Sketch-Based Educational Games: "Drawing" Kids Away from Traditional Interfaces

Brandon Paulson
Brian Eoff
Aaron Wolin
Joshua Johnston
Tracy Hammond
Sketch Recognition Lab
Computer Science Department
Texas A&M University
911 Richardson
College Station, TX 77843-3112
bpaulson@cs.tamu.edu
bde@cs.tamu.edu
awolin@cs.tamu.edu
jbjohns@cs.tamu.edu
hammond@cs.tamu.edu

Abstract
Computer-based games and technologies can be significant aids for helping children learn. However, most computer-based games simply address the learning styles of visual and auditory learners. Sketch-based interfaces, however, can also address the needs of those children who learn better through tactile and kinesthetic approaches. Furthermore, sketch recognition can allow for automatic feedback to aid children without the explicit need for teacher to be present. In this paper, we present various sketch-based tools and games that promote tactile learning and entertainment for children.

Keywords
Sketch recognition, LADDER, PaleoSketch, automated feedback, educational games

ACM Classification Keywords
K.3.1 Computer Uses in Education: Computer-assisted instruction (CAI).

Introduction
It has been shown that there are four basic learning styles present in child education and development: auditory, visual, tactile, and kinesthetic [7]. When creating educational materials using technology for children, it is often the case that auditory and visual styles prevail over tactile and kinesthetic approaches. We believe that creating sketch-based educational tools and games addresses the needs of children who learn better through tactile and kinesthetic methods, while still providing visual and auditory feedback.

Sketching is an intuitive interaction technique for children, particularly for those at a young age.

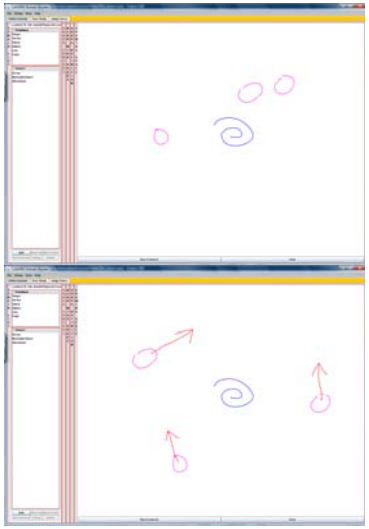

Figure 1: APPLES planetary physics simulation game.

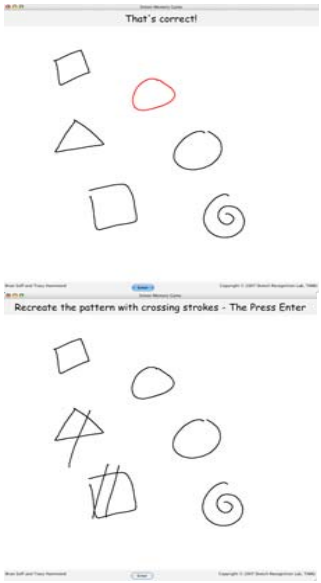

Figure 2: "Simon Says 'Sketch!'" game play.

Sketching engages children in a kinesthetic and tactile manner, allowing them to use their hands to actively interact with a computer system. Through sketch recognition, we provide automatic feedback to children to improve and enhance the learning process [4, 5].

Sketch recognition is the task of automatically understanding what a user has drawn. It has been used in many industrial and higher education domains, including recognizing circuit diagrams, architectural drawings, and mechanical engineering models [2]. However, it has not been actively used in an educational setting for children.

In this paper, we present several sketch-based interfaces and games that promote kinesthetic and tactile learning. Such applications include memory games, simple physics simulation games, games to learn shapes and geography, as well as a system for providing feedback about sentence diagramming. We propose that the applications presented here are just a small sample of the possibilities of sketch-based games, and should be used as a springboard for a wide and varying array of different games and game types.

APPLES: Animated Planetary Physics Learning and Entertainment Simulation

APPLES (Figure 1) allows children to draw simple shapes within a planetary physics environment. The system, which was created in LADDER [1], allows children to draw circles, arrows, and spirals. LADDER recognizes each of these components and animates the sketch accordingly. Arrows drawn next to circles (i.e., planets) propel the planets in the pointed directions, and spirals create gravity fields that pull planets into orbits. Planets can also bounce off one another in elastic collisions. Children can also continue to sketch within the program as it is animating, providing a new level of interaction for students since they can see immediate feedback from their drawings.

Physics simulations like APPLES familiarize children with the concepts of gravity, motion, and collisions at an early age while being tactile and entertaining. As students progress through their education, more complex sketch games could be created to provide children with greater control over the simulation while introducing new concepts such as friction and inertia.

Memory Games: Simon Says "Sketch!"

This memory pattern and location game was created to test if giving people freedom to position game pieces affected their ability to recall stimulus changes. The player is instructed to draw six figures of their choosing. In the first round of playing, the player must remember the order in which two of the shapes change their color. The number of shape stimulus changes that the user must remember and recreate increases by one each round. Figure 2 shows screenshots of the game play. The user recreates the order of stimulus changes by marking through the shapes in the same order. Due to the limitations of chunking memory, most adult players are unable to make it beyond recalling nine stimulus changes.

Memory Games: Go (Sketch-a) Fish

We've also implemented a sketch-based memory card game within the LADDER sketch recognition framework. Users are allowed to draw a pre-defined set of shapes, including a star, simple fish figure, and hourglass (see Figure 3). Drawing a rectangle around single shapes turns that shape into a memory card. The user can

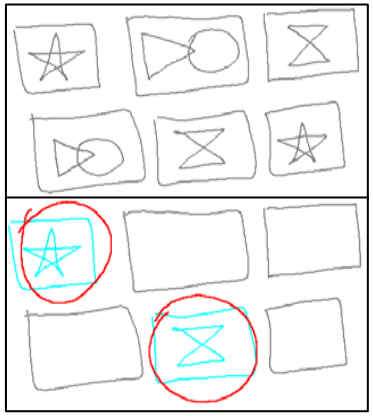

Figure 3: Example drawn cards in "Go (Sketch-a) Fish" (top), and the hidden cards selected with a sketched circle (bottom).

Figure 4: United States geography game.

then hide the cards and allow a friend to play memory. Drawing a circle around a card selects it for play and flashes that card face (the shape drawn earlier). The purpose of the game is to select two cards with the same face, removing them from the board, until all card pairs have been removed.

Sketch-based Geography Tools

We have created a simple geography tool that allows maps to be presented to children for labeling through sketch. For our prototype, we displayed a United States map (Figure 4) and asked children to label each state by circling it, marking it with an 'X', or simply drawing a line through it. The system also allows them to make changes by simply scribbling out previously sketched marks. This tool is capable of determining which state has been marked by the user and can gives automatic feedback stating whether the user was correct or not. Such a tool can be easily expanded to recognize more complex sketched marks such as special symbols to denote landmarks, capitals, and changes in landscape. Another interesting expansion would be to allow children to draw rivers on the map.

Learn Your Shapes!

The "Learn Your Shapes" game is a tool that allows children to learn their basic shapes through sketching (see Figure 5). Sketching shapes, rather than using simple visual recall, can be more beneficial to children who learn better through tactile and kinesthetic means. This prototype system contains sketch recognition technology that can automatically determine whether or not a child has sketched the correct shape [6]. Children are allowed to sketch shapes as they would naturally; they are not constrained to draw them in a particular way. In a children-centered design experiment using the Palm Pilot character recognition program, Graffiti, researchers found that some children had difficulty in using the system because characters were not being recognized correctly. This misrecognition occurred because characters had to be drawn in a pre-defined manner which was unnatural for some children [3]. Our program uses recognition technology that does not place such limitations on a child's natural sketching manner. Currently, this game only supports very basic shapes, but can be easily expanded to allow the recognition of higher level shapes and diagrams which can be defined using the LADDER language.

Sentence Diagramming

A tool for automatically providing feedback about hand-drawn sentence diagramming exercises has also been implemented in the LADDER architecture. The application allows for arbitrary sentences to be input into the system. Once the teacher/instructor has informed the system what the correct parts of speech are for the sentence, students can be instructed to diagram it. The system can then provide any level of feedback, from simple correct/incorrect responses, to telling the student what parts of speech were mislabeled and why (Figure 6). This simple prototype could serve as the basis for a game reinforcing grammar rules.

Results

We have informally had several children play with our games. However, a serious fault in our paper (making it a work-in-progress) is that we have not yet performed an in-depth user study on children. We are currently pursuing such a study, but are delayed by institutional review board (IRB) constraints. We have presented

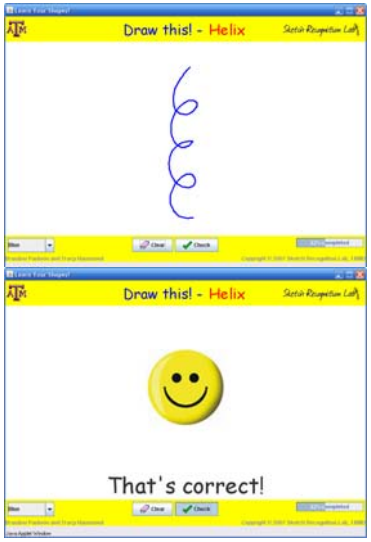

Figure 5: "Learn Your Shapes" game

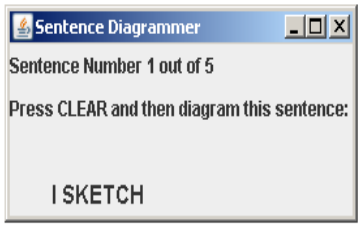

Figure 6: A simple sentence diagrammed with the sentence diagramming application. The diagram itself was drawn by hand. The text was entered by keyboard.

the "Learn Your Shapes" game to an expert in children's education and received positive (third party) comments, including "I agree it is cool. I would imagine that tools like this would have some utility for young learners. The navigation (and look and feel) was clear and easy to grasp … Thanks for sharing it."

We have, however, performed preliminary, in-depth user studies on the graduate student population available to us in an effort to remove obvious bugs before formally testing the software on children. Four graduate students were given APPLES and instructions for what objects could be drawn. We were interested in how users enjoyed playing with the system and how the recognition rate of the shapes affected their interaction. Overall, users thought APPLES was "fun to play with", with "cool" features. Users enjoyed the inclusion of physics in a sketch-based program and wanted to see some more options, such as the ability to fix obstacles, or allow for gravity to be changed. Users also wanted to draw other objects besides circles.

The "Simon Says 'Sketch!'" game has gone through two iterations of formal user testing on graduate students in preparation for children's testing to analyze the shapes and flow of the game. The first study was to test and improve shape recognition accuracy. The second study tested usability. The same six users were asked to interact with the game and report suggest improvements to overall game usability.

Conclusions & Future Work

We have presented several sketch-based tools and games that promote kinesthetic and tactile learning. Many of these games also take advantage of sketch recognition technology to provide automatic feedback.

For future work we would like to perform studies with actual children to assess the value of our sketch-based games and tools. To date, we have yet to test with actual children due to IRB constraints.

Acknowledgment

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References

[1] Hammond, T. and Davis, R. LADDER, A Sketching Language for User Interface Developers. *Computers & Graphics 29*, 4 (2005), 518-532.

[2] Hammond, T., Eoff, B., Paulson, B., Wolin, A., Dahmen, K., Johnston, J., and Rajan, P. Free-Sketch Recognition: Putting the CHI in Sketching. In *Proc. CHI 2008,* ACM Press (2008), to appear.

[3] Jones, C., McIver, L., Gibson, L., and Gregor, P. Experiences obtained from designing with children. In *Proc. IDC 2003*, ACM Press (2003), 69-74.

[4] Malmi, L. and Korhonen, A. Automatic feedback and resubmissions as learning aid. In *Proc ICALT 2004,* ACM Press (2004), 186-190.

[5] Odekirk-Hash, E. and Zachary, J.L. Automated feedback on programs means students need less help from teachers. In *Proc. SIGCSE 2001,* ACM Press (2001), 55-59.

[6] Paulson, B. and Hammond, T. PaleoSketch: Accurate Primitive Sketch Recognition and Beautification. In *Proc. IUI 2008*, ACM Press (2008), 1-10.

[7] Reid, J. The Learning Style Preferences of ESL Students. *TESOL Quarterly 21,* 1 (1987), 87-111.