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# MS-EXPLORER: Multimodal Spatial Access to Information for Visually Impaired People

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**Abstract.** The objective of the MS-EXPLORER project is to provide a new interaction paradigm for document access for visually impaired people. This paradigm aims to preserve spatial structure of information, in particular two-dimensional information such as mathematical formulas, maps, web pages, arrays, diagrams, etc. The approach consists in combining different interaction modalities to present the information and relies on the definition of three levels for information access. First, the *spatial level* allows the user to perceive the overall spatial structure of the information without being bothered by the details. Then, the *type level* allows having access to the type of information currently explored by the user's fingers (image, paragraph, list, array, menu, etc.). Finally, the *substantial level* allows getting the detailed content of the currently explored element. Different modalities and devices (dynamic tactile graphics, braille, speech synthesis) will be used to provide access to these different levels. A first prototype has been developed and a preliminary study to determine how to render the spatial structure has been conducted.

**Keywords:** Multimodal, Spatial, Access, Visually, Impaired.

## 1 Introduction/Background

Blind people can have access to digital documents using specific software: screen readers. Screen readers allow to present in a linear way, either through speech synthesis or braille, the content of a document or elements of a graphical interface to a blind user. However, it is not so easy for a blind user to explore 2D structures in this way [10]. The user faces many problems such as disorientation and difficulties to memorize and to build a correct mental model of information. This represents a major obstacle to access to advanced-level studies for blind people. A major problem with the screen reader approach is that it leads to losing the spatial structure of information, which is very important for different kinds of information such as maps [2] [9], mathematical formulas [1], graphs, arrays, electronic schemas, diagrams [3], etc.

## 2 Methods

To preserve the spatial structure of information, we propose to combine different modalities and devices with three access levels to information (see Fig. 1). This paradigm allows visually impaired people to explore a document in a 2D space (the refreshable dot-matrix display) in the same way they do with a static embossed document [7], except that the document here is dynamic and that they can interact with it.



Fig. 1. The 3 access levels to information

### 2.1 Spatial Level

Using a refreshable dot-matrix display, this level allows the user to perceive the overall spatial structure of the information (size, position...) without being bothered by the details.

### 2.2 Type Level

This level allows the user to have access to the type of information currently explored by the user's fingers (image, paragraph, list, array, menu, etc.). This level can be rendered either by using speech synthesis or braille.

### 2.3 Substantial level

This level allows the user to get the detailed content of the currently explored element such as the description of an image or the text of a paragraph. This level can also be rendered either by using speech synthesis or braille.

## 3 Challenges

This paradigm raises different scientific and technical challenges.

### 3.1 Spatial structure rendering

A first challenge is to determine the best way to render the spatial structure: which geometrical shapes should be used and how to render them (empty, solid, vibrant...) (see Fig. 2).

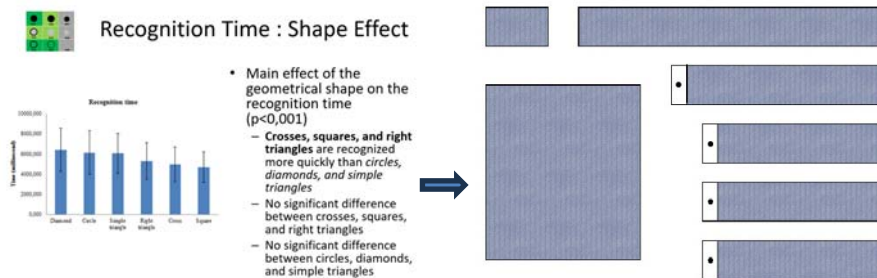


Fig. 2. Spatial structure rendering.

### 3.2 Exploration strategy

It will be interesting to analyze the exploration strategy that users will use to explore the document. This may have an impact on the rendering technic that should be used. Also, it will be interesting to compare such a strategy with the one involved when exploring an embossed document [8].

### 3.3 Modalities and devices Assignment

Different modalities and devices can be used for each access level. For instance, speech synthesis may be used for type level and braille for substantial level, but the opposite is also possible. It is also possible to use speech synthesis or braille for both levels. For the spatial level different devices [4] [5] can also be used (refreshable dot-matrix display, braille mouse, Laterotactile Display...). It will be interesting to study different scenarios to analyze the user's preferences regarding the modalities and devices assignation for each level.

### 3.4 Fingers position and identification

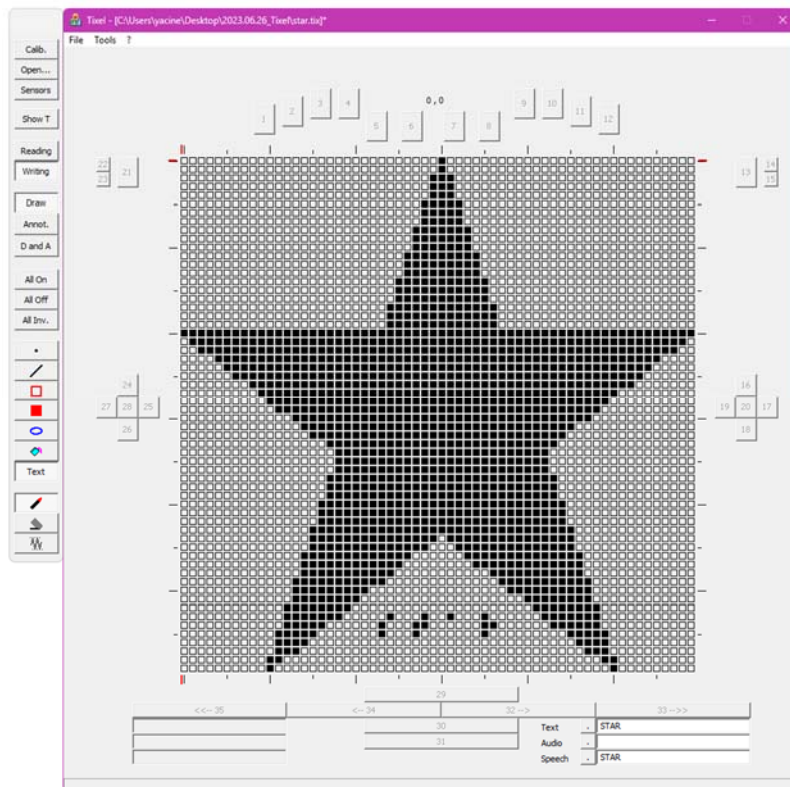
It is necessary to be able to detect accurately the fingers position and to identify them to define a strategy for choosing which information under which finger (right index, left index, both...) should be communicated to the user.

### 3.5 Navigation interaction techniques

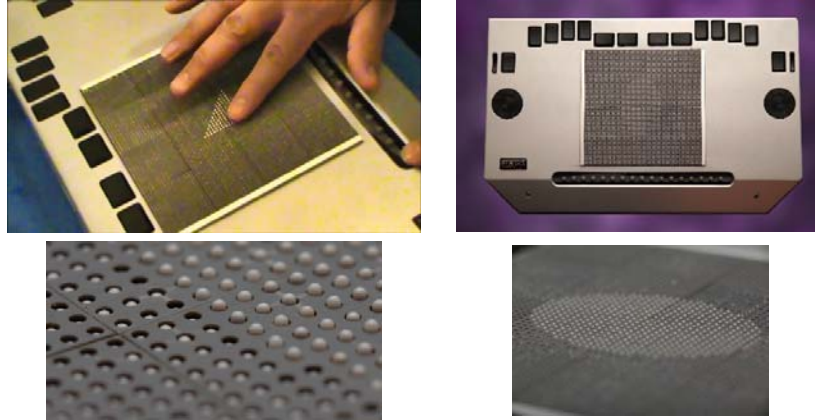
Due to the small size of dot-matrix displays and similar devices, there is an important need for efficient interaction techniques that allow fast and easy navigation in the spatial structure (zooming / panning / scrolling...). Such interaction techniques for visually impaired people still have to be developed and evaluated.

## 4 Preliminary User Studies

A first prototype allowing to create documents using the described paradigm has been developed (see Fig. 3). This software called MS-EXPLORER EDITOR allows to easily create documents following the described paradigm using a 3600-dot-matrix display (60x60 dots) from metec AG (see Fig. 4) and Microsoft Speech Synthesis. Concerning braille rendering, the software allows displaying braille characters in any area of the dot-matrix display. An important benefit of this metec device is that it is equipped with sensors allowing to determine the position of the fingers on the dot-matrix display.



**Fig. 3.** MS-EXPLORER EDITOR.



**Fig. 4.** Metec AG 3600-dot-matrix display.

Of course, the final objective is to be able to generate automatically the spatial structure from a source document, but as a first step toward this objective, we have used this editor to conduct two preliminary studies.

The first study has been conducted with 40 sighted subjects (31 men and 9 women), aged from 18 to 40 (M age = 23.7; SD age = 5.2). During the experiment, subjects were able to touch the dot-matrix display but cannot see what is displayed on it thanks to a raised cover that hides it.

A second study has been conducted with 52 visually impaired subjects (31 men and 21 women), aged from 17 to 85 (M age = 46.8; SD age = 19.7).

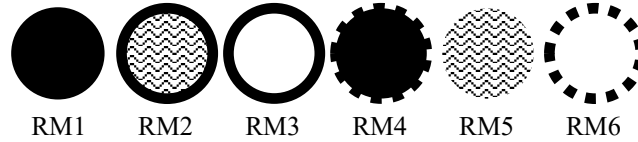
In this paper, we present the results of the first study. The results of the second study are still under analyze process and will be presented in future publication.

The objective of the first study was to address the first challenge (see Section 3.1) to determine the rendering features that allow the fastest and most reliable recognition of geometrical shapes. Six different shapes were used in the experiment. These shapes are the same as the ones used in [6]: square, circle, simple triangle, right triangle, diamond and cross (see Fig. 5).



**Fig. 5.** The six shapes used in the study.

Six different rendering methods were used depending on the way the outline and the inside of the shapes are displayed (static, vibrating or empty). Fig. 6 illustrates the 6 rendering methods.



**Fig. 6.** The six Rendering Methods (RM) used in the study.

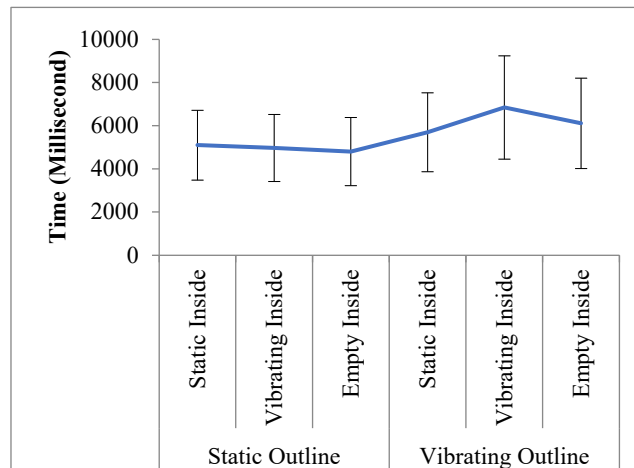
Finally, we used three different sizes: small, medium, and large which correspond respectively to 2, 3 and 4-cm bounding square.

During the experiment, the geometrical forms varied according to the shape, the size, and the rendering method. The order of the shapes, sizes and rendering methods was randomly generated across participants. In all, each participant had to recognize 324 shapes (6 forms x 3 sizes x 6 rendering methods x 3 sessions).

## 5 Results

For each shape, we recorded time to recognize it (in milliseconds) and participant's answer. Results show that recognition rate do not vary according to geometrical form, size, and rendering method. The global mean of the recognition rate is 95%.

However, we observed a main effect of the rendering method on the recognition time ( $F(5, 195)=73,237, p<0,001$  see Fig. 7). Post hoc comparisons suggested that the best configuration is when the rendering method combines static outline with empty inside (RM3). Participants recognize faster the shapes with this configuration compared to other configurations. In addition, post hoc comparisons suggested that the worst configuration is when the rendering method combines vibrating outline with vibrating inside.



**Fig. 7.** Recognition time according to the combination of inside and outside rendering.

We observed also a main effect of the geometrical shape on the recognition time ( $F(5, 195)=39,295, p<0,001$  see Fig. 8). Post hoc comparisons suggested that participants tended to recognize more quickly crosses, squares, and right triangles than circles, diamonds, and simple triangles. There was no significant difference between crosses, squares, and right triangles. In addition, there was no significant difference between circles, diamonds, and simple triangles. This can be explained by the fact that most users had a strategy that consists in looking for right angles to identify the form.

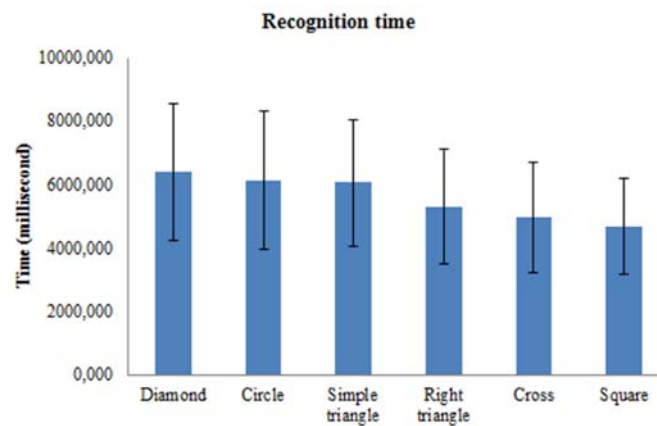


Fig. 8. Recognition time according to the geometrical shapes.

Finally we observed a main effect of the size on the recognition time ( $F(2, 78)=86,157 ; p<0,001$ ). Post hoc comparisons suggested that participants recognized more slowly, small shapes than medium or large shapes. There was no significant difference between the medium and large shapes.

## 6 Discussion

Objective results showed the forms are well recognized regardless of the geometrical shape, the size, or the rendering method. Furthermore, the best rendering method is to use shapes with right angles and with static outline and empty inside. Indeed, the recognition times appears to be significantly better with crosses, squares, and right triangles than with circles, diamonds, and simple triangles. This result provides an interesting cue about the exploration strategy that participants followed. Some of them said that they start by looking for right angles in the shape, which help them to identify rapidly the form (only 1 right angle for right triangles, 4 for squares and a lot (12) for crosses). According to some subjective commentaries, solid shapes can be used when learning a new shape. However, when trying to identify an already known shape, empty shapes allow faster identification. The rendering methods that include vibrations seem to disrupt the participants even if there is no impact on the recognition rate. Participants spend more time recognizing the shapes rendered with vibrations than those rendered with static outline and empty or static insides.

## 7 Conclusion

The MS-EXPLORER project is a long-term project as several challenges are still to be addressed. However, some results have already been achieved. A first prototype allowing to experiment the proposed paradigm has been developed and the results of a first preliminary study have been presented. A very interesting feature of the metec AG dot-matrix display is that it contains sensors allowing to detect touch coordinates on the dot-matrix surface. Future work will focus on the exploitation of this feature which will allow us to start addressing remaining challenges.

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