Immersive Redliner: Collaborative Design in Cyberspace

Thomas Jung, Design Machine Group, University of Washington, USA

Ellen Yi-Luen Do, Design Machine Group, University of Washington, USA

Abstract

The Immersive Redliner supports annotation of three-dimensional artifacts in collaborative design. It enables team members to drop annotation markers in a VRML world that are linked to comment text stored on a server. Visitors to the world later can review the design annotations in the locations where they were made. We report on two phases of the Redliner project: the first involves a hypothetical design scenario, the second a real application on a rehabilitation in a residence building in Strasbourg.

Keywords: annotation, collaboration, design, virtual worlds, redlining.

1   Introduction and Motivation

Comments and critique are essential components of a successful design process. In physical domains such as architectural design, critique and comments usually refer directly to design components or are otherwise bound to a particular location. Traditionally, designers record and exchange review comments and critiques through annotation of design drawings, or 'redlining'.

Design collaboration can occur in a synchronous or asynchronous way. With the rapid development and information accessibility of the Internet and the World Wide Web, we explore the idea of putting a three-dimensional design representation on-line for asynchronous virtual visits, commentary, or redlining.

Our Immersive Redliner provides a framework for Web based critiquing of three-dimensional designs. The current system employs a VRML browser, Java applets, and server-side CGI scripts to mediate the actions of multiple viewers who visit a virtual model and leave behind annotation markers (like PostIt notes) with comments on the design.

2   Communication and Collaboration in Cyberspace

Collaboration among architects, their colleagues, and clients by commenting on design documents is a well-accepted practice. The traditional method of communication and collaboration among designers at different locations is sending the information via paper media. For example, when designing the Carpenter Center for the Visual Arts, Le Corbusier collaborated with the site architects in Boston by mailing documents, drawings, and photographs of the physical models from France (Sekler 1978).

Currently, architecture firms use communication modes such as express mail, telephone, and fax machine to communicate with colleagues around the world. Some use electronic media such as email and file transfer to send drawing files or specification spreadsheets to their collaborators at different locations. This is a straightforward way of communication. However, sending files across the Internet creates new management problems. Architects must consider time differences between remote locations and provide version control mechanisms for shared documents. It is therefore desirable to have a virtual space for all concerned parties to visit, review and make changes to the design at their convenience. Our Redliner project explores the idea that the space should take a three-dimensional form that allows reviewers to leave their comments for others to consider later.

3 Related Work

The Redliner project was developed with three major concerns in mind: collaboration, annotation and 3D representation. It supports indexed annotation of 3D artifacts in a virtual world for workgroup collaboration. Below, we briefly review some related research projects and commercial software.

Annotation has been studied in various domains of collaboration. Marshall (Marshall 1998) studied annotation of physical texts to understand the implications for hypertext authoring in a shared commentary practice. Many papers at Human Computer Interface (HCI) conferences emphasize the need for and focus on the means to enhance awareness of collaboration from remote locations (Greenberg, 1992). In design, many systems have been built to support three-dimensional representation (Schweikardt, 1998), on-line critiques (Wojtowicz, 1995), synchronous collaboration through drawing (Qian, 1999), and using gestures to create virtual worlds (Donath 1996).

With similar goals to ours, McCall et al (McCall 1998) added to his PHIDIAS system a 3-dimensional representation module called "Web PHIDIAS". Based on VRML, it allowed users to click on certain objects and leave comments about these pre-selected objects on a system server. Craig and Zimring at Georgia Tech developed a system that allows people to drop arrows and other objects in a VRML scene (Craig, 1999). Campbell tried communicating construction documents with a contractor through 3D VRML models to fabricate a flight of stairs (Cambell 1998). Although similar to our Immersive Redliner, these systems are less versatile, because the design objects must be specially prepared to accept annotation. In the Immersive Redliner, any VRML model can be imported and serve as the basis for annotation.

Some commercial applications also allow users to annotate while viewing 3D objects. For example, eZ (http://www.ezmeeting.com/) viewer, like Microsoft's NetMeeting, provides viewing of operations and mark-up on documents stored at the server site from all client sites. It supports synchronous communication but the viewer does not capture or record the process or results of the collaboration for future reference. The SolidView program from Solid Concepts (http://www.solidview.com/) provides utilities to make presentations such as a slide show or cross section measurements of a prepared three-dimensional model. Users can send the proprietary viewer or slide player to collaborators to show design concepts or assembly procedures. Collaboration by sending explanations with model slide shows is useful, but it is limited to one-way communication.

In the Redliner system design we focus on the need for different stakeholders to choose their own time and pace to explore the design and to post questions and proposals for other participants to review, and thereby to engage in communication and collaboration. We built the Redliner project to facilitate communication among all parties involved in the design development process: architects, engineers, contractors, and clients can review and comment about design issues directly on the design artifacts. We used VRML and Java to build Redliner so it is accessible and easy to use for anyone with a Web browser.

In the following, we describe our efforts building a system that supports critiquing of designs in a virtual environment, and the lessons we learned from our experience with real use testing of this system.

4 First Study: Pavilion House

This section explains the first test of the Immersive Redlining system. We report here a collaboration process and interaction between different design team members in a shared virtual world. A detailed explanation of the functions and features of this scenario is reported elsewhere (Jung, Do, Gross 1999). Here we summarize the procedures of using the basic Redliner system. The second study described in the next section (5) is an extension of this system with more versatile functionality with layer control.

The first step in using the Immersive Redliner is to post a VRML model, constructed using a standard 3-D modeler (we used autodessys's form•Z), on the Redliner Web site. Once it is posted, all design team members can visit the model using a VRML browser. Each visitor can browse the initial model, or the model augmented with annotation markers left by other team members.

Figure 1 below shows an initial login screen. One enters the system by registering name, email address and choosing a color for annotation marks.

Figure 2 shows the layout of the Redliner site. User identification and comments are displayed on the left with a white background; the VRML model of the design is displayed on the right with a

black background.

Architects also provide a set of viewpoints (Figure 3) to guide reviewers through the design space. This provides an easy means of navigation, a guided path to experience the design. Of course, reviewers can also wander off at any time and explore the design independently of the path. Any annotation markers dropped later on will also generate a new viewpoint into the list.

4.1 Posting Annotation Markers

To add an annotation to the model, the visitor clicks on a surface or an object, leaving an 'annotation marker' (a color-coded sphere: each visitor selects a color for their markers). The Redliner pops up a comment window for the visitor to enter a title and text for the annotation. The Redliner numbers each visitor's markers sequentially. Figure 4 left shows the interior of an architectural model ("the Pavilion House") and Figure 4 right shows a numbered annotation marker with its associated type-in comment window.

Visitors can view comments left by others by clicking on an annotation marker in the model. Each annotation marker records the visitor information and viewing position and links to a time stamped comment stored in a text file on the server. Visitors can also view comments made by each of the other visitors individually, or the entire comment collection sorted by authors and time sequence. Each comment links back to its marker in the model, so a visitor browsing the comment logs can easily examine the part of the model under discussion. In the same way, all annotated models can be displayed on the "list of projects" for easy retrieval of the last annotated project. Figure 5 shows the comment log left by one of the Redliner visitors.

4.2 Design History

The Redliner framework allows posting of any design in a VRML format to facilitate "on site" design communication and collaboration. The three-dimensional space functions not only as repository for comments in the space (on location) but also as a design history, because all comments are time coded and can be retrieved by author index as well.

4.3 Design Alternatives

In addition to annotating the 3-D virtual world and viewing annotations left by other users, makers of Redliner models can offer visitors design alternatives. Figure 6 shows how, using a menu at the bottom of the browser window, visitors can select among several wall arrangement alternatives for defining the lower floor corner area in the Pavilion house. Alternatives are stored as partial VRML models, and the Redliner adds them to the base model in response to the visitor's requests.

5 Second Study: Housing Rehabilitation

With the initial success of using Redliner for a simple, single residence design, the Pavilion House, we decided to put the system to test in a real design situation involving renovation of an apartment building in Strasbourg, France. We next describe extensions of the original Redliner to accommodate this usability test.

5.1 Building site and program

The site is adjacent to the center of Strasbourg, located at about equal distance from the train station and the universities. It is situated at the edge of the historic area with a view of the well-known cathedral. Although the neighborhood is currently in decay, the city has recently been encouraging construction to revitalize the district. For example, the new Modern Art Museum of Strasbourg has just been built in front of our building, and the new tramway will run through the street right next to the site. The building is a densely occupied four-story apartment complex. The owner wanted to create two new apartments in that space at the top of the building to make maximum use of the space under the eaves of the roof.
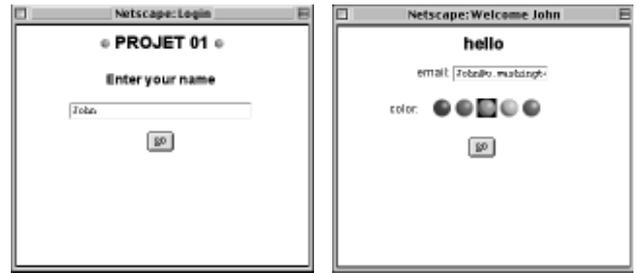

Figure 1. Login screen (left), user inputs email address and chooses an annotation color (right).

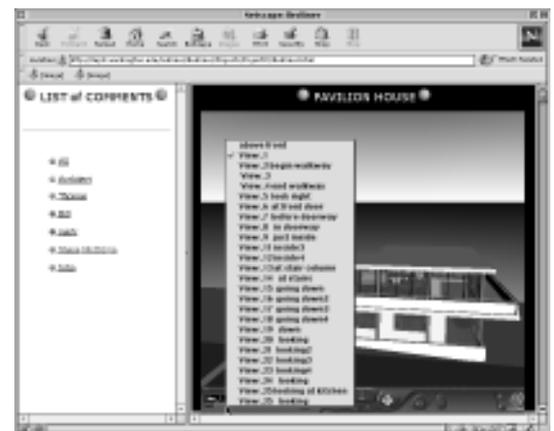Figure 2. The Redliner basic layout (text on the left, white – model on the right, black)

Figure 3. Pre-set viewpoints guide visitors through the design.
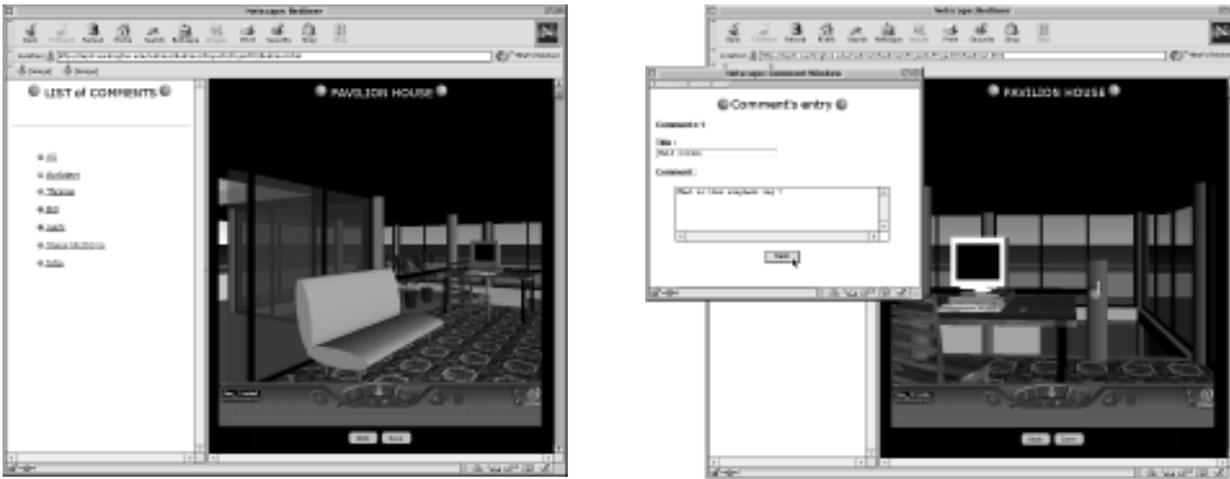
Figure 4. Pavilion house interior (left). Annotation marker in the scene (on the railings) with a comment window (right).

Figure 5. Architect's comments (left) and list of projects with different visitor's annotations (right).

The owner contacted the ARIM, (Association for Building Rehabilitation) to identify an architect. Then we assigned roles to the participants in the experiment: Two architects (including one of us) were part of the architectural team that renovated the whole building, the client also the owner of the building, and a contractor, a technical person from the CRAI (Center for Research in Architecture and Engineering). We used this opportunity to test how the Redliner could work to facilitate communication among members of this team and the client.

During the course of design, participants were informed via postings on the Internet. The information included presentation of the design proposals as text files, plans, sections and pictures of the spaces at the existing stage as pdf or jpg files. Most importantly, the actual design project was presented in Redliner as a three-dimensional model for the design team to explore and comment on.

The project took place over a period of three months with three design phases. The first phase was a "coded" representation of the upper two floors - a hybrid representation combining a traditional 2-

Figure 6. Design alternatives: painted wall (left), wood panel wall (right). Bottom menu allows visitors to mix paint by changing RGB value and selecting wall texture options.

D floor plan with some 3-D model elements. These were represented in an explanatory form. A module was added to Redliner to allow users to view or filter selected layers of the model. For example, figure 7 shows the possibility to view either one or two floors of the same model and figure 8, below, displays either the existing structural constraints such as columns, beams or the existing plumbing configuration, or/and the first design intentions concerning the design of the new apartments.

During the second design phase the architects incorporated comments and suggestions made during the initial 3-D/VRML representation of the site and posted to Redliner a remodeling design proposal (figure 9).

Finally, the third phase involved a proposal of several design alternatives in response to the user comments. We posted on the Redliner several design options concerning issues that were raised
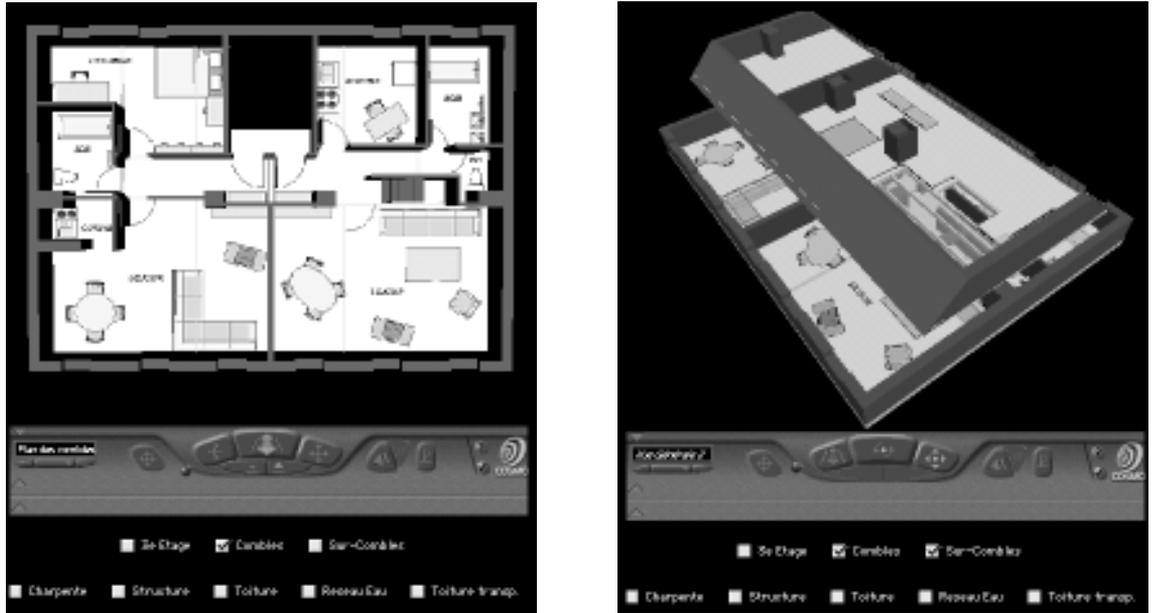
Figure 7. Design Phase I (Hybrid representation). The 3-D model of the existing building embedded with several layers (checkboxes at the bottom of the browser) for participants to explore different design issues. Left. floor plan with furniture layout. Right. the relationships between two floors.
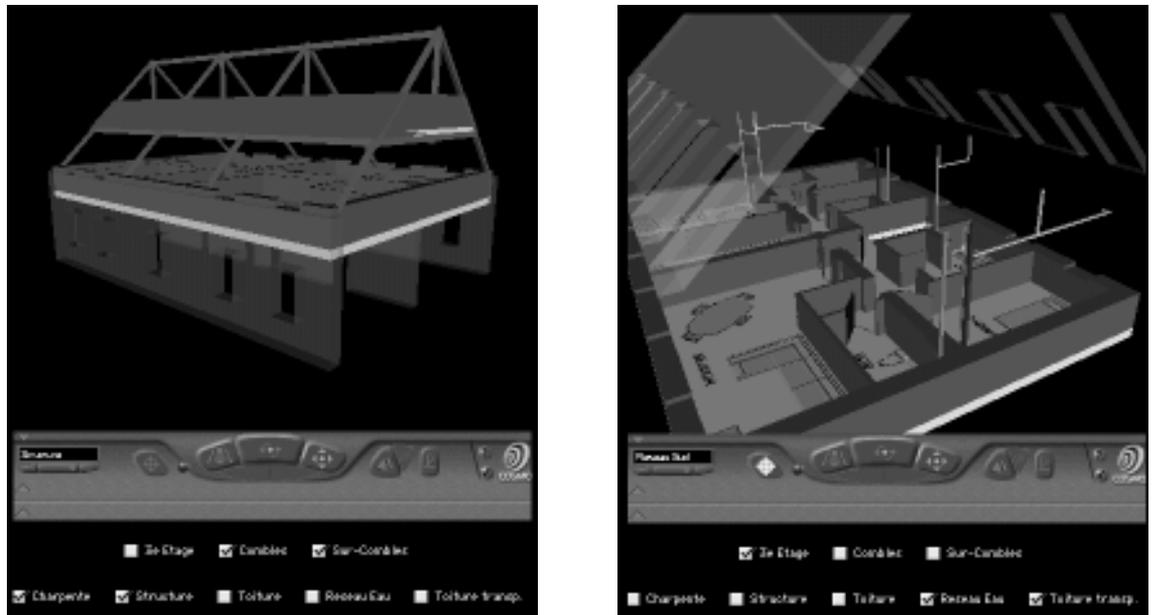
Figure 8. Participants can select only the layer showing structure system (left) or the water supply system (right).
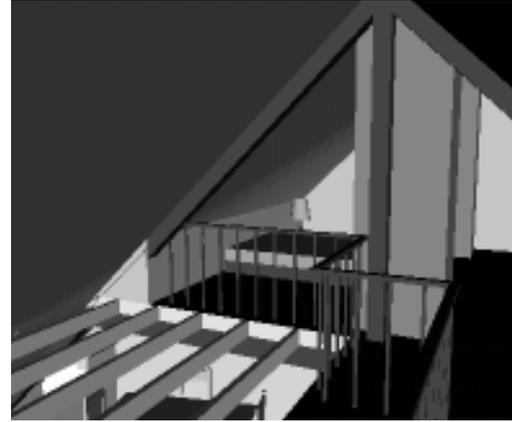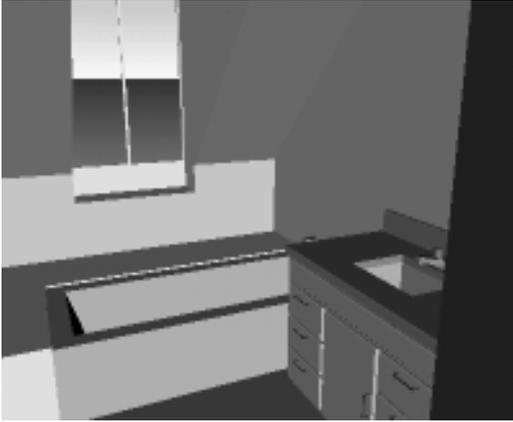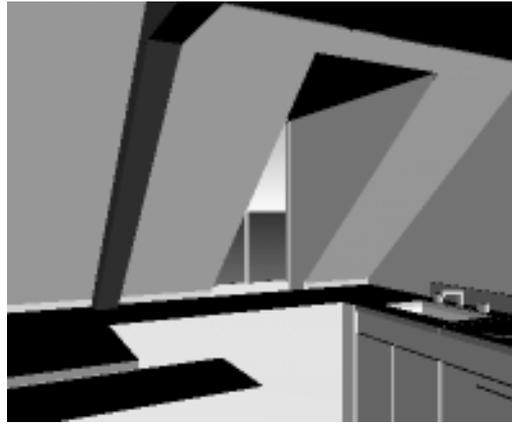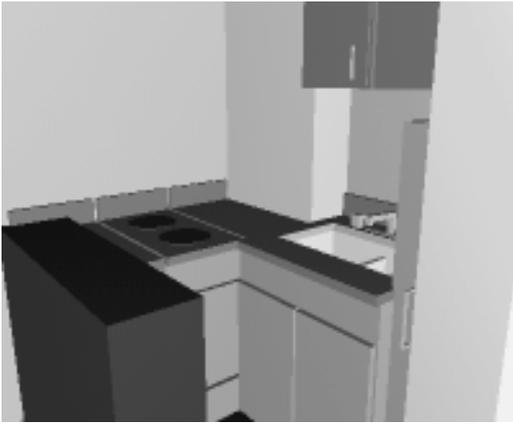
Figure 9. Design Phase II (3-D Model). The design proposal in 3D VRML form for Redliner showing different views (kitchen alternatives, bathroom, corridor).

during the first and second phases of this project. For example, the building owner had asked the architects whether the beams above the living area could be removed. The contractor commented that it would increase the remodeling expenses. The architects then responded with two design alternatives. Figure 10 below shows two views of the same space with and without the beams.

5.2   *Design development through comments*

Each table presents some comments and responses made by different participants and the design modifications that were proposed. We show below, examples of conversations that occurred in Redliner concerning different design decisions.

This first example shows the basic interaction between the two architects. They used the markers
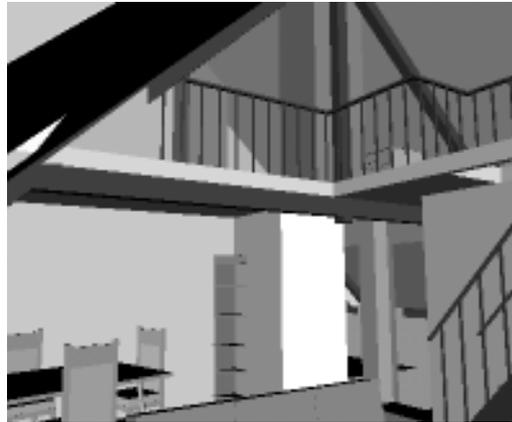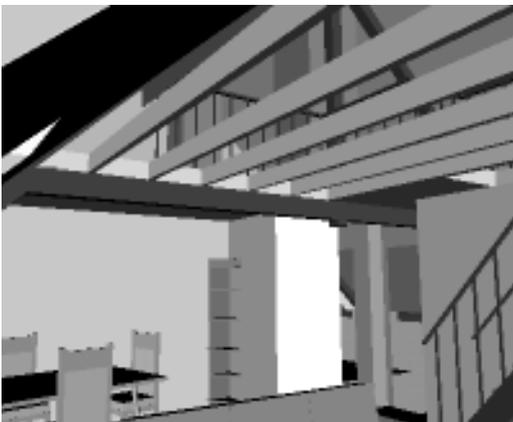

Figure 10. Design Phase III (Alternatives). The client questioned whether perhaps the space would be better without the beams.

Table 1. Code regulation discussion between two architects.

posted on the Redliner model to discuss design alternatives on a building code problem. The 3D see-through view of the floor plans provided visual tests for how the proposed modification would impact the rest of the building. The alternatives are shown in Figure 11.

Table 2 shows a typical owner-architect discussion over a question of organizing the space. The owner observed that the space in front of the stairs appeared to be too small when he browsed the 3D model. He left an annotation marker to identify which space he was referring to. Later the architects responded to his concerns with several design alternatives.

The following transcript shows a longer conversation that took place between the architects and the contractor about replacing windows in different places. The Redliner annotation markers helped identify which windows were under discussion and the approximate locations for the new additions. Seeing markers on the scene and "on the spot" directed attention to the right place.

6 Implementation
6.1   System Architecture
The current version of the Immersive Redliner uses the Java External Authoring Interface to connect and communicate with a VRML scene. A touch and proximity sensor for the entire scene is the only VRML interactive command in the system; Java handles everything else. When the system event handler detects a click, the touch sensor code identifies the object the user designated and

Table 2. Daylighting discussion between the building owner and the two architects.
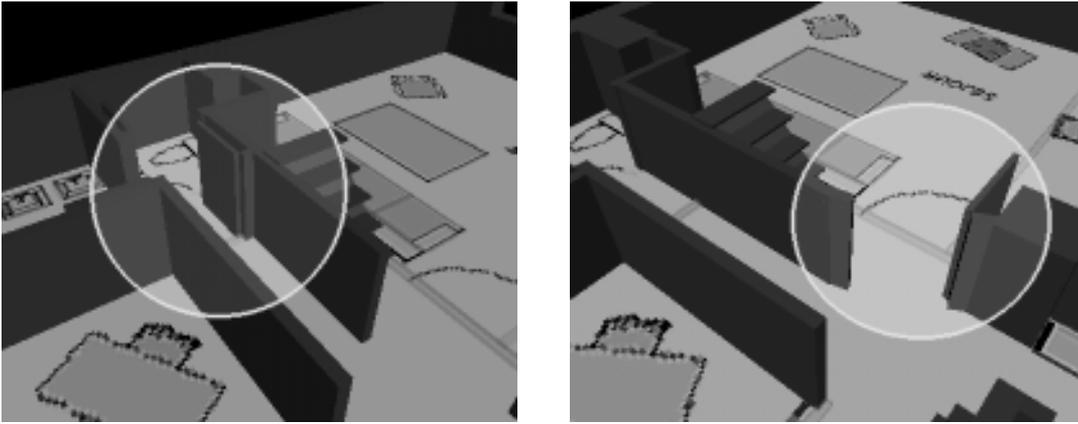
Figure 11. Another architect remarked on the need for two doors between the living room and restrooms. Two design proposals responded to this comment. Panels showing wall additions, portions to be retained and existing walls to be demolished.

Figure 12. Architect's alternatives to answer the owner's question about daylighting in the corridor. Original design proposal (left), with a hole (middle), with a glass door (right).

sends the coordinates of that click to the main Java class. Java then pops up a type-in window for the visitor's comment and sends back VRML code to implement the new 3-D sphere with its associated number. Once this is done and the user decides to save the comment, the text and its references are sent to a CGI Perl script running on the Redliner server to log the files containing the annotation markers (with links to text files) for each user. When the visitor exits the world, another part of the Java code writes the VRML code for the 3-D spheres, and with the help of a CGI script creates a new VRML file on the server. When later a visitor wishes to see the current visitor's comments, the Redliner loads the base model and the new annotations VRML file. Each annotation marker links to its respective user comment file and selected color.

6.2   Event Handling

The annotation events are handled by a Java applet named Sticker. The Sticker applet runs whenever the selected VRML model is open. A Java "callback" method waits for VRML events. When the user clicks in the model the callback method collects the click coordinates and the normal vector of the selected surface, and writes a VRML string to place a sphere on the surface. Another "action" method waits for events to happen inside the Java applet. When the user hits the save button, the action method takes all the accumulated VRML strings corresponding to the annotation spheres and sends these to a Perl script running on the server. That script then organizes the information it receives and creates or appends to HTML and VRML files on the Redliner server.

Displaying different layers of design concerns (e.g., structure, roof, pipes, etc) is handled through a DisplayLayer Java applet. It collects user input of a single or a multiple-view selection and uses the getEventIn method to load VRML files as requested.

7   Discussion and Future Work

Participants from our Redliner design experiment provided interesting and useful feedback for the future development of the system. For example, the architects found that interacting with three-

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> STAGE ONE (Hybrid representation)

• 05/06/99 at 9:03 am -  **Contractor**: Issue: **Windows**
"Will we have to replace all the windows?"

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> STAGE TWO (3-D model)

• 05/06/99 at 7:14 pm -  **Architect** (note 1):
"Yes, we want to change all the windows for PVC ones. We're keeping the shutters though"

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• 05/06/99 at 7:20 pm -  **Architect** (note 2):
"We're also going to add two roof windows. Here to bring some light in the living room"

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• 05/06/99 at 7:23 pm -  **Architect** (note 3):
"And here for the bedroom"

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• 05/13/99 at 1:13 pm -  **Contractor**:
"How may are they, total?"

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• 05/15/99 at 11:55 am -  **Architect**:
"All of them: 10.
So we have 10: 160x80 PVC windows
And 2: 78X128 PVC roof windows"
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dimensional design models is a good way to explore design alternatives. The contractor appreciated seeing comments and discussions positioned at the right locations and this reduced confusion and miscommunication. Some participants at first questioned how realistic the models are (color, texture, space) and whether the view angle in VRML might misrepresent the real space (too wide, too narrow). However, later they commented that they were able to connect the projected reality of the design space to the on-screen VRML model. They agreed that seeing the design in 3D helped them to visualize the space and to communicate with each other. The architects, contractor and the client all wanted more functionality in the Redliner so that they could explore making or modifying designs in the virtual space.

In sum, the communication system in Redliner was used to efficiently communicate ideas and exchange points of view without scheduling a face-to-face meeting. Everyone could view the latest design proposition and react, annotate, question or respond at any time from anywhere. Retaining a trail of what happened and how certain decisions were taken along the design process is also useful for the architects as well as for the clients.

We are currently porting the system to a Java3D platform and extending the annotation capabilities to allow both written text display and sketching modifications onto the VRML objects. We are also structuring user comments in a hierarchy to organize the threaded history of modification decisions.

Table 3: Window discussion between an architect and the contractor.
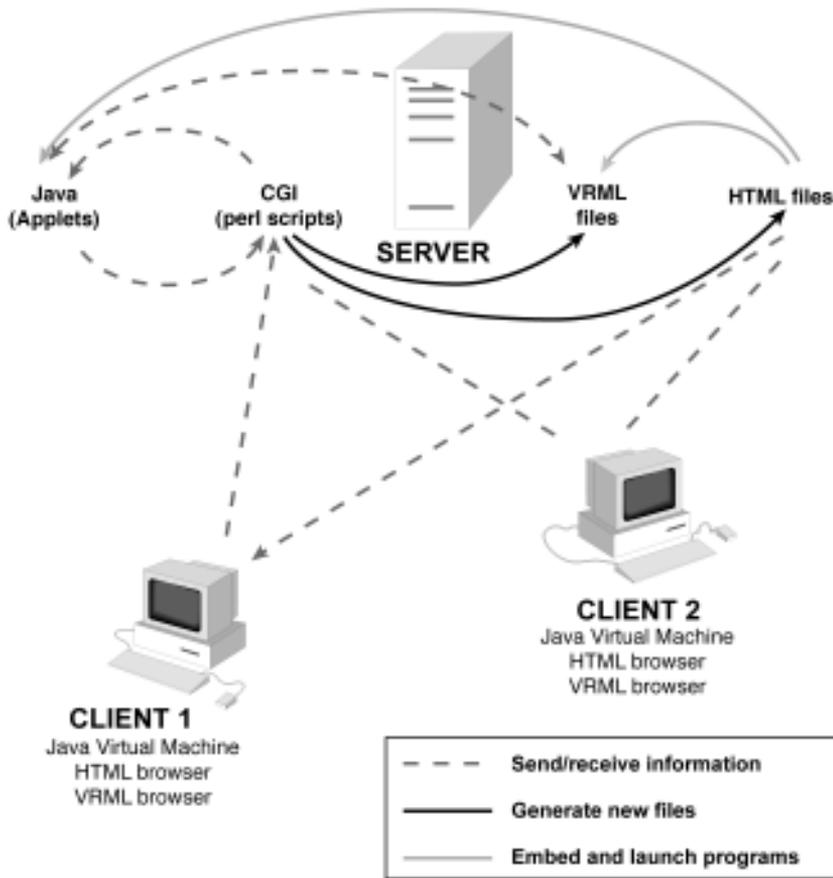
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Figure 13. System architecture of the Redliner.

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