A View of Learning Environments at MERL

A Program of Fundamental Research in Learning and in Computer Technologies Supporting Learning

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Originally appeared as Note 93-17, Mitsubishi Electric Research Laboratories

> ***The charter of Mitsubishi Electric Research Laboratories*** *(MERL) is to conduct basic research in computers and their uses. In our view, this means demonstrating entirely new categories of possibility rather than merely making incremental improvements to what is now possible. By solving fundamental problems that arise in expanding the productive use of computers, we hope to contribute to the advancement of science and society as a whole.*
>
> *-MERL introductory brochure, 1991*

This paper addresses new categories of possibility that emerge as we consider certain societal needs, trends, and directions in concert with the development of immersive learning environments. It describes ways in which synergies between networked graphics and simulated dynamics, epistemology and psychological development, and studies of human and animal locomotion can fuel an interdisciplinary program of research.

The vision is to create an electronic toy, a window into a place that is both fanciful and informed by important aspects of physical and social reality. In this domain, children (of all ages) can play with each other and with ideas that will ground their participation in an increasingly technological and international world.

The learning environment is part zoo and part circus – we might call it a *Zircus*. Ultimately, it includes cartoon-like renditions of the best of both worlds: acrobats, clowns, trapeze artists, unicyclists, jugglers, and animals roaming freely through naturalistic terrain, demonstrating peculiar gaits and habits. Children both observe and create creatures and events. They discuss the phenomena with their friends, who are present simultaneously in the networked environment.

Key technologies, to be developed as intermediary versions of the environment evolve, may include real-time graphics, a network capable of supporting images and sound, speech recognition and generation, multimedia databases, autonomous agents, various experimental input devices, image processing, and high-level software for the specification of animation components and audio/video sequences.

Needs, Trends, and Directions Influencing the Research

Several unrelated societal needs, trends, and directions converge as indicators for the approach presented here. One indicator is the pervasiveness of electronic games and the way in which they have entered the lives of young people, many of whom will be joining the adult political and economic spheres within the next decade. Another is the emergence of an increasingly global economy and the accompanying issues of broader cultural awareness. Another is the deeper development of popular understandings of the human body as debates and trends involving health care proliferate. A fourth indicator is the outcry for improved education – throughout life, and both in and outside of schools. Many contend that needs related to this outcry are so vital as to demand a reconsideration of the nature of learning itself.

Electronic Games

No one can ignore the phenomenal sweep of technology into the cultural mainstream that Nintendo has effected. By 1990, an estimated one of every three homes in the United States had a Nintendo system.[1] In 1991 alone, its sales worldwide exceeded three billion dollars.[2] In this country, Sega sales are beginning to surpass those of Nintendo.[3] In addition to these two contenders, NEC, Atari, 3DO, and others vie for places in this burgeoning market. Silicon Graphics, Inc., (SGI) and Nintendo have just pooled resources in an attempt to redefine and capture significant parts of the market.

A new, but related, genre of entertainment may be emerging: George Zachary, former marketing director of VPL, Inc., has projected that "virtual reality" will become a $2-$4 billion industry within five years.[4] By that time, he predicted, the price of technologies now embodied by the SGI Reality Engine will have shrunk by a factor of ten.[5] "Desktop VR" will become a (real) reality. Howard Mirowitz, MELA vice president of advanced products, focused such predictions by describing "VR games" as a product concept for potential development.[6]

MERL researchers' interests are less in the earnings and potential markets associated with electronic games than in the reasons why people – particularly young people – like to play them. We are especially interested in what kinds of learning may occur and how, as designers of learning environments, we may glean cues for broadening and deepening the learning experiences.

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[1]See Jenkins and Fuller, work in progress.
[2]*Electronic Business Market Share Reporter,* 1992.
[3]Trip Hawkins, Chairman, Electronic Arts, 3DO. TED 3 (Technology, Entertainment, Design) conference. February 1992, Monterey CA.
[4]George Zachary. VPL, Inc., seminar. September 1992, Foster City CA.
[5]The current cost of an SGI Reality Engine ranges from about $100K to $650K.
[6]See Mirowitz, 1992.

An Increasingly Global Economy

At MERL's opening ceremony, Harvard lecturer and (now) U.S. Secretary of Labor Robert Reich gave several examples of how business has become so international that location can no longer be taken as an indicator of nationality.

He cited a *Wall Street Journal* article that complained about the United States virtually giving away the television industry after having spawned it: a Japanese company (Sony), a Dutch company (Phillips), and a French company (Thompson) now make most of the televisions sold here; Zenith is the only remaining American television manufacturer. Reich pointed out, however, that not only is Zenith making most of its television sets in Mexico, but 28-30,000 American workers are making televisions – albeit as employees of Phillips or Thompson. "Who is *us?*" he asked. "Who is *them?*" Reich cited other examples of cross-national set-ups as well, including the research facilities that IBM, Texas Instruments, and Motorola are opening around the world. Texas Instruments has a new research facility in Japan and now makes 80% of the chips it sells to Japan, in Japan.

Such blurring of lines of propriety in business are just one indicator of greater exchange between economies and cultures. Obviously, there is a corresponding trend in people's lives as they transport their families to other locations and cooperate with peers from other nationalities. Schools, museums, and other community-level organizations are beginning to adjust their outlook and programs accordingly.

Many of the cartoon-like inhabitants of the environments envisioned here will be bilingual or multilingual. Some researchers interested in the project will be concerned with how users might improve their understanding and speaking of languages other than their own through interacting with these seemingly international characters.

Beyond these interactions, we can envision a phase of the project in which networked users from different countries are present simultaneously in the environment. As these young users play together with the creatures in the *Zircus,* they are likely to develop shared vocabularies and idioms that are the essence of language learning: eventually, the environment could support its own international culture.

Health Care and Popular Awareness of the Human Body

Consider the multiply determined increase in public awareness of health and body-related concerns:

Health clubs, exercise videos, and running shoes comprise big businesses. More and more people are diet-conscious, restricting their intakes of fat and cholesterol, learning about the effects of vitamins, and so on. Televised sports have made slow-motion and instant-replay studies of body movements commonplace. Gradually changing attitudes toward health-care providers and the medical establishment are evidenced in such phenomena as the proliferation of birthing centers and the appearance of the Hollywood film *Doctor*. Health insurance dilemmas strongly influenced political platforms in the last election year and continue to command national attention. AIDS is an everyday topic of conversation. Imaging technologies such as sonogram and MRI are increasingly pervasive and enable people to know and discuss more about their bodies.

Such trends are likely to continue: as the baby boom grows older, more people will have a need to know about their own changing health profiles. Geriatric services may become a significant industry in the 21st century!

Aside from such shifts in awareness, it is important for our purposes to note that young children build lots of knowledge about their bodies and how they move, simply by playing in the world and reflecting on how to do the things they would like to do – riding bicycles, pitching softballs, etc. Well designed learning environments can tap this knowledge and use it to bootstrap the construction of new knowledge.

Acknowledging awarenesses of the body can be valuable for several reasons: The topic suggests a set of content areas that is likely to be interesting to many people. Learners can feel comfortable by bringing something they already know about, however implicitly, to their experiences within the learning environment. Furthermore, research with children using the Logo computer language has shown that many of these young programmers draw from knowledge about their own movements as they figure instructions for the movement of a graphical object.[7] It will be interesting to see how a similar transfer might occur as learners play in environments that simulate variable dynamics of lifelike creatures.

Education and Learning

Many believe that contemporary institutionalized practices and settings for education are undergoing changes that will result in a dramatically different face by the end of the decade. Whether or not that is the case, change in education is a widespread theme, and technologies will surely play a role in many of the attempts. While many so-called "multimedia" applications cast users as "students" and computers as "teachers," others strive to develop scenarios in which users "teach" the computer – and in the process, themselves and one another. Computer technologies become tools with which can users construct programs and playthings, and with them, certain ideas and understandings – as a scientist might work through phases of an experiment or as an artist might develop a painting.

> *Decisions about what domains of knowledge are important for children to learn should not be made only in terms of the utility they will have when the children enter the adult world. Some domains of knowledge are important developmentally because their possession enhances the process of learning.*
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> *– Seymour Papert, Principal Investigator, "New Images of Programming"*

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[7]See Papert, 1980.

That process, of course, continues throughout life. One of the domains that enhances it is reading: "in addition to being an indispensable skill for full participation in contemporary society, [it] potentially enhances the learning of pretty nearly everything else." Fluency with technological objects is rapidly becoming another such domain: the use and creation of programs and devices are increasingly needed skills. Aside from being useful in their own right, these activities spawn ways of thinking – about genetic code and organizational management, for example – that are useful in understanding many phenomena in today's world.

Several discussions at MERL have acknowledged the need for students, workers, and citizens to maintain curiosities and a love of learning throughout life. We've had to echo others' chagrin, however, in noting that too often, people seem to become resistant to new ideas or "turned off" to the very process of learning. The electronic environment described here encourages interactions conducive to *learning about learning,* as well as to learning about some key ideas in the dynamics of physical and social systems.

We can start by considering two important paths of entry to the environment. First, most young people love playing with and thinking about animals. By developing the *Zircus*, we would create a context in which they can learn about a variety of animals and animal-like creatures. Users can "ride," modify, construct, and animate these creatures – in the process, developing intuitions about motion but also about anatomies, including properties and functions, and relationships among parts of bodies. Playing with these creatures, many of which will be human-like, will draw from the users' already rich knowledge of their own bodies and dynamics. These familiarities constitute a second path of entry into the learning environment as a fun place in which children can leverage new knowledge with existing knowledge. Awareness that this sort of leveraging is possible constitutes a lesson about learning itself.

Years of research with Logo and LEGO/Logo[8] indicate that thinking about the motion of a graphical or robotic object as a reflection of one's own movements helps many children to become involved in a domain that could otherwise seem abstract and remote. Characteristics of programming, such as sequential instructions and algebraic expressions, become means to an end: that of spending time with a likable, fanciful object, finding out what it can do, and getting it to do things.

In the *Zircus* environment, programming can take the form of "creature building" and assembling "letters" to friends, which are like miniature shows of aural and visual material. This material could come from a database of images and sounds stored within the environment. Eventually, users may be able to import their own video, shot with a home camcorder or a camera that comes with the system.

By constructing human- and animal-like creatures and endowing them with characteristics and behaviors to be demonstrated in the *Zircus,* children would work not only with certain principles of programming. They would also be dealing with notions of

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[8]See Papert, 1980, 1993.

systems, control, and principles of motion – all of which they will encounter in other walks of life.

Designing an Environment for Learning and Learning Research

In order to pose questions about how people learn, we need to take a developmental perspective. Our concern is with how people construct understandings through actions in the world. Work with children can be especially fruitful: they are naturally curious and less affected by the cumulative acculturation that often inhibits adults.

Learning researchers are challenged to design experimental environments that focus a child's attention and activity on a particular set of ideas. As the child works in the environment, he or she learns about the core ideas and the researcher can gain access to the process. The result is both better understanding of how learning about the particular ideas can occur and, more generally, about how learning itself can occur. These contributions to epistemological knowledge can, in turn, feed back to the design of learning environments and the development of software to implement them.

Constructing one's own creatures, changing their properties, and observing the resulting changes in dynamics are activities that, through direct involvement, can foster learning especially well. Creature construction in the Zircus can focus attention on concepts of motion and control, as well as the associated concepts of system dynamics. Situating these themes within the *Zircus* complements other approaches to motion study and adds the structure and processes of human and animal bodies as topics for epistemological inquiry.[9] In addition to the previously noted advantage of inherent interest for both children and adults, this approach reframes the study of systems. Learners can look particularly at the component circulatory, respiratory, bone, and muscle systems, or consider broader phenomena of emergence, control, and interrelationships among constituents as they try to set the bodies into motion.

Preliminary Considerations in the Environment Design

In addition to encouraging learning and providing evidence of the changes in thinking, interactions within early versions of the Zircus can inform and improve the development of later versions. Three points are of particular interest: how users can manipulate objects in the graphical environment, how users' presences should be represented in the environment, and how users may construe and construct objects and characters to populate the simulated world.

Among the key activities as learners play in the *Zircus* are creating and modifying creatures: adding limbs, stretching legs to see how gaits change, and so on. Although it would be possible to devise means of effecting such changes using a mouse, touchscreen, or other input devices, we should try to create a more direct kind of involvement.

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[9]See Gruber and Vonèche, 1977, pp. 481-642; Harel and Papert, 1991; Ramadas and Nair, 1992; Wadey, 1988.

Emulating playing with clay would seem close to ideal, and toward this end we should think about how datagloves or other devices might be used to simulate two-handed manipulations of objects in the environment.

Characterizing the user as a two-handed participant influences how the user might appear in the graphical space. VR environments typically include an image of the user's gloved hand and an implicit representation of the eyes, through the depicted point of view. We may consider the possibility of showing both hands, derived from the datagloves, and a semblance of the face, which would be processed from the output of a video camera pointing at the user. The resulting ghost-like representation – a sketchy, floating face and a pair of hands for each user – would be reminiscent of pantomime. This graphical and theatrical precedent, as well as whatever inspiration its gestural vernacular might provide, are associations that may lead people to accept and enjoy this representational approach.

Other possibilities include the simpler alternative of having a set of characters whose identities users can assume upon entering the environment. An interesting twist on the creature-construction activity would be for users to design characters that can be added to this set.

Example Phases in the Evolution of the Learning Environment

The development of an environment such as the *Zircus* would depend on the researchers involved and what technical areas they might like to pursue. Nevertheless, it is intriguing to imagine what some of the different phases might involve:

A user controls a robot biped as it moves through a house and tree-dotted, prairie-like terrain, occasionally encountering ostriches, kangaroos, and another biped robot.

Two users control robot bipeds within the same graphical environment.

Two users control gymnasts in a duet floor routine. Users speak with each other and with online gymnasts.

> Intermediary milestones:
>
> *"Mr. Ed"-like talking-horse character with complete set of gait*
>
> *Expanded set of creatures: gymnast/acrobats, unicyclists, trapeze artists, jugglers, clowns, biped robot guides, ostriches, kangaroos, horses, elephants*
>
> *Bilingual and multilingual creature-characters*
>
> *User-programmable characteristics of size, limbs, gaits, color, language, etc.*
>
> *Experimental interface devices: spaceball, touchscreen, stylus, doll/s, glove/s, camera and image processors to bring a representation of the user into the environment*
>
> *Multimedia database: still images, clips of video and audio*
>
> *Projection-mapped video within the real-time 3D graphics environment*

Networked multiusers create and play with an array of creatures in outdoor (varied terrain) and indoor (circus tent) scenes.

Example Software Features

Some of the considerations for a "creature construction kit" might include:

body parts
- limbs, centers of mass, sensory apparatus
- adjust sizes, masses, colors

action of parts and composites
- stretchable, move along xyz axes, adjust speeds
- model gaits: specify number of limbs, placement of joints, type of gait (walk, hop, run, pronk, pirouette, somersault)

relationships among parts
- movement dependencies

behaviors
- food needs, affinities for and avoidances of places or other creatures

terrain
- specify elements and contours

Focuses to Remember

Morningstar and Farmer have produced a revealing analysis of a multiuser graphical environment that they designed and built, "Habitat."[10] In the analysis, they cite important lessons that they learned. One of them is that "a cyberspace is defined more by the interactions among the actors within it than by the technology with which it is implemented."

As engineers, Morningstar and Farmer made certain assumptions about what was important in the environment. They were concerned with technicalities like the speed of the graphics, how many users the system could accommodate at one time, and so on. They also devoted a large amount of time to the development of an elaborate game that they thought the users would like to play. Much to their surprise, they found that the users spent very little time with it. Instead, they wanted to interact with each other and to extend the environment in various ways.

Morningstar and Farmer summarized by saying that what is important to the "inhabitants" of an environment like Habitat (or, we might infer, like Zircus) are the capabilities available to them, the characteristics of the other people they encounter there, and the ways in which these various participants can affect one another. It would behoove us to pay attention to this difficulty learned wisdom.

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[10]Morningstar and Farmer, 1991.

Interestingly, these lessons correspond well with principles in learning environment design and learning research.[11] By focusing on particular properties of spoken language, locomotion, and systems behavior, and by providing extensible facilities for working with these properties, we can forge a rich environment in which people can learn and in which we can learn about their learning.

Acknowledgments

Some of these ideas stem from discussions with members of MERL's learning environments group: Bill Freeman, Andy Golding, Marc Raibert, Chuck Rich, Michal Roth, Yves Schabes, Mark Torrance, and Dick Waters. Many ideas for the *Zircus* reflect work and discussions with Seymour Papert and Marc Raibert.

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[11]See, for example, Gruber and Vonèche, 1977; Harel and Papert, 1991; and Papert, 1980, 1993.

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