"From Dots To Shapes": an auditory haptic game platform for teaching geometry to blind pupils

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Abstract

This paper describes "From Dots to Shapes" (FDTS), an auditory platform composed by three classic games (“Simon”, “Point Connecting” and “concentration game”) for blind and visually impaired pupils. Each game was adapted to work on a concept of the Euclidean geometry (e.g.) The tool, , is based on sonic and haptic interaction, and therefore could be used by special educators as a help for teaching basic planar geometry.

KEYWORDS

Games, blind pupils, geometry concepts, multimodal interface, 3D virtual sound space.

1.Introduction

Over the past few years, the computer has become an important tool for educators as a teaching medium. This is further confirmed since the coming of the WWW and the opportunities concerning distance learning [10]. For teachers specialized in the training of visually handicapped pupils, computers have been their unique way to teach some curriculum themes such as reading or writing. For other domains like geometry, this is not the case because educators favored touch as the input perception channel and tactile devices are very expensive [3,4].

Recently, triggered by the advent of 3D audio technology, various investigations have been made regarding the use of 3D auditory cues to convey visual information [2,11]. The results of the research points out the fact that the use of 3D immersive soundscape could be useful by the blind to mentally represent the topology of a graphical environment.

According to these results, we have created "From Dots to Shapes", an auditory game platform whose goal is to help educators in their teaching blind and visually impaired students basic Euclidean geometry. Here, we found two advantages for working with auditory instead of tactile. The first advantage concerns the easy adaptability of this method for distance learning strategy by using low cost devices. Also, by interacting on a 3D sound environment, blind pupils also enforce their orientation and mobility skills [5]. Auditory perception however does not allow as precise a shape recognition as touch; "From Dots to Shape" is therefore not aimed as an alternative but as a complement to the classical training methods.

2.Game description

The three games we have developed correspond to the three stages that blind pupils undergo during their planar geometry learning curriculum, that is the learning of:

- Points : identify and define the coordinates of a point in a plane;

- lines : identify or define the length, orientation, starting and ending point locations;

- Polygons and curves: recognize, identify and analyze their relationships concerning lengths or orientations.

In this "classical training", the first stage is accomplished by positioning small pawns (representing the points) on a tactile grid (see figure1.a). The second training stage, aiming at teaching the line concept, consists of linking the points defined before (see figure1.b). In the final stage, 2D shapes such as circles and squares, educators use embossed pictures as shown on figure 1.c or use real examples in nature such as book boundaries to represent rectangles or squares [7].

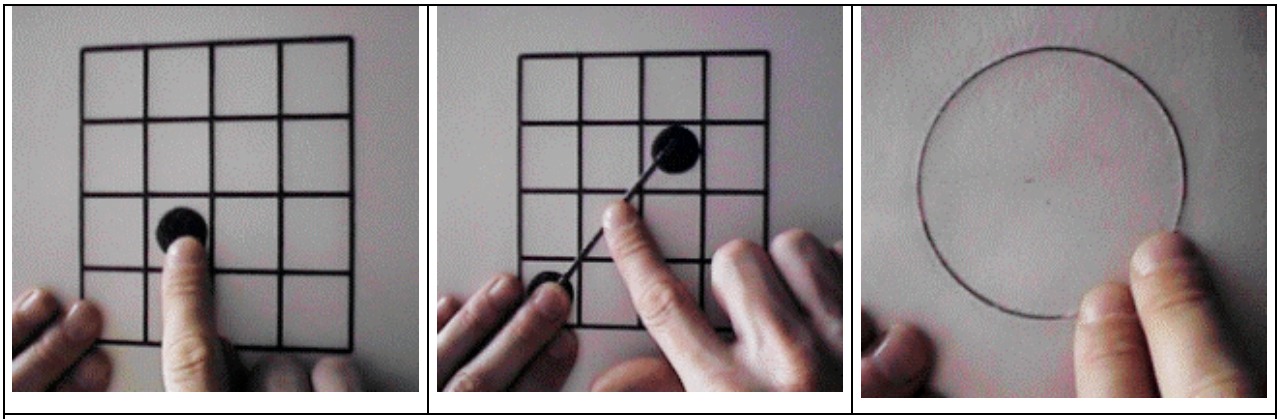

Figure 1. the three classical learning stages with: (a) point localisation, (b) line recognition, (c) shape identification.

With our tool, these three stages are respectively complemented by means of the three sonic games "Simon", "Points Connecting", and "Concentration" described below. For all these games, the output feedback is provided by means of a "sound screen" which is an auditory image of the game board (see section Sonification Principle), while the input device is a graphic tablet (see section on Haptic Interaction).

2.1.Simon

In this game, the player hears a sequence of sounds characterized by their tone, as well as by their location on the sound screen. The player has then to reproduce the sequence in the correct order and at the correct locations on the graphic tablet. This game allows to practice the localization of points within a plane.

2.2.Points connecting

This game could be played in two different ways. On the first mode, the player listens to two auditory cues located at two different positions on the sound screen. The objective is to define the line that connects the two points by means of the graphic tablet. On the second mode, the user hears an auditory cues which represents the line. Here, user have to locate the starting and ending points of the line.

2.3.Concentration game

The rules are similar to those of the traditional concentration game, and aims at teaching planar shapes. Our game has three different levels, each level offering 4 pairs of geometrical shapes of increasing complexity that have to be matched. These shapes, such as a horizontal line, a square, a circle, a rectangle, are first sonified (see Sonification Principles below) and then randomly hidden "behind" a rectangular array comprising eight cells numbered 1 to 8. The goal is to associate the 4 pairs of shapes together, after the player has heard all the 8 auditory cues. For instance, if our array is configured as {square, rectangle, rectangle, circle, square, triangle, circle, triangle}, then the expected answer will be {(1,5),(2,3),(4,7),(6,8)}.

2.4.Network extension

In addition, “FDTS” also provides two students the opportunity to play together by using two different computers connected through the network. Therefore, we adapted "Simon" and "Points connecting" games. In this case, the sequence of sounds is that perform by the second player by means of graphical tablet.

3.Sonification principle

In order to represent the geometrical elements (points, lines, polygons and curves) on a plane, we have investigated an approach based on sound localization using headphones [12]. Two models can be used to map the plane into the sound screen, the discrete model and the continuous model. In the discrete model, the auditory plane is decomposed into N * M position cells; this model is

used to represent points. The continuous model is used to represent lines and shapes. In this model, a moving sound that is acoustically drawn within the sound screen renders the shape. For instance, if the shape to be rendered is a square in a vertical plane, the player will hear in that plane the sound moving horizontally from the upper left to the upper right, descend vertically, move horizontally from the bottom right to the bottom left and finally ascend to reach the initial position. The use of one model or the other depend of the game.

For both models, the bidimensional sound space can be either horizontal or vertical plan according to the players wish. Concerning auditory perception, several research results point out the difficulties in localizing a sound in the azimutal plane, as well as in differentiating the front from the back. A number of functionalities were therefore added to enhance the auditory perception, such as:

- for the discrete model, the player can choose the granularity of the virtual sound screen by varying either the horizontal or the vertical cell size;

- a reinforcement of the elevation rendering is done when using the vertical plane by means of a frequency variation [11]. Thus, a decrease in height will be perceived as a frequency decrease;

- the use of the Doppler effect [1] to enhance the front/back differences

- the possibility for the player to choose their sounds, as either melodic (for instance pure tones), ecological (such as the sound of an helicopter), or speech like (such as an interjection);

- a particular coding of line junctions for patterns composed of several lines (e.g. square, triangle) by using alarms such as a "beep".

4.Haptic interaction

The studies of Lumbreras and al. [6] and our earlier work [8,9] validated the hypothesis that a 3D immersive virtual sound environment combined with haptic manipulation and audio feedback,

can enable blind users to construct a mental representation of the spatial environment. Therefore, we use as the haptic device, a graphical tablet that provides a direct positioning of the finger in the auditory plane. The haptic interaction is used for the first two games.

In the case of the Concentration game, this haptic interaction is only used during the training phase. During this phase, in order to enable students to familiarize themselves with the auditory shapes, we have created for all the geometrical shapes their tactile representations using a specialized thermal printer that produces output on swell paper. The swell paper outputs are placed on the graphic tablet so that the user is able to follow the shape edges with his/her fingers. Simultaneously, the system responds with an audio feedback related to the finger position on the graphical tablet.

5.Hardware configuration

The implementation and preminilary evaluation of the program was made on a Pentium PII equipped with a SoundBlaster Live sound card and a Sennheiser headphone. For the 3D sound rendering, we used the DirectSound3D Library available from Microsoft. For the haptic interaction, we took a WACOM Intuos A5 graphical tablet.

6.Preminilary evaluation

We choose to first test the game with adults rather than children because blind adults have a longer experience in using geometrical shape representations, and they can provide more useful feedback to help in the design of the game.

6.1.Participants and scenario

The concentration game was tested with four blind people aged 20-35. Two of them were totally blind since birth, the third since the age of 8 and the fourth since the age of 13. Three participants have musical experience. The evaluation session evolved each participant to complete whole game level for a period of one hour. Each level was defined using the following shapes:

- level one : horizontal line, vertical line, diagonal line starting at the upper left corner, diagonal line starting at the bottom left corner;
- level two : one diagonal, square, triangle, circle;
- level three : square, rectangle, circle, oval.

At each level, the participants were asked to perform the following two tasks:

- to associate the corresponding auditory cues;
- to determine to which geometrical shapes the auditory cues corresponded. At the end of the experiment, we asked the users to comment on the difficulties they encountered.

6.2.Results

The results showed that the participants recognized and were able to match all the shapes that we proposed, except for the oval and the circle. After further training on these shapes, only one user was not able to distinguish between them. We also observed that the training task was more useful for people blind since birth, and that blind people with musical experience had more facility playing with this game. Finally, all users believed that this game could be very useful for young pupils in their education.

7.Conclusion

This paper has described the design of an auditory game platform that could be use by special educators as complement of their geometry learning. The preliminary evaluation on blind adults indicated that in general, our auditory coding techniques are understandable by the blind. The next step in our work will be the evaluation of the whole platform with young pupils in order to enforce our preliminary results. The final goal of this study is to prove that geometry can be also adaptable on computer by special educators as a learning instrument with no need of additional equipment.

In addition, we are currently finalizing the design of an exploration tool for graphics, which allows blind users to analyse simple drawings by using sounds and force feedback as output devices.

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