

Traditional methods of manual mapping continued until the early 1960s when computers began to edge their way into the world of cartography. The advent of computer cartography has substantially changed the way maps are created. However, as cartography embodies a set of basic concepts and practices

unrelated to drafting, fundamental theories such as those involved with symbolization remain the same no matter what technology one uses to produce a particular map.

Computer cartography in the United States goes back to 1959 when a graduate student at the University of Washington, Waldo Tobler, wrote the paper—"Automation and Cartography." After the idea was brought up by the student, the adoption of computer cartography went through three stages. According to scholars, the first stage involved the reluctance to use computers in the 1960s. People were reluctant to use the new technology and computer cartography was generally ignored for some time. The second stage was the replication stage, where technology attempted to replicate cartographic drafting without exploring other potentials available through the use of computers. The last stage was the full implementation of the new technology in which maps were not only drafted by computers, but map data bases were manipulated for the purpose of conducting analysis. Today, cartography sets at the departure point where computer mapping is becoming the accepted method for producing maps of all types.3

During the early years of computer cartography, the emphasis was on the creation of algorithms which would provide


ways of doing things mechanically that were previously done by hand. So, in the past, where contour lines were drawn by a cartographer, using his knowledge about the lay of the land and his perceptions about how the map should look, later, the computer was given this ability by the programmer. The cartographer took on the analytical role of deciding how best to get the computer to represent the lay of the land rather than how to draw contour lines by hand.4

In the 1970s, as people began to realize the potential commercial value of computer cartography, many companies started to employ cartographers and computer scientists to produce some really effective and cost-competitive cartographic software. Government agencies at the federal, state, and local levels also took the initiative in producing mapping software.

One of the primary influences that computer mapping brings is speed. Many time-consuming and tedious chores can now be handled by computer. Some geographic data exist in machine-readable form, such as census tapes, so that information can simply be fed to the computer's memory, eliminating the need to search pages of tabular data and to copy columns of numbers by hand.5

In addition to eliminating time-consuming chores, the use of the computer has resulted in several other advantages

4Clarke, 1-11.
5Tyner, 33-34.
including cost reduction, flexibility, and the ability to experiment. The initial expense of a computer system dedicated to mapping can be high, but if a great many maps are needed, such a system can be cost-effective. Another advantage is flexibility. Computer assistance permits tailor-made maps, that is, maps for very specific situations. For example, it is possible to create a series of marketing maps tailored to a company's exact needs or a series of temperature maps showing daily variations. Computer mapping also allows practical and cost-effective experimentation with different presentation of the same data.6

The Ability of Computer Mapping Software to Accomplish the Goals of Traditional Cartography

Problems in Computer Cartography

Computer cartography is not without problems, and one of these problems arises when it comes to dealing with text. A map is not just a collection of lines, colors, and polygons, it also provides important information in the form of text. Dealing with text has been a particularly difficult issue for computer cartography. The selection, placement, and production of text is a very important part of cartography. Until recently software programmers were still trying to enable mapping packages to position text wherever appropriate.7

6Ibid.

7Clark, 5-11.
Symbolization is another area in which computer software needs to make improvements because effective use of symbols can enhance not only geographic communication but also the aesthetics of the map. In traditional cartography, the choice of font, color, spacing, and other symbols enabled individual cartographers to give a map a certain style. Today, many are still of the opinion that computer-produced maps still look "artificial"; they have requested software developers to give computer cartographers greater control over some intangible aspects of maps.8

Given the advantages and disadvantages of computer mapping, an interesting question arises as to what extent can computer mapping programs accomplish the task of traditional mapping. How can computers help convert geographic information into symbols? If computers have this ability, then can they do it satisfactorily? The study of symbolization in computer mapping, therefore, is an important issue. In an effort to understand this issue, this project has focused on some of the most commonly-used mapping software packages. Since these packages have been selected so as to be representative of a fast developing field, the findings of this research may also shed some insights on other similar software packages not included in the present study.

8Ibid.
Literature Review—Computer Mapping Software

There have been several studies comparing the capabilities of different mapping software packages. However, few of them have discussed the use of symbols in mapping programs in adequate detail. Instead, most studies have compared mapping packages by looking at the four steps of the mapmaking process. The four steps are: boundary files and data files creation; data analysis; map creation; and image processing. Most of these authors then compared each package by examining its capabilities relative to each of the steps.

Other researchers have suggested that a checklist for evaluating mapping software should include features such as map types, boundary files, data files, and user aids such as manual and tutorials. Only one recent comparative study of different packages did cover map symbols, scaling, and so on as well as data files, memory, and device support. However, compared with the total length of the article, the part


concerning symbolization takes up only a tiny space. The article only enumerated in tabular form the total number of symbols and colors that each of the software packages had. In no way did it treat each different symbol as it might be modified by various scales of measurement. Thus, the present study is exclusively about symbols, and it is intended to cover a void in the study of symbolization as concerns computer mapping.

Problem Statement

Symbols are the graphic language of cartography. If used effectively, they can enhance the communication between the map maker and the map reader. The study of symbolism used in computer packages will help users to become more knowledgeable about each package in particular and computer cartography in general.

During the past several years, a number of computer mapping software packages have appeared. Powerful personal computers and operating systems such as DOS and Windows have made it possible for mapping software to be widely available.

Different software may have different usages because of their strength or weakness. It is hoped that the present study will find out to what degree the various computer mapping software packages accomplish the goals of traditional cartography in dealing with the scaling and symbolization of geographic data, and to provide cartography students and
professionals some insight into the usefulness of mapping software.

Methodology

The first thing that the author did was to identify the main types of symbols that exist in traditional mapping. These symbols are selected from two sources--general purpose atlases and books on cartography or thematic mapping. A random sample of them was then selected for the survey. Based on the selected symbols, the survey questions were designed to find out how some computer mapping packages accomplish the goal of traditional mapping.

After consulting with the advisor, the author designed a preliminary survey. This preliminary survey was pretested with two professionals involved in computer mapping in order to ensure that a representative sample of symbols have been selected and the appropriate questions asked.12

Altogether, eight commonly used packages were selected for the present study. Companies that designed the packages were contacted. They were informed that questionnaires would be mailed to them inquiring about the kind of symbols the software use and the kind of mapping they can accomplish. At the same time, available literature which concerns the

12The author wishes to thank Dr. Laurence W. Carstensen Jr., professor of geography at Virginia Polytechnic Institute and State University, and Mr. Pat Madison, president of Golden Software Inc., for participating in the pretest, and for their valuable comments and suggestions about the survey.
software (journals, trade magazines, texts, monographs, etc.) was studied.

Mapping capabilities of the selected software programs are evaluated by examining two variables—symbols and scaling. All of the packages are evaluated by examining the number of symbols and the number of scales they are able to accomplish. The percentages of symbols on all the scales that can be mapped are considered a measure of the general capabilities of the computer packages in accomplishing the goals of traditional mapping.

This chapter has discussed the introduction of computers into the world of cartography, and the problems that mapping packages have yet to overcome in producing traditional maps. It also has pointed out that the computer's ability to create symbols is an area that needs more study, and this is the focus of the present study. The method used for the research is a survey of eight software products. However, before any further discussion is made of the survey, it is important to familiarize the readers with the use of symbolism in mapping.
CHAPTER 2
CARTOGRAPHIC SYMBOLS

The Science of Cartography

Development of Cartography

To study symbolism in mapping, it is first of all necessary to examine some aspects of the science of cartography, its definition and its development. Cartography is the art and science of mapmaking. A map is a graphic representation of the physical and social phenomena that are distributed over the earth's surface. Mapmaking or mapping, then, refers to the processes of symbolizing, compiling, and producing maps.

No one knows when the first map was prepared. Primitive people assembled maps from sticks or drew them on clay tablets in order to gain an overview of the important things in the world and to create tools for navigation. The earliest paper maps seem to have been made in China over 2500 years ago. In Europe, mapmaking occurred about 300 years later. By the seventeenth century, European influences began to affect the Chinese cartography, particularly through the work of missionaries. Thereafter, the mapmaking of the Eastern and Western worlds ceased to be very distinctive. Virtually all
mapping in the seventeenth century was concerned with the most literal aspects of the physical environment such as improvements of charts and navigation. Throughout history, advances in printing, engraving, and interest in overseas exploration all gave impetus to the development of cartography as a profession.¹

Special subject, or thematic, mapping began in 1701 with Edmund Halley, the famous astronomer-cartographer. Halley published a map showing the angular difference between true north and south. He portrayed this by connecting points of equal values or intensities with isogonic lines (see Figure 2-1).²

Later, many other new ways of showing thematic data were devised, ranging from variable shading to show the incidence of disease or criminal activity, to proportional flow lines to portray the transportation of goods and people by road systems. By the beginning of the twentieth century, thematic mapping had become well established. Of course, the most profound changes in the field of cartography were brought about by the continuing development of electronic techniques associated with telecommunication, automation, and computer applications.

²Ibid., 20-40.
Figure 2-1. This is a portion of Halley's isogonic chart of 1701 showing curve lines (isarithms or isolines), which are intended to connect points with the same variation of the compass.  

Types of Maps

There are hundreds of possible map types and they can usually be grouped into a few categories. One categorization is based on map function. These functional categories are general-purpose maps, special-purpose maps, and thematic maps. There is not complete agreement among cartographers about these terms or categories.

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3Ibid., 34.

General-purpose maps do not emphasize one type of feature over another. They show a variety of geographical phenomena (political boundaries, cities, and the like) and present a general picture of an area. They are used for reference, planning, and location. Commonly, the state or regional maps in an atlas belong to this type.

Special-purpose maps are created to satisfy very specific types of interests. Geologic, soil, and cadastral maps are included here. Such maps are usually large scale, and the user often knows the subject well. Navigation maps, which include all kinds of maps created for route finding, such as aeronautical charts, nautical charts, and road maps, are often called special-purpose maps (see Figure 2-2).

Thematic maps normally feature only a single distribution or relationship; any other information shown serves as a spatial background or framework to help locate the distribution being mapped. Thematic maps may be either qualitative or quantitative. That is, they may show some characteristic or property, such as land use, or they may show numerical data, such as temperature, rainfall, or population (see Figure 2-3).

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5Tyner, 8-10.
6Ibid.
Figure 2-2. Nautical chart used for navigation.

Figure 2-3. Thematic maps normally feature a single distribution or relationship.
Cartographic Generalization

No matter which type of maps cartographers make, they can always be viewed as a collection of geographical phenomena. There are so many types of geographical phenomena that mapmaking involves several operations including selection, simplification, classification, and symbolization, collectively known as cartographic generalization. Selection involves decisions regarding the geographic space to be mapped, map scale, map projection and aspect, data gathering methods and data variables. Simplification is the process of determining the important characteristics of the data, eliminating unwanted detail, and retaining and possibly exaggerating the important characteristics. Classification is the ordering or scaling and grouping of data. Symbolization is the graphic summarizing and coding of essential characteristics, comparative significance, and relative positions.

Symbolization occurs after selection, simplification, and classification; it encodes or assigns symbols to various data or categories of data. Symbolization is most important in the process of generalization because it makes generalization more visible and can either enhance or destroy the effectiveness of cartographic communication. All the marks on a map are

symbols, from coastlines to cities and from rivers to mountains. By using these marks or symbols, the cartographer is symbolizing a concept, a series of facts, or the feature of a geographical distribution.

Map Symbols

Cartographic Classification of Geographic Phenomena

Anything that has a spatial component can be mapped, whether it is an actual physical feature on earth, a concept, or even an opinion. If a phenomenon varies with respect to location, it constitutes a geographic reality and can be displayed in map form.

All geographical or spatial phenomena can be classed in four categories: points, lines, areas, and volumes. Point phenomena exist at discrete points and may be actual or conceptual. The location of a city is a point phenomenon. Although this feature has area in the real world, when reduced to the small scale of a world map it may be considered as a point.

Linear phenomena are features that are line-like in reality and may be thought of as having only one significant dimension—length. Some are tangible, such as rivers or roads. Others, such as political boundaries, cannot normally be seen on the earth’s surface, and still others are conceptual and derived from data over time, such as average traffic volume on a highway.
Area phenomena have two dimensions, length and width, and are distributed over a defined area. Similar to point and linear phenomena, area phenomena may be either directly observable or conceptual. Examples include vegetation types or land use patterns and living preferences.

Volume phenomena, such as area phenomena, extend over areas, but they are considered as having a third dimension. This dimension is a value or quantity such as elevation and precipitation. Other examples are population density and percentage of land used for crops.

Symbols That Relate—Points, Lines, and Areas

Geographic data are gathered by measuring and calculating the features and attributes of real-world or geographic phenomena. There is obviously an unlimited variety of geographic data that can be mapped, all of which must be represented by symbols. In order to consider the ways in which signs can be employed to symbolize the variety of data, it is of help to classify them. There are normally three classes of symbols: point, line, and area. Volume phenomena are often shown by point, line, and area symbols.

Point symbols are signs such as dots, triangles, and so on, used to represent place or point data such as a city, or volume data such as a city’s population. The actual map

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symbols may cover some map space, but when they conceptually refer to locations, they are point symbols.

Line symbols are linear signs used to present linear data, and also volume data such as elevations. Area symbols are ordinarily shades, patterns, or colors that extend throughout a map area to indicate that the region has some common attribute, such as water, administrative jurisdiction, or some other measurable characteristic.

Volumetric symbols are somewhat complex in that they must exist on paper at points (dollars in a bank), along lines (migration of workers from Mexico), and over areas (precipitation). Thus, flow lines of transportation can show the tonnage or volume, but they are also linear in form. Any symbol that represents a quantity or volume like population and production can be seen as volumetric symbols.9

Scaling Systems for Map Symbols

Traditionally, the mappable features or data have been divided into scaling system of four classes: nominal, ordinal, ratio, and interval.10 Scale of measurement is of primary importance in map symbolization. These four kinds of scaling systems are discussed in the following paragraphs.

Nominal Scales. Nominal scales are employed when we distinguish among sets of things only on the basis of their

9Robinson, Elements of Cartography, 140-141 and 277-279.

intrinsic character. The distinctions are based only on qualitative considerations without any implication of quantitative relationships. For example, nominal scale might distinguish between agricultural and nonagricultural land but exclude the productivity or any measurable characteristics of the land.

**Ordinal Scales.** Ordinal scales involve nominal classification, but they also differentiate within a class of data on the basis of rank according to some quantitative measure. The order of the variables from lowest to highest is given, but not any definition of the individual numerical values. In the case of agricultural land, ordinal scale might assign each unit of land to a grouping, starting with the least productive and progressing to the most productive.

**Ratio Scale.** The distinguishing characteristic of a ratio scale is that it has both a nonarbitrary starting point and a constant distance between increments. From the preceding example about the agricultural land, the number of kilograms produced on each hectare of field could be measured. The scale of production, on this basis, would begin at zero, with no production, and range upward to the most productive.

**Interval Scale.** If the scale used for measurement has an arbitrary starting point, it is referred to as an interval scale. An arbitrary starting point is a zero value that does not mean the complete absence of whatever is being measured. The best example of this is the Celsius temperature scale.
The temperature zero degree Celsius does not mean that there is "no temperature."

A Cross-Classification of Symbols

These above classification and scaling systems can also be cross-classified. When they are, the result describes the way that various data have been represented by appropriate symbols in traditional mapping.

Figure 2-4 shows clearly that every symbol has two aspects. It can be classified as point, line, or area symbols and at the same time can be measured at nominal, ordinal, ratio, or interval level. For example, the railroad sign in Figure 2-4 is a nominal line symbol, since it represents linear phenomenon and has no quantitative characteristics.

The Interplay of Graphic Elements

Good mapping design quality also requires that the cartographer make changes in hue, value, size, shape, spacing, orientation, and location of symbols to represent the different data in meaningful fashion. This leads to the graphic elements, which, together with the classes of symbols, comprise the essential ingredients of all geographic communication. Each of the graphic element can be applied to point, line, and area symbols. The seven commonly used graphic elements are briefly described in the following paragraphs (See Figure 2-5):
Figure 2-4. Examples of the three classes of symbols and the scale of measurement being used in mapping.\(^{11}\)

**Hue.** Hue refers to color. When we say things are of different colors, we are usually describing the hue differences of red, blue, green, and yellow, etc. Hue connotes a nominal scale of measurement and can be used for place, linear, or areal data types.

**Value.** As a graphic quality, value refers to the relative lightness or darkness of a mark or an area, whether of black or any other hue. Value connotes order and can be used to display ordinal aspects of data sets. By addition of legend numbers, value can be used to portray interval or ratio

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\(^{11}\)Tyner, 132.
Figure 2-5. The primary graphic elements with some examples of their simple application to the classes of symbols.\textsuperscript{12}

\textsuperscript{12}Ibid., 143.
aspects of data sets. Value can show place, linear, or volumetric data.

Size. Symbols vary in size when they have different apparent dimensions—diameter, area, width, or perspective height. Size connotes quantities and can be used to portray data sets at the ordinal, interval, or ratio scale of measurement.

Shape. Shape means the distinctive appearance of (1) a regular form, such as a circle or triangle; (2) the outline of an irregular area, such as a state or island; or (3) the contour of a linear feature, such as a river or coast.

Spacing. Spacing refers to the spacing of a series of dots or lines that are the component marks of a symbol. A fine spacing is one in which the symbols (and thus the geographical phenomena) are close together; it contrasts with a coarse spacing.

Orientation. Orientation refers to the directional arrangement of an elongated individual mark or the parallel lines of marks as they are positioned with respect to some frame of reference. Orientation is used to differentiate nominal aspects of data sets and for place, linear, or areal data types.

Location. Location is the visual element on the map plane and is applicable to those components that can be moved about, such as titles, legends, or some of the typography.
The graphic elements of size and value order the data in some way. The remaining elements of spacing, hue, orientation, and shape are differential variables used to portray the nominal scale of measurement and the place, linear, or areal aspects of data. They should not be used for higher scales of measurement or for volumetric data.\textsuperscript{13}

**Summary of the Symbolization Problem**

Generally speaking, symbolization can be done either by changing the scale of measurement aspect of a data set or by changing the data type aspect of a data set. After the cartographer has decided which data to portray, he or she must then decide upon the appropriate graphic elements to use in order to enhance cartographic communication. Table 2-1 summarizes the symbolization problem where it is shown that certain combinations are possible while some are not. Thus, the available symbols in mapping are numerous and full of varieties when elements of symbolization are used in different combinations.

**Map Symbols and Computer**

Computer cartography is concerned with methodologies and techniques of mapping in an automated environment. It basically pursues the same goals and uses the same principles as traditional cartography, although it also uses new technology and holds many new potentials for mapping.

\textsuperscript{13}Ibid., 142-143 and 280-281.
The selection and design of symbols are important steps in creating a successful map, because symbols are the graphic language of maps. Just as mathematicians and musicians who use symbolic notation to enable their works to be understood, cartographers use symbols to facilitate graphic communication with map readers and users. Symbols on a map show the position, nature, and sometimes value of geographic phenomena. All symbols have locations on the map, which correspond to the actual position of the object on earth.

Cartography deals with the conversion of spatial information into map symbolism. The conversion process is

Table 2-1. The symbolization problems. X indicates that no graphic element is appropriate.14

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<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>spacing</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>orientation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>X</td>
<td>value</td>
<td>value</td>
<td>value</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>size</td>
<td>size</td>
<td>size</td>
<td></td>
</tr>
</tbody>
</table>

14Ibid., 281.
important to both manual and computer mapping. It translates
data into visual symbols that are meaningful to map readers.
There are two fundamental approaches used to represent spatial
data with a computer: the vector model and the raster model
(see Figure 2-6). In the vector model, objects or conditions
in the real world are represented by the points, lines, and
areas, each defined by pairs of x-y co-ordinates. The raster
model consists of a regular grid of square or rectangular
cells or pixel, which is defined by its row and column
numbers.\(^\text{15}\)

There are differences in the way vector and raster data
are collected, stored, manipulated, and displayed. Both
systems have advantages and disadvantages depending on the
ways in which the data are to be used. The raster model is a
simple data structure and is usually used where it is
necessary to integrate topographic and thematic map data with
remote sensing data. Whereas the vector system employs a more
compact data structure and is more efficient in handling
topological information. As the demand for high resolution,
compact data structures, and the power of flexible data
analysis increase, the use of vector and raster spatial data

Figure 2-6. Comparison of the Raster and Vector Models. The landscape in A is shown in a raster representation (B) and in a vector representation (C). The pine forest stand (P) and spruce forest stand (S) are area features. The river (R) is a line feature, and the house (H) is a point feature.
structures as complementary components of a geographical information system will increase in importance.\textsuperscript{16}

Most of today's computer mapping software packages allow users in one way or another to produce symbols. They may store a certain number of symbols in the program's libraries so that wherever the user needs a particular type of symbol, he can just call it up. Some programs can also allow users to import symbols from external sources or create symbols as desired. Map symbolization has become an important and integral part of different mapping software packages.

The choice of one particular symbol over another may be affected by the cartographer's conception of the geographical phenomena, identification of the basic spatial attributes of the phenomena, the measurement of the data, and so on. But the overriding concerns are clarity and appropriateness. The symbols must be clear and readily identifiable and appropriate for the purpose and audience of the map.

CHAPTER 3
A SURVEY OF SOFTWARE PRODUCERS

An Overview

The assistance of computers has revolutionized mapmaking in many ways. But, throughout the previous chapters the questions have been asked repeatedly: Are computers and their programs capable of mapping all the various symbols that may be used to make maps? Can the computer handle quantitative data and map them the way cartographers used to do manually? In order to gauge to what extent traditional geographic symbols are used in computer mapping, a survey was designed and sent out to professionals associated with the above GIS programs.

Selecting the Software Producers

Rational and Criteria

Because of the large number of mapping software packages now available in the United States, it is almost impossible to survey all of them. Therefore, the programs selected for this study are mostly those commonly used in the northwest Rocky Mountain region. To fit the purpose of this study, only those that have mapping capabilities and can be run on personal computers in DOS and/or Window environments were selected.
After the initial list of programs was obtained by reading related journals and publications, the author consulted with the advisor and several GIS professionals. Altogether, only eight software programs met the previously mentioned criteria and were therefore selected for this study.

The Companies

The programs included were: ARC/INFO, AtlasGIS, GRASS, MapInfo, MapViewer, MOSS, PAMAP, and SURFER. Table 3-1 lists all the software producers and also the respondents for each of the programs. Because the author was unable to get in touch with producers of two programs used in federal agencies, GRASS and MOSS, principal users were selected to fill out the surveys instead.

The Software

The following are brief introductions of each software program:

ARC/INFO (Version 7.0). This program was designed by the Environmental Systems Research Institute, Inc. It is a raster- and vector-based geographic information system. It is available on a wide range of platforms from large mainframe computers to workstations to PCs, and can be run using either DOS or UNIX operating system. ARC/INFO can be used for land records management, urban and regional land use planning, thematic mapping, and for environmental and natural resource
Table 3-1. Software Programs and Survey Respondents

<table>
<thead>
<tr>
<th>Programs</th>
<th>Companies Names and Addresses</th>
<th>Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARC/INFO</td>
<td>Environmental Systems Research Institute</td>
<td>Michael Blongewicz</td>
</tr>
<tr>
<td></td>
<td>Suite 213</td>
<td></td>
</tr>
<tr>
<td></td>
<td>606 Columbia St. NW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Olympia, WA 98501</td>
<td></td>
</tr>
<tr>
<td>AtlasGIS</td>
<td>Strategic Mapping, Inc.</td>
<td>Paticia Breslin</td>
</tr>
<tr>
<td></td>
<td>3135 Kifer Road</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Santa Clara, CA 95051</td>
<td></td>
</tr>
<tr>
<td>GRASS</td>
<td>Soil Conservation Service</td>
<td>Kristin Gerhart</td>
</tr>
<tr>
<td></td>
<td>Federal Building, Rm 443</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 East Babcock St.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bozeman, MT 59715</td>
<td></td>
</tr>
<tr>
<td>MapInfo</td>
<td>MapInfo Corp.</td>
<td>Phil Levesque</td>
</tr>
<tr>
<td></td>
<td>200 Broadway</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Troy, NY 12180</td>
<td></td>
</tr>
<tr>
<td>MapViewer</td>
<td>Golden Software, Inc.</td>
<td>Patrick A. Madison</td>
</tr>
<tr>
<td>and SURFER</td>
<td>809 14th St.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Golden, CO 80401</td>
<td></td>
</tr>
<tr>
<td>MOSS</td>
<td>Bureau of Land Management</td>
<td>Dennis Leonard</td>
</tr>
<tr>
<td></td>
<td>3255 Fort Missoula Rd.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Missoula, MT 59801</td>
<td></td>
</tr>
<tr>
<td>PAMAP</td>
<td>PAMAP Technologies Corp.</td>
<td>Deresa Moir</td>
</tr>
<tr>
<td></td>
<td>Suite 200, 6772 Oldfield Rd.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Victoria, B.C. Canada</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V8X3X1</td>
<td></td>
</tr>
</tbody>
</table>

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management, including forestry, agriculture, fish and wildlife, and so on.

ARC/INFO incorporates dBase as its relational database manager and can also import data from other file formats such as Lotus 1-2-3 or Excel. It contains a series of computer mapping and display capabilities for generating high quality cartographic displays. These displays are generated by associating geographic data with tables of graphic symbols and shades. Users can also specify size(scale) symbols and adjust and combine features to produce maps.¹

**Atlas GIS (Version 2.1).** This program was developed by Strategic Mapping, Inc., is a PC-based geographic information system that is a viable alternative to those who cannot afford a workstation or mainframe GIS. It is a polygon- or vector-based GIS that is designed for use in both DOS and Windows environments. Atlas GIS supports a number of GIS-type operations including overlays, buffering, and address matching. Its potential users are as diverse as human geography, demography, market research, election campaign consulting, or urban-regional planning.

Data information is stored in the same file format (the .DBF file) that dBase and FoxBase use; users can also import

data from Lotus 1-2-3 and various ASCII-based files. The program integrates database, mapping, and analysis functions in a single package. It also has extensive digitizing and mapping editing capabilities.²

GRASS (Version 4.0). GRASS, initials for Geographic Resource Analysis Support System, was developed by the U.S. Army Construction Engineering Research Laboratory (USA CERL) at the beginning of 1980s. GRASS is a raster-based GIS written primarily to assist Army installation land use planners. It also has wide application in natural resource and environmental planning and management. It runs under the UNIX operating system and is written almost entirely in "C."

GRASS software is comprised of three main subsystems: MAP DEVELOPMENT (digitizing), for turning hard-copy maps into digitized products; GRID (grid-cell analysis), for overlaying, analyzing, and displaying grid-cell data bases; and IMAGERY (Image processing), for extracting and classifying images and scanned aerial photographs.³


MapInfo for Windows (Version 2.11). This program, designed by MapInfo Corp., is available in DOS or Windows for use on personal computers, or on Sun or HP workstations. Based on vector data structures, the program will read and maintain .DBF files directly and also reads Lotus 1-2-3, Excel, and ASCII files.

MapInfo is a map-drawing and map-querying package. Users can build a map image as a series of layers. Its mapping capabilities allow users to digitize their own maps or import maps from other formats. The geocoding process will then enable imported data to be associated with features such as postal codes and street addresses. One main advantage of MapInfo is its careful attention to the user interface. The multiwindowed interface database allows users to manipulate records from multiple files using dialogue boxes and SQL (structured query language) commands, as well as by drawing or selecting regions on the map. It has wide applications in land use planning, delivery and routing, territory management, and monitoring federal programs such as environmental protection and crime analysis.4

MapViewer (Version 2.1). This program, produced by Golden Software, Inc., is a vector-based thematic mapping package that runs under Microsoft Windows. It displays data associated with specific geographical areas to produce thematic maps, including choropleth, prism, dot-density, pie, and symbol

maps. MapViewer allows users to visualize geographic data by creating black and white or full color maps from spreadsheet data. It can be used to determine sales territories, track population trends, plan direct mail and advertising campaigns, and map income distribution and demographics.

Creating a map with MapViewer generally involves importing a boundary file, loading a data file, selecting from a gallery of supported map types, and adding other features users might wish to include on the map. Maps are then saved complete with all features.5

SURFER (Version 4.01). Another program that is produced by the same company as MapViewer, Golden Software, Inc., is SURFER. SURFER is designed to produce maps of both two- and three-dimensional surfaces from randomly spaced data on IBM compatible personal computers with DOS operating system. It is raster- and vector-based and can create full-color contour and 3D surface maps from any X, Y, Z data set. Applications include terrain analysis, geologic mapping, contouring of contaminant concentrations, and groundwater modeling.

All programs are menu driven through the menus which list options for creating contour maps and surface plots of XYZ data. Adjustable default settings provide preselection of all options to suit specific needs and save them for next time.

SURFER is a practical tool to create three-dimensional diagrams, contouring, and isarithmic maps. The functions of user-interface and automatic defaults make this program easier, especially for people with a minimal knowledge of mapping principles.\(^6\)

**MOSS.** This package was developed by Autometric, Inc. Known as Map Overlay Statistical System, it was designed for use in resource management. MOSS can operate on several hardware platforms, including DOS-based PCs and UNIX workstations. The MOSS family of GIS software supports both vector and raster data analysis. MOSS has been used by U.S. federal agencies since the late 1970s to support the broad resource management responsibilities throughout the West and Alaska. The major federal users of MOSS software includes the Department of Interior, Department of Agriculture, Department of Energy, and Department of Defense, as well as many state and local governments.

The system consists of five components: the Automated Digitizing Systems (ADS), the Analytical Mapping System (AMS) for digital data entry; the Map Overlay and Statistical Systems (MOSS) and Map Analysis and Processing Systems (MAPS)

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\(^6\)Thomas W. Hodler, "SURFER". *Cartography and Geographic Information Systems*, 17 (July 1991): 251-254.
for data processing, analysis, and display; and the Cartographic Output System (COS) for plotting.\(^7\)

**PAMAP (Version 3.00).** This program is a decision support system used to optimize often conflicting economic and environmental concerns of industry, government, and the public. It was produced by PAMAP Technologies Corporation of Victoria, British Columbia in Canada. Originally designed for the resource management field, PAMAP has been expanded to serve a wide range of disciplines. These include agriculture, land use planning, property assessment, and surveys, among others. PAMAP is used professionally in a variety of government, university, and private agencies throughout Canada and the United States.

The PAMAP geographic information system is a vector-based system with a raster capability to perform analytical functions. It is menu driven and therefore easy for new users to learn, thus making it attractive for classroom use. The system is made up of several modules which can be customized by users to satisfy their own needs. The PAMAP GIS is designed


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as the only fully-functional GIS which is capable of running in micro, mini, and workstation computer environments.

The Survey

Description and Explanation

The survey began with a cover letter explaining that it was designed to provide information for the author's thesis, the subject of which was to compare various mapping software packages' abilities in dealing with symbol presentation (see the survey form in the Appendix). Following that was a short introduction of the technical terms used in the survey. Respondents were first asked to identify the specific versions of the software on which they base their answers. Then, they were asked to indicate whether their software had certain symbols built in the library or whether the program had either the ability to allow the user to create symbols or to import the symbols from an external source, or none of the previous choices.

The symbols selected for these choices were nominal point symbols including symbols for school, church, airport, mine, windmill, cemetery, exposed wreck, campground, ski area, and bench mark; nominal line symbols including river, boundary, bridge, tunnel, pipeline, and highway; nominal area symbols including forest, desert, swamp, Indian Reservation, and park

---

or recreation area; and ordinal symbols including proportional squares, highways, and boundaries.

Another category included closed-ended Yes or No questions about ratio and interval symbols such as circles, cubes, spheres, triangles, bars, pie charts, dot maps, flow lines, and isarithmic lines. Additional questions inquired after the ways the software handled data such as land use, population, or other graphic elements including color, spacing, orientation, and so on.

Questions such as the purpose of the software and its challenges in meeting the goal of traditional mapping were attached at the end of the questionnaire. All of the symbols were grouped into three categories—point, line, and area symbols and four levels of nominal, ordinal, ratio, and interval scales.

Pretesting

An early draft of the survey was first pretested by a professor in computer cartography and an executive in the software industry. The author contacted them first and both expressed interest in participating in the pretest. They were particularly asked to see whether appropriate samples had been selected and relevant questions had been asked in the survey or not. The pretest generated very useful comments and

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9Dr. Laurence W. Carstensen Jr., Professor of Geography at Virginia Polytechnic Institute and State University, and Mr. Pat Madison, President of Golden Software Inc. participated in the pretest.
suggestions. Afterward, the questionnaire went through modifications.

Conducting the Survey

The author called the companies that produced the programs and asked for the names of professionals qualified to fill out the survey. GRASS and MOSS were exceptions for reasons that were explained earlier. As both programs are used mainly in federal agencies, two principal users in the state of Montana were selected. Altogether eight professional users were identified and the author contacted them to obtain their willingness to participate in the study before sending out the surveys.

The questionnaires were sent out to the different professionals associated with the selected programs on July 15, 1993. Follow-up telephone calls were made a few weeks later. The final response was received on October 1, 1993, with a 100% return rate.

With few exceptions, the respondents answered almost all of the questions. They were, therefore, all determined to be valid and appropriate for analysis in this study. Tabulations and analysis of the data from the survey will be provided in the next chapter.
CHAPTER 4

RESULTS AND ANALYSIS

Examining and Tabulating the Results

The symbols and measurement scales presented in the survey are the ones that are typically seen in traditional mapping. To obtain these symbols, the author went through the collection of the general purpose atlases in the Mansfield Library; only those symbols that appeared at least twice were selected for use in the survey. Although the symbols cover a wide range of geographical phenomena, they nevertheless do not include all that are available in traditional mapping.

Results of the survey are presented in this chapter in the same order as they appear in the questionnaire (see the survey form in the Appendix, pp. 83-90). Following an overview, discussion and analysis deal with the sections in the survey which cover the types of symbols used (point, line, and area), types of frequency distributions for choropleth maps, the presentation of graphic elements, thematic maps, and mapping software's challenges and utilities. When it is appropriate, results of the survey are tabulated.

The mapping capabilities of the software programs in this study are considered to be dependent mainly on two related variables—symbols and scaling. Nominal and ordinal scaled
symbols provide four possible choices for answers in the questionnaires: (a) "Library"—symbols are available in a library file built into the software; (b) "Import"—symbols can be imported from an external source; (c) "Create"—users can create symbols using tools in the program; (d) "None"—none of the above. Ratio and interval symbols, graphic elements, special maps such as dot maps and choropleth maps have questions which call for "Yes" and "No" answers. At the end of the survey there are open-ended questions which concern the program's usages and limitations.

Whenever possible, numerical values were added in order to allow for the comparison of the capabilities of the different programs in handling particular category of symbols. If respondents chose any of the first three options for a particular symbol, it was assigned a value of one. If the choice was "None," it was assigned the value of zero. If respondents did not give an answer, then it was treated as a missing value. With regard to the "Yes" or "No" questions, "Yes" was assigned the value of one whereas "No" meant zero.

Types of Symbols Used

Point Symbols

Nominal Point Symbols. Survey results which concern nominal point symbols can be found in Table 4-1. It seems software producers were very reluctant to check the "None" column even when no other answer was checked. For example,
Table 4-1 Nominal Point Symbols

<table>
<thead>
<tr>
<th>SYMBOLS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>6360</td>
</tr>
<tr>
<td>Church</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>6360</td>
</tr>
<tr>
<td>Airport</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
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<td>✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>6360</td>
</tr>
<tr>
<td>Mine</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
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<td>✓✓✓✓✓</td>
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<td>2370</td>
</tr>
<tr>
<td>Cemetery</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
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</tr>
<tr>
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<td>✓✓✓✓✓</td>
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</tr>
<tr>
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<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
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<td>✓✓✓✓✓</td>
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<td>4460</td>
</tr>
<tr>
<td>Ski area</td>
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<td>✓✓✓✓✓</td>
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<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>1470</td>
</tr>
<tr>
<td>Bench mark</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
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<td>✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>✓✓✓✓✓</td>
<td>2480</td>
</tr>
<tr>
<td>TOTAL</td>
<td>101010</td>
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<td>010100505100</td>
<td>0101003833640</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

MOSS, had no check marks in the "Library," "Import," and "Create" columns for the windmill symbol. The "None" column was not checked either even though, logically, it should have been.

If a software package can import any one of the symbols, it should be able to import them all. As can be seen from Table 4-1, ARC/INFO, MapViewer, and SURFER can import all the symbols, whereas MOSS can import only three of them. It is reasonable to say that if MOSS can import these three, it can probably import others too.

Similarly, if a software package can be used to produce any one of the nominal symbols it should be able to create them all. The only possible exception is the bench mark symbol. Since that symbol is comprised of crossed lines and two letters, it might be possible to create it with a package.
which could not create more complex symbols. Data indicate that, except for MOSS, all the packages have the ability to create nominal point symbols.

Three of the boxes in the "Create" column for AtlasGIS were checked. However, these checks are opposite blank boxes in the library. In other words, the respondent might have thought that although AtlasGIS did not have windmills, ski areas, and bench marks in the library, it could create these symbols. Of course, the software also could be used to create any of the other symbols. MOSS could only create bench marks, but not the rest of nominal point symbols. MOSS probably does not have an algorithm specially designed for creating elaborate nominal point symbols.

Thus, four of the software packages have the ability to import nominal point symbols: ARC/INFO, MapViewer, MOSS, and SURFER. All except MOSS have the ability to create nominal point symbols. The only questionable cases include AtlasGIS and MOSS, which indicated they can respectively create and import some of the symbols. In these cases, we can reasonably assume they must be able to create or import the rest of the symbols too.

With regard to symbols which are available in a library, Table 4-1 shows that the most common symbols include school (6), church (6), mine (6), and airport (5). Others which are less common include campground (4), exposed wreck (3), cemetery (3), bench mark (2), windmill (2), and ski area (1).
Of course, not all of the nominal point symbols which can possibly be made were included in the survey, the ten which were selected were merely a sample.

ARC/INFO is the only program that has all ten of the selected symbols in its library. This is consistent with the strength of this software package in other aspects. AtlasGIS (7) and GRASS (6) also have relatively good representations of nominal point symbols in their libraries. MapInfo and PAMAP each has five of the ten possible symbols in their libraries. Neither MapViewer nor SURFER possess nominal point symbol libraries. The producer has chosen to rely upon the ability of the programs to import or create symbols instead.

In general, computer mapping software shows great potential for providing the user with nominal point symbols. While not all of the surveyed software packages have complete libraries of such symbols, it is always possible to either import or create them when using these programs.

**Ordinal Point Symbols.** Only one symbol, the square, was selected in the survey with the assumption that if a program can produce or import a square, it should be able to produce or import other ordinal point symbols such as circles, triangles, or spheres (see Question 11 in Appendix). Likewise, if a program cannot produce an ordinal square or does not have it in its library, it is unlikely that it can produce or has other similar symbols. Another reason for choosing the square
symbol is to avoid presenting some of the common symbols such as circles and triangles twice in the survey.

Table 4-2 shows that six of the packages allow users to create ordinal square symbols: ARC/INFO, GRASS, MapInfo, MapViewer, PAMAP and SURFER; and five have this ordinal point symbol in their libraries: ARC/INFO, AtlasGIS, GRASS, MapInfo and MapViewer. ARC/INFO and MapViewer are the only two programs that have the symbol in their libraries and at the same time can import and create the symbol. MOSS is the only program for which "None" was checked on this question.

Thus, with the exception of MOSS, all the programs can produce ordinal point symbols in one way or another, with ARC/INFO and MapViewer having the ability to produce three functions pertaining to ordinal point symbols. GRASS and MapInfo have the symbol in the libraries and can create it also. PAMAP and SURFER can only create such a symbol.

**Ratio-Interval Point Symbols.** The section of the questionnaire concerning ratio-interval point symbols is comprised of a set of "Yes" or "No" questions. These questions can be seen as comprising two subsets (see Questions 12

<table>
<thead>
<tr>
<th>SYMBOLS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>6</td>
</tr>
</tbody>
</table>
through 18 in Appendix). The first subset asks whether a program can produce proportional symbols including circles, cubes, spheres, triangles, bars, and pie charts. The second subset asks about how each package manipulates data to scale ratio or interval point symbols. Results of these questions are tabulated in Table 4-3.

Of the six ratio and interval point symbols, only Mapviewer can produce all of them, followed by ARC/INFO and

Table 4-3 Ratio and Interval Point Symbols, Data Manipulation Methods

<table>
<thead>
<tr>
<th></th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A: RATIO AND INTERVAL POINT SYMBOLS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>6</td>
</tr>
<tr>
<td>Cubes</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Spheres</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>2</td>
</tr>
<tr>
<td>Triangles</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5</td>
</tr>
<tr>
<td>Bars</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Pie Charts</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td><strong>B: DATA MANIPULATION METHODS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square Root</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Flannery Technique</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>0</td>
</tr>
<tr>
<td>Scale One Point at a Time</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Others</td>
<td>✓ ✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>17</td>
</tr>
</tbody>
</table>

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SURFER, both of which can produce four of the symbols (See the section of Table 4-3 which is labeled "A"). AtlasGIS, GRASS and MapInfo can produce both circles and triangles. MOSS indicated the ability to produce bars only, whereas PAMAP checked "No" at all the six choices.

If we look at the frequencies of all the symbols that can be produced, it is not hard to see that ratio and interval circles and triangles are the most commonly available symbols. Circles can be produced by six of the programs and triangles by five. Cubes and bars are available from three of the programs. Not surprisingly, spheres and pie charts are the least frequent with each being able to be produced by two of the mapping packages.

Section "B" of Table 4-3 displays information about the ways the programs manipulate data for scaling ratio or interval point symbols. Respondents were asked to indicate whether their programs scaled ratio-interval data by calculating the square root of the data values, by using the Flannery technique, by requiring that the operator scale the symbols one at a time, or by some other method. ARC/INFO and PAMAP did not give any answers in this section. This could be explained by the reluctance of respondents to give negative

---

¹A procedure devised by James J. Flannery to compensate for the underestimation of the sizes of large circles relative to small ones. The procedure is to psychologically scale the circles by taking the log of the data, and then multiply the log by 0.57 instead of 0.5. Robinson, Elements of Cartography, 292.

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answers, a phenomenon that has been noted at the beginning of this chapter.

Except for SURFER, which has two data manipulating methods (taking the square root and scaling point symbols one at a time), the rest of the programs use one of the methods. Three programs (AtlasGIS, MapInfo, and SURFER) indicated that they scaled symbols by calculating the square roots of data values. Three other programs (GRASS, MOSS, and SURFER) indicated that users must scale point symbols one at a time. Only Mapviewer checked the "Others" box and indicated that its program could scale symbols proportionally by setting the width and height ranges.

All of this points out that as the symbols become more complicated (for example spheres as opposed to circles), fewer programs are capable of producing them. While circles and triangles are readily available, symbols such as spheres and pie charts remain unavailable in the majority of the selected packages. On the other hand, methods to manipulate data for ratio and interval symbols remain varied between programs, with most of them offering one method to change symbol sizes.

Dot Map. Dot maps are probably the most common point symbol maps where each dot represents a specified number of the phenomena being mapped, i.e. one dot represents 1,000 people. The size and the value assigned to the dots are two of the principal variables to be manipulated. When the dots represent data which have been given for areas (e.g.
counties), traditionally the dots have either been spread randomly throughout each area or they have been positioned where the cartographer knows them to exist, avoiding lakes, empty areas, etc. Random placement of dots is inaccurate, whereas placing dots where the phenomena are known to exist constitutes an improvement.

Six "Yes" and "No" questions were presented in the survey to explore each package's ability to create dot maps. These questions ask whether a program can manipulate the values, sizes, and densities of dots; designate areas without dots; and whether it can position dots randomly or individually. MapViewer checked positive answers in all six questions, followed by AtlasGIS (5), ARC/INFO (4), and MapInfo (4). GRASS and PAMAP could perform only two of the functions (see Table 4-4).

Table 4-4 Dot Map

<table>
<thead>
<tr>
<th>FUNCTIONS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can it manipulate the value of the dots?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>4 4</td>
</tr>
<tr>
<td>Can it manipulate the size of the dots?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>4 4</td>
</tr>
<tr>
<td>Can it position the dots randomly?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>4 4</td>
</tr>
<tr>
<td>Can it designate areas without dots?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>4 4</td>
</tr>
<tr>
<td>Can it control the density of dots?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5 3</td>
</tr>
<tr>
<td>Can the user position the dots individually?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>2 5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4 2</td>
<td>5 1</td>
<td>2 4</td>
<td>4 4</td>
<td>2 6</td>
<td>0</td>
<td>6 2</td>
<td>4 0</td>
<td>5 23 24</td>
</tr>
</tbody>
</table>

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MOSS does not have the capability to produce dot maps since all the six "No" answers were checked. Five "No" were checked for SURFER leaving blank whether it can position dots individually. It is plausible to assume that SURFER cannot produce dot maps either.

Of those that are capable of making dot maps, five can control dot densities within individual units and four can manipulate the dot values, change the dot sizes, designate areas with no dots, or position dots randomly in each area. Positioning dots individually is the least common technique and only two packages have that function.

While some of the programs have the algorithms to place the dots randomly and others allow users to place the dots individually, none of them have algorithms which will automatically place the dots avoiding empty areas within enumeration districts. Generally speaking, MapViewer is most capable in handling dot maps. AtlasGIS, ARC/INFO, and MapInfo can also do reasonably well in making dot maps. GRASS and PAMAP are slightly better than MOSS and SURFER which are unable to produce any dot map.

Line Symbols

Nominal Line Symbols. Table 4-5 lists results of the part of the survey concerning nominal line symbols, and it can be seen that ARC/INFO, GRASS, and PAMAP had all of the chosen nominal line symbols in their libraries. MOSS (4), AtlasGIS (3), and MapInfo (3) had about half; whereas MapViewer and
Table 4-5 Nominal Line Symbols

<table>
<thead>
<tr>
<th>SYMBOLS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rivers</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Boundaries</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Bridges</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Tunnels</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Pipelines</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>TOTAL</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>

SURFER had none of the symbols in the libraries at all. Of the six symbols, the most common are bridge (6), pipeline (6), boundary (5), and tunnel (5). Rivers (3) is the least common symbol.

With regard to the ability to import nominal line symbols, ARC/INFO and PAMAP checked all the symbols in the "Import" column. The remaining six packages did not have the ability to import such symbols at all.

How about the ability to create nominal line symbols? MapViewer did not check anything, it stated instead that users could make solid lines of any width and color and could choose four dashed line styles. MOSS indicated that it could create the river symbol and had the rest of the symbols in its built-in library. As it is speculated in the section on nominal point symbols, MOSS could probably also create the rest of the symbols too. The respondent checked the river symbol only, probably because it was not available in the library. The same is true with GRASS, where the respondent only checked "Create"
in three places. GRASS can also be understood to be able create the rest of the nominal line symbols. With these assumptions, it can be concluded from Table 4-5 that all of the programs except MapInfo can create the selected nominal line symbols. MapInfo was the only program that indicated it could not create or import river and tunnel symbols, nor did it have them in its library.

To summarize, ARC/INFO and PAMAP scored full points in importing or creating nominal line symbols and storing these symbols in their libraries. MapViewer and SURFER are capable of only creating all these symbols, and the rest of the programs could produce all the symbols by a combination of "Import," "Create," and "Library" functions.

Ordinal Line Symbols. The ordinal line symbols considered by the survey include two sets: highways (interstate, state, and county) and boundaries (national, state, and county boundaries). Most of the software packages have both types of symbols in their libraries with boundaries present in six and highways in five of the software libraries (see Table 4-6). ARC/INFO, AtlasGIS, MapInfo, MOSS, and PAMAP have both sets of symbols in their libraries, whereas GRASS has only boundaries in its library. However, Mapviewer and SURFER have neither sets of the selected ordinal symbols in their libraries.

The ability of the computer programs to import such symbols is limited; three programs are able to import
Table 4-6 Ordinal Line Symbols

<table>
<thead>
<tr>
<th>SYMBOLS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highways</td>
<td>✓ ✓ ✔</td>
<td>✓ ✔</td>
<td>✔</td>
<td>✔</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
</tr>
<tr>
<td>Boundaries</td>
<td>✓ ✓ ✔</td>
<td>✓ ✔</td>
<td>✔</td>
<td>✔</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>2 2 0 2 0 1 1 2 0 0 0 0 2 2 0 0 0 0 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>115 6 3</td>
</tr>
</tbody>
</table>

boundaries and two are able to import highways. Among the eight programs, ARC/INFO and PAMAP are the only two that can import both sets of symbols. MapViewer can import only boundaries. AtlasGIS, GRASS, MapInfo, MOSS, and SURFER do not have the capabilities to import either set of symbols.

The results in "Create" are complicated by MapViewer where the respondent did not give very clear answers. Instead of checking in the "Library," "Import," and "Create" columns, the respondent wrote "No" beside interstate and state symbols and "Yes" beside the county symbol. This is contradictory since a program capable of producing a solid line as the symbol for county highways, could also produce interstate and state highways. From the respondent's answer in the section on nominal line symbols, it is learned that MapViewer could create solid or dash lines. Therefore, it must be able to produce highway symbols also. It is clear from Table 4-6 that ARC/INFO, Mapviewer, and PAMAP could create both sets of ordinal line symbols. AtlasGIS and GRASS could create only boundaries. The rest of the programs—MapInfo, MOSS, and SURFER—do not have the function to produce both symbols.
Thus, most of the computer mapping programs offer the ability to produce ordinal line symbols. ARC/INFO and PAMAP can import and create both sets of symbols and also have both in their libraries. SUFFER is obviously an exception here as it is mainly a program for making two- or three-dimensional maps. The producer may have chosen not to include the ability to produce ordinal line symbols.

**Ratio and Interval Line Symbols.** To gauge each program’s ability in handling ratio and interval line symbols, two questions were advanced. One asked whether the programs can produce flow lines, the other inquired after isarithmic lines to show elevations. Results in Table 4-7 show that four of the programs can produce isarithmic lines and only three can produce flow lines.

ARC/INFO, AtlasGIS, and SURFER can map both flow lines and isarithmic lines. Among the rest of the packages, only

<table>
<thead>
<tr>
<th>SYMBOLS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Lines</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Isarithmic Lines</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
PAMAP can map isarithmic lines; GRASS, MapInfo, MapViewer, and MOSS all checked "No" for both symbols. All this indicates ratio and interval line symbols are not very common in the majority of the packages selected for the present study. Other than ARC/INFO, AtlasGIS, and SURFER, all of the other programs have limited or no ability to produce such symbols.

Area Symbols

Nominal Area Symbols. Of all the five nominal area symbols, swamp and Indian Reservation appear in the libraries of four packages, and the rest—forest, desert, and park or recreation area are available in three libraries (see Table 4-8). Programs that have relatively more area symbols in their libraries are ARC/INFO (5), AtlasGIS (4), and MapInfo (4). Others, such as PAMAP (2), GRASS (1), and MOSS (1), have fewer symbols in their program libraries. However, these symbols are not available in libraries of MapViewer and SURFER.

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5</td>
</tr>
<tr>
<td>Deserts</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5</td>
</tr>
<tr>
<td>Swamps</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5</td>
</tr>
<tr>
<td>Ind. Reservation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5</td>
</tr>
<tr>
<td>Recreation Areas</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 4-8 Nominal Area Symbols
Three programs have the ability to import nominal area symbols: ARC/INFO (5), SURFER (5), and MOSS (2) (also see Table 4-8). Yet, these symbols could not be imported from external sources by using AtlasGIS, GRASS, MapInfo, MapViewer, and PAMAP.

All the programs are better at creating nominal area symbols than importing the symbols or providing them in their built-in libraries. Table 4-8 illustrates that all the symbols appear at least five times in the "Create" column. Indian Reservation (7) and park or recreation area (6) are the most common symbols. Five programs—ARC/INFO, GRASS, MapViewer, PAMAP, and SURFER checked all of the five symbols under "Create." MOSS checked two symbols, AtlasGIS checked one, and MapInfo did not check any in the "Create" column.

In general, ARC/INFO again outperforms others in mapping nominal area symbols. It not only stores all of the selected symbols in its library, but also can import and create all of these symbols. The other programs can map nominal area symbols by "Import" or "Create" or "Library" functions. Thus, most computer programs will enable users to obtain nominal area symbols. MOSS checked "None" for forest and desert, perhaps because it does not have the computational procedures to produce these relatively more difficult area symbols. MapInfo checked "None" for swamp, but MapInfo had all the other nominal area symbols in its library. It seems that the program
does not allow users to import or create any nominal area symbols at all.

**Ordinal and Ratio-Interval Area Symbols.** Ordinal and ratio-interval area symbols are discussed in this section together because either can be represented on the map by the same types of symbols. Their results are shown in Table 4-9. When respondents were asked to indicate whether their programs were capable of producing ordinal area symbols, seven of them indicated "Yes." SURFER gave the only negative answer in this category.

Survey results for ordinal area symbols were obtained when respondents were asked a similar question about ratio-interval area symbols—seven of the programs answered "Yes" and only SURFER gave a "No."

Overall, there is no difference between the programs' abilities in producing these ordinal and ratio-interval symbols. The two samples used in this section are very common symbols: land use and population density area symbols.

Table 4-9 Ordinal, Ratio and Interval Area Symbols

<table>
<thead>
<tr>
<th>SYMBOLS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land Use</strong></td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>7</td>
</tr>
<tr>
<td><strong>Population Density</strong></td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>14</td>
</tr>
</tbody>
</table>

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Therefore, it is not surprising that most of the programs have the capabilities to produce these two ordinal and ratio-interval area symbols. As for SURFER, it may be that the program was produced to create two- or three-dimensional graphics rather than more general thematic mapping types. General purpose maps such as those in these two questions may not be the primary concern of SURFER.

**Types of Frequency Distributions for Choropleth Maps**

Question 41 in the survey is concerned with the way data for choropleth symbols are classified. Altogether, ten techniques to group data were identified. They are: continuous, counts, discontinuous, equal steps, normal distribution, numerical progression, optimal, percentage, quantile, and standard deviation. Abbreviated definitions of these frequency distribution methods are provided in Table 4-10. Respondents were asked to indicate which method(s) their software packages use for designing the frequency distributions needed to categorize data for choropleth maps.

Results of the this part of the survey are presented in Table 4-11. It can be seen that the most commonly used data manipulating techniques are continuous (5), quantile (5), equal steps (5), percentage (4), standard deviation (4), counts (4) and discontinuous (4). Less common are such methods as nominal distribution (2), optimal (1), and numerical progression (1).
Table 4-10. Types of Frequency Distributions for Choropleth Maps

<table>
<thead>
<tr>
<th>Types</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Entering the maximum value for each range</td>
</tr>
<tr>
<td>Counts</td>
<td>Entering the number of data value for each range</td>
</tr>
<tr>
<td>Discontinuous</td>
<td>Users enter the desired maximum and minimum values for each range</td>
</tr>
<tr>
<td>Equal Steps</td>
<td>Enclosing equal amount of the range of the mapped quantity within each class interval</td>
</tr>
<tr>
<td>Normal Distribution</td>
<td>A distribution represented by a bell-shaped curve and used as a basis for comparison in many statistical measures</td>
</tr>
<tr>
<td>Numerical Progression</td>
<td>Geometric progressions which increase at either increasing or decreasing rates</td>
</tr>
<tr>
<td>Optimal</td>
<td>Ranging maximum GVF using Fisher/Jenks method</td>
</tr>
<tr>
<td>Percentage</td>
<td>Entering the percentage of data value for each range</td>
</tr>
<tr>
<td>Quantile</td>
<td>A division of the number of observations in the data array into equal parts</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>The square root of the arithmetic mean of the squares of the deviations from the mean; a measure of the dispersion form the mean in a frequency distribution</td>
</tr>
</tbody>
</table>
Table 4-11 Methods for Categorizing Quantitative Data

<table>
<thead>
<tr>
<th>METHODS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantile</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Equal Steps</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Percentage</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Normal Distribution</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Numerical Progression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Continuous</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Counts</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Optimal</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Discontinuous</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>

Of the eight packages, AtlasGIS (8), ARC/INFO (7), and MapInfo (7) have more grouping methods and are better at classifying data for choropleth maps than the rest of the programs. PAMAP has four methods, while GRASS and MapViewer both have three methods to group data. MOSS uses only standard deviation for data classification. SURFER did not check any answer; and, it is very likely that these techniques are not available in SURFER, because such methods are usually used in producing choropleth maps which SURFER is not capable of making.

Obviously, the software programs in this study have not fully utilized all the techniques to manipulate quantitative
data yet. The most common methods for grouping data in choropleth maps are continuous, quantile, equal steps, percentage, standard deviation, counts, and discontinuous methods. AtlasGIS, ARC/INFO, and MapInfo are the most flexible in handling data manipulation frequency distributions for choropleth maps.

The Presentation of Graphic Elements

The Use of Colors. Color is another important element in today's computer mapping. The accessibility of plotters and laser printers has made color an important element in effective visual communication. Response to the question of how many colors each program supports shows that ARC/INFO and GRASS support unlimited colors. AtlasGIS supports 510 colors; both MapInfo and PAMAP support 256 colors. MapViewer indicated that it could use hues and colors to attain certain graphic qualities. It is not immediately known whether it has unlimited or a certain number of colors. MOSS supplies 16 colors. In the case of SURFER, the respondent wrote "Red, Green, Blue" instead of a specific number. According to the reference manual, however, SURFER has 16 different colors.\(^2\)

Colors can be mixed for all the software programs. Of the three color definition systems, RGB (red, green, and blue) is the most popular system with seven programs supporting it (see Table 4-12). MCY or Process Colors (magenta, cyan, and yellow)

is supported by four of the programs and HLS (hue, luminosity, and saturation) is supplied by three programs. ARC/INFO supports all the three color definition systems. AtlasGIS, GRASS, and MapInfo use two systems: RGB and MCY. PAMAP supports RGB and HLS and the rest have one color definition system: MapViewer (HLS), MOSS (RGB), and SURFER (RGB). The author's own experiences with the programs reveal that MapViewer has RGB system and SURFER has MCY system also.

For some of the advanced software like ARC/INFO, the supply of color ranges from many to unlimited; but for others such as MOSS and SURFER, it seems the use of color is very limited. Most of the programs allow the use of one or two color definition systems. Except for SURFER, all respondents

<table>
<thead>
<tr>
<th>GRAPHIC ELEMENTS</th>
<th>ARC/INFO</th>
<th>AtlasGIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can color be missed?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>8</td>
</tr>
<tr>
<td>Definition system:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>red, green, blue</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>7</td>
</tr>
<tr>
<td>Definition system:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>magenta, cyan, yellow</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>4</td>
</tr>
<tr>
<td>Other definition system:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mainly, HLS</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Can color be assigned to</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>7</td>
</tr>
<tr>
<td>thematic mapping?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do it have the function of</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>7</td>
</tr>
<tr>
<td>spacing?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do it have the function of</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>7</td>
</tr>
<tr>
<td>changing orientation?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>43</td>
</tr>
</tbody>
</table>

Table 4-12 Graphic Elements
also said their programs' colors could be assigned to thematic mapping categories.

**Other Graphic Elements.** The graphic elements of spacing and orientation were chosen as sample symbols to measure each package's ability in handling graphic elements. The results show that all of the programs, with the exclusion of SURFER, are able to handle spacing and orientation in order to differentiate data. The two sample symbols presented in this survey are by no means exhaustive, but the obtained survey results tell us that graphic elements are mostly available for most of the programs. The situation with SURFER as a two- or three-dimensional mapping program may explain why it does not also have these graphic elements.

**Thematic Maps**

This section of the questionnaire deals with some thematic maps: dot maps, choropleth maps, contouring maps, hachures, three dimensional maps, and cartograms. As Table 4-13 shows, only ARC/INFO has the ability to produce all of these different types of thematic maps. In contrast, MOSS could produce none of them. The rest of the programs can produce between three or four of the selected maps. Dot maps, choropleth maps, and isarithmic maps are the most common thematic maps. Each of them is available in six of the programs. Cartograms seem to be the least common and they are only available in ARC/INFO. Hachures and three-dimensional
Table 4-13 Thematic Maps

<table>
<thead>
<tr>
<th>THEMATIC MAPPING TYPES</th>
<th>ABC/INFO</th>
<th>Atlas/GIS</th>
<th>GRASS</th>
<th>MapInfo</th>
<th>MapViewer</th>
<th>MOSS</th>
<th>PAMAP</th>
<th>SURFER</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dot maps</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Hachure maps</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Choropleth maps</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Isarithmic maps</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Cartograms</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Three Dimensional Diagrams</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

maps could be produced in four and three programs, respectively.

All of the selected thematic maps can be made in traditional mapping without the help of computers and are usually considered difficult to produce even with software packages. Therefore, it is significant that, except for three-dimensional maps, virtually all thematic maps are available in about half of the programs.

It should be cautioned, however, that the ability to produce a thematic map does not necessarily mean a program can produce a map with all of the qualities as could be done manually. The particular survey question here is too general to reveal many of the details involved in the process of making a thematic map. For example, PAMAP could create a dot map, but it could not control the density and manipulate the
value of dots as would be expected in traditional manual mapping. So, we may conclude that PAMAP has the ability to produce a dot map, but not necessarily a "true" dot map. The same can be said about the rest of the programs.

Mapping Software's Challenges and Utilities

The last two questions were open-ended. Respondents were asked: (a) What challenges does your software face in meeting the goal of traditional mapping? (b) What kind of purposes do you believe the software is most appropriate for? Why? (see Questions 47 & 48 in Appendix). It turned out respondents were less candid in answering the first question. Two respondents (ARC/INFO and PAMAP) left the question blank.

Among those who did provide answers, the respondent for AtlasGIS said that cartographic training is needed in order for users to run the program, otherwise novices are prone to make mistakes. GRASS mentioned it had yet to fix bugs in its digitizing module and improve mapping output. MapInfo listed its limitations in areas such as its displaying and printing environments. MapViewer said that the biggest challenge is "meeting the demand for thematic mapping and geocoding." MOSS said that unless data are digitized first, it is more costly and slower to produce maps by the program than by hand.

As far as the programs' utilities are concerned, results are consistent with the descriptions of each program's purposes in the previous chapter. Most of the respondents expressed the belief that the particular software they produce
or use is powerful in accomplishing the tasks it was supposed to do. This means, despite the different capabilities in handling symbols, all of the packages are very useful for respective purposes. It is clear, computer packages do not do everything that might possibly be expected of them; but within specific tasks, each program is a powerful tool.

**Summary**

Overall, the survey results indicate that computer programs are powerful tools in producing different types of symbols at different levels of measurement; but, at the same time, there is a limit as to what they can do. Symbolization capability seems to vary considerably across the different programs we have surveyed here.

ARC/INFO is the strongest in mapping nominal and ordinal symbols. It has all of the symbols in the library and can allow users to import all symbols from outside sources or to create their own symbols. ARC/INFO does well in other areas too. It supplies unlimited number of colors and has most of the ratio and interval mapping capabilities.

PAMAP is strong in handling nominal and ordinal symbols, yet it has only two of the nine ratio and interval functions. It enables users to create all the nominal and ordinal symbols. Both MapViewer and SURFER are very capable in creating and importing symbols, as well as in manipulating ratio and interval data.
AtlasGIS, MapInfo, and GRASS allow users to create most of the nominal and ordinal symbols and are average in handling quantitative data. MOSS can do a little of everything, but the majority of the symbols it uses are available only from its library.
CHAPTER 5
CONCLUSIONS

Interpretation of Results

As has been stated earlier, symbols are the graphic language of cartography. Used effectively, they can enhance cartographic communication. Symbolization can be done either by changing the measurement or the spatial attributes of the data. Traditional mapping has developed an elaborate system of producing the desired symbols.

But are computers, devices that are believed to have revolutionized the mapmaking process, capable of producing symbols commonly used in traditional cartography? To answer this question, the author has designed a questionnaire and surveyed eight commonly-used mapping packages on their symbolization capabilities. The packages included in the study are: ARC/INFO, AtlasGIS, GRASS, MapInfo, MapViewer, MOSS, PAMAP, and SURFER. Analysis of the survey results in the previous chapter shows that all of the symbols can be obtained in the mapping programs but with various limitations. Some programs may be stronger in producing one set of symbols and weak in other areas.

In dealing with nominal and ordinal symbols, all the programs have flexible ways to produce symbols. If symbols
cannot be created, they are either available in the libraries or can be imported from outside sources. "Create" is a more frequently available mapping function than either "Library" or "Import" throughout the eight programs.

When it comes to ratio and interval symbols, it is apparent that as the symbols become more complicated, fewer programs are capable of producing them. Among the ratio and interval point symbols, circles, triangles, and land use areas are more readily available than complex symbols such as cubes, spheres, bars, and pie charts. Likewise, half of the programs do not produce ratio and interval flow lines and isarithmic lines.

It seems that to match traditional cartography in producing nominal and ordinal symbols, mapping software producers need to expand the number of symbols available in their software libraries and, at the same time, need to improve their software's abilities to import symbols from external sources. There is also much room for improvement in ratio and interval symbols. In particular, more sophisticated algorithms need to be developed to allow users to manipulate the sizes or ratios of symbols other than those commonly seen.

Most of the programs that can produce dot maps match traditional methods only in certain respects. Computer techniques can allow users to have considerable ability to manipulate the size, value, and the overall density of dots. However, most of the programs can only allow users to place
dots randomly. The accuracy of computerized dot mapping can be improved if future programs will allow the users to have locational control over dot placements inside the areas represented by the data.

Most of the programs have a limited supply of colors. Some have only 16 colors. Almost all of the programs support the red, green, and blue definition systems. Therefore, program developers should try to expand their programs' color supplies and color definition systems such as the magenta, cyan, and yellow system and the HLS system.

The survey also shows that some methods to categorize quantitative data such as continuous, equal steps, and quantile are more popular. Other methods such as counts, discontinuous, equal steps, normal distribution, numerical progression, optimal, percentage, and standard deviation are less available. Cartograms and three dimensional maps are less commonly seen among the thematic maps than others such as dot maps, isarithmic maps, and choropleth maps. Thus, methods of data quantification and special thematic maps are another two areas that software producers should pay attention to in order for their programs to produce maps of comparable qualities to those of traditional cartography.

The survey also reveals that all programs seem to be adequately useful for their respective fields. A good example is SURFER, which has been designed for terrain analysis and geologic mapping. Therefore, its strength is in handling line
symbols. Its weakness in handling area symbols or colors probably matters little to users. Computer mapping in general also offers other advantages that can overcome the limits in handling symbols. We all know computer mapping is respected for its speed in handling large amounts of data. It is more cost-efficient and less time-consuming now to produce maps with computers. The existence of various programs have made mapping possible for people in various other fields and for those without much training in cartography.

What the Study Accomplished

This study is a first attempt at comparing mapping software packages by looking at their symbolization capabilities. The results are relatively reliable because: (1) the mail survey gave respondents sufficient time to think over the details covered before answering the questions; (2) the respondents are all familiar with the particular packages about which they were queried. Findings from the present study should help users and producers of mapping programs see the difference between traditional mapping and computer mapping from a new perspective. Users may benefit from this study by realizing the computer’s strength and limitations in symbolization. Producers may learn where they should improve the performance of their products.

The capabilities in mapping symbols are an important part of any package. Symbolization is part of the overall performance of the software, and good symbolization
capabilities can add to its overall strength and performance. Otherwise, the mapping capabilities of a package will be limited.

Limitations and Suggestions for Future Study

The present study is limited in that it is concerned with the use of symbols in only eight software packages and that respondents are only a small number representing a growing and competitive industry. Further study is encouraged to include more GIS packages, especially those commonly used in diverse regions and for different purposes. Future surveys should be sent to more than one professional involved in the use or the production of a package so as to minimize human errors or sampling mistakes.

Researchers interested in comparing the use symbols in computer and traditional mapping can also try other research methods. While a mail survey of those associated with the programs may result in respondents' reluctance to say bad things about their own products, methods such as using and analyzing the programs, or interviewing frequent users are apt to yield more objective findings. No one method is clearly superior to the other. Different methods will complement each other and will collectively bring us closer to the truth.

Since the use of symbols would have a direct impact on the communication effect of cartographic output, study in this direction is not only necessary but important. The present study is only a first attempt in this direction.
APPENDIX

The Survey

Introduction

All geographical phenomena or data can be classed in four categories -- point, line, area, and volume. There is also a scaling hierarchy that cartographers employ to cross-classify geographical data. The four scales in the hierarchy are nominal, ordinal, interval, and ratio.

1. Nominal—in which the data are differentiated but not ranked, e.g., forest or grass, steel mill or cement plant, etc.

2. Ordinal—in which the data are differentiated, as above, and are also ranked into categories, e.g., large, medium, and small cities, etc.

3. Interval—in which the data are differentiated and also are ranked on some consistent but not absolute numerical scale, e.g., temperature on the Centigrade scale, height above sea level, pH of soils, etc.

4. Ratio—in which the data are differentiated and are ranked on an absolute scale, e.g., income of people, population density, steel mill production, etc. One distinguished characteristics of this scale is that it starts from an absolute value of zero.

Mapping is a process of using combinations of the above scales and differentiations to communicate geographical data to map readers. During this process, graphic elements such as hue, value, size, shape, spacing, orientation, and location also come into play.

*******************************************************************************

--- Which mapping software is used as the basis for answering the following questions? Please check one.

  ___ARC/INFO    ___GRASS    ___Atlas GIS  ___SURFER
  ___MapInfo    ___MapViewer  ___PAMAP     ___MOSS

--- Which version is the software?(Be specific.)
NOTE: Please check the appropriate answers in the following questions. If two or three answers apply, check them all. (The symbols that appear to the right of the questions are merely example. The ones produced by your software maybe slightly different.)

The choices are:

(1) **Library**—means the symbols are available in a library built into the software.

(2) **Import**—means the symbols can be imported from an external source.

(3) **Create**—means the program has ability to allow user to create the symbols.

(4) **None**—means the answer(s) is none of the above.

Questions:

**Nominal Point Symbols**

<table>
<thead>
<tr>
<th>Library</th>
<th>Import</th>
<th>Create</th>
<th>None</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td>School</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td>Church</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td>Airport</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td>Mine</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td>Windmill</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td></td>
<td></td>
<td>Cemetery</td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td></td>
<td></td>
<td>Exposed Wreck</td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td></td>
<td></td>
<td>Campground</td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td></td>
<td></td>
<td>Ski Area</td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td></td>
<td></td>
<td>Bench Mark</td>
</tr>
</tbody>
</table>

**Ordinal Point Symbols**

Does it (your software) have different symbols such as circle, sphere and triangle to represent the different
sizes of cities, settlements, natural reserves, and population areas? For example:

<table>
<thead>
<tr>
<th>Library</th>
<th>Import</th>
<th>Create</th>
<th>None</th>
<th>Large</th>
<th>Medium</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Ratio and Interval Point Symbols**

Does it have proportional or graduated symbols like circles, squares, bars, pie charts, spheres, triangles and so on to show different quantitative data?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.</td>
<td>Circles</td>
</tr>
<tr>
<td></td>
<td>O</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>Spheres</td>
</tr>
<tr>
<td></td>
<td>O</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.</td>
<td>Bars</td>
</tr>
<tr>
<td></td>
<td>I</td>
</tr>
</tbody>
</table>

18. How are the data manipulated in order to scale ratio or interval point symbols?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>By calculating the square root of the data values;</td>
</tr>
<tr>
<td></td>
<td>By using the Flannery technique for visually proportioning the symbols (antilog n =log n x 0.57);</td>
</tr>
<tr>
<td></td>
<td>User must scale point symbols one at a time;</td>
</tr>
<tr>
<td></td>
<td>Others; (Please explain: )</td>
</tr>
</tbody>
</table>

**Dot Map**

Dot maps are special kinds of point symbol maps where each dot represents a specified number of the phenomena being mapped, i.e. one dot represents 750 people. The size and the value assigned to the dots are manipulated in order to produce the best visual representation. When the dots represent data which have been given for areas (e.g. counties), traditionally the dots have either been spread randomly throughout each area or they have been positioned where the cartographer knows them to exist, avoiding lakes, empty areas, etc. The latter is preferred. Questions:
19. ___ ___ Does the software allow the user to manipulate the value of the dots?

    Dot Map

    Each dot represents 75 persons

20. ___ ___ Does it let the user to manipulate the size of dot?

21. ___ ___ Will the software position the dots randomly throughout each area?

22. ___ ___ Can the user designate areas which have no dots?

23. ___ ___ Will the software allow the user to control the density of dots inside individual units (counties, etc.)?

24. ___ ___ Can the user position dots individually?

    **Nominal Line Symbols**
    Library Import Create None

25. ____ ____ ____ ____ River

26. ____ ____ ____ ____ Boundary

27. ____ ____ ____ ____ Bridge

28. ____ ____ ____ ____ Tunnel

29. ____ ____ ____ ____ Pipeline

    **Ordinal Line Symbols**
    Does it have the symbols to show the ranks of line data sets like highways and boundaries?

    Library Import Create None

30. ____ ____ ____ ____

    Interstate
    State
    County
31. ___ ___ ___ ___
   National Boundary ___ ___
   State Boundary ___ ___
   County Boundary ___ ___

**Ratio and Interval Line Symbols**

Does it have lines to show elevations and the volume of flows between places like transportation tonnage, and immigration numbers? For example:

Yes No

32. __ __ Flowlines

33. __ __ Isarithmic lines to show elevation

**Nominal Areal Symbols**

Does it have nominal area symbols like the following ones?

<table>
<thead>
<tr>
<th>Library</th>
<th>Import</th>
<th>Create</th>
<th>None</th>
<th>Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>___</td>
<td>___</td>
<td>___</td>
<td>___</td>
<td>[Forest symbol]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Desert</th>
</tr>
</thead>
<tbody>
<tr>
<td>___</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Swamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>___</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indian Reservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Indian Reservation symbol]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Park or recreation area</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Park or recreation area symbol]</td>
</tr>
</tbody>
</table>

**Ordinal Areal Symbols**

Will it build choropleth map with area data like landuse, vegetation type, and agricultural production? For example:

Yes No

39. __ __ Landuse [Intensive] [Less Intensive]
Ratio-Interval Areal Symbols
Can it produce ratio-internal symbols like the following, employing a frequency distribution of ranked ratio-interval data values?

Yes  No

40.  ____  Population Density

41. Data for quantitative area symbols (choropleth symbols) may be grouped into categories by a variety of techniques. Your software has the algorithms for which of the following techniques. (Check all that qualify.)

____ Quantile. A division of the number of observations in the data array into equal parts.

____ Equal steps. Enclosing equal amount of the range of the ranged of the mapped quantity within each class interval.

____ Percentage. Entering the percentage of data value for each range.

____ Normal Distribution. A frequency distribution represented by a bell-shaped curve; used as a basis for comparison in many statistical measures.

____ Numerical Progressions. Geometric progressions which increase at either increasing or decreasing rates.

____ Standard Deviation. The square root of the arithmetic mean of the squares of the deviations from the mean. It serves as a measure of the dispersion from the mean in a frequency distribution.

____ Continuous. Entering the maximum value for each range.

____ Counts. Entering the number of data value for each range.

Discontinuous (arbitrary or user defined). User enters the desired maximum and minimum values for each range.

**Graphic Elements**

42. What can the software do for use of color? Particularly,

How many colors does it support?

Yes No

Can colors be mixed?

What kind of color definition systems does it use?

Yes No

Red, Green, Blue (RGB)

Magenta, Cyan, Yellow (Process Colors)

Others (specify) ________.

Yes No

Can the colors be assigned to thematic mapping categories?

Yes No

Does it vary the spacing in arranging the lines per inch of patterns such as dots, lines and crosshatches, etc.?

Spacing

Does it use orientation or the directional change of elongated marks to differentiate data?

Orientation
46. There are some symbols that computer can not map, whereas they can be drawn in traditional mapping. Does your program have the following symbols or does it allow the user to create them?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dot map</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Choropleth map</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cartograms</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hachures</td>
<td>Isarithmic map</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Three dimensional diagram</td>
</tr>
</tbody>
</table>

47. What challenges does your software face in meeting the goal of traditional mapping?

48. What kind of purposes do you believe the software is most appropriate for? Why?
BIBLIOGRAPHY


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