GRID - Graphic Intelligence in Design:  
An Expert Layout System

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Submitted to the Department of Architecture on January 16, 1987  
in partial fulfillment of the requirements for the Degree of  
MASTER OF SCIENCE  
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ABSTRACT

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ABSTRACT
Expert systems provide tools to make intelligent decisions using a 'knowledge base' that has in it the methodology related to the resolution of a particular problem, while design and layout are concerned with aesthetic and qualitative issues. GRID is a graphical system, which has attempted to use these decision making techniques to make intelligent tools for the designer, for assistance in design of layouts. The tools implemented use grids, as an organizational structure, to apply design principles.

Thesis Supervisor: Muriel Cooper
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To Anish

For innocent assurance that made it all worthwhile
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INTRODUCTION

Design activity often involves defining the problem, identifying the constraints within the problem domain and visualizing the solution in its final environment; evaluating the results each time until the desired solution is reached. Various methods, some of which are personal and others are universal, are adopted by designers, to aid in the process of design.

The art director is usually called upon to integrate visual and textual material so the publication appears to be a unified document inspite of representing various points of view from different authors. The art director, may receive all the visual material from the author, or an idea for the appropriate visual. In any event, if the publication involves many authors, the art director/editor decides the placing of the material in physical reference to each other. The relationship of the visual material to the text and the relationship of one article to the other follows the methodology of the designer. Every art director has a certain set of rules that he or she follows to lay out the publication. These rules may have their origin in the corporate image that the publication should represent,
or certain rules that have been set up to handle big jobs that need to be
done relatively faster, like newspapers and weekly magazines or may be
rules that a designer has defined to incorporate her own personal
methodology.

These rules may exist in the form of a written style guide or in the mind
of the designer if it is an individual who is working on the publication.
Normally if more than two people are working in a team, then they need to
specify the rules that they are going to use, very clearly, so each person
has a complete understanding of the purpose and the goals of their work.
The more the number of people that are involved, the more specific the
rules and guidelines have to be.

Once these guidelines have been established by the designer, they are
conveyed to the team in a certain way and format. In smaller teams,
these may be a few pages written informally, in a bigger team, or where
the implementors are located at different locations, these guidelines need
to be very specific. Examples of this can be found in large corporations
that are scattered throughout the country and have local publications but
should confirm to the identity requirements of the corporation. In such a
case the designer follows format requirements that are published in the
guidelines for the corporation.

This sample taken from a style guide shows how
corporate identity manuals define rules for
things that can and cannot be done quite clearly.
These lend themselves to becoming rules in a
rule based system.
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The rules in published style guides come in the varying degree of specificity. While in one company the rule may specify the exact location of the company logo, e.g. upper-left hand corner, another corporation may have a few options that the designer can consider to solve the problem at hand.

With this thesis, GRID (GRaphic Intelligence in Design), I have tried to explore the option of using these rules of the style guide to constrain the usage of tools in the desired ways. GRID tries to demonstrate how the style guide can be computerized to provide intelligent tools for the designer.

CONTEXT

Typically an electronic publishing system consists of input devices for image and text, methods for processing, creating and assembling this information and to output it to the desired medium in the proper form. Electronic publishing is replacing the traditional means of production and distribution of information. The process of creating words and images is accomplished through word-processors and computer-aided design systems. These changes have come about to achieve greater efficiency and productivity, savings in time and materials, and the ability to make corrections painlessly. Over the last decade, improvements have been
made to make these systems with a better interface that the users can relate to in their normal working environments and techniques. These tools provide quick and easy interactive visualization methods for planning, through direct manipulation of visual elements on the screen. The tools that are available are those that incorporate the traditional process and give the user a better visualizing environment such that changes can be reviewed in a relatively shorter time.

The current systems need direct intervention by the user in making most high level decisions about formatting -- number of columns, pagination conflicts, composition, etc. Some have default values set up, but cannot deal with special cases given the rules to reach the solution.

GRID incorporates a knowledge base of formatting rules and style information allowing for user intervention, and proposes solutions accordingly.
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DESIGN METHODS

In design, many solutions will satisfy the same constraints; the choice depends on the designer's preferences and is in fact what distinguishes good designers from poor ones. If a layout is poorly designed it will be unattractive and difficult to read. Functionality in graphic design depends on both objective and subjective criteria. A knowledge based design system, to be successful, should allow for making a variety of designs within the constraints provided, to allow the designer to make subjective and qualitative judgement.

In an automated system, rules of a particular style will be built into the system. The designer will use them to implement a design that will conform to this pre-established style. The conventional style guide tells the designer what the rules are in that particular context. In an intelligent and dynamic style guide, the designer will define the context and the system will apply relevant rules of the style to solve that particular problem.

Although design is a personal activity that often has original results, it is possible for the designer's role to also include the establishment of specifications, for subsequent designs to follow. The design of a corporate identity, or design of a basic infra-structure by the architect for a few
rules to deal with facades, materials, etc. for a housing project are examples. This kind of rule-based design is used to keep large design projects consistent, even when a large number of people are involved in them. A recent and successful example is the environmental art Sussman/Prejza designed for the 1984 Los Angeles Olympics. In this case, certain design guidelines were set up specifying the color palette, how it will be used, what graphic elements will be used and how certain situations will be handled. This information was then passed on to the designers, who could then design particular instances and keep within the style. This approach to design gave a consistent look to the whole project, inspite of the involvement of many designers and artists.
COMPUTERS IN DESIGN
Computers up until now have provided visualizing tools that give the user an opportunity to interactively manipulate the design and assist in the decision making, by making it easy to make and look at changes in a relatively much shorter time span. This gives the advantage of speed and material to modern designers. The CAD/CAM systems used for three dimensional design assist the designer in modelling the design, and viewing it from any direction in real time. These systems give an advantage to the designer and eliminate the process of complicated model building at least from the preliminary stages. There is research in progress, to allow the computer to maintain a list of interactions so the designer can go back to a solution or trace the reasoning for the solution.

GRID is the system that explores the potential use of the computer as an intelligent assistant, which can produce the initial solutions for a designer to evaluate and refine, given a stylistic choice. It uses an expert system to make its decisions and produce possible candidates in that style, given certain parameters. It is an attempt to make the computer generate solutions for the designer, giving the designer the option to select and modify. The process of design transformed from - starting with nothing - trying out solutions and selecting and rejecting in the process to narrow down to a solution; to starting with many solutions produced by the
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In the Intelligent Design project currently underway in the Visible Language workshop, the concern is to give qualitative help rather than manipulative tools. In the Intelligent Tools, the concern is to give qualitative help rather than manipulative tools. For example, if the designer is making a chart with certain structure, the manipulative tools are not enough, the designer may sit eternally to align certain elements in a certain way and refine the details, this means spending more time and frustration to achieve the desired result. On the other hand, if the system has the rules about how certain elements join others, e.g., how a cylinder connects with a box, and these relationships are constrained then the designer needs to simply indicate the intention by placing a certain element in a certain location, and the system will be able to figure out the exact refinements. This liberates the designer from petty details to concentrate on other serious issues. This is a different approach from the current systems. The current systems provide tools for manipulations, but the Intelligent Tools focus on giving qualitative help. This gives an opportunity to the designer to try out the solutions that he/she may not have tried due to lack of time or due to repetitively working on a similar problem. It is the qualitative issues in design that are more difficult to handle. GRID helps the designer to visualize and compare the solutions for their quality.
but do not affect the process itself. The new intelligent tools can translate the intentions of the designer into visual form. In layout design, optimization is not the criterion, it is for the designer to decide how information is to be presented. There are rules of thumb that the designer uses along with personal preferences. For expert systems to be used in layout design, this information needs to be encoded in the knowledge base in terms of rules. The method for design is defined as picking out elements and combining them in the most attractive and understandable manner.

The role of the designer then becomes to create a type or class of an image rather than the image itself. Any number of images may then be produced using the particular style or class specification. The creativity then lies in specifying the parameters and constraints for the system.

It is easy to understand why a designer might be skeptical of computer-aided design. While the machine facilitates making structured and repeatable patterns, it seems to eliminate the innovation that the designers favor. But areas do exist in the design and production of newspapers, magazines, and books where the designer can find the computer useful, by applying computer technology to absorb dull and repetitive chores.
GRID AS A TOOL
Grid systems are widely applied in modern publication. Working grids are used to maintain the organization of the publication while dealing with individual pages as the material is compiled. Grid systems unify the pages by maintaining horizontal and vertical columns, the use of gutters and by the treatment of void spaces.

Each designer may have a different method to deal with a grid, and to deal with a particular problem. For example if certain text in a grid needs to be emphasized then what kind of treatment should be adopted - whether it should be underlined, bold, colored, or have a colored background, and if so then should the background follow the grid lines in which case it abuts the text; it maybe given a little margin if it overflows in the gutter, or the text may be made a little less wider to solve the problem. This demonstrates that there are many solutions to a problem, when dealing with design, the designers chooses the appropriate solution, but once the designer makes the choice, of the solution, then the same solution is followed throughout the document. This can become the rule for the system. Once the designer has set up rules and parameters for the particular layout then the system knows the rules for achieving a quality, in the example above -- emphasis. The designer then does not need to tell the system each time what needs to be done when emphasis is needed.
he/she can just indicate that the certain piece of text needs to be emphasized. This also affords the designer the freedom of changing his/her mind, in which case he/she only need to change the rule for emphasis and rest is taken care of by the system. This method of working not only liberates the designer from meagre work but also gives him/her the freedom to be creative.

Similarly the rules for proportion of margins can be set up and other rules about the overall density of the page, the relation of solids and voids etc. can be defined. In newspaper design, the rules about each page can be set up that defines the kind of information that goes on each page and the percentage of each category of information. For example if stories were to be rated on a certain scale of importance, then rules of newspaper design can guide which story needs to go on first page and so on. The relationship between area covered on each page by advertisements and news items can be defined and the intelligent system can figure out the information that goes on each page and come up with a layout. It should be kept in mind that the computer is generating ideas that can at any point be overridden by the designer, the computer is helping the designer to start with something and change it to fit his/her needs rather than begin with nothing.
TOOLS NOT SOLUTIONS

Working grids, horizontal and vertical guidelines for margins, columns etc., can be adapted for use in computerized systems, where they can guide the final layout on visual display terminals. They can also be fed to computers to prepare pages in a fully automated preset program. This is the aim of this research, in which an attempt is made to demonstrate how the computer can become a tool that can provide qualitative help rather than just speed and number crunching, by using expert system applied on the grid structures for design of layouts.

Numerous attempts have been made at generating computer graphics randomly or with the use of certain mathematical algorithms, e.g. fractals; but in these approaches, the designer has had little control over the end result. The use of expert systems is an aid to the designer only when the designer has control over the system and can use it as a tool. It is therefore very important to provide a system for the designer that is a tool, rather than a solution to the problem.

The problems in design keep changing, usually no two problems are exactly alike in their requirements and constraints. This suggests that there cannot be a universal solution that can be applied to every problem. It will though, be useful to have an intelligent design tool that has built
into it the methodology to solve the problem and deal with it, as it is presented. This is what an expert system will embody. It will have in it, all the constraints applicable, built into it so that it can find a solution with any combination of given parameters. Simple visual elements joined in different ways give rise to a different style. The methods to join these elements to make a particular style will form the constraints of this new tool for the designer; the designer then needs to specify to the system the visual elements and the required style, the solution will then be produced. The user can always override the system to make any refinements or reject the solution completely, after having generated some ideas from the system.

The decision to use an expert system for the designer is an important one. The designer has to make a conscious choice to select the appropriate tools. At some point designers made a decisions to use the grid system for structural organization. With the new technological era, they now have an opportunity to have an intelligent design assistant. This assistant not only gives the designer the structural system to work with it also gives a method with which to use this structure. Grid system in design provides the basis for the designer, but how the information is laid out on the grid is the designers job. The expert system on the other hand, has the knowledge of how this design structure can be used in a particular
context. The system is capable of dealing with the selected material to lay it out in the desired style, dealing with the particular problems as they are raised.

Technology and advancement have until now produced more tools, and made them available to the designer. In an expert system, the designer will have a direct control of tools, by defining how a certain tool should behave. For example, a tool that is used to change the color of a certain image will have the range of possible colors that can be used in a certain context, e.g. a skin color, and will provide the palette to the designer selectively, this will narrow the search for the designer who will not need to search the whole gamut of colors to find a proper skin tone. Similarly, a cropping tool, given the content of the picture, will know not to cut the head of a person into two. It should be remembered that the designer can at any instance override the rules to achieve the desired effect. Then in the normal usage of these intelligent tools, the designer needs to specify -- crop and size this image to fit this area on the page; the tool will intelligently crop the image and then size it to the given area. The cropping information can be encoded into the system in various ways -- either the designer can establish areas of importance for the picture, or the picture can have with it certain rules of cropping in a different context. An example of this application is found when using certain
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copyrighted works of arts -- certain pieces of art cannot be cropped, some may be cropped only in a certain way and so on. The tool then becomes an intelligent help to the designer to establish the options on hand.

To sum this discussion the tools can be differentiated in the following way: traditional tools are picked and applied by the designer directly while computational tools are picked for a desired effect and applied by the computer, which "knows" what the tool is capable of doing.

SCOPE OF THESIS

The field of design is wide and varied. It would be futile to attempt to encode all of a designer's knowledge in such a short time. Every kind of person, e.g. a designer, a layperson, a production artist, will need a slightly different version of the system. While the designer would like to use the system as an intelligent tool, a novice would like to use it as a surrogate expert. Each implementation requires varying degree of complexity in its knowledge encoding.

To limit the scope of this thesis, I have chosen to design a cover based on a specific grid structure. I chose a cover instead of an inside page because an internal page involves many editorial decisions that are not
trivial to be encoded in a system. GRID has been designed to assist the
designer in laying out this particular kind of cover to demonstrate how
such a system may be used. The rules that are encoded with this system
deal with the visual qualities of the pictures -- e.g. saturation and
intensity, the threshold of which can be changed by the user at will.

This thesis is intended to serve both as an investigation of and as a point
of departure for the use of expert systems in design. In this particular
application I have used only layouts based on grids, but a grid is not
restricted to be regular, and the single image may be replaced by a word
representing a title or it may represent a block of text that is a chapter.
The aim is to lay it out, to achieve the desired visual effect, in a
particular context needed by the user.
BACKGROUND

Man strives to augment his abilities by building tools. From the invention of the club to lengthen his reach and strengthen his blow to the refinement of the electron microscope to sharpen his vision, tools have extended his ability to sense and to manipulate the world about him. Today we stand on the threshold of new technical developments which will augment man's reasoning; the computer and the programming methods being devised for it are the new tools to effect this change. -PETER SZOLOVITS

In the field of design and specially in graphic design, computer based expert systems have not been applied for two reasons: a) the knowledge applicable to graphic design does not usually have absolute or even best solution, there may be many solutions that 'work' and are based upon subjective choice, b) it is believed that design is a personal activity that cannot be taken over by an outside agent. In this thesis I have tried to explore a scenario that makes use of expert systems in design, with the hope that when the system is implemented in its full capacity, it will make a very handy tool that can become a partner to the designer, by understanding and translating the intentions of the designer into physical form.
EXPERT SYSTEMS IN GRAPHIC DESIGN

'Expert Systems' is the applied side of Artificial Intelligence, which provides tools to make intelligent decisions using a 'knowledge base' that has in it the methodology related to the resolution of a particular problem. Grid systems are the modular design techniques used to maintain consistency and organization throughout the design of a repetitive publication. The encoding of design knowledge as applicable to grids in the knowledge base of the expert system is one way of automating part of the design process and creating intelligent tools for designers.

Expert systems have been applied to various fields of engineering, economics, and medicine, and their successful use in these fields has relied heavily on the objective information that is an inherent part of these problems. Since the knowledge in these fields is objective, and decisions are based on relational conditions, i.e. one decision affects the next and so on, makes them appropriate candidates for the use of expert systems. Design, in contrast, uses intuition and subjective information. This implies that any attempt to use expert systems in graphic design will have to maintain a close user interaction by providing intervention by the user at every stage and allowing for further refinements in the solution provided by the system.
WHAT IS AN EXPERT SYSTEM?
Expert systems are among the most exciting new developments in computer science and technology. Emerging as a practical application of research in artificial intelligence, these programs embody knowledge of a particular application area combined with inference mechanisms, which enable the program to use this knowledge base in problem-solving situations. Prototypical systems are now in use around the world in areas such as medical diagnosis, mineral prospecting, chemical structure elucidation, and computer-system configuration. Major efforts are now underway in industry and science to exploit this technology and extend it to new applications, for automating processes that need to make decisions in the same domain over and over again. These programs are designed to represent and apply factual knowledge of specific areas of expertise to solve problems. In visual design, expert systems can be used to maintain an order and consistency in the implementation of large or repetitive projects.

THE BASIC IDEAS OF INTELLIGENT PROBLEM-SOLVING
The central notion of intelligent problem-solving is that one must find the solution selectively and efficiently from a range of alternatives. When resource-limited, the expert needs to search this space selectively, with as little unfruitful activity as possible. An expert in the field works by
applying knowledge to spot useful data early and avoid low-payoff efforts by pruning blind alleys as early as possible. An expert system achieves high performance by using similar knowledge to narrow down the solution domain by rejecting solutions that do not confirm to the constraints in the context.

KNOWLEDGE AND SKILL
Knowledge is not the same as information. It is information that has been pared, shaped, interpreted, selected, transformed and consists of descriptions, relationships, and procedures in the domain of interest. Skill is the ability to apply this knowledge to the problem in a domain in the most useful way.

An expert system consists of a knowledge base and an inference engine. The knowledge base consists of the facts and heuristics in the form of rules; and the inference engine consists of the processes that work over the knowledge base to infer solutions. Each production rule in the knowledge base describes an inference that can be made about a specific situation. The premise, or IF part, of each rule describes the situation and the THEN part is the conclusion that can be made when the premise is valid.
The descriptions in a knowledge base of an expert system identify and differentiate objects and classes by defining their primitive features or concepts. Some of these descriptions concern relationships between objects, that express dependencies and associations between items in the knowledge base. Procedures specify operations to perform when attempting to reason or solve a problem.

Expert systems that are currently used in the design of circuit boards etc., construct descriptions of objects in various relationships with one another and verify that these configurations conform to stated constraints. Similar approach of object description and relationships can be adopted for graphic design; the difference being that the constraints in graphic design will be related to visual qualities, as we know them.

PRODUCTION RULES IN EXPERT SYSTEMS
Production rules is a method of encoding an experts knowledge in the knowledge base. They usually have a Premise (IF part) and a Conclusion (THEN part). They have several advantages for knowledge representation over conventional programming techniques, such as the following:

* Users can understand and relate to production rules as "rules of thumb"
* Rules are very modular and thus easy to change
* Rule specification is nonprocedural (the system determines when to apply rules)
* Rules allow for an explanation of system conclusions as a chain of logical steps

While the production rules define the static knowledge about a domain, another portion of the system maintains the dynamic facts about a particular consultation. These facts are called parameters and include any features that the domain expert feels are relevant to the problem. The values of these parameters determine which production rules are applied during a particular consultation thus controlling the state of the sub-goals. The effect of a production rule is usually to conclude a new value for a parameter. For example a rule stating that picture with red should not be placed next to picture in majenta is the static knowledge in the system, whereas the current position of picture in red is the parameter, that the system changes after applying a particular rule.

**SHORTCOMINGS OF EXPERT SYSTEMS**

Expert systems fall short on dimensions requiring general intelligent behaviour:
* They are unable to recognize or deal with problems for which their own knowledge is inapplicable or insufficient.
* They have no independent means of checking whether their conclusions are reasonable.
* Explication of their reasoning processes is frequently silent on fundamental issues.
* They often need stylized input/output languages.

GRIDS
The use of the grid system gives freedom of design while maintaining a consistent appearance, so it is particularly useful for serial publications or for establishing corporate identity. Contemporary design techniques are being influenced by modular design in general and grids in particular. Grids range from horizontal and vertical equally spaced lines that make a square module, to more casual typographic grid, in which the primary function of the lines is the identification of margins, column measures, and principal spaces within the design.

Grids were used by Renaissance artists as a method of scaling their sketches and cartoons to fit the proportions of monolithic murals. Grids are basic to cartography, perspective drawing, scaling and other representational graphics. From the time of Gutenberg, typographers have used grids to design letters and complete the makeup of the printed page.

Since the time of Gutenberg, typography has worked with fixed rules. These rules facilitate functional and aesthetic design.
Many systems have been developed for the harmonious use of grids, some of these are: the Golden Section, Dynamic Symmetry and the Modulor. Le Corbusier developed an elaborate design system based on the golden section and the human proportions called the Modulor. The Modulor gave inspiration to the typographic designers of Germany and Switzerland to create modular systems that would transform utilitarian makeup sheets to design-oriented modern grids.

**DESIGNER’S GRID vs SIMPLE GRID**

The factors that distinguish a designer’s grid from ordinary makeup sheets are the grid’s regard for proportion and its compatibility with the solution to the design problem.

There are two ways that the designer can bring mechanical form into harmony with those aesthetic considerations that help to determine the quality of a design. One way is through the use of his own natural and intuitive sense of proportion, and the other is through the application of certain systematic principles of proportion developed by mathematicians, artist-designers, and architects throughout the course of design history. In the implementation of GRID, I have used the systematic principles derived quantitatively. These principals lend themselves easily to use, in such a system that relies heavily on methods. For example a
mathematical system to achieve balance can be described as follows: balance can be achieved by analyzing the visual elements in terms of their size and intensity, and laying them out on the page, such that the visual weight is distributed evenly on the page, for example to balance a patch of black some proportion of white is required. In GRID this rule is implemented by dividing the grid into a courser grid and distributing the picture values such that each of these big grid divisions have similar weight, to achieve balance. This is a very basic way of establishing balance, and can be elaborated to incorporate complex visual phenomena.

THE GRID AS AN ORGANIZATIONAL TOOL
Since graphic designers took up the grid as an organizational element, it has been used with such skill and freedom that a casual observer would never suspect that the design was related to a mechanical form or a modular system. When used with skill and sensitivity, a grid can lead to the production of handsome and effective pages and can give the overall design a sense of cohesion with a distinctive unifying effect. But when priority is given to the structure rather than the creative concept, the use of grid can produce dull layout and rigid format. Therefore it is essential to know how a grid structure can be used creatively. This knowledge can become part of the system that will help the designer in using grid structure in laying out a document.

Balance can be analyzed quantitatively by dividing the page and calculating the visual value of these divisions.

Same grid may be used to lay out pictures in different configurations depending on the area required by the pictures and the effect desired. In this case pictures are organized in a vertical column. figure - MULLER-BROCKMAN '81
Paul Rand points out, that at a glance a grid may seem very simple to work with, but it is not. Much depends on the material the designer is called on to incorporate into his designs and the virtually endless surprises he encounters. "In the process of designing, the designer selects a line to follow, only to learn that the constraints he encounters send him back to probe another direction until he finds a clear path to the solution."

It is this quality in the process of design that can be simulated in a computer using an expert system. A computer can mathematically find out the possible solutions to the problem, and backtrack if a decision leads to a dead end in the process. Unless the knowledge base is rich enough a computer will not be able to act as designers who intuitively reject solutions even before attempting to try them as they are aware of their failure, by experience.

In typographic grids, the vertical lines of a grid control the inner and outer margins, define the type columns and determine the space between them. The horizontal lines determine the head and foot margins, the depth of the type columns, and the location of the headlines and visual material. In the design process the working grids can take several different forms. The grid may be an actual size overlay rendered on tracing paper, or it can be an underlay that shows through the layout sheets. The grid may also form rectangles or squares that are printed on
the page to give a certain structure and cohesiveness to the layout.

Even though it may appear that grids can solve all problems of design and introduce structure in the layout, it does not liberate the designer from their task. Grids act only as a tool for the designer to work with and do not necessarily provide any solutions. As Le Corbusier in his comments about the *Modular* points out "I still reserve the right, at any time, to doubt the solutions furnished by the *Modular*, keeping intact my freedom, which must depend on my feelings rather than my reason." Control always remains with the designer, even though computerization is used to create solutions or for generating options for quick evaluation, that the designer can then fine tune.

As publication is very often a repetitive process, which uses organizational principles to unify material from different sources, a lot of it can be automated. Grids have a real advantage in this automation; they can bring a sense of proportion, order and continuity. A grid also facilitates the automation by providing a reference structure that can be addressed for defining the rules of layout.

Some repetitive publications like weekly guide for TV programs do not change in their format, only the information changes from one week to the next. This kind of publication may be automated so that the information is entered and the layout is generated from one week to the next. figure - HURLBURT '78
DESIGN WITH GRIDS
Design, whether following a structure, namely grids, or not, takes into account various properties of visual design that dictate how a final design shapes up. The description of these properties can be found in a wide body of literature on vision and cognitive science. These descriptions can be encoded in the knowledge base of an expert system in order to simulate some of the designer's work. This is a non-trivial task. In my project I have taken a small portion of these descriptions to test and demonstrate the ideas for this thesis.

PARTS AND WHOLE OF THE IMAGE
The organization of parts creates a whole that finally effects the viewer. Various properties play an integral role in making a whole from parts and hold the image together. Each element of the image has visual properties, which are brightness, hue and saturation and physical properties, which define the boundaries and the shapes of these elements. Combined, these two help in perception of these parts. The relation between these properties of parts among themselves is defined by principles of balance, rhythm and harmony, which help us to perceive them together as a single image sharing the same physical space. One can not perceive visual units as isolated entities, but relationships. It is these perceived relationships that give meaning to the entire image.
Color and value of an image are always perceived in relation to the immediate surrounding surfaces. A brightness value can be amplified or blotted out by the other values. Color and texture can be intensified or neutralized in the same way. Sizes and shapes are perceived in relation to the background and their specific perception quality is due to their respective frames of reference. Same sized dot is perceived to be large when surrounded by smaller dots, and appears to be small when surrounded by large dots instead.

There is neither an absolute quality of color, brightness, saturation, nor absolute measure of size, length and shape, as all visual properties derive their qualities from their neighbors. It is therefore important to create the right frame of reference for each unit, for it to maintain its identity and exist in unity with the others.

In layout, each image is an entity and may be a very pleasant work of art, but if it fails to relate to its environment then it ceases to create harmony and thus creates contradiction and tension with its environment. Therefore it becomes very important to tie different objects together to create harmony, so that the mind can zoom in to details one at a time rather than dealing with several different identities at the same time.
Only by using relativity of optical differences creatively can one create an optical image that is attractive. It is the aim of this thesis to encode some of the knowledge about these inter-relationships in the form of rules so that the images can be laid out on a background surface using these rules to achieve the desired effect.

The four borders of the two dimensional space generally assume the main directions of the image. The optical units derive their spatial quality from these borders. They appear to advance or recede from the center based on where on the surface they are placed. The elements also appear to be moving left, right, up, down, and to be receding or advancing, in respect to each other, depending upon their relative position. When laying out images on a page, contextual and visual relationship between individual images can be defined to determine the physical relation to each other and to the whole. For example two images placed diagonally apart on the page will seem to pull the page apart, and is not desirable unless this effect was desired to convey certain meaning i.e. contradiction. Similarly all elements cluttered together towards the center will seem to create a mass of information with no relation to the physical boundaries of the page.

Layout of various images, on a page that are by nature different in size,
color, brightness and texture is bound to create contradiction. This contradiction is resolved by creating balance and rhythm, of the visual properties of elements with each other.

There are endless ways that a given set of images may be arranged on a page. Each of these placements not only gives rise to a different emotion but can also change the meaning. Just as the letters of the alphabet can be put together in innumerable ways to form words which convey meanings or not, so the optical measures and qualities can be brought together in a number of ways. Each particular relationship generates a different sensation of space. The meaning to be conveyed then depends on the designer's making a particular choice. The computer may be useful in generating these endless solutions, but may not be that successful in the right choice because it lacks emotions and understanding, unless it was very explicitly spelled out that a particular meaning is desired and the way that it may be achieved. The designer can tag the images on a particular scale of emotion, and specify rules based on these values. For example, the designer can specify, with each image to be used, how cheerful it is on the scale of 1 to 10; then the system can use these values and the related rules to achieve the needed solution.

**BACKGROUND**

spatial organisation is the vital factor in an optical message

Alphabets make words only when combined with meaningful voids, similarly visual elements can be combined in various ways, but there are limited number of solutions that 'work'.

Balance need not be symmetrical, it can be achieved in various interesting configurations.
INTERNAL FORCES
The relationship of void and solid is very important. It is the presence of voids that emphasize the solids, and it is the solids that create the voids. The two are inseparable, they justify the existence of each other and reinforce each other by their presence. The window could not exist without the wall; meaningful words would be impossible to write without the existence of intercepting solids and voids. It is very important that the interplay between voids and solids be meaningful and the placement of solids create meaningful voids. In a grid placement this play between solids and voids is even more important. The advantage of using grids is that varying amount of information may be laid out on the same amount of surface, creating varying amount of voids. The interplay between these voids and solids governs the innovative use of grids.

COLOR BALANCE: Color balance plays an important role in any design problem and governs the components that may be laid out adjacent to the other. For example a white complemented by black gives rise to contrast and tension. On the other hand a white complemented by a lighter shade of gray creates a rhythm and white with a very light gray looses its integrity. This applies to both intensity and hue.
SPATIAL TENSION - DYNAMIC EQUILIBRIUM: A random placing of visual elements on a picture surface opens up the space, but if the forces are haphazardly arranged, they will not reach a balance in which forces are equal and opposite to balance each other.

If the visual forces are of equal quality and spatial strength, a balance will be reached, but it will be without tension, static and lifeless. To achieve balance and still create tension, opposing forces will have to be arranged accordingly. These forces may be different in terms of their optical measures and qualities - that is, opposite in direction, weight, intensity - but, if they are equal in strength in terms of their spatial fields, the picture surface will reach a dynamic equilibrium. A light image that is big in size may be equal and opposite to a very dense image that is small, balancing each other in opposite directions.

ORGANIZATION
In any optical field one can see clearly and in their individual characteristics and relationship, at one time, only a limited number, five or six, of visual units. Confronted with a complex optical field, one reduces it to basic inter-relationships. The organization of objects is perceived before the recognition of visual element itself. Organization is an important criterion in the use of grids. Misuse of grids can make the
end-product appear disorganized and unattractive, whereas an intelligent use of the same grid with same material can be very attractive if the page appears to be organized in its appearance and content. Grids provide a good organization tool, which when misused can give undesirable results. Proximity and similarity of visual elements provide a basis for organizing them.

PROXIMITY: Generally speaking, optical units close to each other on a picture-plane tend to be seen together and, consequently, one can stabilize them in coherent forms. This leads to the rule that if the relationship between images needs to be emphasized, then they need to be placed in proximity to each other to get the desired meaning across. A reader will generally not establish connections between the units that are placed across the page with no visual connection. This principle is used continually when giving visual support for text. The proximity of illustration is important for it to serve its purpose. If the story about a U.N. conference was given on the lower left corner of the page on the newspaper, and a picture of Reagan speaking in the conference, was placed somewhere on the upper-right corner, then it may become confusing for the reader to establish the connection.
SIMILARITY OR EQUALITY: We tie elements into stable relationships if they have common qualities. Equal sizes, similar shapes, directions, corresponding colors, values and textures tend to be seen together. In a layout this applies to visual qualities as well as contents of the elements. Therefore one groups the headlines on the front page of a newspaper, even when they are interspaced by blocks of text. It is the similar size bold type that attracts our attention. In newspaper design, this quality has been exploited for various purposes including advertising. One will not find an advertisement related to a computer in the sports section unless it is advertising for computer software for analyzing a sport.

CONTINUANCE: Continuance is perceived when there is graduation or progression of hue, value and chroma. The eye moves along a direction of hue or value gradation similar to the way it moves along a line. This condition can be used if a certain "buildup" is required. It has to be avoided if the visual units need to preserve their identity.

CLOSURE: Forces of organization tend to shape optical units into closed compact wholes. A closed area appears more formed, more stable, than one which is open and without boundaries. A psychological filling-out of the intervals between the units occurs, and one constructs latent connections. This factor of closure may act on the flat dimension.
generating from open linear units the experience of a closed shape.

RHYTHM: The orderly repetition or regular alternation of optical similarities or equalities is the rhythm of the organization. But simple rhythmic pattern possesses a regularity that becomes monotony. If the image is to hold the viewer's interest, the relationships within it must have progressively changing aspects. One cannot long look at the same visual relationship without exhausting attention.

Perfect balance or rhythm may become very monotonous, there is a need to provide visual surprise. The figure below, is balanced in its overall configuration and holds the viewer's interest as against the one above, showing that objective solutions do not exist to achieve desired visual qualities[KEPES '61]
PROJECT DESCRIPTION

There exists a variety of expert systems, some of which are widely in use while others are being tested. Most of the expert systems available fall into three categories, high level e.g. KES, middle level e.g. HP-RL, KEE; and low level e.g. lisp programming environment.

High level expert systems have a sophisticated interface and are easy to use, but are not suitable for research purposes as they do not give as much control to the developer. In the case of graphic applications, interface between the expert system and the graphic routines is also very limited.

Middle level expert systems provide functionality of a developed expert system and provide control to the developer. This kind of expert system is usually the ideal choice for development and conducting research. The non-availability of these systems when I needed it, prompted me to develop my own system, using low level tools i.e. Common Lisp and Object Oriented Graphics on Hewlett Packard 9000 Series 300 Workstations. Even though developing my own system did not give me access to high
level tools for inferencing and justification, it provided me direct control of the program and direct manipulation of graphics. The emphasis in this thesis is the use of expert systems for graphics, to provide some degree of intelligence to the tools, giving the design process, some degree of automation.

Listed below are the possible scenarios of design in descending degree of manual interaction and ascending degree of automation:

Scenario 1: * The designer designs the layout
  * The computer does not play any role

Scenario 2: * The designer places pictures on the grid
  * The system echoes the placement that satisfies the constraints more appropriately

Scenario 3: * The designer locks certain images on the grid
  * The system takes that as given and lays out the rest of the images

Scenario 4: * The designer places a few images that s/he wants in a certain position
  * The system lays out the rest according to the rules, and may change the user specified image, if it does not satisfy the constraint entirely

Scenario 5: * After getting a solution from the system, the designer
tags the pictures that are approved, the remainder are laid out again
- The system tries to lay out the requested images again, according to the rules

Scenario 6:
- The user specifies the pictures to be used and their properties
- The system lays them out entirely based on image properties

Scenario 7:
- The user specifies the pictures to be used
- The system finds the properties and the appropriate layout

Scenario 8:
- The user requests a layout in certain context
- The system chooses the images relevant to the context and lays them out according to their visual properties

IMPLEMENTATION
GRID (Graphic Intelligence in Design) is the system that has been implemented as the test-bed for ideas discussed in this thesis. GRID falls somewhere in the middle between being totally automatic and totally manual. Placed on the scenario scale described above, it is placed somewhere between scenario 4 and scenario 6.
The implementation includes techniques for selection of pictures or information that needs to be laid out on the page. The source of this information can be a data-base of images that is accessible to the designer in the form of picture library. Searching images has been implemented in various projects e.g. 'archfile' at Architecture Machine Group at MIT, and Aga Khan Disc for images of Islamic architecture produced at MIT, which allow images to be retrieved from a video disc given keyword search methods. An illustrator may use digital paint techniques to make the illustration or convert it to digital data after having drawn it. Similarly the written text may be fed from the word processor.

Once the information has been selected, the designer can specify to the system the style in which the information needs to be presented. Some example of style chosen are ganging in a vertical column, ganging in a horizontal column, or balance over the whole page. The style specification will generate the layout in that style using rules that describe it. The designer may also specify that a certain kind of information should go in a particular location of the page i.e. title; this information will further constrain the solution to the problem.

Given this information about the selected style and the input parameters i.e. pictures, the rules that are already in the knowledge base determine
the best layout on the given page within the required structure of grids. The solution presented by the system may be accepted or rejected by the user, who may either modify the criteria, change the parameters or just ask for another solution.

SOFTWARE
The project has been implemented in various software modules:

Inference engine: this processes the rules according to the goals that need to be deducted. The inference engine implemented with the system has been programmed, using Common Lisp and Object Oriented programming methods. The inferencing is controlled by implementing the notion of states, by setting states to be a certain value, when the subgoal is reached.

Knowledge base: consists of the rules that help derive the layout given the input parameters. In the knowledge base implemented with GRID, the design knowledge discussed in earlier chapters has been encoded. This knowledge base is activated and rules are fired as the corresponding state is set to be true.

Objects, classes and methods: these create instances of graphic objects for manipulations by the user or by the systems' rule base. The
instances of the graphic objects are created according to the input parameters from the designer. The rule base, after deducing properties of these objects, i.e. position, draws them on the graphic screen in the assigned position.

**Graphic routines:** these consist of routines that draw, erase and echo the user interactions. Most of these routines have been implemented using 'C', to gain speed in drawing routines.

**GRAPHIC OBJECTS**
Graphic objects have been implemented such that relevant knowledge can be shared by each object. It is important that an object knows not only about itself, but also knows about other objects in the layout and their relative position and characteristics. To achieve these characteristics, the structure of grids was very helpful. The grid division is the basic unit in the system. Each division knows about itself - its coordinate points, its position on the grid and its occupancy by a picture. In this kind of implementation any unit can find out about any other unit by inquiring. For example if a picture that is two-grid-units by two-grid-units needs to be laid out, then an inquiry can be made regarding those grid divisions that can make the layout of such an image possible. This structure is also helpful when implementing rules that are relational, that in other words
involve information about the other picture, to establish their own position. It also aids in backtracking. For example if there is a large picture for which there is no appropriate space on the grid, then one of the images needs to move to make space for it. For executing this kind of backtracking, it is not helpful to just undo the last solution, but it needs an intelligent decision about the appropriateness of the image to be moved. In the object structure implemented, it is possible to find this out by asking points on the grid the appropriate question.

PROCEDURE
Each graphic object is made into an instance of the object type picture, which represents any visual element - picture, illustration or a block of text, which has full description of itself, including its intensity value, its size and content description. The user selects the picture by pointing at it, using a tablet. The image of the selected picture is echoed on the screen to inform the user that the picture has been selected.

After selection of the picture the user selects an item from the menu, which describes the style in which the layout has to be made. This essentially instructs the inference engine about the goal to be achieved. The search is therefore goal-directed i.e. backward chained. The inference engine applies all the rules that will lead to that particular goal,
by achieving sub-goals in the form of different states. If the goal is not directly deducible, then the rule that achieves the sub-goal is fired instead. This sequence continues until the goal is achieved.

The problem of back-tracking is very important in graphic manipulation of objects. A picture may satisfy certain conditions originally but when more pictures are laid out, the whole layout may not satisfy the constraints. In other words, graphic decisions are not linear and require multi-dimensional decision-making to achieve the desired results.

Back-tracking is implemented, not by undoing the previous decision, but by evaluating, which decision lead to a dead end, based on the current configuration. After having undone this decision, the inference engine tries to achieve the goal, given the updated information. After the inference has been made, the final pictures are layed out on the screen according to the inferred order.

SEARCH METHODS IN THE DOMAIN

If there are six selected pictures in various sizes and colors, they can be laid out in various ways, the possible number of solutions depends on the number, variation and variety. The constraints cut down the number of possibilities by a great deal, but still there exist enough possibilities that
can be explored. A human mind can process this information during creativity, but cannot go through all possible combinations.

From all the combinations that are possible, some can be disregarded simply because they do not appeal to our aesthetic sense, while the remaining solutions can be further explored. These decisions that help us decide or select one from the other can be used as constraints on the system which will then present visually pleasing solutions.

If two pictures of equal size and intensity were laid out on a grid of two by two, then there would be six possible solutions, as shown in figure. Then depending on the criteria, some solutions may be disregarded outright and others may be explored further to arrive at the most appropriate solution. For example if it is important that each image maintain its identity, then b, c, e, and f can be disregarded as they seem to merge the two pictures. On the other hand if the intention is to make horizontal column then solution b and f are the candidates for consideration. Again during selection from b and f, the constraints will further guide the selection, whether the overall look needs to be top-heavy or bottom-heavy, and on the composition of the whole document. One should bear in mind that when a designer tries to solve a similar problem, she intuitively disregards the candidates that will not be.

There exist six alternatives, if two pictures are laid out on a two by two grid. The criterion of selection changes if image quality is changed, in this case intensity.
possible solutions, even without any analysis.

To carry the example further, if the color or intensity of one of the images is changed, then the resulting configurations, as shown in figure, will go through a different kind of analysis. Solutions a and d will no longer be the only candidates to preserve the identity of the images. The criteria for decision will change accordingly.

If the size of one picture is changed and the basic grid is increased from 2x2 to 3x3, then there are 42 possible ways as shown in figure, that these two images can be laid out on the given grid. Again the selection of the appropriate image will depend on the selection criteria and the goals sought. If a third image is introduced in the above layout then the number of solutions is increased six times as shown in figure, these six solutions correspond to the permutations and combinations of one solution from figure. Therefore, the resulting number of solutions is 252. This demonstrates that the increase in a parameter, like number, type, size of images, directly exponentiates the possible number of solutions. Then the problem is to selectively filter out the solutions so that the applicable constraints are satisfied. Designers narrow their domain of search for possible solutions by intuitively rejecting a few that they know will not satisfy the constraints, and then by going through a process of filtering...
out the possible candidates until a good enough solution is found. By using an expert system, the designer can look at those possible solutions that satisfy the constraints, and then decide which solution solves the problem in the best possible way. This method also has built into it the chance of arriving at a solution that one may not have thought of.

SAMPLE RULE IMPLEMENTATION

If the intensity of picture A is x and the intensity of picture B is y and if x and y are different by less than z then A and B cannot be adjacent to each other.

This rule is justified by the fact that if two pictures almost equal in their intensity values are placed next to each other then the pictures lose their identity and are also difficult to perceive as a whole.

If the content of picture A is x and the content of picture B is y then A and B can have the following relationships: A and B can be adjacent to each other OR A and B can be in proximity to each other OR A and B cannot be in proximity of each other. This kind of methodology can be found in use when laying out information that comes in from different contexts and it is important to establish the relationship between the content e.g. newspaper design, where an advertisement for a sports gear...
will be placed near the news covering that sport and not in the business section. If this contextual information is encoded in rules then the decision about the layout of a complex document may be automated.

The types of rules described above are simpler to implement because the decision is almost linear, in that parameters affect each other directly. Balance rules are more complicated to implement. All the pictures need to be considered when laying out a page which is visually balanced. A shift in one picture may result in a shift of many pictures. To solve this complex problem, the unifying structure of the grid has been employed. The grid may be divided into a much coarser grid to achieve overall balance. That is, if a grid has four by four divisions, then the coarse grid may be two by two giving four divisions. The pictures are then placed in such a way that the value of the picture/s in each division is almost the same.

Rules of proximity and balance have been implemented. Rules of closure, organization, rhythm etc. are much more complex, but not totally unreasonable and may be implemented at a later date.
This chapter contains the description of a case study, the derived scenario of an intelligent workstation for designers, and an example session with the implemented project.

CASE STUDY

In GRID, the knowledge base reflects some of the design rules formulated by observing Joan Musgrave, Art Director from IBM, Thornwood, designing the cover of the technical publication -- 'Perspectives in Computing'. The cover of each 'Perspectives in Computing' follows a grid structure, and represents articles in a particular issue, by using at least one image from each article.

For the following description, the design process has been divided into 3 major steps:

1) Selection of images
2) Sizing and Cropping
3) Layout of these images

The first two steps are discussed to demonstrate the process and how
the related knowledge might be converted into a knowledge base. GRID does not have this knowledge encoded and provides interactive tools to the designer to make these decisions. The last step -- layout of images, has been implemented in the knowledge base of GRID.

1) Selection of Images:
Selection of images is based on the following criteria:

**Representation of articles** - Each article inside the publication is represented on the cover by the presence of one image, to reflect the editorial content of the issue and to give equal importance to all the articles.

**Method:** IF there is no image selected from an article THEN select an image from that article based on the content, and relation of images to the others selected.

This rule can be implemented by keeping a log of all articles in a particular issue and their related images.

**Content is important** - The content of the image is important for two reasons:

A) Image's content should be a good representation of the internal content.

**Method:** IF the content of the image is a good representation of the article THEN select the image, ELSE try another image from that article.

There can be rules in the knowledge base that describe the content of
pictures and articles. The rules will then try to correlate the two and find the best candidate. The rules will also take into consideration the kind of images, the contents, the legal matters e.g. copyright etc..

B) The overall color should be **pleasing** to the viewer i.e. an image with a overall **disturbing** color scheme will not be used on the cover, to avoid a disturbing feeling from the publication.

**METHOD:** IF the color scheme of the image is acceptable THEN select the image, ELSE try another image from the same article.

A pallette of colors can be defined in the system to establish which color schemes are pleasing and which are not. This is a whole field of study in the cognitive and vision sciences and may be quantified for the purpose of usage by the computer.

**Relation of images:** The images should balance each other in various ways:

A) COLOR: The images selected should be mutually agreeable in color and produce appropriate contrast. i.e. if all images had a common color for their background, then they will probably not work together.

**METHOD:** IF overall color dominance is not similar and has the desired degree of contrast THEN keep the selected images, ELSE reject the image that has least popularity OR change the color of the image.

The color dominance of an image can be analyzed by the computer by
sampling the image. This information can be used to derive the information about color compatibility within the images.

Rules for appropriate conditions to effect the change in color may be defined as:
IF the image is a photo of people THEN only color of the surroundings may be changed.
IF the image is an abstract illustration THEN the color may be changed to..
(more rules can be added here describing HOW the colors will be affected).

B) CONTENT: The content of the pictures should be of different kind. i.e. all images of only people, or computer images will project a monotonous look, but a mixture of above will make an interesting mix to provide a balance of content.
METHOD: IF number of images selected is less than or equal to the categories of content THEN IF more than one selected image fall in the same category THEN change the selection of the image from same category of content to the one that has different content.

C) STYLE: A mixture of different style of images, i.e. photographic, sketches, paintings, line drawing, lithograph etc. is desirable, to get a mixture of styles.
METHOD: IF the images are of a similar style and there exist more styles to choose from THEN select an image from the style not already selected.

D) IMAGE DOMINANCE: The images should have a variety - the overall flow and curves, transparency of colors, use of lines in a similar style, should not be conflicting or repeated in the images to achieve a balance of visual style.
METHOD: IF images selected have a similar use of color THEN select another image in the same context with a different color. IF images selected have similar lines of dominance THEN select the image with a variety of dominance, and so on.
It is assumed here that the images are tagged for their quality, and style, so that the computer can implement rules of this nature. Some of these features can be derived by sampling and image processing.

2) Sizing and Cropping:
The images will be sized and cropped depending on the content, color, etc.
A) SIZING: The images with strong theme, details etc. will be large and those with relatively uninteresting detail will be made smaller
METHODS: IF the image has a strong theme THEN make the image to be large ELSE IF it is comparatively uninteresting THEN make it small. IF the image has minute interesting detail THEN make the image large.
To implement the above method rules that describe the themes that are interesting or dull are needed. These rules may have categories of pictures e.g. landscape, people etc.

B) CROPPING: The image will be cropped based on the content, its emphasis and the grid proportions.
METHODS: IF the image proportions are vertical THEN size the area of interest and crop the image to 1 to 2 proportion.
IF the proportion of the image is square THEN crop the image to 1 to 1 proportion.
Cropping may be implemented automatically if the tools exist that help the designer define the area of interest, and a table of possible sizes that are compatible with the layout is maintained.

Selection, as clear from rules above is a multi-step process, back-tracking and checking to see if the right decision is made is an integral part of it. As illustrated by rules regarding the relationship of images with each other, a decision may be changed at any point, if a conflict is encountered at a later stage of design, and another image may need to replace the selected image. The process then is summarized by PICK - LOOK - WEIGH - DECIDE - PICK and so on. The process continues until the desired set of images is selected.
In the implementation of GRID, the interactive selection tools are provided for the designer, to make the above decisions. GRID assists the designer in the next stage, to prepare a layout using the selected pictures.

3) Layout of Images on the Grid:
The laying of selected images takes into consideration the visual quality of the images and strives for the overall balance in the layout. Appearance of the images is more important than the content, when laying them out.

The rules here depend on the various ways that the images interact with each other in their visual quality.
A) SIZE: The layout of images is related to their size i.e. all large images will not be placed together on the grid, so that the balance between them can be achieved in terms of size.
RULES: IF the size of the image is large THEN do not place another large image next to it.
IF the size of the image is small THEN do not place too much white area surrounding it.
B) CONTRAST: Contrast of images - in style, color and value is primary decision factor when placing images next to each other.
RULES: IF color of image is dominant in a color THEN do not place another image with similar color composition, adjacent to it.
IF there is a small dark image on one corner of the layout THEN balance the image by placing a large gray image in the opposite corner.

These rules are based on the values associated with the quality of the images that are quantifiable, i.e. value, color and size. As the rules about balance of these parameters are quite explicit, this is the area where computer intelligence can be most applicable and useful.

REPETITION
It is desirable that repetition of a layout is avoided so that each entity maintains its identity inspite of having common origins in rules. This can be an integral part of the knowledge base such that the expert system, having knowledge about the past solutions can determine, which layouts are repeats and avoid them.

The other rules that are implemented have to do with the kind of layout. The user can request for a layout that achieves balance on the overall page, or can make horizontal/vertical columns. The threshold for intensity and color adjacencies can also be changed by the user interactively. The user also has a choice to refine the options generated by the computer interactively.
A few samples of 'Perspectives in Computing' to show how variables on a structure contribute to visual interest and familial relationships.
CONCLUSIVE SCENARIO

Outlined below is the scenario of the workstation that a designer would need based on the design process discussed above. This is specific to one person's mode of work. It can be generalized by implementing more generic knowledge bases and intelligent graphical tools that are either very general that can be used by everyone or by providing facility for one to be able to personalize them for oneself in a particular context.

1) The designer specifies the type of grid/structure to be used to lay out the pictures or text.
2) All the pictures/text that could be used in the layout are displayed on the screen in an iconic version, for designer's reference and selection.
3) The designer picks out the pictures from this 'directory' of pictures based on her own choice and criteria, or instructs the system to do it by placing a request for an image given the criteria.
4) The selected pictures appear in an enlarged version on the screen, for further manipulation and modification.
5) The designer crops and sizes these pictures using an interactive input device i.e. a tablet. Image processing may also be done. These tools have the context defined in them so they can provide intelligent assistance to the designer.
6) Given these selected pictures in their sized and cropped version the computer makes possible layout solutions on the given grid, as it has built into it as to how to use a particular kind of grid and how to deal with particular problems.

7) The designer either chooses a solution, disregards it completely or tells the system what is right and what needs to be laid out again. The designer may also modify the layout herself, given interactive manipulative tools.

8) Based on the designer's request the system either tries out a different set of solutions or tries to lay out the pictures again, that are not liked by the designer.

9) The process continues until a satisfactory solution is found.

PROJECT SCENARIO
The project implemented in support of this thesis document is described below. The ideal scenario and how it can be used in the context of designers work environment in the technological era, is given. The pieces that have been implemented are described, along with the example of rule implementation.

When a designer begins to design a magazine or a newspaper, she has available to her the articles by different authors, the visuals, or an idea
of what the visuals should depict, and various sources to visual libraries, that may be on-line, which has become possible as technology has provided solutions to store large number of pictures on electronic media. Design workstations have now begun to incorporate these kinds of sources for retrieval of pictures and data. Text is usually input through the use of word processors.

The designer usually begins by inputting the available data into the system, and has the capacity to retrieve any data or visual that may be on line. Once the needed information has been input into the system, the designer needs to compose this information on a page in the desired style of the publication. This is where this project plays an important role. Once the designer has compiled and selected the information to be laid out, it needs to be pulled together in a consistent style throughout the document. One can easily compose a few pieces of visuals on a page; but book design is not like poster design, it needs to follow some conventions of style throughout the document, for continuity. This is where the constraints of a style play an important role. These constraints give important guidelines to the designers for treating information that needs to go on each page, to maintain continuity of the document. Grid systems often become an integral part of these constraints to give an organizational structure to the document. Each designer has certain rules
that they use to solve various problems within this grid structure. These rules may be personal to the designer, design philosophy of the design firm, style guide of a corporation or a publication; but they do exist to achieve the desired results and maintain the consistency. Knowing that the designer has to deal with these rules repeatedly, they are ideal candidates to become a part of an intelligent tool that the designer can use to solve design problems. For example, if the designer has decided to deal with the relationship of text and pictures in a certain manner on the page -- intercepting text and pictures, separate columns for pictures etc. then these rules can become inherent part of such a system. The exceptional situations can also be described explicitly. For example when using two vertical columns, one for text and the other for visuals, as in this thesis, and if a large picture does not fit in the picture column, then it can be treated in various different ways: it may occupy a separate page, or it may become part of the same page and be placed in the text column, or it may be reduced to fit the column, and so on. These decisions are usually taken in advance, in case of a publication involving more than a certain number of pages. Therefore they can become part of the descriptions in a system that will then have a knowledge of dealing with exceptional cases as they are presented.
Some information like title block, page format, page number etc. remain constant throughout the document. The system can provide a template of information that needs to be on the page as a given parameter to the designer. Some magazines do not put page number and other such information on a full page advertisement, this can form another rule in the system. Thus when designer specifies that a certain page is an advertisement then the system can deal with it directly, in the required way.

For example if one of the rules is defined as follows: the page is divided into two columns -- one that is 2.5" wide and the other that is 4.5" wide. The pictures are laid out in the smaller column and the larger one is to place text. It has also defined in it that if a picture is upto 4" wide then it will have to be cropped and sized to fit 2.5" otherwise it will need to be sized to fit the bigger column, depending on its importance value. It is assumed here that the pictures will be tagged by the designer, for their importance value, whether they are primary or secondary in supporting the text. The system will then be able to deal with the pictures accordingly, when the case arises. Conditions can also be identified when designer's intervention is needed, so that the system may be able to query the required information from the designer.
This kind of an intelligent tool for sizing, cropping, color modification, emphasising, etc. can become an integral part of the designer's environment. These tools are referred to as intelligent because they will know the rules in the particular context for which the design is being made. This kind of intelligent assistance will also save the designer frustration of performing endless searches for an appropriate solution in a wide domain, wading through information that is not even applicable in the present the context. These tools will narrow down this search for the designer and provide solutions, based on the rules, that the designer can accept, modify or reject. In any event, the designer is given a solution or a few solutions to select from or to begin with. These solutions may not be the final ones but they can help the designer in the thinking process and realizing what is it that they want to achieve through their design. Usually the constraints of material and time prevent designers to try out various solutions, reject them and remake them. An assistance in generating the first set of solutions helps the designer in visualizing the final solution. In the traditional media, if a design is reassembled in a different configuration, then the designer usually loses the previous solution and has no way of recreating or comparing it to the current solution, unless she has saved a photo copy of it, in which case the comparison is not fair. The computer provides a tool where, elements can be replicated easily, so that the designer can compare one design to
the other under the same conditions.

Initially it may seem like a big and cumbersome task to translate designers rules into computer language. But if done methodologically, it is not a task that cannot be accomplished. The example of one of the rules implemented in the project is adjacency and is described below.

The rules that govern the adjacency for two pictures are stated in the following way, to work within the grid system:
- Take two adjacent grid divisions.
- If both are void, then do nothing.
- If there exists a picture and the adjacent one is void, then do nothing.
- If the grid divisions are occupied by the same picture then do nothing.
- If the grid divisions are occupied by different pictures then find out the intensity of both the pictures.
- If the intensity difference is more than the threshold specified by the user then do nothing.
- If the intensity difference is less than the threshold then move the smaller of the two pictures to another location on the grid.
- Test the next two adjacent grids. and so on.

There are similar rules for saturation, content, picture quality etc. The
The reason that it becomes so cumbersome to implement these rules is because a computer does not have eyes, emotions or feelings and does not know what 'works'. This shortcoming makes it essential that anything a person does intuitively is spelled out for the computer. For example, a designer does not go through the elaborate process described above to see if two pictures work together. This shortcoming has prevented expert systems to be used for designing. But once these rules are converted into computer language, then the user can have control over them to define their own personal choice. In the example above, they can specify, the value of the threshold, and can set it to zero, if that parameter does not concern the designer.

EXAMPLE SESSION
This section has some interactions between the designer and GRID. The solutions provided by GRID are shown, along with the user selections and modifications.

User indicates the size of grid that he/she wants to use on the control panel and selects the pictures that need to be laid out. He/she can then indicate the type of layout that one is looking for. The area of the screen where user makes selection is shown here.
User selected a few pictures, requested for a layout on a 5x4 grid. GRID responded with a design solution. User then decided to change the size of grid to 5x4 and asked for another solution.
User then decided to try another solution on a square grid of 4x4 and then on 3x5 for different page orientations. In the last solution, user decided to move the small image off the grid, thus over-riding GRID rules.
User then decided to replace one image with two other images to try out another solution using different set of pictures with the same grid size. GRID failed to lay out all the pictures as it did not find space for the horizontal pictures, so it provided a solution with one less picture.
User then decided to increase the size of grid to 6x4 using the same set of pictures. GRID provided the solution shown.
User then constrained the system to group all the images in a horizontal column. First GRID tried a version but failed as the only available space did not satisfy the intensity constraint. It again failed as it did not find proper location for another picture. Finally in the third attempt it succeeded and arranged all the images in the desired configuration.
In another series of interaction, user selected six images and 4x6 grid. The three solutions provided by GRID are shown. In the last instance the user constrained the pictures to be constrained in a horizontal column.
User tries another solution by instructing GRID to make a vertical column using the given pictures. GRID provides the shown solution.
User gets an idea and changes the provided layout by interactively moving the pictures. The solution made by the user is shown.
CONCLUSION

GRID successfully supports the user in defining and manipulating some of the parameters of design. It is an attempt to test out the ideas of creating an intelligent work environment for designers. The rules implemented, allow the designer in specifying the kind of layout they are looking for. The designer can request to make a balanced layout, or gang the given pictures vertically or horizontally, checking to see that the pictures satisfy the constraints of adjacency. The constraint of adjacency can also be modified by changing the value of threshold that is desired by the user. GRID supports user interaction of making appropriate choice of parameters, the set of pictures that can be added and deleted at will, the grid dimensions, that can also be changed at will of the designer. GRID provides support for the designer to interactively move the image on the solution created by GRID, thus allowing for user intervention.

FUTURE WORK
GRID can be improved in its functionality and become a realistic system for designers to use, by incorporating a number of facilities to its environment that better match the design methodology and workstations.
of the designers.

SIZING AND CROPPING
Traditional grid systems divide the given page into the required divisions, GRID, on the other hand makes the size of the page as big as the size of the grid. This is a constraint on the user and is not the way that designers work traditionally. To accomplish a correct correspondence in working methodology sizing and cropping tools need to be implemented. These tools will carry out operations intelligently, and will go a long way to help the designer in visualizing the solutions in a much better environment.

INNOVATIVE GRID SYSTEMS
Designers don't always use equally spaced grids in their design, various methods of dividing a page using proven ways of creating harmony, e.g. dynamic symmetry, golden proportion etc. can be incorporated in the system for a much more creative environment. Rules for chunking and organizing information based on these systems should also be implemented in the system.

SUBTLE RULES FOR DESIGN
No attempt has been made to define the subtle qualities of design, that are much more complex in their visual impact then are intensity and
saturation. Rules to implement these qualities need to be derived very carefully and is a non-trivial task. In fact no two designers may agree with the similar set of rules. This leads to the question of personalization of these tools for a particular designer. If the palette of colors can be personalized for each designer in their own system, and the rules define the relationships within this finite relationship, then it becomes a much more useful tool for a designer, who may not be concerned with the rest of the colors. For example in a publication of a children's book, there is a finite set of colors that are used, and are used in a particular way. This can become the rules for a designer who designs children's books, but will not be relevant to the magazine section of say New York Times. These personalizations will go a long way in customizing design environments for users.

PERSONALIZATION
There needs to be a way that the designer can define their own preferences to the rule base so the standard rules may be modified to suit the tastes of the designer in question. The interaction of the designer with the rules needs to be implemented in terms that are familiar to the designer and matches their way of thinking and working.
BIBLIOGRAPHY

Anderson, J. R. & P. J. Kline
Design of a Production System for Cognitive Modelling
Proceedings of the Workshop on Pattern-Directed Inference Systems, SIGART Newsletter 63,
pp. 60-65, 1977

Arnheim, Rudolf
The Dynamics of Architectural Form
University of California Press, California, 1977
Art and Visual Perception,
Berkeley and Los Angeles, 1974
Visual Thinking
Berkeley and Los Angeles, 1969

Buchanan, B. G.
New Research on Expert Systems
BIBLIOGRAPHY

Davis, R. & D. Lenat
Knowledge-based Systems in Artificial Intelligence

Dondis, Donis A.
A Primer of Visual Literacy
The MIT Press, Massachusetts, 1973

Eastman, C.
Recent Developments in Representation in the
Science of Design
In Proceedings of the 18th Design Automation
Conference, IEEE Computer Society and ACM,
1981

The Representation of Design Problems and
Maintenance of their Structure
In J. C. Latombe, ed., Artificial Intelligence and
Pattern Recognition in Computer Aided Design,
pp. 335-373, North-Holland, New York, 1978

Feigenbaum, E. A.
Knowledge Engineering, The Applied Side of
Artificial Intelligence
Heuristic Programming Project, Computer
Science department, Stanford University,
Stanford
Addison-Wesley, Reading, MA, 1983

Foley, J. D. & A. Van Dam: Fundamentals of Interactive Computer Graphics
Addison-Wesley, Reading, MA, 1982

Freeman, P. & A. Newell: A Model for Functional Reasoning in Design
In IJCAI 2, pp. 621-640, 1971

Gerstner, Karl: Designing Programmes
Alec Tiranti Ltd., London, 1964
The Spirit of Colors, The Art of Karl Gerstner
The MIT Press, Massachusetts, 1981

Ghyka, Matila: The Geometry of Art and Life
Practical Handbook of Geometrical Composition and Design
Alec Tiranti Ltd., London, 1952
<table>
<thead>
<tr>
<th>Author</th>
<th>Title</th>
<th>Publisher and Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hambidge, Jay</td>
<td>Elements of Dynamic Symmetry</td>
<td>Yale University Press, New Haven, 1920</td>
</tr>
<tr>
<td>Kahn, Kenneth</td>
<td>A Knowledgeable Diagram Maker</td>
<td>In Creation of Computer Animation from Story Description, pp 277-290, 1980</td>
</tr>
<tr>
<td>Kepes, Gyorgy</td>
<td>Language of Vision</td>
<td>Paul Theobald and Company, 1961</td>
</tr>
</tbody>
</table>
Klee, Paul  
Pedagogical Sketchbook  
Frederick A. Praeger, New York, 1953

Le Corbusier  
The Modulor  
MIT Press, Massachusetts, 1954

Muller-Brockmann, J.  
Grid Systems in Graphic Design  

Rand, Paul  
Thoughts on Design  
Van Nostrand Reinhold Company, New York, 1971

Rosenberg, Steven  
HPRL: A Language for Building Expert Systems  
Computer research Lab, Hewlett Packard, CA  
In proceedings of IJCAI, W. Germany, 1983

Sausmarez, M.  
Basic Design: The Dynamics of Visual Form  
Reinhold Publishing Corporation, New York, 1964
Shea, T. Use of Computer Based Rule Systems in Graphic Design
Graduate Thesis at MIT, 1986

Simon, H. A. The Sciences of the Artificial
MIT Press, Cambridge, Massachusetts, 1969

Stevens, Peter S. Handbook of Regular Patterns
The MIT Press, Massachusetts, 1981

Tufte, E. The Visual Display of Quantitative Information
Graphics Press, Cheshire, CT, 1983

Vignelli, Massimo Grids: Their Meaning and Use for Federal Designers
Federal Design Library, 1978

Winston, P. W. Artificial Intelligence
Addison-Wesley Publishing Co. Inc.,
Reading, Massachusetts, 1977

AIGA Journal of Graphic Design
Volume 3, Number 3, 1985
LA 84: Games of the XXIII Olympiad
In Design Quarterly 127
MIT Press, Cambridge, MA, 1985

HGS Designer's System, User Interface Design
Visible Language Workshop, 1986

The IBM Logo, Its Use in Company Identification
International Business Machines Corporation, NY

Perspectives in Computing, Applications in the
Academic and Scientific Community,
International Business Machines Co., NY,

Technical Report: Personal Consultant,
Expert System Development Tools
Texas Instruments, 1984

The Best of Newspaper Design
Society of Newspaper Design
R. J. Berg & Co., Inc., Indiana, 1986