Constructing Collaborative Stories Within Virtual Learning Landscapes

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Abstract: In this paper we present an approach for applying virtual reality (VR) to the creation of a family of educational environments for young users. The immersive and interactive attributes of VR technology can be a powerful tool for education, allowing the learner to actively participate in the surrounding environment. Our approach is based on constructionism, where real and synthetic users, motivated by an underlying narrative, build persisting virtual worlds through collaboration. This approach is grounded on well established paradigms in contemporary learning and integrates ideas from such diverse fields as virtual reality, human-computer interaction, CSCW, storytelling, and artificial intelligence. The goal is to build an experiential learning environment that will engage children in authentic activity. Our prototype system explores the above ideas within the CAVE(tm) virtual reality theater.

It is generally recognized in educational circles that an essential part of the learning process lies in "hands-on" construction. The success of children's educational activities based on building blocks, has come to support this theory(Resnick, 1991). Another central pedagogical theme in problem solving is collaborative work, which is necessary for engaging students in group activity and social interaction. Yet constructive activity and collaboration are skills that need to be developed. A powerful technique for teaching children to work collectively is to engage them in the construction of story structures. This process allows children to create an intellectual product that results in an obvious pride of accomplishment.

We present a virtual reality landscape consisting of a family of learning environments for young users, that embodies a set of common principles. In this shared virtual environment, participants interact directly with the world to create story threads. The methods of interaction between the participants and the world are natural, reflecting daily real-world interaction. Our approach is based on constructionism, where real and synthetic users, motivated by an underlying narrative, build persisting virtual worlds through collaboration with other human and simulated agents. In terms of learning environments, this encompasses nearly all the major contemporary dogma: constructionism, collaboration, problem solving, and authentic experiences.

Children's narrative is used by conventional media, such as the storybook or the cinema, to present imaginary worlds. We adopt virtual reality because it expands these traditions by encouraging active participation in the creative process, and thus redefining the relationship between the audience and the work. In this research, it takes on the role of a distributed participatory theater where children at various locations can share the same virtual stage. The children, challenged by the vividness and the sensation of this new space, craft stories by constructing imaginary ecosystems. Simulated agents, which we refer to as genies, co-populate the landscape and encourage a progression of events in a narrative. The child's actions in the space and interactions with the genies determine the general direction of the narrative, without restricting its outcome. These stories have a life beyond the child's short term interaction with the virtual space; they persist, allowing others to experience and further the ongoing narrative. They may also persist in the form of an artifact that records the child's accomplishments.

In the following sections we will explore the various aspects of our approach, as well as describe our prototype implementation that embodies some of these concepts.

Narrative Immersive Constructionist/Collaborative Environments

Many examples of computer-based learning related to interactive storytelling have been developed, both for commercial and educational purposes. These range from a simple level of interaction (e.g. Living Books by Broderbund Software) where the user has no control of the outcome, to the level where children collaborate to form the outcome(Steiner, 1995; Steiner & Moher, 1992; Steiner & Moher, 1994). These examples have been developed mainly for two-dimensional display environments, thus lacking the immersive qualities of a VR environment.

More elaborate models, primarily research oriented, are efforts such as the Oz Project(Bates, 1992), where the focus is on creating believable agents with emotions, or Laurel's Interactive Fantasy system(Laurel, 1991). The UNIVERSE system(Lebowitz, 1984) deals with narrative, characters, and coherent plot structures, while the Virtual Theater group at Stanford investigates these areas in relation to children. Seymour Papert's Epistemology and Learning Group at MIT works primarily around the idea of constructionism, building systems based on Legos(tm) and other construction kits(Papert, 1991). HITL researchers at the University of Washington address educational issues in VR at a more theoretical level. Finally, there are the text-based virtual communities of MUDs (Multi-User Dungeon) and MOOs (MUD Object-Oriented) that follow narrative structures, but lack the immersion provided by 3D graphical VR systems.

Some of these projects are research tools and do not directly address educational issues, while others remain at a theoretical level. Our work integrates concepts from these projects but also attempts to extend the above efforts into a complete environment that shares common characteristics. It uses immersion to provide a natural and familiar style of interaction; creates a basis for collaboration and construction in the environment; sustains a narrative as a basis for coherency.

Constructionism

Constructionism is one of the major contemporary dogma in education theory. As the basis for learning, it is a well-established methodology(Papert, 1991; Resnick, 1991). It deals with the ways children assimilate knowledge, accomplished through constructive tasks. In our virtual constructionist playground, kids can pick up objects, hand them to other characters, combine them to build new objects, and use them to solve problems. The goal is to foster creativity, and to motivate learning through activity. The case has been made that learning is more effective when approached as situated in activity rather than received passively(Brown *et al*,1989).

The experience should result in a virtual or tangible artifact. No one enjoys creating something in the knowledge that it will be quickly discarded. Artifacts allow the student and others to reconstruct and evaluate the learning process. In addition they add enjoyment and a feeling of accomplishment. Constructionism asserts that people learn with particular effectiveness when they are engaged in creating personally meaningful artifacts(Papert, 1991). The artifact can be anything from a written, illustrated version of the narrative, a video of the experience itself, or the persistence of constructed objects in a virtual space. The artifact that is currently generated by our system is an electronic version of the scene, saved as an object that can be shared over the Internet.

Narrative Elements

The experience is framed in a narrative context. However, it is not defined by it. The focus is not on building environments that achieve complete narrative structures, but on using the power of the story form as a communicative medium. We look at stories as the motivational basis for activity and interaction, to provide construction with a purpose. The reason we choose narrative to be our motivational trigger lies in the indisputable value of storytelling(Applebee, 1978; Briggs & Wagner, 1979; Eagan, 1992) in enhancing the learning process. Stories can stimulate imagination, entertain, and improve communication abilities(Briggs & Wagner, 1979).

The stories in our virtual world take the form of multiple threads. We adopt Lebowitz's approach, where an entire story cannot be planned out(Lebowitz, 1984), since the kinds of stories we envision theoretically do not end. Instead, once a body of events has been planned, that portion of the story is told.

When we say narrative we refer to multiple persistent narratives; various stories have a life beyond the short term interaction with the physical space, they persist in the sense of a longer temporal scope. The virtual world stays extant. It may continue to evolve in the child's absence or remains suspended until their return.

Characters are necessary to maintain coherence and consistency in a story(Lebowitz, 1984). The user guides the plot structures through character interactions; characters and the environment influence the narrative. Characters consist of children interacting with the virtual environment and computer controlled agents within the environment. We call these simulated agents genies. Genies take the role of "side-kicks", companions and acquaintances. The participant begins by choosing a side-kick that serves as a guide and loyal companion that

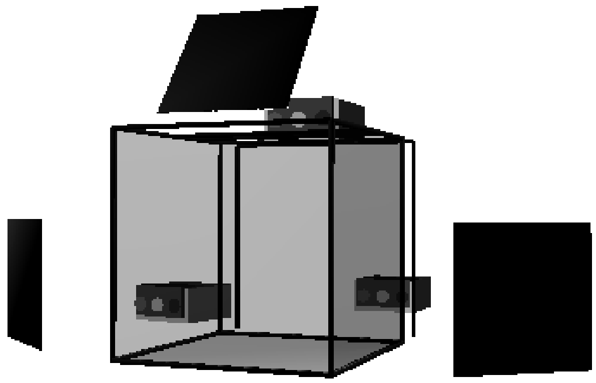

Figure 1: The CAVE Automatic Virtual Environment(tm)

remains with the participant throughout the narrative. The side-kick answers the participant's questions in the environment, suggests possible actions that help drive the narrative, and introduces participants to other companions.

In addition to side-kicks, participants may encounter and invite companions to join them. These companions may each have special knowledge about the environment or possess special abilities to help the child (e.g. the fire-flies provide light in the night time.) Finally, participants interact briefly with casual acquaintances who provide supplementary information about the environment but do not join the entourage (e.g. a talking sign post may point the way to a scenic route, or warn of potential danger in the area.)

Collaboration

Many educational systems assume that knowledge is individual and self-structured. We believe that the constructionist work that goes on in the building of any world should be the product of collaboration. Working in a group is more efficient than working individually. It provides a way to collectively explore a problem domain, and appreciate the roles needed to complete a task. Most importantly, collaboration promotes the social construction of knowledge through social interaction. Our perspective points to the importance of considering storytelling and narrative as an act of communication and shared experience, which is reinforced by collaborating with other students. Collaboration may include interactions between "virtual communities" of students who are geographically separated, or between students and genies.

Implementation

These ideas are being developed in a prototype system named GULLIVR -Graphical User Learning Landscapes In VR. Specifically GULLIVR allows multiple participants to share in the exploration of a virtual space, interact with each other, and perform simple tasks. A simple agent architecture based on a frame system, is being developed to support the actions and personalities of the characters. For the purposes of our current user testing, the simpler agents are controlled by the computer, while the more intelligent agents are controlled by members of our group.

GULLIVR is an outgrowth of CALVIN (Collaborative Architectural Layout Via Immersive Navigation) (Leigh *et al*, 1996a; Leigh *et al*, 1996b; Leigh *et al*, 1995), a networked collaborative environment for designing architectural spaces. GULLIVR provides the underlying architecture to support constructionism and allow collaboration. It is designed to run in the CAVE(Cruz-Neira *et al*, 1993) virtual environment. The CAVE is a 10 foot by 10 foot by 10 foot room constructed of three translucent walls. Stereoscopic images are projected onto the walls and floor (fig. 1).

A participant entering the CAVE dons a pair of LCD shutter glasses to mediate the stereoscopic imagery. A magnetic tracker, attached to the glasses relays the position and orientation of the user's head to the computer. The user interacts with the virtual environment using 'the wand', a simple tracked input device containing a joystick and 3 buttons. The CAVE's room-sized structure allows for multiple users to move around freely, both physically and virtually surrounded by vivid displays. It is much like being in a theater with the difference that, unlike a traditional theater, the viewer is on the stage as opposed to just observing the stage as audience.

However, only one person is being tracked in each CAVE, thus reducing the participation of all the children in the same CAVE at one time. One child can set the viewpoint, another child may handle the wand to pick and place objects, while the other children can observe and give their verbal input. We have observed that this has not decreased the feeling of presence and immersion of the participants that are not tracked and the children may exchange roles at any time.

The core of GULLIVR is the CAVE library. On top of this GULLIVR uses SGI Performer and Open GL to render the virtual environment. Although GULLIVR was originally conceived for the CAVE, the CAVE library is capable of supporting a number of different VR platforms including the Immersadesk virtual reality table, a BOOM, fish-tank VR systems, and simple graphics workstations. GULLIVR's network component allows multiple networked participants to explore the same virtual space. Multiple distributed GULLIVRs running on separate VR systems are connected via a centralized database server that guarantees consistency across all the separate environments. The communications library supporting GULLIVR is based on a client-server model where the number of remote clients is limited only by bandwidth and latency.

The wand is the physical interface to the virtual world. It is used to navigate around the virtual world, and to manipulate virtual objects within that world. The user can move around within the confines of the CAVE, walking around or through virtual objects, and can press the joystick on the wand to move the CAVE through the virtual environment. GULLIVR provides the option of flying over the world, or adjusting the floor of the CAVE to coincide with the height of the landscape, thus allowing the user to climb over terrain or ascend and descend stairs, by physically walking in the CAVE. Every element of the scene in GULLIVR is treated as an object. Hence, every object serves as a building block for the construction of other objects. The child can pick up objects in the virtual environment by using the wand as an extension of her hand. She moves the wand over to an object and clicks a button on the wand to pick it up. She can then move the object to an appropriate place and let it go.

Description of the Setting

The current story is set on a fantasy island (see fig. 2). The terrain is fairly large and includes a variety of spaces that invite exploration. The children can climb a dormant volcano, build a bridge crossing the waters to reach another smaller island, and explore a labyrinth of caverns winding under the island.

The main constructive activity is to build and develop small local ecosystems on the bare parts of the island. The terrain serves as an open land which the child explores to decide where to plant and populate. Various seeds for planting garden vegetables and trees are stored in crates and serve as starting points for building micro-ecosystems on the island. Additionally, the child can elicit the assistance of several genies, such as a cloud genie to provide rain, or the fire-flies to illuminate the vast underground expanse. Our immediate plans are to have the genies make their actions explicit, in the case where the child cannot perceive cause and effect right away.

When the user drops a seed on the ground, the corresponding plant, flower or tree will start to grow. The pace in which this happens can be predetermined; we may choose to see the system grow very quickly, or, in the case of a school project, extend it over the period of a semester.

The tomatoes, carrots, pumpkins and other plant objects contain a set of characteristics that contribute to their growth. They all have values for their age, the amount of water they hold, the amount of light they need, their proximity to other plants of their kind. These values determine the health of the plant and its size. Visual cues aid the child in determining the state of a plant or flower. When the cloud has been pouring rain over it for too long, the plant opens an umbrella; when the sunlight is too bright, it wears sunglasses. Sound in the environment also enriches the surroundings in a variety of ways. Different environmental sounds are experienced depending on where each participant is standing (e.g. the children by the shoreline will hear the water, in the rainforest will hear the birds, etc.)

The narrative, as implemented in this stage, revolves around the construction of the ecological microworlds and the decisions being made through the interaction with the genies. Every action is being recorded and even when there is no interaction, the world continues to evolve through time. Each child may choose to join or leave the story set at any time, while the stories on the island continue and others can explore its mysteries. Parts of the island, as well as all of the objects and agents, are Inventor models. This allows the current scene to be easily saved and converted into VRML (Virtual Reality Modeling Language), creating a 3D snapshot of the world at any given time as an artifact that can be browsed on the Internet.

The above activities can be performed collaboratively between children at two or more remote CAVEs or Immersadesks. Each tracked participant's presence in the virtual space is established using an avatar. These avatars consist of a separate head, body, and hand. As each person's head and hand are tracked, this allows the environment to transmit gestures between the participants such as the nodding of the user's head, or the waving of user's hand to the other participants. As these avatars have sufficiently detailed representations, the

Figure 2: A scene from the GULLIVR Story Set: at the bridge.

participants can communicate notions of relative position to one another with phrases such as “it is behind you” or “turn to your left.” (fig. 3). We have found this to be effective in establishing co-presence over our previous experiences in transcontinental collaboration(Leigh *et al*, 1995).

The children communicate with other remote participants using their voice. A high-speed ATM voice conference system is used to allow the various human participants to talk to each other. In a similar way, the children interact with the computer-controlled agents using a speaker independent voice recognition system. In this case, the child wears a wireless microphone and communicates actions using simple phrases (e.g. “fire-flies, get brighter!” or “signpost, where is the bridge?”) In trials of this technique, the system was able to reliably respond to the user’s utterances even in relatively noisy conditions. Live video for the communication of the remote participants has also been tested. However, we would like to investigate whether this feature effectively improves communication or instead destroys their suspension of disbelief.

Given that some of the genies possess a wide range of capabilities and personalities that have to be believably represented, we have chosen to take an approach commonly used in human-factors circles. Rather than investing enormous amounts of time architecting a complex artificial intelligence engine to realistically simulate artificial agent behavior, we use the Wizard-of-Oz prototyping technique to quickly simulate the behavior of pre-built software systems. In GULLIVR, Wizard-of-Oz prototyping is used for controlling the ‘helper’ genies that possess a more anthropomorphic character. A remote human being takes on the role of each genie- controlling their behavior in response to changing conditions. The child is unaware of which characters in the environment are controlled by the computer and which by a human operator.

While the behaviors of some of the genies (e.g. the fire-flies or the sign post) will be realizable in the short-term, the side-kick may always require a human operator to maintain the illusion of believability.

Discussion

Our current user testing is based on informal trials of the system. These trials revealed that our appropriate age group consists of children between 6 and 10 years old. The children of this age group were eager to explore the landscape, adapted rapidly, and were generally less inhibited in their exploration of the space than adults. Younger children are constrained by physical (size of stereoglasses,wand) and conceptual difficulties. Previous studies of children interacting with The Graphic Storywriter (an earlier 2D storytelling environment)(Steiner & Moher, 1992) has shown that children prefer to keep the narrative alive even though the system was constrained to produce structurally complete stories.

Much of this project’s efficacy is hypothetical considering the limited resources of today’s schools. The prohibiting cost of VR systems, such as the CAVE, make this work of little use in the normal classroom. However, this system aims to serve as a prototype for future integration of important educational elements into virtual reality systems, and can provide a testbed for hands-on learning and concept visualization. The experience does not claim to educate children by precisely simulating the real-world environment, nor does it hope to replace a real playground or classroom. Nevertheless, we believe that it contributes to the learning

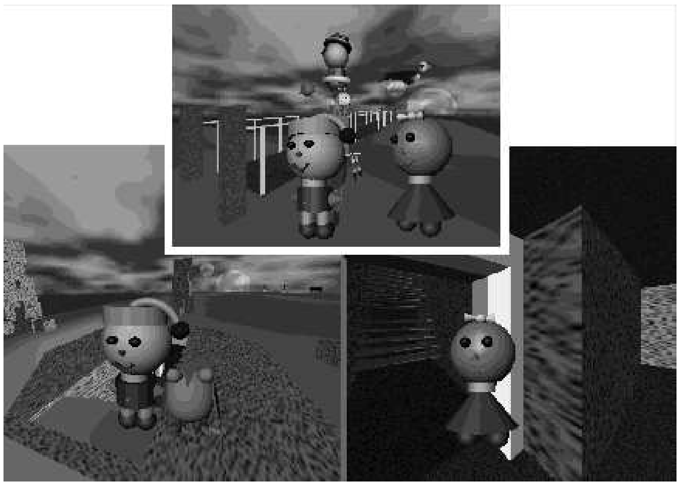

Figure 3: Some of GULLIVR's Avatars: at the bridge, at the cavern entrance, and inside the cavern.

process, by allowing the child to do things that can't be done in the playground. It may, for example, demonstrate ecological interrelationships which cannot be visualized in an outdoor classroom. The children can plant trees in their actual schoolyard to attract birds and observe their behaviors. But on the virtual island they have the ability to scale and position every part of that ecosystem, or factor time to observe quickly and directly the effects of the changes they make to it. They can take on different roles, change their own size, or visualize abstract ideas that have so far eluded representation. Other extensions of the system may include its use in areas like Computer Based Training and Special Education, or to the introduction of ideas of social interaction and group dynamics to children that might not thrive socially.

Additionally, the fantasy elements invoke the child's active imagination, and provide the ability to have fun and to learn at the same time. We think that efforts in this direction may help to extend the pedagogical potential of virtual reality a step further, in the direction of promoting learning within the nexus of activity and engagement.

Further Work

Much research, both in the theoretical as in the practical, remains to be pursued as this project continues to evolve. Part of the next phase of our research will focus on expanding the functionality of the agent architecture and improving the flexibility of persistence. In terms of the space and interaction, our goal is to develop an interface that will offer natural modes of interaction. The thought of replacing the wand with a 'magic mirror', for improving the direct manipulation of objects and adding to the fantasy, is currently being discussed.

Presently, the only artifact created, besides the obvious video documentation of the interaction, is saving the scene into a VRML object. We would like to expand the idea of the artifact into something that does not require a computer for it to be experienced. Our next extension towards this direction, involves the actual written output of the story. Every action can be printed out in written form using simple phrases that describe it, much like a text-based MUD. Snapshots of the agent models may be included as images in the printout, which the child can then keep as a record of the interaction.

Finally, we would like to define a methodology for qualitative and quantitative assessment of learning in the environment. Significant user testing remains to be performed in order to evaluate the efficacy of the system and justify its purpose as a learning environment. The process of incorporating virtual reality into the school environment is highly complex and involves substantial financial and human resource investment. Thus, conducting educational assessment is a significant point that needs to be addressed.

References

Applebee, A. N. (1978). *The child's concept of story: ages two to seventeen*, University of Chicago Press.

Bates, J. (1992). The Nature of Characters in Interactive Worlds and The Oz Project. *Technical Report CMU-CS-92-200*, http://www.cs.cmu.edu/afs/cs.cmu.edu/project/oz/web/papers.html

Briggs, N.E. & Wagner, J.A. (1979). *Children's Literature Through Storytelling & Drama.* Wm.C.Brown Company.

Brown, J. S., Collins, A., Duguid, P. (1989). Situated Cognition. *Artificial Intelligence and Education*, vol.2, pp. 254-268, eds. Robert W. Lawler, Masoud Yazdani, c1987-1991.

Cruz-Neira C., Sandin D.J., DeFanti T.A. (1993). Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE, In *Proceedings of the ACM SIGGRAPH Computer Graphics Conference*, pp. 135-142.

Eagan, K. (1992). *Imagination in Teaching and Learning: The Middle School Years*, The University of Chicago Press.

Laurel, B. (1991). *Computers as Theatre*, Addison-Wessley Publishing, NY.

Lebowitz, M. (1984). Creating Characters in a Story Telling Universe. *Poetics*, vol. 13, pp. 171-194.

Leigh, J., Johnson, A., DeFanti, T.A. (1996). CALVIN: an Immersimedia Design Environment Utilizing Heterogeneous Perspectives. In *Proceedings of the IEEE International Conference on Multimedia Computing and Systems*, Hiroshima, Japan.

Leigh, J., Johnson, A., Vasilakis, C., DeFanti, T.A. (1996). Multi-perspective Collaborative Design in Persistent Networked Virtual Environments. In *Proceedings of the IEEE Virtual Reality Annual International Symposium*, pp.253-260, Santa Clara, CA.

Leigh, J., Johnson, A., DeFanti, T., Kelley, M. (1995). Transcontinental Collaborative Design in a Shared Virtual Environment, *Demonstration in the CAVE in the GII Testbed*, Supercomputing 1995.

Papert, S. (1991). Situating Constructionism. *Constructionism*, eds. Idit Harel and Seymour Papert.

Resnick, M. (1991). Xylophones, Hamsters, and Fireworks: The Role of Diversity in Constructionist Activities. *Constructionism*, eds. Idit Harel and Seymour Papert.

Steiner, K. E. (1995). Representation and Interaction with Symbolic Structures in Individual and Shared Learning Environments. *PhD Thesis, University of Illinois at Chicago.*

Steiner, K. E. & Moher, T. G. (1992). Graphic Storywriter: An Interactive Environment for Emergent Story Construction. In *Proceedings of the CHI Conference*, pp.357-363, Monterey, CA.

Steiner, K. E. & Moher, T. G. (1994). Scaffolding Story Construction with Interactive Multimedia. *The Journal of Educational Multimedia and Hypermedia*, v3(2), pp.173-196.

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