Diagram Query and Image Retrieval in Design

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Proceedings, 2nd International Conference on Image Processing, Crystal City, Virginia, IEEE Computer Society Press, 1995

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DIAGRAM QUERY & IMAGE RETRIEVAL IN DESIGN

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ABSTRACT

Architectural designers are voracious consumers of visual images, which play a crucial role especially in conceptual and creative design. Consequently architectural education revolves around visual references. Yet key word, texture and color retrieval schemes do not suit designers' needs. Designers need shape based retrieval that is driven by free hand drawing, and ways to integrate retrieved images into their design environment. The paper describes Drawing Analogies, an image retrieval scheme for design based on the need for image retrieval that can be integrated with the act of free hand drawing. Our scheme does not perform feature extraction of stored images, but relies on users to create an index of diagram keys. Automatic and semi-automatic feature extraction from database images would be a useful extension of our Drawing Analogies system, but likely would not supplant the need for designer's supervision of the indexing process.

1. IMAGE RETRIEVAL IN DESIGN EDUCATION

1.1 Designers learn by looking at images

Visual images play a valuable role in many design domains, from architecture to mechanical engineering. Especially during the conceptual stages, when the designer is searching for relevant ideas to employ, collections of visual images are crucial aids to design. Ferguson points out in Engineering and the Mind's Eye [1], mechanical engineers have relied on visual images for centuries, but nowhere is the use of visual images more pronounced and acknowledged than in the educating of architectural designers. Students of architectural design spend hours looking at slides in lectures, leafing through picture books and magazines. Whether the topic is structural stability, functional layout of spaces, or the proportioning of facades, architectural designers learn as much from studying pictures as from reading books and listening to lectures.

Many books written to educate young designers urge the use of visual references in design, and drawing as a tool to understand and transform visual references. For example, Laseau's Graphic Thinking for Architects, McKim's Thinking Visually, and Antoniades's The Poetics of Architecture [2-4] all point out the importance of learning by studying visual references.

Interestingly, the visual references used by designers are not solely within their design domain, though of course domain-specific references do play an important role. Architects don't look just at buildings, but also at art, at machines, and at natural forms. A glance at Leonardo da Vinci's notebooks reveals a varied range of sources for his designs[5]. Designers are likely to search in diverse digital image libraries for pictures with specific form characteristics and spatial relationships, a strategy that is unlikely to match any domain-specific indexing system.

1.2 Designers need shape-based retrieval

For the most part, designers browse to find the references they want. The reason is simple: when they are indexed at all, picture books and magazines simply describe the picture by a few key words. For example, a picture book of buildings by Frank Lloyd Wright will simply list the images by the building name, and the date of construction: "Willits house, 1903". Likewise, the traditional slide library is indexed by name, date, place, architect. In other words the circumstances of the image are indexed but not its content. This form of indexing is useful for historians, but less so for designers. Therefore, the slide library in most schools of architecture is used mainly by historians and lecturers, and do not serve as a design resource for learning to design. A designer is likely to be looking for a spatial configuration of components relevant to her task at hand. A key word description of the configuration, even if available, would be unusably tedious. So the designer flips pages looking for a picture of a closely matching configuration.

1.3 Color and texture retrieval won't work either

If image indexing and retrieval schemes based on key words often won't work for the designer, neither will retrieval schemes based on color and texture. For example, we have explored using a histogram-matching retrieval scheme designed for multimedia databases [6] to retrieve architectural images. Their eMMaC system (figure 1) allows the user to paint visual queries, then using a histogram matching scheme, finds images with a similar color or shading profiles. We found it is difficult to compose succesful queries, and that the colors and shading features are unimportant for our task.

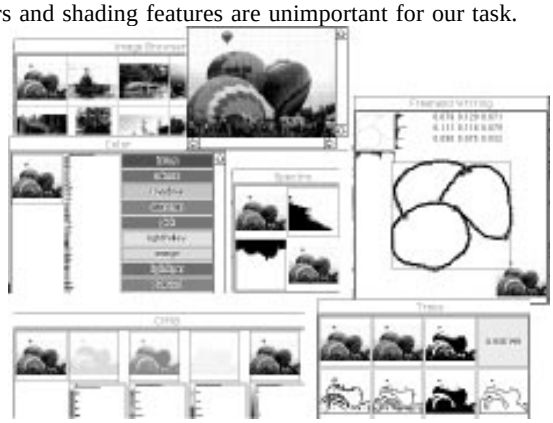


Figure 1. Nakakoji et al's histogram-matching image retrieval scheme

2. DRAWING IS PRIMARY

Drawing is the primary medium of design, and therefore any scheme for retrieving reference images for architects must be integrated into the designer's environment for drawing. Designers are trained to think with a pencil, and they sketch, diagram, doodle, and draw to understand and assimilate new information they find in visual references. This is true in not only in architecture, but also in other design domains. For example, Ullman's "The Importance of Drawing in Mechanical Design" [7] outlines several reasons why the act of drawing is key in mechanical engineering design.

Digital libraries of architectural images have been built (e.g. [8, 9]) . However, in these schemes, retrieval is by browsing and by key word, and images are simply displayed in a window for the designer's appreciative gaze. The designer needs to find images by drawing, and then to engage retrieved images in the design process, for example by tracing over them and by extracting their key features.

3. DRAWING ANALOGIES ON AN ELECTRONIC COCKTAIL NAPKIN

We have developed a prototype, Drawing Analogies, for indexing and retrieving images from digital libraries based on diagrams of image form. The Drawing Analogies program rests on a design environment for recognizing, interpreting, and managing hand drawn sketches and diagrams, the Electronic Cocktail Napkin.

3.1 Electronic Cocktail Napkin

The Electronic Cocktail Napkin is a design environment, written in Macintosh Common Lisp, that reads and recognizes hand drawn diagrams input from a digitizing tablet. It uses low level features of the free hand input to identify the simple elements of a drawing. These features are: pen path through a 3x3 grid, number of strokes, number of corners, aspect ratio, and size (see figure 2). In addition, the low level input routine records drawing pressure, and implicitly (because input sampling happens at a constant rate) drawing speed. These characteristics provide enough information to match hand drawn symbols (such as shapes, lines, and alphanumeric characters) against a set of previously trained templates.

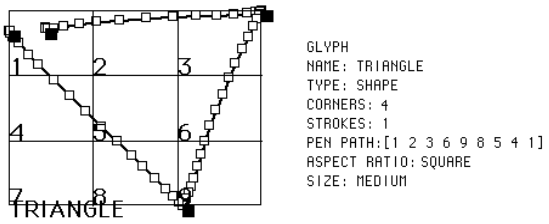


Figure 2 - Low level glyph features

A diagram is composed of a simple glyphs, or symbols, arranged in a certain spatial configuration. For example a "tree diagram" is composed of a set of line segments and circles, arranged so that the lines connect the circles, and the connected circles are more or less above one another on the page (figure 3). A user-defined set of "higher level recognizers" parses the free hand drawing and identifies these configurations in the designer's drawing.

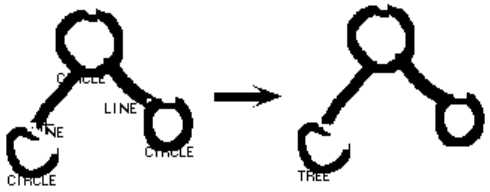


Figure 3. Tree is configuration of lines & circles.

In addition to the low level recognizers, and higher level parsing, the Electronic Cocktail Napkin provides designers with tools for working with diagrams. For example, a simulated tracing feature enables the designer to selectively copy from previously made drawings and to use retrieved photographs, maps, and drawings as drawing underlays. In addition, a simple constraint language enables the user to assert recognized relations as constraints to be maintained on the drawing. The environment also supports collaborative work, in which two or more designers either share a single tablet with different pens, or each draw on their own tablet. In addition, a simulated sketchbook provides a filing system for designers to accumulate their work and to paste in relevant visual references. The sketchbook also provides the interface to a diagram based query and retrieval scheme for multiple databases (see figure 4).

3.2 Drawing Analogies

We have developed a working prototype of a scheme for indexing and retrieving database items by making diagrams. We call it, "Drawing Analogies" because a designer can make free hand drawings to find visual analogs for an emerging design. We have used the Drawing Analogies program to connect to three databases: a case based design aid for architects, Archie II[10]; a CD-ROM library of famous buildings[11], and a home-grown database of flowers.

Drawing Analogies enables a designer to make a sketch or diagram as she browses a database, and to use these diagrams as visual bookmarks to later find the keyed items in the database. For example, as the designer browses the Great Buildings Collection, she might make a simple diagram of Wright's Guggenheim Museum. The helix diagram she draws is typical of the diagrams designers draw for this building, and it reflects the museum's internal circulation path. She stores the diagram as an index key for the building, and later can retrieve the Guggenheim entry in the Great Buildings Collection by making another diagram of a helix. Of course, the Drawing Analogies program would also retrieve all other buildings indexed with a helix diagram.

Figure 4 shows (counterclockwise from lower right) (1) a simple hand drawn query diagram which retrieves first (2) a similar previously drawn Sketchbook page, which is linked to (3) a page in the Archie case based design aid, (4) Palladio's Villa Capra in the Great Buildings Collection, and (5) a page in a flower database.

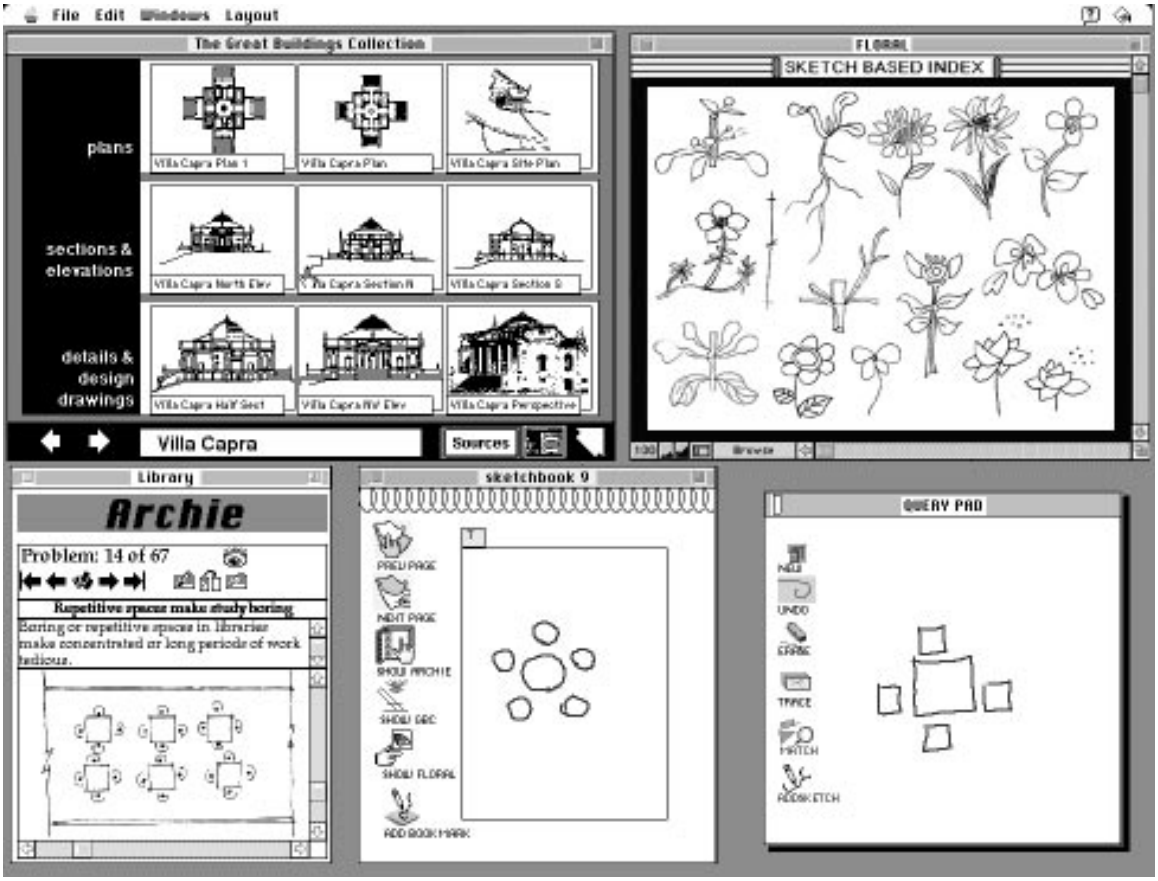


Figure 4. Diagram query (lower right) retrieves items in several image collections.

Although the idea of visual bookmarks seems highly idiosyncratic, we have performed several pilot studies that suggest that at least architects share a language of diagrams that will enable a diagram index to be shared[12, 13]. In one experiment we asked 50 design students to make representational diagrams of ten slides of buildings, 5 plans and 5 photographs.

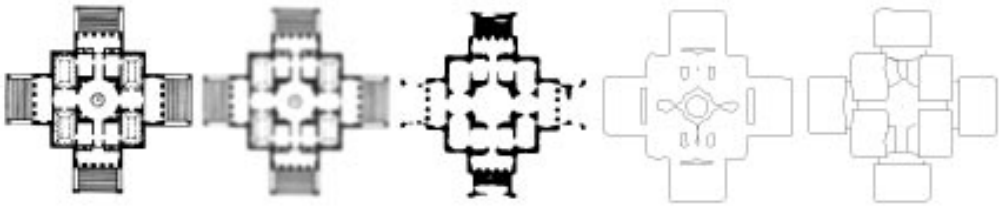
The diagrams they made revealed that most designers observed the same features in the images, and used a small repertoire of representational techniques to draw them. In a second experiment, we asked 20 designers to diagram three well known buildings from memory. Again, the diagrams showed considerable consistency (e.g. three simple diagrams accounted for over 90% of the Guggenheim drawings). In a third experiment, we asked designers to make diagrams of architectural concept stories, described in text (e.g. "sunlight from windows causes glare on CRT screens"). Designers used a small and consistent graphical vocabulary and many of the same spatial arrangements to illustrate the stories.

4. DISCUSSION

We have argued that (1) designers are voracious users of visual images and (2) the act of drawing cannot be separated from this use. Therefore we have developed a query by diagram scheme for designers to find visual references for their designs while making drawings, and to integrate the retrieved images into their designs.

Our Drawing Analogies program recognizes features of free hand drawings, and compares these features with the diagram keys of previously indexed images. Thus our approach relies on a previously indexed database; we have argued that designers are likely to agree on diagrams for images.

Like others (e.g. [14, 15]) we would like to employ image processing techniques for digital images to automatically obtain diagrams similar to those that designers would make. To this end, we experimented with off-the-shelf image processing tools (Adobe Photoshop and Streamline) to convert a scanned gray scale plan drawing into simple line figures (see figure 5). Although this approach cannot work for all images (e.g. no drawing or photo of Wright's Guggenheim museum reveals its helical form), a set of image processing tools could well aid the indexing task.



[a] [b] [c] [d] [e]

Figure 5. Using Adobe PhotoShop and StreamLine to convert a scanned drawing to a diagram: [a] original; [b] resolution reduced to 72 dpi, apply Gaussian blur; [c] bitmap conversion, grays darker than 3% to black; [d] vectorized version, outline method with curve path option; [e] vectorized version, center and outline method, with noise suppression, line thinning, and straight line path option.

We have also observed that the kinds of drawings designers make while designing (as opposed to in a focused image database query) are likely to be more complex than the typical diagram index. For example, the drawing in figure 6-a is typical. In order to successfully match the diagram index (as in figure 4), it is necessary to discard extraneous lines in the drawing. Figure 6-b shows what remains in the figure after filtering for geometric shapes (discarding lines and unidentified glyphs). Figure 6-b is easy to match against the index key.

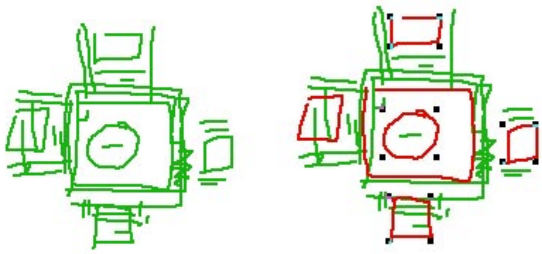


Figure 6 - Free hand drawing of plan of Palladio's Villa Capra (see also figure 4) [a] as drawn, [b] filtered for geometric shapes.

We believe that a drawing-based approach to image retrieval will work well for designers in all domains. We plan to test the Drawing Analogies prototype in small design studio settings at Colorado, using a variety of digital libraries and design information databases.

ACKNOWLEDGMENTS

The support of NSF grant DMI 93-13186 is gratefully acknowledged. Thanks to the Oregon Integration Laboratory, Kumiyo Nakakoji, and Janet Kolodner (respectively) for permission to reprint figures from the Great Buildings Collection CD ROM, eMMaC, and Archie II.

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