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Virtual Archaeology as a Teaching Tool

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Abstract. This paper summarizes early efforts to develop an educationally immersive, 3D, virtual environment that faithfully reproduces an archeological site, Like-a-Fishhook Village/Fort Berthold, in the northern Plains of the United States. This virtual archaeology environment will provide a medium for teaching aspects of archeology, cultural anthropology, and history. The site is rendered as two discrete models—the first representing the site during excavations in 1954, and the second representing the site when occupied by Native Americans along with European Americans, circa 1858. These virtual environments will support "time travel" to enable students to visit both times and to visualize the relationships between the 20th century excavation and the village setting when it was occupied a century earlier. Through this game-like format, students will learn critical thinking and problem-solving skills.

Keywords. Virtual archaeology, immersive, education, role-based.

1 Introduction

Since the early 1980s, a small number of archaeologists, both anthropological and classical, have been working with three-dimensional (3D) graphics and virtual reality modeling for archaeology. In fact, the CAA conferences and publications have been the primary showplaces for such works, with many of the virtual models also made available via the World Wide Web. Those applications have predominantly aimed at creating limited virtual reality environments. While such efforts have increased in sophistication and number, especially in the last few years, they still are not common, especially in the United States. Moreover, they have primarily been used as "display pieces" and not as tools for interactive education. Certainly the creation of a virtual archaeology environment is itself an instructive exercise for the creator(s), and once constructed, the world can be informative to those who find it on a Web page or running at a museum. Yet, despite the value of these applications, virtual archaeology can play a much more significant educational role.

This paper summarizes the concept behind and the early work toward a virtual archaeology environment designed as an explicitly educational tool. This tool, tentatively called Virtual Archaeologist, features an exploratory, goal-driven, role-based simulation for learn-by-doing exercises. This virtual environment will facilitate "time travel" between different times at the same locale. Our goal is to create an authentic, immersive, virtual environment enabling students to experience virtual archaeology first-hand. This web-based virtual environment is designed to "immerse" the user in the paradigms of a discipline. In contrast to the traditional definition of the term in the field of computer visualization, "immersive" is not used to describe an all-encompassing visual experience of the user, but instead relates how the user is surrounded by the roles, ideas, beliefs, and methodologies of the discipline in which the user is to be educated.

2 Pedagogical Underpinnings

The approach to learning that this project promotes, long known as apprenticeship and more recently referred to as "cognitive apprenticeship" or "authentic instruction" (Brown et al. 1989), is both time-honored and modern. In the traditional course of an apprenticeship, the apprentice models the master to learn what to do and how to think. "Authentic instruction" refers to an emerging pedagogy that treats content as support knowledge needed to solve challenging, real-world problems (Brown et al. 1989). This approach places the learner in the environment of the professional, wherein the learner assimilates the practices and beliefs associated with a particular discipline. This assimilation is a direct result of the learner performing activities typical of that discipline.

Modern educational technology has focused on interactive software systems and simulations that give students—thus far primarily in the sciences—the chance to explore virtual worlds and impossible places, learning the practices of science by conducting simulated experiments and solving authentic (albeit virtual) problems. In this way, science students have had access to otherwise unlikely experiences and have learned their craft—the doing of science—within authentic and immersive contexts. We have gathered results showing that these systems are effective in geology and biology (McClean et al. 2001), and we are using comparable methods to develop an immersive, interactive, learning game for students in archaeology and related fields. We use a game-like format in all of the immersive virtual environments at NDSU because games have the power to engage students in a way that textbooks cannot.

Traditionally, archaeology students learn about the conduct of archaeological research by taking a field school course, but there are limitations to such courses. Field schools are typically costly for students, especially those that require travel to distant locations. Moreover, the number of students that can be accommodated in a field school is limited, and many institutions do not have the faculty or resources to conduct field schools. As a result, field courses are not able to benefit the large numbers of students that can be reached through introductory-level courses. By eliminating economic and locational limitations, authentic learning can support the active engagement of student-centered collaborative learning of those principles and practices that define archaeology. Properly designed computer-aided courseware that renders archaeological sites can support such authentic instruction wherever a computer is available.

3 The Like-a-Fishhook Story

Prior to the coming of European Americans, the Mandan, Hidatsa, and Arikara tribes of central North America lived in earthlodge houses clustered into fortified villages. Despite a basic similarity of economic and social life, these peoples differed in language and customs (Meyer 1977). One of the most important of these village sites was Like-a-Fishhook, which was occupied simultaneously by all three tribes, which are known today jointly as the Three Affiliated Tribes.

Like-A-Fishhook Village was located on the bank of the Missouri River in central North Dakota, USA (Fig. 1).

Figure 1. Map showing location of the Like-a-Fishhook site in North Dakota, USA.

As the last earthlodge settlement of the upper Great Plains, the site documents an extraordinary episode of cultural transformation (Smith 1972). The first permanent residents of Like-a-Fishhook Village were Hidatsa who arrived in 1845 (Smith 1972:4-5), joined shortly thereafter by a group of Mandan. At about the same time as the Hidatsa built their first earthlodges, a white trading company established a post at the site, with log structures and a stockade that became known as Fort Berthold 1. A wooden palisade on three sides of the village (the river bordered the fourth) protected the inhabitants from raiding parties of the nomadic Teton Lakota Sioux. A new trading post, Fort Berthold 2, was built in 1858 as regional trade increased. Fort Berthold 1 was burnt to the ground in an attack by a Sioux war party in 1862, and that same year remnants of the Arikara arrived at the site.

Over the decades, more European Americans moved into the surrounding region, which changed significantly. In the 1860s, Fort Berthold, by then a mixed community of Native Americans, European Americans, and mixed bloods, “was a base for Federal military units campaigning in the Dakota Territory against fugitive remnants” of local tribes (Smith 1972:17). However, in the late 1880s the village was abandoned, as native residents were forced to leave the site and take up occupation on new areas of the then Fort Berthold Indian Reservation.

All that remains of the Fishhook site are the artefacts collected during excavations. That collection, along with rich ethnohistorical resources, provides testimony to a significant period in American history. The co-residence of the three sedentary tribes and white traders tells of the significant impact that the coming of white Americans had upon Native American cultures and traditional enemies. Peoples with similar but distinctly different Native American heritage closed ranks and banded together, setting aside their differences in response to increasing pressures brought upon them by contact with European Americans and hostile neighboring tribes. At the same time, however, the cultures retained many of their distinctive cultural characteristics. The history of Fishhook is a story of both continuity and change, as well as one of unique societal interactions.

4 Project Rationale

Though the importance of the Fishhook site is clear, what is not clear is how it can be most effectively used as a teaching tool. Given its inaccessibility, how would faculty go about using it to teach their students the practice of archaeology (or anthropology, or history, or creative writing)? This is where traditional pedagogy fails and where immersive technology, with its emphasis on student problem-solving, shines.

Teaching the principles and reasoning of archaeology through the use of problem-solving exercises is an age-old pedagogic method. For decades, some archaeology faculty have used text-based problems wherein students are given a set of data and are required to answer questions or “reconstruct” a site by applying what they have learned to the available data. Sometimes these problems are based on real sites and data, while other times they are fictitious. Books are also available that present interpretive and/or methodological problems (e.g., Daniels and David 1982; Patterson 1994). The application of computer technology has also been used for teaching archaeology. As long ago as the mid-1970s, for example, Dr. David Grove at the University of Illinois used the Plato computer to create a digital excavation, although it was largely a text-based effort. More recently, commercial programs and user manuals have been available, for example Adventures in Fugawiland (Price and Gebauer 1997), Virtual Dig (Dibble et al. 2000), and WinDig (Campbell 1996).

The problem-oriented approach is excellent for teaching critical thinking and analytical skills, although the approaches mentioned above have weaknesses. For example, such efforts often do not provide a great deal of real domain content (Dibble et al. 2000 is an exception). Moreover, even the computer-based projects use unsophisticated technology; lack 3D graphics, are not immersive, and are limited in interactivity. Archaeological excavation is inherently spatial, and the spatial relationship of the material traces of past life is critical to the enterprise. In a strictly 2D world, that spatial quality cannot be easily expressed or understood. Therefore, the computer-based projects currently in use cannot provide students with an accurate archaeological experience. In fact, true virtual archaeology—that is, not just text and illustrations viewable with a computer—has rarely been used effectively for teaching archaeology (Sanders 1997).

The project discussed here differs significantly from previous efforts with computer-based approaches by creating a 3D, immersive, virtual-reality re-creation of an actual site: Like-a-Fishhook Village/Fort Berthold. This will be a dual-level environment representing the identical place at different times. The primary level will depict the site as it existed circa 1954, when it was undergoing excavation. (For pedagogic convenience, all excavation, which in reality took place over a four-year period, will be condensed virtually into a single season of work.) The second level will virtually recreate the site as it existed a century earlier (ca. 1858). Student users will be able to do what every archaeologist has dreamed of: travel back in time and see how artefacts were used, what soil features really represent, what activities actually took place at a specific location, and much more. Through the use of virtual environments, students can jump back and forth through time, from excavation evidence and lab analysis to the past where they can check their conclusions. They will be able to interact with these objects in their cultural—albeit virtual—context.

The virtual Fishhook site will thus possess a critically important feature that enables all problem-solving projects to be effective in reaching students: it will be interesting. It is our contention that those books and CDs that exist are not as engaging as they could be. They are either too simplistic or too intent on teaching archaeology methods more in line with advanced undergraduates than beginning students. Along with teaching archaeological methods, the Virtual Archaeologist will teach scientific methods and critical thinking in a way that is much more broadly applicable. In other words, this learning experience is designed to go beyond teaching domain-specific content.

We are basing the immersive environment on an actual site rather than invent one for three reasons. First, and foremost, we are striving to make the immersive experience as authentic as possible. Experience shows that students find the assignment more enjoyable and fulfilling when they know they are working on an actual site and with actual data. Thus, while it would be easier in many respects simply to create a site, unfettered by the constraints of reality, that approach would, we believe, be less satisfying to students. And, while we will still need to engage in speculation at times (as it is impossible to recover every detail of the excavation and site), we will use all of our sources to ensure that it is informed speculation. Furthermore, we will make information available on which aspects of the re-creation are speculative and which are not, as well as the level of speculation that is involved.

Second, even though we are designing the game explicitly to teach students how to think like archaeologists, there are other domains of learning that will be incorporated through the use of an actual place and time. Virtual Archaeologist will also provide a learning environment for cultural anthropology, as students come to understand, for example, how a tobacco pipe or house alter fit into, and informs us about, the belief system of a group of people. We are also creating an environment in which students will virtually experience a significant period of American history. Students also will be exposed to information and techniques in ethnohistory, Native American Studies, and culture change. Additionally, we plan to make the virtual environment available as a platform for developing historical fiction.

Third, we are involving local organizations in the project. We plan to use the virtual Fishhook Village as part of a new museum exhibit at the Heritage Interpretive Center, which is the state museum for North Dakota. Through this virtual exhibit, the museum can display information about the past in a stimulating visual context (e.g., see Kerendine 1997; Kadobayashi et al. 2000; Purcell 1996; Terras 1999).

5 Immersive Virtual Archaeology

Virtual Archaeologist is being developed in a game-like format in order to engage students more effectively. A player will use his/her mouse to travel from one level to another, navigate through the virtual site, and visit earthlodges (not all of them will be activated for entry), the fort or its rooms, and different activity areas, (such as food preparation areas, a hide-tanning spot, etc.); or, the player may wander down to the gardens to view the crops and how they are grown. Within a given earthlodge, players will be able to scan around the room, viewing the architectural elements and objects within the scene. Players will be able to click on many of these objects to bring up new viewing screens wherein the objects will be shown in larger scale as 3D models that can be manipulated and examined from all perspectives. By clicking on identified hotspots, the player will be able to open new windows with a variety of textual information about an artefact or activity, and they will be directed to bibliographic information for further research. Information will also be made available on what is real and what is speculation for a given object or activity.

The premise of the game incorporates a “time arcing device” that allows players to travel back in time. They are told that an extremely important Native American site was destroyed in 1954 by flooding caused by the construction of a hydroelectric dam. This site is a potential source of invaluable anthropological and archeological knowledge, but only limited archaeological excavations took place at the site. The student assignment is to go back to the site and assist the archaeologists of the 1950s in interpreting the data gathered. They can also apply modern methods to aid in their interpretations.

When the student players arrive at the site in 1954, they are greeted by a software guide who will give them instructions throughout the game. The players are told where to go and what to find out. The guide will point out what sources of help and information are available in the system and will describe the virtual tools and instruments the students have at their disposal. In addition to locating the feature or artefact they have been assigned, the students are asked to describe and interpret what they have found. Students are also advised that software tutors will visit them if they are stuck or need help providing their answers. Periodically, the students can activate their time-arcing device, allowing them to visit the site as it was a century earlier. Once the students complete their first goal, they are immediately assigned another one. In some instances, students will also be provided with interpretations of similar features or artefacts published by an eccentric archaeologist many years previously. The students will be asked to assess the validity of those interpretations against their interpretations of the archaeological data, as well as their observations back in time. The interpretive goals will increase in complexity as the game progresses, eventually leading to interpretations of more abstract socio-cultural phenomena (e.g., religion).

5.1 Technical Foundation

The virtual environment will be simulated on a MOO ("MUD, Object-Oriented", where MUD stands for "Multi-User Domain"). MUDs are typically text-based electronic meeting places where players build societies and fantasy environments, and interact within them (Curtis 1998; Haynes and Holmevik, 1998). Technically, a MUD is a multi-user database and messaging system. The basic components are "rooms" with "exits", "objects" and "players." Players enter and leave rooms via entrances and exits (in this case, the rooms will be locations on the village/excavation site, and the entrances and exits will be designated by geographical directions). By moving from room to room, players can navigate their way through the environment. Objects found within rooms can be picked up, examined, and used. The MUD supports the object management and inter-player messaging required for multi-player games, and at the same time provides a programming language for writing the simulation and customizing the MUD. Because this project is intended to be a platform-independent distance education system, the client software for the project is launched from a browser. This enables connections from Macintosh, Microsoft Windows, or Linux X-Windows machines.

The Virtual Archaeologist game will be designed on the client-server model with client software implemented primarily in Java and server processes hosted on LambdaMOO. The client software will be delivered over the Internet using standard browser software. The server database will host the simulation environment, manage student logins and history records, synchronize the interactions between multiple simultaneous users, and effectively store everything necessary for maintaining a consistent and coherent immersive experience. In particular, the server will maintain the different time levels of the archeological site and will store the descriptions and orientations of the geography and structures, along with the locations of the embedded artefacts dispersed throughout the environment. Thus, the server will contain the information necessary for the client to know which VRML elements to load for a player's current state and what information a student is requesting or storing.

The client applet will be a wrapper for three main components: 1) a telnet application for connecting to the virtual archaeologist MOO server; 2) Java3D libraries for supporting the VRML rendering and navigation control; and 3) additional code and data for interfaces, interactivity, and so on. The student will have access to a set of virtual tools (such as the virtual calipers we have developed for the DANA project) for taking a variety of object measurements. This scheme is modeled on the one developed by Slator and colleagues for the Virtual Cell virtual environment, which has proven to be successful and well accepted in user testing over the last few years (McClean et al. 2001).

5.2 The Virtual Environment

The Virtual Archaeologist environment will consist of two worlds to support "time travel" that will enable students to visit both times and to visualize the relationships between a "dig" and its corresponding village a century earlier. The 1954 level consists of a distribution map of archaeological features and floor plans (or bird's-eye views) of those features. The archaeological features revealed include linear trenches with wooden-post remnants, circular house features (20 excavated) with a series of stains from structural posts, and a variety of soil discolorations from pits, fireplaces, and other features. In the 1800s level, those remains are seen as archaeological traces of palisades, earthlodges, cache pits, scaffoldings, and more of the Native and European American residents.

We will employ a variety of source materials beyond the excavation records for the creation of the virtual site. Thus far, we have identified over 400 historical, ethnohistorical, anthropological, and archaeological documentary materials spanning 260 years (A.D. 1738 to present day) of European-American interaction with the Mandan, Hidatsa, and Arikara. These materials are available in a range of media formats, including hand-written and printed texts (journals, maps, European-American and Native-American narratives, field and laboratory records, technical reports, theses, and professional publications), art (sketches, paintings, and photography) (e.g., Fig. 2), video (ethnographic studies), and audio (music, oral histories, and ethnographic studies). The roll call of explorers, naturalists, geographers, artists, historians, archaeologists, ethnographers, ethnologists, and sociologists who have studied, visited, or lived among the Three Affiliated Tribes is impressive and includes many foremost disciplinarians of the times. Accounts of traditional lifeways, set down by tribal members or recorded by scholars, are also available. To the extent possible, all of these materials will be made available to student participants through traditional library and Web access (for a bibliography of resources see http://vcell.ndsu.edu/fishhook/biblio.html).

Our re-creation of the site and the creation of the game begin with text-based, descriptive versions of the site at both time periods. This reconstruction is currently composed of approximately 150 discrete locations and hundreds of object representations of cache pits and assorted artefacts. We plan eventually to capture the entire 40-acre site at both time periods in this manner.

Figure 2. Photograph inside Like-a-Fishhook Village.

We have been experimenting with different software packages and methods for creating the structural remains of the site. We begin by creating precise digital versions of the floor-plan maps produced during archeological excavations. Structural features of each lodge, cabin, and the palisades have been created using Form-Z (an architectural modeling program), 3D Studio VIZ, and Alias/Wavefront's Maya Unlimited 3D authoring software. At this point, most of the work is being done with Maya (Fig. 3). In another attempt, staff from Spacial Data Services Inc., (http://www.spacialdataservices.com) of Vancouver, Canada, used a Cyrax laser scanner to capture the exterior and interior of an existing re-constructed lodge from a slightly earlier Mandan site, On-a-Slant Village, (now a State Park) (Fig. 4). A detailed point cloud obtained from that scanning was used to create a model of the structure (Fig. 5) (a video clip of that process can be viewed from the SDS Web page.).

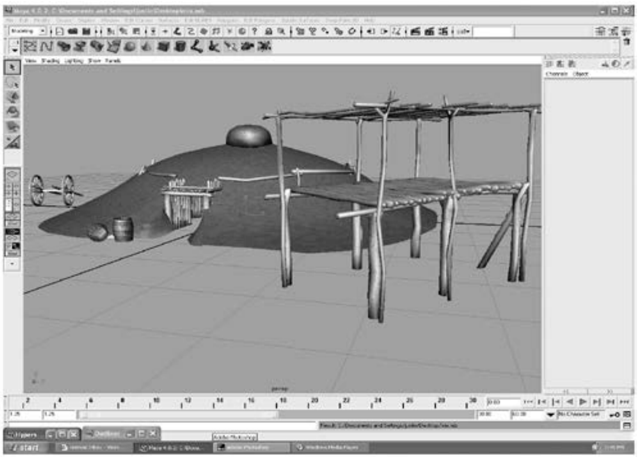

Figure 3. Preliminary construction of earthlodge and scaffolding.

Some structural features known from the documentary sources to have been present at Fishhook are not represented in the archaeological record (e.g., beds, horse coral, lodge alter). These are being produced in AutoCAD 2000 and Maya together with DeepPaint3D from documentary information. Other objects produced with those packages include various large artefacts, such as carts, barrels, bison-skin boats, and more. We are also using information from the physical reconstructions of lodges and interior accoutrements produced by the State of North Dakota at On-a-Slant Village and the U.S. National Park Service at Knife River Indian Villages (Fig. 6).

Figure 4. Photograph of two reconstructed earthlodges at On-a-Slant Village in central North Dakota.

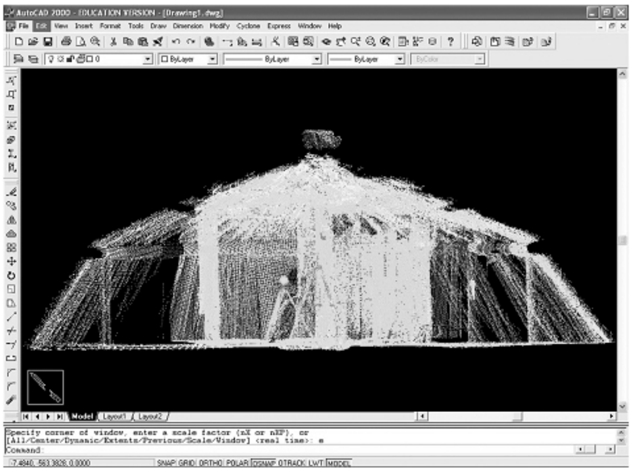

Figure 5. Point cloud of data points from SDS scan.

Figure 6. Interior photograph of reconstructed earthlodge at Knife River Indian Villages National Park.

We are also using laser scanners to create 3D models of the several hundred artefacts recovered from excavations at the site. Furthermore, we are collaborating with the State Historical Society of North Dakota to develop a digital database for the Fishhook artefact collection. This database contains 3D models of material objects that have sufficient precision to allow for a wide range of measurements through the application of specially created virtual tools. The Fishhook database will ultimately be part of a larger, Internet-based network of interoperable databases forming the Digital Archive Network for Anthropology (DANA) that will link researchers, students, and the general public to realistic, accurate, visual representations of a variety of objects of interest to anthropologists (Clark et al. 2002).

Artefact models will be drawn from DANA and distributed throughout the virtual site. Thus, students will not only explore two faithful reproductions of an archaeological site, they will also discover reproductions of actual artefacts from the site, in the locations from which they were unearthed. In the world of the 20^{th}-century excavation, the objects will appear as the existing artefacts; in the world of the 19^{th}-century village, the objects will appear as the original items in their proper contexts and forms, having been virtually reconstructed on the basis of documentary data and ethnographic collections.

6 Conclusion

The Virtual Archaeologist project summarized above represents a new approach to computer-based education for archaeology. It will employ a game-like format in the context of a highly interactive virtual environment that provides "live" simulations for exploration and discovery. In that way, we hope, it will provide a means to engage learners while treating them to a plausible synthetic experience. Within this context, the student makes decisions similar to those of an archaeologist, using simulated tools and the techniques of archaeology in conjunction with actual data from a real excavation. Slator and colleagues have implemented similar systems to teach in a learn-by-doing manner the scientific method, problem-solving strategies, and fundamentals of geology (e.g., Saini-Eidukat et al. 1999; Slator et al. 1999) and biology (White et al. 1999). We are confident that Virtual Archaeologist will be equally successful in conveying the critical thinking and interpretive skills required for the construction of prehistory.

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