

Research and Development of Virtual Worlds for Immersive Instruction

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Introduction

We are engaged in developing a range of Virtual Environments for Education spanning a variety of disciplines, from Earth Science to Anthropology, and from Business to Biology. All of these projects share a strategy, a set of assumptions, an approach to assessment, and an emerging tool set, which allows each to leverage from the insights and advances of the others.

Each project has the following properties in common. They are role-based and goal-oriented; they are immersive simulations intended to promote learning-by-doing; they are spatially-oriented, exploratory, and highly interactive; they are multi-user and game-like; and they employ software agents as tutors.

The Group

The NDSU World Wide Web Instructional Committee (WWWIC) is a group of faculty who have a strong and active interest in applying information technology for instructional purposes. In its first year of operation the WWWIC functioned as a bellwether for what was then novel Web-based initiatives such as home pages. The NDSU campus was only just waking up to the fact of the World Wide Web, and the need was for the technologically advanced and the "early adopters" of technology to learn from each other and spread what they knew. The WWWIC was a clearing house for this type of technical content and advice, and became a focal point of the rapid Web development occurring on the NDSU campus since that time. The WWWIC explored and mastered the new technologies before they were well-understood, and served as a techno-support group and facilitator to the fledgling Web-based efforts. As a consequence of this and other efforts at NDSU, the World Wide Web established a small but solid foothold and became a campus presence.

In its second year, the WWWIC became more of a facilitating and evangelizing group. An active effort was made to enlist the "second wave" of technology users, and the resources of the committee were expended in the attempt to spread the available technologies across the NDSU campus. Largely as a consequence of the WWWIC's success in this mission, the World Wide Web has made its way into every corner of campus which has seen the NDSU Web presence transformed by startling growth.

Now, administrative initiatives have changed the face of the World Wide Web effort at NDSU. The Information Technology Roundtable (ITR) has endorsed a proposal for a Center of Multimedia Information Technology (COMMIT). The Center for Academic Information Technology (CAIT) has been approved, and funding is in place for two full-time staff positions,

initially in support of the Academic Technology Partnership (ATP) program which was initiated at NDSU for the summer of 1997. These overt signs of institutional support signal the beginning of formalized structures to foster campus efforts in instructional technology. They also signaled the end of the facilitating role of WWWIC.

The Strategy

WWWIC projects are designed to capitalize on the affordances provided by virtual environments listed above. Specifically, WWWIC projects each design from the following overarching principles.

Role-based: Simulated environments enable learners to assume roles in particular contexts and have meaningful, authentic experiences. In the popular culture, this approach is captured in the John Houseman adage, "learning not the law, but learning to think like a lawyer". More formally, WWWIC promotes a learning strategy based on ancient apprenticeship where, in modern terms, the student progresses by "modeling the expertise" of the master. Role-based learning is learning-by-doing, but not the mere goal oriented "doing" of a task. Role-based learning is learning-by-doing within the structure of playing a role in context. Rather than simply teaching goal-based behavior and tactical task-oriented skills and methods, the role-based approach communicates a general, strategic, manner of practice (McLuhan, 1964).

Exploratory: Exploratory simulation means enabling students to pursue their own interests. This approach to what is usually referred to as User-centered design promotes a learning environment where learners are self-directed and given the freedom to structure, construct, and internalize their own experience (Duffy, Lowyck, and Jonassen, 1983; Duffy and Jonassen, 1992).

Game-like: The value of play in learning can hardly be overstressed. Students quickly tire of rigid tutorial systems designed to teach at any cost and at some predetermined pace (Schank, 1991). However, since simulations can be adaptive and responsive, playing a role in a simulation can be fun. Players will throw themselves terrier-like into an environment if it feels like a game. Insofar as possible, educational software should be engaging, entertaining, attractive, interactive, and flexible: in short, game-like (Slator and Chaput, 1986).

Goal-oriented: Goals are important, but within the context of roles. It is through goals that obstacles leading to problem solving are encountered. It is within a goal-based framework that techniques and methods are learned and rehearsed. Practice and repetition in problem-solving is how apprentices learn the master's craft. Goals provide problems to solve.

Highly Interactive: One major challenge for science educators is to develop educational tools and methods that deliver the principles but also teach important content material in a meaningful way. At the same time, the need for computer-based education and distance learning systems has become increasingly obvious, while the value of "active" versus "passive" learning has become increasingly clear (Reid, 1994).

Immersive: The combination of role-based environments and spatially oriented simulations is conducive to an immersive atmosphere. The concept of immersion has long been shown valuable in foreign language learning (where, it is anecdotally understood, the key moment arrives when the learner succeeds in reaching the point where they are "thinking in X", where X is French, German, Farsi, or whatever). Immersion, then, is elemental to the concept of role-based learning where it is strategic thinking the apprentice eventually learns to model

Learn by Doing: This is achieved by crafting simulations that support the setting and achieving of goals within role-based frameworks. When these experiences are structured and arranged such that playing a role in the environment illustrates the important concepts and procedures of the simulated domain, students are able to "learn by doing" (Dewey, 1900). Experiences are the best teachers.

Multi-user/player: One challenge is to craft role-based, goal-oriented environments that promote collaboration as well as the more easily conceived competition. The answer lies in designing systems where student/players have multiple roles to choose from. In any case, WWWIC educational systems are uniformly multi-user, and hosted on the MOO architecture.

Spatially oriented: WWWIC simulations are spatially-oriented to leverage off the natural human propensity to towards physically plausible context. In this way, simulations promote the "willing suspension of disbelief" which in turn reinforces the role-based elements of the environments.

The MOO Architecture

WWWIC projects typically build simulations on a MOO ("MUD, Object-Oriented", where MUD stands for "Multi-User Domain"). MUDs are typically text-based electronic meeting places where players build societies and fantasy environments, and interact within them [Curtis 1992]. Technically, a MUD is a multi-user database and messaging system. The basic components are "rooms" with "exits", "objects" and "players". MUDs support the object management and inter-player messaging that is required for multi-player games, and at the same time provide a programming language for writing the simulation and customizing the MUD. One of the major shortcomings of MUDs, however, is their low-tech communication system: text. Because of this, WWWIC games usually supply a graphical user interface layered on top of the networked multi-user database and messaging system that MUDs provide.

The Projects

The NDSU World Wide Web Instructional Committee (WWWIC) is currently engaged in several virtual/visual development projects: three NSF-supported, the Geology Explorer, the Virtual Cell, the Visual Computer Program, plus the ProgrammingLand MOOseum, the Blackwood Project, Virtual Polynesia, the Dollar Bay Retailing Project, as well as others. These have shared and individual goals. Shared goals include the mission to teach Science structure and process: the Scientific Method, scientific problem solving, deduction, hypothesis formation and testing, and experimental design. The individual goals are to teach the content of individual scientific disciplines: Geoscience, Cell Biology, Computer Science, as well as History, Anthropology, and Microeconomics.

The Geology Explorer

The Geology Explorer (Saini-Eidukat, Schwert, Slator, 1998, 1999; Slator et al., 1998; Slator, Schwert, Saini-Eidukat, 1999; Schwert, Slator, Saini-Eidukat, 1999), is a virtual world where learners assume the role of a geologist on an expedition to explore the geology of a mythical planet. Learners participate in field-oriented expedition planning, sample collection, and "hands on" scientific problem solving. The Geology Explorer world is simulated on an Object Oriented Multiuser Domain (a MOO).

To play the game, students are transported to the planet's surface and acquire a standard set of field instruments. They are issued an "electronic log book" to record their findings and, most importantly, are assigned a sequence of exploratory goals. The students make their field observations, conduct small experiments, take note of the environment, and generally act like geologists as they work towards their goal. A scoring system has been developed, so students can compete with each other and with themselves.

You can visit Planet Oit at

<http://oit.cs.ndsu.nodak.edu/>

The Virtual Cell

The Virtual Cell (McClellan, et al., 1999; White, McClellan, Slator, 1999) is an interactive, 3-dimensional visualization of a bio-environment. The Virtual Cell has been prototyped using the Virtual Reality Modeling Language (VRML; Hartman and Wernecke, 1996), and is to be available via the Internet. To the student, the Virtual Cell looks like an enormous navigable space populated with 3D organelles. In this environment, experimental goals in the form of question-based assignments promote deductive reasoning and problem-solving in an authentic visualized context.

In today's classroom, simply presenting that knowledge in a two-dimensional manner does not compel the student to understand the various relationships of that knowledge. The 3D world is much better suited for that type of knowledge. If the student has access to a 3D world that ties the knowledge base together, improved student learning may result. Therefore, a 3D dimensional graphical image of a eukaryotic cell will be developed. This cell will be navigable via a VRML plugin for WWW browsers. The image will contain all of the different cellular structures such as mitochondria and chloroplasts, the nucleus and unique topological features such as the cytoskeleton.

Because 3D rendering and interactivity is a relatively new field, we will provide prototyping efforts necessary for future development. Answers are not yet known to questions such as how best to use computer and network resources to deliver this type of 3D content. Other unknowns include the dynamics of traveling through such a display and updating the module. Students are often confronted with information that is dynamic and has deep interrelationships.

You can view the latest version of the Virtual Cell project at

<http://www.ndsu.nodak.edu/instruct/mcclellan/vc/>

Visual/Virtual Computer Programming

The Visual Program (Juell 1999), attempts to provide an environment in which students can study and learn programming techniques using visualizations of AI programs.

The goal of the project is to produce visualization tools to help students to understand programs and algorithms. The Visual Program uses animation, fly through 3D images and interactive images to provide critical information to the viewer/participant with respect to the image. This mode of presentation and interaction shows the behavior of the programs over time and allows the user to see patterns in the behavior. At this point we have produced a number of packaged visualizations to help in understanding a concept or process (such as searching). We have also developed tools to allow the user to easily produce visualizations for their own programs.

You can view the progress of the Visual Program at

<http://www.ndsu.nodak.edu/instruct/juell/vp/>

ProgrammingLand MOOseum

The ProgrammingLand MOOseum (Hill and Slator, 1998; Slator and Hill, 1999), implements an Exploratorium-style museum metaphor to create a hyper-course in computer programming principles aimed at structuring the computer science curriculum as a tour through a virtual museum. ProgrammingLand is being developed on the Valley City State University (VCSU) campus as a Virtual Lecture adjunct to introductory programming language classes. The paradigm employed is that of a museum. Students peruse the exhibits of the museum, reading explanatory text that is displayed when they enter a room. A topic may be covered in one or more connected rooms.

In addition to the displayed text there are a number of interactive demonstration objects in the museum that clarify or demonstrate the concepts. One such object is a code machine. It contains a short portion of programming language code and can perform any of the following functions: merely display the code; display the code with a line by line explanation of the purpose or syntax of each line; or display an execution of the code on a line by line basis. The goal of ProgrammingLand is to facilitate programming language courses, either locally or at a distance. At the beginning of this course the MOO had four wings, each incomplete. One of these was an introduction to using a MOO, each of the other three dealt with the one of the following programming languages: C++, Java and BASIC. The ProgrammingLand Prototype can be visited at

www.cs.ndsu.nodak.edu/~slator/html/PLANET/wwwic-pland.html

Blackwood

WWWIC is in the process of designing a virtual environment to simulate a 19th Century Western town. We will populate this town with intelligent software agents to simulate an economic environment representative of the times. This spatially oriented virtual environment, will borrow freely from historical records and digital images from archives at the NDSU Institute for Regional Studies.

The educational "game" will be one where players join the simulation and accept a role in the virtual environment. Rather than everyone vying for a portion of the same economic market, roles will be variable and specific. For example, in this simulation players will be purveyors of dry goods, food stuffs, blacksmithing services, mortuary services, saloons and gambling establishments, banks, barber shops, apothecaries, messenger services, news stands, gunsmiths, implement dealers and so forth. Therefore, players will only directly compete against other players with similar roles, or with software agents in the same profession, but not be in instant competition with every other player.

In addition, the environment will support period-authentic atmosphere in the form of entertainments. For example, the circus might come to town, the weekly train will arrive from the east, a cattle drive will appear on the scene, preachers and circuit judges and medicine shows will pass through, and the occasional crime will be reported. Blackwood can be visited at

<http://www.cs.ndsu.nodak.edu/~slator/html/blackwood/>

Virtual Polynesia

WWWIC is in the process of designing an immersive, synthetic environment where students, in their role as anthropologist or trader step ashore on an island in western Polynesia, in the south Pacific, near the turn of the 19th century. That island, and the culture encountered, is modeled after the Samoan islands at a time a time when Samoan culture was still unaltered by Western goods and ideas. The environment will focus on a small valley and surrounding territory which represent a microcosm of Samoan society. The anthropologist is able to observe and explore the traditional society as it had developed to that time. He/she is also able to witness the contact of cultures as the trader enters the picture. While the environment will be fictitious, it will be based on careful attention to actual Samoan materials and cultural traditions.

Virtual Polynesia is another experiment in creating virtual worlds where more than one role is available to students. In this scenario, the most obvious roles are trader and anthropologist. The trader will visit the culture looking to exchange western goods for items in Samoan culture that would have value in the west. The anthropologist will look to the discovery of cultural artifacts that in some way illuminate our understanding of Samoan society.

Related Work

Far and away the most common approach to implementing synthetic multi-user environments is the text-based MUD: the multi-user, text-based, networked computing environments that are mostly for "gaming." MUDs, or Multi-User Dungeons, are an outgrowth of computer chatlines and bulletin boards plus the popularity of adventure role-playing as exemplified by Dungeons and Dragons. They are environments which one can log into from a terminal connected to Internet, and then interact in text with objects, places, and other players within a gamelike setting (Carlstrom 1992).

In a recent search of the World Wide Web it was clear that MOOs for different ability levels are becoming a reality. Amy Bruckman, a doctoral student at the Massachusetts Institute of Technology has built a programming language to make it simpler for children to construct objects and participate in MOOs (Bruckman, 1993). She has combined construction and community in the hope of creating a constructionist learning culture in her MOOSE-Crossing MOO.

MOOs have shown their importance in elementary schools. Two in particular, MariMuse, and MicroMUSE have been geared so that elementary school students can participate full-time. One notable success has been on underachieving students who had left school. These students reportedly became involved, started to form friendships, and began to take a greater interest in school (Poirer 1995).

Mineral Venture by Eighteen Software is a recently developed software environment that simulates business-oriented mineral exploration from a technical and economic perspective. This is not a multi-user spatially oriented exploration system, but rather a simulation intended to pose planning and resource management problems that geologists routinely face.

SELL is a multi-layered, networked game that teaches basic marketing and micro-economic concepts. Players are immersed in a simulated environment where they are expected to save a failing retail outlet. The tools of the retail trade, (hiring, advertising, ordering, pricing), are made available, and the underlying simulation is crafted to respond to game play in plausible ways (Slator and Chaput, 1996; Hooker and Slator, 1996).

Conclusion

These projects are designed to capitalize on the affordances provided by virtual environments. For example, to

- control virtual time and collapse virtual distance,
- create shared spaces that are physical or practical impossibilities,
- support shared experiences for participants in different physical locations,
- implement shared agents and artifacts according to specific pedagogical goals,
- support multi-user collaborations and competitive play.

Other projects related to those described above include the Virtual Tools project which is designed to create software tools that will enable content experts to craft virtual worlds for instruction with a minimum of intervention or oversight by computing professionals. These tools include software for building abstraction hierarchies, concept frames, object interfaces, virtual maps, agent attitudes, and others.

Software agents are another of the continuing pursuits of WWWIC projects (Slator and Farooque, 1998). Several of the games implement a variety of agents from simple avatars providing atmosphere, to characters that contribute to game play, to tutors that visit players when they have made an error of certain types.

Assessment is another continuing research topic. WWWIC is developing a strategy and interfaces to a subjective evaluation of student progress that relies on player recall rather than

objective recognition. These assessment instruments are being developed and incorporated into the pedagogical framework under which all the projects are working.

Future plans include the implementation of the "second generation" of virtual environments which seek to do two things:

- press the role-based elements in order to create more local player contexts that promote collaboration as well as competition.
- cross discipline boundaries by incorporating, for example, social science elements into a microeconomic context.

The Blackwood game and Virtual Samoa, are intended to be simulations of this second generation type.

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