

Reasoning about cases with diagrams

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Reasoning about Cases with Diagrams

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Abstract

This paper investigate how diagrams can be used as indices and queries in a case based functional design environment. Case bases for functional design need diagramming support for two reasons: First, most designers prefer to sketch early design ideas with a pen. They sketch diagrams to explore possible adaptations of old cases to current design tasks. Second, functional design tasks that deal with layout configuration such as arranging pipes and wires for building facilities often benefit from previous successful or failure cases. Therefore, we are developing an interactive tool called the Electronic Cocktail Napkin to enable designers to index, access, and adapt case knowledge for design using diagrams. The Napkin program has links to a case based design aid Archie to support reasoning with diagrams for case retrieval.

1. Introduction

Design and construction of large buildings involves the layout and integration of service systems: pipes, wires, and ducts to provide heating, ventilation, air conditioning, hot and cold water, drainage, gas, telecommunications, and electricity. Conflicts involving these systems can be costly, confusing, and complicated. Conflicts are often resolved by ad hoc schemes, which result in further difficulties later in the design and building life cycle. Our approach to managing interference conflicts in the layout of systems uses a case library of previously encountered conflicts. We describe our current effort to construct a case library of subsystem conflicts, part of a larger project (Gross 1994) on avoiding conflicts by coordinated layout. In this paper we focus on a scheme to index and access cases through hand drawn diagrams. Diagrams are a quick, convenient, and conventional way to identify a design configuration of service system components.

Architects traditionally use diagrams in the layout of building systems; and more generally diagrams play an important role in design thinking. Designers make diagrams to explore ideas and solve problems during early, conceptual, design.

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Therefore we are exploring the idea of using designers' diagrams to retrieve references from case libraries.

Diagrams differ from other kinds of design drawing: they express concisely and abstractly complex real world problems and solutions. A prior study (Do 1995) showed that architectural designers use diagrams conventionally, even when no set symbol system is explicitly provided. A building system diagram uses simple geometric primitives to abstractly represent the components and connections of a service system (the pipes and valves of a water supply line, for instance) as well as the rooms and corridors of the building. The common use of conventional diagrams suggests that we can use diagrams to index and retrieve design information about building systems and services.

The remainder of the paper is organized as follows. In section 2 we review related work on case based support for design, focusing on the Archie project at Georgia Tech. In section 3 we present a system for parsing hand drawn diagrams, and its application in indexing and retrieving cases. Section 4 shows how our system might be used to retrieve relevant examples from a library of service subsystem cases by drawing examples. We conclude in section 5 with a discussion and some directions for further work.

2. Case Based Support for Architectural Design

In practice architects have always employed case studies in their design process. Various case-based reasoning systems have been built to support architectural design. For example, CYCLOPS (Navinchandra 1991), supports landscape layout; CADSYN (Maher and Zhang 1991), supports structural design decision making, and JANUS (Fischer and Nakakoji 1991), kitchen design. FABEL (Consortium 1993), is a case base of complex building components; MEMORABILIA (Oxman 1993; Oxman and Oxman 1994), an architectural precedents library.

Our own experiences have been with ARCHIE (Goel 1991) & ARCHIE II (Domeshek and Kolodner 1991; Domeshek and Kolodner 1993; Domeshek and Kolodner 1992; Zimring et al. 1994), is a case library of architectural post occupancy evaluation (POE) stories. It has been developed jointly by artificial intelligence researchers and the architectural post occupancy evaluation (POE) team at Georgia Tech.

These projects use case-based reasoning to aid design decision making, learning, and problem solving. For example, Archie provides case stories to help designers solve design problems. Its case base comprises on-line access of documentation and evaluations of existing complex buildings. Archie suggests a role case-based systems can play in helping design practitioners and planners learn from past experiences. It provides designers with stories about previous successes and failures during the early phases of problem solving.

Archie contains stories, problems, and responses from post occupancy evaluations of courthouse, library and tall buildings. Domain knowledge in Archie was elicited from POE studies and interviews conducted with design engineers. Archie's domain knowledge comprises case studies—text documents, photographs, and floor plans—of various public buildings. Archie also includes a library containing

design principles, previously encountered problems and resolutions to help designers anticipate and avoid conflicts among the service systems. Figure 1 shows a screen from the current Archie case base. The top “Library” window consists of three panes: Problem (left), Response (right) and Story (middle). At bottom is the Artifact window: containing a Design pane, in this case a building floor plan with several ‘hot spots’ (small circles) linked to a list of one-sentence annotations at the left. The various panes and windows are interconnected. When the designer selects an annotation, relevant stories (and problems, and responses) appear in the upper Library window.

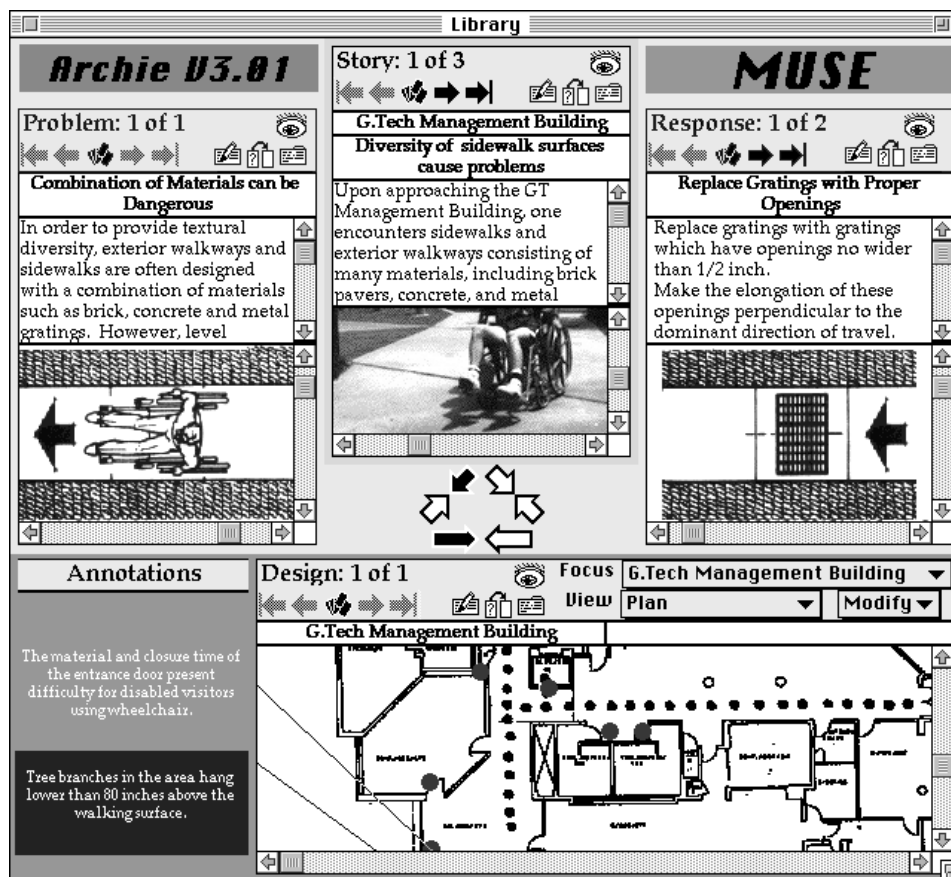


Figure 1. Archie screen: problem, response and story on the top; design artifact and annotation on the bottom.

In previous work, Do conducted an experiment to test the Archie user interface. She asked designers to use Archie to provide information during the initial phases of solving a design problem (Do et al. 1994). She found designers reluctant to use Archie's keyword interface to find relevant information. In short: designers prefer to draw; they are reluctant to stop drawing and use text (menus, dialogs) to retrieve information, even when they may need that information for their further designing. This motivates our current approach, enabling designers to draw diagrams to access architectural knowledge bases.

3. Electronic Cocktail Napkin — a system for hand drawn diagrams

The Electronic Cocktail Napkin (Gross 1996) is a freehand (pen based) sketching environment with trainable recognition capabilities that end users can program. Its purpose is to support diagramming as an interface to knowledge based systems for engineering and architectural design. Figure 2 shows the Napkin's Drawing Board used for making new diagrams and the Sketchbook used for storing diagrams and linking them with external applications and knowledge bases.

The Napkin recognizes common simple shapes (e.g., circles, boxes, lines) and it can be trained to recognize additional domain specific symbols (e.g. a 'ground' symbol for circuit diagrams). End users can also program the Napkin to recognize configurations of simple shapes in certain spatial relations. For example, we programmed the Napkin to recognize the configuration of a triangle containing a circle as a symbol for 'pump' (see figure 2).

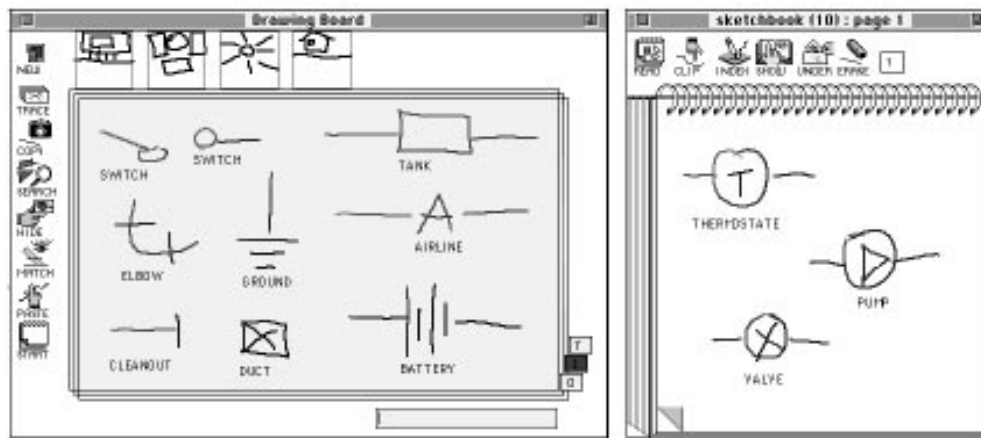


Figure 2. Electronic Cocktail Napkin program: drawing board and sketchbook.

4. Retrieving Cases by Diagrams

In layout drawings of building support systems, graphical symbols show in abbreviated form the general location, and connections for pipes and wiring, switches, panels, ducts and other equipment. Handbooks for building subsystem design such as Heating, Ventilation and Air Conditioning (HVAC), Plumbing, Electrical and Mechanical systems (Lewis 1986; McGuinness et al. 1980) stress the importance of using standard graphic symbols to convey information to manufacturers, installers, and facility managers. For example, a rectangle represents a tank, a letter T inside a circle is a thermostat or a thermometer, a line labeled with the letter G indicates a gas line.

We have built a prototype of a diagramming tool that enables users to find cases in the Archie database using hand drawn diagrams. For example, a designer might sketch a diagram to layout a water tank and a pump without thinking about insulation requirement for a boiler and water tubes. Concerned about what fittings and valves her arrangement requires, she can use her diagram to retrieve related knowledge

from the case base to help avoid possible failures. By looking at case stories about similar plumbing configurations, she can learn the information she needs to know to perform the task at hand. Figure 3 shows how our program retrieves a case story about the cooling system in a tall building, given a diagram of a tank, pump, and valve.

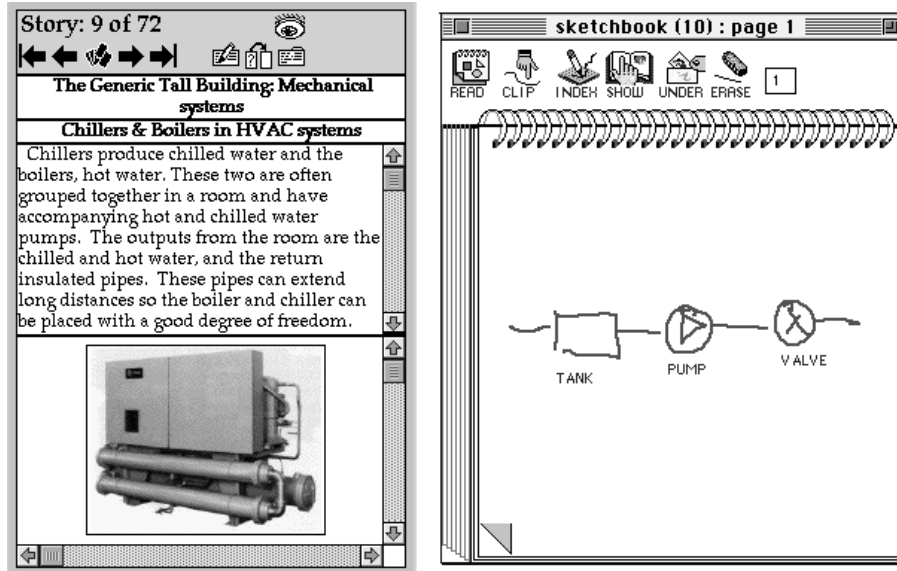


Figure 3. A diagram (right) of a tank, pump, and a valve retrieves an Archie story (left) about how a boiler and cooler work in an HVAC system.

When designing lighting and appliance branch circuits for buildings, the design work consists not only of determining outlet locations, but also using basic knowledge of electricity and standard configurations for outlets, circuit runs and control mechanisms. The designer's diagram of electrical symbols will help retrieve precedent knowledge for selecting the right device, and conform to standard locations for load devices and spacing of outlets and junctions. For example, Figure 4 shows information about the principles and guidelines for electrical equipment utility space design is retrieved by making a partial circuit diagram.

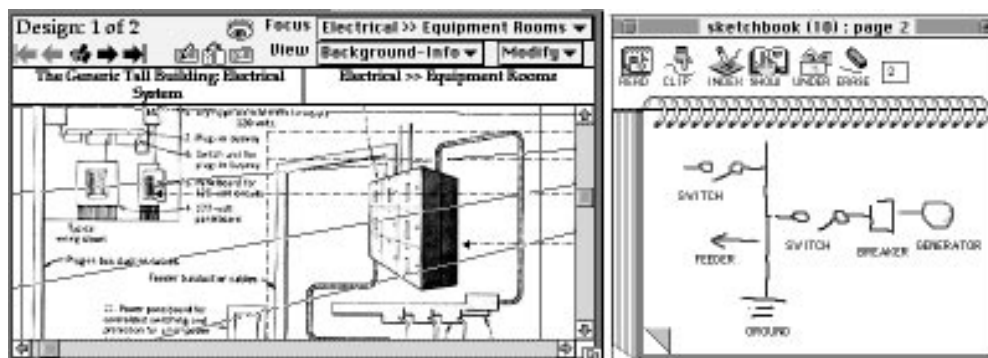


Figure 4. A diagram with several switches, a circuit breaker, a power generator, and a ground connection activates a design principle of electric room design in Archie.

5. Discussion and Further Work

We have demonstrated a simple system that recognizes and parses building service system diagrams, and its use in indexing and accessing a case base of technical knowledge about architectural design. Our effort comprises two parts: (1) the Electronic Cocktail Napkin, a free hand drawing program that recognizes diagrams, and (2) Archie III, a case based design aid with its associated library of Tall Building cases. We are currently collecting case stories about conflicts and resolutions among service systems and building system integration, to enrich Archie's case library.

We are considering two directions for further work. First, we plan to strengthen the Electronic Cocktail Napkin's recognition facilities and clarify its user interface, so designers can use it with minimal training. The present system works well, once a designer has trained the program to recognize her own drawing style and has learned the quirks of the Napkin's human computer interface. We plan a round of user testing and formative evaluation to clarify the interface. Second, we plan to connect the Napkin and the case library with simulation tools, enabling the designer to explore the behavior of a proposed system during the early and conceptual design stages, before investing a great deal of time in specifying the system in detail. Thus, in addition to a case library of design stories, problems, and responses, the designer could access causal models of a proposed design by drawing a system diagram.

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