PLAY AND LEARNING IN THE DIGITAL FUTURE

VIDEO GAMES AND TOYS PROMOTE LEARNING AS WELL AS ENTERTAINMENT. THIS RESEARCH REPORT DISCUSSES ONGOING PROJECTS AT THE MIT MEDIA LABORATORY THAT AIM TO UNCOVER AN IMPROVED WAY TO PLAY AND LEARN.

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Video games are vastly improved; they include embedded computers and new, improved expressions in graphics and music. Soon games and toys will become communication tools that connect with one another through internal embedded technology. Eventual convergence of the visual cyber community and the physical world would let users move toward a new stage of play and a new way of learning. Developing the future digital toys and games so that the toys and their users work in a harmonious way is a task with far-reaching implications for everyone involved in the learning process, but especially for children.

In this effort, the Toys of Tomorrow consortium at the MIT Media Laboratory is researching children's play and learning. Here, we comment briefly on the increasingly profitable and influential game and entertainment industry, introduce the various MIT research projects, and discuss how we expect their results to affect our world and enhance the learning process.

Bits meet atoms

The game and entertainment industry is growing rapidly; in 1998 its US software market amounted to $6.3 billion. Electronic Entertainment Expo (E3) is one of the most important events in the video game industry. At the Fifth E3 in Los Angeles in May 1999, 1,900 titles from 400 companies were exhibited. However, the most important characteristic of video gaming is that both machine capability and the styles used in design and development are improving. Hardware manufacturers, software developers, content creators, and even game players have been stimulating each other, and every appearance of a new video game machine has reformed the whole industry.

E3 this year had two remarkable topics. One is the fall 1999 introduction in the US-Europe market of a new video game console, Sega's Dreamcast, as a rival to Sony's PlayStation and Nintendo's Nintendo 64. Its audiovisual performance ranks with that of a high-end personal computer. In addition, it includes a network capability with an embedded 56-Kbps modem. The gaming console is now expanding its territory from entertainment to the Internet and is invading homes with a price under $200.

Interactive digital expressions have become the main communication mode for our cyber society, not only for entertainment but also for e-commerce and online education. Therefore the appearance of online games affects much more than a user's guarantee of a pleasant experience. The fact that game consoles are becoming Internet machines will acceler-

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ate the integration of visual entertainment and communication. (The progress of online games looks slow because they haven't yet found a good business model.)

Another topic at E3 was the combination of digital hardware and toys. Toy manufacturers Lego, Mattel, and others exhibited their products. The point is not that toy manufacturers have started making video games, but that robots and stuffed dolls are becoming computers with increasingly sophisticated microchips embedded in their bodies. An example is Lego's MindStorms, which was launched in 1998 and lets users assemble a robot with plastic bricks that include embedded CPUs, optic sensors, and touch sensors. Players can make their own special robots and program them. Stuffed dolls that recognize and study language also attracted attention at E3.

Children pat, squeeze, embrace, and talk to these toys. They are computers with adequate interfaces and communication terminals. They recognize, talk with, and interact with children. They also let children talk with each other. Moreover, they themselves will start connecting and chatting with each other. Communities of toys might appear.

In the future, other objects will become computers and get connected. Clothes, cars, furniture, and other objects will incorporate digital functions and "live" with people. Even our bodies may become Internet terminals through wearable computers. Computers as we know them, with the specific displays and keyboards that we are familiar with, might disappear. Although the shape of this new world is still unclear, we know that after toys will be developed as concrete objects, children and other users will become used to them and will exploit the new field. Then we will arrive at a new stage with convergence of the visual cyber community and physical world.

Toys of tomorrow

The MIT Media Lab is investigating the harmony between a new technology and humans. Its scope of research is too wide and deep (ranging over whole the territory of media) to summarize here. If forced to classify its research tangents, we would list learning and common sense, information and entertainment, and perceptual computing.

Learning and common sense includes theoretical and applied work in many aspects of artificial and human intelligence: software agents, machine understanding, and learning methods.

Information and entertainment ranges from the basic physics of computation to the social engineering of virtual communities, including advanced interface design, object-oriented and holographic video; and tools for creative expression.

Perceptual computing embraces human and machine vision; hearing; speech interfaces; wearable computers; and affective computing, a new branch of interface design intended to include emotion.

A special feature of the Media Lab is that research is conducted with the open collaboration of 180 sponsors. One of the Lab's research results is Lego MindStorms, a product currently on the market. Lego and the Media Lab have continued their collaboration on this project for more than 10 years.

Most of the Lab's research is organized into several consortia. Each consortium focuses on a unique theme running across the three major topics just mentioned. Among them is a project group devoted to playing: Toys of Tomorrow.

Toys of Tomorrow, announced in October 1997, explores how the digital revolution will transform the world of toys and play. The consortium provides a research environment for inventing a new generation of toys and creating new forms of playing, learning, designing, and storytelling. In the past, new technologies were born in the workplace and ended up in toys. In the future, toys will be the trendsetters, setting the standard for a digital infrastructure that really works and really plays.

Six professors, Mitchel Resnick, Tod Machover, Justine Cassell, Bruce Brumberg, Brian Smith, and Michael Hawley, work in this project Toys of Tomorrow:.

In March 1999, at the Tokyo Toy Fair, the Media Lab, with support from Tomy, a Japanese toy maker, hosted a booth to let people touch and feel toys. Through this kind of fieldwork to measure the distance between advanced research and practical use, each group of Toys of Tomorrow is actively making progress.

Lifelong kindergarten

Mitchel Resnick's group is researching new computational toys and tools to help people

Figure 1. Programmable Bricks prototype.

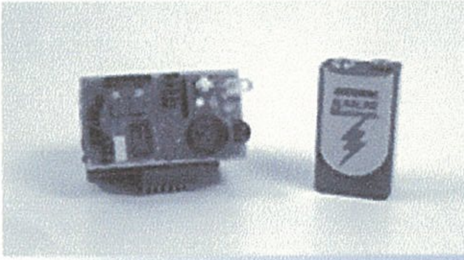


Figure 2. Crickets prototype.

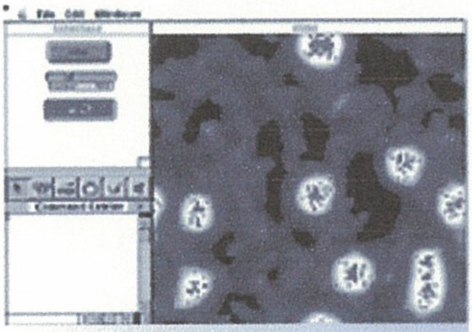


Figure 3. Starlogo.

(particularly children) learn new things in new ways through playing with them. They study how and what children learn when they design and invent with these new technologies. In kindergarten, manipulative materials (such as Pattern Blocks) are enabling children to explore mathematical and scientific concepts (such as number, shape, and size) through direct manipulation of physical objects. The group is trying to expand on this idea to create a new generation of manipulatives with embedded computation. These new "digital manipulatives" are intended to help children of all ages continue to learn (and learn more advanced ideas) using the kindergarten approach.

Programmable Bricks is a construction kit that builds computational power directly into Lego bricks. It is intended to help children learn through and about design (see Figure 1). A child writes a Logo program on a personal computer then downloads the program to the Programmable Brick (typically, via infrared communication). After that, the child can take (or put) the Programmable Brick anywhere; the program remains stored in it. Each Programmable Brick has output ports for controlling motors and lights, and input ports for receiving information from sensors (for example, light, touch, and temperature sensors). Lego MindStorms was an inspiration of this project from the long-time collaboration between Lego and the Media Lab. The latest version of the Programmable bricks, called Crickets and shown in Figure 2, is smaller, lighter, and cheaper—roughly the size of children's Matchbox cars and action figures. Crickets can also communicate with one another (and with other electronic devices) via infrared signals.

Starlogo, a programmable modeling environment, is designed to introduce a very different approach to the study of complex and decentralized systems such as traffic jams and economies. (See Figure 3.) To use Starlogo, children do not need to master advanced mathematical formulae. Rather, they write simple rules for individual objects; children observe the group patterns that arise from the interactions among the objects.

Virtual Fishtank, exhibited in the Boston Museum of Science, is developed with a similar concept to Starlogo. Through creating their own artificial fish and observing the patterns that form as their fish interact with one another on huge, wall-size displays, people gain an understanding of emergent phenomena, discovering how complex patterns can arise from simple rules.

Opera of the future

Tod Machover's group has a special interest in inventing musical instruments that "understand" the artistic intentions of the performer, allowing for the enhancement and extension of musical expression. They design these instruments for use by highly skilled performers, as well as for students, novices, and amateurs. They also explore how new media technology can modify music itself and how such concepts can in turn be applied to interactive intermedia art and entertainment forms, of which opera is a particularly sophisticated example.

The hyperinstrument project was started in 1986 with the goal of designing expanded musical instruments, using technology to give extra power and finesse to virtuoso performers. The group designed the hyperinstruments to augment guitars and keyboards, percussion and strings, and even conducting. They have been used by some of the world's foremost performers, such as Yo-Yo Ma, the Los Angeles Philharmonic, Peter Gabriel, and magicians Penn and Teller.

Brain Opera is an attempt to bring expression and creativity to everyone, in public or at home, by combining an exceptionally large number of interactive modes into a single, coherent experience. The project connects a series of hyperinstruments designed for the general public with a performance and a series of real-time music activities on the Internet. Audiences explore the hands-on instruments as preparation for the performance, creating personal music that makes each performance unique. The project is attempting to redefine the nature of collective interaction in public places, as well as to explore the possibilities of expressive objects and environments for the workplace and home.

Sensor Chair (see Figures 4 and 5) is one of the attractions in Brain Opera. The person seated in the chair becomes an extension of a transmitting antenna placed in the chair cushion. The person's body acts as a conductor, which is capacitively coupled into the transmitter plate. Four receiving antennas are mounted at the vertices of a square, on poles placed in front of the chair. These reception, or pickup, areas receive the transmitted signal with a strength that is determined by the capacitance between the performer's body and the sensor antenna. The pickup signal strengths are digitized, and the computer estimates the hand position. A pair of pickup antennas are also mounted on the floor of the chair platform, and are used to similarly measure the proximity of the feet, providing a set of pedal controllers. Therefore, all movements of the arms and upper body are measured very accurately and turned into different kinds of music.

A current direction in this group is to develop musical toys for children of all ages. Toy Symphony is an international music performance and education project designed to develop and employ new concepts and technologies for introducing musical creativity and expression to children with musical toys. In particular, Toy Symphony strives to give children new expressive musical toys for crafting, shaping, and composing pieces of music, using familiar materials such as clay and plush interfaces. Toy Symphony's goal is to revitalize the orchestra with an infusion of youthful and enthusiastic collaborators and open doors for children to the instruments, sounds, and ideas of the 21st century.

Gesture and narrative language

Justine Cassell's group studies how artifacts (such as agents and toys) can be designed with psychosocial competencies, based on human linguistic, cognitive, and social abilities. Their current projects include a) the integration of gesture, speech, intonation, and facial expression in autonomous, animated conversing agents and avatars; b) the exploitation of children's language and play skills in the construction of technological toys that appeal to both boys and girls; and c) systems that elicit stories from children and adults.

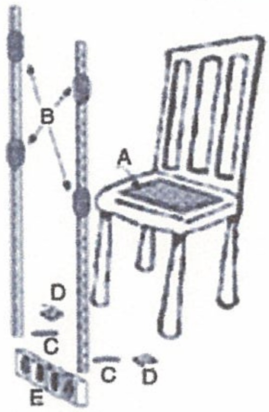
In the Rea project, the group develops autonomous agents that are capable of having a real-time, face-to-face conversation with a human. These agents are human in form and communicate using both verbal and nonverbal modalities.

As shown in Figure 6, Rea has a humanlike body and uses its body in humanlike ways during a conversation. Rea uses eye gazes, body posture, hand gestures, and facial displays to organize and regulate the conversation. The group is designing Rea to respond to visual, audio, and speech cues that are normally used in face-to-face conversation: speech, shifts in gaze, gesture, and nonspeech audio (feedback sounds). Rea will also express these cues in gestures, ensuring a full symmetry between input and output modalities.

The system consists of a large projection screen on which Rea is displayed and in front of which the user stands. Two cameras mounted on top of the projection screen track the user's head and hand positions in space. Users wear a microphone for capturing speech input. A single computer runs Rea's graphics and conversation engine, while several other computers manage the speech recognition/generation and image processing.

BodyChat (Figure 7, next page) is a graphical chat system using avatars that allows expression as well as simple body functions such as eye blinking. The system allows users to communicate via text while their avatars automatically animate attention, salutations, turn-taking, backchannel feedback, and facial expressions. A BodyChat evaluation showed that users found an avatar with autonomous

Figure 4. Brain Opera's Sensor Chair.



A Copper plate on chair top to transmit 70-KHz carrier signal into occupant
B Four illuminated pickup electrodes to sense hand positions
C Two pickup electrodes to detect left and right feet
D Two tootswitches for generating sensor-independent triggers
E Four lights under chair platform nominally controlled by foot sensors

Figure 5. Sensor Chair diagram.

Figure 6. Rea.

conversational behaviors to be more natural than avatars whose behaviors they controlled. Users also found that BodyChat increased the perceived expressiveness of the conversation. Interestingly, users also felt that avatars with autonomous communicative behaviors provided a greater sense of user control.

Story Mat stores children's storytelling play by recording their voices and the movements of the toys they play with. These stories revive on the mat when other children play and tell their own stories. The mat recognizes the toys and their movements. When children tell their stories on the mat, the mat responds with stories that are related to the children's stories. Children see and hear their stories and other children's stories that were played on the mat previously. In listening to the stories of others as well as their own, children react by telling more stories and telling stories collaboratively.

Synthetic characters

Bruce Blumberg's group focuses on building interactive animated characters for use in virtual environments such as immersive storytelling systems, games, and Web-based worlds. Their research includes the role of emotion and motivational state in action selection, learning and adaptation, directability (the integration of external control with autonomous behavior), synthetic perception, and models of motor control for expressive movement. A range of disciplines including artificial life, ethnology (for example, animal behavior) and cognitive science, classical animation, computer graphics, and artificial intelligence form their approach.

The Swamped! project is an interactive experience in which instrumented plush toys are used as a tangible, iconic interface for directing autonomous animated characters. See Figure 8. Each character has a distinct personality and decides in real time what it should do based on its perception of its environment, its motivational and emotional states, and input from its "conscience," the guest. By manipulating a stuffed animal corresponding to the character, the child can influence how a given character acts and feels. For example, the child could have the character wave its arm at another character, squeeze it to make it squawk, or direct the character's attention by moving the stuffed animal's head.

The stuffed animal includes a wireless sensor package with pitch and roll sensors, orthogonally mounted magnetometers that sense orientation with respect to magnetic north, flexion sensors for wing position, squeeze sensors embedded in the body and beak, a gyroscope sensing roll velocity, and a potentiometer to sense head rotation about the neck. The characters incorporate a novel model of behavior and emotion, multitarget motion interpolation, and new techniques for real-time graphics. Automatic camera and lighting control help reveal the emotional content of each scene. See Figure 9.

Explanation architecture

Brian Smith's group is concerned with how and why questions about the world and understanding ways to help people answer them. The group primarily focuses on the role of explanation in learning contexts, and their research involves the development of technologies to facilitate face-to-face collaboration and explanation. There is also a strong emphasis on developing tools to allow people to learn how to use images and video in nontraditional ways.

Image Maps is a learning tool for understanding historical, architectural, and cultural changes, and is specially designed for kindergarten to 12th grade students. The research attempts to integrate images from historical archives into learning communities by augmenting digital cameras with position and orientation data to retrieve historical images from ordinary tourist photos. Students take pictures of their local communities with their digital cameras to capture images of the present day along with metadata that is used to retrieve images of the past. When they return to their classroom, students download their images into a Java application. When one of their photographs is selected in an image viewer (see Figure 10), its enlarged image is displayed along with a set of historical thumbnails matching its location. The goal is to engage children in playful investigations of community change by giving them access to a historical "time machine."

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