The NICE project: Narrative, Immersive, Constructionist/Collaborative Environments for Learning in Virtual Reality

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Abstract: This paper describes and discusses the NICE project, an immersive learning environment for children implemented in the CAVE and related multi-user virtual reality (VR) technologies. The NICE project provides an engaging setting where children construct and cultivate simple virtual ecosystems, collaborate via networks with other remotely-located children, and create stories from their interactions in the real and virtual world.

The NICE project is an effort to build Narrative-based, Immersive, Constructionist/Collaborative Environments for children. Developed at the Interactive Computing Environments Laboratory (ICE) and the Electronic Visualization Laboratory (EVL) of the University of Illinois at Chicago, NICE aims to create a virtual learning environment that is based on current educational theories of contructionism, narrative, and collaboration, while fostering creativity within a motivating and engaging context.

NICE is an outgrowth of two previously designed systems, CALVIN and the Graphical StoryWriter. CALVIN (Collaborative Architectural Layout Via Immersive Navigation) is a networked collaborative environment for designing architectural spaces [Leigh and Johnson, 1996]. The Graphical Storywriter [Steiner and Moher, 1994] is a shared workspace, where young children can develop and create structurally complete stories. Extracting and building on elements from these previous works, we have created a prototype learning environment for young children which presents simplified ecological models of various ecosystems within a fantasy setting.

The software is primarily designed to run in the CAVE, a multi-person, room-sized virtual reality system developed at EVL. It is, however, capable of supporting a number of different VR platforms, including simpler graphics workstations. The CAVE is a 10 x 10 x 10 ft. room constructed of three translucent walls [Cruz-Neira et al., 1993]. High resolution stereoscopic images are rear-projected onto the walls and the floor and viewed with light-weight LCD stereo glasses to mediate the stereoscopic imagery. Attached to the glasses is a location sensor. As the viewer moves within the confines of the CAVE, the correct perspective and stereo projection of the environment are updated and the user may walk around or through virtual objects. The CAVE's room-sized structure allows for multiple users to move around freely, both physically and virtually. The user interacts with the environment using ''the wand'', a simple tracked input device containing a joystick and 3 buttons. It is used to navigate around the virtual world, and to manipulate virtual objects within that world.

In the following sections we will explore the various aspects of our approach, as well as describe how our current implementation embodies some of the concepts we base it on. Let us first describe an example of a typical session in NICE.

Description of a NICE experience

Amy and a group of other 8-year olds wear stereoglasses and enter a CAVE. The children are represented in the virtual space by an avatar, a three-dimensional model of a character, in this case a little girl. While moving around in the space the children meet the talking signpost, one of many ‘‘intelligent’’ guides or ‘‘genies’’, which helps to direct them in the virtual world. Among the interesting spaces to explore is the garden. When they enter the vegetable garden they notice a crop growing there already. Claudio and his friends, represented by a little boy-avatar, is waving at them. They have been planting vegetables in the same virtual garden from another, remotely-located, computer [Fig. 1].

When the kids pick a seed from one of the crates and drop it on the ground, the corresponding plant, flower or tree begins to grow. The children must make sure that their plants are not too close together, and that they get enough water and sunlight. They can water the vegetables by pulling the rain cloud over them and provide sunlight by pulling over the smiling sun genie. When a plant is adequately watered, it pops up an umbrella and the children pull the cloud away; when the sunlight is too bright, the plant wears sunglasses; when it feels crowded it starts moving restlessly. The two groups of children work together to keep their garden clean and healthy. They exchange seeds and flowers, they clear out the weeds by recycling them in the compost heap, and they gather the successfully harvested vegetables in a barrel. The heavy barrel can only be lifted with the help of all remote participants and carried away from the garden. Sofia, the friendly owl genie, provides constant assistance, and the birds help with the planting.

This simple ecosystem will continue to evolve and the kids can come back and check on their progress at a later time. More children can choose characters to represent themselves, and join in from remote computers. Teachers or parents can participate, either as members of the groups, or disguised as genies. This allows teachers to advise the children in person or to direct parts of the activity from "behind the scenes". They can also predetermine the pace at which the world evolves; they may choose to see the plants grow very quickly, or, in the case of a school project, extend their growth over the period of a semester. Upon leaving the virtual environment, the children can obtain an illustrated version of their experiences in the garden they have created.

Figure 1: Children, represented by avatars, plant a NICE garden.

Combining Constructionism, Narrative, and Collaboration

NICE focuses on bringing together concepts of constructive group activity and narrative, within the nexus of motivation and exploration. A theoretical framework which combines the ideas of constructionism, narrative, and collaboration provides the underpinning for this environment. In the following sections we will describe the technical aspects as well as the underlying pedagogical principles of the system.

Constructionism and Exploration

Constructivism is an approach to learning that has received much attention in the educational technology circles and is being applied to many current educational software projects. Based on the learning theories of Dewey [Dewey, 1966], Piaget [Piaget, 1973], and others, constructivism deals with the ways learners assimilate knowledge by engaging in self-directed learning activities which are accomplished through constructive tasks. Exploration and the process of constructing objects are viewed as integral parts of these learning activities. We too believe that learning is situated in the activity of making [Brown et al., 1989], manipulating, and exploring objects, systems, and ideas. In NICE, constructive play is made possible with virtual building blocks that contain characteristics physical toys or learning tools do not: the kids can pick up heavy or large objects, hand them to other remotely located children, combine them to build new objects, or instantly observe their changing attributes over time. They can determine the environment characteristics, change their own body size [Fig. 2], disappear, fly, or leap high in the air.

All the objects, avatars and genies in the world are VRML models, which can be moved and scaled by the child in real time. The plants, trees, and flowers are simple agents with common rules of evolution and behaviour which are based on simplified ecological models. They contain a common set of characteristics that contribute to their growth, such as their age, the amount of water and sunlight they need, and their proximity to other plants. The combination of these attributes determines the health of each plant and its size. As soon as Amy drops the carrot seed on the ground, the carrot will start to grow.

When she pulls the cloud over to water it, the carrot will grow faster. Visual and audio cues aid the children in determining the state of each plant or flower. The carrot will pop up a small animated umbrella to let Amy know that it doesn’t require any more water. These models are handled by a central behavioural server called LIFE, which also controls the actions of the genies and story structures. LIFE can be operating constantly on any centrally located computer thus maintaining a persistant virtual world [Fig. 4].

Figure 2: Becoming small in the carrot garden.

Narrative

Papert believes that learning takes place when engaged in the construction of a personally meaningful artifact, such as a piece of art work, a story, or an interactive computerized object [Papert, 1980]. One of the products of constructive activity in the NICE environment is the narrative, the stories formed and created by the kids that participate. The narrative revolves around the construction of the ecological microworlds and the reactions or decisions taken while interacting with the genies. Every action in the environment adds to the story that is being formed continuously, even when there is no interaction by the kids. Each child may choose to join or leave the story set at any time, while the world continues to evolve through time; the plants grow, the animals populate newly formed ecosystems or migrate to other areas, the weeds take over neglected gardens, and the flowers wilt when not watered. The narrative structure captures all of these actions in the form of simple sentences such as: "Amy pulls a cloud over her carrot patch and waters it. The tomatoes complain that they didn’t get enough water. Claudio plants his first tree."

This story sequence goes through a simple parser, which replaces some of the words with their iconic representations and publishes it on a WWW page. This gives the story a picturebook look which the child can print to take home [Fig. 3]. Most of the time these stories do not accomplish narrative closure, rather they come across as a series of interactions between the characters and the world. Nevertheless, the children enjoy this process, especially when they get to take home the written and illustrated version of the narrative in either printed or electronic form, or an electronic version of the scene, generated as a virtual model. The two-dimensional version of NICE also allows the children to interact with the three-dimensional VR space and create their stories through the use of Java applets on the Internet.

Figure 3: A NICE story in Java and on the WWW.

Collaboration

Equally important to the construction of one's knowledge is the experience gained by participation in group activity. Collaboration is emphasized in our framework through the combination of collaborative learning across both virtual, as well as physical communities. Collaboration of virtual communities refers to communication and shared experience between children who are geographically separated. The network component of NICE allows multiple networked participants at different locations to interact with each other and share the same virtual space. The representation of each tracked child in the virtual space is established through the use of an avatar with 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 the user's hand to the other participants. Visually, the wand is mapped to the arm of the child's avatar. As the child waves her hand in the real world, her avatar waves its hand in the virtual world. As these avatars have sufficiently detailed representations, the children can communicate notions of relative position to one another with phrases such as "it is behind you" or "turn to your left." The use of audio (with wireless microphones) between the various sites enhances the communication process.

The number of participants is limited only by bandwidth and latency of the network. Multiple distributed NICE applications running on separate VR systems are connected via the central LIFE server to guarantee consistency across all the separate environments. The communications library uses multicasting to broadcast positional and orientation information about each child's avatar, and uses

TCP/IP to broadcast state information between the participants and the behaviour system [Fig. 4].

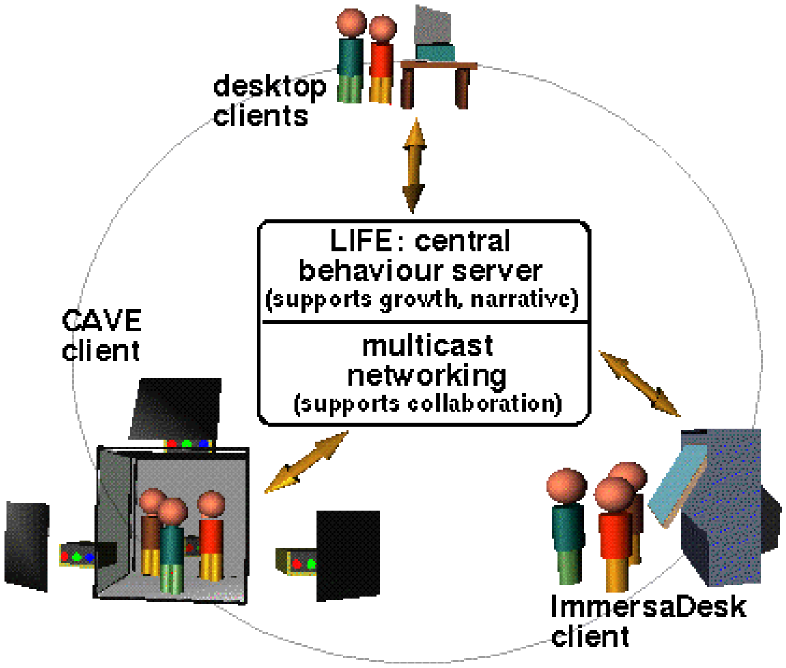

Figure 4: The NICE system architecture.

Collaboration in NICE may also include the interaction between the kids and the computer genies, which populate the virtual environment. The genies operate as interface and feedback mechanisms, disguised as helpful character guides that interact in the virtual world. They provide a way to replace menus and other traditional interface techniques with a more transparent and effective method for use by young children. Many times, when developing and testing the system, we use the Wizard-of-Oz prototyping technique [Wilson and Rosenberg, 1988], where actual people, disguised as genies, simulate agent behaviour. The children may be unaware of which characters in the environment are controlled by the computer and which by a human operator.

Collaboration also involves the social interaction among children located in the same physical space. Theories that emphasize the importance of social interaction in cognitive growth [Vygotsky, 1978] suggest that successful collaborative learning involves more than the final creation of a learning product. Learning that is contextualized in a social setting may involve verbal interaction, collective decision making, conflict resolutions, peer teaching, and other group learning situations characteristic of a classroom setting. With the use of VR technology that supports multiple users in the same physical space, as well as appropriate interaction techniques, a number of kids can participate in the learning activity at the same time, without having to take turns or wear heavy and intrusive hardware devices.

Evaluating the Virtual World

You may ask whether Amy and Claudio really need to enter a virtual environment to learn about ecology or social interaction. Wouldn't it be better if they planted a natural garden as part of a real outdoor classroom activity? Issues on the viability of VR versus traditional teaching methods are of concern to the educational world, which likes to take into account both pedagogical and practical issues.

While there are no substitutes to planting a natural garden or interacting with other children in the playground or at school, a VR environment can provide rewarding learning experiences that are difficult to obtain otherwise. As an example, ecological systems are usually complex models with many variables and behaviours that young children have difficulty visualizing. Computers can be effective at reducing the complex models into simpler qualitative representations. VR adds the qualities of immersion, direct manipulation, and exploration of such models. While in a real garden children can learn how to plant, in the virtual garden they can learn how to think about plants, scale and position parts of an ecosystem, take on different roles, become small to observe the roots, talk and interact with children at distant locations, or factor time to directly observe the effects of their changes.

However, in order to justify the educational value of the technology, effective evaluation methods need to be established to discover if conceptual learning takes place. Yet, very little has been carried out in the direction of evaluating VR environments for their educational effectiveness. In the past few months, we've observed small groups of children, 6-12 years of age, using the system, while in its various development phases. [Fig. 5]. We are particularly interested in studying the effects of VR as a learning tool, by conducting research on interface, orientation, immersion and presence, affective, cognitive, and conceptual learning issues. We have developed an evaluation framework, which takes into account the measurement of both usability as well as conceptual learning attributes of the virtual environment. With this framework we try to see through the fascination and novelty effect that surrounds this new technology and explore the actual learning experiences it has to offer. A variety of techniques are employed for gathering data, both embedded in the computer and external. The evaluation process includes the creation of a real garden by children participating in school and community-based projects, in combination with the collaborative construction of the virtual ecosystems [Roussos et al., 1996].

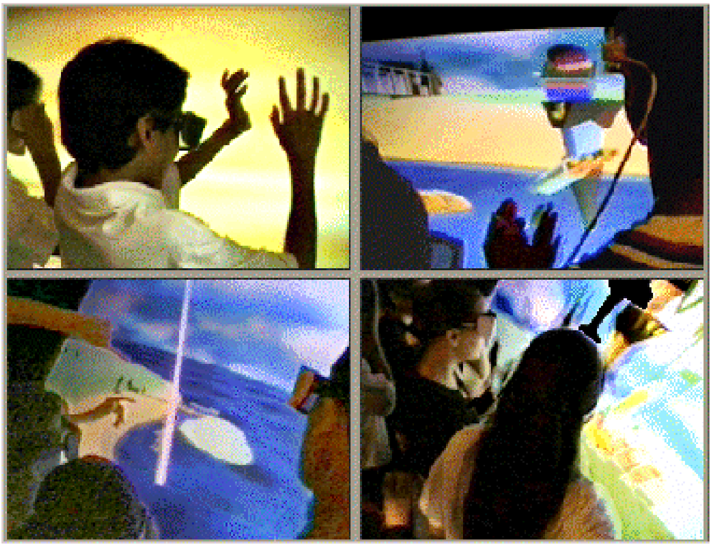

Figure 5: Children interacting with the NICE world.

Although the cost and size of the CAVE, or even smaller VR technologies prohibits their use in today's classroom, it will not be long before the networked and technology-rich classroom becomes a reality. As the technology continuously decreases in cost and increases in power, more museums and cultural centers are beginning to acquire multi-user VR systems which allow for many children to participate in the experience at once.

Future Directions

A current goal for NICE is to further refine the interface by developing techniques for more natural modes of interaction that improve the direct manipulation of the environment and don't interfere with the learning process. Replacing the wand with a data-glove or physical gardening tools is one way of approaching the hardware interface problem. The use of many small and simple artificial guides is another improvement of the interface in the software. "Intelligent" characters can offer a clever alternative to a menu and provide direction to the children while hiding the computer.

An important addition to the present configuration is an authoring tool which will allow for user programmability of the ecosystems. This authoring tool will be in the form of a simple visual language. Visual languages have been shown to be ideal programming languages for children because they can map abstract concepts to pictorial elements that they are more familiar with [Soloway et al., 1996]. We envision a visual language where a system, as complicated as NICE, may be programmed by manipulating iconic representations of data and operators, provide immediate feedback, and can be learned quickly by the kids. Our current direction is a two-dimensional interface where the child, by clicking and draging icons to control the ecological models, can observe immediate feedback and effect in the three-dimensional VR environment.

Finally, in the direction of collaborative learning we are investigating issues of self representation and non-verbal communication. The children greatly enjoy seeing other avatars in the virtual space. One of their favorite activities is to exchange flowers and thank each other by waving, moving their heads up and down, or bowing. They also like to visualize the presence of their body in the reflecting pools in the VR world. These directions provide potential for interesting studies in gesture communication and theatrical improvisation.

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Acknowledgements

We would like to thank the following people who make this work possible: the members of the Electronic Visualization Laboratory and the Interactive Computing Environments laboratory; the educators and children that participate in the evaluation process; the original "Yet Another World" group for their participation in many fruitful discussions. This research is partially supported by NSF grant CDA-9303433 which includes support from ARPA.

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