DOCUMENT RESUME

ED 282 547 IR 012 696

AUTHOR Palazzi, Maria
TITLE The Use of Computer Graphics in the Design Process.
PUB DATE 87
NOTE 81p.; Master's Thesis, The Ohio State University.
PUB TYPE Dissertations/Theses - Master Theses (042)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Animation; *Computer Graphics; *Computer Simulation; Data Collection; Design; Designers; Futures (of Society); Manufacturing Industry; *Systems Approach; Three Dimensional Aids
IDENTIFIERS *Computer Assisted Design; *Industrial Design; Information Management

ABSTRACT

This master's thesis examines applications of computer technology to the field of industrial design and ways in which technology can transform the traditional process. Following a statement of the problem, the history and applications of the fields of computer graphics and industrial design are reviewed. The traditional industrial design process is then described, and the following steps in the process are examined and related to possible computer applications: (1) problem acceptance; (2) problem analysis and definition; (3) ideation; (4) selection of solution(s); (5) implementation of solution(s); and (6) evaluation of solutions(s). Data gathering, information management, and simulation are identified as functions that can be performed by computers in the design process. A discussion of the inevitable restructuring of the design process and ways in which this process can be enhanced through the use of a system created specifically to fit the needs of the industrial designer concludes the report. Five figures are included in the text and a list of 47 references is provided. (MES)

THE USE OF COMPUTER GRAPHICS IN THE DESIGN PROCESS

A Thesis

Presented in Partial Fulfillment of the Requirements for for the degree Master of Arts in the Graduate School of the Ohio State University

by

Maria Palazzi, B.S.

* * * * *

The Ohio State University
1987

Masters Examination Committee:

Thomas E. Linehan

Christian D. Wedge

Approved by

Thomas E Linehan

Adviser
Department of Art Education

THESIS ABSTRACT

THE OHIO STATE UNIVERSITY

GRADUATE SCHOOL

NAME: Maria Palazzi QUARTER/YEAR: Spring 1987

DEPARTMENT: Art Education DEGREE: Masters of Arts

ADVISER'S NAME: Linehan, Thomas, E.

TITLE OF THESIS: The Use of Computer Graphics in the Design Process

In the future, the computer has the possibility of becoming an integrated and necessary component in the design process. This paper examines how industrial designers can productively use computer graphics to create and design in the field of industrial design. To create, not only with the computer as a new tool to perform traditional tasks, but as a partner in the process. Certain aspects of the design process will necessarily be altered with the growing use of computers in the field of industrial design. New steps in the process will be required while retaining the traditional methodology. This paper examines the inevitable restructuring of the design process and suggests ways in which this process can be enhanced through the use of a system created specifically for the needs of the industrial designer.

Adviser's Signature

To My Father

ACKNOWLEDGEMENTS

I would like to thank my advisor Tom Linehan for his support and insight throughout my professional and academic experience. I thank Charles Csuri, the inspiration behind Cranston/Csuri Productions, for giving me the opportunity to work for his company. I thank the staff of Cranston/Csuri Productions, past and present, for their teamwork and creative energies.

A special thanks to Michelle L. Amato, for her friendship, encouragement and grammatical assistance. And most especially, thanks to my father, mother, Richard, Robert, David and Julia for being the roots that nourish my branches.

VITA

March 18, 1959	Born - Pittsburgh, Pennsylvania
1982	B.S., The Ohio State University, Columbus, Ohio
1983-Present	Technical Director/ Senior Animation Artist Cranston/Csuri Productions, Columbus, Ohio

FIELDS OF STUDY

Major Field: Industrial Design

Fields of Study: Studies in Computer Graphics and Animation

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Industrial design encompasses the fields of products and product systems; interior space, the development of interior environments for human activity; and graphics, the translation of ideas and concepts into visual messages. Today's industrial designer repeatedly has been promised, warned, threatened and prophesied to about the effects high-tech electronics will have on the field of industrial design. To date, most are speculations on the impact of change the designer will experience. Initial investment in the equipment, changing advancements in the electronics hardware market and lack of software created specifically for industrial designers' needs, have hampered a faster acceptance of the computer as a necessary part of the design industry.

As prices of hardware and software decrease and users demand more efficient software, the integration of computer technology and industrial design is fast approaching. The effects it will have on the traditional design process are only speculation, but it certainly will have an effect. Most designers have felt the introduction of technology in some way in their field.

Viewing the computer as a tool that only mimics traditional practices of the designer results in the computer and its software being modeled after existing tools. The limitations of the traditional tools also becomes part of the system. The system is just a faster tool.

Though the computer inherently increases speed, it does not assure quality. That is a characteristic of the product the designers alone can bring. Computers in design should not be looked at as just a way to produce the same products quickly, but as a way to gain more insight into what are the needs of the individual or group being designed for, how can they can best be served and does the product reflect these needs.

To ease the adjustment to the use of technology it is important to de-emphasize the technology and concentrate on developing new techniques and strategies in design methodology. [1]

Unique features of the technology make it more than a tool to mimic the traditional tools of the designer. Thomas Linehan of The Ohio State University Computer Graphics Research Group identifies three of these unique features as concrete concepts of computer graphics: The non-material nature of the medium, the digital description of the image and the algorithmic requirements for manipulation of the image. All of these require additional knowledge and new skills for the designer. [2] The physical laws of nature do not exist in this new technology.

Computer graphics is the first field to merge a quantitative description and a qualitative description in order to create a numeric description for aesthetic qualities. This junction is termed a display algorithm, in which each process describes the other and can be used to reconstruct the other. [3] Algorithms must be developed to create new forms. The computer becomes more than a tool, it is a resource.

> Crucial decisions that affect the success or failure of an entire product line are often made during the earliest stages of the design process. It is at this fragile, creative stage - when an idea may be no more than a series of impressions in a designer's mind - where the impact of computer graphics and computer animation has yet to reach its full potential. from the earliest moment of conceptualization. [4]

Design professionals and students must realize the assets afforded by this new technology. Computers can offer designers more in-depth and complete designs. Computer graphics have provided the designer with a new medium and environment in which to create. Designers are offered new creative avenues through a technology not bound by the laws of nature.

This paper will provide a brief history of both computer graphics and industrial design. The traditional design process, as practiced by industrial designers, will be discussed and each step will be examined and related to the possible applications of computers and computer graphics in the process. This is not to serve as a survey of equipment but rather a look at applications of computer technology to the industrial design field and how technology can transform the way the traditional process is performed.

As of this time, the available computer systems do not provide the proper tools to accomplish the specific tasks of an industrial designer. There are many bits and pieces of software that can be used as tools in certain parts of the process.

> "Computer graphics workstations have been technology-driven: the tool came first and then the manufacturers looked for ways it could be used." [5]

It is important that the technology matures into a viable tool and creative resource for the designer.

CHAPTER 2

COMPUTER GRAPHICS HISTORY/APPLICATIONS

> "Computer graphics, is the use of computers to provide pictorial representations of information. Computer graphics expands the possibilities of graphic communication by combining the power of computers to rapidly store, retrieve, and process vast amounts of information with display output devices." [6]

The science of computer graphics is a two-sided vision - a high-tech science which can imitate the laws of physics on the basis of mathematical models, and a practical tool for the creation of educational or entertaining images.

During the 1950's, computers were used almost exclusively to perform complex arithmetic functions. The use of computers as an interactive graphic tool can be traced to the 1960's in a thesis published by Ivan E. Sutherland in completion of his Ph.D. from Massachusetts Institute of Technology. [7] Entitled, "Sketchpad: A Man-Machine Graphical Communication System," this paper a presented program called "Sketchpad" which allowed the user to enter data into the computer and see the results on the cathode ray tube (CRT). The almost immediate display of the data makes it one of the earliest truly interactive systems. In addition to Sutherland's research, other scientific groups such as General Motors, Lockheed

Aircraft and Bell Telephone Laboratories began research projects in interactive computer graphics.

With the evolution of graphics on computers came interest from some fine artists to create art with this new medium. But the artist found it difficult to obtain access to the machines without a tie to the scientific community. Soon collaborations between artists and scientists produced films and still art. At the Ohio State University, Professor of Art Charles Csuri and programmer James Shaffer collaborated on some of the first pieces of figurative computer graphics having purely artistic purposes. [8] Csuri and Shaffer used the computer to aid in pictorial modification. One of the first computer graphic art shows to incorporate interactive vector displays was organized by Charles Csuri at The Ohio State University in 1970. [9]

With the '70s came the development of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) developed for industrial applications. CAD/CAM broke into three major areas of application: electronics design, the design of printed circuit boards; mechanical design, involving three-dimensional modeling; and architecture, engineering and construction (A-E-C), representing the creation of architectural plans, engineering drawings and mapping.

For the artist and designer came paintboxes which use software programs to simulate "paint" on the screen with different brushes, colors and textures. The user interacts with a cursor or "mouse" that takes on the characteristics of a particular rendering technique. An artist can simulate an airbrush, draw with lines or established patterns, fill large areas with color or patterns, and create and use pen tips. Software has been developed for specific applications in design tasks, such as printing, layouts, typesetting interface, diagramming, most of which are in pagination software. This software is used by graphic designers to cut and paste, retouch and resize photographs and lay out type. Most of the software has been designed to imitate the same tasks that a graphic designer usually practices.

Package design is another area in which the computer has been applied. Designers have simulated the construction and graphics of a package on the computer without ever building an actual physical model. Constraints such as volume, shape and graphics can be incorporated into the computer so the designer can design, create and previsualize a prospective product that accurately meets the prerequisites of the design.

Computer graphics enable architects an opportunity to "walk" around and into a building. Data for architectural drawings is input into the computer, allowing the animator to manipulate and create a structure according to the desired design, color, material, and location.

> "Computers enable us to take a 50-story building and position it against a realistic skyline. Before the ground is even broken, we are able to see the building through the eyes of a passing pedestrian, a neighboring tenant or a bird passing overhead." [10]

Production of computer-generated medical imagery has captured international attention. Studies have shown the medical arena accounts for a large percentage of markets in the computer graphics industry. Currently, medical animation explores the relationships of and interactions among organs, tissues and cellular components not possible through current visual methods. Other data portrays detailed processes of the body such as the heart cycle, respiration, blood flow, and transmission of nerve impulses. Applications include commercial use, as well as patient, medical support staff and physician education and training.

Animation of two- and three-dimensional data has provided the entertainment field with a new medium for advertising and promotion where concepts are not bound by the laws of physics and nature. Utilization of computer-generated animation has become a trend for the television broadcasting industry in particular. Computerized graphics are visible on international network campaigns, sports and news promotions, independent stations worldwide, promotions for major corporations and 30-second television commercials. Some of the top production companies have capitalized on their design expertise to push the limits of commercial graphics. They create surrealistic animations by combining state-of-the-art software with design talent.

Computers are profoundly influencing designers of today, all fields of design have been touched by their application. As the integration of the latest computer technology and the competitive market of computer graphic work stations evolves, designers will face one of the biggest changes to their fields since the Industrial Revolution.

CHAPTER 3

INDUSTRIAL DESIGN HISTORY/APPLICATIONS

Design is the visual language of communication. The essence of good design is to communicate a better, more efficient solution to a problem. The manner in which designers apply the elements of design, including form, line, color, texture and material, makes statements about their culture. In turn, the available methods of production effect this design style.

More than one hundred years before the computer revolution, industrial design experienced a revolution of its own. Prior to the 1830's, design was a handcraft technique practiced by craftsmen who had the ability to draw or create with their hands. These craftsmen physically created the products used by the communities in which they existed. With the beginning of the industrial revolution, handcraft techniques were gradually replaced by automation. This time period became known to designers as the "industrial age of design." [11] The industrialization and mass production caused a decrease in the number of skilled craftsmen. Machines out-produced and out-priced the workers. The factory system changed the quality of life and the environment. New manufacturing techniques were met with both acceptance and rejection by the design community. Machine-produced and machine-inspired products presented a threat to the social, ethical and aesthetic values of many designers, while it challenged the imagination of others. Acceptance and rejection of the the new process was expressed through form, function, color, and materials. Those rejecting automation produced works that expressed ornamentation, biomorphic shapes, nature-related colors and materials. Geometric forms and functional designs, machine-based materials and primary color applications came from designers who meshed the new production technologies with their design style.

The designer was paid by manufacturers to specify the standards of an object that was to be made in large quantities of identical groups. The designer no longer knew the user he was designing for, and the producer was an unknown also.

> "Designing for a mass audience required a large number of compromises to be made in order to reach the level of average acceptability." [12]

With the new manufacturing process, no longer did one person control production from the drawing board to the finished product and design became dictated by the efficient use of new technology. [13] From this new trend in design emerged studies in the design process that incorporated a structurally-defined thought process. Design would now encompass a structured thought process for problem solving. Designers would be relied upon to understand the present manufacturing capabilities while designing for future trends.

With the introduction of computers as a design tool, the expansion of design alternatives was a result. Time savings is a prime factor in the acceptance of new technology, but it should not be the only factor. Computers in production allow for a wide variety of individuality without excessive economic hardship. Changes can be made to the computer data bases according to the individual. In turn, the computer guides the machinery in production. In effect, the new technology can offer the individualized work that was abandoned with the Industrial Revolution. And even though there is nostalgic joy for old ways, those ways would undoubtedly lead to unmitigated frustration.

> "This design/production process offers the designer a chance to design for the user in a way that has not been possible with mass production." [14]

In order for the computer to assist the designer in a user specialized way, the computer must provide a way to organize and analyze the information that will lead to intelligent solutions. Software that is applicable to the design process is on the market now. But, software to assist the user in the analytical aspects of the process is still in development.

CHAPTER 4

THE DESIGN PROCESS

The design process frees the designer from confusion presented by a problem by establishing a plan of travel. It enables the designer to concentrate on the separate areas of development rather than the end product.

> "The process of creative problem solving or DESIGN PROCESS describes a series of events, stages, phases or states of energy which must be experienced before completing the entire journey. The design process is a round-trip which carries us through decisions, solutions, actions and evaluations." [15]

The design process can be executed in a wide variety of ways, each of which may be determined by the designer and/or the problem. Though the process is structured, it is not binding.

In its basic form the design process involves:

1. PROBLEM ACCEPTANCE
2. PROBLEM ANALYSIS and DEFINITION
3. IDEATION
4. SELECTION OF SOLUTION(S)
5. IMPLEMENTATION OF SOLUTION(S)
6. EVALUATION OF SOLUTION(S)

The process structures the attack of a problem for the designer. Some of the numerous "attack" approaches to the design process can be circular, linear, branching and constant feedback systems.

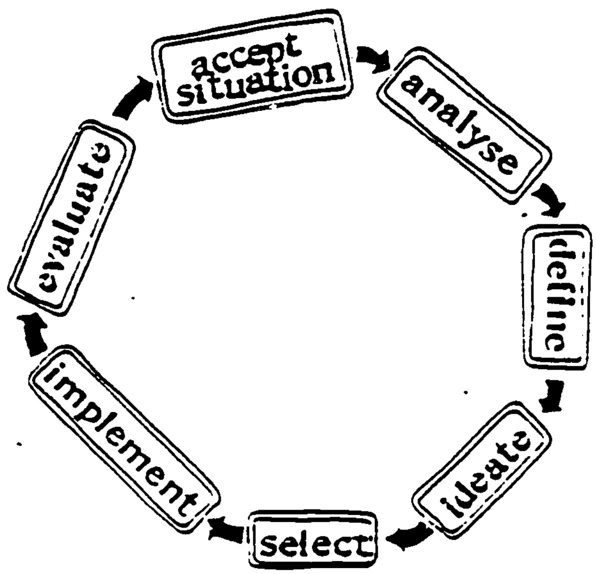

Figure 1.

Circular System Design Approach[16]

Figure 1 represents a circular system, which is an example of a spiraling process, meaning there is continuity but without a beginning and end. The designer can proceed through each step more than once by completing the path and repeating the steps with a more thorough knowledge of the problem and a more focused scope. Just as a carpenter cuts the basic shape for an object and then hones the shape by retracing the path with the tools.

Figure 2.

Linear System Design Approach[17]

Figure 2 represents a linear system which follows a straight path from beginning to end.

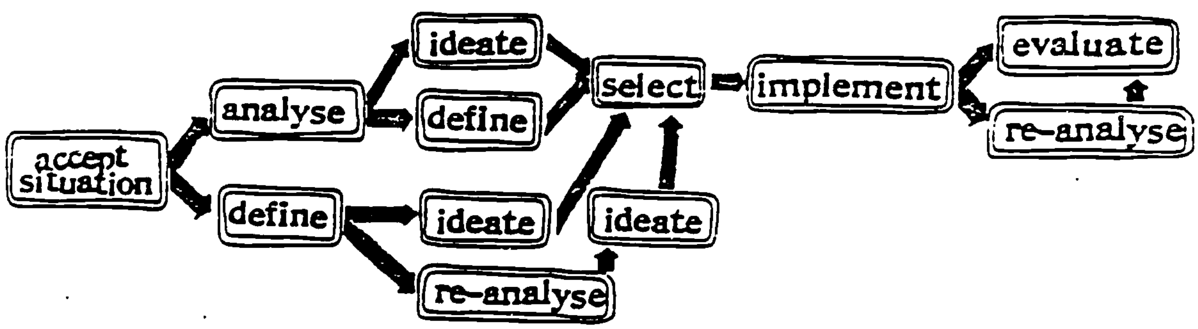

Figure 3.

Branching System Design Approach[18]

Figure 3 represents a branching system which allows decisions to determine more than one direct..on and a solution is achieved through a many-branched excursion.

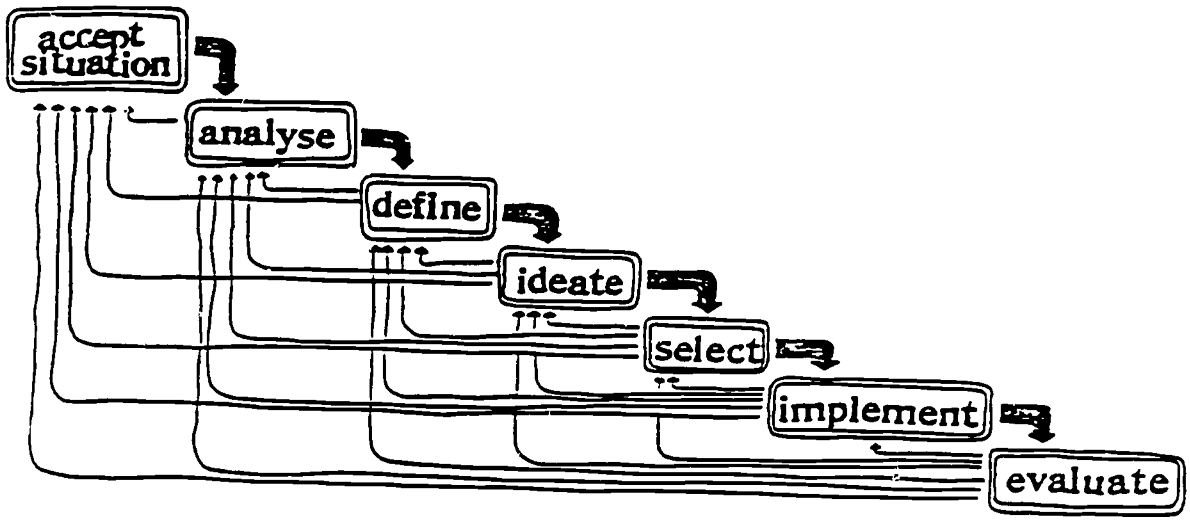

Figure 4.

Constant Feedback System Design Approach[19]

Figure 4 represents a constant feedback system which achieves forward progress by constant backward looping to re-evaluate decisions. [20] After completion of the process, the chosen solution(s) may be re-evaluated, refined and assessed as to the solutions' fulfillment of the problem's criteria. Additional stages of refinement, implementation and re-evaluation may be used in completing the process. This outcome determines if the designer will return to previous events or accept the final solution. Even a return to previous events is not the same as the first trip through the process, as events are now viewed differently because of insight gained along the process. It is a spiraling process of ingredients formulating a product.

Although many design problems have idiosyncratic features, there are common methods of problem solving to all. Common pathways or events provide a structure for the designer in solving a problem.

Just as in the design process, the essence of good problem solving with a computer requires a systematic approach. The computer, as does the designer, follows a path to produce a solution. A computer operates using algorithms as the process for specific problem solving. An algorithm is a procedure for solving a specific problem, expressed as a finite number of rules, which is complete, unambiguous and guaranteed to terminate in a finite number of applications of these rules. [21] The algorithm is a set of conditional statements which are determined to be true or false according to established criteria. With a "TRUE," the computer continues along the specified path. When the switch is a "FALSE," the computer either can take an alternate path or return to the point from which it came.

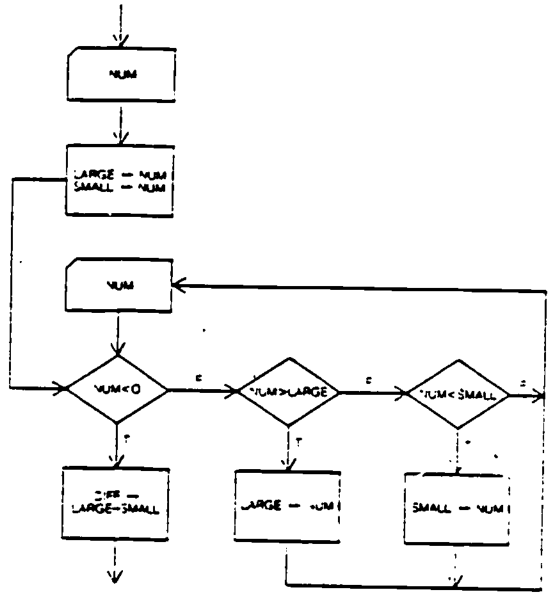

Figure 5

General Algorithm Path[22]

Figure 5 represents a general algorithm path used by the computer to analyze steps and return an answer to a problem. The diagram indicates that the process is one of forward progress and re-evaluation, which can either return to a loop or progress. The diagram resembles the qualities of the constant feedback system in Figure 4. A computer program progresses by analyzing the solution according to established criteria, just as a designer analyzes a solution in the design process. Along with the common structural techniques in the process, for both the computer and the designer, are two major differences in problem solving.

The computer is not limited to linear operations, it can implement several operations at once which may or may not be dependent upon one another. This technique called "parallel processing" breaks a problem into pieces and works on several pieces at once, much like the human brain works. The computer can help to go wider and deeper in the exploration of a problem and become not just a problem solver but a problem finder. Through analysis, it can even help to determine if we are indeed solving the right problem. Computer graphics becomes a mixture of concept (numeric description) and precept (iconic description). [23]

> The numeric description no longer just accounts for the location of an object in space or position on a relative color scale. There are precedents for these. The description accounts for myriad qualitative aspects of the object or scene. It consists of a mode of display (vector-raster), surface description (polygonal, patches, particles), light-space (world, screen, object, observer), surface properties (degree of transparency, shininess, reflection, refraction), and dynamics of motion (path, direction, speed, interval, or duration). [24]

Computer programs can be a predictable systematic world but they can also assist the designer in the freedom to exercise, merge and assimilate. This unpredictable, non-linear form of creativity used by the designer is one that is uniquely human.

Computers have the ability to sift through confusing criteria, organize goals, recall and handle more information than the human mind can register.

The method in which a computer is programmed to solve a problem and that which the designer solves a problem are analogous. The designer's nearly innate process of problem solving serves as a higher understanding of programming theories. Designers will still find it necessary to study basic programming to increase their understanding of the technology and to make them more effective users. The structural training in design education and the implementation of the process in the work place gives a designer a unique insight into the basic logic of the process in which the computer is programmed to respond.

> "A computer does not directly assist you in organizing your thoughts or inventing a solution procedure. You must have your procedure in hand and the computer merely manipulates numbers or information according to your prescription. If your solution procedure is wrong; the computer's output will be wrong. This is why you must master the art of problem solving if you hope to use the computer effectively." [25]

It is this structural aspect of the process that makes the computer an adaptable addition for the design field.

The quality of interaction between the design and the technology is based on the structure and implementation of the the software. A software program's limitations and idiosyncracies will be reflected in the work produced on each particular system. Much akin to the fact that the execution of a product will reflect the abilities of its manufacturer, "tools and material we use in the execution of work effect the emerging form to a significant degree." [26]

> "If designers wish to interface with computers, they must first understand the basic logic and formulas. Only then will they be freed from the limitations of packaged programs and be able to create within the parameters of the system." [27]

CHAPTER 5

PROBLEM ANALYSIS and DEFINITION

Acceptance of a design problem is an acknowledgement that a problem exists and a recognition that the problem is created by a human need. A problem must be accepted to begin the process of design. In this step, the designer says yes or no to the study of a problem and the formulation of a solution.

Upon acceptance, the next step is analyzing and defining the problem. Defining a problem calls for the designer to establish the main issues and goals concerning the problem. Pertinent questions about these main issues and goals are answered through analysis, such as Why does the problem exist? What are the effects of the problem on its environment? Whom does it effect? The industrial designer must meet the manufacturer's goals, production capabilities, material properties, and the consumer's needs and understand the relationships between all of the factors.

The definition and analysis steps work together to direct the designer to the essence of the problem. The designer, through research, interfaces with the needs, criteria and limits a problem presents. Researching helps the designer gather or disregard data according to pertinent information as specified by the problem and allows the designer to predict and control the consequences of a design decision.

A graphic designer who accepts the problem of designing signage for an airport terminal, for example, must analyze the needs of the public it will effect. The pre-established design of the environment in which it will exist, the information content of the signage and the monetary budget the client wants to invest are all factors which will influence the outcome of the design solution. This information, examined and studied at this early step of the process, enables the designer to make more intelligent and efficient decisions in the later stages of the process. These articles of information are the "facts" on which design decisions are based. Although the "facts" are never absolute certainties, they are statements of probabilities given certain situations.

Charles Owen at the Institute of Design, Illinois Institute of Technology, has designed computer programs that break a complicated problem into separate elements. This breakdown helps the designer focus on the basic elements such as costs, style, environment, and usage. These informational factors, examined separately, help designers to not be overwhelmed by the scope of the whole problem.

After examining these separate elements, the information gathered can be applied and structured to the design solution. For example, when describing the look of a automobile, one describes parts or aspects of the product rather than the whole. Descriptions of the body shape, surface treatment and mechanical concept are all parts of the whole. Even these parts may be too broad and may be better described, visualized and understood as yet smaller parts of the whole. All of these aspects come together to describe a whole, complex product.

Alfred Kemper, wrote an article called "Smart Software in the A-E-C Industry", for the Journal of the Association for Computers in Design. [28] The designer's job, he says, "is to gather information (clients' needs), assemble the proper information (technical, codes) and communicate a solution (the design)." He feels Computer Aided Design (CAD) should "simulate this process". He stresses the need for "smart software", software that does not complicate the design process and does provide useful information to the user.

> "The purpose of using CAD is to make vital information available at an earlier stage in design, enabling the designer to make better decisions, i.e., to analyze a design or simulate various solutions." [29]

Many designers have suggested the use of computers as "smart apprentices," as machines programmed to assist the designer by adding new insight into a design problem. These "smart apprentices" would provide a means of organization of information, random manipulation of forms or rule-based evaluations. The role the computer is to form in the design process is what determines the direction the programs or algorithms follow. This direction is largely a result of the programmers' and designers' personal attitude and values. [30] Whether or not the programmer is the designer, designers will find themselves in a position to specify the goals of software and therefore influence the tool. In this respect, it may become difficult for a designer to utilize tools generated according to another designer's values. Therefore it is necessary that a designer identify and communicate personal attitudes and values through the program.

Information Banks

The computer can be used in the gathering and reorganizing of useful information for a design problem. It has the capability of organizing, categorizing and summarizing information faster than any human. Computers process information in microseconds. The computer must be fed the set of rules (algorithm) for it to organize data.

Computer-assisted searches are one way in which a computer can gather and organize information. At present, many academic and public libraries offer this service to their patrons. These institutions usually make available bibliographical searches which use keywords such as titles, subjects and authors in locating sources of information on various subjects.

Similarly, a computer information network dedicated to design information could be developed. The vital information needed by designers includes references to past design problems and solutions. For example, when designing the package for a ketchup bottle a designer might reference companies that also manufacture ketchup. Marketing studies may be available on what age groups are the target audience for the product and the type of graphics that appeal to that audience. The designer would find useful references as being any historical references to packaging types traditionally used by the client, the client's competitors, and the companies the client may wish to compete with. Production techniques, such as printing, point of sale information, and other criteria would be most useful.

A source of data or information banks made available to the designer on a system would provide a more efficient and extensive research phase. Vendors and industrial designers could compile reference materials helpful in researching the background of related projects and stored as a common data bank to be accessed by all system users. This pool of information can be stored and added to as projects are undertaken. This gathering might range from in-house to nationwide reference spots into which all this information is collected and made available to users who can connect through phone lines.

University design departments could compile their own information banks which could contain past and proposed lesson plans for annual design projects. Records of the lesson worked in terms of student productions could also be recorded.

Visual Banks

Visuals of the past student work could be recorded in order for both instructors and students to analyze past solutions. That same designer of the ketchup bottle might be interested in seeing pictorial representations of the competitors' bottles or of bottles used by the client for past production. Examples of labels, typography, and bottle shapes explored for the product provide a valuable insight into the creative process of a particular designer. Being able to view how the competition labels its product and seeing what other containers the product will share the shelf with in a grocery store would be helpful. This information could be available, not only in the written form but in the visual form.

Visual images could provide additional information and in many cases better illustrate an abstract concept. The images could illustrate color and shape studies previously recorded by another designer when tackling a related problem. The ability to call up a black-and-white label and add colors according to the user's own aesthetics, then to compare that color application to the original color would provide an experimental environment for the designer.

Although high-resolution graphics, (600 line), are available, they would probably be impractical in the research phase and, at this time, too expensive for most users' systems. A lower-resolution image (300 lines or less) of past, related solutions would be adequate in most cases. Resolution refers to the number of perceivable black lines over a white field. Images could be available on slides, pen-plotted drawings, print, film laserdisc or videodisc depending on the capabilities of the user system.

Networking software would be necessary when connecting multi-system banks. Software allows one system's code and data to be readable by other systems. In that respect, it can support more than one operating system. Although much refining is necessary in the existing network systems, transmitting data to other sites and to the field can greatly facilitate the design and production cycles. The problem of software/machine compatibility becomes especially crucial for free-lancers who use many different systems. Other types of useful information could provide standards, costs, processes and availability of materials to the designer. This information might be arranged in much the same way a library organizes its collection such as Dewey Decimal, Library of Congress (LC) , or by subject, style, author, date.

Data Gathering

While research is used to study data and establish new facts, data gathering serves to gather and organized known facts. Computers can be used to monitor and gather data about an environment and its users and in compiling information on human factors. The abilities to perform repetitious and objective tasks make the computer the perfect device to gather this data. Monitoring devices, installed at a study site can gather environmental data like temperature range, natural lighting over time, humidity and air currents. The user data gathered could include tallies such as the number of users, average height of the users and noise levels within the studied environment. Through analysis, all of this data becomes information that is useful to designers establishing a working knowledge of their users. This information may be applied in design according to the specifications of the problem. The designer of a beer bottle might be deciding on whether to use a clear or dark glass for the bottle. Temperature absorption properties of the glass and the recorded range of variance in temperature that a bottle experiences from its inception to the store shelf are types of data that will be useful to the designer in decision making. This is information that the designer would use in making a more intelligent decision of selecting the materials for the manufacturing of the bottle.

Information Hierarchy

For the designer, there is still the need to organize the data into a meaningful hierarchy according to the problem. Based on stated and input criteria, the system would have the ability to organize data according to which information would be most useful to each specific problem. A designer may decide, from answering the analysis questions, that in this particular project human factors information takes a higher priority than information on production materials. Through a program, the designer would specify the hierarchy and the program would order the information according to the highest priority.

The designer may have sub-headings under human factors that have a hierarchical value also. The human factors heading could include studies in typeface legibility, average reading height studies and background/foreground treatment of type, all of which would be ordered according to the designer's specified preference. In educational settings, the instructor may pre-program a lesson which calls for students to order information according to their perceived priority and the program will cross check with the instructor's specified hierarchy. The program could then provide the student with a comparison and explanation of the way each step is ordered and the reason for the ordering. All of this information will be applicable as the designer begins to formalize concepts with the ideation stage.

CHAPTER 6

IDEATION

Ideation searches for all the ways of getting to the major goals and alternatives stated in the analysis and definition stage. Ideas begin to flow toward an expression of design to fulfill the criteria established in the preceding stage. In the traditional process, the designer begins with quick sketches or "thumbnails" to record the ideas of form. The drawings flow in varied directions as offshoots of previous sketches or ideas. Scale models, rearranging of type and pictorial representations are other forms that begin to take shape. The cycles of modification and remodification are ones that will be worked on before the form becomes a whole which satisfies its criteria.

The introduction of computers and computer graphics into the ideation stage allows designers to change their minds and compare alternatives with greater freedom than ever before. Designers question and experiment in larger degrees, because change and feedback (input and output) are more spontaneous. Building physical models and rebuilding them as modifications and changes in concepts occurred was the designer's task. The computer has the ability to store the original data in the memory of the machine, to be called up and modified at any time. The results of the modifications can be instantaneous or slower, but do not compare with time spent rebuilding models. Computers can be handed the burden of the "traditional skills," like model building, drafting, and typography speccing, allowing the designer to focus on the process rather than the skill. The designer concentrates on the process of variation and alternate comparison.

The possible implementation of "artificial intelligence," would provide the computer with a bank of knowledge about a design approach. The bank of knowledge would be like a set of instructions. These instructions could even be personalized to a particular user's process. The instructions would be run to investigate alternatives to solutions for the designer.

> ".....you can give it (the computer) instructions about how to do things, about investigating certain ideas, while you're getting on with other things and then the computer comes back later and says, this is what I'm thinking about, this is what you asked me to do." [31]

A study conducted at Carnegie Mellon University's (CMU) Industrial Design Department estimated that most designers spend thirty-five percent of their design time in the ideation phase. [32] This stage of the design process can be most drastically effected by the use of computers in the industry.

Data Generation

Karen Graham's conclusions in the CMU study, supports what many designers have experienced: that the most time-consuming aspect of using a computer in the ideation stage is the initial data generation. Generation of data refers to the way in which the user inputs drawings or objects onto the screen. The computer data input is not yet as quick or fluid in response as a pencil is to paper for some designers. The Graham Study data indicated that "manual subjects engaged in more interactive problem-solving strategies, and their work products were of much higher quality and more complete". Major complaints were the time and difficulty at inputting data and visualizing three-dimensionality.

Data is the informational structure which is input into the computer. Data can be manipulated by the tools a system and its programmer provide. The tools are software and hardware. Software drives hardware, meaning software is the programming that the hardware needs to function. Software is a set of instructions that interpret functions such as color, input and display of objects, perspective, lighting, and surface attributes. The display of the data can be represented as two- or three-dimensional drawings in vector or raster. Vector is a composition of lines representing the connectivity between points and the representation of polygon structure of the data. Raster refers to the solid shading of the polygonal surfaces. This technique though more complex and expensive is more realistic than others.

Data input requires the positioning of X,Y coordinates that define the horizontal and vertical location of a point in space, and the Z coordinate which provides the third dimension.

Some systems provide the user with pre-defined geometric shapes that can be modified. The ability to sketch in two and three dimensions while providing relatively easy interaction for the designer is necessary. The system must have the ability to respond to the alterations with speed that does not inhibit the designer's ideation flow. Ideation on the computer is met with the difficulty and time expense of inputting data.

Just as a designer learns to use the traditional triangle and t-square, the designer must learn to use a computer system. There is always a learning curve a new user must experience before the tool and designer become effective partners. This practical experience will help to ease the flow of creativity. Unfortunately, there are many systems and software packages on the market now, making it virtually impossible to know each set of procedures for every different system. However, most concepts in making data remain the same. For instance, before constructing a 3-dimensional object, the designer must decide which is the best method to use. It is not simply "drawn" in 3 dimensions as one would with a pencil and paper, but instead, constructed. The user must think out the process software uses to make data before users try to make data. In this sense, it becomes necessary for the designer to understand the basic structure of the software and tool in use. There are many data generation techniques that were developed from engineering applications of computer assisted design (CAD): straight projections, in which a two-dimensional outline is projected to a specified depth; solids of revolution, in which a profile or profiles is input and revolved around a two-dimensional path to create a 3-d structure; space paths interpolations, two- or three-dimensional sets of connected points joined together at specified points and places in space; and a 3-dimensional digitizer in which a pen is used to locate points on a model and record them as a data base in the computer.

Most CAD systems are designed for use by engineers in the automotive and aerospace industries. Most of these systems have been tailored to perform engineering tasks. These tasks include system queries for specific engineering details during the conceptual design process, which tend to disrupt the creative flow of the industrial designer. [33] The designer needs to have a specifically-designed package that borrows the relevant tools of these CAD systems combined with the specialized software for the design process of the designer.

> "The system and especially its mathematical basis should be usable by people such as designers, stylists, production engineers, machine-tool operators. They should not need a knowledge of mathematics beyond that typical of their profession, which is mainly geometric. The system should rely on instinct rather than pure science." [34]

A more systematic and visionary track must be established since the sequence of decisions in the problem-solving affect in what way the solution is "constructed" in the computer.

Data generation techniques are being developed with the implementation of scanners and digitizers that make data generation a less time-consuming activity. Graphic design has witnessed the implementation of scanners that can take the video input of an image and allow the user to paint on it, cut and paste with it and change its size and orientation. Some systems provide a data base of point, line forms of typefaces which can also be manipulated in much the same manner. All of the images can be saved and recalled for further manipulation or output. The storing of this data for further reference or application to other problems provides users with a base for a data library.

Tools of the Designer

In this stage the designer needs the ability to transform, translate, and modify in perspective, orthographic and isometric views. Systems can provide these views and perspectives as specified by the user. Once the data has been input, the opportunities to modify, replicate and scale with ease gives the designer more options and exploration without substantial increase in design time. The increase in exploration will hopefully lead to a more efficiently-executed solution. Many tools already developed for other applications can be easily adapted to the designer's needs.

A designer's needs include options that may be unique to this particular field but necessary in order to provide the designer with proper tools. In the world of three-dimensional graphics spatial cues such as perspective, foreshortening and convergence properties, and depth queueing are an integral part of a design system. Algorithms that determine hidden lines in a structure also become necessary visual cues that must be included in a graphics system. All of these properties can be invisible "givens" for the user, yet the user should have the ability to exercise control over all of the properties.

User interaction with a system comes from the ability to distort, translate and warp points in real time. This means that the designer can interact directly with a drawing on the screen by pulling points or stretching select parts of an object. Visualizing with these tools, and eliminating the need to physically redraw ideas or rebuild models, frees the designer to concentrate on ideation. Creativity becomes less inhibited and more extensive as the computer offers the designer the ability to create without restrictions. The computer provides design flexibility and encourages exploration.

Simulation/Previsualization

Simulation in two and three dimensions gives the computer user an advantage over the traditional methods of previsualization at this early stage of the process. The ability to see products, formulates and necessitates evaluation integrated with ideation. The traditional design process begins to merge with the technology as a tool.

Solid modeling is a process used to simulate surfaces, materials and colors in three dimensions. A raster graphics system can produce mathematically-exact renderings of a specified object. The object, having the proposed characteristics of its design, can be rendered to simulate materials such as metal, plastic and glass. The product can be tested for wear, stress and temperature resistance, according to the known or researched properties of a particular material. Programs can gather results of tests and analyze material based on pre-defined rules specified by the user. The package designer of the beer bottle is interested in volume, shape and surface properties of the product. The computer can be programmed to create variations on the bottle by progressively varying the height and width while keeping the volume constant. Tests are conducted by entering temperature absorption properties of the glass and simulating the variance in temperature a bottle might experience from its inception to the store shelf. All of this information was gathered in the analysis stage. The designer, knowing the beer's properties, could determine whether the dark glass will serve to shut out some of the heat created by light and how this heat might effect the product. Shown both graphically and numerically, these answers serve as a basis for intelligent decision making in the implementation stage.

A fundamental tool of the graphic designer is type. Digital typography includes the design and creation of type and typesetting. Just like a traditional typesetter, the computer considers leading, justification, letter spacing and kerning. It also offers data storage, portability and anti-aliasing. Each letter or symbol is stored as an outline of points or as a bitmap. Typography, as a 2-dimensional design element, can be designed, arranged and re-arranged to simulate product graphics. Computer technology gives the user the ability to manipulate, distort and interpolate between typefaces, unlike traditional typesetting. The tools offer the user the ability to create mock-ups of printed materials, to add color, size, texture, lighting and other effects to simulate the environment in which the product graphic will exist.

Despite overwhelming acceptance of technologically-advanced typographical systems, many designers still prefer hot metal or other techniques to phototypography. They feel the new technology does not capture the "sculpted quality" or gracefulness of the metal character to paper. Yet for those whose jobs require mass amounts of typography on short deadlines, like daily newspapers and weekly magazines, the technology has answered and solved many deadline problems. For smaller graphic design firms speccing type and having it printed in the traditional ways retains the aesthetic qualities to the type. [35]

Industrial designers' requirements for three-dimensional design capabilities can sometime ba sufficed with the tools of engineers. CAD systems can play that role. But industrial designers encompass graphic designers also. Systems must produce renderings of product concepts that look at real as photographs. Systems specifically for graphic designers often provide computer primitives such as the arc, polygon, rectangle, circle, dot and the line for manipulation. Shades and patterns are also provided so the user may "paint" with these on the screen. Conventional computer painting systems allow the user to paint lines and shapes, fill shapes with color and patterns and use a variety of brush nibs. Pixels, which are a quantum unit of an image, are assigned a color as the "brush" passes over that area of the screen or tablet. This technique has been useful in color correction and retouching of photographs scanned in on the system. The paint brush itself has a look that is governed by the system.

Steve Strassmann, of Massacussetts Institute of Technology, recently presented his research in a two-dimensional paint system. The brush stroke that he concentrates on is the water color techniques of traditional Japanese painters, called sumi-e. This technique emphasizes the quality of the painter's stroke and uses shades of gray. The objects of the system are the brush, the stroke, the dip and the paper. The brush is an object composed of bristles. Each bristle has its own ink supply and position relative to the brush handle. The stroke is a two-dimensional path of points that measures position and pressure of the brush to the paper. The dip classifies the brush, one brush can achieve a wide variety of strokes and effects just by adjusting the dip function. The paper is a texture map laid over the composition to simulate paper's texture. Mr. Strassmann acknowledges the existing systems but qualifies his advances by the user's ability to specify a more realistic model for painting and painting surfaces by modeling the physical properties of the materials. [36]

Multiple Direction

The traditional ideation stage of design has always been a choice of long and deep ideation vs. short and shallow ideation. The choice is usually based on time and money. Multiple direction in the ideation stage allows the designer to explore all seemingly valid approaches to a problem. These approaches may be divergent form ideas or subtle form changes. Whichever, all of these are changes that take time to create and formalize. The time constraints in the completion of a project dictate the timeline for all stages of the process for both students and professionals. Deep, extensive ideation challenges the designer to delve into varied, deep and complete solution possibilities. The timeline of completion would be extended to encompass the work involved and the monetary value of the project would increase. Performing only the amount of ideation that time and money dictate can result in the loss of exploration into all solutions. There will always be a time constraint on the design process, but it is most important for students and professionals to attempt to exhaust all valid approaches. With the addition of the computer to the traditional design process, the proportion of creative time to execution time changes. The computer becomes an assistant in the exploration of ideas. With the use of a computer, the combination of a shorter and deeper ideation phase exists.

Often design choices are random, personal choices by the designer. Computers can mimic these ways of choosing. Designers can use computers to generate a series of random events which alter graphic output in unforeseen ways. Randomness within a program is controllable. The designer can control which aspects will be determined by random events.

Controlling the range with the random action is also possible. Computers can make selections based on some criteria and can select while developing, and develop selected options. For example, a designer may enter several different elements into the computer's memory and allow the computer to compose a composition by randomly selecting, placing, layering and sizing the elements. This type of composition provides blind variations of compositions. After viewing the "computer creations," the designer may determine that one of the elements should be the foreground image with the others in the background. Other decisions such as composition format, selective color ranges and size limits can also be input. With selective retention, the computer performs the task of constructing more compositions. This process can be used in a very selective format or as a very loose yet controlled form of experimentation. Computers, however, are only "simulating" the creative process. Like traditional ideation, the computer can make stochastic choices by beginning with random occurrences, then continuing with the selection of useful occurrences through a testing mechanism. A designer starts with lots of random ideas then narrows down according to criteria. [37] Architects have used such programs in interior space applications. The user has a certain set of furniture and specified room space. The computer randomly makes different arrangements.

Not aesthetic arrangements, but solutions that eluded the user.

Having used the traditional design process, the designer finds that the traditional way of dealing with complexity is to break it down into single parts. This single, tentative solution allows the designer to focus and evaluate the relationship of the parts to the whole. The use of the computer as a helpful apprentice allows the designer to deal with more complex problems in a more orderly and visual fashion. The traditional ideation stage becomes a new stage in which the proportion of creative time can become a shortened yet more varied and highly explorative stage.

Repetition

In the educational setting, the use of computers to instruct takes advantage of the machine's ability to repeat a task over and over again without losing the effectiveness and consistency with which it began. A program designed to instruct a student in the theory of contrast is able to repeat the information and visuals. The program is also there to teach when a teacher is not available. Programs also allow each student to work at a personally satisfying rate of speed. One student may comprehend a lesson and advance to the next while another student feels the need to concentrate longer on the lesson before advancing.

Brown University has initiated a computer-based experimental classroom. Students sit at their own workstations which have interactive capabilities. Animated demonstrations of what instructors are doing on their workstations are visible on the students' screens. Monitored instruction allows the instructor to observe students as they perform. Interactive graphics use dynamic motion to communicate abstract concepts or generalize and explore problems. The computer- based classrooms have been applied to several subjects, including color theory which eliminates the manual and time-consuming task of painting the colors and allows the student to concentrate on and experiment deeper into the theory of the lesson.

Ray Nichols of The University of Delaware has developed a program which consists of lessons in art fundamentals. Nichols' programs encourage experimentation by users since visual presentations are not hindered by their level of basic technical skills. The computer is used to perform the basic drawing skills, leaving the user free to concentrate on the visual solution. This also encourages the formation of more solutions, since it now becomes easier to change and manipulate elements rather than starting the drawing process over.

The loss of "drawing skills" due to the influx of technology is often a major concern to designers and educators, some of whom feel the ability to draw is the most basic training necessary for a "good designer." Charles Bigelow stated at the 1983 Broadcast Designer's Conference:

> "Whether or not we see the loss of hand skills...is irrelevant. It took great skill to make cuneiform tablets. This was the dominant writing system for almost 3,000 years. And yet nobody makes cuneiform today. Art directors and designers today do not develop the same scribal skills that were in use in the Middle Ages. We don't have the controlled hand to produce finely detailed texts for the page of a book. Instead, we spec type. We allow Claude Garamond or Matthew Carter or Hermann Zapf to put a tremendous amount of labor -- more labor than we could ever amass in out lives -- into the design of typefaces. Part of the skill of being a designer is being able to choose creatively. The same is true of computer-format programs... a programmer and a designer can work together to produce type designs for computers. As the designer using type on a computer, you are calling forth a tremendous amount of accumulated experience and knowledge. Your job is to choose wisely." [38]

CHAPTER 7

SELECTION

"Choosing wisely" is the essence of selection. As cultures become more and more complex, solutions become more complex structures. Many goals and criteria make up the needs of a design problem. In the traditional sense, selection is the step at which a designer must stop ideation and select one of the proposed solutions by determining which best solves the problem. Up to this stage, the designer may have spent as much as fifty percent of the total design time in the research and ideation stages. Essentially, the selection is based on the results of the definition, analysis and ideation stages.

In the traditional process, designers often practice pre-selection, which involves various selections of solutions for parts of the problem. Since the design process is structured to break complex problems into manageable components, the designer may work to solve each component and adapt this direction in solving the other components. In most processes, designers begin to adapt or discard components throughout the process. From those attributes adapted, the designer will continue to elaborate on the solution. Pre-selection changes the focus from one final, formal selection and allows for variation and a wider variety of choice testing.

Computer technology, introduced intc the traditional process, allows pre-selection and selection to occur more often throughout the process. Computers assist pre-selection and selection by computing knowns about the solution and comparing these with standards established through the analysis stage. An algorithm may be used by the computer to select, based on numerical standards such as volume, weight or format. An algorithm, with the help of artificial intelligence, may become part of an "expert system" in which the algorithm serves to gather data which will serve as an information bank on which to base selection. This information could be the basis on which a particular designer chooses and evaluates and this could be applied to the choice at hand, by the computer.

As standards and criteria are applied to the solutions, these evaluations point the designer and the "smart apprentice" toward the final selection. These choices will continue to be refined and selected for the final form.

CHAPTER 8

IMPLEMENTATION

In the traditional process, the implementation stage means that the designer has selected the "best solution," and will implement it as a final form. Implementation means giving physical form to selected "best solutions." The designer in the traditional design process, usually makes detailed technical drawings or layouts from which to build a mock-up of the solution for visual reference. A physical form for evaluation of the solution is usually built at this stage. Implementation involves model building, mock-ups, proofs and scale drawings for production purposes.

The implemented product is one that will be judged by superiors, teachers and clients and peers, as to its fulfillment of the needs of the user. Criteria established in the initial stages of the process will be used to evaluate this implementation of a concept. At this stage, the designer must be very confident as to the outcome of the final product even though it has never been seen as a finished piece.

Ideally, the design process is one that would allow for more than one implementation and evaluation of solution. In the traditional process, re-evaluations may come too late in the design timeline. The implementation stage experiences procedural changes with the introduction of computers. The time efficiency afforded through the use of the computer allows for the designer to interact and simultaneously visualize concepts or modifications to a concept. Implementation does not come as late in the process and occurs more often.

Prior to 1970, all of Procter and Gamble's (P&G) package design work was done through sketching, ren..ering model and engineering drawings and clay and hard shell models. Roland E. Johnson, in conjunction with .e University of Cincinnati Computer Center, became involved in a "parallel bottle design project" for P&G in which he used his traditional package design practices and his interest in computer graphics.

His first step was to input 3-dimensional data for a bottle. Using two orthographic views, he approximated the form. With specially written algorithms from the University of Cincinnati, he developed plottable outlines of the x and y coordinates and used curving programs to smooth the outlines. From these he established front, top, side and perspective views of the principle outlines of the bottle. Cross sections represented the volume and surface, thus the computer model could represent the bottle's linear area and volume measurements. The surface area could be used to determine a material's weight, using wall thickness and density. The bottle's internal capacity could be calculated by subtracting the surface volume from the exterior volume.

The ability to generate these analytical properties represented a diversion from traditional methods.

> "Conventional design procedures depended on the designer's experience to target the bottle to the correct size. The first clay model was a rough guess, and may have been as much as 50 percent off the targeted volume. The model was measured by dunking it into a tank of water and measuring the water's rise." [39]

Although the first computer bottle was not exact in volume, the major improvement was that the dimensions could be easily manipulated. The updated dimensions could be entered and viewed as quickly as ten minutes. Manual methods took up to one month for drawing or redrawing a fully-detailed mechanical from which the new clay bottle would be built. This time savings reduced delivery time for a design. In addition, the repetitive manual manipulation required in the traditional bottle development was taken over by the machine. P&G adopted the system and after modifications to programming, equipment technology and user friendliness, developed a resource that reflects its design philosophies and techniques.

Most of this development took place in the mid-70's and, with current advances, P&G sends computer models directly to milling devices to maintain continuity in design. They have also introduced a vector display device which allows for the designer to add, delete or modify features and the screen is updated to show the change.

> "The computer has provided us with a focal point for design activity. It gives us an infinite number of views that we can represent and analyze with a minimum effort. Changes are easy, and change is the name of the game. We can put out variations and alterations and test them. In short our computer model allows all the designers using it new freedom for design exploration. Contrary to the fears of our early skeptics, design aesthetics have not been compromised. In fact, they have been enhanced" [40]

Three-Dimensional Design

Three-dimensional solutions encompass many more types of simulation. The user may view a product or space from many angles, under different lighting conditions and from different eyepoints. With these options, a designer can simulate an atmosphere in which the graphics are to be applied, or may be subject to, and then evaluate the effects. The package designer may construct the container, place it at the different shelf heights that it will be in the store and check the legibility of the type. The interior space designer may "design" the lobby of an office building by constructing the data on the computer, and then simulate the designed traffic patterns of the users within that environment. This animation allows the user to travel around an area. This effect is useful in testing human factors in relation to the design solution.

Debugging through previsualization helps human factor problems come to light if the solution can be simulated and "used" for the functions for which it is designed. Such previsualization allows both designer and client to anticipate problems that may arise with the actual product. In this early stage, alterations can be made before production begins.

The change most desired when using computers in industrial design is the ability to work a high speeds which encourages experimentation in the work. With this capability, the designer would not have to settle for a solution based on time and have to compromise the aesthetic quality levels that could have been achieved.

In traditional model building and manufacturing, specifications for production were drawn by hand and then transferred to the machine. The transfer of information from drawings to models to final product can result in a loss of accuracy in the translations. With the implementation of computers into the process, the information is entered in digital form, from its first conception where it remains as an accurate format that can be stored in memory, or on disk, and recalled for re-use or modification. [41] This process is also enhanced by the connection of the databases to the production machinery, as milling machines can be guided by the computer to replicate what was designed on the machine. With the use of computer graphic capabilities, simulation of a solution comes as close to reality as visually possible.

Two-Dimensional Design

Many firms using computers in the industrial design field are applying them to word processing and typography as links. The New York Times uses an IBM Standard Graphics System to prepare charts and graphs for their newspaper. They estimate the computer saves sixty percent of the drawing time due to the manipulation capabilities. Similarly, the computer would reduce the time spent in creating a final layout and increase the amount of time left to do re-evaluations and re-adjustments to the final.

Images from two-dimensional solutions can either be scanned in or created with the computer. The ease with which one can change scale, color, and the arrangement of elements instantaneously allows the designer to test the solution decision and make the necessary changes. The real-time saving factor is that the designer does not have to "redraw" any of the elements as in the traditional process. The designer now uses the same data from preliminaries through implementation and calculates at a high resolution for printing or presentation. The final rendering, or layout, can carry color, size, typography, and printing specifications. This completed artwork, still in digital form, can be transmitted via wire and satellite to printing plants equipped to accept the data.

Use of computers as design tools for print graphics is still limited. They have been considered successful in word processing and typesetting, formatting and pagination, charts, graphs and mapping. Computer pixelation (jaggies) is an element which transfers to print materials. High-resolution results are often too expensive to compete with conventional methods. Most affordable palettes are too crude to use. Typesetting with the computer has been a successful implementation of the computer in the field of design.

CHAPTER 9

EVALUATION

Evaluation determines meaning, progress or value as it has been derived from the entire process. Evaluation is a form of research that serves as a feedback mechanism to facts established through analysis. Evaluation is a loop that occurs throughout every step in the process. Similar to the research phase, the evaluation stage organizes the data into a meaningful hierarchy of knowledge to be used as indicators in evaluation of design solutions. Good methodology uses a resource which will do the job less expensively and more efficiently. The computer can effect the process with both of these properties as the cost of hardware and software continues to drop and the specialization of design software grows. Computers would help to provide evaluation during the whole process, not just upon completion of the process.

Computers in design, for the most part, have been applied to synthesizing imagery. But the computer, by its structure, possesses the ability to rapidly gather and analyze information. Though machines alone do not make quality design decisions, those using them can more easily understand what should be designed to fit the new context of the information environment.

During this research phase, criteria formulation can dictate not only what research materials are appropriate but in which direction the designer should focus the solution. Thomas Linehan has suggested the possibilities of computer-assisted analysis of visual preferences. This theory uses the computer to collect and compare data based on numerical descriptions. [42] From this theory might branch the possibility of establishing criteria relative to the project and having it used in the feedback process that the designer follows. Judgements could be made throughout the design process that would check back with the list of criteria that determines if the path to the solution is going to fulfill the needs of the problem.

Artificial intelligence may one day provide users with the ability to have the computer program the aspects of the project such as needs, criteria, limits, and even aesthetic judgements based on design fundamentals. This program would allow the computer to determine if any of these aspects are being violated or disregarded as the process occurs. The designer will make decisions to disregard the evaluation the computer provides, to change the computer's criteria or to accept the judgement and proceed appropriately. The criteria that was established at the start of the process can be used throughout this process to check back or receive feedback from the computer. The final decision can be made based on the feedback the computer provides or on the amount of criticism the designer chooses to accept from the computer. With the computer, the re-evaluation phase becomes easy to apply in every stage as the criteria base for the project may be used to generate responses to design decisions.

This ability to have the computer handle the complexity of visual evaluation is far from being perfected. The most exciting aspect of man designing without machine interface, is evaluation by interaction between designers. This exchange of ideas will probably never be simulated on the computer and it is one that designers should continue to use to the fullest extent.

CHAPTER 10

SUMMARY

Before they commit themselves to any investment, many firms and independents have adapted wait-and-see positions in order to observe the effect computers will have on the design field.

A recent nationwide survey, conducted for the National Art Materials Trade Association (NAMTA) by Edward W. Haggarty and Associates of Lake Forest, Illinois, polled commercial art industry personnel on their thoughts and feelings about computer graphics and its applications to their futures. Twenty-five percent of the 1,200 polled, responded. The respondents included commercial artists, art directors, illustrators, and other job titles in the commercial art field. When asked to rank ten issues according to their importance, the top three choices were:

"Finding new products to shorten or eliminate production steps," chosen by sixty-four percent;

Spending more time on "pure creative" vs. "mechanically putting together," chosen by sixty-three percent; and,

"Satisfying clients' expectations for 'improved quality' look and tonality," chosen by forty-four percent.

Yet in this same survey, the top choices in the "unimportant" column were:

"Finding better computer graphics hardware," ranked unimportant by twenty-nine percent.

"Locating better computer graphics software programs," ranked lowest in importance at 27 percent. [43]

Results of this survey could be interpreted in many different ways. Overall, the results seem to contradict each other and it may be a result of a lack of applicable software that has made it clear to the designer how the computer can assist and apply to the design process. There is no vision that the choices ranked as unimportant could solve the top choices in the important category. For example, the polled designers say they would like to spend more time in the "pure creative" stage vs. the "mechanical" stage. Yet, if better computer graphics hardware and software specifically for use in design was available, it could automate mechanical tasks and provide the designer with more productive "creative" time. Computers can offer a more diverse, more efficiently executed and more elaborate design. [44]

To provide the necessary tools, foundation and software, the manufacturers in these fields must listen to and understand the needs of designers. Software must speak directly to the problems designers face, not push the designer to expound creative energy trying to communicate with a machine. Designers need to interact with programmers so their needs will be addressed. Only with the help of industrial designers will programmers be able to simulate a design environment in a system that will be useful to the design industry.

Designers must realize that every problem will have special needs and, in turn, apply their inventiveness when using software packages. Therefore, it is necessary for the user to become familiar with the basic logic of a computer system. Computer literacy is essential for those trained in design. Perry Jeffe, director of the Pratt Center for Computer Graphics in Design, said 'computer graphics is changing design from a static to an evolving profession.' Perry Zompa, director of Product & Package Design at Avon Products forecasts:

> "As computer technology matures, we can all look forward to ...systems becoming more versatile...and their role in the design process will become even greater." [45]

The theory behind the traditional design process was to offer designers a structured way to break down a complex problem into smaller pieces in order to fully understand the essence of the problem. The computer, as a resource, becomes the "smart apprentice" in the process by helping the designer to draw clearer conclusions, create more realistic concepts and in turn facilitate the needs of the user. The traditional design process, indeed changes with the influx of computer technology to the field of design. With the complexity of information flow and communications of modern day, the computer can only help to make the essence more clear.

The process now contains more overlapping and merging of steps. Designers concepts are enhanced by the ability to explore in more deep and meaningful ways the solutions to a design problem.

> "A design process supported by a computer graphics system is qualitatively different from one carried out with a pencil and paper. It has an altered pace and sequence, brings information to bear on decisions in new patterns, renders the visual effects of geometric, color and lighting decisions with unprecedented speed and precision, and so allows the design ideas and effects to be explored in ways that were unimaginable before now. Computer graphics promises designers an aesthetic adventure, one that is just beginning." [46]

LIST OF REFERENCES

[1] King, Robin G., "A Graduate Level Program in Computer Graphics for the Visual Arts, Computers in Art and Design", Research and Education Conference, San Jose State University," (January 1984).

[2] Linehan, Thomas E., "Digital Image Synthesis: A Critical Need for Aesthetic Theory," Monographs in Education XIV, Art Education: Reflections/Directions, University of Manitoba, (Fall 1985).

[3] Ibid.

[4] Schaff, Robert W., "Graphics and Design," Computer Graphics World, (February 1987), (p.116)

[5] Marcus, Aaron, "Design Workstations Give Artists Powerful Tool," Computer Graphics Today, (March/April 1985), (p.12).

[6] Scott, Joan E., Computergraphia New Visions of Form, Fantasy and Function, Gulf Publishing Company, Texas (1984).

[7] Newman, William M and Robert F. Sproull, Principles of Interactive Computer Graphics, McGraw-Hill Inc, New York, (1979).

[8] Franke, Herbert W., Computer Graphics Computer Art, Phaidon Press Limited, New York, (1971) (p.72).

[9] Dietrich, Frank, "Visual Intelligence: The First Decade of Computer Art (1965-1975)". Computer Graphics and Applications 5,(7),(July, 1985)

[10] "Computer Graphics:Designing in the Third Dimension," Design Graphics World, (June 1983),(p.12-13).

[11] "Victorian Design, The Industrial Revolution Precipitates," A History of Design From the Victorian Era to the Present, Supplement to The Ohio State University Industrial Design 253.03. (1981).

[12] Whitney, Patrick, "Information, Computers and Design." Computer Supported Design, Exhibition Brochure ACM Siggraph 84, Minnesota, (1984),(p.7).

[13] Ibid.

[14] Ibid.

[15] Koberg, Dan and Jim Bagnall, "The Universal Traveler, A companion for those on problem-solving journeys and a soft-systems guidebook to the Process of Design," Supplement to The Ohio State University, Industrial Design History 253.03, (1981), (p.16-19).

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Kochan, Steven G., Programming in C., Hayden Book Company, New Jersey, (1983), (p.4).

[22] Gear, C.W., Introduction to Computer Science, Science Research Associates, Inc., Chicago, (1973), (p.129).

[23] Linehan, Thomas E., "Digital Image Synthesis: A Critical Need for Aesthetic Theory," Monographs in Education XIV, Art Education: Reflections/Directions, University of Manitoba, (Fall 1985).

[24] Ibid.

[25] Scott, Joan E., Computergraphia New Visions of Form, Fantasy and Function, Gulf Publishing Company, Texas (1984).

[26] Linehan, Thomas E., "Beating Sword Engines into Plowshare Engines," The Association for Computers in Art and Design Education Conference, Presidential Address, (July 20, 1985).

[27] Born, Robert, Designing for Television:The New Tools, The Broadcast Designers Association, (1983).

[28] Kemper, Alfred, "Smart Software in the A-E-C Industry," Journal of the Association for Computers in Design, Volume III, No. 2, (May-July 1986).

[29] Ibid.

[30] White, Edward T., <u>Introduction to Architectural Programming</u>, Architectural Media Ltd., Tuscon, Arizona, (1972) (p.5).

[31] Triplett, John, Interview with John Landowne, <u>Computer Graphics, What it Means For Graphic Design Education</u>, Ausgraph (1985), (p.10).

[32] Graham, Karen, "Is CAD Ready for Designers? An Evaluative Study," <u>Innovation, Industrial Design Society of America Newsletter</u>, Vol. 2, No. 3, Industrial Design Society of America, VA, (1983), (p.27-30).

[33] Schaff, Robert W., "Graphics and Design," <u>Computer Graphics World</u>, (February 1987), (p.116)

[34] Bezier, Pierre E., "A Personal View of Progress in Computer Aided Design," <u>Computer Graphics</u>, (July 1986), (p.154-9).

[35] Heller, Steven, "Technophi_ia/Technophobia," <u>The American Institute of Graphic Arts, Journal of Graphic Design</u>, Volume 2, No. 2 , (1984),(p.1-2).

[36] Strassmann, Steve, "Hairy Brushes," <u>Computer Graphics</u>, ACM Siggraph 86 Proceedings, Volume 20, No. 4, (1986), (p.226-227).

[37] Helmick, Richard, "Enhancing Creativity in Art and Des Through Stochastically Generated Computer Graphics," <u>Art Education</u>, Vol. 37 No. 4, (July 1984),(p.36-39).

[38] Davis, Wylie, "The New Technology Threat or Promise?," <u>Designing for Television: The New Tools</u>, Broadcast Designer's Association, Inc.,(1983),(p.11).

[39] Johnson, Roland E., "Packaging Design on CAD, A Look at One Company's Experience," <u>Innovation, Industrial Design Society of America Newsletter</u>, Industrial Design Society of America, VA Vol. 2, No. 3, (1983), (p.24-26).

[40] Ibid.

[41] Bezier, Pierre E., "A Personal View of Progress in Computer Aided Design," <u>Computer Graphics</u>, (July 1986), (p.154-9).

[42] Linehan, Thomas E., "Numerical Taxonomy: A Method of Stimulus Description in Visual Preference Research"

[43] "Everybody's Not Doing It," Art Product News, (September 1986).

[44] Kerlow Isaac V. and Judson Rosebush, Computer Graphics for Artists and Artists, Van Nostrand Reinhold Company Inc., (1986).

[45] "Are Computers the Key to the Future of Design?," Art Product News, (September 1986).

[46] Johnson, Roland E., "Packaging Design on CAD, A Look at One Company's Experience," Innovation, Industrial Design Society of America Newsletter, Industrial Design Society of America, VA Vol. 2, No. 3, (1983), (p.24-26).

BIBLIOGRAPHY

Academic Computing Newsletter, Boston University, Academic Computing Center User Services Department, Boston, MA, (Fall 1986).

The Art of Design Management, Tiffany & Company, New York, NY, (1975).

Berryman, Gregg, Notes on Graphic Design and Visual Communication, William Kaufmann, Inc., (1979).

Bersen, Jens, DESIGN: the problem comes first, Danish Design Council, Copenhagen, Denmark, (1983).

Bertin, Jacques, Semiology of Graphics, The University of Wisconsin Press, Madison, WI, (1983).

Bezier, Pierre E., "A Personal View of Progress in Computer Aided Design," Computer Graphics, (July 1986).

Born, Robert, Designing for Television: The New Tools, The Broadcast Designers Association, (1983).

Cherry, Colin, On Human Communication, Massachusetts Institute of Technology Press, Cambridge, MA, (1977).

"Computer Graphics: Designing in the Third Dimension," Design Graphics World, (pp.12-13), (June 1983).

Dietrich, Frank, "Visual Intelligence: The First Decade of Computer Art (1965-1975)," Computer Graphics and Applications, (July 1985).

Ferderber, Skip, "The Commercial Production Designer," Millimeter, (p.52-4), (February 1983).

Franke, Herbert W., Computer Graphics Computer Art, Phaidon Press Limited, New York, NY, (1971).

Goss, Tom and Carol Stevens, "How Designers Use Computers," Print, (pp.57-69), (May/June 1983).

Graham, Karen, "Is CAD Ready for Designers? An Evaluative Study," Innovation, Industrial Design Society of America Newsletter, Industrial Design Society of America, Virginia, (1983).

Heller, Steven, "Technophilia/Technophobia," The American Institute of Graphic Arts, Journal of Graphic Design, (p.1-2), (1984).

Helmick, Richard, "Enhancing Creativity in Art and Design Through Stochastically Generated Computer Graphics," Art Education, (p.36-39), (July 1984).

Ho, Hsuen-Chung, "Interactive Computer Graphics As A Supplementary Tool In Learning Perspective System," unpublished Masters Thesis, The Ohio State University, (August, 1979).

Innovation, Industrial Design Society of America Newsletter, Industrial Design Society of America, McLean, VA, (1984).

Johnson, Roland E., "Packaging Design on CAD, A Look at One Company's Experience," Innovation, Industrial Design Society of America Newsletter, Industrial Design Society of America, Virginia, (1983).

Jones, Beverly J., "Computers in the Arts and Humanities," The Computing Teacher, (March 1981).

Jones, Christopher J., Design Methods, seeds of human futures, Wiley-Interscience, New York, NY.

Kemper, Alfred, "Smart Software in the A-E-C Industry," Journal of the Association for Computers in Design, (May-July 1986).

Kerlow Isaac V. and Judson Rosebush, Computer Graphics for Artists and Artists, Van Nostrand Reinhold Company Inc., (1986).

King, Robin G., A Graduate Level Program in Computer Graphics for the Visual Arts, Computers in Art and Design," Research and Education Conference, San Jose State University, (January 1984).

Koberg, Dan and Jim Bagnall, The Universal Traveler, A companion for those on problem-solving journeys and a soft-systems guidebook to the Process of Design," Supplement to The Ohio State University, Industrial Design History 253.03, (1981).

Linehan, Thomas E., "Beating Sword Engines into Plowshare Engines," Presidential Address, St. Paul, Minnesota, (July 1985).

Linehan, Thomas E., Computing And The Design Design, Wellington, New Zealand, (1986).

Linehan, Thomas E., "Digital Image Synthesis: A Critical Need for Aesthetic Theory," Monographs in Education XIV, Art Education: Reflections/Directions, University of Manitoba, (Fall 1985).

Linehan, Thomas E., "Numerical Taxonomy: A Method of Stimulus Description in Visual Preference Research."

Marcus, Aaron, "Design Workstations Give Artists Powerful Tool," Computer Graphics Today, (March/April 1985).

National Academy of Sciences, Scientific Futures, Selected Areas of Opportunity, National Academy Press, Washington, DC., (1986).

Newman, William M and Robert F. Sproull, Principles of Interactive Computer Graphics, McGraw-Hill Inc, New York, NY, (1979).

Pilditch, James, Talk About Design, Redwood Burn Limited, Great Britain, (1976).

Rivlin, Robert, The Algorithmic Image, Microsoft Press, Redmond, Washington, (1986).

Schaff, Robert W., "Graphics and Design," Computer Graphics World, (February 1987).

Schmitt, Klaus F., "Typography vs. Technology," PRINT Magazine, (January/February 1984).

Scott, Joan, Computergraphia, Gulf Publishing, Houston, TX, (1984).

Scott, Robert G., Design Fundamentals, McGraw-Hill Book Company, (1951).

Squires, William, "Creative Computers: Premises and Promises," Art Education, (May 1983).

Steiner, Wendy, Image and Code, University of Michigan, (1981).

Strassmann, Steve, "Hairy Brushes," Computer Graphics, ACM Siggraph 86 Proceedings, Volume 20, No. 4, (1986).

Triplett, John, Interview with John Landowne, Computer Graphics, What it Means For Graphic Design Education, Ausgraph, Australia, (1985).

"Victorian Design, The Industrial Revolution Precipitates," A History of Design From the Victorian Era to the Present, Supplement to The Ohio State University Industrial Design 253.03., (1981).

White, Edward T., Introduction to Architectural Programming, Architectural Media, Tuscon, Arizona, (1972).

Whitney, Patrick, "Information, Computers and Design," Computer Supported Design, Exhibition Brochure ACM Siggraph 84, Minnesota, (1984).

Witted, Turner, "Some Recent Advances in Computer Graphics Science," Computer Graphics, American Association for the Advancement of Science, Computers and Electronics, (p.751-754), February 1982.

Zimmer, Fred and Anne, Visual literacy in communication: designing for development, Educational Publications Ltd., Tehran, (1978).