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Technical Report

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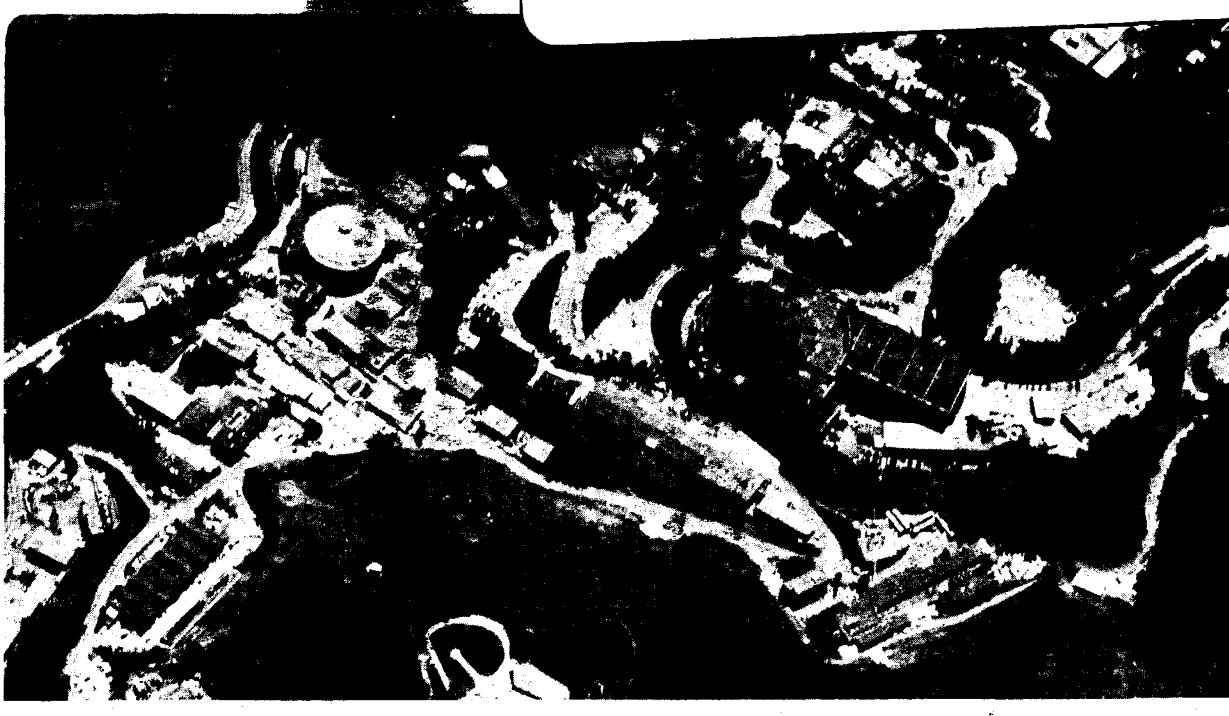

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Technical Report

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Graphic Design for Computer-based Information Management: A Case Study of Seedis

Abstract
This report summarizes the graphic design research, development, and implementation that the author has conducted over the last four years for a large geographic information management system called Seedis. Portions of this report have been assembled from diverse technical papers cited in the references and have been re-edited for presentation to both the computer graphics and the graphic design communities. This report describes Seedis and three different areas in which graphic design principles have been applied.

Graphic Designers and Computer Graphics

Graphic design is the discipline concerned with the communication of informational, emotional, and aesthetic content through the manipulation of visible language, i.e., typography, symbolism and illustration, color, spatial organization, and temporal sequencing [7]. Certain professionals in this discipline are concerned primarily with the communication of complex information through the design of charts, maps, diagrams, and other technical documents. Knowledge from these professionals and their literature can be applied to the task of designing the graphic presentation of computer-generated documents, a task which now faces builders, users and managers of information management systems. After two decades of development from the simplest display of line printer characters and CRT screen vectors, computer graphics is entering a decade of visual sophistication.

A potentially symbiotic relationship exists between graphic design and computer graphics in creating the "three faces" of computer systems: outer-faces, inter-faces, and inner-faces [10,15]. *Outer-faces* are the end display products of data processing: images of information such as texts, tables, charts, maps, and diagrams. *Inter-faces* are the user-oriented human-machine interfaces used to create outer-faces. These inter-faces are comprised of frames (online) and pages (offline) of process control, data structures, and their documentation. *Inner-faces* are the frames and pages of source code operating systems, and programming utilities that builders and maintainers of computer systems require in order to support the inter-faces and outer-faces. By combining intuitive, practical skills and scientific knowledge, graphic designers can help synthesize prototype solutions for any of the three faces and assist in analyzing and developing finished displays that are not merely "pretty," but which communicate information better. There is clearly a need for converting vast amounts of numerically stored data into spatial (sometimes geographical), temporal, and colorful forms so that *significant* patterns emerge from informational graphics.

With respect to outer-faces, many computer graphics advertisements and much professional literature exhibit charts, maps, or other diagrams. If one examines these images carefully with an eye trained in visual communication, one notices oversights or errors in visual thinking that seem clearly unintended, such as color combinations that inhibit legibility, poor typographic hierarchies, or chaotic composition. The situation is often not the result of deficient equipment but simply the result of computer graphics displays created by persons with relatively little training in graphic design, i.e., in typography, color, composition, non-alphanumeric symbolism, photography, and reproduction processes.

Inter-face design also can benefit from graphic design. Graphic design seeks to use simplicity in organizing visible language (Marcus, 1980) and making effective and attractive frames of information. These frames must aid learning of a complicated text, aid memorization, encourage accurate decision making, assist in building a clear conceptual image of the system in the user's mind, and attract and retain the user's attention in situations when the user may be uninterested, unmotivated, or distracted. As computer systems reach out to ever wider audiences, the notion of attracting and holding a user's interests and emotions will not seem so foreign a goal for interface design.

Finally, in the area of inner-faces, the increasing number of computer programs of ever greater complexity require more time and energy for program creation and maintenance. The widespread availability of high resolution display equipment suggests that computer technology itself will benefit from more legible and more readable displays of program source code, operating systems, and related utilities or documents.

Designing visible language schemes for all three faces of computers will be recognized as a distinct and demanding task requiring the assistance of information-oriented graphic designers.

The Relevance of Swiss Design Principles
The basic principles of graphic design in selecting visual signs or symbols and their attributes (such as their location, size and boldness) for presentation on paper, film, and display screens can enhance the legibility of computer graphics as well as its readability, i.e., its appeal or friendliness.

These principles of visual organization and limits of perception form a conceptual basis for the grid-oriented or utilitarian approach to graphic design. It is an approach eminently suited to information display in which many complex relationships must be distinguished carefully and clearly.

The utilitarian approach to graphic design derives from the German Bauhaus and Russian Constructivist artistic trends of the early twentieth century. These movements emphasized functionalism, new technology, and rationalism. The utilitarian approach to graphic communication as seen in posters, books, magazines, diagrams, etc., emerged in a clear form during the 1950s and early 1960s in Swiss graphic design. Swiss graphics has had a world-wide impact upon graphic design education and also took hold in major international corporations. They adopted the principles for the business world because they could be relatively clearly and precisely formulated and because they offered a systematic consistency for a variety of display formats, such as printed literature, signage, exhibits, vehicle graphics, etc.

It is not without significance that Swiss graphic design is called programmatic design [5]. In theory, a significant number of quantifiable attributes of the finished visual design can be traced to a list of needs with priorities. In effect, syntactic conditions can be clearly traced back to semantic relationships, to use the terminology of visual semiotics, the science of signs and meaning [4]. The general visual characteristics of Swiss-oriented graphic design principles can be categorized in the following paragraphs [7].

Sans Serif Type Styles: Following the precedent of the Bauhaus and the Constructivist typographers, the Swiss designers rejected the traditional serif letters in favor of the more simplified *sans serif* letterforms, e.g., Helvetica and Univers. Both typefaces retain the 'machined' look and the uniform letter weight that the rougher versions of the 1930s introduced, but add a greater homogeneity and a new elegance to the curves used in their letterforms. These two faces remain standard typefaces for modern, clear typographic displays.

Simplified Imagery: The standardization of format for Swiss posters prevented the poster designer from relying on the size of the poster to gain impact. Instead, the designer had to work with effective images viewed from a distance much like mural painting. This contributed to a reduction in the amount of primary text presented as well as the use of one essential image for immediate recognition. The typographic emphasis attracted the eye of the viewer through the primary text. When illustration was included it was often geometrical in form. When photography was introduced it was usually treated in scale (e.g., greatly enlarged size) or in tonal emphasis (e.g., high contrast photographs) so as to immediately simplify the image. In conformity with the choice of modern typefaces, the imagery of Swiss design emphasized reduced complexity, flat surfaces, and images that were technically transformed, without traces of manual operations.

Open Space: Carefully used empty spaces devoid of both text and illustration establish a geometric subdivision of the visual field or provide emphasis for the visual elements within the composition. With a fixed format, a limited set of typographic elements, and often no other imagery than type, the designer must rely essentially upon spatial composition to make the informative aspects of the work clear and to provide pleasing aesthetic relationships.

Consistency of Design: No mixing of

typefaces within a graphic image is one immediate result of a desire for simplicity. On the other hand, a variation within one type family (bold), medium, or light; condensed, regular, or expanded letterforms) can occur because of the uniform aesthetic features within a type family. The number of these changes (in the size, boldness, or proportion of the type) is usually limited to two or three. The proportion of these changes is usually a simple and dramatic factor. For example, for the proportional size of primary to secondary type, ratios of 2:1 or 3:1 are commonly found.

Strong reliance on a grid of implied lines that organizes and controls the positioning of typographic and illustrative elements also typifies the Swiss approach. The grid establishes a series of harmonic visual relationships that make coherent the entire visual field. The grid provides many possibilities for the positioning of visual elements, allowing strongly differing variations to occur that are nevertheless clearly related visually.

Swiss-oriented graphic design expertise has been applied to the Seedis project, a research project in information management. The goals of this effort were to increase the effectiveness of Seedis by increasing its visual/verbal consistency and clarity, developing trust in viewers and/or users, and increasing the perceived 'friendliness'' of the system. These changes are intended to induce a more positive response in viewers and users and ultimately more effective communication between human being and machine [9]. The following sections describe Seedis and detail the graphic design improvements.

A General Description of Seedis

Seedis is an experimental geographic information management system for large databases. It developed over the last twelve years in the Computer Science and Mathematics Department of Lawrence Berkeley Laboratory (LBL) for the U.S. Department of Energy and of Labor [17]. Seedis is an acronym that stands for a ''social, economic, environmental demographics information system.'' Users of the system can make reports, maps, and charts from large databases about energy, demographics, environmental conditions, and economics. The Seedis project includes the following:

- A research program within LBL's Computer Science and Mathematics Department to investigate information systems spanning diverse data sources, computer hardware, and operating systems.
- A testbed distributed informational system running on a network of Digital Equipment Corporation (DEC) VAX computers, which is used for selected applications as well as research and development.
- A set of interactive information management and analysis tools for fields such as energy and resource planning, employment and training program management, and environmental epidemiology.
- A major collection of databases for various geographic levels and time periods, drawn from the U.S. Census Bureau and other sources. Policy formulation, implementation, and management depend upon accurate, timely information. Analysts, decision makers, and managers need to locate, retrieve, combine, analyze and display information from a variety of sources. While time and resources usually do not permit collecting new information, there is a wealth of publicly available data from government and other sources that often could meet such needs if it were quickly and easily accessible. Although computers and machine-readable data have made it potentially easier to locate and analyze information, actual use of information from different sources is difficult because of differing storage formats, communications procedures, coding conventions, data structures and units of analysis.

The Seedis Project addresses these information needs and problems through research, design, development, and demonstration of information system components. Seedis software provides a unified framework for data management, information retrieval, statistical analysis, and graphical display. Using Seedis, non-programmer users can efficiently access and manipulate large, diverse, and distributed statistical databases. Seedis permits a relatively computer-naive person to examine data dictionaries, to extract data from databases, to aggregate or disaggregate data between different levels of detail, and to display the selected data in a variety of ways. The data can appear as a labeled table, dot chart, pie chart, line chart, bar chart, or area/symbol choropleth map. The images can appear on a wide variety of display devices because Seedis is programmed to be independent of the detailed requirements of hardware.

Seedis Chart and Map Design

The following examples demonstrate analytical quality and presentation quality dot, line, bar, and circle (pie) charts that Seedis can generate interactively. The images indicate the fineness of resolution for typography, lines, and gray areas that are available to users who are trying to determine the ideal format in which to present their data. The exact size, position, and appearance of titles, figures, and other elements are adjustable. The images come from several different hardware configurations in which Seedis can generate charts.

Basic graphic design principles drawn from utilitarian design have been used to restructure prototype displays of charts and maps. These in turn have led to encoded decisions which govern default displays from Seedis. These principles include the use of a single type family, the use of a simple grid to control placement of all visual elements, flush left ragged right typography, clear gray value distinctions, and clear distinctions of line weight.

The examples of Figures 1 and 2 show typical default displays for color or black and white horizontal bar charts. The original images were displayed on a Dicomed D-48 high resolution film recorder and recorded on black and white 4 × 5 inch film.

The example in Figure 3 shows an area choropleth map of the United States at the state geographic level. Note the use of varying gray values, the ability to create inserts, and high quality software-generated typographic characters. These maps were originally drawn on a Dicomed D-48 film recorder. The image display here is suitable for high quality presentation graphics in black-and-white printed publications or in color slide form.

The example of Figure 4 shows a symbol map that uses circle (pie) charts to show multiple population characteristics of California Standard Metropolitan Statistical Areas (SMSA's). Note the division of the circle symbols into varying gray sectors and the overlapping of circles with automatic erasure of underlying circle areas. Normally these images are drawn in color and are recorded on 35 mm or 4 × 5 inch color film or on 8 × 10 inch Polaroid color prints. This example is a black-and-white adaption of a color image and was produced on a Dicomed D-48 film recorder as a 4 × 5 inch negative. The map composition is not presently a default display; it was restructured using the graphics editing capabilities of Seedis.

One specific chart and map design problem facing Seedis users is reproducing and transferring the image of data for presentation as article illustration, overhead projection image, slide lecture image or poster session illustration. Professionals outside of graphic design often make such transformations casually even though the images are not well designed for such changes. The size of typography, the thickness of chart lines, and the original chart layout are often not suited for most of the above uses except as a publication image of approximately original size (about 15 cm × 15 cm). Any significant reduction in size of the image will require its typography and even its lines to be redrawn by hand by a trained technical graphics person, thereby reducing the cost-effectiveness of the computer-assisted chart making. Even conventional xerographic copying of the original image can often make labels, footnotes, even primary titles illegible. In some cases crucial information could easily be lost.

The design of display prototypes such as

Figure 1

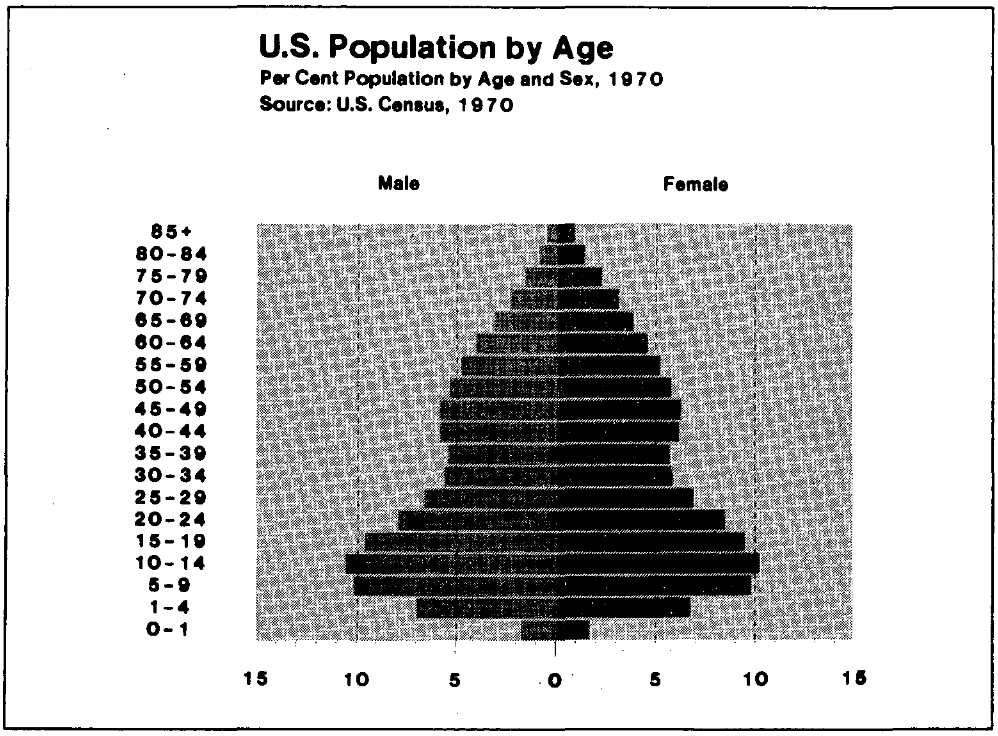


Figure 2

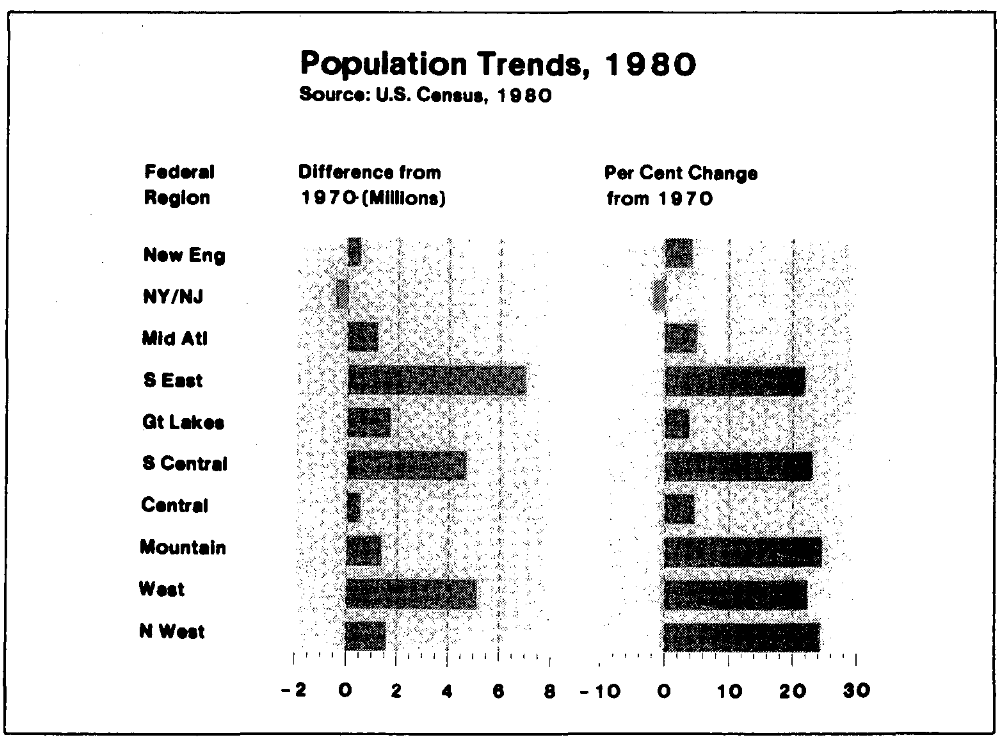


Figure 3

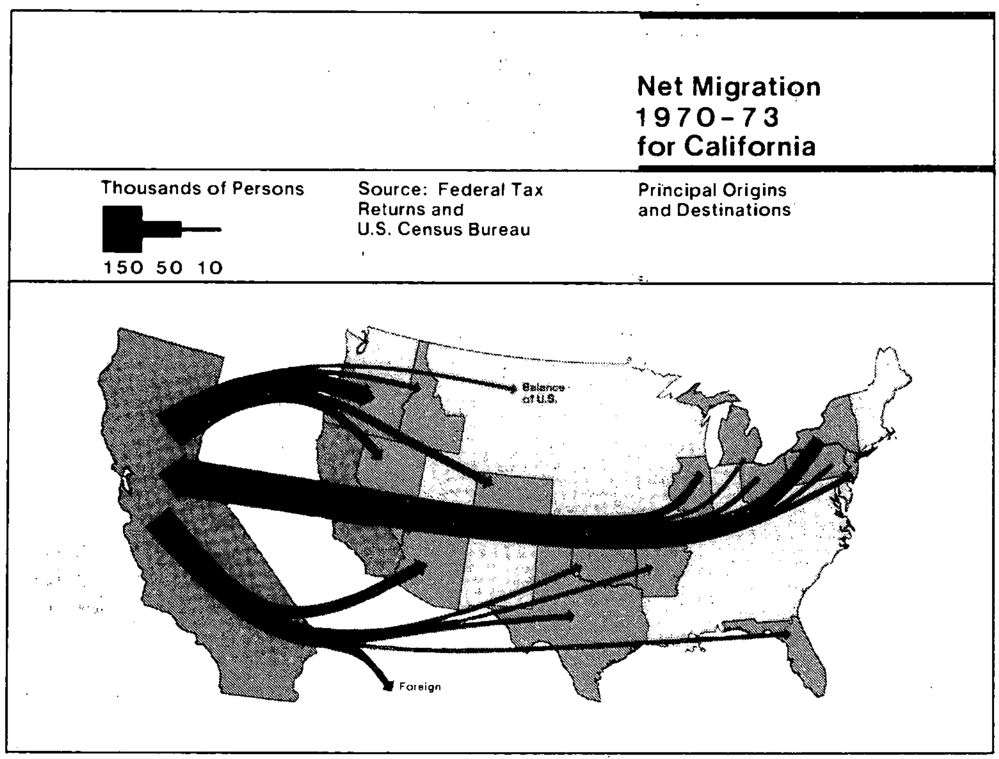
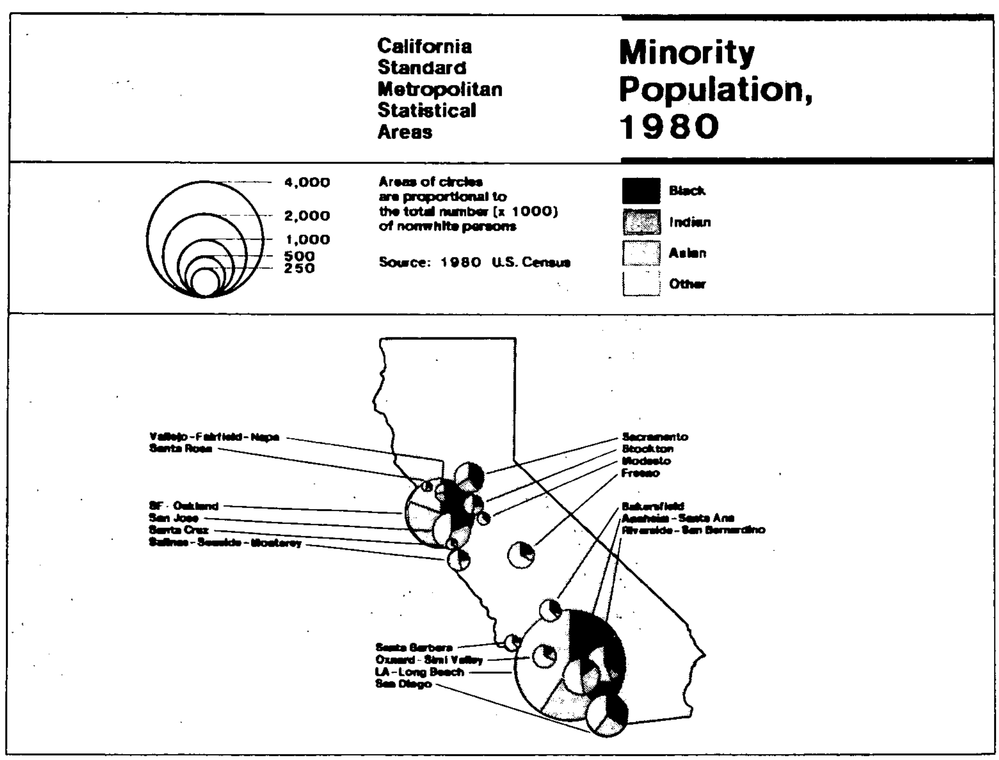


Figure 4



those shown in the figures and eventual default displays are intended to enhance their versatility, e.g., for use as slide and poster images. Border proportions have been selected to easily accommodate typical paper and film formats. In addition, Figures 3 and 4 were re-designed to allow significant change in scale without harm: They can be enlarged to become primary visual images for an exhibit or can be reduced to become secondary, clearly articulated evidence for an article.

At some future time, a skillful algorithm in a well-designed computer graphics system might be able to accept input concerning the eventual use of the image (e.g., as a xerographic print, as a four-color high-quality lithographic image, or as a lecture slide image) and automatically compensate for necessary changes of typesize, line weight, texture, and conversion between color and black-and-white.

Interface Design Principles

Seedis user interface design involves selection of symbols and formats for the standard functional components of a system: menus, prompts, help messages, status reviews, etc. The user interface design also involves detailed specification of standards at a lower level: the determination of a layout grid, selection of typographic styles, sizing, spacing, and means of emphasis, the standard treatment for continuous prose (e.g., help messages), interrupted prose (error messages, system status reports, etc.), and tables/lists (menus, data dictionaries, etc.).

Unlike conventional prose texts, user interfaces have many components and corresponding layouts. These include tables, indices, lists, numbered items, diagrammatic presentations, explanatory notes, and pictorial images. The user interface is not intended for continuous reading as for prose text, but rather is a framework for complex movement with constant shifts in levels of instruction to the viewer and frequent distractions to the viewer's attention.

Designing the layout requires a sensitivity, first of all, to the limitations of the viewing area, i.e., the display screen, as well as to layout for printed copies made at a later time. One must begin with *a reference grid,* a series of lines that determines the overall dimensions of a frame, essential areas for text, number of columns of text, column widths, spaces between columns, some of the intervals above and below standard items such as frame numbers, etc. Many interfaces currently employ fixed-width, non-proportional characters. In such cases, the basic measuring units can be a single character in the horizontal direction and a line spacing in the vertical direction. A reference grid allows the designer to block out the kinds of information that will generally appear in frames. The grid both determines fixed positions, margins, and spaces between blocks of text, as well as providing a framework for variations of composition. The grid lies "invisibly" behind every frame. Sometimes the grid must be "broken" or ignored for special materials. It is not an absolutely unviolated device, but it must work most of the time or else a new grid needs to be devised.

Typographic Parameters

In the situation of fixed-width, non-proportional characters, variation in typesize is either non-existent or very limited. This is not necessarily a limitation; it can be an incentive to make spatial cues and typographic emphasis more potent. As more sophisticated display screens become available, size selection will become more crucial, e.g., to distinguish footnotes from main text, and main text from titles.

Line length is often pre-determined in the sense that typesize variation is limited to one or two sizes. The crucial factor in typography is often the width of lines (Hartley). Long lines slow down reading. Most typographers recommend 40–60 characters per line [2,3,6,15]. Doubling (reading the same line twice), results when lines are too long and without enough space between lines. In interrupted prose, typical of instructional text in interfaces, the lines are essentially unjustified or "ragged right." Their effective visual length will be shorter than the actual maximum.

Line spacing is measured from baseline to baseline between lines of text. This line spacing should be optically at least equal to the word spacing and should be consistent to contrast with transitions to new material and to highlight elements. Normally one to three variations in line spacing suffices.

While fixed-width characters are usually used for typographic display, current typesetting equipment and a growing number of high resolution softcopy devices (e.g., 16-bit microprocessors) and hardcopy devices (e.g., laser printer) can display variable-width characters. This has a significant impact on typefont variation, size of characters, and width of text lines.

General practice suggests the following:

Font variation should usually be limited to a single typeface or at most two, except for special mathematical needs. Within a typeface family, regular (roman) italic, and bold roman are standard means of increasing emphasis. Unless a great amount of effort is expended on the design of characters, adaptions of well-established typefaces such as Times Roman, Helvetica, Garamond, and Univers should be used. Frame presentations often allow for reversed video characters, blinking, variable intensities, and other means of emphasis. These should be used sparingly because of their strength of differentiation from normal text. Type size variation should be limited to at most three sizes for text materials, and these sizes should be quickly and easily distinguished. Generally 9 and 10 point type for a 14 inch viewing distance is standard printed text size. Optimum size will vary with the detailed characteristics of a display device and the viewing situation. Column widths should again be limited to allow 40–60 characters per line.

Letter Spacing and Justification
For maximum legibility and reading ease, the amounts of space between each letter in a word should be optically equal. Likewise, the spaces between each word in a line should be optically equal. Fixed-width characters on many terminals and printers are usually not well designed for good letter and word spacing. They often have too much space between letters and between words and too little space between lines. Typesetting style should ensure a natural flow of text. In justified typography, space is added between words (and sometimes letters) to make all lines the same length. In unjustified typography, equal word spacing and equal letterspacing cause lines to end unevenly. There is a tendency in computer science and information science to assume that justified texts are in some way better, but research shows there is no difference in legibility or comprehension (Rehe).

Tables and Lists
Tables and lists of various kinds for indexes, file directories, etc., are features of many interactive computer systems. Their formats vary considerably, but research suggests that items need to be carefully grouped, both horizontally and vertically so as to convey the context efficiently [6]. For example, Spencer et al [19] examined ten variations for presenting bibliographic material and determined the three best ways of presenting it. Such studies indicate that attention to layout can have a noticeable effect on ease of use of lists. Unfortunately, research in this area is still limited. Linear rules can be used to group selected components of the tables (e.g., column titles) but they should not be overused. Generally, no more than two varieties of rules should be used [6].

Sequencing
Page sequencing and organization in book literature has evolved specific elements for complicated text structures (e.g., title pages, tables of contents, abstracts, indices, and running heads which appear on every page). User interface documents often appear without this standard apparatus, but viewed as literature they should contain such items. In book literature, the visual form of these additional elements varies dramatically. Their appearance depends upon consistency and simplicity in organizing all the visual elements into effective and attractive frames or pages.

Implementation of Interface Design Principles in Seedis
Although the current Seedis network of VAX computers includes a variety of high resolution graphics terminals, printers, and paper

terminals, many Seedis users communicate with Seedis via simple terminals such as the Lear-Siegler ADM3. Therefore, Seedis frames of informational text are designed for a frame 80 characters wide by 24 lines deep. This is an industry-wide standard that will be valid several more years for many terminals.

This lowest common denominator choice makes Seedis accessible from the widest possible variety of terminals. However, it also means that the use of reverse video, italic, or levels of brightness cannot be assumed. These means of visual emphasis are not used, but other approaches are available. For example, there is a strong reliance on a horizontal line of hyphens to highlight certain titles or to separate divisions of the frame.

Even within such severe limitations, attention to graphic design principles can improve the effectiveness of documentation. Consider the use of all upper case words, a typographic approach which much documentation utilizes. The fixed width of the letters are often created by a 7 × 9 or similar dot matrix. In such conditions lower case letters with occasional capitals are more legible. Research shows [2,15] that not being able to perceive word shapes (as is true for words set in upper case characters only) may slow reading speed by as much as 12%. Because line printers and terminals often have little space between lines in comparison to normal textbook typography, lower case letters are particularly important in providing visual space between lines of type and thereby improve legibility. In interactive situations, lowercase typography for machine messages and for the echoes of user input should be used whenever possible. When all capital settings are used, they should be used to highlight a restricted set of primary words and phrases. For example, they identify the module from which the current command prompts are coming and titles for pages or for textual and tabular information.

Because most of the computer's replies are of fairly brief extent, even for lengthy help messages, a line of text 40–60 characters wide is appropriate. In order to separate the computer's statements from the user's the computer will generally type in character positions 21 to 80, while the user will begin typing in character position 1. Examples of typical frames appear in Figures 5 and 6. The visual separation of "voices" in the human-computer dialogue allows users to scan lines on the screen or on paper output more effectively. Users can see the unfolding dialogue to observe patterns of decision making and to find specific information quickly. It is important to assure the users that they are driving the system, not the other way around. The intention of this layout is to emphasize the users' selections from a menu or menu-prompt and the computer system's responses to that selection.

A standard title, page number, prompt line, and user request line are usually displayed on every page. In this way the user's present location, past history (the context part of the prompt message), and future locations (the options of the prompt) are always present. The frame layout has also tried to account for typed paper presentation. Note that the fully 80 character width can be typed out on standard width paper (8.5 × 11 inches). Using pica or elite typewriters (10 or 12 pitch) non-proportional letters, a full width of 8 or 7.2 inches is obtained for 80 characters. Use of 12 pitch typing is recommended to allow a left hand margin for binding and an ample right-hand margin.

The graphic design of the page assumes that most text will appear between character positions 21 through 79 (one less than maximum to avoid automatic line feed in certain terminals). Occasionally tables and lists occupy the entire screen. Because most lines begin or have fields beginning in column 21, there will be a strong visual axis vertically along character position 21. It is along this invisible, implicit vertical line that a user can efficiently scan when searching for information. To reinforce this significance, most database titles, prompts, etc., begin in character position 21. After experimentation with variations the most useful tabular settings appeared to be every 5 characters beginning in column 1 and continuing across the screen. The tab set-

Figure 5

```
READY
  MONITOR.SEEDIS.HELP.

                        INTRODUCTION TO SEEDIS

 The three major processes in SEEDIS are:

 AREA: define a geographic study area (composed of states,
      counties, or census tracts)

 DATA: select data appropriate to the geographic study area
      chosen.  For  example, for a study area consisting of a group
      of states, only state level data, and  not  county  or  tract
      level data, are appropriate.

 DISPLAY: manipulate and display the data in table, chart, graph,
      and/or map form.

 Normally  AREA,  DATA,  and  DISPLAY  are  performed  in the order
 given. However, once the geographic study area is defined (AREA),
 one  may  alternate  between  DISPLAY  and  the   selection   and
 extraction of additional items in DATA.
TYPE MORE TO SEE NEXT SCREENFULL
TYPE ? FOR A LIST OF COMMANDS
```

```
                      SEEDIS: area, data, display, profile
  help
                      USING SEEDIS
                      ---------------------------------------------------
                      LBL's Seedis is an experimental information system that
                      includes integrated program modules for retrieving, analy-
                      zing, and displaying selected portions of geographically
                      linked databases. Program modules in Seedis include:

            area      select geographic area (level and scope of analysis)
            data      select, extract, enter, or transform data
            display   manipulate and display data in tables, maps, and charts
            profile   produce standard socio-economic reports for selected areas

                      Normally Area, Data, and Display are used in the order
                      given. However, once the geographic study area is defined
                      in Area, you may alternate between Display and
                      the selection, extraction, or entering of additional items
                      in Data.

                      SEEDIS: area, data, display, profile
```

Figure 6

```
?
 TYPE ONE OF THE FOLLOWING COMMANDS...
 ?           FOR THIS LIST OF COMMANDS
 HELP        FOR HOW TO GET HELP
 MORE        TO SEE NEXT SCREENFULL
 TABLE       FOR THE TABLE OF CONTENTS
 <N>         FOR PAGE <N>
 * <COMMENT> TO ENTER A COMMENT IN THE LOG
 DATA <SEQUENCE LETTERS>        SELECT DATA CODES
 CANCEL <SEQUENCE LETTERS>      CANCEL DATA CODES
 FOR X <C>   SUBSTITUTE C FOR X IN DATA CODES -
             ALSO XX XXX XXXX Y YY YYY YYYY
 REVIEW      LIST DATA SELECTIONS MADE SO FAR
 SAVE        SAVE DATA SELECTIONS AND RETURN
 QUIT        CANCEL DATA SELECTIONS AND RETURN
 READY
```

```
                      DATA: <line letter(s)>, table, <page number>, CR
  ?

Input                 Description
--------------------  ---------------------------------------------------
<line letter(s)>      select one or more data elements by line letter
table                 display table of contents for this database code
<page number>         display a particular page
CR                    (carriage return) display the next page

?                     list avalable commands in this menu
help                  describe data element selection
show                  display table of contents for this database
review                list current data element selections and history
cancel                delete current data element selections for this database
quit                  return to database selection menu

                      DATA: <line letter(s)>, table, <page number>, CR
```

tings are simple divisions of the jump between the user's starting position (position 1) and the computer system's starting position (position 21). A tab width of 5 or 10 characters allows short fields of 4 or 9 characters and encourages a limited, consistent set of tab stops.

Whenever possible, the codes or other items to be selected in a list are placed immediately preceding position 21, i.e., beginning in positions 16 or 11. When more than one field must be placed in columns 1 through 19 (assuming one skipped character in position 20), the most important field, usually the one containing items to be selected, is placed at the far left so that it can be easily detected. The left-most field and the one beginning in position 21 are the two most important locations. Remaining fields are placed at the far right. Wherever possible, consistency of location is maintained, and fields are arranged in conceptually linked groups, e.g., variables and units.

Page numbers include the word "Page" to reduce confusion about the appearance of isolated digits in the display and to avoid confusion with possible section numbers. Although not completely implemented, it is recommended that "Page 2 of 15" be the convention to indicate further pages. The user will be aware of how much other materials might lie in a module or section.

Horizontal lines formed by hyphens are used to call the reader's attention to titles of tabular or prose material that is subordinate to the main title. The hyphen rule replaces the blank line of space, which normally would have been necessary for visual clarity. The width of the hyphen rule, 59 characters maximum, follows the standard width in order to emphasize the title and the full column width. Within tables, the hyphen rule may be wider than 59 characters in order to include fields in character positions 1 through 19. Normally one character space interrupts the rule between fields.

Where possible, lists of short keywords allow reading down in columns of greater than 3 lines. Lists usually begin with a header, a title, and a hyphen line, and end with a line skip, followed by the prompt. If necessary, lists may occupy the full width of the page, with correspondingly wider hyphen lines. It is generally recommended that long lists of short items appear in multicolumn format. As they grow in length, they should expand into a next frame.

The following two examples, Figures 5 and 6, show a comparison of undesigned and designed welcome messages as frames of the Seedis user-machine interface. In the first undesigned versions note the scattered appearance of text groups, the inconsistency in the use of all caps and lower case, and the order of the text in which the user is told about getting out even before being welcomed. In the second redesigned versions note the order of text elements, the use of rules, lower case, and specific tab settings. The full screen width is equivalent to 80 typewriter characters in width. Information on global commands is introduced in the very first information to the user. Note also the standard form of the menu-prompt which identifies the module in which the user is currently working (all capital letters) and the appropriate non-global commands at this point.

Inner-Face Design Principles

The appearance of computer programs (including documentation) which generates Seedis has not yet been designed. However, the author has helped redesign prototype frames of general program texts [13] and is currently engaged in research with Ronald Baecker, President of Human Computing Resources, Toronto, to develop these prototypes into a working system for typesetting code and comments. Figures 7 and 8 present a "before and after" version of typographic program visualization which are the prototype designs.

Figure 7 presents a program in an elementary typographic form using fixed-width characters of a single font with limited horizontal spacing variation. There is little typographic hierarchy. The program is more readable than those presentations which are all-capital typography and multiple commands per line, but there are still ways in which it can be made more readable.

Figure 8, a protypical black-and-white visu-

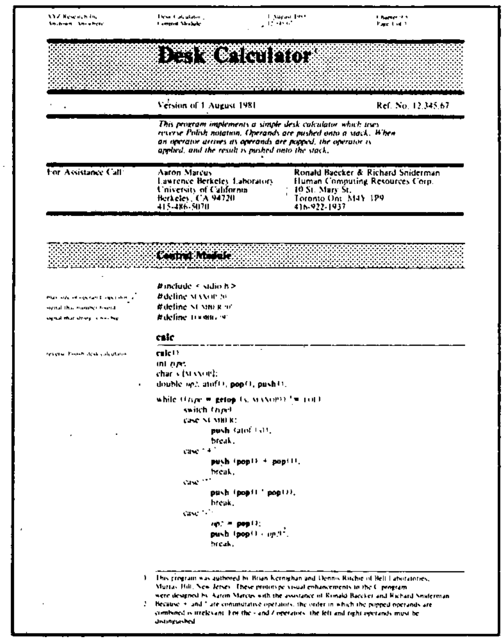
Figure 7

```
#include <stdio.h>
#define MAXOP 20        /* max size of operand, operator */
#define NUMBER '0'      /* signal that number found */
#define TOOBIG '9'      /* signal that string is too big */

calc()      /* reverse Polish desk calculator */
{
        int type;
        char s[MAXOP];
        double op2, atof(), pop(), push();

        while ((type = getop(s, MAXOP)) != EOF)
                switch (type){
                case NUMBER:
                        push(atof(s));
                        break;
                case '+':
                        push(pop() + pop());
                        break;
                case '*':
                        push(pop() * pop());
                        break;
                case '-':
                        op2 = pop();
                        push(pop() - op2);
                        break;
                case '/':
                        op2 = pop();
                        if (op2 != 0.0)
                                push (pop() / op2);
                        else
                                printf("zero divisor popped0);
                        break;
                case '=':
                        printf("%f0, push(pop()));
                        break;
                case 'c':
                        clear();
                        break;
                case TOOBIG:
                        printf("%.20s ... is too long0, s);
                        break;          default:
                        printf("unknown command %c0, type);
                        break;
```

Figure 8



alization, requires a high resolution bit map display terminal or a high quality hardcopy device. The actual images of Figure 8 were generated in Times Roman type using a computer-controlled phototypesetter. Figures 7 and 8 are part of a series of experimental prototype pages for online or off-line documentation which illustrates the full potential of a graphic design approach to textual program visualization. Spatial location, typographic symbol heirarchies, figure-field enchancements, indexes, abstracts, etc., are combined to create a clear, consistent, explicitly structured page that is legible and appealing to the reader. The following paragraphs detail the features of this design and elaborate upon the basic principles suggested above.

Spatial Organization of Program Texts
The entire page/frame is a mosaic of content units with standard locations but in some cases variable area size. In an interactive environment, each of these areas could be a window to a higher or lower level of information.

The upper part of the first page (or frame of a high resolution terminal) is intended to be a standard documentation cluster of header units grouped in a natural order. These include a documentation source, a program title, program subtitle(s), revision or last update, a document code number, chapter reference and page number. The items are then repeated on every frame/page.

In a strong title banner below the headers, the title is presented in a size large than all of the others and on a field of small gray dots to distinguish it clearly, but not in an overpowering way, from the rest of the text. The version date and unique code numbers are intended to advise the reader of the particular version of this program. There may be others similar to it that must be distinguished. The abstract is intended to be a 100 word summary of the function and significance of the program. It appears in italic to set it off from other elements. The author/guide and location band are intended to identify specific persons at the installation site who can be contacted for assistance in interpreting or using the program.

Note the use of a tab setting at approximately half the width of the main column of text for presenting two columns of information.

Modules of the program are indicated by unique gray bands with bold roman module names. Their size is the largest of three standard sizes of type for the textual material of the program. Bold type is used to keep type legible on a gray background.

Comments appear in 7 point type as separate marginalia to the left of the main column of text. These are intended to be single line phrases that can help the reader to understand individual code lines. The comments column is approximately 40 characters wide and appears in the smallest of the three text sizes. As phrases, the comments appear without initial capital or periods. In keeping with all clusters of text, they appear typeset in flush left, ragged right lines.

Footnotes appear as 8 point type in a separate band of space at the bottom of the page/frame set off by a thin rule as wide as the main text. They are more detailed and complete explanations of the significance of code lines (or any other element such as a title). They appear as full sentences with initial capitals and closing periods.

Evaluation
Many variations of page and screen formats were studied before the conventions for Seedis were proposed. An extensive testing procedure in the context of Seedis developments was not available, however, the author acknowledges the appropriateness of a detailed human factors study of these changes in Seedis conventions. After implementing these changes, viewers and users of Seedis displays appeared to notice the differences and to respond favorably to them. The new graphic design has also served as a model for staff preparing new modules, components and documents pertaining to Seedis. It appears that carefully controlled graphic design within Seedis can result in an improvement in the efficiency of the use of information displays as well as the user interface. The application of

graphic design principles outlined in this article and included in a forthcoming graphic design manual for Seedis [12] should enable future programmers to economically prepare, produce and install various modules being developed in such a way as to user their resources to their full potential and to retain over-all visual coherency of the system.

Most of the changes in the Seedis interface have been relatively easy to implement within the software. These redesign features were more than just a "cosmetic" facelift to the system. By carefully considering not only what to show, but also when, how, and why to show it, a better understanding of the functionality of the system emerges in the minds of the builders, the users and the viewers of Seedis and its information. Many of the changes in design constitute working conventions rather than as yet carefully proven standards. However, many of the changes corresponding to recommendations of an independent critique of the system [1].

Future Seedis Research Directions
Seedis will continue as a research project and experimental information system, with major enhancements to facilitate incorporation of 1980 census data. Plans for future developments include:

- Facilities to describe and handle complex data structures, including hierarchical records, multiple occurring data items and repeating groups of items, variable length data, transposed (vertically partitioned) and partially transposed data records.
- Automatic creation of metadata information such as dictionaries and cross database indexes from augmented data definition files.
- Selection of data items by keyword, subject, and/or item values.
- Statistical routines that automatically read and write an underlying self-describing file structure so that the output of any routine can immediately serve as input for any other routine.
- An easy-to-use "report by example" subprogram to create standard and custom reports or profiles which can be subsequently run with either line printer or phototypesetter output for any combination of geographic area.
- Different input and output formats for different types of devices (e.g., dumb crt's, printers and graphics terminals).
- Integration of user interface functions to facilitate experimentation with pictorial and touch-sensitive interfaces, flexible invocation of any Seedis function from within another, and user selection of command, menu, or question and answer mode.

Future Graphic Design Research Directions
The efforts thus far in applying graphic design to computer graphics raise interesting questions which further research in the visible language of computer graphics might explore. These questions can be clustered into six categories [16].

The first research topic deals with the appropriate use of typography to reveal formal syntactic, semantic, and pragmatic properties of data elements. For example, what is the appropriate use of boldface and italics? Should multiple fonts be used? How should color be employed?

A second concern is with the design and layout of graphic elements on the page or screen using systems of grids and overlays. For example, how should secondary text (comments and commentaries) be clustered around the primary text in a multi-window display environment?

A third area for research is the possibility of substituting a set of well-designed icons or symbols (pictograms or ideograms) for certain combinations of alphanumerics that occur repetitively in computer graphics. What should these icons or symbols be? To what extent can documentation become more diagrammatic, and rely less on the linear text forms or current languages?

A fourth set of questions arise out of the possibilities that computer graphics offer for the inclusion of movement, blinking, and other kinds of temporal change into documentation. What should be the relationship between static paper and dynamic screen representations of computer graphics?

A fifth problem area is in the depiction of large directed graphs of great complexity, networks in which nodes are not single points but entire frames (combinations of signs) and in which links are explicitly stated or implied connections between nodes. The spatial layout and user navigation problems that occur may be seen, for example, in the transformation of text statements into organization or process diagrams.

A sixth research topic concerns the ability of a visualization to facilitate the integration of the various conceptual levels at which data may be described. What relation should exist between high resolution detailed views and low resolution overview images of the same content? What is an optimal sequence for the basic units of an interactive book? What would its other parts such as tables of contents and indices look like? How might they be used?

Finally, one may ask in general, what is the relation between reading and writing such complex visual representations?

Summary

The above discussion has introduced some basic graphic design principles that are relevant to the display of information graphics. The examples shown presented a modest set of improvements for the creation, distribution, and consumption of information through computer-assisted graphics in the three faces of computer systems.

Further developments need to be made to design better coordination of typography, line weight and texture, gray values, color, spatial arrangements, and sequence for texts, charts, maps, and diagrams. Wherever more sophisticated graphic display parameters are functioning, even greater benefits can be expected from applying awareness of informational graphic design principles to the technical capabilities of computer graphics display equipment. This report has been intended to educate the graphic design community about information-oriented graphic design for computer graphics and to encourage greater attention on the part of the computer graphics community to the potential contribution of graphic design to more effective visual communication of information.

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Biography

Aaron Marcus is the principal of Aaron Marcus and Associates, Berkeley, CA, an information-oriented graphic design firm specializing in effective computer graphics display. Recently he was a staff scientist in the Computer Science and Mathematics Department of Lawrence Berkeley Laboratory. From 1968–1977 he taught at Princeton University and was a consultant in computer graphics at Bell Telephone Labs, Murray Hill, New Jersey. While at Bell Labs he programmed a prototype interactive page design system. His professional graphic design work has been exhibited, published and awarded internationally. He has both written and lectured extensively on graphic design and on computer graphics for professional journals and conferences of both fields. He recently co-authored *The Computer Image* published by Addison-Wesley, has written *Managing Facts and Concepts,* published by the Design Arts Program, National Endowment for The Arts, and has written *Soft Where, Inc.*, Vol. 2, published by the West Coast Poetry Review. He is on the advisory boards of *Visible Language* and *Information Design Journal.* He has consulted internationally with major computer graphic research and development groups on the subjects of chart, diagram, and map design; on user-friendly iconic interfaces; and on program visualization/documentation techniques.

Mr. Marcus received his BA in physics from Princeton University and his BFA and MFA in graphic design from Yale University Art School. He is on the Advisory Board of the Design Arts Program, National Endowment For The Arts, and is a member of NCGA, ACM, Siggraph, ASIS, The Computer Art Society, Sigma Xi, The American Institute of Graphic Arts, and The Semiotic Society of America.

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