Title: The Vari House; Digital Puppeteering for History Education

Authors: J. Jacobson[1], D. Sanders[2]

Affiliations:

[1]PublicVR (http://publicvr.org). jeff@publicvr.org

[2]Learning Sites, Inc. (http://www.learningsites.com) dsanders@learningsites.com

*Correspondence to: PublicVR, 333 Lamartine St., Jamaica Plain, MA 02130

Abstract:

The Vari House virtual world is a reconstruction of an ancient Greek farmhouse excavated fifty years ago in southern Greece. Implemented in Unity3D, the virtual world features a digital puppet, an avatar representing the teenage son of the farming family that lives there. We project Vari House onto a large screen, so that the house and puppet are life-sized to enhance audience engagement. Under the control of a teacher or puppeteer, the avatar communicates through voice and gesture, moving freely through the virtual space. He discusses the house itself and daily life, but any relevant topic is accessible. For depth of conversation, a human puppeteer is superior to any artificial intelligence. This version of Vari House works well for museum audiences of all ages and fits the ancient history curriculum mandated in most states for middle school.

One Sentence Summary:

Life-sized human-controlled digital avatar/puppet of a Greek farmer gives tours of his house, a powerful technique for educational presentations.

Introduction

The Vari House virtual world is a reconstruction of a Greek farmhouse excavated fifty years ago, in southern Greece near the shoreline [23-24]. The construction, plan, and siting of the Vari House follow the teachings of the ancient writers. For example, the house should be open and face toward the sun, closed off from cold north winds. Also, perishable-building materials should be placed between imperishable materials for protection from the weather; thus, in the Vari House, the mud brick walls and wood ceiling framing and columns are set between a stone foundation and ceramic tile roof.

In 1996, Learning Sites, Inc., developed the original VRML model with linked curriculum materials as an online educational tool to help teach the use of archaeology to investigate life

in the Hellenic world [35]. In 2012, Learning Sites and PublicVR re-implemented the house using the Unity 3D authoring environment (http://unity3d.com), and greatly increased the instructional power of the virtual world by the addition of an ancient Greek farming family. With a moderately fast computer, anyone can explore the house through a Web browser. Unity also supports immersive presentations, like the one we describe in this paper. Vari House is not a film or set presentation. It is an interactive three-dimensional space, now greatly enhanced by the addition, an ancient Greek farming family, most of whom are represented as automated characters going about their business.

The star of the show is an avatar representing a young teenage farmer (Orestes), controlled by a live puppeteer. The operator sees the audience through a Webcam and can move the avatar freely through the virtual space. The avatar addresses the audience directly, in character, according to a flexible script developed for the particular lesson, audience, or situation. The avatar puppet can communicate through voice, gesture, and visual context. He can describe the architectural and archaeological features of his environment, pointing to individual aspects of the house to address specific curriculum needs. He can then use the context to talk about ancient daily life, history, religion, or economics. The action and dialogue can follow a prescribed storyboard or can be extemporaneous, responding to audience feedback.

Figure 1: An audience member converses with the digital puppet, Orestes, "in" the courtyard of the Vari House. His mother is visible in the background.

Optionally, a teacher or second actor can mediate between the audience and the avatar. The teacher/mediator can explain things that would be awkward for the avatar to say in character and can also disambiguate spatial references (e.g., whom the avatar is pointing to).This is important, because we want to present the illusion that the audience and the avatar occupy a contiguous space that extends from the theater or classroom and into the virtual house. We are not trying to fool audience members with an optical illusion, but we do want to make it natural for them to play along with the audio-visual narrative.

The depth and flexibility of conversation of the human-controlled avatar is superior to that of any artificial intelligence. The show can change every day and develop complex narratives allowing teachers to develop curricula flexibly. That said, artificially intelligent characters are low-cost (once developed) and deployable in situations where a human puppeteer is not available. We do not seek to replace automated characters, but compl**e**ment them to round out a better learning experience.

In this article, we will summarize the implications of digital puppeteering in education and cultural heritage, provide the historical underpinnings of Vari House, describe how the application works, and explore a sample narrative.

While the Vari House model is proprietary, an executable will be available free of charge to the public through the PublicVR and Learning Sites websites. The code is based on the open-source code produced by the Egyptian Oracle project (http://publicvr.org/html/pro_oracle.html), which the reader can download to make his or her own applications.

Digital Puppetry

Today, the game industry has provided a host of online virtual environments, where each player controls an avatar. Depending on the structure of the game, the avatars interact with each other, with artificially intelligent "bots," the virtual environment itself, and the narrative generally. The most famous example is World of Warcraft, but there are many other Massively Multiple Online Role-Playing Games (MMORPGs) and a host of acronyms to describe them. When an avatar is visible to other players, the avatar is literally a digital puppet. The one thing that all puppets have in common is control by one or more human beings at performance time.

This is profound, because puppetry is an ancient art with highly developed techniques and technologies for representation, illusion, the evoking of emotion, and the conveying of information. And yet, most avatars are very primitive puppets indeed, controlled through a keyboard and mouse and having a very limited range of expression. If we can convey even a fraction of the expertise in the traditional puppeteering to the game industry, then we will really have made a contribution.

Jim Henson created the first modern digital puppet, Waldo, in 1988. It interacted directly with physical puppets. Today, most of the advanced digital puppets are used for film

production, as in the series “Sid the Science Kid” [19]. The Henson Company and other practitioners have developed a range of innovative control devices, most of them involving the manipulation of physical models.

Most of the highly realistic or lifelike digital puppets, such as Gollum from the Lord of the Rings, are driven by live motion capture of an entire human figure. For Gollum, the actor’s movements were directly translated to the virtual body, which was digitally captured and merged with the live footage. The effect is expressive and human, perfect for detailed humanoid figures. However, it is not the ultimate control interface. The reason why the Henson Company and others use more abstract control mechanisms is the power of caricature. They want to deliberately exaggerate or abstract puppet motions to achieve dramatic effect in a way that would not be efficient or possible with full-body motion capture. Unfortunately, the great majority of digital puppets, the avatars in games and online virtual environments, are controlled by keyboard and mouse, which is limiting. One of our long-term goals is to make better low-cost control schemes accessible to the public.

Puppetry has a close connection with shamanic ritual. The shaman who enters a trance state of consciousness uses a ritual object, such as a mask or puppet. This results in a performance of great excitement, public engagement, and reflection of community [33]. Our goal is to capture some of the excitement and meaning of the original ritual. Beginning with the Egyptian Oracle, we are attempting to enact and further "extend" the meaning of ritual for the digital age, exploring the psychical and technical dimensions of the virtual. The puppet is a transformative vehicle for both the performer and the community, in this case bridging an imagined ancient past with the real world of today.

Digital Puppets for Educational Theater

A small number of dramatic productions use a sophisticated avatar/puppet for direct viewing by an audience. Semi Ryu and her digital puppet performed a shamanistic drama for a live audience [32]. Andreadis and his colleagues [1] created a live performance by avatars/puppets in a virtual Pompeii, which was projected onto a large screen for a live audience. Anstey et al [2] staged a number of dramas with a mixture of virtual and live actors. As with a traditional play, the audience is “along for the ride.”

Vari House is an interactive performance, where audience members may communicate directly with the puppet. There are other notable examples. In “Turtle Talk with Crush,” at Disney theme parks, children see and converse with a virtual digital puppet projected onto the glass of an aquarium [37]. In a cultural sensitivity training scenario employing the Gepetto system [28], a trainer-puppeteer controls virtual Arabs with a single user/audience member. In the TeachMe™ system, used to help middle school children resist peer pressure, a single puppeteer controls five virtual characters, which interact directly with the user/audience [43].

People in Virtual Heritage

"Virtual Heritage" is the use of interactive electronic media to recreate culture and cultural artifacts as they might have been or interpret them as they are today [29][32]. The central element is usually a three-dimensional computer model of a person, place, or thing, especially an ancient site, building, or event.

Applications that include people fall into four categories.

- Virtual people are simply there in the environment, going about their business. They could be simple crowds [38] or participants in a complex drama [1].
- The virtual people interact with the user in some meaningful way [8-9].
- In online worlds such as Second Life (http://secondlife.com), users represent themselves as ancient peoples and interact with each other and artificial people [4].
- The experience is personal, as the user interacts with a single complex virtual person [20][30][22][15].

These same categories of virtual people can be implemented in augmented reality, which is some mixture of the physical world and VR. For example, the LIFEPLUS EU 1st system [31] describes a proposed and later built hybrid where virtual Romans are visible to observers in the physical ruins of Pompeii. The augmented reality also includes reconstructions of some of the architecture but is primarily focused on the people.

Figure 2: Orestes' family (his mother, father, and younger brother). They don't do much, yet, but just their presence provides a scale and social context to the architecture (from the Learning Sites virtual reality model; © 2011 Learning Sites).

Educational Theater and Cultural Heritage

Dramatic productions for educational purposes have a long and productive history. Today, many large science museums have small theaters and workstations where educators give demonstrations and talks, often with audience participation. Children's museums stage puppet shows, introducing children to science topics and social issues. Theater is also educational for student actors in K through 12 schools and higher education. Since the 1920s, students have learned a wide range of subjects and developed their personalities by learning stagecraft [41]. Games, improvisation, and role-play foster communication skills, problem solving, social awareness, and positive self-image.

One of the most widely used forms of theater in education is reenactment of scenes from an historical time period: "An enactment may be cast in the past, the present, or the future, but happens in the 'now of time.'"[42]. This strategy encourages students to interact with the material, challenging them to take on the viewpoint of a character. For example, undergraduate students perform rituals documented in Egyptian religious texts from the Late

or Graeco-Roman periods [13], the Mysteries of Osiris in the Month of Khoiak [17] and Confirmation of Power in the Egyptian New Year ceremonies [18]. These enactments provide a powerful learning experience for the students and reveal aspects of the ceremonies not easily evident in the text.

A much less structured approach is the Living Museum [17]. Actors and the reconstructed or restored historical architecture together simulate a community from the past, which visitors can explore and with which they can interact. The actors play an interesting balancing act between staying in character and recognizing the reality of the modern person talking with them. Examples include Historic Williamsburg (http://www.history.org), Fort Snelling (http://www.mnhs.org), Plymouth Plantation (http://www.plimoth.org), and Old Sturbridge Village (http:// http://www.osv.org). The live actress in PublicVR's Oracle performance also does this. The public wants to see history acted out [17].

Artificially Intelligent Agents and Hybrid Systems

Similar work is being done with artificially intelligent human figures that interact with the audience/user. These are neither puppets nor avatars, but *agents* or *bots*. Sophisticated agents require a great deal of skill and expense to program but have the obvious advantage of being portable, tireless, and potentially connected to databases not directly accessible to human readers. Kenny [26] and Swartout et al. [36] describe their own cultural sensitivity trainer, an AI-driven direct competitor to the puppeteer system, Gepetto, described in Mapes [28]. The Intelligent Virtual Environments group at Teesside University developed another sophisticated AI system. In their "Madam Bovary" simulation, the user takes the role of a major character, the foil for the protagonist [7]. Each of these systems is intended for a single user in a CAVE-like [12] display.

Good, AI-driven interactive storytelling can be developed without extreme cost. For example, Ansty and Pape [2] have also staged interactive psychodramas that respond to the emotional state of the user. Ryu [33] developed a shadow puppet that responds directly to the user. In both systems, the programming for the artificial intelligence is relatively simple, but the artistic and narrative design makes it a powerful experience.

Importantly, the TeachME™ system is a hybrid [43]. When the puppeteer is not directly controlling an avatar, it acts according to a set of pre-programmed rules and behaviors. In this way, all five avatars are active in a way throughout the scenario. Many adventure games allow a single user to control a group of characters, using a similar strategy (e.g., Everquest).

The Vari House Project

Project History

In the mid-1990s, Learning Sites, Inc., began to pursue the concept, new at the time, of using online virtual reality environments to change the way history is taught in schools. There clearly were exciting possibilities of presenting students with immersive

visualizations of places, peoples, and events of the past, along with linked information, lessons, and problem-solving tasks.

By 1998, Learning Sites had designed and released the *Ancient Greece: Town & Country* educational package, which combined and contrasted their virtual reality models of the Vari House and the House of Many Colors (from Olynthus; both Hellenistic in date). The package guides the student-reader through a game-like activity, where they are in the role of an archaeologist. Armed with questions they need to answer, students gathered some of the answers by directly examining the virtual worlds. They could also learn from the linked text, which had information on relevant curriculum-focused topics, such as history, culture, and geography, that helped them interpret the significance of their discoveries[35].

In 2012, the authors translated the Vari house model into Unity, a game development software platform that has become popular among archaeologists and other academics (http://unity3d.com). Then, we added automated models of the family members going about their business, and the digital puppet representing their teenaged son. The programming for the puppet is based on the open source code for the Egyptian Oracle project [21] accessible from http://publicvr.org/html/pro_oracle.html. (Follow the link that says "Application and Source Code").

Eventually we will make this version accessible from the web, as well. But our current focus is on educational theater, as we described in this article.

The Building Itself

The Vari House is located in southeastern Greece, about 4km (2.5 miles) from the coast of the Aegean Sea along a rocky spur of the southernmost foothills of the Hymettus Mountain range. The site is about 18km (11 miles) southeast of Athens; and about 2km (1.2 miles) from the ancient town of Vari. The site was excavated in the summer of 1966 by British archaeologists [23-24], whose final report is the basis for our reconstruction.

The basic structure as excavated is a rectangle with external dimensions of 13.7 – 13.85 m x 17.6 – 17.7 m (about 45' x 58'). The house is set on a stone terrace, which projects 0.5m along the south side. There are four rooms arrayed across the back of the house, a large central open courtyard, and two additional spaces in the front corners of the building. One is a tower, and the other is an extension of the side workspace. Each room has only one doorway, and that doorway opens only into the central courtyard; the building itself appears to have had only one entrance facing south. Thus, the whole house has a southern orientation, which was common for the period. No evidence was found for any other buildings in the immediate vicinity. Based on the surviving bits of pottery and a few coins found, the small amount of wear on the thresholds, and the lack of long-term renovations, the house seems to been occupied only for a short time from the second half 4th-century to the early half of the third century BCE.

Figure 3: Vari House, aerial view (from the Learning Sites virtual reality model; © 2010 Learning Sites).

A verandah roof that shades the Vari House faces toward the south, and the layout of rooms along the north side. This layout follows closely what ancient Greek and Roman writers tell us about the ideal setting for a dwelling: it should be open and face toward the sun, it should be closed off from cold north winds, and it should capture the heat and light of the sun appropriately for the seasons. Further, the distribution of materials follows the teachings of the ancient writers: place perishable building materials (in the Vari House, the mud brick of the walls and wood ceiling framing and columns) between imperishable materials (in the Vari House, between a stone foundation and ceramic tile roof) to protect the perishable materials from the weather [23-24]. The walls between the rooms at the back of the house are thin since they only support their own weight. The corner room's walls are so thick that archaeologists believe they supported a two-story tower.

Evidence of Beekeeping

There is no evidence of Vari House being a farm, in the traditional sense, or that special work was carried out at the house. There are no livestock or other purpose outbuildings. However, many clay vessels were found around the site, with lids and extension rings consistent with bee skeps of the time. They are specially designed and constructed to encourage honeybees to build their honeycombs inside and to allow people to remove the combs and retrieve the honey easily. Wall paintings and carvings at ancient Egyptian sites show very similar vessels for beekeeping and show the process of removing the honeycombs for their honey.

Researchers found microscopic traces of honey inside some potsherds through chemical analysis [14]. All this evidence demonstrates that this was a beekeeper's house, and that honey was harvested here on a large scale [11]. Honey was in ancient Greece, as it still is today, a favorite food topping, ingredient, and dessert [11].

Aristotle mentioned that keeping bees was part of farming activities. Other ancient writers commented that the best honey in the Greek world came from the Hymettus Mountain range, the location of the Vari House [25].

Perception, Interaction, and Hardware

Vari House is projected life-sized onto a screen or a blank wall in a museum, school theater, or classroom (Fig 1, p3). This effectively extends physical space into the virtual world of the Greek farmhouse, giving the audience greater empathy for the material and a more direct interface with the virtual world. Under the control of a teacher or professional puppeteer, the avatar addresses the audience, communicating through voice and gesture.

Optionally, a teacher or second actor can assist communication between the audience and the avatar. She can disambiguate spatial references, such as when the avatar indicates a member of the audience, by pointing or looking. Another solution would be to use a stereographic (3D) projector, which greatly enhances the illusion of the contiguous virtual space. Today, low-cost stereographic projectors are readily available, although members of the audience will have to wear shutter glasses, expensive if the audience is more than a few people. Passive stereo projectors, the kind used in 3D movies, require only low-cost plastic foil glasses, but the projector is much more expensive.

We refer to the Vari House as three-dimensional, but that is really a construction in the cooperating participants' minds. The narrative and the graphics help their imagination, and the better the 3D cues are, the easier it is. The better your hardware and supporting software is, the better the visual cues can be. The demonstration that we describe here uses low-cost hardware, just a laptop, digital projector, and commodity sound system. We wish to present methods that are accessible to everyone.

The operator sees the audience through a Webcam, which he can reorient by remote control. The Webcam image is streamed to a computer monitor, while a real-time duplicate of the audience view appears on a second computer monitor. He controls the viewpoint using the keyboard and mouse and controls the puppet with an Xbox 360 controller. Some of the controls are continuous, such as controlling the puppet's head with a POV (a miniature joystick used with one finger). Others are discrete gestures, which can be blended together, emphasized, or minimized. We will post a more detailed description along with the executable when it is ready. Until then, the documentation for the Egyptian Oracle priest, which is fairly similar, is available online (http://publicvr.org/html/pro_oracle.html).

The first time we implemented the puppet for Vari House, we reused the gestures for Egyptian Priest, because they came with the open source code. The movements worked well

enough, but we had to make changes, and we desire more. Many of the priest's gestures are appropriate for an imperious official, but not quite right for our young tour guide. As with traditional puppetry, digital puppets' form and movements are crafted to support the narrative.

We used a surround-sound system for our first demonstration of the Vari House, the same one described by Nambiar [44]. The house has period background music, which the audience hears while they are "in" the courtyard. When the audience viewpoint is outside, they hear wind and birds, bees near the hives, and so on. The puppeteer speaks into a microphone so his voice comes through the surround sound system. Optionally, the voice of the mediator can also be fed through the sound system, which guarantees that she will be heard and makes her more similar to the avatar.

Navigation

We employed three basic navigation modes in our demonstration to show their relative advantages:

Jump Cut: The operator presses a key on a keyboard, which instantly moves the avatar to a specific location facing the virtual world. It also moves the audience viewpoint to a nearby point, facing the avatar. "Jump cuts" is a term from film, where the location and orientation of the view changes suddenly, but there is always some narrative connection between the two points of view. Most audiences have become used to them from a lifetime of movies and television. Figure four shows a map of the Vari house with six positions. For each one, the camera represents the location of the audience view, and the direction of the camera lens indicates the direction of that view. The overhead schematic of the human figure shows the location of the puppet, facing the direction the human figure is pointing. Changing the narrative requires minor changes in the code to accommodate new jump points, although a little creative coding could make defining jump points easy for an operator. At the first four locations, the puppet stands still and converses with the audience. Position five is the starting point for *free walk, fixed camera* mode, while position six is the starting point for *intelligent following*.

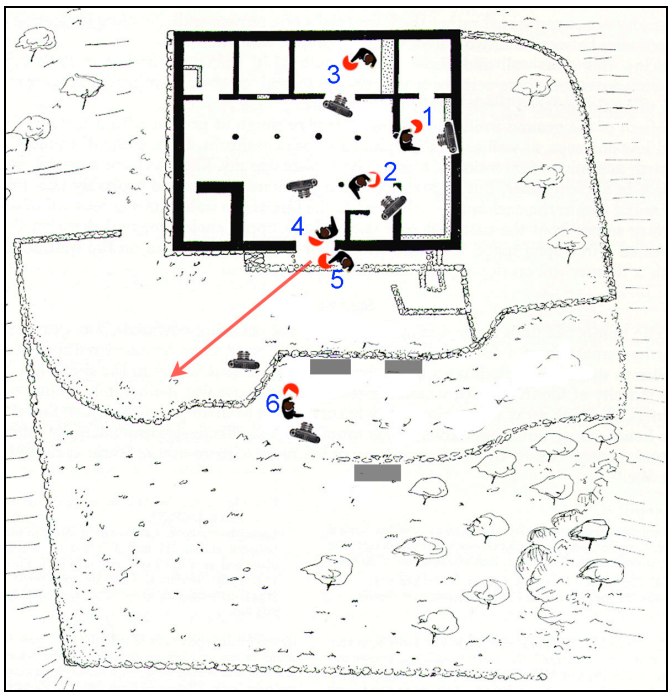

Figure 4: Jump Cut locations (excavator's schematic plan view of the Vari House; final image © 2012 Learning Sites).

Free Walk, Fixed Camera: Initially, the puppet jumps to position **five**, and the camera is placed much further away than with the jump cuts, facing back toward the house. The puppeteer can then walk the avatar across the screen, or back-and-forth, pointing at and describing features or objects. As with the jump cuts, changing the narrative may require changing the initial location of the puppet and the camera. The puppeteer uses the arrow or w, a, s, and d keys on the keyboard to move the avatar, using the venerable *golf cart* navigation scheme: up arrow is forward, down arrow is backward, left arrow rotates him left, right arrow rotates him right.

Intelligent Following: This navigation mode will be familiar to people who have played avatar-based computer games, an old idea that works well. The avatar walks, the camera stays behind him, attempting to maintain a set distance, while avoiding objects. The puppeteer uses the arrow keys to navigate the puppet, just as with the free-walk mode. Additionally, the puppeteer can use the mouse to rotate the view around the puppet at any time. The camera is always looking toward the puppet, but rotating the camera enough will cause it to face him. The puppeteer uses this maneuver when he needs to stop the avatar walking and have the avatar dialogue with the audience.

Intelligent following generally works, and could theoretically accommodate any narrative. Many of the important videogames have players using it to control their personal avatars. However, it has to be skillfully handled in life-size theater to look good. For example, the act of swinging the camera around to the front of the avatar takes time in our current implementation. We will need to experiment with it some more.

Sample Narrative

This is a short, flexible narrative that we used in a recent demonstration. It does not define a fixed dialogue. Instead the storyboard presents material that the actor/puppeteer works with in his conversation with the audience. Much more complex and lengthy narratives are possible with little or no extra programming.

The narrative comes in three phases, each with a different navigation mode (defined above.)

Dialogue in Jump-Cut Mode

Introduction

Figure 5: Screen shot from the Vari House virtual world showing the initial position of the avatar (© 2013 PublicVR and Learning Sites).

- camera position -- not too far away, looking at the avatar with some courtyard in view.
- avatar position looking at the audience (at the camera; figure 5 and #1 in figure 4).
- avatar actions -- gesture to the audience and then around the interior of the house as he talks
- Avatar talking -- "*Yah-sue*....Hello. My name is Orestes; welcome to my farmhouse. What do you think we farm here?" <<pointing to and speaking directly to someone in the audience, identified the person by an item of clothing or some other feature>> "You in the blue shirt! Do you have an idea? We keep bees, and we farm honey. That's all we do, and we here on the slopes of the Hymettus Mountains produce the best honey in all of Greece. My mom's on her way to Vari town to buy food, and my father is out tending to the bees. My kid brother is outside mending pots, so if you follow me, I'll tell you more about our life." <<avatar and camera jump to position 2>>

House Construction & Function

Figure 6: Screen shot from the Vari House virtual world showing position two of the avatar (© 2013 PublicVR and Learning Sites).

- camera position -- not too far away, looking at the avatar and across the courtyard
- avatar position -- looking at the audience (at the camera; figure 6 and #2 in figure 4)
- avatar actions -- points to various parts of the house as they are described
- Avatar talking -- "Ours is a simple house. We built it ourselves from local materials. Rocks, like for the foundation, the courtyard paving stones, and the bases for the posts, were all found out along the hillside. We made the sun-dried mud brick for the walls and cut trees to make the posts, the ceiling beams, and the doors. The rooms are naturally cooled by the breezes coming down the hill behind the house and natural light from this central courtyard spreads everywhere to help us work." <<avatar and camera jump to position 3>>

Dining Room

Figure 7: Screen shot from the Vari House virtual world showing position three of the avatar (© 2013 PublicVR and Learning Sites).

- Camera position -- in the doorway to see both the avatar and plenty of the room.
- Avatar position -- looking at the audience (at the camera; figure 7 and #3 in figure 4)
- Avatar actions -- gestures and points to items there, as described
- Avatar talking -- "This is our Andron (dining room to you)," <<avatar points out features and gestures to other rooms>> "where we lie down on these couches to eat and use the side tables for our dishes. We keep our dried food in jars; other food is prepared fresh each day or smoked and salted for later use. Next door is where we sleep...that is, if we aren't enjoying the evening out there in the courtyard. We go to bed when it gets dark and get up for work at first light. That central courtyard provides access to all the other rooms of the house. It's also our main workspace and where some of the small animals we keep are housed overnight. Over on the side, we have a workplace for repairing the beehives and other stuff. Over in one corner is our kitchen. Now, unlike where most of you live, we don't have any running water, so we take turns fetching fresh water from the streams in the valley nearby." <<avatar points to someone in the audience, and mentions something they are wearing or where they are sitting>> "You get to carry the next batch of water in amphora. As for a bathroom; well, we don't have that either, but there are plenty of trees in the woods outside. We don't even have heat in the house except for the small fire here in the kitchen." <<avatar and camera jump to position 4>>

Look Outside Open Front Door

Figure 8: Screen shot from the Vari House virtual world showing position four of the avatar (© 2013 PublicVR and Learning Sites).

- Camera position -- a bit farther away to see both the avatar and a view out the front door
- Avatar position ---facing the audience beside one door leaf (figure 8 and #4 in figure 4)
- Avatar actions -- points to items there, as described
- Avatar talking -- "I think we picked an ideal location for our house. Besides having the breezes from the hillside, we are also sheltered from winter storms--our house has its back to the north winds, just as Aristotle and Xenophon taught us. And we have a great view" <<look outside>> "all the way down to the coast; that's where my mom needs to go to buy supplies--it's about an hour's walk. Out there, in front of the house, is where we keep the active bee skeps (that's what we call the hives). Hey, Dad, someone to see you....Oh, well, he must still be busy tending to the honey collection. Do you want to go outside?" <<avatar turns to move outside; camera jumps to position 5>>

Dialogue in Free Walk, Fixed Camera Mode

Figure 9: Screen shot from the Vari House virtual world showing position five of the avatar (© 2013 PublicVR and Learning Sites).

- Camera position – facing the house, near the low stone wall with a view of the entire house.
- Avatar position -- facing away from the audience (figure 9 and #5 in figure 4).
- Avatar actions -- gestures to various house parts as he walks from the right side to the left.
- Avatar talking text -- "Here we are outside; I'm under our shaded porch. We like to sit out here and admire our view. Outside you can see the same local construction materials I mentioned before. And over there on the corner of the house is our tower, where we have our locked storeroom and lookout. We keep our valuables safe there and can use the tower to watch for dangers and hide if need be, not that we've ever needed it. Up the hill about half an hour behind the house is a cave of Pan, where he lives and where those of us who live in this area, plus many visitors, go to offer him food and drink so that he continues to protect our bees and the flocks of other farmers."

Dialogue in Intelligent Following Mode

Figure 10: Screen shot from the Vari House virtual world showing position six of the avatar (© 2013 PublicVR and Learning Sites).

Camera position – near the beehives

- See the starting position 6 in Figure 4, near the beehives.
- Avatar actions --gestures to and points to skeps as features are described
- Avatar talking text -- "Here are some of our bee skeps or bee hive containers. The bees won't hurt you, really. Don't mind my dad as he makes sure the containers are working properly. Each skep is made of clay; we make them right here (well, actually me and my brother make them). Each skep has a ceramic lid that's tied to the main skep body by cords wrapped around a forked stick and attached to grooves on the side of the skep. The stick's forked end surrounds a notch in the lid (can you see it?) that acts as a doorway for bees coming in and going out of their hives. The inside walls of the skep body are roughened so the honeycombs can more easily attach themselves. We sometimes remove the lids to check on progress inside; that's probably what my father is doing now. We have dozens of bee skeps scattered across the grounds. Hey, thanks for letting me talk to you about my home. I hope you enjoyed learning about us."

Figure 11: Screen shot from the Vari House virtual world showing another view of position six of the avatar (© 2013 PublicVR and Learning Sites).

Conclusion

Applications like Vari House are relatively rare, but rooted in several converging trends:

- Online virtual worlds with their human-controlled avatars (puppets).
- Game technology and game-like narrative structures for education.
- Immersive displays for a variety of uses.
- Home theater.

Learning through constructive play is powerful, especially when history can be personified in this way. History itself is terribly important, but students gain even more from an interactive virtual worlds experience. Experiences like this show them how to have empathy with other cultures.

Software and animation for Vari House can always be improved, but it is now sufficient for deployment in K-12 schools and in museums. The next stage, now, is to develop the curricula and supporting materials, but that depends on the context. We are currently seeking partners interested in working with schools or museums and that wish to work with us to develop Vari House and similar projects, further.

References and Notes:

[1] Andreadis, A.; Hemery, A.; Antonakakis, A.; Gourdoglou, G.; Mauridis, P.; Christopolis, C.; and Anon. "Training and Conservation in Luxor," ARCE Conservation 2011 [Report]: 1-6.

[2] Anstey, J.; Patrice Seyed, A.; Bay-Cheng, S.; Pape, D.; Shapiro, S. C.; Bona, J.; and Hibit, J. (2009)."The Agent Takes the Stage," International Journal of Arts and Technology, 2009 - Vol. 2, No.4, 277-296.

[3] Biers, William R., (1996)."The Archaeology of Greece: an introduction," Ithaca: Cornell University Press.

[4] Bogdanovych, A.; Rodriguez, J. A.; Simoff, S.; Cohen, A.; and Sierra, C. (2009). "Developing Virtual Heritage Applications as Normative Multi-agent Systems" in proceedings of the Tenth International Workshop on Agent Oriented Software Engineering (AOSE 2009) at the Eighth International Joint Conference on Autonomous Agents and Multi-agent Systems (AAMAS 2009), Budapest, Hungary, May 10-15, 2009. Accepted for publication.

[5] Bowra, C. M. (1965) and the Editors of Time-Life Books, Classical Greece, NY: Time Inc.

[6] CAA (2009). Computer Applications and Quantitative Methods in Archaeology, Williamsburg, VA, USA, March or http://www.caa2009.org/CAA2009_CompletePrelimProgram030409.pdf.

[7] Cavazza, M.; Lugrin, J.L.; Pizzi, D.; and Charles, F. (2007). "Madame Bovary on the Holodeck: Immersive Interactive Storytelling" in proceedings of the ACM Multimedia 2007 conference, ACM Press, Augsburg, Germany, 2007.

[8] Champion, E. (2008a). "Game-based historical learning" in Rick Ferdig, (ed.). Handbook of Research on Effective Electronic Gaming in Education, Information Science Reference, Florida, USA, 219-234. ISBN 978-1-59904-808-6 (hardcover), ISBN 978-1-59904-811-6 (e-book).

[9] Champion, E. (2008b). "Otherness of Place: Game-based Interaction and Learning in Virtual Heritage Projects," International Journal of Heritage Studies, 14(3), 210-228. http://www.tandfonline.com/doi/abs/10.1080/13527250801953686#preview

[10] Connolly, P.and Dodge, H. (1998). *The Ancient City: life in Classical Athens & Rome*, Oxford: Oxford University. Press.

[11] Crane, E.(1983)*The Archaeology of Beekeeping*, London: Duckworth. (esp. Chapter 4)

[12] Cruz-Neira, C.; Sandin, D.; and DeFanti, T. A. (1993). "Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE," SIGGRAPH '93.

[13] Derchain, P. (1965). *Le papyrus Salt 825 (BM 10051): Rituel pour la conservation de la vie en Égypte*, Brussels: Académie Royale de Belgie.

[14] Eversheda, R. P.; Dudda, S. N.; Anderson-Stojanovicb, V. R.; and Gebhard, E. R.(2003). "New Chemical Evidence for the Use of Combed Ware Pottery Vessels as Beehives in Ancient Greece," Journal of Archaeological Science 30.1:1-12.

[15] Economou, D.; Mitchell, W.; Pettifer, S.; Cook, J.; and Marsh, J. (2001). "User Centered Virtual Actor Technology," Conference of Virtual Reality, Archeology, and Cultural Heritage (VAST). ISBN: 1-58113-447-92001.

[16] Garland, R. 2008. *Daily Life of the Ancient Greeks*, 2nd edition, Westport, CT: Greenwood Press.

[17] Gillam, R. (2005). *Performance and Drama in Ancient Egypt*, London: Duckworth.

[18] Gillam, R.; Innes, C.; and Jacobson, J. (2010). "Performance and Ritual in the Virtual Egyptian Temple," Computer Applications and Quantitative Methods in Archaeology (CAA), Granada, Spain, April, 2010.

[19] Henson, B. (2009) "Keeping it Real", American Theater, 87503255, 26.7

[20] Hulusic, V. and Rizvic, S. (2011)."The use of live virtual guides in educational applications," Third International Conference on Games and Virtual Worlds for Serious Applications, Athens, Greece, May. DOI 10.1109/VS-GAMES.2011.31

[21] Jacobson, J. (2011) Egyptian Ceremony in the Virtual Temple; Avatars for Virtual Heritage; Whitepaper and Final Performance Report to the National Endowment for the Humanities. Digital Startup Grant #HD5120910, 2010-2011 academic year. http://publicvr.org/publications/EgyptianOracleFinalReport.pdf

[22] Jacobson, J.; Handron, K.; and Holden, L. (2009). "Narrative and content combine in a learning game for virtual heritage," Computer Applications and Quantitative Methods in Archaeology, Williamsburg, VA.

[23] Jones, J. E.; Graham, A. J., and Sackett, L. H. (1973). "An Attic Country House below the Cave of Pan at Vari," Annual of the British School at Athens68:355-452.

[24] Jones, J.E.(1975). "Another Country House in Attica," Archaeology 28.1:6-15.

[25] Jones, J.E. (1976). "Hives and Honey of Hymettus: beekeeping in Ancient Greece," Archaeology 29.2:80-91.

[26] Kenny, P.; Hartholt, A.; Gratch, J.; Swartout, W.; Traum, D.; Marsella, S.; and Piepol, D. (2007). "Building interactive virtual humans for training environment," in Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) 2007.

[27] Ling, R. (1976).*The Greek World*, NY: E.P. Dutton.

[28] Mapes, D. P.; Tonner, P.; Hughes, C. E. (2011). "Geppetto: An Environment for the Efficient Control and Transmission of Digital Puppetry." HCI (14), v6774, 270-278, Springer.

[29] Moltenbrey, K. (2001). "Preserving the Past," Computer Graphics World, September, 2001.

[30] Neto, J. N.; Silva, R. S.; Neto, J. P.; Pereira, J. M.; and Fernandes, J. (2011). "Solis'Curse - A Cultural Heritage Game Using Voice Interaction with a Virtual Agent," Third International Conference on Games and Virtual Worlds for Serious Applications, Athens, Greece, May. DOI 10.1109/VS-GAMES.2011.31

[31] Papagiannakis, G.; Schertenleib, S.; O'Kennedy, B.;Arevalo-Poizat, M., Magnenat-Thalmann, N., Stoddart, A., andThalmann, D. (2005). "Mixing Virtual and Real Scenes in the Site of Ancient Pompeii," Journal of Computer Animation and Virtual Worlds, 16(1), 11-24.

[32] Roehl, D. B. (1997). "Virtual archeology. Bring new life to ancient worlds," Innovation, 28-35.

[33] Ryu, S. (2005)."Virtual Puppetry and The Process of Ritual," Computers and Composition (C&C.): Elsevier, 2005.

[34] Ryu, S.; Faralli, S.; Bottoni, P.; and Labella, A. (2008)."From Traditional to Virtual Interactive Puppetry: A Comprehensive Approach," Proceedings of ISEA 2008, 14th International Symposium on Electronic Arts, Singapore: July 25-August 3, 2008.

[35] Sanders, D. and Gay, E. (1997) "Exploring the Past," *Hypernexus* v.7(3), 29-31.

[36] Swartout, W.; Gratch, J.; Hill, R.; Hovy, E.; Marsella, S.; Rickel, J.; and Traum, D. "Toward Virtual Humans," AI Magazine, v.27(1), 2006.

[37] Trowbridge, S. and Stapleton, C. (2009). Melting the Boundaries Between Fantasy and Reality, Computer, v 42, n7, 57-62, July 2009, doi:10.1109/MC.2009.228.

[38] Ulicny, B. and Thalmann, D. (2002). Crowd Simulation for Virtual Heritage. First International Workshop on 3D Virtual Heritage, Geneva

[39] VAST (2009). VAST International Symposium on Virtual Reality, Archaeology and Cultural Heritage. Malta

[40] VSMM (2009). Conference on Virtual Systems and MultiMedia (Dedicated to Digital Heritage).

[41] Ward, W. L. (1957). *Playmaking with Children from Kindergarten through Junior High School*, New York, NY: Appleton-Century-Crofts.

[42] Wilheim, J. D. (2002) *Action Strategies for Deepening Comprehension*, New York, NY: Scholastic Professional Books.

[43] Wirth, J.; Norris, A. E.; Mapes, D. P.; Ingraham, K. E.; and Moshell, J. M. "Interactive Performance: Dramatic Improvisation in a Mixed Reality Environment for Learning," HCI (14) 2011: 110-118.

[44] Nambiar, A. (2011) Sound Spatialization For the Egyptian Oracle, Masters Thesis for a Degree in Professional Studies, Department of Digital Media, Northeastern University.

Acknowledgements

Donald Sanders, Ph.D. is an archaeologist, architect, and architectural historian, who have been developing virtual worlds for cultural heritage for over 20 years. As the principal investigator of the Vari House project, he sets all priorities and determines requirements. He also directly supervised the artwork for Vari House itself.

Jeffrey Jacobson, Ph.D., is an educational researcher specializing in visually immersive virtual reality for education. He developed the interaction strategy for the Vari House, which is based on the Egyptian oracle, also his work. He supervised the development of the digital puppet.

Geoff Kornfeld did all of the artwork for Vari House itself and for the farm family members, except for the avatar.

Tatania Roykova created Orestes, the avatar/puppet, modeling his body and look around the bones of the priest from the Egyptian Oracle project. She also improved the animations, which were also carried over from the Oracle project.

Jonathan Hawkins composed and recorded all the music and sound effects.

Cody Johnson programmed the waypoints and the freewalk and greatly refined the intelligent following. He fixed many bugs and generally upgraded Vari House to a professional-level application.

Siddhesh Pandit imported and refined the new animations and models and programmed the first version of the intelligent following.