As if You Were Here - Intelligent Annotation in Space: 3D Sketching as an Interface to Knowledge-Based Design Systems

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Abstract

Sketching in 3D is a useful way to access knowledge-based design systems. In this paper we present a framework for sketch-based interaction with intelligent systems in three-dimensional domains. The Space Pen software written in Java 3D is used as a platform to implement two architectural lighting design tools. Space Pen supports user annotations in the form of sketching, virtual post-it notes, and sketch object insertions. Spot supports access to direct sunlight simulation and visualization in a selected time period with sketching in 3D space. Light Pen suggests placement of lamps to light an intended area in space. In these examples, the 3D sketching front-end serves as an interface to a back-end knowledge-based system. The designer can pose problems by drawing onto a 3D model to which the knowledge-based systems offer a solution by either providing quantitative data analysis or modifying the 3-D model. The specific domain of architectural lighting is implemented, it exemplifies a more general class of 3-D pen-based interaction with intelligent systems.

Motivation – Tools for Design in 3D

Many design domains – industrial, mechanical, civil engineering, and architecture involve designing and manufacturing 3D artifacts. Design collaboration in these domains often is executed with 2D representations of the artifacts (e.g., diagrams, plans, sectional, and perspective drawings) and textual communications (e.g., phone, fax, instant messaging, email, etc). Comments like "That's not what I meant!" or "This is not where I wanted it…" and "What problem area are you talking about?" are abundant in these communication logs. Many problems arise because we can't see the 'views' of our collaborators or the exact locations they are pointing at in 3D. The "wish you were here" problem can easily be addressed with a 3D annotation system. Furthermore, decision support systems can play a role as a collaborating partner, a helpful assistant or an expert advisor in a design process. Three-dimensional annotation coupled with a knowledge-based design system would be helpful to support design activities. Therefore, we implemented several systems to explore the idea of 3D sketching as an interface to knowledge-based design tools.

Many pen-based computing projects have investigated generating and editing three-dimensional models (Zeleznik, Herndon and Hughes 1996; Schweikardt and Gross 1998; Igarashi, Matsuoka and Tanaka 1999; Igarashi and Hughes 2001; Do 2002). However, their focus is the geometry generation and its immediate behavior. On the other hand, diagram interfaces for intelligent systems have mostly supported two-dimensional drawing (Lakin, Wambaugh, Leifer et al. 1989; Egenhofer 1996; Stahovich 1996; Davis 2002). However, physical design domains such as architectural design and mechanical engineering are mostly concerned about geometry and configurations in 3D. Analysis tasks of these design domains often involve building geometric modeling in 3D and entering them into simulation programs. The resulting data are usually output in text and 2D sectional drawings. The designers then use them to reason about design functionality.

Our goal is to bring applications that operate on 3D models into the designer's working environment to more seamlessly integrate design and analysis. Designers' preferred choice of medium for design explorations is informal sketches and diagrams (Herbert 1993; Suwa and Tversky 1996). Therefore, to expand the idea of using a pen-based system to access intelligent systems, we built Space Pen to support annotation in 3D. We then built the Spot and Light Pen systems to demonstrate how such an interface can be used in the domain of architectural lighting design. Spot and Light Pen each add a layer of knowledge-based system to the 3D sketching environment in Space Pen.

3D Annotation Environment in Space Pen

Space Pen supports Web based design collaboration with annotation capabilities in a 3D environment (Jung, Do and Gross 2002). Any VRML model posted by the architects to the Space Pen server is converted into a Java 3D model for viewing in a standard Web browser. Designers and collaborating team members can then browse and annotate on model surfaces by graffiti-style sketching.

For example, as shown in Figure 1 (right), a designer reviewing an architectural design can draw on a wall to indicate a proposed location for a new window.

Designers can mark on any existing model surfaces or on a temporary drawing plane to add geometry to the model.

Figure 1 (left) shows a new wall piece extension sketched on the temporary wall. Simple stroke recognition in Space Pen identifies figures such as arrows, rectangles, and circles. Once recognized, these sketch objects can be rectified as model geometry or interpreted as commands. In short, Space Pen provides a platform for drawing onto and into 3D models.

Space Pen also supports text annotation with Post-It® style tags that can be attached and will remain in the model. The 3D-located threaded discussions are linked to issues and authors. When a new annotation note is made the Space Pen server automatically sends emails to inform all related stakeholders about the feedback.

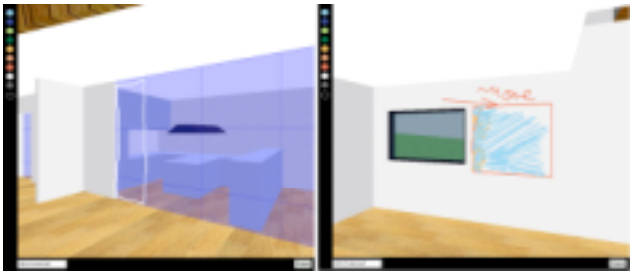

Figure 1. Sketch annotation in Space Pen on temporary surface (left) or existing surface in the model (right).

Sunlight Visualization in Spot

The Spot system supports lighting visualization through sketching. Designer can sketch a boundary shape on the 3D model to indicate the area intended for simulation. Spot then generates a representation of the spatial distribution of the illumination level on a selected surface over time. Spot also enables designers to visualize the temporal information of light distribution over time for a given point. For each point the user taps on the 3D model, Spot generates a calendar diagram of a chart where the X and Y axis represent the months of the year and the time of the day. The color of each calendar cell is the result of the calculation of the light amount reaching this specific point.

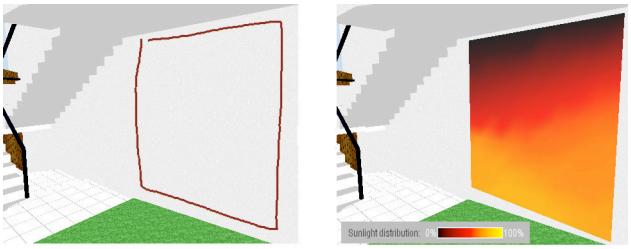

Figure 2. A boundary area sketch (left) on the wall activates sunlight distribution simulation (right).

The Spot system consists of the 3D sketching front end to a rule-based sunlight simulation. Two complementary components are implemented in Spot: 1) Time Projection and 2) Navigable Animation. The spatial variables (x, y, z) of 3D geometry are implemented for easy navigation with standard interface (mouse, arrow keys or joystick) and text annotation and sketching (pen and tablet). The temporal variables (date and time) are displayed in additional views with the appearance of a graphic calendar. The resulting sunlight simulation (in gradient distribution) is displayed on the 3D environment. Spot also supports collaboration over the web. Simple modifications on the model's geometry can be made with freehand sketching input for daylight simulation.

Lighting Fixture Advisor in Light Pen

The Light Pen system connects a 3D sketching front end to a rule-based electrical lighting fixture advisor. The designer interacts directly with the 3D Space Pen environment that supports browsing and sketching. After importing a three-dimensional (VRML) model the designer marks up the model to indicate desired area for lighting effects. The model geometry and the designer's lighting sketch marks are passed to the Lux lighting design advisor. Lux is Light Pen's 'back end' intelligent system, coded as a set of lighting design decision rules. Lux accepts the lighting sketch marks and building geometry as inputs. Based on the desired lighting and the model geometry Lux infers the contexts, recommends solutions, and then selects fixtures from a catalog based on their desired characteristics. Finally it passes these recommendations back to Space Pen, which adds the fixtures to the 3D model to indicate Lux's proposed design solution.

Figure 3. Light Pen recognizes the intended sketch for lit area and places lamps appropriated for the lighting effect.

Discussion

Sketching on a 3D model to identify desired lighting effects sparked the development of the Light Pen and Spot. More generally, we saw that sketching in 3-D could be a direct and natural means to interact with systems that reason about and calculate on three-dimensional models.

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