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AUTHOR(S): K. P. Berkbigler, C-10
P. A. Max, C-10

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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The Graphics Advisor: A Prototypical Advisory Expert System

K. P. Berkbigler and P. A. Max
Computing and Communications Division
Los Alamos National Laboratory

Abstract

The Graphics Advisor is an expert system that helps users of the Los Alamos Integrated Computing Network select the graphics library that is best suited to the characteristics of a specific graphics application. The implementation of the system, using a commercial expert system development tool, is described. Delivery options are discussed. Although the domain knowledge of the Graphics Advisor is oriented toward libraries that are supported by the Computing and Communications Division at Los Alamos, it exemplifies a class of knowledge-based systems that are potentially useful in a variety of advisory situations.

1 Introduction

The Graphics Advisor is an expert system that helps users of the Los Alamos Integrated Computing Network (ICN) select the graphics library that is best suited to the characteristics of a specific graphics application. The expert system determines the preferred library by matching the graphic features required by the user with the features supported in each library using rules furnished by an expert on the graphics libraries.

The Graphics Advisor project was undertaken with several goals in mind. One was to gain some experience with commercial expert system development tools and ascertain their suitability for developing systems in our environment. Another objective was to examine the usefulness of expert systems technology in support of the consulting activities performed in the Computing and Communications Division (C Division). To this end, we searched for an application that is typical of our consulting activities and amenable to implementation as an expert system. The model application should be large enough to exercise much

of the functionality available in commercial tools but small enough to be implemented using several tools so that tools can be compared. The process of choosing an appropriate graphics library meets these criteria and was selected for implementation. Hence the Graphics Advisor serves as a prototype for other advisory systems that might be built in C Division.

2 Background

The Los Alamos ICN consists of computers within the Central Computing Facility (CCF) and a network linking these computers to distributed processors outside the CCF and to terminals and TCP/IP-based workstations in users' offices.[1] Within the CCF are many computers from several vendors, including Cray, CDC, and DEC,¹ running a variety of operating systems. CTSS, a local system, runs on the Cray computers; NOS, a CDC operating system runs on the CDC machines; and the DEC computers run either VMS or a version of UNIX. The ICN is used by more than 8,000 people of which approximately 5,500 are Laboratory employees and 2,500 are located at other installations throughout the United States. These users access the ICN through terminals, distributed processors, or workstations, with remote users connecting via telephone dialup, leased lines, the Defense Data Network, or Telenet.

One responsibility of the Computer User Services Group is to operate the Consulting Office. This group of highly experienced computing professionals consults on a wide variety of topics, including programming languages, graphics and system libraries, and utilities. They also advise users

¹Cray Research, Inc
Control Data Corporation
Digital Equipment Corporation

about what software is available for solving certain problems, how to use the software, and what documentation describes the software.

C Division supports a common set of software across all systems to allow users to move conveniently from one system to another. This software includes Fortran graphics libraries, two of which, the Common Graphics System (CGS) and CGSHIGH, were developed at Los Alamos. Three are vendor-supplied, DISSPLA and Graphical Kernel System (GKS) from Computer Associates and NCAR from the National Center for Atmospheric Research. Consulting on these libraries is provided by the Consulting Office. However, the Consulting Office is not responsible for consulting on third-party graphics software that users might install on individual distributed processors or workstations.

CGS, a library of device drivers and primitives, is the basis for the other graphics libraries. It supports a device-independent file, the CGS metafile, that may be processed on any graphics device in the CCF or may be viewed on any supported graphics terminal, such as the Tektronix 4125. The CGSHIGH library provides high-level subroutines that can produce a complete x-y plot from one call. It also supports subroutines that control plotting defaults, such as color and line style, that are set by the high-level routines.

The DISSPLA library provides middle-level capabilities, including x-y, three-dimensional, and contour plots, graphics arts character fonts, interpolation and curve smoothing, pie and bar charts, and maps of coastlines and political boundaries. DISSPLA is the only library at Los Alamos that supports graphics arts character fonts, so it is used for producing publication quality graphics. GKS, a library of basic functions, provides more than 200 subroutines that output graphical primitives, set attributes, control workstations, perform transformations, obtain graphical input, and handle errors.

The NCAR library provides high-level capabilities, including x-y, three-dimensional, and contour plots, two-dimensional velocity fields, streamline representations of a flow field, half-tone pictures, and geographic maps.

The importance to user communities of an advisory service is well established[2], but as remote computing becomes more prevalent the amount of face-to-face consulting is declining. This has been the trend at Los Alamos for some time. Innovative approaches to providing guidance to users are required, and expert systems have been suggested as a possible solution.[3]

The advisory function is being actively studied from both the behavioral science and computer science perspectives. (See [4] for a comprehensive overview of advice-giving systems, including a review of the literature.) Much of the current research is oriented toward embedding the advisory system within the software system being used, e.g., the operating system or word processing system. These advisory systems are designed to either passively or actively help the user during interactive use of the software. A user model in which the user's goals are dynamically inferred from the user's interactions with the system is generally included. Advice can thus be given in context and geared to the user's apparent level of sophistication with the system.

At this stage the scope of the Graphics Advisor is more modest. It operates as a separate system, so no opportunity exists for observing the user attempting to use the graphics libraries. Furthermore because its purpose is to help the user select a library, the Graphics Advisor will typically be consulted before the user gains any experience with the libraries. The expected users of the Graphics Advisor are primarily new or novice users who need general information on the available libraries and their capabilities relative to specific applications. The implicit user model in the Graphics Advisor is targeted at this audience.

The Graphics Advisor has more in common with the results of the protocol study on one-shot dialogs reported by Aaronson and Carroll.[5] Many of the strategies they found human advisors employ in a situation where no follow-up is possible have also been used in the Graphics Advisor. Some examples are making assumptions about the user's goals, providing alternative solutions, pointing to reference sources, and providing an explanation.

3 Implementation

Several candidate expert system development tools were considered. The Knowledge Engineering Environment (KEE) software from Intellicorp was selected for its powerful functionality and user interface, as well as for its availability on a variety of platforms. (See [6] and [7] for descriptions of a variety of expert system development tools.) Some work has been done with implementing the Graphics Advisor using other expert system tools, but none of these implementations have been completed. Development of the present implementa-

tion of the Graphics Advisor took place on a Texas Instruments Explorer Lisp machine.

3.1 KEE

KEE is a hybrid expert system development tool offering a variety of knowledge representation and reasoning possibilities[8], many of which are used in the Graphics Advisor. KEE is available for numerous hardware platforms in both development and delivery versions. Interactive and programmatic interfaces to its capabilities are provided. The frame system allows the definition of hierarchies of objects or concepts. At the top of the hierarchy are classes that contain slots describing the attributes and behaviors of an object and serve as templates for the creation of individual objects known as instances. Instances inherit the slots of their parent classes and may define their own values for these attributes.

The rule system implements both data-driven reasoning (forward chaining) and goal-driven reasoning (backward chaining) using a single representation for the rules. Rules may be partitioned into classes for efficient handling of subproblems. Variables are permitted in the rules and are bound to values at runtime when the rules are tested. The object-oriented programming and access-oriented programming (demons) paradigms are available by writing code in Common Lisp, the implementation language for KEE. Support for nonmonotonic reasoning is provided in the form of the KEEworlds and truth maintenance facilities.

Research in human-computer interface techniques has begun to produce guidelines for when to use specific interaction styles.[9,10] KEE provides user-interface development facilities for several types of interfaces. Multiple windows are typically used in an application to separate different types of information. Menus can be generated dynamically, if desired, and the ActiveImages facility for building direct manipulation interfaces can be customized. Graphical interfaces may be constructed using components from KEEpictures.

3.2 Graphics Advisor

Knowledge in the Graphics Advisor is represented using both the frame system and the rule system. Figure 1 shows a display of the knowledge base for the Graphics Advisor.

Slots in frames are used to represent facts about graphics libraries such as whether a particular fea

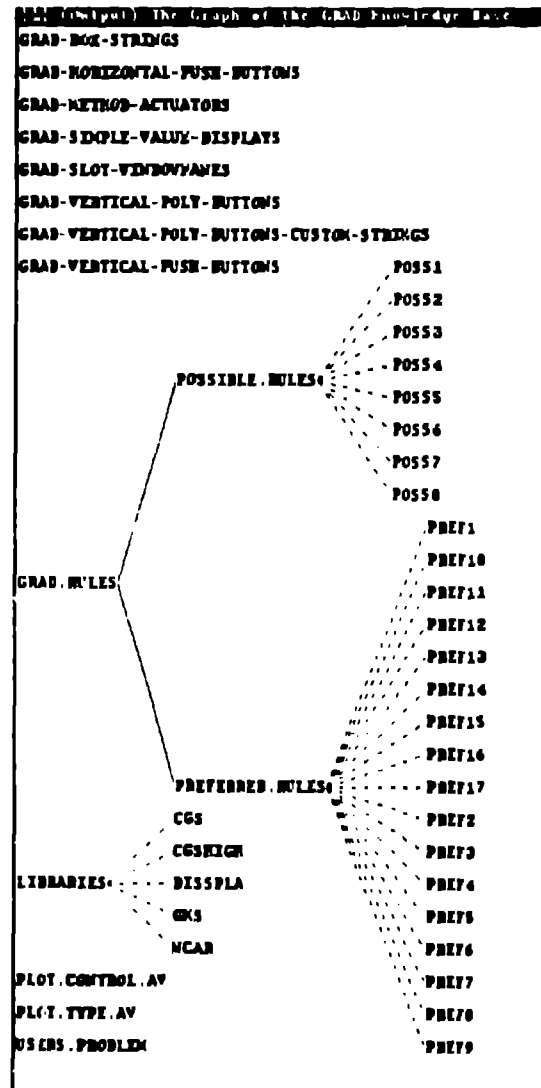


Figure 1: Graphics Advisor knowledge base display.

ture is supplied by the library, definable by the user, or not definable. Attributes are defined for the libraries class and are inherited by individual libraries and assigned appropriate values at the instance level.

Information about the characteristics of the user's application also is stored in slots in a similar frame as the user enters those characteristics. Constraints upon allowable values have been specified and are enforced by KEE. For example, it makes no sense for publication quality to be both required and not required in a single application, and this inconsistency is not permitted. Customized facets have been defined in the frame used to describe the user's problem; they are used to store references to definitions and examples of certain plotting features.

Rules are used to represent the conclusive aspects of the expert's knowledge. The rules in the Graphics Advisor are divided into two classes. One class of rules determines which libraries could possibly be used by comparing facts about libraries with requirements defined by the user. Libraries that do not support a required feature are eliminated from consideration. Another class of rules represents the expert's heuristics for when to use each library. This includes subjective judgements such as whether a library provides superior functionality in a particular area, ease of use, and documentation quality. The expert system operates using forward chaining, with some weighting factors applied within the second rule class. The capability for variable binding within rules is heavily used and is responsible for the ability to express knowledge in the Graphics Advisor in so few rules. It is estimated that it would take 1-2 orders of magnitude more rules to implement the same knowledge using a rule system that does not support variables.

Friendly users who have examined the Graphics Advisor find its user interface very attractive. The interface is implemented in a direct manipulation style using the ActiveImages subsystem of KEE. The primary image panel is shown in Figure 2. The user simply points with the mouse to those features that the application needs and clicks the left mouse button to register the choices. No use of the keyboard is made except in the optional comment facility. The KEE Typescript window is used in conjunction with the output from ActiveImages to provide additional textual information, such as a reference to documentation for the recommended library or an explanation of the reasoning used in arriving at the recommendation.

Some of the operations in the Graphics Advisor are implemented as methods, that is, procedural Lisp code that is executed under the object-oriented paradigm when it receives a message. Messages are sent by the user through the use of method actuator images. For example, when the **Make Recommendation** image is selected, a message is sent to the Lisp method that invokes the rules and displays the possible and recommended libraries on the screen. Other methods are used to initialize the knowledge base to its pre-consultation state and to display explanations of the expert system's reasoning process.

Demons, known as Active Values in KEE, are used to control the display of plot options to the user. General information, such as plot types required and operating system required, is displayed in the primary image panel that is always present on the screen. Options having to do with the appearance of the plot are on a separate panel that pops up only if the user requests more detailed control over plot appearance. Similarly, the output device to be used is only relevant for one plot type, so it is shown only when that plot type is selected. The use of multiple, automatically displayed panels reduces the complexity of the information that the user must deal with at one time.

The explanation component of an advisory expert system is an essential element for the system's acceptance; users often want to know why a recommendation was made. Although KEE provides good rule tracing capabilities for the system developer, we feel that this capability does not provide an adequately user-oriented explanation of the expert system's reasoning. Accordingly, a technique was adopted whereby English statements of the reasons that libraries were eliminated from consideration are saved in a slot in the knowledge base as the reasoning progresses. These accumulated statements are then displayed to the user when an explanation is requested. The explanation capability is illustrated in Figure 3.

Just as the expert system must be able to explain itself to the user, sometimes the user would like to express comments to the system. In the Graphics Advisor, one may do so by using the comment facility. The user is prompted to type in a free-form comment that is saved in a file for subsequent perusal by the expert system developer. This capability is trivial to provide and proved to be useful for obtaining feedback when used in a previous system developed at Los Alamos [11].

The phrases describing the graphics features

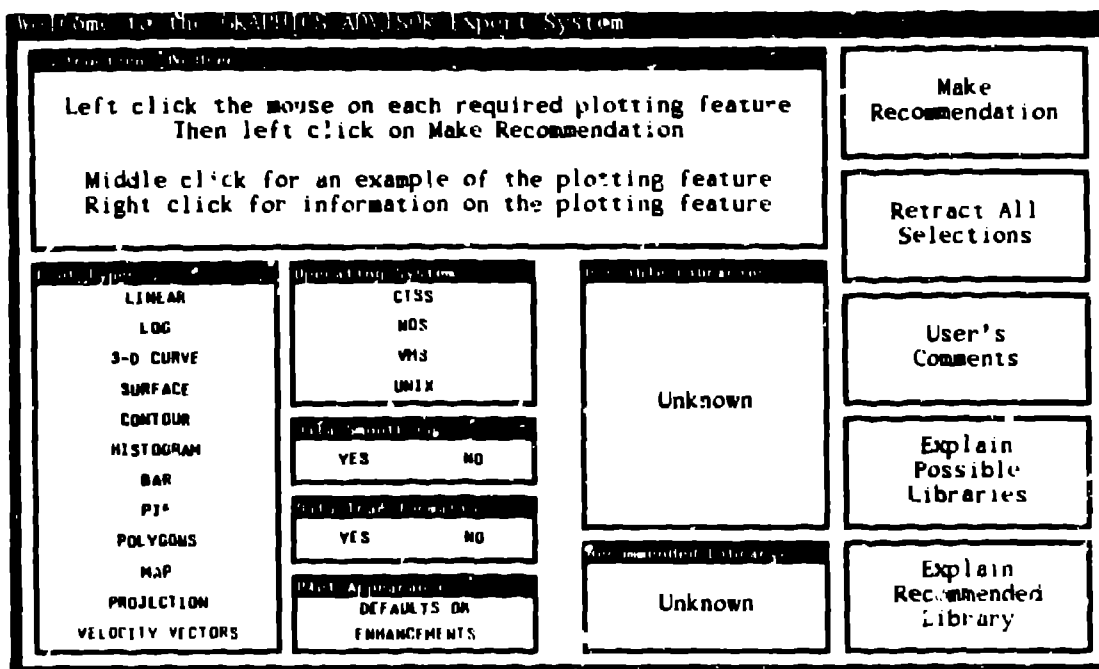


Figure 2: Graphics Advisor image panel.

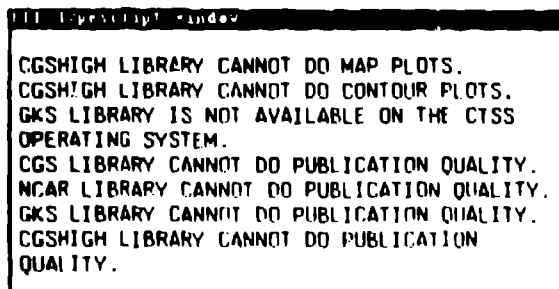


Figure 3: Example of an explanation.

that the user may require are necessarily terse. However, additional definition information describing each feature may be obtained by clicking the right mouse button on the feature. This causes the feature to be described in more detail in the Typescript window. For some graphics features, a picture is worth a thousand words, and an example picture illustrating the feature can be obtained by clicking on the feature with the middle mouse button. KEEpictures was used to implement examples of selected features, so that the user may visualize the meaning of that feature in addition to having it described in words. Figure 4 illustrates an example picture. Making these descriptions available to the user through simple mouse clicks was achieved

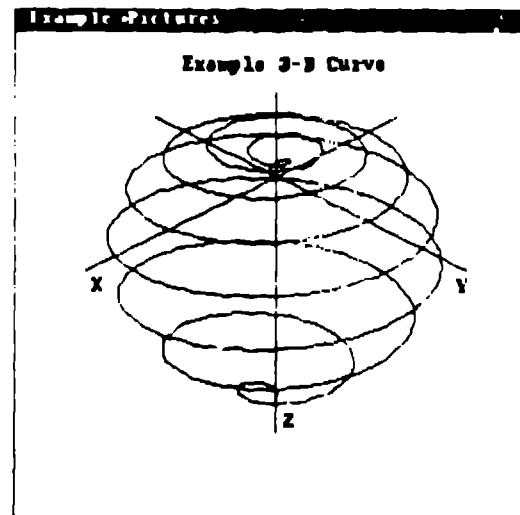


Figure 4: Illustration of a 3 D curve

by customizing the mouse functionality provided in KEE ActiveImages.

3.3 Delivery

Ideally, the Graphics Advisor should be made available to all users of the ICN. However the cur-

rent state of technology does not permit this, at least not as the Graphics Advisor is presently implemented. One of the strengths of KEE is its built-in capabilities for designing direct manipulation user interfaces. Such interfaces are easy to learn and use and allow the user much more flexibility in the order in which operations are performed. Placing the locus of control with the user permits specification of input values in whatever order seems most natural, rather than in some pre-determined order dictated by the programmer. The user interface to the Graphics Advisor requires a high-resolution bit-mapped display with a window system and a mouse, features not available to users with "dumb" terminals. The technical options available today for expert system delivery to ICN users represent varying degrees of compromise between availability to every user and a powerful, flexible user interface. C Division is working on a project aimed at distributing computing tasks between workstations and mainframes, which may alleviate this problem in the future.

More than one delivery option may eventually be implemented, but the first delivery platform for the Graphics Advisor will be to use Runtime KEE on a SUN workstation.² The expert system will be available in the Computer User Services Group and possibly at selected user sites that have a large contingent of new users. The feedback obtained from use of the system at these locations will guide the direction of future efforts.

Other options that were considered and discarded for now included using a distributed delivery system from Intellicorp where the expert system functionality is distributed between a VAX mainframe and IBM/PC frontends. This option is not compatible with much of our current terminal network. Reimplementing the system on an ICN node such as a VAX and redoing the user interface to operate on any VT100-compatible terminal also was considered. This idea was rejected as too time-consuming and too compromising of the desirable user interface in the current implementation. Reimplementing the system in a less expensive expert system tool that could be distributed with the application was abandoned as too difficult to administer.

Although delivering on SUN workstations has a disadvantage, namely the ability to reach only a subset of our user community, it appears to be the best alternative at this time. Accordingly, a Run-

time KEE license for the SUN was obtained, and the Graphics Advisor has been ported to that platform. The system has not yet been distributed, but we expect to do so shortly.

4 Future Directions

Many possibilities exist for enhancements to the Graphics Advisor. The knowledge stored for the graphics libraries could be extended to include information about when and how to use specific sub-routines to accomplish particular plotting operations. Such a system would be appropriate for users having a broader range of skills and may require a more sophisticated user model. As the foundation for distributed computing in the ICN becomes more robust, we may try to implement the Graphics Advisor as a distributed application. It has also been suggested that a similar system to advise on the mathematical libraries available at Los Alamos would be useful. Further work will be governed in part by the feedback received on the prototype of the Graphics Advisor that is about to be released.

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