Touch Tiles: Elementary Geometry Software with a Haptic and Auditory Interface for Visually Impaired Children

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Abstract. The purpose of this paper is to report on the progress of a study that is currently underway. The goal of the *Touch Tiles* project is to create a multimodal interface for a geometry software program that can be used by children with visual impairment. The interface employs both haptic (tactile and force) and auditory (verbal and nonverbal) feedback to enable students to complete pattern creation tasks with geometric shapes. The design of the interface has been emerging and evolving in an iterative process informed by data gained through user testing.

1 Introduction

The lack of math literacy among blind children and adults in the U.S. is a serious problem, exacerbated by the limited availability of accessible tools and resources. The goal of the *Touch Tiles* project is to adapt and redesign a successful children's geometry and pattern creation software program for use by children with visual impairment. This is being accomplished by enhancing and replacing the visual information with haptic and auditory information. For the project to be deemed successful the students must be able to create patterns by arranging plane figures on a grid. The project team has taken an iterative approach to the design by developing small prototypes and pilot testing them with users to guide further design efforts.

The development of computer interfaces for visually impaired users is an obvious application of haptic technology. One of the commonly used haptic devices for research is the PHANToM™ by Sensable Technologies, but the high cost of the device makes it prohibitively expensive for many prospective customers. For this reason, the potential application of low cost haptic consumer mice and joysticks to interfaces for visually impaired individuals is compelling.

Various studies with visually impaired students have shown that haptic technology may hold potential for making mathematics and science software more accessible [1], [2], [3]. Though these studies have been aimed at secondary or postsecondary audiences, all have conveyed mathematical data through haptic graphs. Both Van Scoy, Kawai, Darrah, and Rash [1] and Yu, Ramloll, and Brewster [2] found that confusion can result when visually impaired students encounter intersecting lines. Sjostrom [4] noted that sharp corners on the outer edges of shapes can be disorienting, since this causes the user to suddenly lose contact with the shape. These are both design issues with which we must contend, as part of the users' tasks will involve placing polygons on a grid.

2 First Steps

We are using the Logitech Wingman Force Feedback Mouse™ (WFFM). Although the WFFM appears viable as a tool for educational purposes, a major drawback is that the device is no longer commercially available.

At this point (May 2003), we have informally tested simple shapes with one adult and three children. The participants were recruited from a support organization for the blind or visually impaired. The participants tested a series of screens, each of which contained from one to five shapes. The configurations included: a small square and circle placed side by side; a single large square or circle; a large square which contained a smaller circle; a series of five circles or squares, descending in size from left to right; a series of five circles, descending in force feedback intensity from left to right. There was also a series of five circles framed by squares. Some circles had texture fills, and others did not. Some of the square frames were raised and others were recessed. Two 3 x 3 grids of squares were tested; one had raised lines and the other had recessed lines. The participants were prompted to locate and identify the elements for each screen.

2.1 Preliminary Findings

The adult, a middle-aged man, is totally blind. He is adept at reading Braille, tactile graphics and pin displays. His blindness was acquired later in life, and he mentioned that he has memories of colors, shapes, and objects. He performed better than sighted project personnel did, and quickly found and identified the various shapes.

The children (two 10-year-old boys and one 7-year-old girl) were not as successful as the adult. Although all three children some degree of vision, they were blindfolded during the tests.

The boys moved with quick, almost frantic movements, which caused them to overshoot the shapes. The girl was much more tentative, which caused her to move more slowly. Hers was the more successful approach, because it allowed her to sense the shapes before overshooting them, and she quickly found the first circle. The boys eventually slowed down and consequently were more successful as they continued to work with the prototypes. After her initial success, the girl seemed to be making hopeful guesses rather than clearly identifying the shapes through touch. Her difficulty compared with the boys may have been due in part to the three-year age difference.

We have encountered some of the pitfalls described by other researchers. We have observed and experienced first hand how disorienting sharp corners are when the side of a square ends abruptly. Also, certain textures were more confusing than others. For instance, a grid texture was experienced by one user as the shape (a square) moving when it was in fact static. The 3 x 3 grids were also perceived as moving by some. Recessed grid lines were easier to follow than raised ones, but both led to confusion at the intersections. The circles inscribed within square frames also confused users at the points of convergence.

Regarding the strength of the force feedback effects, one boy stated that the strongest effect was the best. In observing user interaction with the various forces, all users seemed to have an easier time following the shapes when the effect was set at or near the maximum. Project personnel found that shapes were easiest to identify with force feedback settings of between 80% and 100%.

3 Next Steps

Taking into consideration what was learned from these small informal tests, a prototype with sufficient functionality to complete a series of patterning tasks and determine the feasibility of the concept has been developed. This prototype incorporates the following features:

Shape tiles. These include circles (2 sizes), squares (2 sizes), a right triangle, and an isosceles triangle. The shapes are recessed, so participants will trace the inside boundary of the shape. This mitigates the problem of getting lost at the corners of squares and triangles. The tiles can be rotated in 90° increments .

Grids. There are four different grid configurations: 2 x 1, 2 x 2, 3 x 3, and 5 x 5. Due to the perception of the grids as moving, as well as the confusion that resulted when frames and shapes touched, the grids are not rendered haptically. Instead, spoken audio identifies grid cells by number.

Audio support. Verbal and nonverbal audio feedback is offered. User actions are confirmed verbally, and spoken help is available. A different musical tone is associated with each shape tile so that children can choose to listen to the patterns that they create as well as feel them. Individual tones play on mouse entry into the placed shape, and the complete "tune" can be played on command. Empty grid cells have an associated "empty" (soft swish) audio effect so that each cell, whether empty or full, makes a sound. We are anticipating that audio support will enhance the usability of the interface substantially.

Keyboard commands. The keyboard is used to enter commands. For example, a child is able to type "c" for a small circle tile, or enter a number for the associated grid cell. All participants either have keyboarding skills or are in the process of acquiring them. Braille dots or raised bumps on home keys will be available for the keys if desired.

3.1 Methods

Participants will consist of approximately equal numbers of boys and girls with varying degrees of visual impairment who are otherwise healthy (10 – 12 children, ages 7-11). Data will be collected via video and screen capture, observation field notes, task completion check lists, and program logging of user actions. Demographic data such as age, gender, and level of vision will be collected. Quantitative and qualitative methods will be used for analysis.

Participants will be given a series of pattern creation tasks to solve in order of increasing difficulty. The tasks have been reviewed by an expert in elementary mathematics for content and age appropriateness. A total of 34 activities have been developed, but it is not expected that participants will be able to complete all of the activities. The tasks will begin with enabling skills such as locating a particular cell in a grid or locating a particular shape. Intermediate tasks include completing a pattern by placing a missing shape. More advanced tasks include reflecting a pattern across a line of symmetry, or creating various arrangements of five square tiles with whole edges touching (pentominos). Braille graph paper and pattern blocks will be available to physically model unfamiliar concepts for the children.

Wies (personal communication, September 2002) noted that students with low vision were more successful than students who were totally blind. During the initial phase, subjects with partial vision were blindfolded to simulate the most difficult condition, but for the next phase they will be permitted to use whatever visual abilities they possess to help them complete the tasks.

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References

1. Van Scoy, F. L., Kawai, T., Darrah, M., & Rash, C.: Haptic display of mathematical functions for teaching mathematics to students with vision disabilities. Paper presented at the Haptic Human-Computer Interaction Workshop, University of Glasgow. (2000).
2. Yu, W., Ramloll, R., & Brewster, S. (2000). Haptic graphs for blind computer users. Retrieved December 18, 2002, from http://www.dcs.gla.ac.uk/%7Estephen/workshops/haptic/papers/yu.pdf
3. Wies, E. F., Gardner, J. A., O'Modhrain, M. S., Hasser, C. J., & Bulatov, V. L. (2000). Web-based touch display for accessible science education. Retrieved September 18, 2000; from http://www.dcs.gla.ac.uk/%7Estephen/workshops/haptic/papers/wise.pdf
4. Sjöström, C.: Non-visual haptic interaction design guidelines and applications. Doctoral dissertation, Lund Institute of Technology, Lund, Sweden. Retrieved November 2, 2002, from http://www.certec.lth.se/doc/hapticinteraction/