THE COMPUTABILITY OF DESIGN

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A number of architectural design studios (second, third and fifth year) at the School of Architecture at the New Jersey Institute of Technology have undertaken traditional design problems through the use of IBM-AT microcomputer based CAD/Graphics systems. Utilizing three-dimensional modeling software, color graphics "paint" software, and animation software, the studios integrated the use of computers into the very heart of the core program as the primary means of design, simulation, and evaluation. At the same time, other non-computer based studios engaged in similar (and often identical) design problems. Therefore, the opportunity became available to compare and evaluate both the impact the computer made to the traditional architectural studio and also to the building design itself.

Computer graphics involves design simulations that are fundamentally different than those produced "by hand," and develops a fluency and dependency on three dimensional architectural modeling. Traditional two dimensional drawings are replaced by a dynamic system which permits the viewing of building and space from any vantage point and, most importantly, from literally hundreds of locations. Although experienced only through the computer, students understand architectural design in a very different way, having "walked through and around" the site and building. Working from pattern or element creation, through the development of element variations, to a vocabulary of physical elements, the student can develop architectural concepts and theories through three dimensional building elements or spaces. As the composite building is developed in the context of the site, further color studies create variations in transparency, image, contextual relationships, and materials simulation.

Based on the work done thus far, answers to the following questions have begun to be formulated:

- Does the highly structured computer graphics systems constrain architectural solutions which results in unnecessary uniformity? Are the characteristics of microcomputer graphics only useful in select types of architectural problems?
- Does the computer encourage or discourage the generation and evaluation of alternative design concepts?
- What is the "start up time" required by students to become sufficiently familiar with CAD in order for it to become a useful aid in the design process?
- Are there elements and/or levels of accountability in design that are more easily integrated into – or left out of – a design studio when the CAD/Graphics capabilities are introduced?
- Does the interactive 3-D software increase the student’s understanding of spatial relationships, or is the computer architectural model more abstract than conventional design media?
- Does the traditional (generalized) order of the design process moving from the general to the specific change as a result of 3-D modeling?
- What (if any) traditional design techniques, media and processes best complement microcomputer CAD/Graphics systems?
- What are the pedagogical implications of attempting to integrate the use of computers in the design studio?

In concert with other Universities, an IBM compatible microcomputer is being provided to every incoming freshman at NJIT. As a result the school is rapidly becoming a "computer intensive campus." As each student seeks ways to utilize his or her own equipment in architectural applications, the impacts upon creativity and our understanding of architecture in general and architectural form in particular must be considered.

TECHNICAL CAPABILITIES AND SYSTEM SELECTION:

Software and hardware at the School of Architecture at NJIT permits three-dimensional modeling, with hidden line removal with completely compatible painting and shading capabilities. Palettes of 16 colors at a time can be selected from 254,000 and up to 64 palettes can be created and stored in order to facilitate comparative color studies. Screen colors can be changed before, during or after an image is created.

Students work on "stand-alone" IBM-AT workstations equipped with dual screen color monitors (Mitsubishi 6920 19" color monitor with TAT Galaxy 800 board (Verticom M16 or M256 is preferred) and the Princeton Graphic Systems SR-12P with Sigma Designs Color 400H board and the Discortex color enhancer, (which allows the creation of 254,000 colors with 64 increments of red, green, blue). The input devices include the Hitachi Tiger Tablet II with 4 button puck as well as the keyboard.

Output devices include Okidata Microline 182 dot matrix printers at each workstation, and two Calcomp 1043 eight-pen plotters.

The 3-D software used is MegaCADD, Inc. Design Board Professional (requiring 640K memory), Design Board Illustrator paint software (or Halo II based). Additional building design simulation is possible through the simplified animation program
which illustrates travel through a proposed building or throughout its site. Also available is Microtecture’s DataCad 2/3. Supplementary two-dimensional and isometric drafting capabilities are available through the use of AutoCAD by Autodesk, Inc. An additional advantage of PC based graphics is the capability to use of conventional PC-based analytical software.

It is the intention of the computer based architectural studios to explore the changes and new opportunities in architectural design that are presented by the new computer systems. For this reason software has been chosen which most closely relates to the way architects think and create building designs. Software which is architecturally abstract or operationally obscure does not complement the design studio curriculum. Software that is oriented to the production of contract documents generally represents architectural images and ideas in an abstract manner, and is geared to an educational setting oriented to the training of architectural technicians. Clearly the choice of computer system and software is as significant a decision as the development of the studio curriculum itself, references chosen or design methods presented. Additionally, the number of workstations must be adequate for the intense demands of the studio throughout the entire design process. Graphic systems for the architectural studio must not become end products in themselves, involving long periods of learning, or artificial means of working.

INTEGRATION INTO THE DESIGN STUDIO

Students, many of whom had no computer experience, were introduced to and learned about the qualities of the CAD systems on a "need to know" basis as part of the design studio experience. Ultimately, their design requirements and responsibilities were no different than any of the other studios in their respective years except that they had access to certain "machinery" that was able to aid them in their design.

Basic design problems (manipulation of elements, spatial sequence, etc.) were given to the students to work out on the computer with the 3-D software. Also, analysis and simple documentation projects of significant spaces in the area (courtyard of the Cloisters, central hall of the Frick Museum, new vertical circulation space in the Museum of Modern Art, etc.) were required. In the third year studio which focused upon precast concrete design, students were asked to use the ability to create object libraries and were asked to create three dimensional "building block" elements that were appropriate to precast concrete technology. The building elements were then assembled in numerous ways to study both the implications of precast concrete technology and to see the design consequences of alternative arrangements of building parts. Students could literally, in a three dimensional world, build and assemble
precast components. Through the fulfillment of these assignments and reference to the manuals facility with the three-dimensional modeling software came with about 20 to 40 hours of use. Ease of use with the paint software required an additional time commitment of 10 percent. (The range of time required to learn the system varied with the abilities and background of each student.) It should be noted that very little time was allocated specifically to "learn the system" and students were graded on their design and analysis projects according to traditional criteria.

In the studio, students proceeded from three-dimensional modeling and developed alternative designs at the site, building, and room scale. Multiple views and perspectives of the buildings and spaces were part of the required presentation throughout the semester. Specific views were developed using the color palette which provides 16 colors at a time from a choice of 254,000. Alternative color schemes were analyzed and selected.

**EVALUATION**

The structure of three-dimensional modeling software is closely linked to the formal design issues long associated with architectural design. The computer can therefore be an important generative system for the systematic exploration of formative ideas and interpretations, organizational concepts and parts. Geometric concepts such as repetition, translation, reflection, symmetry are all part of the vocabulary of three-dimensional modeling and spatial design. Architectural concepts such as additive and subtractive, symmetry and balance, progressions, transformation, configuration patterns, units to whole are also intrinsically tied to the three-dimensional graphic system. By studying many formative ideas the designer begins to choose the formal result and sees the manner in which differing building configurations generate radically different building types.

The introduction of computer-aided architectural design into the architectural curriculum has resulted in many questions being asked, many of which remain unresolved. Those unfamiliar with current computer graphics capability tend to expect a highly mechanized architecture to result or an architecture whose only determinant is technology and building systems. Others see computers which may circumvent traditional architectural skills, attitudes and philosophies as anti-craft devices. At best the new computer technology is seen as yet another special interest which influences the architectural curriculum such as energy conservation, social issues, historicism, etc. As we have undertaken computer graphics based design studios we have asked the following questions, and based upon our experience thus far suggest the following:
a. Does the highly structured graphics system constrain architectural solutions, resulting in unnecessary uniformity? Are the characteristics of microcomputer graphics only useful in a select types of architectural problems?

Rather than mask the individuality of the student work, the computer systems encouraged a wide variety of design concepts. Students clearly stated that they did not believe the computer hampered creativity. In fact, they found that the computer, once it became a familiar tool, was no more restrictive (and less restrictive in some cases) than the traditional parallel rule and T-square. The new capabilities of the CAD/Graphics systems, combined with a fascination for the technology itself, resulted in an enthusiastic student involvement. Once the operational characteristics of the computer are understood and the software becomes second nature, students felt a confidence in their ability, and a sense of special accomplishment in a new area.

Clearly one of the most powerful characteristics of the computer is its ability to simulate repetitive elements, spaces, or objects, which are attributes of all architectural situations. However, the computer has the added ability to readily develop variations upon a repetitive field. Although current software has the capability to generate complex curved elements or spaces (a facility employed by some students), many students also utilized the computer graphic system to create seemingly complex forms generated through repetition and translation of simple elements.

b. Does the computer encourage or discourage the generation of alternative design concepts?

The computer allowed students to choose from many more alternative designs than in a traditional design process. The speed with which new designs can be drawn and tested make evaluation and selection easier, thereby encouraging a more thorough search for good design solutions. Few students worked in a linear lock step fashion, starting with a single idea/solution and carrying it through the semester. Most designs were developed through the creation of many alternatives from which the ultimate design approach was chosen.

Once alternative directions were selected, variations on a theme were easily and rapidly explored. And finally, because the time involved in generating these alternative was relatively short students (especially beginning ones) felt less apprehensive about modifying their designs. The "feeling of ownership" did not have time to take hold.
c. What is the "start up time" required by students to become sufficiently familiar with CAD/Graphics in order for it to become a useful aid in the design process?

As mentioned above, the three dimensional modeling capabilities of MegaCadd Design Board Professional was mastered on a need to know basis, requiring a time commitment of 20 to 40 hours. Facility of use with the "paint" software required less than four additional hours of use. The two dimensional software system "AutoCAD" required over one hundred hours of use to achieve speed of application. The easier the software is to learn, and the more closely it parallels the way architects think and design, the more likely it will be effectively used in the design studio.

d. Are there elements and/or levels of accountability in design that are more easily integrated into, or left out of, a design studio when the CAD/Graphics capabilities are introduced?

The study of color in architecture, often ignored in design studio or dealt with in a minimal manner (and often limited to the color of available pencils or magic markers) can be easily integrated into the design process with the software and hardware used. The students were able to create, evaluate and propose a variety of detailed designs which considered color as a fundamental property of the built environment as they selected from over 254,000 different colors. Evaluation of different color schemes could rapidly be made as the students were able to "key in" different palettes of color and could view different color schemes instantly without having to redraw the designs. Different palettes could represent different material selections or different colors of the same materials. Finally, as a by-product, students learn about color theory because they create their individual palettes as mixtures of primary colors.

The three dimensional CAD/Graphics capability includes areas of architectural design which have often not been part of the traditional design studio. The computer treats the design as a "whole." Students can no longer design only in plan or only in any other single view. The computer forces students to think of the entire building and the relationship of every part of the building to every other part. Students can now be held accountable for a much more accurate and responsible simulation of the building (without any additional time commitment for production of drawings because the computer can generate multiple views very quickly.) Students very rapidly started to "think three-dimensionally" in a way that made the building design more real and more exciting. Detailed issues of site plan, elevation, building organization, etc. are all viewed in the context of one centralized computer model.
Designing and evaluating architectural proposals through realistic, eye level vantage points illustrated the physical environment as a series of places and events, rather than limiting the design exercises to the study of abstract or functional relationships.

The layering capability of graphics software is a powerful tool for the illustration and development of the analytical aspects of architectural design. It permits the viewing of each of the many faceted characteristics which collectively form architecture. Although initially considered necessary for apportioning drawings for construction documents, layering systems can also illustrate unique and interactive formal or ordering aspects of architectural projects. Layering permits the study of unique building attributes as well as the study of the interaction between many building characteristics or technologies.

e. Does the interactive 3-D software increase the students understanding of spatial relationships, or is the computer architectural model more abstract than conventional design media?

External studio jurors from the architectural profession, during final semester presentation, were particularly impressed by the students' understanding of the three dimensional characteristics of their work, the development of building character/elevations, and diversity of student approaches to the design problem. Although less technically complete than highly rendered presentation drawings, the multi-view capability illustrated the buildings in a more complete and realistic manner. The simulation of the building as a "world to be visited," rather than as rendered artwork, was a fundamental change in the character of the final review and its discussions.

f. Does the traditional (generalized) order of the design process, moving from the general to the specific, change as a result of 3-D modeling?

Based upon our survey of students opinions: The computer was not an effective "thinking" or abstract conceptualization tool. It did not dramatically change the traditional design sequence of moving from the "general" to the "specific." The technical aspects of the students work were not more fully development than the work of other studios.

g. What (if any) traditional design techniques, media and processes best complement microcomputer CAD/Graphics systems?
The need for small freehand "thumbnail" sketching did not change. The familiarity and personal nature of small sketches, and interrelationship between "hand and eye," as well as the visual thinking characteristics of the small freehand sketch, are not comfortably simulated by the computer system. Of course paper and pencil is always available for recording ideas and concepts.

h. What are the pedagogical implications of attempting to integrate the computer into the architectural design studio?

In the studio where the entire drawing presentation was computer generated, final design review discussion was focused on issues of design rather than graphic presentation. The computer homogenized the monochromatic graphics output leaving "naked" the design will all of its good and bad points. There was no opportunity for student with poor building designs to "get by the system" with beautiful, but unrelated, two dimensional graphics. Conversely, the drawings were clear and their diversity was easily communicated to visiting critics who were initially unfamiliar with the projects.

CAD/Graphs can be viewed as a "word processor" for architecture which permits easy and fast changes of design proposals. Traditional studios "cut off" the design process one to two weeks before the actual end of the project to allow time for the production and presentation of drawings. With the CAD/Graphics systems, the design process continued until two days before the final presentation. The cutoff was determined only by the availability of the ink pen plotter or reproduction time for color photographs.

The design process was a more continuous and fluid experience, without time taken out for the drawing of intermediate presentations. In a new way, the design process was continuous, and the final product always immediately accessible.

THE EXPERIMENT: PART II.

The development of CAD/Graphics studios is a continuing one with new and changing questions and issues. Clearly, a greater "sample" over a longer period of time is needed in order to test the accuracy and universality of our data and information.

Additional problems arise as a result of the CAD/Graphics studios:

- What happens to those students who have had an opportunity to use CAD/Graphs systems and want to continue with its use, but no longer have access to a system?
- What are the resource implications (time, space, money) of ever increasing CAD/Graphics capabilities in an architectural program?
- As the capabilities and "inclinations" of the CAD/Graphics systems become increasingly familiar, is there a long term tendency toward a particular set of design solutions?
- Will the type of student attracted to architecture change as a result of an increased reliance (either real or perceived) on computers? And, therefore, will the profession change?
- Do the integrative possibilities of CAD/Graphics, technical analysis, data base systems, etc. so change the way the professional architect practices, that the traditional design studio will become obsolete?
- Does the fast pace of computer technology development suggest that whatever the schools do now will be obsolete when current students enter the profession?
- As entry level "drafting" positions in architectural firms diminish, will architectural education graduates have the increased skills and knowledge to effectively enter at the "middle level" of the architectural profession.

It is the impact of the new media upon the way we view, model and evaluate our architectural world that may change architecture and architectural education. Because computer graphics adds new, varied and extremely powerful tools to the design process, and permits the modeling of architecture in fundamentally new ways, it is a capability which must integrated into the mainstream of studio education. As any new tool or language, its value to a student only becomes clear through use in a productive context.