Novel Approaches to Deaf Education

Nicoletta Adamo-Villani
Purdue University
West Lafayette, IN

Ronnie Wilbur
Purdue University
West Lafayette, IN

ABSTRACT

In this paper, we describe the development of two novel approaches to teaching math and science concepts to deaf children using 3D animated interactive software. One approach, Mathsigner™, is non-immersive and the other, SMILE™, is a virtual reality immersive environment. The content is curriculum-based, and the animated signing characters are constructed with state-of-the art technology and design. We report preliminary findings.

INTRODUCTION

This paper presents two novel approaches to deaf education using 3-D animation technology, one non-immersive and one immersive. Both approaches described here are unique because they: (1) use advanced technology to teach mathematics to K-6 deaf students who know American Sign Language (ASL); (2) provide equal access and opportunities by overcoming known deficiencies in science, technology, engineering, and math (STEM) education as reflected in the under-representation of deaf people in fields requiring STEM skills; and (3) provide a model for teaching technology in general that can contribute to improving deaf education around the globe. Our expertise in language problems of deaf children and linguistic research on ASL structure enables these programs to be appropriate in both English and ASL.

MATHSIGNER™ – A NON-IMMERSIVE GAME FOR STANDARD COMPUTERS

Mathsigner is a 3D animation ASL-based interactive software package which contains sets of activities, with implementation guidelines, designed to teach K-6 math concepts, signs, and corresponding English terminology to deaf children, their parents, and teachers.

Mathsigner is being developed using cutting-edge 3D animation technology. Computer generated and controlled animation presents many advantages over other technologies, including: (a) User control of appearance - orientation of the image (rotation and point of view control); location of the image relative to background; size of image; zoom. (b) Quality of the image - no distracting details as in photos and films; texture and transparency control. (c) User control of the speed of motion. (d) User programmability for: generating infinite number of
drills; unlimited text encoding; real time translation; limitless combinations of signs. Manual signs and facial expressions can be combined in any manner under program control. (e) Whole sentences can be linked together smoothly, without abrupt jumps or collisions between successive signs as would happen combining video clips. (f) Very low bandwidth. The programs controlling animations can be stored and transmitted using only a few percent of the bandwidth required for comparable video. (g) Character control. Animated signs can be easily applied to other characters, including different ages and ethnicity as well as cartoon characters.

Innovations in Mathsigner Compared to Other 3D Animation-Based Signing Products

Accuracy and realism of the signs: We use state-of-the-art optical motion capture system to record the signs directly from a fluent signer, which are captured by 6 cameras and applied to 3D characters in real time for immediate feedback and editing on readability and realism.

Smooth transitions between individual signs: The authors have filed a patent for a technique that allows for real-time blending of individual animation segments which yields smooth signed sentences from sequences of single signs. In other 3D signing programs, the transitions between signs are implemented with cut-and-paste methods or simple linear interpolation; the result is unrealistic in-between movements. A detailed description of the blending technique can be found in (Adamo-Villani, Doublestein & Martin, 2005)

High quality character appearance - organic deformations during signing motion: We use state-of-the-art modeling and rigging techniques to model 3D signers (realistic and fantasy) as seamless polygonal models, a major improvement over the appearance of existing segmented or partially segmented signing avatars, which do not change realistically as they move.

Natural facial expressions: One of the authors has developed a parameterized graphical facial model with a set of 26 parameters each controlled by a letter on the keyboard (US patent pending) (Adamo-Villani & Beni, 2004). The method allows encoding in real-time of significant facial expressions with accuracy and realism. Such facial modeling will represent improvement over existing avatars whose facial expressions are mechanical and limited to a small set.

Ready-to-use software for K-6 math education: Our software is not just animated signing, but an integrated package with math activities sorted by grade level concepts and difficulties. The software can be delivered via web or CD-ROM; no special system requirements or further programming is required to run the program. No other interactive, 3D animation-based software exists for math education of the Deaf.

The Prototype
We have a fully functional prototype that teaches grades K-3 math concepts and related ASL signs. The math content is based on standard, published elementary school math curriculum and has been developed with feedback from the teachers at the
Indiana School for the Deaf (ISD).

The current prototype contains two programs, one aimed at deaf children and the other aimed at hearing parents. Each has two modes of operation - a learning mode and a practice/drill mode. The two modes of usage are characterized by different color schemes (yellow for learning and orange for testing). The screen layout (shown in Fig.1) consists of two frames. The frame on the left is used to select the grade (K-1, 2 or 3) or the type of activity. The frame on the right shows the 3D signer. The upper area on the left (in green) gives textual feedback as appropriate; the bottom area shows the navigational buttons. The frame on the right contains a white text box below the signer, to show the answer (in mathematical symbols) to the current problem. Below this, there is a camera icon and an arrow. The arrow (slider) is used to control the speed of signing; the camera button opens a menu to zoom in/out on the 3D signer, change the point of view and pan to the left or to the right within the 3D signer window. A demo of the prototype learning tool is available at http://www2.tech.purdue.edu/cgt/I3/.

**Design Improvements**

The prototype has been evaluated throughout its development by ASL signers, faculty, and students knowledgeable in sign language and deaf education. These informal evaluations have produced key findings that are currently being used to modify and improve the design of the application. To summarize, the evaluations have produced results at three levels:

1. Recommendations for improved interaction
2. Recommendations for enhancement of overall appeal of the application
3. Suggestions for improved character design

To improve interaction with the application, the screen layout was changed from two to three panels (Fig. 2). Now the tasks of learning and testing are clearly separated. The signer is placed in the middle and, as a result, the user can fully attend to the center and use peripheral vision while moving the cursor over the buttons. In the prototype, the user had to look at the left side to place the cursor on a button, and then at the right side to understand what the button meant. This continuous shift in gaze direction was tiring and difficult to maintain for a long period of time.

Several changes were made to the look of the interface to make it more appealing to the target age group. The icons were redesigned to be more age appropriate and visual distraction was reduced. The screen background now changes when different 3D signers are selected. Fig. 3 shows the screen design that appears when the “space signer” is selected.

Significant changes were made to the original “bunny signer”. The new “bunny” (represented in Fig. 2) has a more human-like anatomy and therefore can sign more clearly. In addition, new characters are being developed; one of them is represented in Fig. 3.
Evaluation Plan

Evaluation of Mathsigner is done with ISD. The formative evaluation focuses on design features and quality of the signing motion. Program success is determined by: (1) deaf children's reactions (willingness to use, time on task), and (2) teachers'/parents’ feedback on the degree to which the program help to meet teachers/parents’ math goals at each grade level.

The animated signing is evaluated by experts who rate it (scale of 1 to 5) on several factors: realism of signing motion, readability, fluidity of transitions between signs, motion timing, sign placement in relation to body, and sign accuracy. So far, the feedback on signing motion has been very positive, especially readability, fluidity, and timing. Placement and accuracy feedback led to the character redesign, including clearly delineated neck and a longer torso to permit greater separation on the vertical axis of the locations of sign formation with respect to the body.

Summative evaluation will start in Spring 2008 and will test the efficacy of Mathsigner with three main questions: (1) Does Mathsigner lead to a learning effect? We compare scores on the SAT (Stanford)-HI (hearing impaired) and SESAT (Stanford Early School Achievement Test for younger children) mathematics subtests in the form: pre-treatment, treatment (use of software), post-treatment. (2) Is learning through Mathsigner more efficient than standard techniques? We compare our student scores with historical norms from the SAT-HI using both the national hearing-impaired norms (available from Gallaudet Research Institute) and the ISD norms. (3) What factors affect learning through Mathsigner? Our hypothesis is that learning gains are correlated with learner effort. We use several ‘effort’ measures including: (1) time spent logged on to Mathsigner; (2) number of items completed; and (3) number of attempts at each item.

SMILE (SCIENCE AND MATH IN AN IMMERSIVE LEARNING ENVIRONMENT) – AN IMMERSIVE GAME FOR STATIONARY AND PORTABLE VR SYSTEMS

SMILE is an immersive Virtual Learning Environment (VLE) in which deaf and hearing children ages 5-10 learn STEM concepts and ASL terminology through user interaction with fantasy 3D characters that communicate in ASL and spoken English.

Background

Research in VR and education is a young field which has recently shown considerable growth. Youngblut reports over forty VR-based learning applications (Youngblut, 1997) and Roussou describes about 10 VLE designed for informal education (Roussou, 2004). Although the benefits of VR experiences need to be more comprehensively defined, studies show that VR can provide a more effective learning tool than traditional classrooms, students enjoy working with virtual worlds, and the experience is highly motivating (Youngblut, 1997). Research also shows that VR is particularly suitable to STEM education because of its ability to ‘bridge the gap between the concrete world of nature and the abstract world of concepts and models’, making it a valuable alternative to the conventional study of math and science which requires students to develop understandings based on textual descriptions and 2D representations (Johnson et al. 2002).
Regarding disabilities education, VR has advantages over other teaching technologies because it can provide for the learning requirements of students with disabilities (Darrow, 1995). Some of the most commonly encountered needs include: access to safe and barrier-free scenarios for daily living tasks; self-pacing; repetition; control over environment; ability to see or feel items and processes in concrete terms (difficulty with abstract concepts); and motivation.

Roussou suggests that there are many compelling reasons for believing that VLE provide effective teaching tools for children’s conceptual learning (Roussou et al.1999). However, due to the use of high-end expensive equipment and non-standard application development, the majority of existing VLE for children is limited to academic and research environments and institutions of informal education, such as museums. One notable example of VLE is the NICE project (Roussou et al., 1999) designed for display in the CAVE VR system (Cruz-Neira, Sandin, & DeFanti, 1993). NICE is an immersive, multi-user VLE in which children learn basic biological concepts while constructing, cultivating, and tending a virtual garden.

VREAL (Virtual Reality Education for Assisted Living) project (Edge, 2001) is, to date, the only VLE for deaf children. VREAL is an immersive virtual environment in which deaf students learn basic life skills, language arts, and mathematics. Five US Deaf schools used the program in 2004 and assessment studies showed a student test score improvement by an average of 35%.

SMILE follows the trail pioneered by projects such as VREAL and NICE, but makes unique contributions to this area. (1) SMILE is the first bilingual immersive VLE featuring interactive 3D animated characters that respond to the user’s input in English and ASL. (2) It includes significantly improved seamless characters compared to existing 3D animated signing, i.e., Signing Avatar (Vcom3D, 2004), with fluidity of signing motion and realism of skin deformations. (3) Its content is designed by a team of experts including specialists in VR application development, ASL and Deaf education, STEM education, graphic design, animation, and game design. Roussou and Barab (Roussou et al.1999; Barab et al., 2005) argue that high-end technological innovations are often associated with disappointing content. SMILE attempts to provide an ideal combination of technological innovation and educational content by presenting an emotionally appealing visual design, an engaging metagame strategy that establishes a meaningful context for participation, and goal-oriented activities that are grounded in research on effective pedagogy. (4) SMILE is designed for formal STEM education and will be available for use by elementary schools and deaf education programs throughout the US. Students will interact using a relatively inexpensive projection-based portable system that eliminates the cumbersome HMD unit, while maintaining the feeling of immersiveness.

**Development of SMILE**

SMILE is an interactive virtual world containing an imaginary town of fantasy 3D avatars that communicate with the user in written and spoken English, and ASL. The user can explore the town, enter buildings, select and manipulate objects, construct new objects, and interact with the characters. In each building the use learns specific STEM concepts by performing hands-on activities developed with elementary school educators (including deaf educators), and in
alignment with standard STEM curriculum. SMILE has an overall story which is introduced through a cutout-style 2D animation at the beginning of the game (fig. 4 shows a frame).

The story includes an overarching goal (restore the lost willingness to smile in the city of ‘Smileville’) which creates a boundary condition that unites all the individual game tasks. Each activity is in the form of a ‘good deed’ whose objective is to make a ‘Smileville’ character smile again by giving him/her a meaningful new object. The ability to construct the object is dependent on the acquisition of STEM skills, and related ASL signs. All game activities are carried out in a cartoon-like virtual world designed to be appealing to the target age group. Key design features include basic geometric shapes with round edges, vibrant and varied colors, and a bright lighting setup with limited shading and soft shadows. The choice of the color and lighting schemes was based on research studies on the impact of color and light on learning (Duke, 1998) (Engelbrecht, 2003), and on the association between colors and children’s emotions (Boyatzis & Varghese, 1994). The visual and game designs of SMILE are described in detail in (Adamo-Villani & Wright, 2007). Fig. 5 shows the exterior and interior of the bakery building, and one of the 3D characters.

The character design is very stylized and consistent with the environment visual style. All characters are modeled as continuous polygon meshes with a poly-count less than 6000 polygons per avatar. A low polygon count maintains a high frame rate and real-time interaction. To realize high visual quality with a limited number of polygons, the 3D surfaces have been optimized by concentrating the polygons in areas where detail is needed the most: the hands, the face, and the parts that bend and twist (i.e. elbows, shoulders, wrists, and waist). With such distribution of detail it is possible to represent realistic hand/face configurations and organic deformations of the skin during motion. Character bodies are set up for animation with a skeletal structure closely resembling a real human. The face is rigged with 20 to 30 joint deformers positioned so that they deform the digital face along the same lines pulled and stretched by the muscles of a real face. For fluidity and realism, the signing uses the same techniques as the Mathsigner project.

**Technical implementation**

SMILE™ can be displayed on different systems: (1) stationary 4-wall projection devices (i.e. the Fakespace FLEX); (2) single screen portable projection systems; (3)
Fish Tank VR systems, and (4) standard desktop computers. The application could also be modified to be viewed through a head mounted display unit. The development of SMILE is described in detail in (Adamo-Villani, Carpenter & Arns, 2006) SMILE™ in the FLEX: The student views the application through a pair of light-weight LCD active stereoscopic glasses projected onto the immersive, four screen display (see fig. 6), which provides the user with virtual environment images projected to the front, side, and floor screens. The user wears an InterSense head tracker to determine the position and orientation of the eyes; this information re-draws the environment based on the user’s perspective, as the direction of gaze changes. The user travels through the environment using an Intersense 6 DOF wand or a Cobult Flux dance platform. Objects can be selected and manipulated with the wand, or with a simple gesture control system (a pair of Fakespace Lab’s Pinch Gloves coupled with an Intersense wrist tracker). The gesture control system allows for input of ASL signs (numbers 0-20), and for travel through the environment.

SMILE™ on portable systems: Because SMILE™ is designed primarily for display in a four-wall projection system, certain objects in the scene exist in the user’s peripheral vision and on the floor of the scene. We have developed a portable version which eliminates unnecessary information from the sides of the environment and moves the important features to the front of the user’s view. This transition from 4-wall display to a single monitor has been accomplished by editing the VRJuggler configuration files. Adding additional devices, such as LCD shutter glasses for CRT monitors or desktop tracking systems, require nothing more than the installation of new device drivers and the creation of new configuration files. SMILE™ has been tested on the following portable systems: (1) a projection-based immersive system consisting of a screen and frame, a high-end laptop, two commodity projectors, a pair of polarizing filters, and inexpensive polarized glasses. (2) a Fish Tank VR system consisting of a DellE520 desktop PC, a CRT monitor, an Essential Reality P5 glove with 6 degrees of tracking and bend sensors for each finger, a pair of eDimensional wireless 3D glasses and an Intersense 3DOF PC head tracker. (3) a standard, non immersive desktop computer system. The application is designed mainly for use with the Intersense IS-900 system. When a tracking system is not available, input can be accomplished via mouse and keyboard. Portable demos of SMILE are available for download at: http://www2.tech.purdue.edu/cgi/i3/smile/demos

Evaluation of SMILE

The evaluation of SMILE includes three forms: expert panel-based, formative, and summative. The expert panel-based and formative evaluations focus on the usability and fun, visual representation quality, and signing motion quality, and are repeated throughout the development of SMILE to identify recommendations for design improvement. The panel consists of experts in VR application development, 3D modeling and animation, and American Sign Language. Each evaluator is asked to perform an analytical assessment in his/her area of expertise. The experts in VR application development have so far assessed the usability of the program by determining what design guidelines it violates and supports. Clear heuristics for the ideal design of VE to guide such evaluation do not exist yet; guidelines used by the experts were derived from work by (Nielsen & Molich, 1990; Nielsen, 1994; Gabbard, 1998).
The 3D modeling and animation experts have been given questionnaires focusing on the visual representation of the virtual world; the experts in ASL have been given questionnaires on the quality of the signing motion. To date, several usability problems have been uncovered and solved; all elements of the visual representation and signing motion have been given high scores by the experts and, therefore, recommendations for improvement have not been necessary. Three formative evaluations with target users have been administered so far (next section).

Summative evaluation assesses learning. Such evaluation with kindergarten and elementary school aged deaf and hearing children will be done in collaboration with the Indiana School for the Deaf (ISD) in Indianapolis, and with two elementary schools in West Lafayette, IN.

**Summary of Initial Findings**

The procedure and evaluation instrument used in the first three formative evaluations are described in detail in (Adamo-Villani & Wright, 2007) and (Adamo-Villani & Jones, 2007).

Overall, children enjoyed playing the game and found the environment and characters fun and appealing. Although they had high expectations, the reported experience surpassed them. SMILE was perceived more fun and easier to use than expected, and slightly more challenging. The ‘Again-and-Again’ table (Read, Macfarlane & Casey, 2002) revealed that the activities the children most enjoyed were the construction of the new objects (i.e. the cake), watching the mysterious machines (such as the animated baker’s machine), traveling through Smileville, and playing the entire game. Observation and think aloud protocol showed that other activities the participants found ‘very fun’ were ‘walking through objects’, ‘throwing objects’, ‘opening doors’, and ‘watching things that move’. As far as usability, children did not appear to have major difficulties with travel, selection, and manipulation tasks. We noticed a few signs of frustration and comments such as ‘some of the objects are really hard to pick up’ and ‘some of the text is hard to read’. Two subjects showed discomfort (dizziness and eye strain) with the head tracker and glasses and stopped interacting with the application after approximately 10 minutes. The main problem was the size of the 3D shutter glasses. Children kept losing the goggles during interaction and were constantly adjusting them on their noses. We are researching different solutions such as customized 3D glasses for children, coupling the goggles with a head band, or using a 3D monitor that does not require glasses (for the Fish tank VR system).

As for engagement, the majority of the students appeared to be very focused on the tasks. Positive comments included: ‘this is awesome because you feel like you are really in a bakery’; ‘….this game is more exciting than a video game because you don’t see anything around you… and you are really inside the building putting a cake in the oven’. Many positive signs were observed such as laughing, smiling, bouncing in excitement, and ‘wow’ sounds.

**ACKNOWLEDGEMENTS**

This research was supported in part by National Science Foundation HRD-0622900. We appreciate the assistance of the Indiana School for the Deaf and the Envision Center for Data Perceptualization at Purdue University.
REFERENCES


http://www.coe.uga.edu/sdpl/articleoftheweek/colorPW.pdf


