ArchiDATA: A Hypermedia Tool for Architecture

Osman Ataman
Temple University

Thomas Richey
University of Utah

ABSTRACT

Design is a cooperative activity at several levels. At one level, clients, architects, financiers, and construction engineers and contractors, all play important roles in creating the design for the building. At another level, the design team may contain architects, interior and landscape designers, lighting experts, heating, ventilation, and air-conditioning experts, etc. At a third level, individual architects "cooperate" with computer-based design tools in creating portions of a complex design. In this paper, this third level interaction is investigated. This paper describes an ongoing project called ArchiDATA, in which we are developing a computational aid for architectural design. This study, which is collaboration between cognitive scientists and architectural researchers, builds on an artificial intelligence paradigm called "case-based reasoning" and work in post-occupancy evaluation and other case study research in architecture.

El diseño es un actividad cooperativa a varios niveles. En un primer nivel, los comitentes, arquitectos, finacistas e ingenieros y directores de construcción juegan roles importantes en la creación del diseño de un edificio. A otro nivel, el equipo de diseño en sí mismo puede estar integrado por arquitectos, diseñadores interiores y/o paisajistas, expertos en luminotecnia, calefacción, ventilación y/o aire acondicionado, etc. A un tercer nivel, los arquitectos individualmente deben "cooperar" con las herramientas electrónicas de diseño (CAD) para poder elaborar el diseño de edificios complejos. En esta ponencia, se investiga este tercer nivel de interacción. Se describe un proyecto llamado ArchiDATA, donde estamos desarrollando instrumentos electrónicos de apoyo al diseño arquitectónico. Este trabajo, que es una colaboración entre científicos cognitivos e investigadores arquitectos, se basa en un paradigma de inteligencia artificial denomidado "case-based reasoning" (razonamiento basado en casos ejemplares) y funciona para la evaluación de calidad de habitación y otras areas de investigación de casos en la arquitectura.

INTRODUCTION

Architectural design is exceedingly complex and sometimes disorganized. Designers may start with only a general view of the problem to be solved; an important part of the design process is often to solve a problem as well as to create it. Moreover, decision-making in architectural design operates at different scales in rapid succession and is seldom linear. Designers often move back and forth between strategic and detailed decisions as a way of defining, and redefining, the means, goals, and criteria for evaluating the final design. In fact, a designer may be fairly far along before he finally decides which of the client's specifications to satisfy and how the client's goals relate to other aesthetic or cultural interests he might have. These complex normative and substantive decisions are difficult to model using computers, and in fact it may not be possible to completely automate design.

Instead, we have spent the past several years using computers to aid rather than automate design. We have developed a computational design aid that we call "Architectural Design Database" (ArchiDATA). ArchiDATA provides human designers easy and flexible access to architectural case studies, and allows the architects to make the inferences and to choose how the information will be used in the design.

In this paper we briefly describe ArchiDATA then discuss three particular issues: 1) How can architectural case information be structured in a database? 2) How can a designer be provided general information in an architectural design aid system while maintaining the advantages of using specific case information? 3) How can cases be indexed for use specifically within architectural design? In the following sections we describe ArchiDATA, explore questions of generalization and indexing that developing ArchiDATA has raised, and suggest some future directions for further research and development.

BACKGROUND AND RATIONALE

ArchiDATA is the result of an ongoing collaboration between the Cognitive Science and Architecture. We are interested in exploring how to develop aiding systems for design, and particularly how to represent design information. We are planning to cover all aspects but initially focusing on conceptual design; during these early stages of design, decisions strongly influence the future course of the project and can be changed relatively easily. Whereas there are many kinds of decisions that are important during these stages, in ArchiDATA, we have created a system to help designers understand different intentions for action of a range of stakeholders in a building project, such as users, owners, and builders, and how these intentions relate to design decisions about building form. ArchiDATA provides easy and flexible access to case study evaluations of buildings (in the present version, schools), that designers can adapt to their own needs. ArchiDATA is intended to help experienced designers make initial conceptual design decisions and/or evaluate their own designs. It also helps novice architects and student users learn design principles, problems, related responses, and lessons.

As computers become pervasive in the design field, particularly architecture, their role is expanding from one of representation to becoming pedagogical. Mental images of architecture, or from other sources, serve as inspiration in the design process. Such images stored and easily retrieved through a computer system can help resolve ill structured design problems. The principal purpose of ArchiDATA is to serve as a design information resource that will facilitate design solutions. In the past few years a number of resources have been conceived and several prototypes have been developed. In this section a brief review of architectural design resources similar to ArchiDATA will be given. Following these briefs a review of ArchiDATA will respond to the shortcomings of these systems

One early initiative started at the Harvard Graduate School of Design a collaborative effort proposed a to make a variety of design materials available over the school’s network. This initiative called DOORS (Sklar, 1995) was to be a multi-platform system that would allow users to browse, compose, present and augment resources located in the school’s Francis Loeb Labrary. Although DOORS served as a model to later visual database design, unfortunately it has not progressed passed the conceptual stage.

ARCHIE, developed by Janet Kolodner (1991), is case based architectural design-aiding system. It retrieves, displays design cases and makes suggestions about situations specified by the user. ARCHIE-2 (Domeshek and Kolodner 1993) is a continuation of the Archie system that takes advantage of DesignMUSE, a CBR shell for design applications. ARCHIE-2 retrieves problems, stories and guidelines about architectural cases when prompted by the user. These stories and guidelines follow graphic depictions of plans and are helpful in the design stage.

Recently, several architectural resources have appeared on the World Wide Web. One of these is AGRAM, a small website that allows browsing of different architects. A more elaborate commercially sponsored system, The Great Building Collection, is a service offered through Artifice Inc. This site allows flexible browsing by architect, building name, type and a range of other more advanced search features. Another online pictorial resource is ArchiMedia, it is an example of a knowledge building system. Inspired by advances in internet services, ArchiMedia recruits architects and architectural students to present their projects using ArchiMedia's standard interface. The goal is to create a database that is "extensive, intuitive and educational".

A project developed at the University of Colorado (McCall, 1990, McCall et al, 1994) PHIDIAS Hypercad system makes use of a CAAD program and a database management system as well. In an effort to consolidate CAAD systems with more intelligent design system PHIDIAS combines vector graphics with a knowledge based system making it applicable to information intensive design problems. Working together, a CAD system and a database purports to enhance designs as it informs designers along the design process.

Although databases such as AGRAM, Artifice Inc.'s The Great Building Collection and ArchiMedia provide a visual reference to numerous buildings and architects they suffers from several inherent flaws. One flaw is that information is organized linearly, the database can be search on only factual information such as an architect, name of building, building type, etc. Additionally, their indexing of building types is also limited. Searches can be done only on broad architectural types such as museums, educational, court, etc. On the other hand, ArchiDATA's hierarchical structure provides greater browsing capacity. ArchiDATA also allows for multiple key word searching that allows searches of issues with building types, a feature that is lacking in ARCHIE-2. Another powerful feature of ArchiDATA is that it provides post occupancy evaluations (POE) taken from a variety of stakeholders involved in the project. These POE's can help designers foresee problem areas when working on similar design projects.

THEORETICAL OVERVIEW AND THE STRUCTURE OF ArchiDATA

ArchiDATA is partially based on an artificial intelligence (AI) paradigm called *case-based reasoning* (CBR) and a specific approach to *post-occupancy evaluation* (POE) case study evaluation of buildings. Case-based reasoning (Schank, 1982; Kolodner, Simpson et al., 1985; Hammond, 1989) is a theory and technology within AI based on the idea that humans often solve problems by using specific past experiences. These experiences, or "cases," are used to explain new situations, are adapted to meet new demands, or are used to evaluate new solutions ((Kolodner and Wills, 1993). For instance, if a designer is faced with the problem of designing the information desk at a community library, s/he may remember similar cases s/he has experienced and adapt one or several of these to her current design. Case-based reasoning has been applied to a wide range of domains, such as scheduling (Mark, 1989), diagnosis (Koton, 1988; Bareiss, 1989), planning (Hammond, 1989), explanation (Kass and Leake, 1988), design (Hinrichs and Kolodner, 1991; Navinchandra D., 1991; Hinrichs, 1992), architectural design (Domeshek and Kolodner, 1991; Goel, Kolodner et al., 1991; Domeshek and Kolodner, 1992; Pearce M., Goel A. et al., 1992; Maher, Balachandran et al., 1995). Effective case-based reasoning depends on having relevant cases in the system that can be applied to the problem at hand, and on retrieving a reasonable set of relevant cases quickly and easily.

In addition, ArchiDATA is based on post-occupancy evaluation (POE). POE is a set of techniques that assesses the effectiveness of buildings that are in use (Friedman, Zimring et al., 1978; Preiser, Rabinowitz H. et al., 1988). Although, it has been used to examine a wide range of technical and social issues, most POE work has focused on learning how successful a building is for various stakeholders, such as different types of building users, clients, or designers. Our approach to POE focuses on a specific set of design problems: how to resolve multiple intentions simultaneously. Any given design decision often must consider multiple considerations. For instance, in a community library, librarians need to be accessible to patrons, yet be able to get their work done without interruption. Depending on the exact context, a successful design must accommodate both of these intentions. In our POE work, we conduct field case studies of buildings to try to uncover these intentions through observation and interview.

The use of cases in design has multiple advantages. Human experts do not simply use systems of rules, they often access libraries of experiences (Riesbeck and Schank, 1989). Cases are often vivid and specific and encourage the designer to consider how the case fits into the current problem. The effort to adapt cases encourages the designer to develop a mental model of the problem and solution. However, whereas specific cases may carry significant lessons, if the designer does not have a sufficient general framework for understanding them, he may not find them useful. In developing ArchiDATA, we have linked specific case descriptions of buildings with more general statements.

ArchiDATA is built using an experimental shell intended to ease construction of corresponding links. Implemented in html and Java, this shell provides a flexible tool for entering text and graphic information, indexing information, search and creating hypertext links.

As seen in the figure 1, the interface is broken into three major frames, each representing a major class of information or aspects of the system's function: (1) Search, (2) Design Categorization, and (3) Knowledge Representation.

Figure 1: ArchiDATA window structure

The entry point to the system and the intended conceptual center is the Design Categorization. The choice of this categorization is very important because the categories represent an interpretation of a situation, one that takes into account the way the user might think about a situation and the circumstances. The most important issue in a database system is retrieving appropriate information and this retrieval is achieved with a successful indexing. The existing ArchiDATA uses descriptive indexing. The indexes are composed of descriptors specifying different design issues, such as structural component, functional system, stakeholder

perspective, and lifecycle. Given information about a part of the design, the system searches for descriptions mentioning that part, and finds relevant guideline information, problems, responses and cases with either “positive” or “negative” outcomes that identify pitfalls and opportunities.

This structure is established with an architectural organization structure as a five-level hierarchy. At the highest level is the core of architectural artifact; the next level is the type of architectural artifact divided into sub-fields (i.e. Residential, Non-Residential); at the third level is the type of sub-fields (i.e. Public and Commercial); at the fourth level are the main general spaces used in those sub-fields (i.e. Public Space, Interface spaces, Private spaces); and the lowest level are specific kinds of (i.e. Lending, Reading, Reference, Seating, etc.). This hierarchy is presented in Figure 2.

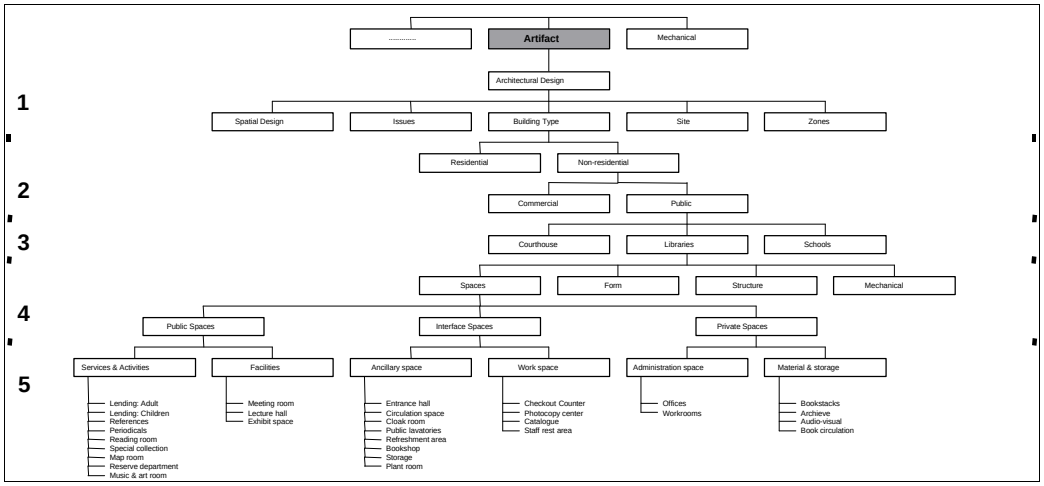

Figure 2: Architectural organization structure

In addition to representing the structural relations between the five levels, this hierarchy classifies the “fixedness” of the architectural artifact: the spaces in the lowest level can be changed according to the domain (library, courthouse, office building, etc.), while the highest levels remain fixed respectively. For example, the requirements for Circulation of libraries and courthouses are different, while the requirements for Circulation of Public buildings always remains the same.

The main issue is to create an indexing vocabulary general enough to cover the range of tasks the case-based reasoner is responsible for and at the same time specific enough to make necessary differentiations among cases in order to retrieve only a small number of relevant information for a query.

The knowledge representation part is composed of a set of resizable frames, where each frame is dedicated to displaying a particular type of information. In the problem frame, the design query is presented with problems. A problem is a general situation that a designer can encounter. It is written to illustrate conflicting intentions with an implementation which results in a troublesome outcome for some stakeholders. Each problem has one or more responses. A response is a general strategic approach to the solution of a given problematic situation. For designers, it usually provides information about the form of buildings. In the ArchiDATA, a response provides important points about positive or negative condition(s) raised in the problematic situation. They also represent one kind of lesson a particular case can teach. It is a strategic choice a designer or organization might make.

A case illustrates a specific example of a general problematic situation. It may also provide a specific example of a general response to a problem. ArchiDATA's current implementation involves the retrieval of design "cases" via specific, previously identified architectural "problems" addressed by each of these cases. Each pair of problems and cases is accompanied by appropriate "responses" - how the architect dealt with the "problem" in relation to a particular "case". This format has many beneficial uses for an architect trying to solve a

problem he is having with a design he is developing. However, this format does not address all of the needs of an architect who is formulating the design for a new building.

This representation is supported by guidelines. The main purpose of guidelines is to provide general information. This information will also help designers communicate with the system more effectively so that they are able to take full advantage of navigation among building descriptions, cases, problems, and responses.

CONCLUSION AND DISCUSSION

ArchiDATA is an early step in what is intended to be a larger research agenda exploring the design issues and the applicability of integrated database systems to those issues. Two important aspects in design are specifically integrated: (1) Visualization, and (2) Analysis. We are primarily providing an analysis tool, but one that provides access to initial analysis of the problematic issues as well as evaluation of the proposed solution, and that provides aid in visualization by presenting cases and guidelines.

ArchiDATA provides a flexible browsing tool that provides access to specific evaluated cases: building descriptions, conceptual issues, stories, problems and responses to these problems. It assists the designer rather than doing design autonomously, and does not suggest a design methodology. Whereas, the links exists, the system does not propose an organizing heuristics in specific situations. We believe that the user will develop an understanding of the design issue through his own design process and interaction with the system.

REFERENCES

Bareiss, E. (1989). Exemplar-based knowledge acquisition: A unified approach to concept representation, classification, and learning. Boston, Academic Press.

Domeshek, E. and J. Kolodner (1991). “Toward a case-based design aid for conceptual design.” International Journal of Expert Systems **4**(4): 201-220.

Domeshek, E. and J. Kolodner (1992). A Case-Based Design Aid for Architecture. Artificial Intelligence in Design '92, Netherlands, Kluwer Academic Publishers.

Friedman, A., C. Zimring, et al. (1978). Environmental Design Evaluation. New York, NY, Plenum Press.

Goel, A., J. Kolodner, et al. (1991). Archie: A Case-Based Architectural Design System, Georgia Institute of Technology.

Hammond, K. (1989). Case-Based Planning: Viewing Planning as a Memory Task. Boston, MA, Academic Press.

Hinrichs, T. (1992). Problem solving in open world: A case study in design. Northvale, NJ, Erlbaum.

Hinrichs, T. and J. Kolodner (1991). The roles of adaptation in case-based design. Proceedings of AAAI-91, Cambridge, MA, AAAI Press/MIT Press.

Kass, A. and D. Leake (1988). Case-based reasoning applied to constructing explanations. Proceedings: Workshop on case-based reasoning (DARPA), Clearwater, FL, Morgan Kaufmann.

Kolodner, J., R. Simpson, et al. (1985). A Process Model of Case-Based Reasoning in Problem Solving. Proceedings of IJCAI-85, Los Angales, CA.

Kolodner, J. and L. M. Wills (1993). Case-Based Creative Design. AAAI Spring Symposium on AI and Creativity, Stanford, CA, Publisher?

Koton, P. (1988). Reasoning about evidence in causal explanation. Proceedings of AAAI-88, Cambridge, MA, AAAI Press/MIT Press.

Maher, M. L., M. B. Balachandran, et al. (1995). Case-Based Reasoning in Design. Mahwah, NJ, Lawrence Erlbaum Associates, Publishers.

Mark, W. (1989). Case-based Reasoning for Autoclave Management. Proceedings of the second Workshop on Case-Based Reasoning (DARPA), Pensacola Beach, FL, Morgan Kaufmann.

Navinchandra D. (1991). Exploration and innovation in design: towards a computational model. New York, NY, Springler Verlag.

Pearce M., Goel A., et al. (1992). "Case-Based Design support: A case study in architectural design." IEEE Expert **7**(5): 14-20.

Preiser, W. F. E., Rabinowitz H., et al., Eds. (1988). Post-Occupancy Evaluation. New York, NY, Van Nostrand Reinhold.

Riesbeck, C. and R. Schank (1989). Inside Case-Based Reasoning. Hillsdale, New Jersey, Lawrence Erlbaum Associates, Publishers.

Schank, R. C. (1982). Dynamic Memory: A Theory of Reminding and Learning in Computers and People. New York, NY, Cambridge University Press.