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ACADIA

ASSOCIATION FOR COMPUTER-AIDED DESIGN IN ARCHITECTURE

FORUM: Computer Literacy

by Yehuda Kalay
SUNY Buffalo

FORUM *is intended to be a regular column in which ACADIA members can discuss relevant topics and issues. This month's column addresses an area widely discussed during the third ACADIA workshop: "CAD Education & Computer Literacy." The ideas stated in this column are the opinion of the author, and do not necessarily reflect the beliefs of ACADIA at large. Hopefully this prologue will lead to future discussion.*

Now that most schools of architecture are finding the means to acquire at least some computing hardware (a formidable task, but one in which ACADIA can help very little, if at all), two important tasks confront us on the academic front:

1. Defining the nature of CAD education in architecture
2. Providing the means to accomplish it

The first task, if I may put it bluntly, is "now that we have the hardware, what do we do with it?" In other words, how can we utilize the resources that were (are) so hard to obtain to their fullest extent? This question includes, but is not limited to, the definition of computer aided design literacy. It also ponders on how we should train CAD specialists, and even how we should utilize these graduates to perform research in CAD that will forward the state of the art.

The second task is coupled with the first one: those of us who have begun pondering these questions realize that one of the major bottlenecks in CAD education is the scarcity of quality software. Its development is time and resource consuming, and no single school can, on its own, develop all the software it could use. A mechanism for exchanging software, suggested by John Wade, is extremely desirable: direct, personal software exchange opportunities; coupled with detailed experience case studies of their application in CAD education, will be most beneficial to our cause.

We should also remember that ACADIA is not an educational organization exclusively. Involvement of practicing architects in its operation will be beneficial to both parties; the practices could benefit from continued educational programs, while the academia could benefit from "real world" experience and expectations.

In my opinion, the development of a curriculum for CAD education in architecture (along with the means to accomplish it), the communication of research between our members, and the extension of our activities to practicing architects, are the major tasks the president of ACADIA should address.

I see the three components of CAD (education, research and real world application) as parts of one whole. If we believe that computer-aided design can benefit the profession of architecture (otherwise we would not be pursuing it), then it is we, ACADIA, that can and should do something about it.

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Membership List

The membership list contains 70 members as of December 18, 1983. Members of the Steering Committee are indicated in bold letters.

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Claire Bassett	Butler County C.C.
Michael Blake	Carnegie-Mellon Univ.
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Software Exchange

The Architectural Research Centers Consortium (ARCC), with the help of a grant from the Design Arts Program of the National Endowment of the Arts, is undertaking the organization of a Designers Software Exchange (DSE). DSE will act as a clearinghouse for public domain software and software donations from its members. Those who submit software will automatically become members with free access to a select number of programs from its library. Others may join by paying a membership fee and a software fee for each program requested. Any school interested should contact:

Prof. Harvey Bryan
4-209 Laboratory of Arch. & Planning
Massachusetts Institute of Technology
77 Massachusetts Ave.
Cambridge, MA 02139

Workshop Abstracts

Editor's note: The following three papers were presented at the third ACADIA Workshop at the Ohio State University in October. Since they were not included in the October Newsletter, *they have been reproduced in this issue in their entirety.*

Graduate Evaluation

How Ohio State CAAD Graduates/Students Evaluate and Value Their Training
by Richard L. Nitzsche

The Graduate Program in Computer Aided Architectural Design at The Ohio State University was established five years ago and graduated its first student in 1979. It has since graduated another five and four more are scheduled for graduation this year. As more CAAD faculty positions have been established, the program was allowed to grow substantially this past year.

The goal of the program is "to produce young architects who, in addition to their professional level of design skills, are capable of managing the CAAD activities of a progressive professional firm." Since its beginning, the program has relied heavily on feedback from its current students as well as graduates for improvements aimed at achieving its goal. The findings presented here resulted from a survey conducted by the author. The survey consisted of informal interviews and covered the six graduates and the four second year students currently in the program.

In spite of the congested design market, our graduates have had no trouble securing multiple offers, and commensurate responsibilities. They express optimism that those responsibilities will expand as their experience and their firm's involvement in CAAD warrants. The compensation, acknowledged to exceed that afforded "traditional" graduates by over 50%, corresponds well with their assigned responsibilities and is progressing at a pace that compares nicely with their perceived skill and leadership development. Their consensus that good architectural software is scarce, has magnified their sense of purpose and contribution to the profession.

Of our graduates, two are employed with architectural firms and another with Intergraph Computer Corp. The remaining three are associated with academia: one in pursuit of a Ph.D. and the other two in junior faculty positions. All expressed sincere satisfaction with their preparation and the manner in which it was conducted, particularly in the area of advanced graphics. Their Computer Science background, though not quite that of the average systems programmer/analyst, has aided credibility and interaction with non-architectural professionals in computing. The few remarks regarding former curricular shortcomings were generally mollified in light of subsequently introduced improvements.

That CAAD curriculum, a result of both solicited and unsolicited consultation between students and the Program Director, has four major components:

1. The Architectural Core: 39 quarter hours of studio, seminar, professional practice, techniques, and electives.

2. The Computer/Information Science portion: 28 quarter hours of topics ranging from Linear Algebra to Systems Programming to Computer Graphics Systems.

3. The Computer-Aided Architectural Design: 23 quarter hours of CAAD studio, CAAD seminar and CAAD readings.

4. The Thesis: students are encouraged to choose a topic/project that contributes to systems in place or under development in the CAAD lab.

The Architectural Core provides what is typically found in the fifth year at other 4+2 programs, a generalist approach to architecture and an important opportunity to associate with peers who have other interests. The Computer Science coursework is also valued for its generic presentation of topics at an introductoryintermediate level. Involvement with non-architects in Computer Science team projects have built the confidence of our students in their own competence. Through the CAAD studios and the Thesis, these topics are synthesized and tested. Interdepartmental communication in large institutions being typically inadequate, the most current information on the quality and content of courses outside our department comes from our continuing students.

The marriage of two of the most time intensive majors on campus in addition to the 50% assistantship (20 hours/week) that the surveyed graduates held, demand motivation and commitment. Academic advisors' firm stands against overloaded quarterly schedules are appreciated, ... eventually. This generally means that none expects to graduate in the typical two academic years (no one has yet) and some anticipate up to three years.

The students want and need the integrated experience of the fifth year and express misgivings regarding the potential for isolation in the sixth year. A holistic attitude towards architecture exists and reflects the students' concerns for the entire field. The promise of the professional M.Arch degree has reinforced their belief that architects are the best people to address issues in CAAD and they have shown a desire to expand the topics addressed beyond graphics. The thesis, for many, is viewed as the greatest opportunity to effect this expansion, in spite of the challenge of such an opportunity.

That these students love to design should be of no surprise. Concern for the quality of design is paramount among them. Dissatisfaction with the state of the profession has served as another prime motivation. Fashionable excesses and the establishment of architectural cults account for much of this. Faced with that situation in 'traditional' architecture, many students are seeking more noble means toward Architecture. Those in our program have found them in CAAD. The promise that CAAD offers to the development of substantive approaches to design and architectural problem solving has, for these students, proven irresistable.

Computers and Design

The Computer and Design at North Carolina State University
by Ken Pittman

The computer was first introduced to the School of Design in 1976 soon after the school met John Tector, an architecture faculty and now member of ACADIA. The introduction came in the form of a DEC LA-36 terminal with a 300 baud acoustic modem that made use of the Triangle Universities Computing Center (TUCC). TUCC is a facility located in the Research Triangle Park twenty miles from Raleigh and shared by North Carolina State University, The University of North Carolina at Chapel Hill, and Duke University. The TUCC system supports academic, administrative, and research computing at all three universities primarily with batch processing. Each university maintains its own computing center where public printers, plotters, and other devices could be accessed through the TUCC system. Early applications in the school on this system were the batch processing of perspective plots, using a perspective routine implemented by John and the use of canned programs such as SYMAP and SYMVU. Hand digitizing, slow turn-around times, and walk across campus to pick up plots were all part of what computing was about in those early times.

However, by the end of 1979, John had convinced the School of Design administration that the school needed its own graphic output facilities. The next semester the school acquired a Tektronix 4010 display terminal and a 4662 plotter. During this same time, plans were being made for a facility in the school that would support architecture, landscape architecture, product design, visual design, and design fundamentals programs with the technical tools of design. The school had for some years maintained a shop facility (woods, metal, plastics) and a media center (photograph, printing, video), both of which are heavily used by students and faculty. The new center for the school would house the school's computer equipment, provide space for a structures lab, and maintain a collection of other devices for the exploration and simulation of the environment (a sun machine, planimeters, digital thermometers, wind meters, soil sample kits, etc.).

The Environmental Simulation Laboratory, as the center was named so as not to limit the functions to only computers or structures or other devices, began operation in the fall of 1980 with a full-time staff position, the two terminals, the one plotter, and four known users. The lab began to attract and recruit other users in the first week through orientations and other means. A group of graduate landscape students were invited to use the perspective routines in a studio project involving part of the campus. This first experiment with using the computer was a success to the extent that batch computing is successful in any design process. It became clear that the batch job was useful for the display of design alternatives but limited in its ability to help in process of designing, mainly due to the lack of a graphic input device. Our tasks that first semester were to make the perspective routines interactive and to write an interactive program that used the 4662 plotter as a digitizer.

In the spring semester that followed, John conducted a computer graphics class with seventeen students, the Landscape program had eight students in a computer cartography class, and we involved a landscape studio of twenty graduate students for six weeks in land analysis techniques on the computer. The demand on the two terminals clearly demonstrated a need for more access to computing resources. The funds to acquire more terminals were simply not available through state sources at the time and the applications on a batch system were not exciting enough to demand a high place among other priorities.

Opportunities for projects that would generate some fund for the lab became a necessity for providing expansion of the facilities. There were two projects that came to the lab that summer. The first was a study of the physical elements on the Research Triangle Park that included a data base of the park's natural, manmade, and legal parts. While some of the processing was done on our system, all of the digitizing, analysis, and plotting was accomplished on a Comarc system at a state-operated facility known as the Land Resources Information Service. This project not only provides exposure for the school but also gained a gift to the lab of our first microcomputer and expands service to TUCC. The second project involved working with a local landscape firm in the production of computer generated perspectives of planting schemes at the new North Carolina Museum of Art. This project was another platform of exposure for the school and for local practitioners and the use of computers in design.

The acquisition of the first Apple II computer opened many doors that had previously been closed. The relatively inexpensive cost of learning about computing was attractive to the school administration.

By the end of the 1981 fall semester two more Apples were purchased, this time with state funds. The students were more motivated in learning about computing because the Apples were so much more direct and interactive than the TUCC system which meant that a student could become familiar faster and more independently. This meant that for the next semester's classes not only was access increased by the number of stations but less time was required to understand the material presented in class.

The lab has continued to grow through both state funds (used to purchase more work stations) and project work (used to acquire peripherals for graphic input and display). A recent allocation of state funds, provided to meet the computing needs has given the lab capabilities that we could have only dreamed negotiated for the purchase of equipment and operation of the lab with targetted industries and organizations, a technique long used by the Schools of Engineering, Textiles, and Agriculture at North Carolina State University.

In addition to those items previously mentioned, the computing facilities in the Environment Simulation Lab now include:

- 11 Apple work stations
- 1 Sage IV multiuser computer (1024 w/18 meg hard disk)
- 1 Vectrix 384 color display terminal (672x480 resolution, 512 colors)
- 1 Houston Instrument Digitizer (36"x47" surface)
- 3 Hipad digitizers
- 1 Apple Graphics Tablet
- 4 printers (2 color printers)

Many paddles, joysticks, trackballs, and cards for the Apples that perform special functions like superimposing Apple graphics onto video tape.

The lab has been organized to meet the needs of teaching and research but an overall policy that everything is available to everyone with no piece of equipment reserved for a single user in an inaccessible place has been a key factor in the success of the lab in meeting the needs of students for computer literacy. The las has one full time director (Ken Pittman), four teaching assistants (one from each program). The lab operates 15 hours per day. An active Apple user group on campus and other similar labs on campus with an interest in computer graphics keeps an ongoing exchange of in-house developed software available. For mor information, or questions, call:

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CADIA at Michigan

by Theodore Hall
University of Michigan

Abstract

The Architecture and Planning Research Laboratory (APRL), at the University of Michigan, has been investigating computer-aided architectural design for over 10 years. Funding has been obtained through sponsored research contracts with several architectural-engineering firms. Since 1980, the APRL has been sponsored in part by the Construction Engineering Research Laboratory (CERL), of the United States Army Corp of Engineers, in the development of a Computer-Aided Engineering and Architectural Design System (CAEADS).

Concept

Inventing a system for computer-aided building design is a design problem in itself. The results are strongly influenced by the initial concept of the system. Before you begin, you must have a clear idea of the meaning of the word "design".

Drafting systems have been commercially available for over a decade. For the most part, they have been conceived as tools for producing drawings. As it has become obvious that there is more to building design than putting lines on paper, some of these systems have been upgraded to include some basic analysis capabilities.

The CAEADS project, at the Architecture and Planning Research Laboratory (APRL) of the University of Michigan, sponsored by the Construction Engineering Research Laboratory (CERL) of the U.S. Army Corp of Engineers, has taken the opposite approach. Building design is a decision-making process. Decisions must be based on some type of meaningful analysis. Therefore, a system for computer-aided building design must have broad analysis capabilities. The system should not be based on computer graphics, but on computer modelling. If the building is properly modelled, the production of drawings is only one of many uses for the model.

Obstacles

Many engineering analysis programs have been developed over the years. However, most of them are "stand-alone" programs which deal with one aspect of architectural engineering and exclude all others. Integrated analysis has been nearly impossible. For example, the Corp of Engineers has an energy program called BLAST (Building Loads And System Thermodynamics), and a cost-estimating program called ABES/CACES (Automated Building Estimating System/Computer Aided Cost Estimating System). Both programs base part of their analysis on the wall materials used in a building. Presumably, both programs analyze the same walls. Yet each program has its own materials library, from which the walls of the building must be selected. The two libraries are incompatible. Therefore, the process of assigning materials to walls has to be repeated for each type of analysis, and in the end there is no guarantee that the materials assigned in BLAST are consistent with those assigned in ABES/CACES.

Another problem with many existing analysis programs has been the difficulty of gathering the data. They have been implemented as "batch" programs which attempt to deduce a building design from a stack of punched cards. Even if the punched cards are replaced by lines in a text file, the entire input process is tedious and highly error prone.

The goals of the CAEADS project are to provide:

1. a "user-friendly" input method for describing a building design to a computer;
2. integrated analysis of the many systems which must work together to produce a building;
3. an easy way to modify the design, based on the results of the analysis, and to repeat the process until a satisfactory design is achieved.

Implementation

The two most important issues to address are:

1. How does the user describe the building to the computer?
2. How is the building description stored?

CAEADS is being implemented as a system of interactive graphic menu-driven subsystems, which communicate through a relational database in which the shape of a building element is just one of several possible attributes.

Floor plans are entered in the SKETCH subsystem[4], which allows walls to be sketched as a network of line segments. Each line segment represents a particular wall type, and therefore implies a certain thickness, R value, cost per square foot, etc. Room polygons are generated automatically by applying the wall thicknesses to the network. (By default, interior walls are centered on the network lines, and exterior walls are flush with the outside face. The designer may change the offset of any wall at any time.) Floor areas are calculated automatically from the room polygons. Using floor-to-floor heights and floor-to-ceiling heights, the two-dimensional room polygons are extruded into a three-dimensional solid polyhedral model, from which surface areas and volumes can be calculated. Of course, pictures of the model can be drawn at any time, from any viewpoint.

By manipulating the shapes of walls, doors, windows, and furniture, the designer automatically manipulates all of the non-shape attributes associated with them. This data is available for many kinds of analysis. CAEADS includes an interface program which produces an input deck for the BLAST program. There are also analysis programs for lighting, firesafety, handicapped accessibility, quantity take-offs, and cost estimating. An interface to STRUDL (a structural analysis program) is nearing completion. Since all of these programs retrieve the required data from the CAEADS database, it is no longer necessary to redefine the building for each different type of analysis. The CAEADS database insures consistency in the building attributes passed to the various analysis programs. If thermal considerations lead to a change in wall material, there will be an impact on the structure, cost, and firesafety of the building.

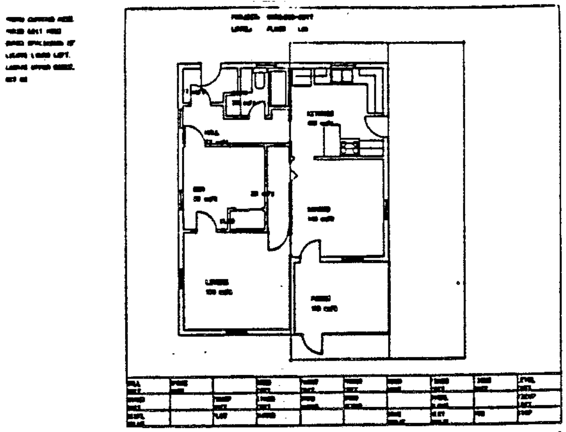
Future Development

The relational database was chosen because it offers great flexibility. New attributes can be added as new analysis programs are developed, without having to rewrite existing programs.

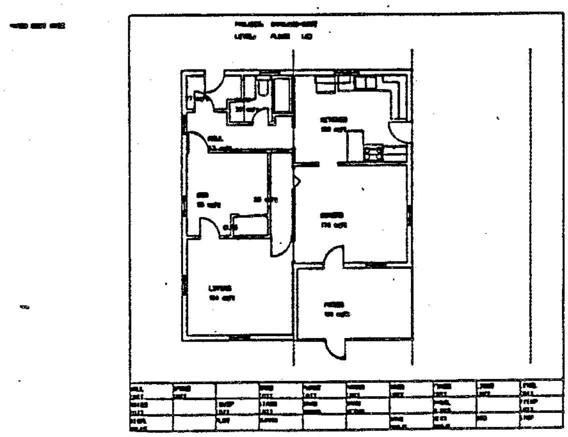
Over the years, the Architecture and Planning Research Laboratory has developed its own geometric modelling relational database system - ARCH:MODEL[2]. It includes a relational editor, a geometric editor (2-d and 3-d), and FORTRAN subroutines which make the operations of both editors accessible to application programs. In ARCH:MODEL, geometry is treated as a shape attribute of an object, and may be included in relations along with an object's other attributes. This makes it possible to draw relations. However, ARCH:MODEL is very dependent on the MTS (Michigan Terminal System) operating system, and therefore only partially transportable.

The Boeing Company has also developed a relational database system - RIM[1]. It is more transportable than ARCH:MODEL, and there are versions of RIM running under several different operating systems. However, it has no geometric modelling capabilities, and is less versatile than ARCH:MODEL.

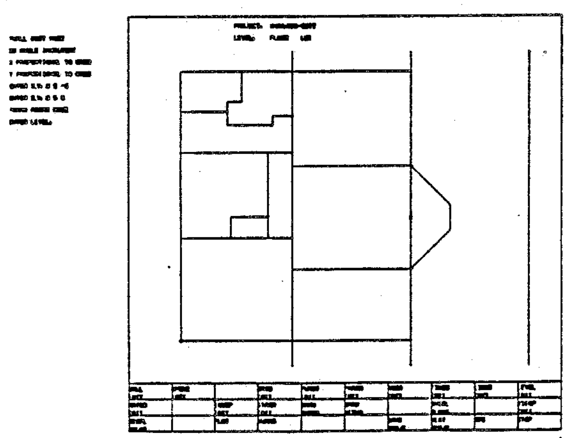
A version of ARCH:MODEL'S geometric editor is being interfaced with RIM. Future work will probably include more enhancements to RIM, or rewriting ARCH:MODEL to be more transportable, or both.



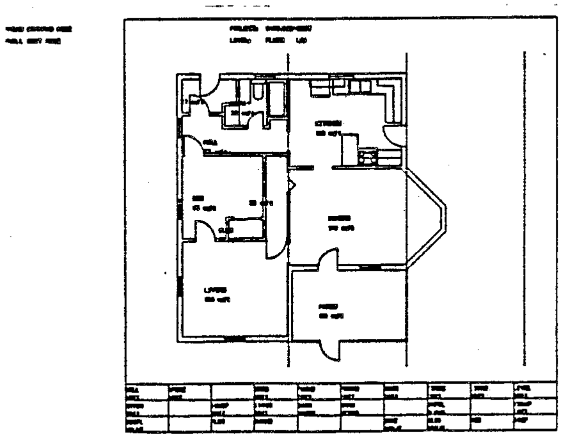
1. The existing rooms and areas are displayed. The spacing of the grid lines is increased from 12'-5-1/4" to 15'-0".



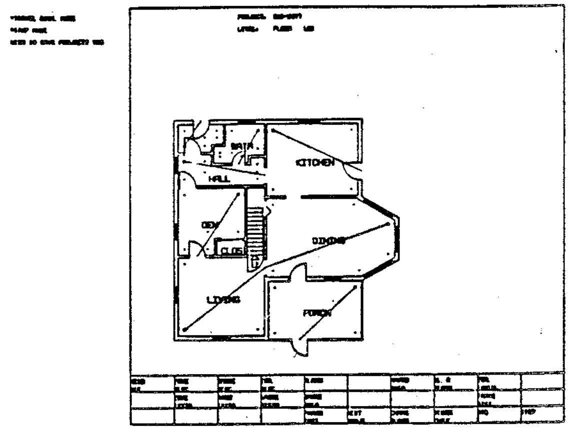
2. The building plan stretches with the grid. Areas are automatically updated.



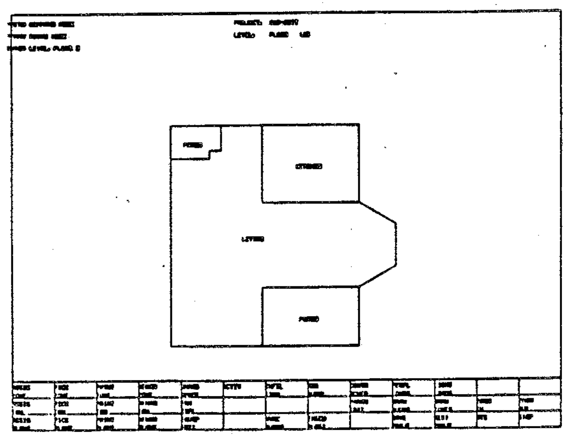
3. The east wall of the dining room is deleted from the network, and a bay is sketched.



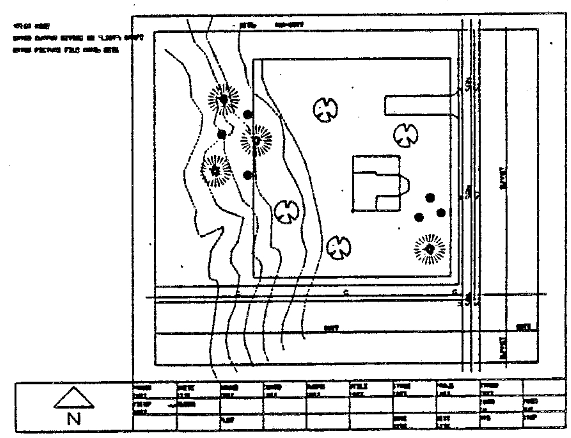
4. The new room polygons are generated automatically. Areas are updated.



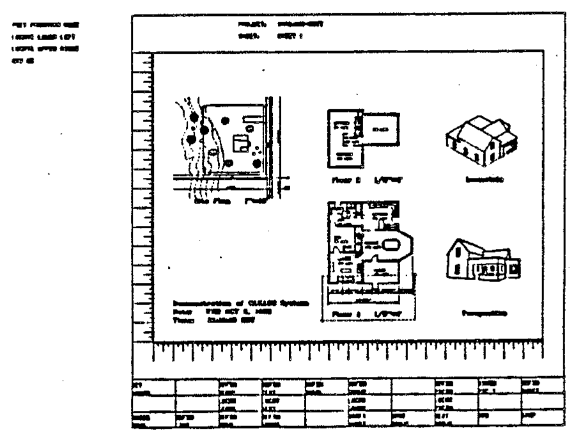
5. Smoke and fire barriers are defined. Maximum travel distances across rooms are checked.



6. Rooms are assigned to H.V.A.C. zones. Equipment is selected.



7. The building is located on the site, along with contours, trees, streets, utilities, and surface types.



8. Images are collected from various stages of the design process and arranged on sheets. Titles are placed interactively, using user-defined fonts.

It is anticipated that more types of analysis will become available to CAEADS, either by writing interfaces to existing programs or by writing new programs. The relational database should make this process much easier, since programs can share the necessary data through the CAEADS database.

The College of Architecture and Urban Planning at the University of Michigan hopes to offer a studio course in computer aided design in the Fall of 1984, using CAEADS. The Army Corp of Engineers plans to make computer aided design available to all of its district offices. It is hoped that CAEADS will be moved from UM's mainframe computer to a personal workstation in the near future.

The CAEADS system should become more versatile as new elements are added to the project-independent database. A sort of electronic "Sweet's Catalog" should evolve, from which CAEADS will select the necessary items to build a project-dependent database for each specific design.

REFERENCES

[1] Boeing Commercial Airplane Company: "User Guide: RIM 5.0", February, 1982.

[2] Borkin, Harold J., McIntosh, John F., McIntosh, Patricia G., and Turner, James A.: "ARCH:MODEL - A Geometric Modelling Relational Database System", June, 1982.

[3] Johnson, Robert E.: "Economic Analysis", in ACADIA, Vol. 3, No. 1, October, 1983.

[4] Turner, James A., Borema, P. Lynn, and Hall, Theodore W.: "ARCH:SKETCH - An Architectural Plan Sketching Program", July, 1983.

CAD in Arch. Education

by Yehuda Kalay
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ABSTRACT

This paper examines the impact the computer revolution is having on architectural education, in terms of training professionals and the enhancement for the educational process itself. It presents a triad methodology and describes its experimental implemetation for training students in the use and development of computer-aided architectural design tools. At the same time the process utilizes the tools thus developed to increase the intuitive feel of students for the impact and significance of design decisions through generation, representation and evaluation of solutions to design problems.

THE PROBLEM AND ITS SOLUTION

Schools of architecture are now faced with two related fundamental questions when they embark on instituting computer-aided design as part of their curriculum. These questions are (1) how can they fulfill their dual obligation to society as centers for training students in the use of computers for the design of physical artifacts and as centers for CAD research, and (2) what are the components (details) of this effort?

A close examination of these questions quickly reveals a circular dependency that makes them seemingly impossible to solve: in order to train students to function in the future professional environment of CAD we need to know what this environment will look like. The current state of the art, however, leaves much to be desired, and it is safe to assume that it does not accurately reflect the future architectural practice. In order to train students we need, therefore, project a scenario of the future practice that is different from the current one, and develop the tools that will be used by it. In order to do so we need students or staff proficient in CAD, which we cannot have until they are trained...

How, then, can we break this circle and gain a starting point from which to proceed? This is not an easy question to answer, and different schools will no doubt find different solutions. The solution we found at the School of Architecture and Environmental Design in SUNY-AB divides training in CAD into three complementary and mutually dependent parts, which we call the CAD TRIAD: SERVICE, EDUCATION, and RESEARCH, as depicted in Figure 1.

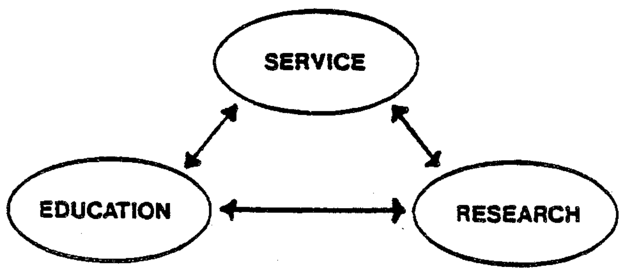

Figure 1: The CAD environment triad

SERVICE

Service is the category that includes the training of students to use computers for designing buildings and other artifacts. It consists of providing students with instruction, the tools needed to practice the generation of solutions to design problems, the representation of such solutions in a computer (in 2D and 3D form), and their analysis according to various criteria.

The reason this category exists despite the lack of adequate CAD tools and a clear vision of the future is inherent in the nature of architectural education. Architectural design can best be taught through practice. That is the reason architecture has been traditionally taught through apprenticeships, much like painting and sculpturing. Architectural studio classes are the modern embodiment of apprenticeship, where the instructor leads a small group of students through design problems focused on selected aspects of the design process. Such "toy projects" introduce the students to the process of design through experience rather than theory (although some topics are still best covered theoretically). The necessary simplification of real world design problems to fit in the condensed time frame in which each project must be completed (typically no longer than 3 months) allows us to simplify the CAD tools we apply to their solution, without compromising too much either the experience gained or the resulting products. For example, a simplified analysis program that provides only approximated, generalized information about the thermal qualities of a building may be quite sufficient for the use of students, whose design errors are far greater than those of seasoned professionals. They can, therefore, be made visible even through a simple program. Such down-scaled CAD tools are available, or they can be developed in a relatively short period of time.

Such tools not only introduce students to the use of computers in the design process, but they also enhance their intuitive "feel" for making the right decisions by providing them with fast, accurate and easily readable feedback on their design decisions. For example, 3D geometric models allow students to examine the spatial relationships between building elements in a manner which is far superior to physical scale models, and much easier to generate and to modify.

The SERVICE component of the CAD environment thus fulfills two distinct functions: (1) it introduces students to the use of computers in the practice of designing buildings, and (2) it enhances the process of learning design itself.

EDUCATION

Education is the category that includes training of students to become CAD specialists who can not only use computers to design buildings but also develop and modify the programs that make it possible.

CAD education thus supports two important aspects of the CAD triad: (1) it trains a cadre of professionals who will be capable of pushing forward the frontiers of CAD, and (2) it establishes a pool of students from which to select research assistants within the school itself. As CAD specialists the students will bridge the gap between architects and computer scientists, understanding the requirements and objectives of one discipline while aware of the potentials and shortcommings of the other. They will be qualified to provide informed advise on purchasing CAD systems by virtue of their understanding the manners by which such systems operate. Once purchased, they can utilize in-house computer systems to their fullest capacity. They can go beyond the "canned" software packages provided by vendors, tailoring existing systems to the particular applications of the office. As potential research assistants they are tuned in to the philosophy of the principle investigators, thereby facilitating better communication within the research group.

The skills that are required in order to become CAD specialists derive from two sources: (1) understanding the design process itself, and (2) understanding the power and the limitations of computers. The combination of these skills provides students with an understanding of the different roles computers can assume in the design process, and how they can be utilized best.

The basic concepts of computing provide students with the understanding they need of the tools they will be using. These include such topics as programming, structured problem solving and computer graphics. A programming course develops the skills necessary to master computers. Structured problem solving, through algorithm design and analysis, encourages a disciplined approach to the design process as a whole. When dealing with computers such an approach is particularly important due to the computer's inability to infer the implicit intentions of the designer unless explicitly formulated. Computer graphics have become the standard means for interacting with CAD systems, due to the traditional way of communicating design between humans through drawings, and due to the ease with which graphic and pictorial information can be disseminated, compared with text and numerals.

In addition to these three basic CAD oriented skills it is also desirable to introduce students to some general mathematical concepts from the domains of search and graph theories, as well as to increase their descriptive geometry skills. Search is one of the major tools used for solving design problems, and was formalized in the last few years by the Artificial Intelligence branch of Computer Science. Graph theory proved to be particularly suitable for representing design problems in computers. For example, floorplans, scheduling networks and manifolds enclosing solid objects have a natural representation through graphs.

Familiarity with the process of design is a skill taught in all schools of architecture, though not necessarily from a problem solving point of view. Hence, after students have been introduced to the basic concepts of computing, the next step is a review of design as a problem solving process. The two essential components of CAD that are thus taught include the generation and evaluation of design solutions, represented as mathematical symbol structures in the computer's memory.

The representation of design solutions in the computer, otherwise known as MATHEMATICAL MODELING, deserves particular attention as it is the most significant deviation from non-computerized design practices. Mathematical modeling is the means by which we overcome the computer's inability to deal directly with physical entities. It provides a set of techniques for representing the physical environment as symbol-structures that are understood by and can be manipulated by computers.

Solution generation and evaluation are mostly task-specific, but some common principles can be derived by generalizations such as spatial location, dissection and shape grammars methodologies, accompanied by quantitative as well as non-quantitative analysis procedures.

A seminar on selected topics in CAD will provide students with case studies that tie all the components together into one whole, prevent them from repeating mistakes, and show them how computers have already been utilized in the process of designing physical artifacts.

RESEARCH

Research is the culmination of all the efforts included in the CAD triad. It sets the orientation and the pace of the school within the general community of CAD educational centers, and fulfills one of the two important obligations of the school within society, the obligation to be an innovator and inventor in the field of CAD. It also provides a constant source of both inspiration and software for use by the other two componenets of the triad.

IMPLEMENTATION

The concept of CAD as represented by the triad has been proposed to and consequently adopted by the School of Architecture and Environmental Design in the State University of New York at Buffalo. Its implementation began there in Fall 1982, entailing new courses (with a restructuring of the curriculum to accomodate them), changes to existing courses, and acquisition of computing hardware.

Four new courses, representing the EDUCATION component of the triad, have been added to the curriculum. They include an introductory course, two advanced courses and a seminar. The introductory course familiarizes students with the basic concepts of programming, the PASCAL programming language and with computer graphics. The first of the two advanced courses teaches the principles of representing physical artifacts and environments in the computer's memory by means of mathematical symbol-structure (in 2 and 3 dimensions), while the second advanced course teaches the principles of generation and evaluation of solutions to design problems. The seminar address a wide range of current issues in CAD.

The SERVICE component of the triad is still in an experimental stage. It provides students in advanced studio classes with the option to use computer-aided drafting as an alternative to manual drafting and modeling, and a variety of excersises pertaining to performance programming, basic design, energy and construction technology courses.

The research component of the triad focuses primarily on knowledge-based, context sensitive CAD systems for use by architects. Spinoffs of this research, sponsored by local A/E firms, have produced the drafting tools used by the SERVICE component. In addition, research has been undertaken in geometric modeling, man-machine interface, color graphics and various Artificial Intelligence aspects in CAD concerning visual perception and image understanding.

CONCLUSION

The components of the CAD education triad represent three aspects of the same concept: the use of computers to teach students how to use CAD for the design of physical artifacts as well as the design of the CAD tools themselves. It is made feasible by introducing a strong sense of gradation between the three components: lowest for service, higher for education and highest for research. Such gradation does not imply differential quality of the tools, but rather to their scope and generality. The "toy project" nature of studio classes in architecture allows the successful utilization of "toy CAD" systems, designed by the EDUCATIONAL and the RESEARCH components of the triad. RESEARCH also provides more general and more sophisticated tools for the purposes of the EDUCATIONAL componenet, and draws its strength from its graduates.

The success of implementing the triad is still too early to be determined. It has been well received by both the students and the faculty, the courses notoriously over subscribed. It is the goal of the School to expand this CAD environment and enhance its components via the circular re-inforcments of the triad, thereby fulfilling both its missions as part of the higher-education establishment to train professionals and to advance the state of the art in the discipline of Architectural Design.

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We hope that this and future issues of the *ACADIA Newsletter* are of value to you and others in your environment. ACADIA, the Association for Computer Aided Design In Architecture, was formed in October 1981 for the purpose of facilitating communication and information exchange regarding the use of computers in architecture, planning, and building science. ACADIA activities include the distribution of the *Newsletter* and the organization of annual workshops. Membership dues are set at $15, which may be sent along with the attached form to:

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