Gorillas in the Bits

GIT-GVU-96-16

Don Allison, Brian Wills, Larry F. Hodges, Jean Wineman
Georgia Institute of Technology (*Georgia Tech*)

Abstract:

The Virtual Reality Gorilla Exhibit is a system for teaching users about gorilla behaviors and social interactions. The system includes an accurate model of the Zoo Atlanta gorilla habitats and anthropometrically correct gorilla models and behaviors. In the virtual environment the user assumes the persona of an adolescent gorilla. By exploring the habitat and interacting with other gorillas, the user learns about issues in gorilla habitats and about gorilla social hierarchies. Results from preliminary user testing indicate the system successfully accomplishes its goals.

1.0 Introduction

This paper presents an overview of our first prototype of the *Virtual Reality Gorilla Exhibit*. The VR Gorilla Exhibit is an immersive virtual environment in which a child may assume the persona of an adolescent gorilla, enter into one of the gorilla habitats at Zoo Atlanta, and interact as part of a gorilla family unit. The exhibit combines a model of Zoo Atlanta's Gorilla Habitat 3 (home of Willie B, a 439 lb. male silverback gorilla and his family group), with computer generated gorillas whose movements and interactions are modeled to be accurate representations of gorilla behaviors (see Figure 1). The goal of the VR Gorilla Exhibit is to create an experiential educational tool for kids to learn about gorillas' interactions, vocalizations, social structures and habitat.

2.0 Previous Related Work

2.1 VR and Education

There has been lively discussion, both in the popular press and within the educational and scientific communities, about the impact and appropriateness of VR for educational applications (see, for example, [Helsel92], [Roblyer93], [Tiffin95], [Durlach95]). Even articles focusing on other aspects of VR mention the educational possibilities (e.g. [Avis94], [NYT94], [WSJ90]). However, there have been few actual applications of VR to education, and the majority of those have focused more on adult task training (piloting a plane, driving a tank, etc.) and not on general information acquisition.

From a theoretical perspective, Wickens ([Wickens92], [Barfield95]) summarizes research by others and argues that VR might make doing lessons easier while reducing retention. [Damarin93] on the other hand, argues that by allowing students to experience a subject from multiple viewpoints and by allowing self-directed exploration, VR enables students to construct new knowledge expeditiously.

Figure 1: Virtual gorillas in the virtual habitat

At the implementation level, Brelsford ([Brelsford93]) compared a VR physics simulator, which implemented simple Newtonian mechanics, with lectures on the same material. For both junior high and college students, the groups that used the VR simulation showed higher retention than those receiving the lecture.

The Spatial Algebra system of [Winn92] replaced algebraic variables and constants with boxes, and algebraic operations with box positions, letting the students learn algebraic manipulations by analogy with manipulation of boxes. In a related project [Byrne93], [Winn95] used VR to teach students about VR, assisting them in building virtual worlds which the students then explored.

2.2 Interacting with Computer-animated Agents

From an implementation point of view, some recent work at the intersection of the graphics and artificial life communities on interacting with computer-animated agents is of interest. Joseph Bates and his coworkers on the Oz project at CMU have been building autonomous agents with interesting, emotional behaviors for users to interact with, called Woggles (see [Bates93], [Bates94]). Barbara Hayes-Roth and fellow researchers at the Knowledge Systems Laboratory at Stanford have used Bates' Woggles system as the basis for a user-directed improvisation system (targeted at children) where the user(s) specify possible scripts that control their characters' interactions ([Hayes-Roth95]). Both of these systems focus more on action selection and direction and less on the interface, which is still mouse-based. The user also views the action from a third-person point of view, controlling one of the Woggles more or less directly.

Two systems with more interesting interfaces include the Alive system [Maes95], in which the user is tracked using silhouettes from a single camera and watches video images of herself (obtained through a variation of blue-screening) interact with computer creatures on a big screen display, and Neuro Baby [Tosa93][Graves93] by Naoko Tosa, which does away with a computer representation of the user and user tracking, interacting with a stylized baby's head through inflections in the user's voice.

3.0 Motivation for Virtual Gorillas

Gorillas are an endangered species. [Fossey83] reports that only 242 mountain gorillas remain and the population is dropping 3% a year due to poaching and people destroying gorilla habitat for farming purposes. Zoos are spending more efforts on public education about gorillas and their plight to raise public awareness and to motivate people to take action, either through financial contributions to help fund conservation efforts, or through political activism to encourage the governments of Rwanda, Zaire, and Uganda to actively prosecute poachers and promote conservation. We felt that a well-designed virtual environment could contribute to these educational efforts, augmenting them in ways not possible through normal educational media.

There are many aspects of gorilla life that students can only learn through third hand reading. Even spending hours at the zoo observing the gorillas on exhibit won't help students observe the entire spectrum of gorilla behaviors and interactions. For example, the introduction of a new gorilla to a group is done off-exhibit, so students rarely get the chance to observe the establishment or reinforcement of the dominance hierarchy, and challenges to it. There are also things that no amount of observation will show students. For the animals' own protection from disease and because of the logistics problems it would cause the keepers, people normally are not allowed to observe the night quarters, or the routine involved in letting the gorillas out in the morning and bringing them in at night. Given the distance separating the gorillas from the students, it is hard to observe gorilla vocalizations, although they play an important part in indicating gorilla moods. Also, gorillas are active in early morning and late afternoon, sleeping most of the middle of the day, but because of the logistics of class scheduling, most school children visit the zoo during the middle of the day. A virtual gorilla exhibit solves these logistical problems, letting students observe a broader set of gorilla behaviors, time-shifting behaviors that they would normally not see, and letting them visit areas that are normally off limits.

From a pedagogical point of view, constructivist theories of education advocate that the more viewpoints presented to the student, the better she is able to construct knowledge. With the virtual reality gorilla exhibit, the student not only gets to explore areas that are normally off limit to students, she also can assume a gorilla identity and interact with other gorillas as a peer, something not possible in the real world. By allowing the student to interact with other gorillas, she learns through first hand experience the social structure of a gorilla group and accepted social interactions. Also, the realistic but simplified environment focuses attention on the important parts of the system, guiding the user to the most important concepts to be mastered.

Before presenting information to a student, the teacher must first capture her attention. Since virtual environments are a reasonably new technology to most students, the novelty of being in a virtual environment helps hold their attention while the system presents information about gorillas and their behaviors. By presenting information in the first person instead of the third person, this information is likely to be retained longer if absorbed, and by holding the student's attention through the novelty of virtual reality, students are more likely to pay enough attention to actually absorb the knowledge.

From a teacher's viewpoint, a virtual gorilla exhibit would also be useful for several reasons. It could be used in preparation for an actual zoo field trip to help students learn what to look for and give them practice in observing and understanding gorilla behaviors. It could also be used in place of a zoo visit (when the nearest zoo is too far away, or too far away to visit often enough to develop a consistent set of observations). By bringing the zoo to the schools, it could increase interest in and awareness of the plight of the mountain gorilla. Also, since students are learning by putting themselves in someone's shoes other than their own, they are broadening their horizons and learning tolerance and understanding of others, lessons that are normally hard to teach using traditional methods.

Finally, we had available one of the world's premiere gorilla exhibits at Zoo Atlanta, along with the accompanying gorilla experts who were willing to share their expertise.

4.0 Basic Gorilla

One of the goals of this project was to present an accurate simulation of gorilla behavior. While there are many sources of information describing general primate behavior (for example, [Dolhinow72], [Eimerl74]), two major published studies specifically of gorilla behavior proved useful; that of Schaller in the late fifties and early sixties ([Schaller63]) and that of Fossey from the mid-sixties to the mid-eighties ([Fossey83]). While these two works focused on gorillas in the wild, and in particular, mountain gorillas, Maple's book ([Maple82]) summarized what is known about all three gorilla types (eastern lowland, western lowland, and mountain), and provided information about how gorillas live and interact in captivity as well.

While books were useful for finding out what gorillas did, seeing them do it was necessary for accurate simulation of their behaviors. Several hours of video were shot at Zoo Atlanta. Additional footage was provided by the gorilla researchers at Zoo

Atlanta, including some behind-the-scenes footage of gorilla introductions. These sources were used as a basis for constructing the gorilla models and motions. The models were then reviewed by Zoo Atlanta gorilla experts and further refined based on their comments.

As reported by Fossey, normal gorilla groups spend about 40% of their day resting, 30% of their day feeding, and 30% of their day traveling or simultaneously traveling and feeding. Gorillas are chiefly diurnal, arising in the morning from their night nests, feeding, then napping during the hottest part of the day. In the afternoon they travel and feed some more, settling down for the evening in their newly constructed night nests around dusk.

A gorilla group is centered around the dominant male silverback, so-named because the hair on his back is gray or silver instead of black. The group is generally composed of blackback males, females, juveniles and infants. The silverback male is usually father to most of the infants and juveniles in the group, and in fact it is not uncommon for the silverback to kill the infant of a newly acquired female if it was sired by the silverback of a different group.

Just as there is a pecking order among all the gorillas in the group, so there is also a pecking order among the females, with the head female getting most of the silverback's attention. Among the juveniles and infants, not as much attention is paid to rank.

Mothers of infant gorillas tend to be very protective of their young, carrying their infants or keeping them close at hand for about the first three years. As the infants grow into juveniles they are allowed to range farther from their mothers and to have more interactions with their siblings and the other adults. While infants and juveniles can be quite playful, chasing each other, climbing trees, and so on, as gorillas mature the play sessions become more infrequent and tree climbing becomes much rarer.

Gorillas use sounds, gestures and motion to establish or reinforce position in the hierarchy of the group, and to interact between groups. Displays such as ground slapping, chest beating, or charging, combined with vocalizations such as grunts or hoots are used to establish dominance, correct disobedient youngsters, or chase off another group from a group's territory. Sound is also used to give warning by the sentries, or just to express contentment or alert the other gorillas of one's group as to one's location.

5.0 System Implementation

Implementation of the VR Gorilla Exhibit required construction of a gorilla habitat model and gorilla models that encapsulated gorilla geometry, movements, and vocalizations. Basic VR software support was available through Georgia Tech's Simple Virtual Environment (SVE) Toolkit [SVE94]. SVE provides a set of software tools for common VR actions such as head-tracking, model maintenance and locomotion.

Figure 2: Willie B and the virtual silverback

5.1 Gorilla Construction

Five different gorilla models were built: adult male silverback, adult male blackback, adult female, juvenile, and infant. The formulas derived in [Jungers85] were used to calculate limb lengths, based on reasonable mass approximations for each type. Limb circumference data was available for adult males, adult females and juveniles ([Burks96]), and was used to scale limb diameters. (Circumference data for the infant was generated by proportionally scaling juvenile data.) All models currently have 11 joints and 28 degrees of freedom (see Figure 2). The models were developed iteratively, with the gorilla experts at Zoo Atlanta providing feedback at each stage of the modeling process.

Next, gorilla motions were generated as a series of poses. Each pose specifies desired joint angles, global body orientation, and translation offsets to be achieved at a given time. Body orientations and translations are accumulated instead of being specified absolutely. Unlike traditional keyframing, each parameter is specified in relative, rather than absolute, terms. This technique allows one set of poses to be reused in many situations. Conversely, unlike dynamically simulated systems, the motion of several gorillas can be controlled in real time, and each pose is actually realized at the specified time. Currently, intermediate positions are generated by linearly interpolating between poses. Since each pose is reached after a specified time interval independent of frame rate, the motions look the same (only more or less smooth) within a range of frame rates.

Poses were primarily based on video footage of the gorillas at Zoo Atlanta. Additional information was provided by the gorilla researchers at Zoo Atlanta who at times would actually act out a motion sequence for us. Sounds that were associated with each motion were also used to help determine timing details for each pose. For example, in the roar and chest beat sequence, the timing of the transitions between rising up and charging, and between charging and stopping were determined by the sound file of a bluff charge.

5.2 Modeling the Habitat

One of our goals was to create an accurate representation of one or more of the existing gorilla habitats at Zoo Atlanta. The modeling effort began with site measurements, photographs, and the original architectural plans for the entire gorilla exhibit area. Topographical data was used to generate a three dimensional TIN (Triangulated Irregular Network) mesh for the gorilla habitats and dividing moats. In addition to the site plans and measurements,

Figure 3: Gorillas of the Cameroon Interpretive Center

final architectural construction documents were used to model the two buildings within the area of focus-the Gorillas of the Cameroon Interpretive Center and night holding structures (see Figure 3). The building and terrain models were created in PC based CAD and modeling packages (AutoCAD release 12, Easy Surf for AutoCAD, 3D Studio release 4 and 3D Studio Max). Photo-texture maps were scanned or custom created for the models with a close attention to limiting their file size (in order to not exceed texture memory limitations).

After creating an initial terrain model of the entire gorilla exhibit area, we decided to undertake a more detailed modeling effort that focused on Habitat 3. Habitat 3 was chosen because it was one of the largest, and even though it has three different external viewing positions, there are still parts of it that an external observer can't see. The detailed model included accurate representation and placement of foliage, trees, and rocks in the habitat.

A number of optimization techniques were introduced in order to create an accurate visual impression while still maintaining real-time performance. The TIN model was rebuilt with a reduced number of polygons by removing vertices using the criteria that their removal would not change the terrain slope by more than five degrees over a two foot interval within areas that the user could explore, or by ten degrees of terrain slope in areas that the user could see but not explore. The floor of the moat surrounding Habitat 3 was averaged over the entire site and represented by a single polygon.

We also employed a "point of view" heuristic to delete unseen building and terrain faces. Within the modeling program, a single, directional light source was used to represent the user's field of view. The light was constrained to a boundary similar to the user's available range of movement within the environment. The light was then manipulated in real time, and cast in all visible directions. Faces that remained in shadow across all of the possible viewing angles were identified, and removed.

Curved surfaces (rocks, tree trunks, and support structures) were modeled with as few polygon faces as possible, while using applied smoothing angles to remove the "boxy" look the resulting objects would normally have. Texture mapping was used whenever possible in order to enhance the "realism" of the environment while also reducing the number of polygons used within the model. Surrounding vegetation was rendered using applied transparency maps to two curvilinear polygonal surfaces of varied heights, spaced ten feet apart, in order to achieve a sense of motion parallax as the user moved throughout the environment.

5.3 Integration of Gorillas, Habitat and Users

Terrain following is done by positioning each gorilla based on the orientation of the ground it is on. To do this, the positions of the extremities are computed and the gorilla is offset in the vertical direction to insure that no toe or fingertip is below ground. A separate (from the TIN model used for rendering the terrain) table of elevation values on a regular grid (terrain heightfield) is used for efficient computation of ground height values, with off-grid values being bilinearly interpolated from the closest grid points.

The terrain heightfield is also used for obstacle avoidance and to control where gorillas are allowed to roam. Areas that are off limits (such as the interiors of trees or the moat surrounding the habitat) return a large negative value for the height. The gorillas are programmed to avoid these areas, turning away from them as they get too close, with the sharpness of the turn determined by how close to one of these areas they are.

A student user has a similar terrain heightfield that controls her height above the terrain as she explores the habitat. Since users are allowed access to a larger area, this height field also includes the Gorillas of the Cameroon Interpretive Center, the moats, and the rock formations. In this way, the student can explore features of the terrain avoided by the other gorillas, learning the details of the techniques used to insure the gorillas remain within the habitats.

Each gorilla in the system can have its own model and its own control routines, or can use one of the five generic ones. Each gorilla is animated by a sense-act loop that senses the environment, takes care of any reflex actions such as avoiding holes, and then performs any other actions specified if no reflex actions were taken. The body parts are then moved to their new positions, and the gorilla is redrawn.

5.4 Physical Setup

While users were in the virtual environment, they stood on a circular platform that had a handrail completely encircling them (see Figure 4). This was partly to provide support in case they became disoriented in the virtual world, and partly to keep them from wandering beyond the reach of the tracker and HMD cables. The HMD provided a biocular (both eyes see the same image) display and monaural audio to the user, and had a single tracker attached to it to provide head tracking (position and orientation). Additional audio feedback was provided by a subwoofer concealed beneath the circular platform. Movement in the virtual world was accomplished by "virtual walking," using the buttons on a joystick connected through the mouse port to control movement.

6.0 The Virtual Reality Gorilla Exhibit

Once we had created working virtual gorillas and the gorilla habitat, we began a series of meetings with personnel from Zoo Atlanta to define a list of educational goals. For our first prototype of the Virtual Reality Gorilla Exhibit we defined two major goals. First, we wanted middle school kids to experientially learn about social interactions between individuals in a gorilla group based on their place in the dominance hierarchy. Second, we wanted them to learn about the design of outdoor gorilla habitats for zoo exhibits. To support these goals an initial scenario was defined to create learning opportunities while allowing the student freedom to explore and control the pace and intensity of her experience. In this scenario the student takes on the role of a juvenile gorilla. This was a natural match to our target audience of middle school kids since juveniles are younger, generally more active, and haven't yet mastered all the social conventions of gorilla society.

After donning the head-mounted display, the student finds herself in the Gorillas of the Cameroon Interpretive Center at Zoo Atlanta. The Interpretive Center is a building with large glass windows through which visitors can view gorilla Habitat 3, the home of male silverback Willie B and his family group. The student is first encouraged to explore the Interpretive Center itself to become familiar with wearing the head-mounted display and with the use of a handheld control stick that allows her to "walk" around the environment.

After the user becomes comfortable with the system, she is told that she can actually walk through the large glass windows and enter the gorilla habitat. She is also told that, upon entering the gorilla habitat, she becomes a juvenile gorilla and the other gorillas will react to her according to her new identity.

In addition to herself, two other gorillas are in the habitat, a male silverback gorilla and an adult female gorilla. Initially, the adult male and female gorillas are sitting or lying quietly and intermittently making contentment vocalizations. At this point, the student is free to explore the habitat and examine details that are not visible from the viewing areas, or the student may try to interact with the other gorillas.

If the student approaches one of the other two gorillas in a threatening manner or stares continuously at one of them, that gorilla will become annoyed. If the student approaches slowly and meekly as an invitation to groom, the female will remain in a contented state, while the male will almost always decline and become annoyed. If the student attempts to hit one of the gorillas or remains in their personal space, that gorilla will become aggressive, and a fight will ensue. Since the student is low man on the totem pole, the only way to terminate a fight is to submit to the superior gorilla by gesturing submission (which will only work for the female gorilla), or by fleeing the area (which will work with either).

Since we suspected that not every student would react according to our script, we also instituted a safety feature. If the student persists in disruptive behavior annoying the adult gorillas, she is removed from the group and placed in "timeout." This is depicted by the inside of a black cube, with the phrase "You are in timeout" on each wall, and symbolizes the process of removing a disruptive gorilla from the group that is done in real life. To represent reintroduction into a different group, the student then is placed back in the interpretive center, to begin exploring the environment and interacting with the other gorillas from the starting point.

Figure 4: A student interacting with the virtual gorillas as Willie B looks on

7.0 What Real Kids Did With Our System

Once we had fully implemented our prototype system we conducted an informal usability study with school kids from Westminster School, Trickum Middle School, Midway Elementary School, Slaton Elementary School, and Fayetteville High School in Atlanta. These kids, who ranged in age from seven to fifteen, were part of an existing educational program sponsored by Zoo Atlanta and had been coming to the Zoo on a regular basis to study gorilla behaviors. Since the kids were already accustomed to visiting the zoo and working with the gorilla exhibit staff, we moved an entire VR Exhibit setup–circular platform, computers, tracker and head-mounted display–into the Gorillas of the Cameroon Interpretive Center at Zoo Atlanta for a day (see Figure 4). From 9:30 am until 4:00 that afternoon, we continuously had groups of kids coming in and trying out the system.

The reaction of the students that participated in testing our first prototype at the zoo was uniformly positive. Students stated that they thought it was fun, and that they felt like they had been a gorilla. More importantly, they did learn about gorilla behaviors, interactions, and group hierarchies, as evidenced in later reactions when approaching other gorillas. Initially they would just walk right up to the dominant silverback and ignore his warning coughs, and he would end up charging at them. Later in their interactions, though, they recognized the warning cough for what it was and backed off in a submissive manner. They also learned to approach the female slowly to initiate a grooming session, instead of racing up and getting bluff-charged. The observed interactions as they evolved over time give qualitative support to the idea that immersive virtual environments can be used to assist students in constructing knowledge from a first-hand point of view.

Since each user was free to explore as they wished, with minimal guidance from one of the project staff, each could customize her VR experience to best situate her new knowledge in terms of her pre-existing knowledge base. It was interesting to note that younger students spent more time exploring the environment, checking out the corners of the habitat and the moats and trying to look in the gorilla holding building. Older students spent more time observing and interacting with the other gorillas. Each tailored her experience to her interests and level of maturity, yet everyone spent some time on each of the aspects (investigating the habitats, interacting with the other gorillas).

Originally we had envisioned users physically gesturing at the other gorillas, using motions they had learned from their previous observations at the zoo, but most stood still in one spot except for occasionally turning around to look or move towards something behind them. This lack of movement might have been due to their feeling restrained by the enclosure and the wires to the HMD and tracker, or it could just be that they were unfamiliar with the user interface. It will be interesting to test future versions of the system on the same students to see if they gesture more as they become more familiar with the system and its interface.

Several comments from the students suggested areas for improvement. Some students tried to look at themselves after they had moved through the glass of the interpretive center and out into the gorilla habitat. They were told that when they passed through that barrier that they had "become a gorilla," and they wanted to examine their gorilla bodies. Since we were only using one tracker to measure head position and orientation, we didn't have enough information to provide reasonably placed arms and legs. One possible partial solution would be to add more trackers and interpolate non-tracked body parts. Another suggestion was to provide a mirror that the user could look in. By scaling and positioning the mirror appropriately and by adding hand trackers, it might be possible to give the illusion of seeing oneself as a gorilla.

Sound was a very important part of the system, adding realism and also providing additional cues as to a gorilla's internal state (we had a range of sounds for contented, annoyed, and angry gorillas). In our prototype system, though, our sounds played continuously at a constant volume, no matter where the gorillas were in relation to the student (even if they were still inside the interpretative center). Students sometimes found the constant volume confusing, hearing a gorilla rumble and looking around for it since it sounded like it was quite close, even though it was further up the hill. Ideally we would like to evolve towards using spatialized sound, but a first step, possible with the current system, is to disable sounds when the creator is more than a given distance from the student, or when the student is inside the building. Depending on the success of this approach, we could modify our sound library to implement something like an inverse square law rolloff of the sound volume based on distance from the student.

Some students expressed disappointment that they were not able to actually touch the other gorillas and feel the fur as they were grooming the female. Actually, interactions in our environment were deliberately structured to minimize the need to touch or physically manipulate objects. Since we don’t have the equipment to provide haptic feedback, we designed all interactions with our virtual gorillas to occur while they were a short distance away from the user. The only interaction allowed with the terrain was to move at a constant height over it. However, gorillas do interact with their environment, playing with sticks or blades of grass, picking up food from the ground, and occasionally touching each other. As we expand our repertoire of interactions, we will need to carefully design them to minimize the need for haptic feedback, since it appears that there will be no general solutions in the near future to the problem of virtual touch.

Along the same lines, some students wanted a peer that they could interact with, someone that they didn't have to be subservient to. This seems like a reasonable request, but there are two potential problems that must be dealt with when implementing this. The first is that when two juveniles interact, they often do so in ways that involve touching each other, or manipulating objects in the environment. Since these types of interactions are currently difficult to implement in a virtual reality system, the allowed interactions must be carefully choreographed to minimize the need for tactile inputs.

It was interesting to note that even though they were free to interact with the environment in novel ways, most users interacted as they would have if they had actually physically been in the real environment. For example, the moats were 12 feet deep, and in the real world most people don’t willingly jump into 12 foot deep ditches. Even though the virtual environment was designed to allow users to easily enter and leave the moats, few did. Also, most users avoided running into the rocks on the habitat building wall, or trying to fly through trees, and had to be coaxed up to the top of the rocks initially. It seems reasonable to infer from this that the students transferred their knowledge of the real world to the virtual one quite easily, and that their sense of immersion was good.

Finally, we noticed that students seemed to do better when they had a knowledgeable guide to talk them through the first few minutes of interaction with the system. We expected that they would need a quick introduction to how to look and move around in the virtual environment, and so we started them out in the virtual interpretive center with someone there to get them used to looking around and moving about inside the building. However, it also proved useful for the guide to remain by their side once they had ventured out into the habitat to answer their questions and talk them through their first interaction with the other gorillas. It was too far outside the students' experience for them to be able to interpret the sounds and head gestures of the other gorillas without someone asking leading questions to connect what they knew with what they were experiencing, even though they had spent several weeks observing gorilla behavior from outside the habitats.

This problem illustrates one of the advantages of using virtual reality in education, and at the same time demonstrates the need for experiences to be on the fringes of what we know in order for us to learn from them. By the time zoo visitors observe a gorilla group, the members have already been introduced and have a fairly good idea of their place in the group hierarchy, so there are not a lot of challenges for dominance. Thus most visitors don't ever get to see the dominance hierarchy in action, except indirectly (for example when one gorilla will approach another and the second will vacate its position in favor of the first), and even when they do, they often don't realize what they've seen. With virtual reality, our students were able to experience interactions that normally occur in the holding building or in the fifth, out of view, habitat and that are used to determine each gorilla's place in the group hierarchy. However, because it didn't correlate with behaviors they had observed on previous zoo visits, they had trouble interpreting what they saw and heard without a guide to help.

8.0 Future Work

Given that learning can be greatly enhanced by such a guide, we are investigating ways of providing an automated facilitator to help students make connections between their current experience and prior knowledge when they need it. Originally we had thought that having other students around making comments to the student in the virtual environment as they watched what was displayed in the HMD on large screen monitors would help bridge between knowledge and experience, both for the student in the virtual environment and for those still waiting their turn. It didn't work out that way, perhaps because the crowd of other adults around inhibited such interactions. In any case, we are planning to experiment with various adjuncts, such as audio annotations, scripted sequences of interactions where the student is led on a preprogrammed path through the world and shown the salient features, and even status indicators that function similar to a gorilla mood ring, to see which proves most useful in helping the student relate what they are experiencing to what they already know.

Having done a trial run with our initial prototype system, we now have a better idea of the types of questions we need to answer when building a virtual reality system for educational purposes. However, even the results of our first trials seem to indicate that it is possible to use virtual reality as a general educational tool for children, allowing them to experience the real world from viewpoints other than their own, and letting them learn from first-hand experience in environments that would normally be too dangerous or impossible for them to experience in the real world. By providing a rich, but accurate environment in which to interact, students are able to personalize their experiences, and internalize the content presented through first person interactions. Although the final conclusion is still out, some research (see, for example, [Brelsford93]) seems to imply that knowledge constructed through first person interactions is retained more completely and longer than that constructed through third person presentations, such as lectures, or reading books. Given our initial success, we are planning on expanding our system along some of the lines described above, adding more content and enriching the interactions. With the accelerating rate at which computer games and personal computers are driving the cost of the hardware down, virtual reality will be available as a technology to schools sooner than might be expected. Therefore it behooves us to determine appropriate uses for it now, if we are to protect tomorrow's students from bad applications of this technology to education.

Acknowledgments

Partial support for this project was provided by Zoo Atlanta and The Edutech Institute. Special thanks to Terry Maple, Debra Forthman, Lori Perkins, Kyle Burks and Kristen Lukas from Zoo Atlanta for their advice and guidance. Thanks also to Silicon Graphics for hardware support at Zoo Atlanta and to Hewlett Packard for helping us port our software to their HP/Freedom hardware.

Web Page

A web page providing further information about the VR Gorilla Exhibit, Zoo Atlanta, and how the virtual gorilla is integrated with Zoo Atlanta’s ongoing gorilla conservation efforts is available at:

http://atlanta.arch.gatech.edu/city/gorilla/gortop2.html.

This site provides movies of users in the environment (in QuickTime, AVI and MPEG formats). It also has QuickTime VRs of the simulated and real gorilla habitats and of the gorilla models.

References

[Avis94] Nick Avis and Robert Macredie (1994). Problems, possibilities, and potential. *Computer Bulletin*, Series IV, Volume 6, Part 5, October, pp. 8-9.

[Barfield95] Christopher D. Wickens and Polly Baker (1995). Cognitive issues in virtual reality. In *Virtual Environments and Advanced Interface Design*, Woodrow Barfield and Tom Furness eds., Oxford University Press, pp. 514-541.

[Bates93] Joseph Bates, James Altucher, Alexander Hauptman, Mark Kantrowitz, Bryan Loyall, Koichi Murakami, Paul Olbrich, Zoran Popovic, Scott Reilly, Phoebe Sengers, William Welch, Paul Weyhrauch and Andrew Witkin (1993). Edge of intention. *Siggraph '93 Visual Proceedings*, pp. 113-114.

[Bates94] Joseph Bates 1994. The role of emotion in believable agents. *Communications of the ACM*, 37:7, July, pp. 122-125.

[Brelsford93] John W. Brelsford (1993). Physics education in a virtual environment. *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting*, pp. 1286-1290.

[Byrne93] Chris Byrne (1993). Virtual reality and education. HITL Report Number TR-93-6.

[Burks96] Kyle Burks (1996). Personal communication.

[Damarin93] Suzanne K. Damarin (1993). Schooling and situated knowledge: travel or tourism? *Educational Technology*, March, pp. 27-32.

[Dolhinow72] George B. Schaller (1972). The behavior of the mountain gorilla. In *Primate Patterns*, Phyllis Dolhinow, ed., Holt, Rinehart and Winston, pp. 85-124.

[Durlach95] Nathaniel I. Durlach and Anne S. Mavor, eds. (1995). *Virtual Reality, Scientific and Technological Challenges*. National Academy of Sciences.

[Eimerl74] Sarel Eimerl and Irene DeVore and the editors of Time-Life Books (1974). *Life Nature Library: The Primates*.

[Fossey83] Dian Fossey (1983). *Gorillas in the Mist*. Houghton Mifflin Co.

[Graves93] Gaye Graves (1993). This digital baby responds to coos and goos. *Computer Graphics World*, July, pp. 16-17.

[Hayes-Roth95] Barbara Hayes-Roth, Lee Brownston and Erik Sincoff (1995). Directed improvisation by computer characters. Stanford University Knowledge Systems Laboratory Tech Report KSL-95-04.

[Helsel92] Sandra Helsel (1992). Virtual reality and education. *Educational Technology*, May, pp. 38-42.

[Jungers85] William L. Jungers (1985). Body size and scaling of limb proportions in primates. In *Size and Scaling in Primate Biology*, William L. Jungers, ed., Plenum Press, pp. 345-381.

[Maes95] Pattie Maes, Trevor Darrell, Bruce Blumberg and Alex Pentland (1995). The ALIVE system: full-body interaction with autonomous agents. *Computer Animation '95 Proceedings*, IEEE Press, pp. 11-18.

[Maple82] Terry L. Maple and Michael P. Hoff (1982). *Gorilla Behavior*, Van Nostrand Reinhold.

[NYT94] Peter H. Lewis (1994). Sound bytes: he added `virtual' to `reality'. *The New York Times*, Section 3 (Business), September 25, page 7.

[Roblyer93] M. D. Roblyer (1993). Technology in our time: virtual reality, visions, and nightmares. *Educational Technology*, February, pp. 33-35.

[Schaller63] George B. Schaller (1963). *The Mountain Gorilla: Ecology and Behavior*. University of Chicago Press.

[SVE94] Drew Kessler, Rob Kooper, Jouke C. Verlinden and Larry F. Hodges(1994). The simple virtual environment (SVE) library. GVU Tech Report GIT-GVU-94-34, October.

[Tiffin95] John Tiffin and Lalita Rajasingham (1995). *In Search of the Virtual Class*, Routledge.

[Tosa93] Naoko Tosa (1993). Neuro Baby. *Siggraph '93 Visual Proceedings*, page 167.

[Wickens92] Christopher D. Wickens (1992). Virtual reality and education. *1992 IEEE International Conference on Systems, Man, and Cybernetics*, October, pp. 842-847.

[Winn92] William Winn and William Bricken (1992). Designing virtual worlds for use in mathematics education: the example of experiential algebra. *Educational Technology*, December, pp. 12-19.

[Winn95] William Winn (1995). The virtual reality roving vehicle project. *T. H. E. Journal*, December, 70-74.

[WSJ90] (1990). Artificial reality: computer simulations one day may provide surreal experiences. *The Wall Street Journal*, volume CCXV, number 16, January 23, pp. A1 & A9.