3

Software

3.1 SOFTWARE TRENDS

In Chapter 2, we examined the physical tools available for computer cartography. These tools, however, are merely expensive doorstops without the sets of computer instructions designed especially to allow the use of hardware for making maps. The computer instructions that interact with the cartographer and allow the manipulation of data, hardware, and design for computer mapping are collectively known as software. Computer cartographic software includes all the data, programs, packages, and interactive systems necessary for mapping.

Several general themes pertain to software. First, as computers have moved from large mainframes alone to a diversity of mainframes, minicomputers, workstations, and microcomputers, computer mapping software has tended to become available over the full range, so that capabilities which were once available only on mainframe computers are now available to all. Computer mapping has moved away from mainframe computers toward smaller and more efficient microcomputers and workstations with dedicated graphics capabilities. Software has reflected this trend, with a movement away from large special purpose mapping programs to small, general purpose programs.

The early computer mapping software programs other than the large commercial systems tended to be single-purpose, stand-alone programs. As software has moved away from the large computer companies and academia, the programs have become more integrated, sharing a user interface, common data structures, and capabilities.

Many automated mapping systems now are really just parts of much larger systems such as statistical analysis or surveying systems. In addition, computer cartography now overlaps with the field of GIS. GISs are integrated systems for the management and analysis of spatial data with computer mapping capabilities. Many systems designed for data presentation, for image processing, and for computer-assisted design, have some computer mapping capabilities.

In 1974, the International Geographical Union's (IGU) Commission on Geographical Data Sensing and Processing started to inventory the computer software for computer mapping, analytical cartography, and GIS (Brassel, 1977). Their three-volume report, published in 1980, was the first comprehensive survey of computer mapping software.

Volume 1 of the IGU report was a catalog of complete geographic information systems. Volume 2, entitled *Data Manipulation Programs*, surveyed general geographic software. Volume 3, which surveyed cartography and graphics (Marble, 1980), was the result of a survey that was conducted during 1978–1979, and as such gives a view of the types of computer mapping software available during the early years of computer mapping.

Many years have now passed since the inventory was started, and current inventories would be veritable dictionaries of systems. A few sources now survey, review, and evaluate software, and these are considered later in this chapter. Of current interest, however, is how the software of the IGU report was a portent of the contemporary distinctions between computer mapping software packages. The report will be examined by section, with a discussion of the current software in each category.

3.1.1 Geographic Information Systems

The report listed 38 complete mapping systems, defined as groups of programs with multiple mapping functions. In the list are several early prototypes of what later became GISs, which were initially developed as computer mapping systems. These prototypes show that until computer mapping software became fully integrated with database management systems, there was very little difference between computer mapping systems and GISs. The distinction is still vague, and indeed many GIS packages contain extensive control over the design and production of maps.

Software that falls under this category today, that is, systems with both data management capabilities and user controlled map display, include Arc/View and Arc/Info by ESRI, GIS Plus by Caliper Corporation, ERDAS Imagine (Map Composer) by ERDAS Incorporated, Intergraph's Modular GIS Environment, ATLAS*GIS by Strategic Mapping Incorporated, IDRISI by Clark University, and GRASS by the U.S. Army Corps of Engineers, among many others.

Typically, cartography within these systems is performed by building a *macro.* A macro is a master control language program that selects data; establishes map geometry, extent, and scale; specifies how symbolization is to be done (for example, color sets, line properties such as solid or dashed); places the symbols; and finally writes the map into a format compatible with an output device. The device driver is bundled with the software, so that a given set of output formats are provided. This is similar to the batch control of mainframe computers. Interaction is by directing the macro output to the screen, noting problems, and editing the macro file to correct it.

3.1.2 Map Design and Computer-Assisted Drafting Systems

Twenty-five listings were systems for data collection, editing, and development, while seven of the systems were designed to do automated lettering. Editing systems were essential, because in the early days manual digitizing produced map data that were very error prone, and all translations, rotations, and so forth, had to be conducted by stand-alone secondary programs. Twenty-seven systems performed basic drafting operations and design.These were systems that allowed you to draw in some interactive way on the computer screen.

Many of these systems evolved into the basis for an entirely new industry by themselves, the computer-assisted drafting and design (CADD) industry, which overlaps into architecture, facilities mapping, and engineering. More recently, these systems have spun off microcomputer and workstation versions that put basic drafting capabilities, such as the manipulation of high-quality linework and text, into the hands of the cartographer. CADD packages used extensively in cartography for data capture and especially editing are AutoCAD, VersaCAD, TurboCAD, and ArcCAD.

Inexpensive design industry versions of the original CADD systems have also evolved into specialized computer packages for the graphic arts and publishing industries. Only those with extensive graphics control, and import/export capabilities are of use in cartography. These include CorelDraw! by Corel Systems Corporation, FrameMaker by Frame Incorporated, Adobe’s Illustrator, FreeHand by Freelance Software, MapGrapfix by ComGrafix Incorporated, Designer by MapGrafx Incorporated, Island Write/Paint/Draw by Island Graphics (Figures 3.1 and 3.2), and MacDraw II by Claris Corporation.

A common property of these systems is that they manipulate graphics as objects, that is, as a set of graphic primitives such as lines, text, and filled areas that can be *grouped* into a complex feature, termed a *segment* in GKS. As such, these graphics editors can be termed *object-based*. Active objects are usually highlighted by a box with corners drawn around the bounding rectangle for the object (Figure 3.1). Objects can be hierarchically grouped.

The package then allows a whole group to be rotated, translated, dragged, scaled, deleted, flipped and so forth, as a whole, rather than as constituent parts. Most systems also allow features to be layered, that is, some features can appear in front of or behind others. CADD systems allow snapping and copying of features between layers. Some packages allow erasure to “reveal” another layer, or translucence of layers. Others, for example CorelDraw!, feature raster-to-vector and vector-to-raster conversion and feature tracing.

Directly related to these *object-based* draw packages (not *object-oriented*, a different concept entirely) are the raster-only packages, commonly called *paint programs*. Paint programs allow the manipulation of images or bitmaps one pixel at a time only. Fills and text are immediately translated into bit maps, and object manipulation is not possible. But images can be resampled, sections can be cut out, areas can be color-increment shaded and so forth. Examples are Publisher’s Paintbrush and PC Paintbrush V Plus by Zsoft (partially incorporated into the Windows Paintbrush), Superpaint by Claris Corporation, Dr. Halo by Media Cybernetics, and Adobe’s PhotoShop.

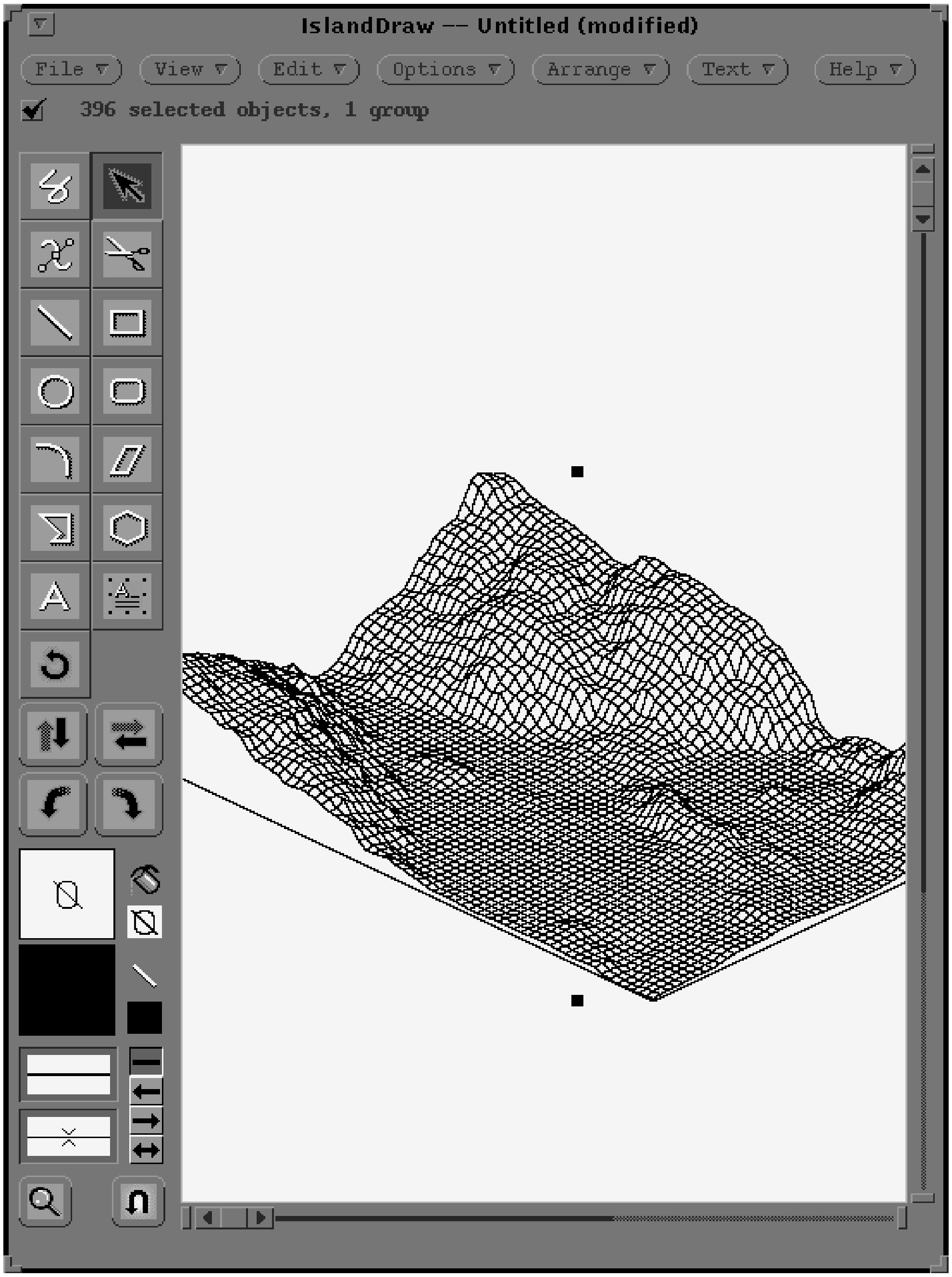

Figure 3.1 An object-based graphic editor: IslandDraw by Island Graphics. (Hewlett Packard Graphics language file imported from Surfer by Golden Software.)

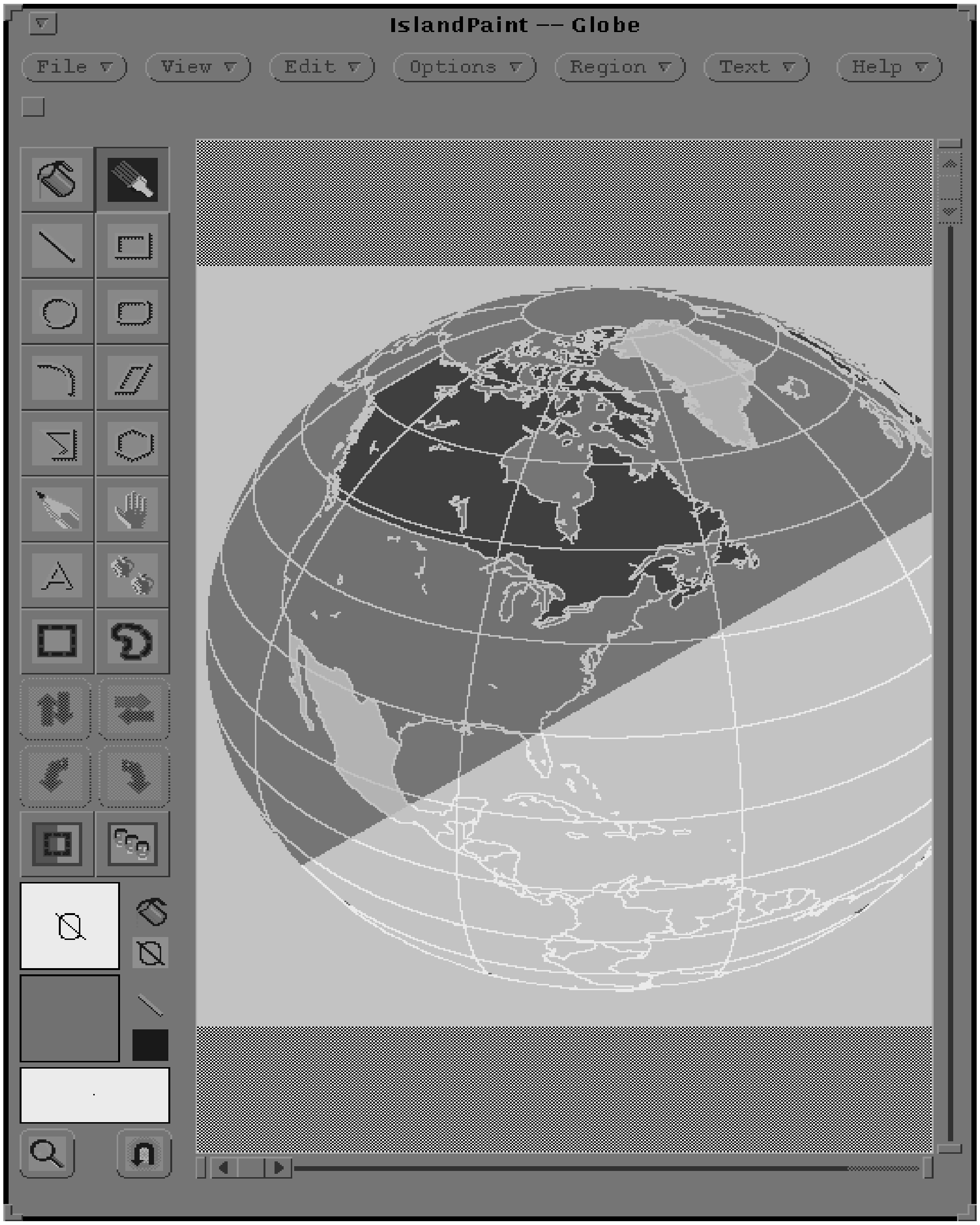

Figure 3.2 A paint type graphic editor: Island Paint by Island Graphics. (Hewlett Packard Graphics language file imported from MicroCAM.)

A key element that has arisen recently is the ability for these programs to share data. Plot files in many of the industry standard formats, such as PostScript, DXF (AutoCAD's Digital eXchange Format) or HPGL (Hewlett Packard Graphics Language), or in the International Standards Organization standard CGM (Computer Graphics Metafile) format can be moved between packages, even across operating systems and computer platforms. Because many stand-alone GIS and computer mapping packages can generate these plot files, this allows the major software packages to be used to generate maps, and then a CADD or design package can be used to add text, neat lines, special symbols and so forth. This is a particularly powerful combination, because the batch macro style of many of the basic mapping and GIS packages makes layout and design particularly tedious.

3.1.3 Systems for Map Displays of Data and Statistics

Nineteen of the packages displayed diagrams rather than maps, for example pie charts and histograms. Ten of the systems produced cartograms, which are maps with geographic space distorted to show an attribute other than area. Although not specifically cartographic, these packages have become another new industry, called presentation graphics. The vendors in this area have made the presentation of statistical and other information into a communications art and have produced some very effective products that take advantage of hardware devices such as projectors and slidemakers.

Products in this area break down further into statistical packages, presentation packages, digital Atlases, and animation packages. Statistical packages are those that are normally used to tabulate data and compute basic or advanced descriptive and parametric statistics. Some of these packages include additional commands which allow georeferenced data to be displayed, usually only as choropleth or point symbol maps. Among these packages are SAS Graph by SAS Institute and Harvard GeoGraphics by Harvard Graphics.

Presentation packages allow maps or graphics from other sources to be included within elaborate and highly attractive graphics backgrounds, so that presentation slides or posters can be made. Typically text and graphics can be laid out against a background that is supplied as a design template. Examples are FreeLance Graphics by Lotus, PowerPoint by Microsoft, Show Partner by IQ Technologies, and Charisma by MicroGrafx.

Digital Atlases are sets of ready-made maps grouped around a particular area. These packages have become extremely popular, and in many cases have replaced the basic printed Atlas. Because any map in the Atlas can be selected, cropped, and printed out, custom maps can be made, for example of highways in a given city. Special versions also exist for highway route planning. Examples are PCGlobe and PCUSA, Global Explorer and Street Atlas USA from DeLorme, and AutoMAP from R. Donnelley.

Animation packages can either take sets of maps as single frame images and play them in sequence to make animations or allow sophisticated editing and even "directing" of animation sequences. The packages often integrate with MultiMedia and Hypermedia authoring systems and are covered in detail in Peterson (1995). Examples are MicroMind Director and MediaDeveloper by Lenel Systems.

3.1.4 Feature Mapping Systems

Thirty-one of the systems in the IGU report did point and line mapping, producing maps of what is now called “cartographic spaghetti.” These systems were often dedicated to specific databases, such as the World Data Bank, or a single type of plotter device. In 1980 many of the systems produced thematic maps, in particular the choropleth maps much in demand for statistical cartography. Here we see the split in technology, since 26 of the systems did area shading using grid or raster technology and 22 of them used vector technology. Almost all produced line printer output, printing and overprinting symbols to make patterns and shades.

Today, these packages represent the bulk of basic computer mapping programs. Key to these systems is the variety of data formats they support, the device drivers, and their particular ease of use for editing and design. Examples are MapInfo by MapInfo Corporation, Arc/View by ESRI, Atlas*PRO by Strategic Mapping, MacChoro II by Image Mapping Systems, GIMMS by Gimms Corporation, MapViewer by Golden Software, and FMS by Facility Mapping Systems.

These packages allow the capture of geographic data from basic sources (such as TIGER and DLG files), and can be used for annotation; symbol placement; line, color, and pattern control, and so forth. Many perform point symbol and choropleth mapping only, but some have more sophisticated choices, such as perspective views, stepped statistical surface maps, and cartograms. As mentioned above, a critical element is the ability to generate plot files that can be brought into other packages for layout and design.

3.1.5 Surface Mapping

Thirty-four of the systems did contouring and surface interpolation. Surface interpolation consisted of taking data collected as point samples, with an attribute such as elevation or the depth of a drill hole, and gridding the data for the purpose of making a contour map. Many of these systems have come about due to the needs of the oil exploration industry. Early versions of these systems produced very crude maps on a line printer using printed symbols, and lines had to be drawn in by hand afterwards. Few of them labeled the contours; instead, they printed legends along with the maps. The more sophisticated ones, packages like SURFACE II (Sampson, 1978), produced vector output, allowing smoothing and annotation, and had adequate user and reference documentation and support. Thirty-one systems were for three-dimensional mapping although most simply generated gridded perspective diagrams.

Three-dimensional surface symbolization, including contouring, is particularly well served by the software industry. Many of the major GIS packages, such as ERDAS and Arc/Info, have these capabilities. Other packages are MicroDEM by the U.S. Naval Academy, Surfer by Golden Software, Gridzo by Rockware, Inc., and PacSoft by PacSoft. High-end software for three dimensional surface representation overlaps with scientific visualization software and includes Dynamic Graphics, Precision Visuals, Silicon Graphics, and IBM’s Data Explorer software.

The user interfaces for these packages vary considerably, and in the workstation software cases include entire fourth generation languages and program libraries for graphics, using interfaces to X-windows and in some cases proprietary graphic windowing systems. Many of the packages have advanced capabilities for using different interpolators, surface representation methods, contouring methods, and support grid, TIN, and other data structures.

3.1.6 Coordinate Conversion and Map Projections

Sixty-seven systems did either map projection transformations or other cartographic transforms such as translation, rotation, scaling, and distance measurement. These capabilities have found their way into most computer mapping software and rarely exist now as stand-alone programs. Operations supported by these routines include changing map projection, converting between coordinate systems, rubber-sheeting, affine transformations and many others.

Surviving computer programs under this heading exist for specific purposes such as coordinate conversion and education. Examples are the Geographic Calculator by Blue Marble Geographics, a special-purpose set of conversion routines to translate locations between datums, coordinate systems, and file formats; GeoLink by GeoResearch Incorporated, which reads and differentially corrects GPS data and writes the data directly into GIS and other mapping formats; and the General Cartographic Transformations Package, a set of FORTRAN programs available on the Internet and written by NOAA that translates between a list of map projections and ellipsoids.

In the education arena, the MicroCAM package, written by Scott Loomer of West Point and available through the Microcomputer Specialty Group of the Association of American Geographers, is unexcelled. The package runs on IBM-PC compatible microcomputers. It supports many map projections, point-symbol mapping, text placement, and so forth, and writes files into a number of standard formats.

3.1.7 Cartographic Data

Seventeen of the “systems” included in the original IGU report were actually data; in other words, they were not software as such but files containing data. As a function, the supply of data has sometimes remained attached to software; for example, several computer mapping software vendors offer ready-to-use data with their systems. Increasingly, however, data suppliers have emerged that supply redistributed government and other special purpose data sets. Among the leaders are ETAK, Geographic Data Technology, American Digital Cartography, and MapInfo.

Even where government agencies have produced comprehensive free cartographic data, private data suppliers have made an extensive business out of supplying digital maps, and recent years have seen data being produced by government and private partnerships. As a result, large sections of the surface of the earth are now available at many map scales, and both new and updated data become available all the time.

3.2 MAP SOFTWARE CHARACTERISTICS

3.2.1 Machine and Device Independence

One of the features listed in the IGU software survey was device dependency; that is, if a particular program required a specific type or brand of computer. In 1980, the level of hardware dependence was substantial, with much of the software not only requiring particular word sizes, computers, programming languages, and compilers, but also specific input and output devices made by only one manufacturer.

Although in some cases this level of machine dependence remains today, far more items of computer mapping software run on a variety of microcomputers, workstations, and mainframes. Many run under multiple operating systems, a particularly important feature. Software packages also support long lists of different input and output devices and even have installation menus and prompts that allow the support of multiple plotters, printers, digitizers, and other peripherals. Hardware vendors have realized the advantages of this, and they often manufacture devices so that they emulate the protocols of the more popular devices.

Unfortunately, the trend toward independence of machine and software is not yet complete. This means that as the market changes, devices already purchased are sometimes left without applications software. When purchasing software, it is more important to match the software against mapping needs rather than against your existing hardware. Similarly, if hardware is available, software that supports the most general and highly supported devices and standards is preferable.

3.2.2 Transportability

Machine and device independence and the ability to move software and data between computers are functions of the transportability of software. Transportable software can move between computers, operating systems, and devices with no more work than recompilation. Some computer programming languages are not transportable, with major variations from compiler to compiler and version to version. Software written in these languages will eventually disappear as programming environments change. Even operating system upgrades can make applications unusable, let alone the major changes that come about when new computers are installed.

The principal way in which transportability of cartographic software is ensured is by separating the graphics functions from the language. Even graphics functions change over time, and the only way to ensure against the loss of graphics capabilities is to use graphics standards, which will be supported over time.

Within computer cartography, many vendors have been slow to write standards-based software, meaning that many computer mapping programs remain tied to a particular set of devices, operating system, or working environment. As highly portable languages such as C and Pascal form the basis of more mapping systems, and as graphics standards such as GKS, CORE, and PHIGS are used to build new software, users will be freer to transport software and even maps between computers and through operating systems.

In the last few years, a convergence of operating systems upon a set of loose standards widely known as Open Systems has significantly increased the transportability of software. Programs that once ran only on one platform or under one operating system, such as the Macintosh, now cross over platforms. At the same time, operating systems have become less attached to platforms. UNIX and Windows NT are likely to support a large number of platforms.

Unifying elements have been the OS/2 operating system, the Motif Graphical User Interface, and the X-Windows system. Some systems even allow the coexistence of more than one operating system on one microcomputer or workstation, significantly expanding the pool of software that suits a particular computer. Without any doubt, the ties between software and a single working environment have quickly eroded to the extent that they rarely constitute a problem as far as cartography is concerned any more.

3.3 TYPES OF SOFTWARE

3.3.1 Software for Workstations

Computer mapping software for large computers is mostly that which runs on minicomputers and mainframe systems. Among the many vendors are Synercom, Intergraph, and ESRI. Large computer systems often require special hardware that can be purchased only though the software vendor. Many vendors manufacture their own workstations rather than depending on other manufacturers, and they supply software and hardware bundled together in “turnkey” or ready-made packages. Most minicomputers and mainframes have been used for graphics and mapping, but the more popular types are DEC’s VAX and microVAX computers, and minicomputers by Prime, IBM, and others. These use a large variety of operating systems, such as DEC’s VMS and Prime’s PRIMOS.

The lower end of the minicomputer market, however, has been completely overtaken by the workstation market. Leading workstation manufacturers are Silicon Graphics, Sun, Hewlett-Packard, and Digital Equipment. Although the workstations use a variety of systems, most use the UNIX operating system. Languages common to many of these systems are Pascal, FORTRAN 77 (in which a large amount of computer mapping software is written), and, increasingly, C. These languages and their compilers are becoming standardized over the various hardware environments due to the efforts of the standards organizations, especially the American National Standards Institute (ANSI). The use of an ANSI standard version of a language means that a program written on one computer and sent to another by tape, file transfer, or network link will compile without problems arising from the specifics of the machine on which the compiler is running.

Most of the major software packages for computer mapping and GIS have been ported to the workstation environment. In many cases, the first ports were simply a translation of existing software. Later versions, however, have been completely rewritten, usually in C and using X-windows, to support the full set of functions available in the workstation environment. Erdas Imagine, AutoCAD, Arc/Info, Arc/View, and CorelDraw! are examples of software that have recently undergone this important translation.

3.3.2 Software for Microcomputers

There are a great many computer mapping systems that run on microcomputers. It should be recognized, however, that microcomputers vary just as much as workstations and minicomputers in speed, size, capability, and peripherals. The first microcomputer mapping software appeared after the popularization of the microcomputer by Apple, and then by IBM during the very early 1980s. In the years since the origin of microcomputer software, the microcomputer has become infinitely more powerful, to the point where the boundary between PCs and RISC workstations becomes very blurry. Many vendors have produced software to take advantage of this power. Like the industry itself, which has produced "shakedowns," some vendors have produced fine products and then disappeared completely.

The microcomputer programs surveyed above are simply the tip of the iceberg. Information about new and existing software can be found as software reviews in *The Professional Geographer*, published by the Association of American Geographers; and in *Cartography and Geographic Information Systems* (formerly the *American Cartographer)*, the journal of the American Cartographic Association of the American Congress on Surveying and Mapping. Computer journals, such as *Byte*, *PC World*, and *InfoWorld*, and periodicals and trade journals, such as *GeoInfoSystems*, *GPS World*, *Government Technology*, *Computer Graphics World*, and *GIS World*, all carry product reviews and announcements, advertisements, and other product and supplier information.

Some sources can be considered "lists of lists." Among these are *Resource Guide for GIS* (Supplement to Government Technology, 9719 Lincoln Village Drive, Suite 500, Sacramento, CA), *International GIS Sourcebook* (GIS World Inc., 155 E. Broadwalk Drive, Suite 250, Fort Collins, CO 80525), and *Environmental GIS Applications Guide, 1993* (Digital Equipment Corporation, 444 Whitney St., Northboro, MA 01532).

Three books reprint software reviews and list software:

Cassettari, S. (1993). *Introduction to Integrated Geo-Information Management.* London: Chapman and Hall. Lists about 150 programs, classified by broad category (for example, GIS, CAD) and platform (PC or Macintosh).

Clarke, K. C. (1990). *Analytical and Computer Cartography*, 1st ed. Englewood Cliffs, NJ: Prentice Hall. Appendix A lists 68 software products with vendor names, addresses, and phone numbers, plus references to reviews of the software in other journals. The appendix was not included in this edition because it is now too long a list.

Dent, B. D. (1993). *Cartography: Thematic Map Design* (3rd ed.) Dubuque, IA: W. C. Brown. Appendix reprints reviews from journals of several programs.

3.3.4 Software for Software

Software development tools are pieces of software designed for writing computer mapping systems. They are designed to assist programmers, or in some cases advanced users, in producing their own software for automated mapping. Early software development tools were simply large collections of FORTRAN subroutines to support mapping and graphics. Among the suppliers of workstation and microcomputer graphics toolboxes are Precision Visuals (DI-3000 and GKS-2000), GSS*GKS by Ematek, UNIRAS, and Halo. Many of these packages are devoted to a particular device and a particular graphics card, such as the EGA graphics on an IBM-PC. Graphics support is usually provided with program-callable functions which plot points, lines, and areas. Other functions allow color selection; plot symbols and text; and control other graphics capabilities. Although some packages support their own macro language, most assume at least a working knowledge of a computer programming language such as C or Pascal.

Some microcomputer versions of programming languages have a limited support for graphics, by using simple extensions to the language using plotting functions. Very often these also are highly restricted to the particular graphics card in use, the size of the screen, the color mode in use and so forth.

In the chapters to come, a particular software tool, the GKS graphics standard, and the various bindings of this standard to the C language are discussed. The strength of this tool is its device independent nature, that is, the fact that the production of maps on a specific device is controlled by a separate piece of software called a device driver and not by the hardware used. The device driver interacts with more generic software, the standard, which does most of the map production. This system is highly flexible and is well suited to the demands of both computer and analytical cartography.

3.4 SOFTWARE RESOURCES

Computer cartography is a rapidly changing field. Anyone who purchases software can almost be certain that the next year will bring more and better alternatives. Computer mapping software can also be expensive, although prices are continuing to fall. An alternative source of software can be found in the user group and in shareware. Shareware is software supplied at cost or at a nominal fee to anyone interested. In the United States a major clearinghouse for shareware is PC-SIG (PC-SIG, 1987). Software also circulates free on many computer bulletin boards and is published in journals such as *Byte* and *The C Users Journal.* An immense quantity of software is available via the Internet, covered in Chapter 6, and it can be located and retrieved using the Internet tools discussed there.

Within the field of geography, the Association of American Geographers' Microcomputer Specialty Group also distributes shareware. This group's newsletter also reviews software packages. Many databases and computer programs are available from these sources, although their quality, scope, and languages vary considerably. These sources are excellent tools for getting a close look at the capabilities of computer mapping systems before spending money on a more comprehensive mapping system. Cartographers in particular, especially those capable of producing computer cartographic software, should make an effort to support these organizations.

3.5 REFERENCES

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