Touching geometry for visually impaired pupils

Sophie Rouzier[1], Bernard Hennion[1], Tomás Pérez Segovia[1], Denis Chêne[2]

[1] France Télécom R&D, DIH/OCF, 28 chemin du Vieux Chêne, 38240 Meylan, France
defiscience.balg001@rd.francetelecom.com
bernard.hennion@rd.francetelecom.com
tomas.perezsegovia@rd.francetelecom.com
[2] France Télécom R&D, DIH/UCE, 38-40 av. Général Leclerc, 92794 Issy-les-Moulineaux Cedex 9, France
denis.chene@rd.francetelecom.com

Abstract. This paper describes a system based on haptics and sound, to assist teaching planar geometry to visually impaired pupils, and then provides more details on experiments carried out in a specialized school. This system allows to haptically read, measure and construct geometrical figures. Moreover, it can help blind pupils to shape a mental representation of geometrical and topological concepts.

1. Introduction

Geometry is certainly one of the most difficult subjects to teach to blind pupils [1] and one of the most useful at the same time, as it is necessary for the construction of their own mental space representation [4]. This mental representation is essential for education as well as for everyday tasks.

Classic geometry teaching is based on visual modality: drawings, graphs, lines, curves, etc., all of these being unavailable to blind people. We propose to use haptic and auditory modality as a substitute for such visuals to teach simple geometric shapes [2].

In the following section, we present our system called SALOME. Section 3 details the context, the organization and the results of the first two experiments carried out in a school for visually impaired students. Section 4 describes our current work at improving the system, taking into account the results of the experiments. Sections 5 and 6 conclude with future work and perspectives.

2. System description

The system is first described from a technological point of view, and then from a functional one.

2.1 Technological description

The basic technology used in SALOME is the haptic force feedback device. We developed a software application that uses this haptic device like an active haptic pen, writing with friction on a virtual page. Geometrical figures are coded as haptic *magnetized rails* that attract the pen towards the different elements of the diagram. Points generate attractive forces, leading to hollows or "magnetic points". Straight lines generate haptic narrow grooves and circles circular grooves. Each element has also an audio description (synthesizer voice) that enhances the proprioceptive perception of the element. The sequential audio-haptic perception enables to shape some spatial representation of this figure. The pen runs on a virtual haptic plane and may be pulled or not along each groove, leading to passive or active exploration mode; it may also be kept inside, outside, or on the outline of any closed figure, triangle, circle, etc.

2.2 System functionalities

Figure reading. To understand the figure, visually impaired pupils have to move their *haptic pen* and feel straight lines, points, curves, angles, etc, with it. A synthetic voice module tells the name of the element being touched either at their request, or in a continuous mode. A notion of the relative spatial positions of the different elements is so sequentially built in the blind person's mind.
Figure measuring. The user can quantify the length of segments or the spread of angles thanks to a graduated ruler with centimetre-separated notches and a haptic circular protractor regularly notched, every 30° for example (see Fig.1).

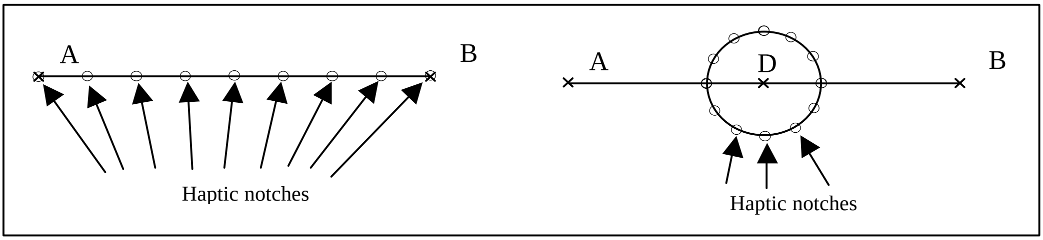

Fig. 1. Haptic ruler and haptic protractor

Figure construction. Lastly, the user can make nice and precise drawings. Currently, the following functions are available: i) Place a point anywhere (at the current position of the pen); ii) Draw a line, given two points; and iii) Use the haptic ruler and protractor.

3. Experiments

The context and the organization of the experiments will be described first. Then, some results and observations on these experiments will be given.

3.1 Context presentation

This work is carried out in collaboration with the EREADV of Villeurbanne, a specialized school for the visually impaired near Lyon in France. There are 14 pupils per class at the most. Pupils with amblyopia and blind pupils are mixed. However, both groups don't work at the same pace. Their geometry curriculum is the same as for the sighted ones. However, the time spent with each blind pupil is much longer! The main request of teachers is to reduce the time spent with each pupil by making the wording of the exercise understandable by all pupils at the same time and by giving the possibility to each pupil to solve it by himself. The main request of pupils is to make nice drawings so that they *can be proud of their work*. Usually, a plastic sheet is used to draw, and all lines, even construction lines, leave so many raised traces that at the end of the exercise the drawing becomes illegible.

3.2 The organization of the experiments

We chose to start working with secondary school pupils, as the difficulty level in geometry is not too high yet while not being a starting one. We carried out two experiments in this specialized school with six teenagers and two adults testing SALOME. These experiments are described in this section. Comments of the first experiment guided some developments used in the second experiment a couple of months later.

First experiment. The goal of the first experiment is to test on blind subjects the usability both of the haptic device and of our application, observing their difficulty to get used to it and their ability to describe and recognize simple 2D figures. After a few explanations and a few minutes to get used to the force feedback device, a series of single 2D geometrical figures is presented to them (Fig.2.). They have to recognize these shapes using the three haptic modes to explore a figure: *exterior*, *interior* or *contour* modes. They also have to describe them, answering questions such as: which edges are equal? Is it an acute or obtuse angle? Which edges are parallel? What is the smallest edge?

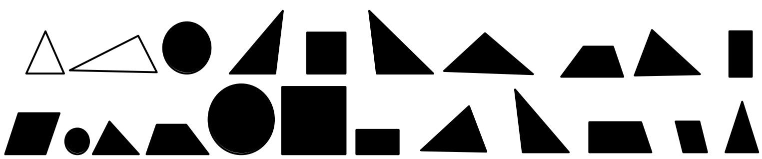

Fig. 2. Simple geometrical figures for the first experiment

Second experiment. The goal of the second experiment is to evaluate the ability of the subjects to describe and recognize more complex 2D figures, composed of several simple figures and to make a simple geometrical construction exercise : draw the perpendicular bisector of a segment.

Like in the first experiment, subjects start by getting used to the system with its new naming functionality, then train on a few simple figures. After that they have to describe and recognize a series of seven figures (see Fig.3.). We particularly pay attention to the following: do the pupils touch every object of the figure? Do they use the naming functionality? Do they check out every characteristic of the figure?

Finally, subjects are asked to draw the perpendicular bisector of an eight-centimetre horizontal segment. To do this, subjects have two haptic tools at their disposal: a haptic graduated ruler and a haptic protractor (see section 2.2).

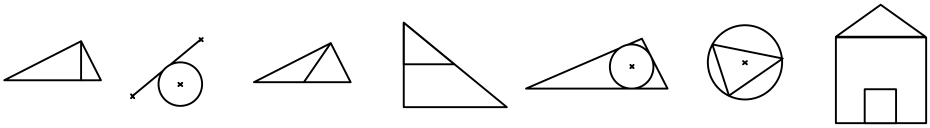

Fig. 3. Composed geometrical figures for the second experiment

3.3 Results from experiments

First experiment. This was the first presentation of our system to visually impaired subjects. The haptic device was accepted very quickly by the children but not as quickly by the two adults. They all were able to discriminate the length of two segments if they differed by more than 20%. The angles were also discriminated within about 15°. During this experiment, some perception bias was noticed qualitatively regarding differences in radial vs. tangential perception [5] as well as the influence of the size and orientation of the shape in the recognition time and rate. The *exterior mode* was discarded, as it is very difficult to recognize shapes with it.

C*ontour mode* vs. *interior mode*: No better mode could clearly be distinguished. One person preferred *contour mode* for triangles and *interior mode* for quadrilaterals; another preferred *contour mode* to identify the shapes and *interior mode* to perceive their characteristics. Other points were noticed: when the stylus is held not firmly enough it vibrates; and when it is held too firmly, the motors get so warm that the overheating protection is activated.

Second experiment

2D composed geometry *Using hollow points* enhances angle perception, but may mislead too: one person perceived an angle where there wasn't any. He perceived a quadrilateral instead of a triangle with a point on one of the edges. Another confusing intersection was in the “triangle and inscribed circle” figure (see Fig.4.) where one of the angles (“B”) was never reached. The stylus passed from the segment AI to the arc IJ and then to the segment JC, the subjects not perceiving the triangle.

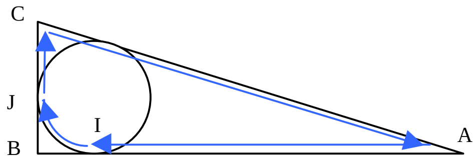

Fig. 4. Triangle and inscribed circle (black) and the exploration path (grey).

All the intersections are a problem as it is difficult to express haptically the number of segments and their distribution on the intersection. This difficult problem is still to be solved.

Construction *The* haptic ruler and the haptic protractor were enthusiastically received. All the subjects were able to get to the end of the job.

Conclusion

All of the subjects were enthusiastic about the experiments. We did not notice any kind of rejection and every subject could do what we asked them to. In the simple 2D geometry experiment, the results were better than expected in shapes, lengths and angles recognition. Unfortunately, we did not make any quantitative evaluation of shapes recognition. In the 2D composed geometry experiment, results were encouraging in spite of a number of pitfalls like the intersections.

4. Current and future work

Following the second experiment, it was decided with the teachers to develop an embryonic haptic editor that would allow a pupil to do a real geometrical exercise by himself. Thus, we are currently implementing more commands to create elements with some characteristics (place a point in the middle of a segment, draw a parallel given a line, draw a circle given a centre and a radius), and the ability to manipulate geometrical objects. The goal of the next experiment is to test SALOME in a real teaching situation between a teacher and a pupil. The pupil will have to do a geometric exercise (refer to the appendix) that corresponds to his geometrical knowledge. We will observe the behaviour of the pupil and the teacher, collect their remarks and concentrate on the following questions: what could be modified in the system to improve the interaction between the pupil and the system, the teacher and the system, the pupil and the teacher through the system? How could the system integrate the teaching process?

There are some issues that need further consideration and which, therefore, will be at the focus of our future research. How could the user be prevented from leaving a figure unless doing it intentionally? How to discriminate straight lines from curves? How to differentiate different kinds of points like the vertex of a triangle and the intersection of two lines? The same problem arises with right angles and other angles, and with construction lines and final ones. The *ruler tool* is currently a measuring tool only for segments; therefore, we have to add a tool for measuring all kind of distances. One major difficulty is to find out haptically if two lines are parallel,