

**ARCHVILLE:
A distributed VR system for teaching
real-time design collaboration**

Topic Category:

Collaborative design environments

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Abstract

Archville is a distributed, Web-based VR system that allows multiple users to interact with multiple models at the same time. We use it as a platform to exercise collaborative design. The pedagogy is based on the Cardboard City exercise, which required each student to construct a 3' x 3' structure within a 'city' formed by all students in the studio. Like the original exercise, Archville requires students to build individual buildings as part of a city, or village, and share some common formal convention with their neighbors. Unlike the original exercise, Archville uses VRML rather than cardboard. In addition to architectural design and computer modeling, the exercise immerses students in the political and social aspects of designing within a community, where many of the design constraints must be negotiated, and where group work is often required. As a Web-based system, Archville also demonstrates the advantages of up-to-date information and real-time communication in a virtual environment. The paper describes both the pedagogical and the technical attributes of the Archville project.

1) Introduction

When Alberti started managing building construction from afar, the workers were forced to rely on drawings and written instructions.¹ Today's buildings have become far more complicated and need to be completed in far less time, but we are still relying on drawings and written instructions to communicate with workers from afar. In addition, the amount and complexity of information has grown as well as the number of people who need information and have information to share.

Due to these changes, the potential for error is increasing accordingly. A large contributor to these errors is professionals relying on incomplete or incorrect information. We can reduce the potential of these errors significantly if we provide complete, up-to-date information for all those involved in the project. By accessing the information from the source instead of from a paper copy, the viewers will always be assured that they are using the latest information. With the advent of animations and virtual environments, we can now interact with spatial information. By moving through an environment, animating objects, or even hiding and un-hiding different design alternatives, we can begin to think of the information display as an ever-changing dynamic medium instead of the static medium of paper.²

When we are able to view information from various sources, and when the means of communication becomes transparent, we begin to perceive the information as a Gestalt.

¹ Bertrand Jestaz (1995). *Architetcure of the Renaissance: From Brunelleschi to Palladio*. Discoveries, Harry N. Abrams, Ltd., New York.

² Hienz R. Pagels (1988). *The Dreams of Reason: The Computer and the Rise of the Sciences of Complexity*. Simon and Schuster, New York.

The design information is seen as one large document instead of a series of documents that need to be resolved against each other.³ For example: imagine someone makes a Web page. Displayed on this page is a title and three articles. The title was created by the person who made the page. The articles, however, are actually pulled automatically from other documents. Once viewed in conjunction with the other articles, each article's meaning and impact is affected by the others. When a reader goes to the page, the reader may or may not be aware that the page is a collection of separate articles, instead, it is viewed as a single Web page.

When we can make this example work with 3D communication, as it already does for Web pages, the same results will occur. We will begin to think of a design document as a Gestalt instead of a collection of documents, and it is then that we will see the beginning of a new paradigm in design communication, which may lead to changes in the design process itself. The ability to navigate a space at one's own volition can substantially accelerate cognitive understanding, as information about the environment is no longer abstracted into a static 2-dimensional image; the viewer does not have to make a cognitive leap to understand the environment that is being presented. Using VRML, Java and HTML, we can now create an environment that will allow information from various specialists to be viewed simultaneously by anyone at anytime. We can also expand the nature of that information by allowing animations, as well as allowing the user to choose

³ Gestalt theory is a broadly interdisciplinary general theory which provides a framework for a wide variety of psychological phenomena, processes, and applications. Human beings are viewed as open systems in active interaction with their environment. It is especially suited for the understanding of order and structure in psychological events, ... (as) opposed (to) the elementistic approach to psychological events, associationism, behaviorism, and to psychoanalysis. SOCIETY FOR GESTALT THEORY AND ITS APPLICATIONS (1998) <http://www.psych.uni-osnabrueck.de/fach/gta/>

what information is to be viewed This paper describes such an environment, called Archville. Currently it is being used in the instruction of collaboration of design and as an example of using the internet to exchange information in a digital format.

2) Cardboard City

The inspiration and guide to the work reported here was a design studio, called ‘The Cardboard City,’ which was intended to teach students about the collaborative aspects of architectural design. Its premise was that Architecture is a collaborative enterprise, where virtually all building projects are the product of the contributions of many professionals, as well as public agencies and users. Traditional design studios in most schools, however, ignore the social, political, and other collaborative dimensions of the problem, and instead promote the individual experience of each student. This abstraction is intended to equip students with the basic proficiencies needed for their professional careers. Having been sheltered from the social, collaborative dimensions of the problem, graduates are often shocked to discover that the ‘real’ world of architectural design is very different from their academic experience: it is much ‘messier,’ in terms of the number of individuals who are involved in the decision-making process, and in terms of the constraints their ‘creations’ must meet.



Figure 1 View of Cardboard City

The Cardboard City exercise was given to third-year architecture students from the late seventies until nineteen eighty seven. It was intended to teach them, among other things, how to deal with the creation of spaces as a collaborative form-making effort, rather than as an individualized effort. The exercise involved the design and physical construction of a cardboard 'city,' on 3'x 3' plots in a pre-designed 'urban landscape' (Figure 1). Students were assigned 'city' plots through a lottery system, and instructed to design a 'defined place for sitting.' Although the project was assigned as an individual design task, students were given the option to join with other students and build a larger

structure collectively. Many students opted to work in groups, thus maximizing resources. As in real life, group work often entailed endless discussions and political power plays, which offset the time and resources saved.



Figure 2 Design phase of Cardboard City

Students were also required to make an effort to conform their designs to the designs of their neighbors, or come to some common agreement on the vocabulary of form. This last requirement, together with group work effort, turned the Cardboard City project into

an exercise in collaboration, as much as it was an exercise in physical design (Figure 2). Students learned the importance of politics in design, the destructive force of separatists, and the impact of decisions made by others on their own designs. It became the ‘right of passage’ exercise to upper-level studios, and a source of pride to the students who participated in it. But the creation of Cardboard City by 75 students also inflicted so much damage on the design studio facilities, in terms of cardboard mess, gauged tables, floor tiles, and any other surface the students could use for cutting, that the exercise had to be discontinued.

2.2) Resurrecting the City



Figure 3 View of Archville in a VRML player

The advent of computing technology, in particular the Internet, allows us now to resurrect the Cardboard City exercise, using computer visualization in lieu of cardboard. Archville, as the new exercise is called, is pedagogically similar to the Cardboard City exercise (Figure 3). As with the Cardboard City exercise, each student is given a plot in an urban landscape. Instead of a physical space, where urban plots must be chalked on the ground, Archville uses a computer model of a hypothetical city. Instead of reduced-scale 3' x 3' plots, students are assigned full-scale virtual plots. Instead of designing a

‘defined place for sitting,’ students design houses or other structures. As in the Cardboard City exercise, students must design their houses for each plot in agreement (or disagreement) with their neighbors. Specifically, they are required to establish some common design elements with their closest neighbors.

Archville allows students to walk through the ‘city’ at anytime to experience their design as well as those done by others in the class. Students can interact with the model and query information from it. They can also see each other walking though the environment, in the form of avatars, and communicate with fellow students. Finally, work that has been done in previous semesters need not be “taken down” at the end of the exercise. Rather, buildings can be left where they are, creating a sense of history and a city that can grow and evolve over the semesters. If more space is needed, the instructor can simply create more landscaping within the computer model. Since we are working within a virtual environment, there is no limit to the size of Archville.

3) The Archville System

Archville is a distributed, Web-based VR system⁴ that allows multiple users to interact with multiple models at the same time. Using a combination of HTML, Java and VRML⁵,

⁴ The idea behind distributed VR is very simple; a simulated world is stored not on one computer system, but on several. The computers are connected over a network (typically the global Internet) and people using those computers are able to interact in real time, sharing the same data in the same virtual world.

⁵ The Virtual Reality Modeling Language (VRML) is a language for describing multi-user interactive simulations -- virtual worlds networked via the global Internet and hyperlinked within the World Wide Web. VRML is to 3D what HTML is to 2D. Rather than describing the location of 2D text and images on a page, VRML files describe the location of objects in a 3D space. As with HTML, VRML objects

the system can display information, such as text and images, in a single dynamic environment. It does so by calling files from distributed sources, integrating those files, and then displaying the information.

The heart of the Archville system is a small set of files referred to as the ‘Address Book.’ These files contain, in a structured manner, the URL address of each student that is involved in the project. Were as each file is read from the Address Book it is loaded from the Internet, and the VRML viewer integrates the file’s content into the scene. This continues until all the files have been loaded. If a file cannot be found, the visitor is alerted and the program then goes on to the next file.

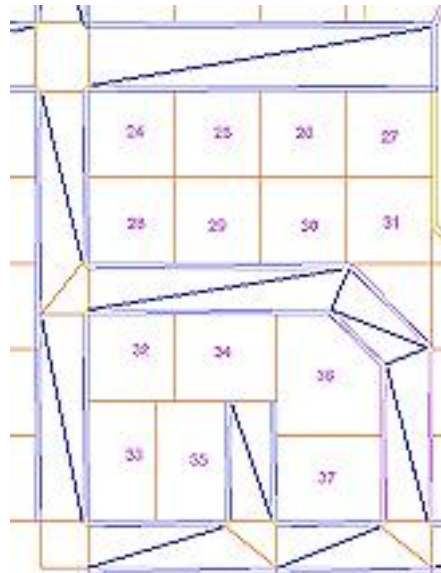


Figure 4 Plots used in Archville

may be links to other objects, URLs, inline images, movies and sounds. In addition to the properties of HTML, VRML objects may be animated and interact with other objects and the user.

The students create all the files, with exception to the landscaping and the urban layout, which is created by the instructors (Figure 4). A model of the urban layout is placed on the Web in the format of the 3D tool employed that semester. Students then download the model to their computers. Students locate the site they are assigned; and design their own building within it. When the students are finished with their design, they ‘post’ it by saving the file in a public directory on their own computer that is accessible by the Archville program through the Internet. The URL of their file is entered in the Address Book, so the file can be loaded into the combined scene. When the student accesses the Archville Web site, his or her model is displayed on the plot they were assigned, along with all the other students’ buildings.

Once in the VRML viewer, the visitor can walk around the urban scene. When a visitor enters a building, the VRML scene will reload with just the interior of the building, thus allowing higher levels of detail. If the designer of a structure added pre-defined viewpoints in their file, then the visitor can take a pre-set tour of the structure by moving from viewpoint to viewpoint. A viewpoint can also be animated for a tour.



Figure 5 Elevator doors opening in VRML player

Although currently implemented in 3D Studio Max (3dsMax), the Archville system will work just as well using AutoCad, MicroCad, FormZ, or any other 3D-modeling program that supports the VRML format. There are also many translator programs that can convert most 2D and 3D vector formats into VRML. 3dsMax was chosen because it supports some VRML nodes (programming) within the modeling program itself. Many of these nodes support attaching hyperlinks to 3D objects, for starting animations based on the viewer's location or the clicking on an object (Figure 5). For example, the elevators in the office buildings are programmed to take the viewer to the floor selected on the elevator control panel. Once there, the VRML scene is reloaded with the interior of the selected floor. Another example is the sculpture in Archville's central park. One student programmed the rings to move when the user presses a button at the base of the sculpture. The other button takes the viewer to that student's Web page. This student had no idea about VRML programming; this was all done in 3dsMax. (Figure 6)

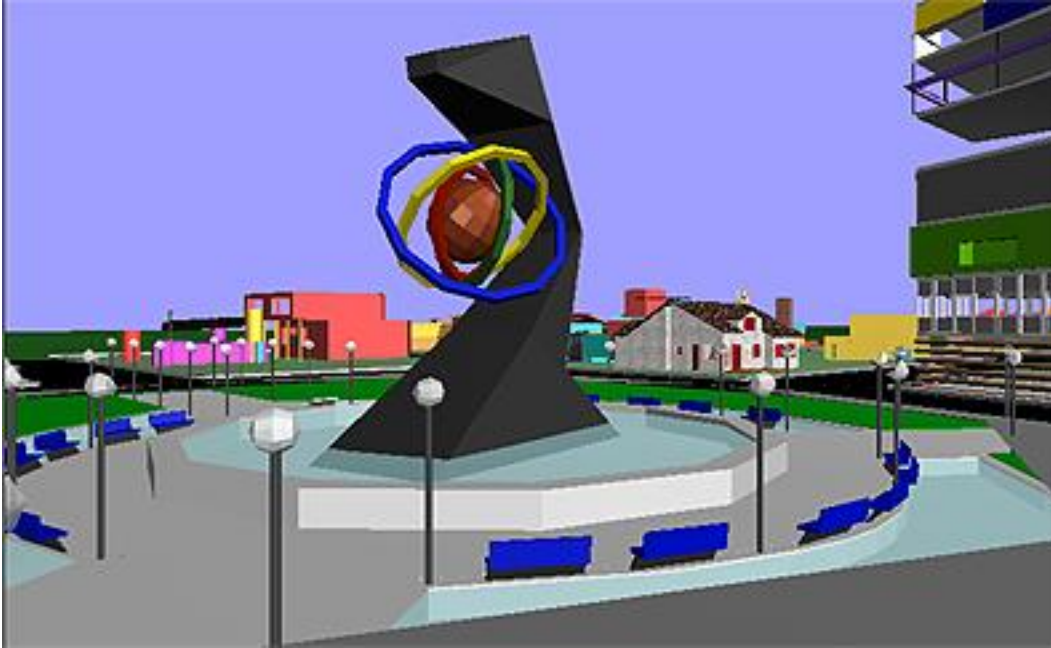


Figure 6 View of the central park and sculpture

The viewer can control the content of the displayed scene. When Archville is launched, only the landscape (streets and sidewalks) appears in the 3D scene. Using a set of buttons located at the bottom of the browser window, the user can load selected files. Once loaded, that same button controls the visibility of those files. For example, the students can load only those files that were created by their classmates. Alternatively, they can load files created in former semesters. This facility helps avoid information overload, and the problems associated with displaying a large model on a relatively slow machine. If they use a powerful enough machine, all the files can be loaded. With over 90 students in the class, and with 1000 polygons per student, the VRML scene quickly

approaches 100,000 polygons every semester, not including structures that were left behind from previous semesters (Figure 7).

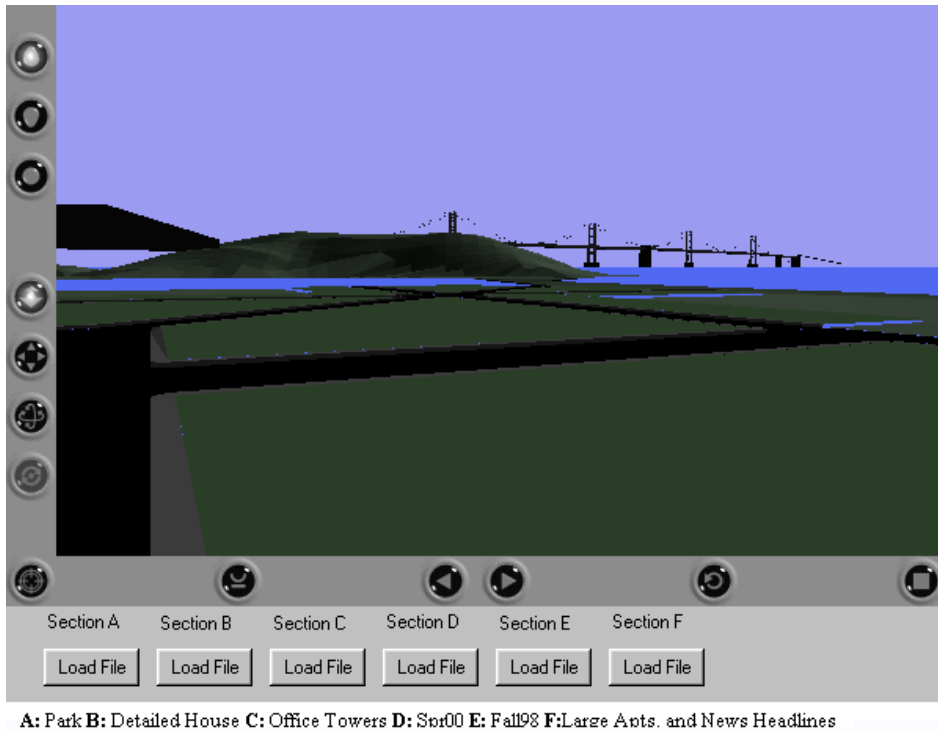


Figure 7 Archville with only streets and backgrounds

Also available to the viewer is a 'chat box.' Using a Java program created by Stephen White called Vnet, this program displays a window below the VRML viewer that allows users to talk to other users who are logged onto the system. When Vnet first appears, the users are asked to choose a name to login as, and then choose an avatar to represent them in the VRML scene. When encountering other users in Archville, they can see each other and talk to each other. Conversations can be logged for future examination to track the evolution of the design.



Figure 8 Vnet chat box within Archville. Avatar in center

3.1) How Does Archville Work?

The students create all the 3D files, with exception to the landscaping and the urban layout, which is created by the instructors. A model of the urban layout, known as the ‘master reference model,’ is placed on the Web in the format of the 3D tool employed that semester.

The file that links the works of individual students with the site is a simple HTML file that loads a VRML file and any Java applets that are to be used in the scene. The HTML file (Archville.html) looks like this:

```
<HTML>
```

```
....
```

```

<BODY>
<embed src="Root.wrl" width="600" height="400"
<APPLET CODE="visibilityControl.class" WIDTH=600 HEIGHT=100 maytag></APPLET>
.... </BODY> </HTML>

```

The third line loads the VRML viewer and the VRML file called Root. The next line, which is optional, brings up a Java program used to load/hide/unhide groups of geometry within Archville.

The VRML file (Root.wrl) that is loaded looks like this:

```

#VRML V2.0 utf8
DEF Start Viewpoint {
    description "one"
    position 40 5 10
    orientation 0 1 0 0
}
Background {
    skyColor [0.62353 0.62353 1, ]
    groundColor [.3 .4 1, ]
}
DirectionalLight {
    ambientIntensity 1
    color 1 1 1
    direction -0.612 -0.4598 -0.6435
    intensity .7
    on TRUE
}
Inline { url "streets.wrl" }
Inline { url "treasureIsland.wrl" }
Inline { url "groupA.wrl" }
Inline { url "groupB.wrl" }
Inline { url "groupC.wrl" }

```


...

This code sets up the basic environment of an initial viewpoint, lights, and background. The Inline statements load the street geometry and the surrounding landscape. The other Inline statements call the geometries of the different groups of students contributing to Archville.

The URL address of each student's individual file is placed into a file based on the student's subgroup. These files are known as the Address Book. A typical group file (groupA.wrl) looks like this:

```
#VRML V2.0 utf8
# Group A, Spring Semester
Inline { url "http://...berkeley.edu/~studenta/plot12.wrl" }
Inline { url "http://...berkeley.edu/~studentb/myhouse.wrl" }
Inline { url "http://...berkeley.edu/~studentc/assignment4.wrl" }
```

...

When the student accesses the Archville program (Archville.html), his or her model is displayed on the assigned plot, along with all the other students' buildings. Since the students created their geometry on the assigned sites, the geometries will appear exactly where they should. For example, if the student's plot was 154' from the center of Archville, when that student starts building his or her model, she or he is building it 154' from center. When it is viewed in Archville, it will appear 154' from center.

At the most basic level of Archville, all of the geometry that has been created by the students is loaded. As each file loads, that geometry appears in the scene, so as time goes on, more and more objects 'pop' into the scene. Each time the viewer goes to the site, or when the viewer clicks on the 'refresh' button on his or her browser, he or she will always see the latest files.

3.2) Pedagogy

The Archville exercise is currently a three-week exercise used in two classes. The first class is an introduction to computing course using FormZ or 3dsMax with an average student enrollment of 90. The second class is an introduction to 3D modeling using 3dsMax. This is a 7-week course given twice a semester with an average enrollment of 17 students per half-semester.

After an introduction to using the selected 3D software, the length of which varies depending upon the course, the students are assigned a site within an urban layout. The students in the first course are instructed to build a single-family house on that site. In the second course they have more freedom, and can design a house, a sculpture, or any other object, as long as it stays within their site. The only limitation is that their designs polygon count cannot exceed 1000 per site. Typically, a wide range of designs are created by the students, from common looking houses to interesting sculptures, to a tree house designed by one student (Figure 9).

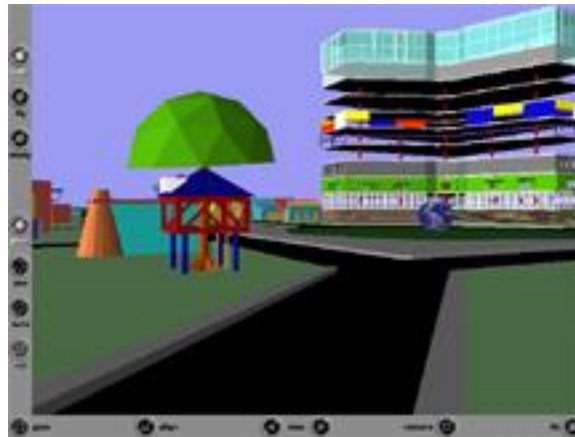


Figure 9 Tree-house

After one week, students are told that they must adapt their design, and/or convince their neighbor to change theirs, such that there is an agreed-upon design element in common with each of their local neighbors. Local neighbors are those students whose properties are directly across from, and adjacent to, the student. This keeps the number of collaborators in check. After another week has passed, the third part of the assignment is given. Each student must now design a walkway that connects to his or her neighbors' properties. This forces the students to react to geometries that are not under their control. So far, we have not implemented the third part of the exercise because of time constraints, but this issue is being addressed.

The end result is an urban setting that is populated almost overnight with 90+ buildings. Since each student can see what his/her neighbor has done as soon as it is posted, comments can be made immediately. For example, a student may be working on some element in his or her design that is intended to match the neighbor's design. If the neighboring student is online, he or she can look at the proposed design and make suggestions. The first student can immediately make the change in the modeling program and re-post the model. When both students refresh their Web browsers the change is displayed, and they can continue to deliberate its desirability. Alternatively, if the neighbor is not online, the proposed changes will be waiting when he or she goes to Archville.

4) Conclusions

Although computer visualization cannot replicate many of the advantages of the physical exercise, like the ability to actually experience what a 3' x 3' space feels like, or the impact of actually building something that can be inhabited, it gives us many other advantages over the original one. Other than the pedagogical benefits discussed earlier, the greatest advantage of using Archville as a teaching tool is the immediate feedback students get from their work and the work of other students. Creating a large virtual environment takes quite a bit of work. By sharing the task, a virtual world can be created in a week. This is an example of different professionals working together to create something that is too large and diverse for one person to create alone. Although in our case each student is creating the same thing (a building), this idea is not hard to expand into different specialties (Engineers, HVAC, etc.) working on the same building. The Archville system also shows students the power of the Internet for sharing up-to-date information. Many students were able to work from home and still interact with other students in the labs.

For many students these classes are the first exposure they have ever had to 3D modeling, or to being able to walk through a model on the computer. By providing an alternative view to drawings and scale models, the students begin to deal with issues of multiple views, of movement within an urban context, and issues of how other students interact with their designs.

The Archville exercise has been offered successfully for the last three semesters. Students seem to be very excited about building models that can be walked through and interacted with on the computer. Some more ambitious students have even dabbled in animations and simple programming. The level of student interchange has been limited because of time constraints - both the time it takes students to become comfortable with the software and the time available to complete the exercises themselves. It is quite clear that

Archville needs to be more than a three-to-seven week exercise. We are currently exploring the possibility of extending it into a semester-long design studio. In this studio, students will not only create VR models, but also create the data behind those models. We will also look at issues like construction costs. For example, we can give students a certain budget that they can spend on ‘purchasing’ the property they want. The more they spend on the property, the less money they will have left over for their building. Each building will be priced based on the number of polygons they use. The students may then have to form associations with other students to combine their resources. We have also discussed the possibility of students working in teams, in which one student will be responsible for the circulation of the building, another for the façade and landscaping, and another for the layout of the rooms or offices.

There are problems however: the biggest problem is time. Learning how to use a 3D modeling program is difficult enough, but to also understand the principles of low-polygon modeling is an extra learning step. This also goes for the teaching assistants, most of whom only have a functional understanding of the software, much less are trained in low-polygon modeling.

Archville is now viewable over the Internet at any time. We are also beginning to invite other universities to participate. Since all files are accessed over the Internet, including the original source files, anyone can participate in using the system. The computer power required to run Archville has become quite accessible to most institutions. Currently we are using PentiumII450 with OpenGL graphics cards. Today a machine of this level costs around \$1200.

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