SoundLines: Exploration of Line Segments through Sonification and Multi-touch Interaction

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ABSTRACT

We demonstrate *SoundLines*, a mobile app designed to support children with visual impairments in exercising spatial exploration skills. This is achieved through multi-touch discovery of line segments on touchscreen, supported by sonification feedback. The approach is implemented as a game in which the child needs to guide a kitten to find its mother cat by following with a finger the line connecting them.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in accessibility*; *Accessibility systems and tools*; *Touch screens*; *Auditory feedback*; • **Social and professional topics** → **People with disabilities**.

KEYWORDS

Visual impairment, multi touch interation, spatial understanding.

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1 INTRODUCTION

Embossed paper, thermographic prints and 3D models [3, 12] are some of the tactile materials commonly used by people with visual impairments or blindness (VIB) to access spatial representations. To explore such materials, a common strategy is using both hands to assess the overall size and structure of the examined object, acquire relative positions between the explored parts, and thus build a mental model of the object [13]. However, tactile materials take time to model, require special instruments and often need sighted operators to be created. Furthermore, the quantity of information they can convey depends on their size, and once created they cannot be changed or updated [5].

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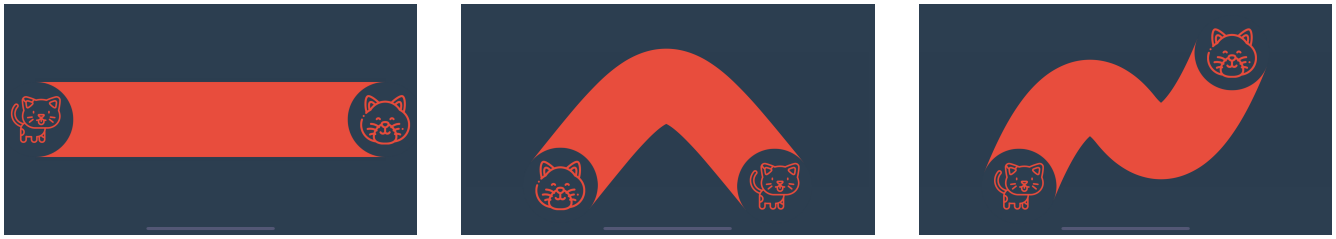
Mobile devices with touchscreen interfaces can be used in place of tactile materials to support access to spatial information. These devices can provide the overall understanding of absolute and relative positions of the spatial elements on the screen through proprioceptive exploration, conveying additional information about the explored parts through audio-haptic feedback [8]. Such approach can be useful at different education levels: from grade school [7] to higher education [1]. However, existing approaches commonly support only single-touch exploration, which is a limitation when the aim is understanding how different elements relate spatially, and it is in contrast with the habitual multi-touch exploration approach used for exploring physical objects [13].

To explore different forms of interaction, we developed *SoundLines*, a mobile game that children with VIB can use to exercise spatial exploration skills. The game's goal is to help a kitten reach its mother cat by following the line connecting them with a finger on the touchscreen, while guided through sonification. The child first explores the touchscreen to find the kitten, then the mother cat, and finally to follow the line that connects the two, without going too far from the line. *SoundLines* implements two exploration modalities. In single-touch modality, the mother cat and the kitten are found in sequence and then connected, all with one finger. In multi-touch modality, the mother cat is found with one finger as before; then, while holding the first finger on the screen, the kitten is found with another finger, which is then used to trace the line between the cats. Three sonification guidance modalities are available while tracing the line: volume modulation, pitch modulation and period modulation. Exploration can also be performed without sonification, relying only on proprioceptive sensing.

2 *SOUNDLINES* SYSTEM

SoundLines was defined together with two experts in accessibility and education for children with VIB. Its goal is to provide children with VIB, who are most impacted by the lack of accessible spatial information [11], with a means for exercising with spatial concepts. To support this goal we define a list of design guidelines:

(D1) Enable accessible, autonomous and inclusive usage by children with VIB and signted children.
(D2) Stimulate prolonged usage through entertaining, engaging and interesting interactions.
(D3) Allow care-givers (teachers, parents) to supervise the usage through the visual interface.
(D4) Explore usage with single- and multi-touch interaction and diverse sonification modalities.



(a) Straight Line (b) Curved Line (c) Broken Line

Figure 1: *SoundLines* exercises with different types of line.

2.1 Gamification

As suggested in prior literature [2], in order to be engaging for children (D2), we developed the app as a mobile game. The game is structured in a series of simple and quick rounds. In each rounds, the child explores the touchscreen surface in search for two randomly positioned elements: a kitten and a mother cat. Then, the child guides the kitten to reach the mother cat by traversing a thick line that connects them without going out of the line.

The line connecting the cats is a bezier curve [4], generated as a Scalable Vector Graphics (SVG) path [6]. It can be a straight, curved or broken line (see Figure 1) of arbitrary width. The cat and line elements are announced through audio and displayed visually in order to also allow sighted children to play (D1), and care-givers to follow how the child is interacting with the system (D3). To support the children in playing the game autonomously, before each round, instructions on how to play the game, including the exploration and the sonification modalities used, are displayed visually and read through the system's text to speech functionality (D1).

2.2 Interaction Design

We designed two exploration modalities: single-touch exploration with only one hand, and a multi-touch exploration with both hands (D4). In single-touch exploration the user scans the area of the touchscreen with one finger only, relying on proprioceptive sensing to understand the position of the explored surface, while auditory feedback provides supporting information such as the presence of elements of interest [1].

In multi-touch interaction, we replicate a technique commonly used by people with VIB for the exploration of tactile materials: multi-touch exploration with one static hand and one moving hand [13]. In this approach, one finger is used as an anchor for a previously accessed element of interest, while a second finger explores other elements. Proprioceptive sensing conveys the spatial relationship between the explored elements and the element anchored by the static finger. Auditory feedback (as in single-touch exploration) is also possible as a reinforcement cue.

2.3 Sonification Modalities

To support touchscreen exploration, *SoundLines* translates spatial information into non-speech audio [9] (D4). We sonify the distance d between the user's finger and the centre of the line connecting the cats. The distance ranges between 0 when the user's finger is on the line centre and 1 when it is exiting the line.

We adopt the following sonification modalities[1]:

Volume modulation [14] - A pure sine wave sound ($440Hz$) is played continuously, having the volume set to minimum (0, that is no sound) when the distance $d = 0$, and to maximum (1, that is maximum device) when $d = 1$. Thus, the sound is louder when the finger is about to exit the line.

Pitch modulation [1] - Again, a pure sine wave sound is played continuously. Its frequency is set to minimum ($250Hz$) when the distance $d = 0$, and to maximum ($650Hz$) when $d = 1$, resulting in a higher pitched sound when the finger is about to exit the line.

Period modulation [10] - A ping sound of a duration of $0.1s$ is played repeatedly. The time between two sounds is set to maximum ($0.5s$) when the distance $d = 0$, and to minimum ($0s$) when $d = 1$. Similarly to the sound produced by car parking sensors, this sonification results in more frequent sounds when the finger is about to exit the line.

Additionally, we also consider the following condition:

No sound - In this condition, no sonification is used. The user can only rely on proprioceptive sensing for the exploration. Clearly, this condition can only be used for straight lines, for which the direction to follow is known.

3 CONCLUSION AND FUTURE WORK

SoundLines is a prototype of an edutainment mobile application aimed at supporting children with VIB in exercising spatial exploration skills. This is achieved through proprioceptive sensing, stimulated with single- or multi-touch interaction on the surface of the device touchscreen, coupled with different possible sonification feedback modalities used as reinforcement cues.

As future work, we will run user studies and longitudinal experiments to evaluate the ability of *SoundLines* to support children with VIB in exercising spatial skills. We will also experiment with different exploration modalities, such as simultaneous exploration with two hands, which is commonly used for tactile exploration [13].

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[1]The sounds used can be found at https://soundlines.netlify.app/

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