Incorporating Guidelines Into A Case-Based Architectural Design Tool

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This paper discusses an ongoing project called Archie, a collaboration between cognitive scientists and researchers in artificial intelligence and architecture, aimed at creating computer-based aids for conceptual design. Archie is a "case-based design aid" (CBDA): a tool that provides designers flexible access to evaluated examples of past experience that they can use in their own designs. Archie is a "clever" hypermedia database aimed at aiding conceptual design in architecture. It contains about 200 problems, responses, stories, and building descriptions derived from evaluations of six libraries and two courthouses.

In this paper we provide a brief history and description of Archie and discuss some issues that have come into focus through developing and initially evaluating the system: how specific architectural case information can be structured in a CBDA while maintaining the advantages of using specific case information? 2) How can architectural case information be structured in a database? 3) How can cases be indexed for use specifically within architectural design? In the following sections we describe Archie, explore questions of generalization and indexing that developing Archie has raised, and suggest some future directions for further research and development.

Howard's End

ACADIA 1994

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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 s/he finally decides which of the client's specifications to satisfy and how the client's goals relate to other aesthetic or cultural interests s/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 series of computational design aids that we call "case based design aids" (CBDAs). CBDAs provide human designers easy and flexible access to past experiences, and allows the humans to make the inferences and to choose how the information will be used in the design.

In this paper we briefly describe a CBDA called "Archie," then discuss some particular issues: 1) How can architectural case information be structured in a database? 2) How can a designer be provided general information in a CBDA 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 Archie, explore questions of generalization and indexing that developing Archie has raised, and suggest some future directions for further research and development.

They themselves over time and adapted themselves to different conditions. In a series of house designs, for instance, Frank Lloyd Wright modified basic models of human habitation to produce a wide range of variations which adapt themselves to specific environments while maintaining their essential organization or logic. Suppose we adopted an organic metaphor, conceiving of communications and
Background and Rationale

Archie is the result of an ongoing collaboration between the College of Computing and the College of Architecture. We are interested in exploring how to develop aiding systems for design, and particularly how to access to cases can aid design. We are focusing on conceptual design; during this early stage 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 conceptual design, in Archie 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. Archie provides easy and flexible access to case study evaluations of buildings (in the present version, libraries and courthouses), that designers can adapt to their own needs. ARCHIE 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.

Archie is 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 (Hammond K., 1989; Kolodner J. et al., 1985; Schank R., 1982) 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 new demands, or are used to evaluate new solutions (Kolodner J., 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 w., 1989), diagnosis (Barries E., 1989; Kotron P., 1988), planning (Hammond K., 1989), explanation (Kass A. & Leake D., 1988), design (Hinrichs T., 1992; Hinrichs T. & Kolodner J., 1991; Navinchandara D., 1991), and architectural design (Domeshek E. & Kolodner J., 1991; Domeshek E. & Kolodner J., 1992; Goel A., et al., 1991; Pearce et al., 1992). 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, Archie is based on post-occupancy evaluation (POE). POE is a set of techniques that assesses the effectiveness of buildings that are in use (Zimring C., 1987; Friedman A. et al., 1978; Preiser W. et al., 1987). 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 C. & Schank R., 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, s/he may not find them useful. In developing Archie, we have linked specific case descriptions of buildings with more general statements.

The structure of content in Archie

Archie is built using an experimental shell intended to ease construction of Case-Based Design Aids (CBDAs) called "Design-MUSE" ("Design Memory Utility for Significant Experiences").

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A technical implementation of Archie is discussed in depth elsewhere and we will only review it briefly here (see Domeshek E. & Kolodner J., 1991; Domeshek E., et al., 1992; Goel A., et al., 1991; Kolodner J., 1993). The essential part of our system is a library of cases that is intended to cover the set of problems for which the users may need help during conceptual design. Cases are composed of: "designs" (graphic or written descriptions of buildings); general problems; general responses; and stories describing how these operate in actual buildings. The stories include "successes," "failures" and "mixed outcomes," and are indexed for the user's domain.

The case library and the user interface, which in our case is provided by the Design MUSE shell, are the main parts of our system. Most windows are divided into several panes which provide some particular type of information. Concerning the content of cases, full advantage is taken of the facilities provided by the Design-MUSE shell, namely to fill and use the panes PROBLEMS, STORIES and RESPONSES from the LISPSSN window. At the same time, the system is enhanced by using the facilities offered by the DESIGN window of Design-MUSE. The following paragraphs describe the kind of information associated with each pane of the window and how this information is structured.

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. The components of a problem include:

- The context, which provides information for indexing.

In our system the context includes the following:

- General cross building concerns that may be applicable to all sorts of buildings such as economics, fluent circulation path, functional adjacency, HVAC, lighting, acoustics and anthropometric considerations;
- General usage concerns focusing on the nature of the building category, such as privacy, efficient construction, security and safety concerns that might be specific to public or private buildings;
- Concerns that are specific to a certain building type (in our case, libraries and courthouses).

Intensions, that is, goals for action in the building that have significance for different stakeholders, and especially those which might result in conflict situations.

Impacts: prediction about or observation of outcomes, or implication of situations and the difficulties of trying to balance conflicting intentions.

Abstract and concise graphic illustration, which can vary from bubble diagrams to scaled details.

For example, our evaluations of libraries revealed the following problem that has significant influence on their layout:

Unrestricted access to the toilets from the reading rooms is required, but users may take advantage of the seclusion to tear out pages from books.

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. As we write a response in the Archie program, it 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 response should be general, but not too abstract, and should be suggestive rather than imposing a solution on the user. Furthermore, the general response should describe the outcome, which means the resulting state of the world when the solution was carried out. This outcome may need to record points of view of several different stakeholders. Consequently, some possible responses to the problem given above are:

**In public buildings, allow an easy access to the restrooms from the outside or entrance hall, after the visitors/users have passed out through check out and control areas.**

Place restrooms near: building entrance; supervised children’s reading area, or other spaces where staff members are present.

Locate the entry to the restrooms where users must pass by the desk of a librarian or other staff members.

**Stories**

A story illustrates a specific example of a general problematic situation. It may also provide a specific example of a general response to a problem. A story consists of the following components:

- A brief description of the existing design involving the entities mentioned in the general problematic situation.
- Brief interviews of the users involved, verifying the evaluation component. They should mention if the users face any other problems connected with this situation and how it can be solved, and also any suggestions made by users.
- Response to the problem indicating if the intentions were satisfied and that mention how and why.
- Graphic illustrations to support the story.

Consider the following story that illustrates one implementation of the problem, and responses listed:

**In Buckhead Public Library, the public restrooms are located adjacent to the public lobby near the circulation desk at the main entrance. Visitors can easily access the restrooms from the reading areas, but they must pass through the circulation area on the way. However, visitors complain that they have to walk all the way to the entrance.**

Nonetheless, this pathway makes it difficult for visitors to smuggle books into the restrooms without being noticed by staff members working at the circulation desk. The arrangement allows unobstructive supervision of the visitors without their being subjected to close scrutiny.

The library had been designed so that the public meeting rooms could be kept open after library hours, and the restrooms were accessible from outside the library itself. But now, the access is closed since the public meeting room is not kept open after the library hours. So the only access is from the circulation desk.

ARCHIE's current implementation on the Design-MUSE involves the retrieval of design "stories" via specific, previously identified architectural "problems" addressed by each of these stories. Each pair of problems and stories is accompanied by appropriate "responses" — how the architect dealt with the "problem" in relation to a particular "story." This format has many beneficial uses for an architect trying to solve a problem she is having with a design she is developing. However, this format does not address all of the needs of an architect who is formulating the design for a new building.

We conducted several small scale usability tests, in which we asked architecture students to use the system to evaluate existing plans of small libraries. Whereas students generally found the system interesting and engaging, almost all of them stated that the indexing was confusing and the indexing vocabulary was awkward. They also indicated that they needed more information while viewing the cases’ problems and responses. This need was due to factors such as lack of sufficient architectural background, lack of detailed information about the specific case/problem at hand, and, at times, terminological confusion. Consequently, we are currently considering how to add "guidelines" to the system and how to refine the indexing.

**Guidelines**

The main purpose of guidelines in the Archie system will be 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, stories, problems, and responses.

As they are employed in architecture, guidelines include one or more of several components: (1) goals, such as "make circulation accessible to able-bodied and disabled users"; (2) rules of thumb or standards for implementation and evaluating implementations, such as "all corridors should be 36" clear"; (3) lists of stakeholders and their intentions, such as "disabled people would like to enter buildings in the same graceful way as able-bodied people"; (4) critical design features affecting the intentions, such as "it is critical that the path of disabled people is continuous; that is, it has no steps or barriers anywhere along the route."

There are some points to be stressed. First, we did not intend to cover all related information (and in fact, it is almost impossible to do so). Rather, we hope to help designers understand a set of key issues and give them the background necessary to access the specific information in the system. Second, we believe that there is no single way of approaching the design process. Guidelines in our system should not be seen and used as rigid sets of sequential instructions but rather as loose frameworks. Moreover the guidelines are intended for a wide spectrum of users -- from non-architects to novice architects, from architectural students to experienced architects.

Below is an example of how guidelines may be organized in our system:

**Circulation spaces**

**Entrance**

Stakeholders and their activities: The entrance allows people to recognize the way into the building, and should be easily identifiable. Disabled persons, children and older people are frequent users of libraries. They do not like being labeled as different, and if possible the main entry should be easily accessible to everyone. Often people wait outside for the library to open or for a ride and, depending on the climate, need some kind of protection from the weather.

Lobby/entrance hall

Stakeholders and activities: The entrance hall normally accommodates the flow of the public through the space and various other facilities: people looking at the notice board, the building directory, display cases, public telephones. If the entrance hall also serves meeting and/or lecture rooms, etc., consideration must be given to the maximum number of people leaving these areas at any one time.

Several areas may have direct access from the entrance hall, for example, the circulation desk (which should be visible from entrance) and all public areas including vertical circulation which are not behind the control counter; also ancillary facilities such as exhibition space, meeting rooms, cloakroom, lavatories etc. If ancillary facilities are to be used outside library hours it must be possible to close off the library areas, preferably with one set of doors.

Rules of thumb: International Federation of Library Associations and Institutions (IFLA) recommends that 10-15 % of all public areas and 20-25 % of all staff areas should be allowed for circulation. These figures make provision not only for entrance hall, corridors and stairwells.
The Buckhead Library has a large public lobby of approximately 24 sq m. It is large enough to accommodate many patrons at once. The library is equipped with bulletin boards, public telephones, waste receptacles, and many other public utilities. The lobby thus serves as an anteroom and a rest area. It opens onto the main internal library and the Circulation Desk, but double doors between the two sections keep noise from traveling from one area to the other.
After reading these stories, s/he wants to double check if there are any acoustical problems s/he has forgotten about. So, s/he retrieves the Guidelines for "Acoustics" (Figure 4). As seen in the example, the user has access to detailed information about a particular area throughout the interaction process. Even though some design principles are provided in the Response section, the Guideline section covers the whole investigated area regardless of a particular problem.

![Figure 4: The user retrieves the Guidelines for acoustics.](image)

For example, the following problem addresses circulation in libraries:

- If the public lobby is very small, the visitors waiting for an event in a community room tend to gather inside the library, near the circulation desk, and produce noise that bothers other users.

The responses for this problem are:

1. Provide a separate lobby for the community room.
2. Use stacks or other features to separate the reading areas from the noise of the lobby.
3. The area should be well insulated.
4. finishes: absorbent ceilings; flooring to reduce impact noises.
5. Acoustical wall treatments.
6. Provide absorbent, soft, absorptive materials, for example, noise of air conditioning equipment.
7. Provide resilient pads and/or springs between the machinery and the structural frame or the building.
8. The noise level can be reduced to a minimum by the use of carpet.
9. This type of noise can be contributed to the use of heavy, durable, absorbent materials, for example, those used in foyers, proscenium arches, and stage wings.
10. Noise originating from the machinery can be controlled by mechanical and/or spring mechanisms between the machinery and the structural frame or the building.

short periods of consolidation or agreement around a given architectural dogma. He asserts that the avant-garde, rather than the architectural movements, has provided the central impetus for the development of architecture. After a period of experimentation and rapid change, of great validation. We’re seeing ourselves trying to regroup, to integrate, to bring...
The guideline for circulation, however, covers more general principles. In this case, whenever the user gets confused or cannot proceed any further because of the lack of more detailed (or general) knowledge, at any stage, she can access those guidelines in order to learn more about the area.

Indexing

The most important issue in case-based reasoning is retrieving appropriate cases (Kolodner J., 1993). The index of a single case determines how and when the case should be retrieved. The choice of indexes is very important because the indexes represent an interpretation of a situation, one that takes into account the way the user might think about a situation and the circumstances in which the user might want to recall the situation.

A first concern is what kind of stories are to be dealt with. This system focuses mainly on libraries, but the fact that a library shares many features with other public buildings challenges the indexing vocabulary to be easily scaled to cover other public buildings. In our case, systems about courthouses are indexed similarly with the library stories and show the inter-domain compatibility of the system.

Second, our initial usability testing showed some problems in specific use of indexes by architects. There was a general desire for a different format for accessing the case information. They preferred structures that use architecture's general functional/spatial decomposition as a way of indexing the problems/responses/stories already in the system.

The existing ARCHIE 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 stories with either "positive" or "negative" outcomes that identify pitfalls and opportunities (Domeshek E., et al., 1992). However, the current indexing style does not have an architectural organization structure. Without having an architectural organization structure, the links between different categories as well as the search process may be confusing for architects.

To resolve this, we are refining the indexing 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 (Residential, Non-Residential); at the third level is the type of sub-fields (Public, Commercial, etc.); at the fourth level are the main general spaces used in those sub-fields (Public Space, Interface spaces, Private spaces); and at the lowest level are specific kinds of activities (Lending, Reading, Reference, Seating, etc.). This hierarchy is presented in Figure 5. 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 remain 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 stories for a query.

How the system addresses the needs of the users

The kinds of decisions that users make are related to their design goals and to the information that they need in order to accomplish their goals. A good indexing vocabulary should provide adequate items to handle users' decisions. Initially, our indexing vocabulary used just a functional approach. However, in order to address the users' needs the vocabulary was refined to also use a reminding approach. Consider the Buckhead public library story presented earlier as an example of how the system addresses the design goals.

In order to evaluate these goals we need the following information:

- statistical information about the books damaged or stolen, in order to know how bad the situation is
- can the presence of storage spaces really improve the situation?

Figure 5: The index hierarchy.
when a story is retrieved. This visual information is crucial if this system is to provide significant help to an architectural designer. Designers are graphics-oriented. Shown below is a sample run from current ARCHIE (Figure 6).

Children have an interest in free play, noisy play, and access to books in a safe, secure environment. Parents have an interest as parents in their children's use of library facilities, but also have separate needs as library users who may wonder what might be there will cease to be anything new. We provide a context for continuity and change, for communication and invention.

The functional/spatial breakdown of the indexing vocabulary to represent the stories was done to make it more user-friendly and correspond to the designer's architectural mind. Spatial entities and functions are the entities that an architect thinks about when designing. We followed this approach in organizing the system: the case presentation first addresses the spatial entities and functions addressed by the particular story. Concluding each story with "user recommendations or comments" is also very "designer logical" as a designer's goal is to satisfy and please the user as much as possible.

In building the initial case library, one approach tried to provide coverage of the common problems encountered in the design of libraries. In the testing and training phase, the inadequacies present in the case library, in the content of cases, and in the indexing scheme should be fixed. It is hard to tell at this point without significant usability testing exactly what all of these inadequacies are. However, we discovered up front that, because each story addresses so many issues in a design or could help in so many different design situations, many of the indexes for stories are similar. This often leads to the retrieval of large numbers of stories that the designer has to wade through. In order to retrieve a limited number of the stored stories, using the current search option, "Matching All of the Interests" choice should be avoided, while using, "Matching Most of the Interests" seems to work well. Along this same line, the more specific the user is up front about his/her area of interest the better. If no suitable stories are found, one can make retrieval specifications gradually less specific to enlarge the number of stories or problems retrieved to browse.

ARCHIE currently exists as a set of 200 analyzed stories, 82 problems, and 148 responses, plus building descriptions, derived from evaluations of six libraries and two courthouses. We are refining the indexing to provide user support for a broad set of stories and problems. We are adding some stories to more generously fill out the indexing hierarchy. The most significant addition that should be made to this system to make it more useful is for inclusion of complete architectural drawings, corresponding to each story, that could be brought up in the Design window when a story is retrieved. This visual information is crucial if this system is to provide significant help to an architectural designer. Designers are graphics-oriented. Shown below is a sample run from current ARCHIE (Figure 6).

Figure 6: Sample run of ARCHIE in its current state.

The vocabulary, presented as menus, eliminates the problem of users trying to find appropriate terms to retrieve information, although, in general, the user is assumed to be an architect or at least to be familiar enough with the architectural jargon. Further, the implementation of the Goldielike dimension provides assistance for filling in a user's knowledge gaps concerning general architectural terms and issues for the novice user and concerning the terms for the library suite for an experienced architect out of her domain of expertise.

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we cease to wonder what might be, there will cease to be anything new. We need to provide a context for continuity and change, for communication and invention.
As a general case-based reasoning tool, this application of Design-MUSE takes advantage of one of the most significant offerings of CBR: extended, non-volatile memory. As a reminding or educating device, the system's ability to store and retrieve far more information than any architect, experienced or novice, can remember is its key attribute. Our goal is to support the creative development of an architectural design idea.

We are currently initiating a program of testing Archie with architecture students at various levels, from beginning to advanced. We are also revising the interface to make the system more intuitive to use, and are adding new material to the system.

Acknowledgments
The Archie project has involved many people and benefited from the contributions of many others not directly involved. In addition to Janet Kolodner and Eric Domeshke, who initiated this project, and Ashok Goel and Richard Billington, who helped shape this project at the earliest stages, we have been fortunate to work with CS students Anna Zacherl, Vijaya Narayanan, and Martin Simina, architecture students Ali Makhaw, Ellen Do, Amin Farooq, and Hussian Khalil. This work has been supported in part by the Defense Advanced Research Projects Agency, mentioned by ONR under contract N0014-91-J-4092. All views expressed are those of the authors.

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