Integrating Computer Aided Design into Building Construction

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ABSTRACT

A research and development grant was awarded to the Graduate School of the College of Architecture at the University of Houston by a Texas-based building and construction corporation to study the integration of computer aided design into the building process. A team of University faculty and graduate students studied the organization of the firm with respect to functions that could be automated. Its determination was that by utilizing an integrated data base, with information to be extracted from the computer generated drawings, the entire process of bidding and building a structure could be made more efficient and more cost effective. The research team designed a system in which cost estimating could be done directly from the drawings. As drawings were modified, new reports could be automatically generated. In addition, once plans were drawn, a program written by students would automatically generate elevations of wall panels to be sent to the construction department for its use, and it would also generate material reports. The project manager determined that the productivity of a project more than doubled in the first two months after the system was implemented.

INTRODUCTION

It has been estimated that in the AEC industry, slightly less than 20 percent of automation budgets are spent on computer software, as opposed to more mature markets, in which about one-third is spent on software. Buying existing architecture, engineering, and construction (AEC) software has been a difficult task, because of lack of availability and problems with integrating existing software packages. Though availability of suitable software is increasing, practitioners have often had to settle for third-party software which is less costly and less time-consuming than developing their own. [1,2] To have the skills to modify and enhance existing computer software in today's world is an asset to a new graduate as well as to the profession which he enters.

Taking advantage of its location in a large urban area, some members of the faculty of the College of Architecture at the University of Houston have turned to area practices to examine and assess how the computer is being used. Historically, the Harvard University business faculty was set up in 1919 as an alternative to the apprenticeship method of teaching, and it was here that the case method of teaching emerged. Recently, there has been considerable attention given to the case method in other disciplines including architecture. [3] As an additional teaching strategy, the idea is to use a concrete experience for facilitating the testing of concepts by students, teachers, researchers, and practitioners of diverse disciplines.

As a form of case study, students in the computer program at the University of Houston College of Architecture sought to study how firms integrated the computer into various aspects of the AEC practice. The experience of analyzing the capabilities of an existing computer aided design and drafting (CADD) package and modifying it to better the product for a particular application was felt to be a valuable exercise. As an applied research and problem-solving activity, it forces the student to be aware of how the design process is approached, be it manually or otherwise. This examination was also perceived to be a worthwhile skill for the graduate to take into practice.

PROJECT BACKGROUND

A unique set of circumstances presented itself to provide interesting exploration of the computer in the architectural, engineering and construction (AEC) industry from the standpoint of practice as well as that of education. Located in Austin, Texas, one of the fastest growing cities in the US, are the corporate headquarters of Nash Phillips/Copus, Inc., the largest privately owned homebuilding company in the U.S. Some one hundred and fifty miles east of Austin is the University Park location of the University of Houston, a major urban university dedicated to creating a computer-intensive environment for all its students. Its College of Architecture instituted a computer program in September 1983.

In its forty years of existence, the homebuilding firm has opened offices in eight cities, and as part of its expansion plans, it is pursuing locations in seven additional cities. The firm has the full scope of AEC activities. Its realty department locates land and works with the architecture and planning department to determine its fate. Working in concert with the engineering department, the architects study design solutions and produce drawings that are forwarded to the construction department, which is owned by the firm. The realty department then markets the properties.

In the fall of 1983, the firm's data processing manager made the decision that the architecture and planning department could benefit from a CADD system. With 1984 revenues exceeding $400 million, and a goal of over $500 million the following year, the firm had projected it must build over 5,000 units in 1985. Its management hoped that by automating the design process, the ambitious production rate could be met. [4,5]

Meanwhile, the College of Architecture at the University of Houston had obtained, through a research and development grant from Prime Computer, Inc., a 32-bit minicomputer with CADD software that had been developed for mechanical engineering. The vendor was seeking assistance in enhancing the software for architectural applications. Seizing this as a means to get started with CADD, the College viewed the venture as an opportunity not only to provide a meaningful set of learning experiences, but also to engage in research activities.

CADD SYSTEM TAILORED TO ARCHITECTURE DEPARTMENT

In the spring and summer of 1984, a small group of graduate students worked with the architectural planning department of the homebuilding firm to maximize the efficiency of the CADD package in the design and drafting phase of its use. Initially, exercises ranged from the creation of libraries of symbols to the writing of macro commands. By the linking together of existing commands of the program language, the user was given the capability to achieve, with a single command, a task which previously required a series of several commands.

As is common in CADD, as well as other applications now, the system in use by this group is one driven by a menu which offers a selection of commands by probing a tablet as opposed to, or in addition to, typing the commands at a keyboard. As the students familiarized themselves with the capabilities of the program, they analyzed the standard menu with respect to adjacencies and functionalities.

At an even deeper level, the students assessed the menu with respect to naming conventions, layering conventions, intelligent line and text types, system defaults, and attributes which could lead to extraction of information from the drawings for other purposes. A new menu was designed by student Ross Davis. Davis also wrote a manual for the documentation of the menu and the training of new system users. By the end of its first year, the firm had acquired three more workstations and had traded its computer for one with more processing power.

Anthony Salvaggio, head of the NPC Architectural CAD System, said that "the revised menu is much more efficient for users within the firm, and its use

has yielded a greater productivity within the architectural planning department. With the better adjacencies of commands on the menu, as well as the incorporation of the macro commands and line-type and layering conventions, the CADD productivity of the department has at least doubled."

CADD SYSTEM OFFERED EXPANDED CAPABILITIES

For the homebuilding firm, the story was just beginning. For the students, an awareness of the total AEC process was being realized. The implications of using the computer in the integration of that process were signficant. Members of the building industry agree that purchasing and estimating are emerging as important computer applications. The major benefits are derived from linking together the many activities and information from estimating right on through to site management. [6,7,8]

Much attention has been given recently to comparison of microcomputer versus minicomputer use in an architectural practice. These students had been encouraged to compare the systems and to be aware of the benefits and limitations of each. Many factors make the microcomputer attractive, not the least of which is purchase price. Not only is hardware more powerful and less expensive, but software costs are finally beginning to decrease. In the case of CADD, it's very much an issue of supply and demand. When architects could not afford the cost of graphic hardware, little software was being written to meet their needs. What was available then was in little demand and was thus expensive. With more architects now using microcomputers, the software developers can sell more application packages, such as CADD, at a lower cost and yet reap the same dollars in return.

As a teaching tool, the benefits of microcomputer CADD are many. At a lower cost than with larger systems, students can learn CADD concepts. More systems can be available for the same dollars, and thus the use of the tool is more widespread in student activities. With proper attention to the design process, the computer can be used as a tool to explore spatial implications of a design decision and to compare alternative solutions, not only aesthetically but now also practically. But in a practice where large quantities of information must be assimilated, the use of larger machines which allow for the complete integration of software is important. [9]

During the selection process of the CADD system by the homebuilding firm, a number of factors had been considered, not the least of which was the need for a system with strong data base capabilities. [10,11] In the world of CADD, this means that non-graphic, or alphanumeric, attributes can be associated with the graphics. Information collected from the drawing automatically rather than manually can be processed for a myriad of uses. Reports can be generated. Analyses of data can be run.

Realizing the potential for tremendous productivity gains throughout NPC, the data processing manager used this feature as well as the system's modelling capabilities to justify his decision to purchase the Prime/Medusa system. In studying the automation of the firm, the students were able to appreciate from first-hand experience the capabilities of the mini-based system as utilized by this firm in the building process.

DATA BASE EXTRACTION UTILIZED

Students engaged in comparing functionalities of various systems became fascinated by the degree to which the CADD system could be used in a complex organization such as the AEC firm whose operations they were studying. One group, consisting of Robert Delgado, Subhas Mazumdar, Mark Kindrachuk, and Paul Saphos, worked with the data processing department to build links to the accounting department so that a cost analysis could be made directly from the drawings. They observed that, by existing procedure, drawings were delivered to the estimation department which was in a different building. There an estimator went through the drawing, room by room, and made a list of materials that would be used. Plans were also sent to contractors, such as electricians and plumbers, for bids.

Students worked with the architectural department and the estimating department to determine methods for information retrieval. One method was to attach attributes to the previously built libraries of symbols. Transparent to the designer, when a door symbol, for example, is placed on the drawing, a non-graphic code is incorporated into the data base of the drawing file. The sheet is then scanned for codes and other pertinent information. Reports can then be generated using information retrieved from the drawing.

The research team, with Anthony Salvaggio of NPC, wrote programs to generate such reports as a listing of room information and a list of all materials needed for the construction as designed. Linking this output to the estimating department provided a basis by which vendors could be accessed and cost analysis performed. It then tied in by computer to the accounting department, in yet another location, which kept current cost information, and which used the data for job scheduling. Whereas it previously took about four weeks to fully estimate the cost of a large project, the job was done in a matter of hours. [4]

Another aspect of the total AEC process which the students observed was the way in which the construction department operated. Once again, drawings were delivered manually to a different location where wall panels were laid out by hand. The drawings were then passed on the plant where the panels are assembled and then delivered to the construction site. Why not, the students and practitioners determined, apply the same technique of data base extraction to offer a simplification and clarification of the job for the construction department.

After the estimation department determined exactly what materials were to be used, code numbers of parts selected were fed back to the drawing file. The research team then wrote a program for the automatic generation of wall panel drawings. A powerful feature of the CADD system was a programming tool which allows for decision-making withing the CADD software. The program produced read through the contents of the drawing file and determined where openings and intersections occured. It then located the length and location of the wall panel and determined how the panel was to be laid out.

From information input from job specifications, such as the size of studs and their spacing, plans of the wall panels were produced for transmission to the wall panel plant. A wall panel layer of the base floor plan drawing was automatically generated.

Each wall panel was drawn and annotated with information such as exact length of panel, stud spacing, and location of openings and intersections. Information was also given such as the length of cripples needed per panel and spacing of the sheathing with respect to each stud. In addition, stacking information was obtained to aid in the loading of trucks to insure less damage and more job-site convenience. Reports indicated to the construction department exactly what building materials were needed per panel, and these materials were then automatically subtracted from the plant's inventory.

A second part of the wall panel program extracted data from the same base of information, loaded it to a new program and produced a drawing of the elevation of the wall panel. A simple macro file written within the CADD program set buffers that allow the user to load the data and run the program. Thus, sitting at the terminal miles down the road from the architectural and accounting departments of the firm, the construction manager could simply sit back at his CADD station, probe the digitizing menu four times, and observe as the wall panels were automatically drawn in elevation. A hard copy taken off the display screen was sent to the field. The wall panel was assembled, loaded onto the flatbed truck, and taken to the building site.

MODELLING SYSTEM STUDIED

Finally, one member of the research team, Mark Jacob, explored modelling techniques available on the system. He created traditional three-dimensional symbols that were used often in order to decrease drawing and modelling times. He compared the wire, surface, and solid modelling capabilities of the system in terms of time needed for the user to create the model, for the computer to generate the model, and for file size. The length of time for the user to input the information needed for creating the model was virtually the same for all three techniques. The surface model took 25% longer to generate than did the wire model, and the solid model took 50% longer than the wire model. Repeated tests showed that the wire model had the smallest model file size but the largest sheet file. The solid and shell models had approximately the same model file size but the surface model had a smaller drawing file size.

Jacob made recommendations to the firm as to how it might best utilize this capability of the system for client presentations. These techniques are being utilized to aid an in-house artist in the creation of perspective renderings. A member of the architectural department inputs the information for the computer to generate a surface model of the building. The artist can then view the building from a variety of orientations and select a perspective view to be plotted. Using the plot as a basis, he then renders the drawing for presentation to the clients.

CONCLUSION

The opportunities provided by this venture were invaluable to the students involved. Not only were their problem solving skills strengthened, but they also had the opportunity to learn more about the computer and how it might be utilized in a number of areas within the AEC industry. Benefits to the homebuilding firm were realized as well. Its management team believes the firm was able to move toward integration of automation more quickly and effectively as a result of the joint project.

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Towards an integrated C.A.D. for building projects

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Summary :

     Under the term Computer-Aided Design, a wide range of products, corres-
ponding to varied purposes and means, are available today for the practicers
in the building field : from common two dimensional Computer-Aided Drawing
systems to full three-dimensional Computer-Aided Design systems which are
generally derived from tools developed for other applications. Wathever the
approach may be, these products show limitations from the building C.A.D.
point of view : since they are not based on the same description of the
objects, the proposed softwares are inconsistent with each other and require
either tedious and manifold data acquisitions or too numerous interfaces.
In fact, the problem of incoherent information from different and unlinked
sources has not been solved up to now by these tools which use a specific
and partial representation of the building project still the relationship
between the various practicers involved in the construction act stands
typically in the building project : drawings and documents. The PROJet
Informatique du BATiment (PROJIBAT), proposed by C.S.T.B., is a part of the
French programme named INPROBAT, and will be developed around a computerized
graphical and technical representation structure of a building project.
PROJIBAT achievement will allow information transfer between the various
practicers in the field and at the various stages during the building design
process. Handling of data required by the softwares will be partially managed;
at most n interfaces for n softwares. A preliminary prototype applied to
energy and structure calculations illustrates the approach and the benefits
of PROJIBAT.