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Analysis of Parametric Design Applications for Modeling Military Standard Facilities

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The overall objective of this research is to develop methods for creating intelligent models of military building systems. The objective of this aspect of the research was to evaluate available commercial and public programs to determine if they have the analytical power needed to effectively support an all-encompassing intelligent building model.

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This research was performed by the Architectural Design and Management Team, Facility Systems Division (FF), of the Infrastructure Laboratory (FL), of the U.S. Army Construction Engineering Research Laboratories (USACERL). In addition to the authors, Russell Glaeser of USACERL also was involved in the study. Mr. L. Michael Golish is the Team Leader of the Architectural Design and Management Team, Mr. Alan Moore is Division Chief of CECER-FF, and Dr. Michael J. O'Connor is Laboratory Chief of CECER-FL. The technical editor was Gloria J. Wienke, USACERL Information Management Office.

COL Daniel Waldo, Jr., is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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ANALYSIS OF PARAMETRIC DESIGN APPLICATIONS FOR MODELING MILITARY STANDARD FACILITIES

1 INTRODUCTION

Background

Architects are developing and managing increasingly complex drawings as military building design processes become more involved. To accommodate the design information requirements, Architect/-Engineer/Construction (AEC) professionals are using computer aided drafting and design (CADD) technology. The technology has evolved greatly from the early computer aided drafting (CAD) tools that were often cumbersome and difficult to use. As the hardware and software technologies have matured, system capabilities have developed from simple drafting tools to advanced design tools.

Currently, CADD technology uses integrated data bases and applications developed for specific disciplines. Although CADD has well-defined, robust applications, development has reached a plateau. The technology foundation of CADD has been expended; new technologies are simply refinements of existing algorithms and added conveniences. For CADD technology to progress, breakthrough techniques have to be developed. The integration of artificial intelligence and CADD technology is one breakthrough technique being developed by both the research and commercial communities. The combination is defined as intelligent CADD (I-CADD). The future of CADD technology is in the development of I-CADD systems.

I-CADD technology has been developing rapidly over the past several years. Although I-CADD has not yet reached the envisioned capabilities, several development techniques are available on the commercial market. These techniques have matured enough to yield valuable products and applications for specific domains (building or system types). Within the U.S. Army Corps of Engineers (USACE), the Facilities Standardization Program[1] offers a wide selection of varying problem domains. The domains are well defined for specific programmed needs. Using the evolving technologies, the design knowledge for the Facilities Standardization Program can be captured for specific domains, offering design professionals a robust design tool.

Objective

The overall objective of this research is to develop methods for creating intelligent models of military building systems. The objective of this aspect of the research was to evaluate available commercial and public programs to determine if they have the analytical power needed to effectively support an all-encompassing intelligent building model.

Approach

Researchers surveyed parametric applications from commercial and public sources to evaluate the systems' capabilities for modeling building systems. They selected one system to use as the base to create

[1]*Facilities Standardization Program* (U.S. Army Corps of Engineers, September 1989).

a prototype application that will model a military standard facility. The work is continuing as researchers use this working prototype to model a military standard facility.

Mode of Technology Transfer

The results of this research will be used to create an operational prototype modeling system that will be available in 1995. Following field testing, the system will be distributed to all USACE design/architectural offices.

2 PRODUCTS EVALUATED

Mechanical Engineering Workbench (MEW)

MEW by Iconnex, Pittsburgh, PA, is an independent program for a 386 DOS-based computer. It is not built around any CAD package and communicates with other programs via DXF. It does not have the capability to connect to a data base. As a parametric application, it is designed for working with numerically variable dimensions tied to graphical templates. The data is obtained from the user and applied to the numerical relationships created; the system does not work with nonnumerical relationships. Because the system is limited with respect to the ability to create parametric details, it was not selected for further research.

DesignView

DesignView by Premise, Cambridge, MA, operates on a 286/386 DOS-based computer and has its own primitive drawing environment. It is a Windows-based application that communicates with other programs via DXF. The application is capable of the standard numerical connections with graphical information. The program includes a direct link with Excel, achieved by using DDE (dynamic data exchange) in Windows, that enhances the usability for architectural applications. The program is still defined with numerical variables, but the dynamic link with Excel allows more versatile parametric applications.

ParaDesign

ParaDesign by CERO, Anaheim, CA, is a kernel program within AutoCAD* for a 286/386 DOS-based computer. The program has defined relationships between graphic and numeric data. It also has defined symbols that can be numerical and/or variable controlled. A dBase connection allows variables to be controlled by a database; however, the package lacks a knowledge base connection for expert system style rules. Of the commercial packages available, ParaDesign has the most robust control system for generating parametric applications.

Synthesis

Synthesis is another kernel program within AutoCAD for a 286/386 DOS-based machine. This package is similar to MEW. It has a spreadsheet that can be used to define variable dimensions and it uses a master drawing for the graphical data. Synthesis uses associations that are completely numerical; it lacks knowledge capabilities and is very costly ($5500), although it is specifically designed for engineering applications.

* The USACE standard is Intergraph, not AutoCAD.

Micro Paradise

Micro Paradise by Intergraph, Huntsville, AL, is implemented within Microstation by Intergraph/Bentley on an Intergraph workstation using Clipper. The parametric design system consists of an interpreted graphics language called Parametric Design Language (PDL) and a display processing executive. This arrangement provides a parametric design capability for interactively generating graphics that have relationships in shape and form, and vary in size and position. Both two-dimensional (2D) and three-dimensional (3D) design files and graphics are supported. The literature suggests the system is more for modeling than detailed parametric applications. Unfortunately, it is currently available only within Europe.

Dynamic Detailer

Dynamic Detailer by Vertex, San Francisco, CA, is a kernel program implemented within AutoCAD for a 286/386 DOS-based machine. The program is not strictly a parametric application but it does offer some unique solutions. The program is based on AutoCAD blocks that are inserted as components (building blocks) that form the details. Although the intelligence is not embedded in the drawing, it is a step in the direction of intelligent drawings by offering integrated information management for components that form details.

TamCADD

TamCADD by Tamko, Joplin, MO, is a kernel program implemented within AutoCAD by Architectural Synthesis. It is designed for a 286/386 DOS-based machine. The program is a parametric application with the parametric capabilities coded within Lisp and C routines. It was developed by Tamko Roofing Products to prepare roofing details and outline specifications. The program is an example of a specific application for details and, as such, does not provide any capability as a platform to develop new details.

Pella Designer

Pella Designer by Pella, Pella, IA, is a kernel program implemented within AutoCAD by ASG as part of ASG Architectural. It runs on a 286/386 DOS-based machine. This package is an extension of Architectural for AutoCAD and allows for the detailing of windows and the placement of windows in 2D and 3D drawings. The system is another example of a parametric application design for a specific system/manufacturer.

Design++

Design++ by Design Power Inc., Copertino, CA, was demonstrated on a Sun Sparc workstation. The main requirement is Unix. After meeting with the president at AEC Systems, the company is talking with Intergraph to develop a version for workstations with Microstation. The system has several desirable features, including the fact that it uses SQL (standard query language) data base links. The system allows models to be developed with objects that have integrated knowledge. There is also a declarative language for defining relationships between objects. Design++ appears to be the best suited base for an intelligent detailing system. The development system provides robust features at an affordable price.

3 VARIATIONAL GEOMETRY SYSTEMS FOR PARAMETRIC APPLICATIONS

Parametric CAD applications are the next generation of CAD systems being developed widely for the commercial market. The main target markets for these systems are the engineering disciplines; the products are excellent for well-defined engineering problems. An example of a defined engineering application for parametric CAD is a machine part design. The properties that define the part are explicit numerical relationships. To obtain a specific part, values are inserted into the model of the part and the parametric CAD system generates the mold automatically. Within the engineering disciplines, there is an endless supply of similar problem domains.

Variational Geometry

The basic component of parametric systems developed today is variational geometry. All parametric systems have the ability to control variational geometry, which controls the physical size of predefined geometrical shapes. A collection of the shapes is located in a "template drawing" that has keys to a control file that determines the numeric values. Using the calculated values and the template drawing, a new drawing is produced. The drawing is constructed from geometrical elements such as lines and arcs. The intelligence (numeric and relational data) of the model is buried in the template file and control file. Once the drawing has been produced parametrically, the finished drawing and its data file are no different than a drawing produced manually on a CAD system; the intelligence has been washed out of the new drawing.

Enhancements to Variational Geometry

In addition to variational geometry, parametric systems may have several other capabilities, including connection to a database. This connection allows selection of dimensional variables based on data base queries. An example is a data base of valves. Depending on which valve is selected, the dimensional characteristics can be extracted from the data base.

Some systems have a connection to a spread sheet. By dynamically connecting values in the template drawing to slots in a spread sheet, the geometry is determined. This allows the user to change values in the spread sheet and have the changes reflected immediately. Both of these capabilities are excellent for engineering problems.

The most robust feature available in some parametric systems is block or cell selection. This feature provides the ability to control geometry shapes as well as the geometry dimensions. As an example, a template drawing can request the placement of a toilet in a stall. Although several types of toilets are available, the template drawing can only have one type. Instead of placing the toilet's geometry, the template drawing places a block representing the toilet's geometry. This feature greatly expands the capability of a parametric system; both the geometry and the dimensional values can be controlled.

Developing Applications for Variational Geometry

To complete the evaluation of parametric technology, researchers purchased the ParaDesign development system, which has all the features described in this chapter. The first templates developed were for different categories of architectural details, such as door jamb details. A door jamb detail can be produced based on material, door size, wall thickness, and wall material. The intelligent information that constructs the detail is located in the template drawing and control file. The finished detail drawing is a collection of geometry information. The level of information is the same as a detail produced manually on a CAD system or paper. Once the drawing is created, there is no way to go backwards. The intelligence used to create the drawing vanishes. The drawing cannot show you what data was used to create it and why that data was selected. For the level of effort required to assemble the parametric information, the finished drawing should maintain the information instead of losing it.

The problems described for details increased greatly when researchers applied parametric technology to a larger body of information: floor plans. Not only was the intelligence lost when the floor plans were drawn, the plans could then be modified with no concern for known design decisions. The design decisions made in the template drawing and control file no longer have control once the drawing is created. Because plans can be modified without understanding previous design decisions, it is possible to violate the established design decisions with new modifications. The ramifications of the modifications would go unknown to the designer. This larger body of information (the domain of floor plans for all building types) was determined to be too large for initial research. A natural subset of this domain for the Department of the Army is the building types in the Facilities Standardization Program. This program has identified 33 building types that are built repeatedly throughout Department of Defense installations; Definitive Design documents have been prepared for all the buildings. Of the facilities in this program, the firehouse was selected for modeling because it offers the right degree of difficulty and can be accomplished using parametric applications and knowledge-based systems.

The variational geometry approach has a major shortcoming to developing standard facility designs. A standard facility design (SFD) would be comprised of a collection of independent parametric template drawings and control files; the combined files are not a coherent model. Changes can be made on one drawing without being reflected in any other drawings. The ripple of information does not have a path to follow. The changes would have to be coordinated. To effectively implement SFD, the system will have to be capable of constructing a coherent model.

4 KNOWLEDGE BASED SYSTEMS FOR PARAMETRIC APPLICATIONS

University Research

Research programs at several universities are addressing issues that can be applied to SFD requirements; the SFD problem is a subset for these research programs. Generally, the universities take a holistic approach to all design problems; the scope of SFD is narrower. These systems all come under concurrent engineering thrust. Each university's methodology is different though answering similar problems.

At the University of Illinois, Urbana, IL, the Knowledge Based Engineering Systems Research Laboratory (KBESRL) is conducting research in concurrent engineering. The program has close connections with the Energy Systems Division at the U.S. Army Construction Engineering Research Laboratory (USACERL) and is developing a system, Designer Software, that is based on a blackboard architecture. Independent knowledge sources (KS) are attached to the blackboard. As a KS needs information, a request is posted on the blackboard where the blackboard controller decides which other KS can answer the request for information. The answers are then posted back to the blackboard where the requesting KS can obtain them. Designer Software is currently integrating constraint-based reasoning developed at KBERSL.

Designer Software can communicate with CAD systems via the blackboard and has a KS that can manipulate geometry and transfer requests for information. Another feature that has been implemented is an integrated link to MasterSPEC specifications, which ties design decisions directly to specifications. The software is written in Goldworks Lisp for a 386 personal computer. The software has reached a usable state, but documentation has not been completed.

At California Polytechnic State University, San Louis Obispo, CA, the CAD Research Unit is working on a design environment similar to Designer Software. The environment is the Intelligent Computer Aided Design System (ICADS), which runs on an IBM RS/6000 platform and uses the same blackboard architecture as Designer Software, with only a few minor differences. Grammatically, the knowledge sources are known as Intelligent Design Tools (IDTs). The geometry interface is built into the controller for the blackboard instead of a separate knowledge source. The system is a prototype developed primarily for Department of Energy (DOE) research for energy analysis during design activities.

At Carnegie Mellon University (CMU), Pittsburgh, PA, a consortium, the University/Industry Computer-aided Design Consortium (UICC) is being established to address computer-aided design issues. One project underway is a joint effort between CMU and the University of Karlsruhe, Federal Republic of Germany, based on the German ARMILLA system. Using faculty expertise in a specific simulation area, the modeling techniques developed at CMU for radiant energies will be integrated in the ARMILLA environment. From this integration effort, a general model for analysis and simulation tools will be developed for an integrated decision support environment. While the research is important, the project is not far along; implementation tools will not be available for several years from the UICC efforts.

At Stanford University, Stanford, CA, the Center for Integrated Facility Engineering (CIFE) is developing a knowledge-aided data base management system called KADBASE. The system is an outgrowth of BB1, the blackboard architecture information management system, and contains a single global data space that can be accessed in a distributed environment. Through this distributed global data space, independent applications can access required data without looking through all data available. While a complete KADBASE system will be capable of providing the required function, the system is currently a collection of complex independent programs molded together through special integration applications.

Although the work currently underway at the academic level has great potential, realities of the academic environment make it difficult to align with any one effort. The goal of academic research is not to produce commercial grade software, but to develop proof of concepts and validation of ideas. For these reasons, the systems currently under development at academic institutions are not being pursued at this time.

Industry Development

Industry development is ahead of academic research in knowledge-based CADD (KB-CADD) systems because industry identified the need for the technology before the academic fields could respond. Also, companies can afford to invest heavily because the pay-offs are great. Several independent companies, realizing the value of KB-CADD systems, have developed systems that meet market-driven requirements. The applications using KB-CADD are comprised of complex design domains that are so large they are difficult to manage.

Design++ by Design Power is one commercial system that provides many capabilities. In the Design++ environment, graphical data is represented as objects. Besides alphanumeric information, objects can have rules associated with them that can reference any object and reason on the information. The rule decides what the value of the object is. The object representation also facilitates hierarchical representations that can be referenced independently as libraries. Each library encapsulates a specific knowledge domain; for example, structural; heating, ventilating, and air-conditioning (HVAC); building code; and spatial information. Design++ can also be linked with other commercial software programs with the values of slots in the system determined from the results of the other programs. Links with data bases are also possible through SQL statements. Design++ capabilities provide a complete, usable development environment for KB-CADD. Of the commercial systems available, Design++ shows the most promise.

Another KB-CADD system commercially available is the ICAD system (ICAD Inc., Cambridge, MA). ICAD is a development system with features similar to Design++, but aimed at the machine design domain; the exact explanation of the capabilities is not available. The system is for the developers' in-house use only. When the ICAD system is purchased, the development services of ICAD are hired to develop the application for the client. The ability to use the system for other domains is limited and the delivered system price is too high for SFD research. Also, the understanding of the domain knowledge must already exist. Using the ICAD system to investigate data structures for unsolved domains is not possible.

5 SUMMARY

Researchers evaluated commercial variational geometry systems to determine if they have the analytical power needed to effectively support an all-encompasing intelligent building model. Five of the systems are based on AutoCAD. Only one system is based on the USACE standard of Intergraph, but it is available only within Europe. Two systems were created by manufacturers for modeling specific building details and are therefore inappropriate for further research. Other systems lack a connection to either a data base or expert system style rules.

Researchers also evaluated development systems available through university research activities. Several systems are under development that can model standard facilities; however, the systems' stability for application development to research modeling techniques of standard facilities is uncertain. The systems are not designed to be commercial grade software; they are designed as pilot systems.

Consequently, Design++ was selected as the development system to research modeling techniques to be used in the Army Standard Facilities Program. The Design++ development system is a complete tool with available support for developers and users. Researchers at USACERL have developed a working prototype to model a standard firehouse facility using Design++. An operational prototype will be available in 1995.

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