Interpreting Physical Sketches as Architectural Models

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Abstract. We present an algorithm for the automatic interpretation of a rough architectural sketch as a consistent 3D digital model. We compare our results to the designer’s intended geometry. We further validate the algorithm by studying the variations in possible interpretations made by other humans for a set of relatively ambiguous sketches. In our system, the user sketches an architectural design by arranging small-scale physical wall modules and simple markers for windows on a table. These color-coded elements are captured by a camera mounted above the scene and recognized using computer vision techniques. The architectural design is automatically inferred from this rough physical sketch transforming it into a consistent and manifold 3D triangle mesh representation. The resulting digital model is amenable to numerous building simulations including lighting, acoustics, heating/cooling, and structural analysis.

1 Introduction

Sketching, drawing, and diagramming are fundamental components in architectural design. The evolution, communication, and documentation of a design are performed through various styles of visualization. These broad categories of visual communication in architectural design use a variety of artistic techniques; however, these representations are usually stylized and employ common conventions.

One important category of architectural illustration is the figure-ground diagram. This visual representation uses two contrasting colors, positive and negative, to partition space into two sets by filling in large regions of the diagram with solid color. In architecture, a figure-ground diagram is most often drawn in plan (from above) to convey either the rough overall massing shape of the building or the public freespace; for example, a public plaza surrounded by private buildings. Often architects will execute diagrams in both forms when considering different aspects of the same project. Another important class of diagrams used in the early stages of architectural design, circulation diagrams, visualizes how people will use the space
and highlights the common movement paths within the proposed design. By analyzing and anticipating common paths, the relative placement of spaces within a design and the relationship to the existing site can be optimized to minimize path lengths or to add interest or drama by highlighting views and enhancing the experience of circulating within the design.

Figure-ground and circulation diagrams are used primarily in the early stages of design when the spaces and relationships are still evolving. In contrast, technical architectural CAD drawing, used in the later stages of design and in construction documentation, is highly precise and detail-oriented and more strictly follows diagrammatic conventions. Few architects would claim that traditional CAD modeling tools and detailed technical drawings are essential to the early, creative stages of architectural design.

In addition to pen-and-paper sketches, small-scale physical 3D models (often built from scrap cardboard) are fundamental tools for architectural design. These study models can be essential for understanding complex spatial relationships, documenting the evolution of a design, and communicating the concept to the client. Even with the wholehearted adoption of computer technology for drafting and 3D visualization, the physical study model has not been abandoned as a tool for architectural design. In fact, rapid prototyping technology has increased the expectations for physical prototypes of complex designs.

1.1 Tangible User Interface for Architectural Design

The architectural modeling system at the center of our project uses a tangible user interface, which involves manipulation of physical props for interaction with computation (e.g., [Ben-Joseph et al. 2001]) rather than the typical mouse/keyboard/monitor interaction between human and computer. Well-designed tangible interfaces are attractive because they are inherently simple, natural, and intuitive. Furthermore, these interfaces generally support collaborative work environments.

In our system, shown in Figure 1, one or more users gather around a table and construct a small-scale (1:12, 1” = 1’) sketch of an architectural design using simple foam board flat and curved walls in three different heights (5”, 8”, and 10”). Special markers slip over the top edges of the walls to indicate windows, and the overall orientation of the architectural design on the site is specified with a “north arrow” token. This design environment is simple to operate and requires essentially no instruction to use. The only restriction on the designs is that wall elements must be upright, resting on small “feet”, so that each wall surface is perpendicular to the table surface. A new design can be quickly constructed in under a minute by selecting and arranging wall and window elements from a modest collection of parts on a neighboring table. Similarly, the design can be edited in seconds by adjusting any of the physical pieces. Image capture and processing of the detected geometry is completed in a couple of seconds. The system supports viewing and editing by multiple users who are gathered around the table. The interactive modeling environment encourages creativity and collaboration.