

# Exercising Collaborative Design in a Virtual Environment

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## Abstract

In the last few years remote collaborative design has been attracting interest, and with good reason: Almost everything we use today, whether it is the structure we inhabit, the vehicle we travel in, or the computer we work on, is the result of a number of participants' contributions to a single design. At the same time, more and more design teams are working in remote locations from one another. In a distributed design situation with remote players, communication is key for successful and effective collaboration.

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 by requiring students to build individual buildings as part of a city, or village and must share some common formal convention with their neighbors.

The Archville exercise demonstrates to students how we can use computing and the Internet to design collaboratively. It also points out the need to have correct up-to-date information when working on collaborative projects because of the dynamic nature of the design process.

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. The paper describes both the pedagogical and the technical attributes of the Archville project.

Keywords: Collaboration, Virtual Reality, Design Studio, Real-time, VRML

## 1 Introduction

When Alberti started managing building construction from afar, the workers were forced to rely on drawings and written instructions (Jestaz 1995). Today's buildings have become far more complex and need to be completed in far less time, but we are still relying on drawings and written instructions to communicate. In addition, the amount and complexity of information have 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 who must rely 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, viewers will always be assured that they are using the latest information.

The need to move design communication from static 2D pieces of paper is not a new idea. Researchers from the early 1970s have been trying to come up with a system that can improve communication and reduce the number of errors in design. What has changed is the power of computing and the explosion of access to the internet. We can see evidence of that change occurring already. There are now services that can provide document tracking for a project, but we are still bound to the limitations of the 2D media, i.e, multiple documents that refer to the same entity. Making sure that all documents reflect the same information is a difficult task and requires a large number of labor hours to maintain. Many companies offer services that will store and track documents for production companies. They

also support virtual meetings, virtual whiteboards and video conferencing. The next logical step would be to have the information to be displayed, whether 2D or 3D, created from a single reference and only by storing this information in a 3D format can this be accomplished. Although the tools to create 2D drawings from 3D are still in their infancy, we have already seen some of them make their way into professional CAD packages. Consider this review from *CADENCE AEC Tech News # 22* (March 17, 2000) by Geoffrey Moore Langdon:

For years, architects with AutoCAD have been wishing they could make that leap from 2D CADD drafting to the 3D CADD architecturally smart building model approach (where plans, sections, elevations, and details get generated automatically) without disrupting their whole office (by switching to software other than AutoCAD) and now here with Bricnet Architecturals there is a very good way of making that transition.

The software uses a system of organization called Styles, which automatically keeps track of how the building is presented on screen and on paper, showing different floor stories, showing proper sections, rendering perspectives, and displaying construction documents as well as presentation drawings. Built into the software is even an ability to automatically post the drawings, if desired, on an architect-controlled project web site on the Bricnet Project Center extranet service.

With the addition of animations and virtual environments, we could interact with the 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 (Pagels 1988).

When we are able to view this information informally from various sources, we begin to perceive the information as a Gestalt; that is, design information is seen as one large document instead of a series of documents that need to be resolved against each other. [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/>]. For example; imagine someone creates a Web page. Displayed on this page are a title and three articles. The person who created the page wrote the title. The articles, however, are actually pulled automatically from other documents. Once viewed in conjunction, each article influences the other articles meaning and impact. When a reader goes to the web page, the reader may or may not be aware that the page is a collection of separate articles; instead, the page is viewed as a single document. When we can make this example work within 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. (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 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.) We can also expand the nature of that information by allowing animations, as well as allow the user to choose what information is to be viewed. This paper describes such an environment, called Archville. Currently it is being used as an example in the instruction of collaboration of design and the use of the Internet to exchange information.

## 2 Cardboard City

The inspiration and guide to the work reported here was a design studio, called ‘The Cardboard City Exercise,’<sup>1</sup> 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, gouged tables, floor tiles, and any other surface the students could use for cutting, that the exercise had to be discontinued.

### 2.1 Resurrecting the City

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 and 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 through the environment, in the form of avatars, and communicate with fellow students. Finally, work that has been done in previous semesters need not



Figure 3. View of Archville in a VRML player.

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.) 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. As each file is read from the Address Book it is loaded from the Internet, 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.

A model of the urban layout is placed on the Web in the format of the 3D tool employed that semester (Figure 4). Students then download the model to their computers. Students locate each site they are assigned; and design their own buildings within it. When the students are finished with their designs, they 'post' them by saving the files in a public directory that are accessible by the Archville program through the Internet. The URL of each file is entered in the Address Book, so the files 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.

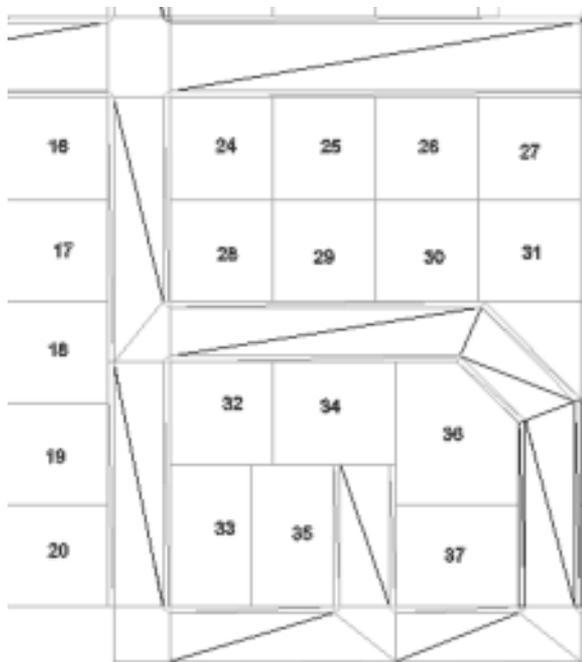


Figure 4. Plots used in Archville.

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. 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). Recently, students have been asked to

place 'mail boxes' in front of their building such that anyone can email the author or download a copy of their model.

A Java applet 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

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.

### 3The Archville System

Archville is a distributed, Web-based VR system that allows multiple users to interact with multiple models at the same time. Using a combination of HTML, Java and VRML, the system can display information, such as text, images and geometry, in a single dynamic environment. (The idea behind distributed VR is

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 using Archville each semester, and with 1000+ polygons per student, the VRML scene quickly exceeds 100,000 polygons every semester, not including structures that were left behind from previous semesters.

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.

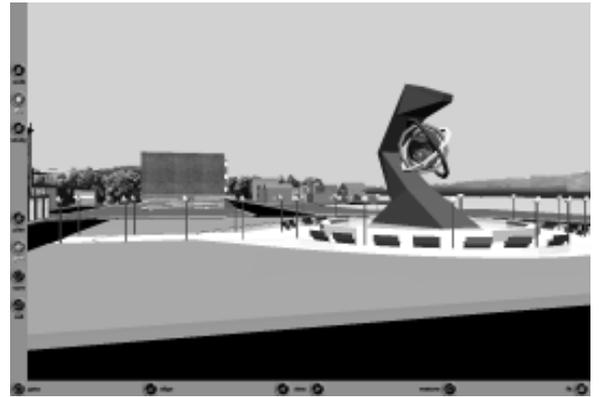


Figure 5. View of the Central Park and sculpture.

### 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 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" }
...
```

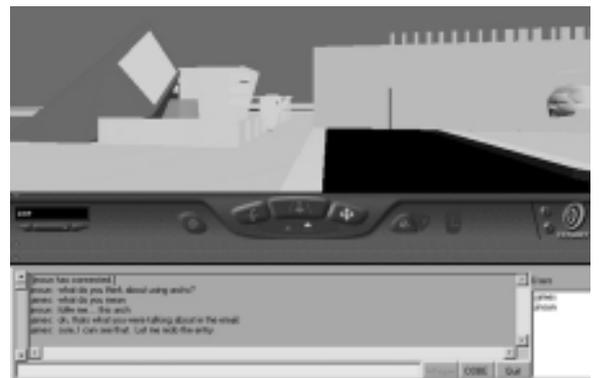


Figure 6. Vnet chat box within Archville. Avatar in center.



Figure 7. A group of houses using color and shape to resolve collaboration effort.

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 Address Books of the different groups contributing to Archville.

The URL address of each student is placed into a file based on the student's subgroup. This file is 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" }
...

```

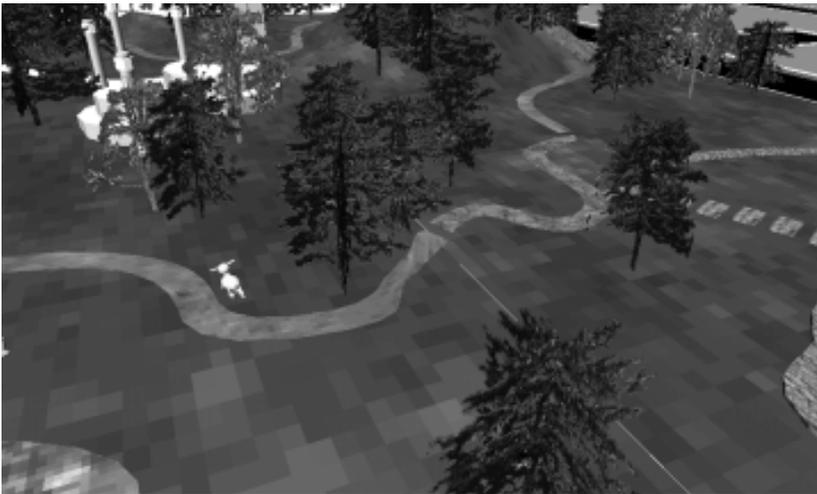


Figure 8. View of paths that do not completely match up.

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. 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

Archville is not a computer program as much as it is a teaching tool. In most design schools, students tend to work in a vacuum, unaffected by what is done by other students. By going through the Archville exercise, students are exposed to the idea that design is derived from

more than a grand concept from one person, but from the cooperation of many people.

Although Archville is used in two courses, the collaborative aspect of the exercise is only explored in the Introduction to 3D Modeling course. This is a 7-week course that meets once a week, given twice each semester with an average enrollment of 17 students per half-semester. Here the students spend three weeks on the exercise and although the amount of time the students are exposed to the environment is far too short, the students still get hands-on experience with posting files, loading files and collaborating with others in a design environment.

The exercise begins with a quick explanation of collaborative design as well as an explanation of the Archville system. Students are assigned a plot in the landscape that they are to build on and then shown how to place an external reference of that landscape into their computers. This is an example of referencing library objects. The 3D model for the urban landscape resides on the server, and any changes made to the streets are automatically updated in the students' models.

Typically the students are allowed to build anything they wish and encouraged to let their imaginations run free as long as the model does not exceed 2000 polygons. 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. The first part of the assignment is due the same day the assignment is given to encourage quick and highly abstract designs. Students are then shown how to post their VRML models to a web site and then look for their model when they open Archville. The end result is an urban setting that is populated almost overnight with 17 unique buildings. Surprisingly, the most common question I get from students is: 'How does my model show up in the correct place in the urban landscape?' Since the landscape model is the same model of which the VRML landscape was created, the coordinates will have the same points of reference. 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 exported and then viewed in Archville, it will appear 154' from center.

After one week, students are told that they must adapt their design, and/or convince their neighbors 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. Normally color is used to accomplish this but scale and language is acceptable also. The idea is for students to experience the challenge and frustration of a moving target when designing. As a student makes a change to work with one neighbor, that element may no longer be valid because that neighbor changed to meet the task criteria for some other neighbor. Surprisingly, by the end of the week, most issues have been resolved. Students begin to realize the importance of up-to-date information that is easy to access. In the Cardboard City exercise, students would not know what their neighbors' design changes would be until a week or more after the changes took place.

The third week of the exercise asks the students to make a path that connects from one neighbor to another. This forces the students to rely on files from other people. To accomplish this, students must now share their models with each other instead of just viewing them. Using 3dsMax, the students are shown how to make links in their VRML models to allow others to download the VRML file to their computers. This is a difficult task in such a short amount of time for beginning students. Typically less than half of the class is able to complete this phase.

#### **4 Conclusions**

The Archville exercise demonstrates to students how we can use computing and the Internet to design collaboratively. It also points out the need to have correct up-to-date information when working on collaborative projects because of the dynamic nature of the design process. Archville also allows the students to think about their designs more dynamically since 3dsMax supports animation and simple interactive programming for VRML.

Over the many semesters Archville has been used, there have been certain problems that have been difficult to resolve. First, there is never enough time. This course is an introduction to 3D modeling. Students are just learning how to create objects much less learning how to deal with the difficulties of collaborative design. To mediate this problem we underplay the design aspect of the exercise as much as possible. This allows the students to do what they like without worrying about "good" design. Second, the students who already have some 3D experience, or are quick studies, tend to have a greater influence on design conflict resolution than more beginning students. To reduce the influence of the more experienced students, we try to cluster students with like skills as much as possible. Finally, 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 skill is also important for the teaching assistants, most of whom only have a functional understanding of the software, much less are trained in low-polygon modeling and VRML environments.

Despite these problems, student feedback on the exercise has been positive. For many students these classes are the first exposure they have had to 3D modeling, or being able to walk through a model

on the computer in real time. 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. Many students are amazed at the ease they can create virtual environments and some go beyond the scope of the assignment to create wonderful models with interesting animations and VRML programming. Students are also surprised at the difficulty of working with others on a project, especially one that progresses as fast as Archville does. And it is just this understanding, as well as the benefits that having a collaborative digital environment, that Archville is meant to demonstrate. Creating a large virtual environment takes quite a bit of work. By sharing the task, a virtual world can be created in a short amount of time. 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.

It is quite clear that Archville needs to be more than a three-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.

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