Towards Digital Image Accessibility for Blind Users *via* Vibrating Touch Screen: A Feasibility Test Protocol

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Abstract—**The World Health Organization (WHO) estimates at 285 million the number of people affected by visual deficiencies, among which 39 millions are totally blind. In our modern society saturated with visual media tools and applications (images, videos, web pages, etc.), accessing visual information becomes a central need for all kinds of tasks and users, including the visually impaired. In this context, various adapted tools of assistance (screen readers, Braille terminals, screen magnification, etc.), have been increasingly helping persons suffering from a visual incapacity to access and manipulate information. While effective with textual contents, nonetheless, existing solutions remain very limited when it comes to accessing and understanding visual contents. The goal of our work is to provide a computerized solution, investigating the use of the vibrating touch screen technology in providing a contour-based presentation of simple images for visually impaired users. This could prove very useful in allowing blind people to access geographic maps, to navigate autonomously inside and outside buildings, as well as to access graphs and mathematical charts (for visually impaired students). To achieve this, we develop a detailed experimental protocol, *EVIAC*, testing a blind user's capacity in learning, understanding, distinguishing and identifying basic geometric objects using a vibrating touch screen. Preliminary tests on blindfolded candidates show promising results with respect to traditional paper embossing.**

Keywords—Visual impairment, data and image accessibility, tactile image, vibrating touch screen, paper embossing, experimental evaluation protocol.

I. INTRODUCTION

The World Health Organization (WHO) estimates at 285 million the number of people affected by visual deficiencies, among which 39 millions are totally blind; these numbers are even expected to double by the year 2020[36]. Yet in our modern society saturated with visual media tools and applications (televisions, books, posters, graphics, web pages, etc.), accessing visual information becomes a central need for all kinds of tasks and users. However, thanks to adapted tools of assistance (screen readers, Braille terminals, screen magnification, etc.), computerized solutions are increasingly helping persons suffering from visual incapacities to access and manipulate information, and perform various kinds of activities previously deemed unfeasible for the visually impaired.

While effective with textual contents, e.g., [1, 2, 6, 10, 31], nonetheless, existing solutions remain very limited when it comes to accessing and understanding visual contents. Most prominent studies in this context, e.g., [14, 15, 22, 32, 38], target low-vision users (i.e., users who are not totally blind) providing visual aids and image enhancement techniques, e.g., adapting image spatial frequency, or applying dedicated image filters in order to adapt image quality to the user's visual deficiency. Other approaches exploit tactile imaging [14, 28] and 3D models [19, 20] in order to reproduce images in an embossed representation, highlighting the senses of depth and distance in an image with different layer structures. Yet, such techniques require expensive equipment (e.g., a 3D printer).

The long term goal of our ongoing study is to provide an accessible and affordable (cost-efficient) solution for presenting simple (contour-based) pictures to visually impaired users.Accessing contour (edge)-based images could prove very useful in allowing blind people to access geographic maps [13, 34], to navigate autonomously inside and outside buildings [11, 30], as well as to access graphs and mathematical charts [3, 26] (e.g., for visually impaired students [18]). Here, we focus on image accessibility for totally blind users [1] ,in distinction with existing studies targeting low-visionusers, i.e., those with some residual vision (e.g., [22, 32, 38]). We also aim to provide a low-cost digital presentation of images, in contrast with existing tactile (3D) paper (or plaster) embossing techniques (e.g., [19, 20, 28]), which remain extremely expensive (e.g., a typical tactile image printer costs around ten thousand dollars). In an attempt to achieve this, we study the usability of the vibrating touch screen technology based on low-level image processing, namely image filtering and contour detection.We investigate the usability of vibrating screens in presenting image contours, developing a detailed experimental protocol, entitled *EVIAC* (EValuation of Vibration ACcessibility) in order to test a blind user's capacity in learning, understanding, distinguishing and identifying basic geometric objects. A dedicated prototype system has been developed based on the proposed experimental protocol. Preliminary experiments on blindfolded candidates show promising results in comparison with the traditional paper embossing technique.

The remainder of this paper is organized as follows. Section 2 reviews the background and related works on data and image accessibility for the visually impaired. Section 3

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[1] Total blindness underlines the complete lack of light perception, and thus the lack of any residual vision.

presents an overview of our ongoing study and image accessibility framework. Section 5 develops the *EVIAC* experimental protocol. Section 6 presents preliminary experimental results. Section 7 concludes the paper.

II. BACKGROUND

Providing information and data accessibility for people with visual deficiencies has been investigated since the early 1970s, namely for text-based data [1, 2, 6, 10, 31]. In most cases, given an input text-based document, the output is a text-only document with a transcription of the structure, content, and illustrations from the original document, such as the transcription is accessible to the visually impaired via tactile (e.g., Braille print[2]) or acoustic (e.g., text-to-speech) means. The process can be briefly described in four main steps: i) *Document pre-processing* to identify the syntactic structure of the document (sections, paragraphs, tables, figures, etc.), ii) *Optical Character Recognition* (*OCR*) in order to identify the meaning of textual contents, iii) *Metadata structuring*, extracting tags and labels from the original document in order to describe the output document's structure (title name, section name and identifier, page numbers, etc.), which is central in order to allow navigating the document afterwards, and iv) *Output file generation*, exporting the output document to the target delivery format, which is generally *Braille print*, *pdf*, *(X)HTML*, *XML*, or a structured *.doc* file [10, 33]. Note that with non-Braille output formats, an embedded audio support (text-to-speech) system is generally used [2].

In addition, recent studies have focused on accessing specific kinds of textual contents, such as chemical chains [31] and mathematical formulas [6] mainly for educational purposes (accessibility for visually impaired students [18]).

While proficient with textual contents, however, existing solutions to data accessibility for the visually impaired remain very limited when it comes to handling visual contents. Understanding and manipulating digital information has become even more complex due to the massive intrusion of images and graphical interfaces in computer-based systems and on the Web, with different presentations of text layouts, fonts, shapes, colors and orientations[5]. In order to deal with these constraints, various kinds of devices have been developed, such as: refreshable Braille display terminals, screen readers, text-to-speech synthesizers, talking browsers, etc. Most prominent studies in this context, e.g., [14, 15, 22, 32, 38], target low-vision users (who are not totally blind) providing visual aids and image enhancement techniques, e.g., image contrast manipulation [24], spatial filtering [21], adaptive thresholding [23], and compensation filters [8], in order to adapt image quality to the user's visual deficiency. Other approaches exploit tactile imaging [12, 14, 28], where an image is printed by carbon-containing ink on a special paper coated with microcapsules which can be foamed thermally. Then, a stereo copying machine processes the paper such as the black portions of the image are raised so that the image becomes tactile for the visually impaired. More recent studies have explored 3D modeling [9, 19, 20] in order to reproduce images in a layered representation. This technology consists in representing shapes by two-dimensionally compressing three dimensional objects, representing the senses of depth, distance and the spatial composition of a picture with different layer structures (i.e., different levels of thickness). While 3D representations have been shown effective in allowing blind persons to appreciate drawings and art works [19, 20], yet their production remains largely expensive, requiring: i) a 3D projection and sculpting solution to produce an adapted 3D representation for an (original) 2D image, ii) a 3D modeling software or a 3D scanner to digitalize the obtained 3D sculpture, and iii) a 3D molding machine [20], a Braille printer [9], or a haptic feedback device [3] in order to produce the output tactile image to be perceived by the visually impaired.

On the other hand, recent works in [4, 5] have focused on Web pages accessibility for visually impaired Web surfers. Nonetheless, these works focus on (text-containing) Web graphics and the visual arrangement/design of (text-based) objects in a web page, and do not specifically target (text-free) images.

In a nutshell, most studies in the literature focus on text accessibility for the visually impaired (e.g., [1, 2, 6, 10, 31]). Some studies have targeted accessibility to text-based visual contents, namely Web pages and graphical contents [4, 5]. However, accessing (text-free) images remains an ongoing challenge. On one hand, most prominent studies in this context target low-vision users by providing visual enhancements and aids (e.g., [14, 15, 22, 32, 38]). On the other hand, studies targeting image accessibility for the totally blind exploit expensive (and sometimes non-affordable) techniques such as 3D modeling, Braille printers or haptic feedback devices (e.g., [9, 19, 20]), and thus remain moderately practical. In short, *pictures remain largely inaccessible for blind people* [19].

III. PROPOSAL OVERVIEW

The goal of our work is to provide an accessible and affordable (i.e., cost-efficient) means of presenting pictures for visually impaired (blind) users. Our approach relies on efforts made in the fields of image processing and content-based image retrieval. In fact, the automatic retrieval of information in pictures is usually based on extracting low-level information such as colors, shapes and textures, as well as more global objects such as: face detection, and other object recognition processes. Yet, without the ability to automatically analyze low-level image contents, accessibility must only rely on textual metadata such as captions or keywords [35]. While keywords can be easily made accessible to the blind using text-to-speech synthesis, nonetheless, they are often laborious or expensive to produce (such as with manual/semi-automatic annotation) [16, 35].

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[2] The Braille system is a method based on tactile contact, widely used by visually impaired people in order to read and write text. A Braille character is made of six dot positions, arranged in a rectangle containing two columns of three dots each. A dot may be raised at any of the six positions to form sixty-four (2^6) possible subsets (character encodings), including the arrangement in which no dots are raised.

In this context, our ongoing study aims to improve the accessibility of image contents retrieved based on automatic analysis of low-level image features (rather than extracting textual annotations). More specifically, we aim to provide a contour (edge)-based representation of a digital image (obtained using low-level feature extraction and filtering), which could be easily accessible to blind users using a fairly sheep and affordable technique: tactile perception on a vibrating touch screen.

Note that we report the complementary step of exploiting (and generating) image annotations and text-to-speech synthesis to a future phase.

To achieve vibration (contour)-based image accessibility, we study in this paper the usability of the vibrating touch screen technology, based on low-level image processing, namely image filtering and contour detection, in allowing blind users to access simple images. The overall architecture of our ongoing approach is depicted in Figure 1. It is divided into three main parts: i) image preparation, ii) image presentation, and iii) user feedback.

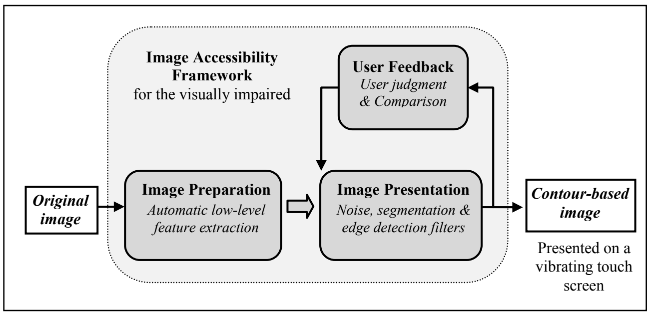


Fig. 1. Overall image accessibility framework architecture.

i. **Image preparation** consists in extracting the visual features and semantic properties of images. Typical low-level (color, texture and shape) feature extraction and salient object identification techniques are used here [16, 17]. Automatic feature extraction can be augmented by manual/semi-automatic annotations, in order to better describe salient objects and semantic characteristics. However, note that we report the complementary step of exploiting (and generating) image annotations and text-to-speech synthesis to a future phase.

ii. **Image presentation** consists in processing the prepared feature-based image via dedicated noise reduction, segmentation, and edge detection filters. Here, we dynamically combine different techniques, namely linear (convolution) and non-linear (median and mean) local filters [17], as well as Sobel, Roberts, Laplacien, and Canny edge detection filters [25, 27], in order to produce an adapted contour-based representation which can be effectively rendered and presented on a vibrating screen. Note that the resulting contour-based image presentation does not necessarily respect the standards and norms of tactile presentations (e.g., stipulating that a single contour line is at least 1 to 2 millimeters think, whereas the separation between two contour lines is at least 3 millimeters think, etc.) [29], since the resulting image is to be presented on a vibrating screen, and not on an embossed paper. In fact, a dedicated experimental study is required to evaluate the difference between tactile perception (for a blind user) on an embossed paper, on one hand, and perception on a vibrating screen on the other hand (which is out of the scope of this study).

iii. **User feedback and filter adaptation** allows the user to interact with the system by providing information concerning images that were perceived correctly and those which were not perceived accurately. In fact, relevance feedback has been exploited with traditional image access and retrieval systems in order to improve image search results [7, 37]. Here, the question becomes whether the output presentation of the image is too complex to understand by touching on a vibrating screen. Hence, user feedback allows to simplify images to such a degree that visually impaired users can understand. Yet, another question here is to what extent images should be simplified, which could depend on the groping strategies used by visually impaired people [28]. Thus, experiments to examine hand movements of visually impaired people while touching contour (edge)-images presented on a vibrating touch screen are required. Consequently, based on the user's judgments in comparison with the actual contents of images, the system dynamically updates its filter configuration strategy and sorting functions (e.g., selecting certain filters, and re-ordering filters) to give a better contour-based presentation of the actual image. In other words, we attempt to bring the user in the image processing loop in order to dynamically adapt the result.

In order to develop the framework architecture briefly described above, we first identify the need to investigate the feasibility of adopting the vibrating touch screen technology as a means for presenting contour (edge)-images. To our knowledge, this is the first approach to study the usability of the vibrating touch screen modality in presenting images to the visually impaired.

IV. Vibrating Touch Screen Evaluation (*EVIAC*) Protocol

In the following, we aim to prove the following hypothesis: *a properly formed contour-based image can be effectively perceived by the visually impaired when presented on a vibrating touch screen* (with respect to the traditional paper embossing technique). This is an essential prerequisite to developing our image accessibility framework (cf. Section 4).

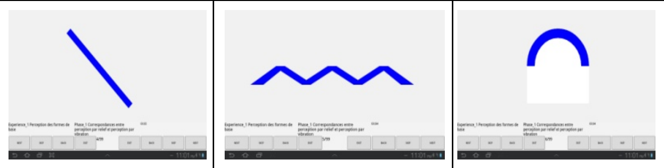
In order to prove this hypothesis, we develop a dedicated experimental protocol (and prototype), entitled *EVIAC* (EValuation of Vibration ACcessibility). It describes the various steps to be followed by a test *coordinator* (e.g., a normally sighted person), in order to administer a set of experiments regarding image accessibility on a vibrating touch screen to a *tester* (e.g., a blind or a visually impaired person). *EVIAC* consists of three main experiments: i) Recognizing basic shapes, ii) Recognizing simple geometric objects, and iii) Recognizing spatial relations between simple geometric objects. Each experiment consists of 4 main phases: i) Mapping between embossed paper and vibrating screen tactile perceptions, ii) Distinguishing between geometric objects (presented on a vibrating screen), iii) Identifying geometric objects (with multiple choices), and iv) Recognizing geometric objects (without multiple choices). All experiments are detailed in the following sub-sections.

Note that prior to executing the experiments, an *environment familiarization and discovery* step is required, in order to explain for each test candidate: the experiments to be conducted, the nature of each experiment, the tasks to be completed, as well as how to handle the vibrating screen (prototypical) environment (e.g., how images are presented on the vibrating screen, control buttons, etc.). In addition, test subject profile data (e.g., name, age, gender, nature of visual deficiency, etc.) are recorded at this stage.

A. Experiment 1: Recognizing Basic Shapes

The goal of this experiment is to prove the following hypothesis: *The visually impaired (blind) are capable of distinguishing, identifying and understanding basic shapes presented on a vibrating touch screen.* To do so, we utilize the 6 basic shapes presented in Figure 2. These generally constitute the simplest shapes which compose basic geometric objects (such as circles, squares, etc.).

a. Horizontal line | **b.** Vertical line | **c.** Sloping line 1



d. Sloping line 2 | **e.**Zigzag line | **f.** Curve line

Fig. 2. Prototype snapshots of the basic shapes in Experiment 1.

The experiment is divided in 4 main phases, allowing to confirm the experiment's main hypothesis (stated above).

- **Phase 1:** Mapping (correspondence) between embossed paper and vibrating screen tactile perceptions.

  The objective of this phase is to test if a blind person is capable of identifying the correspondences between shapes presented on an embossed paper, and their counterparts presented on a vibrating touch screen. It is also considered as a learning phase, providing the *tester* with the correct answers in order to allow the blind person to learn the right correspondences.

  The experimental procedure here is conducted as follows:

  i. Presenting to the *tester* each of the 6 basic shapes (cf. Figure 2), on an embossed paper, in a row, while vocally naming each shape,
  ii. Presenting to the *tester* each of the 6 shapes on a vibrating touch screen, in a row, while asking the tester if she is able to recognize each shape,
  iii. Following each response, the *coordinator* informs the *tester* if the answer is correct or not, and (in case of a false answer) provides the *tester* with the correct response,
  iv. The procedure is repeated until the *tester* is capable of positively identifying the correspondences between embossed paper and vibrating screen presentations for all basic shapes.

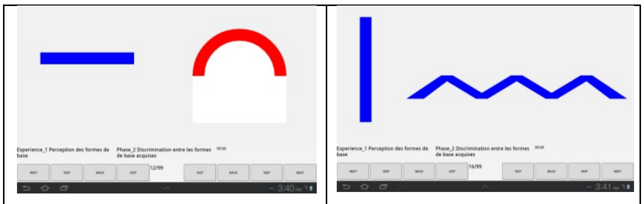
  The number of correct answers, as well as procedure (and phase) execution time, are test parameters that are stored and analyzed later (in order to study and compare the difficulty levels and training times required by different test candidates). This is repeated for each and every experimental phase in *EVIAC*.

- **Phase 2:** Distinguishing between basic shapes

  The objective of this phase is to test if a blind person is capable of distinguishing between the basic shapes acquired in the previous phase, presented as doublets on a vibrating touch screen.

  The experimental procedure here is conducted as follows:

  i. Presenting to the *tester* a number of doublets of basic shapes among those in Figure 2 (for instance, a doublet can be formed of a horizontal line and a curved line, cf. Figure 3), on the vibrating touch screen, without any additional indications. Objects in a doublet are distinguished using two dedicated auditory signals (i.e., one of two audio signals yelling: *Object 1* or *Object 2*, is activated when touching each object).
  ii. Asking the *tester* if she is able to identify whether the two shapes presented in each of the doublets are identical or not (by answering: *true* for identical or *false* otherwise).



a.Doublet consisting of a horizontal line and a curved line | **b.**Doublet consisting of a vertical line and a zigzag line

Fig.3. Prototype snapshots of doublets of basic shapes used in Experiment 1.

Note that the tester's answer is acquired by the coordinator without providing the tester with any feedback (i.e., without telling her whether the answer is correct or not) - which is also the case for the remaining phases (2, 3, 4) of the experiment. This is different from phase 1 (where feedback is provided to the tester), since phase 1 is partly a learning phase.

- **Phase 3:** Identifying basic shapes (with multiple choices)

  The objective of this phase is to test if a blind person is capable of identifying, via multiple choice interrogations, the basic shapes already acquired in the previous phase, presented on a vibrating touch screen.

  The corresponding experimental procedure is conducted as follows:

  i. Presenting to the *tester* a number of basic shapes (among those in Figure 2) on the vibrating touch screen,
  ii. Providing (vocally or on an embossed paper) for each of the presented shapes, multiple choices (e.g., 3 possible answers), concerning the name of the shape at hand,
  iii. Asking the *tester* to identify the basic shape presented on the vibrating touch screen, by choosing one answer from the multiple choices.

- **Phase 4:** Recognizing basic shapes (without multiple choices)

  The objective of this phase is to test if a blind person is capable of identifying, without any additional indications (i.e., without multiple choices), the basic shapes already acquired in the previous phases, presented on a vibrating touch screen.

  The corresponding experimental procedure is conducted as follows:

  i. Presenting to the *tester* a number of basic shapes (among those in Figure 2) on the vibrating screen,
  ii. Asking the *tester* to identify the basic shape presented on the vibrating touch screen, without assistance or additional indications (e.g., without multiple choices).

B. *Experiment 2: Recognizing Simple Geometric Objects*

The second experiment in our protocol aims to prove the following hypothesis: *The visually impaired (blind) people are capable of distinguishing, identifying and understanding simple geometric objects presented on a vibrating touch screen.* To prove this hypothesis, we utilize the 4 simple geometric objects presented in Figure 4. These generally constitute the simplest objects used in drawing images (e.g., vector-based images).

Similarly to its predecessor, this experiment is divided in 4 main phases, allowing to confirm the experiment's main hypothesis (stated above).

– **Phase 1:** Mapping (correspondence) between embossed paper and vibrating screen tactile perceptions,
– **Phase 2:** Distinguishing between simple geometric objects,
– **Phase 3:** Identifying simple geometric objects (with multiple choices),
– **Phase 4:** Recognizing simple geometric objects (without multiple choices).

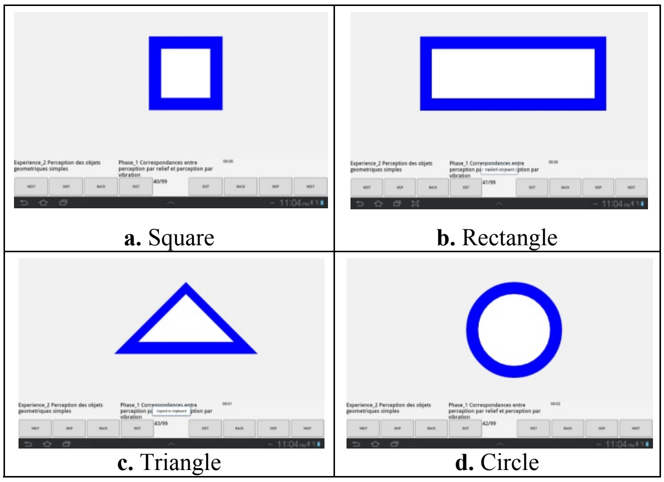

a. Square **b.** Rectangle
c. Triangle **d.** Circle

Fig.4. Prototype snapshots of the simple geometric objects used in Experiment 2.

C. *Experiment 3: Recognizing spatial relations between simple geometric objects*

The goal of our third experiment is to prove the following hypothesis: *the visually impaired (blind) people are capable of distinguishing, identifying and understanding spatial relations between simple geometric objects presented on a vibrating touch screen.* In this experiment, and in order to simplify the task for the *tester*, we perform the tests on one specific geometric object: the square (cf. Figure 4.a).

The experiment consists of 3 main steps focusing on each of the three main categories of spatial relations: i) directional, ii) metric, and iii) topological relations. For the sake of simplicity, we only consider the following relations in our current experimental protocol (cf. Figure 5):

- **Step 1:** Evaluating directional relations: *top-of*, *bottom-of*, *left-of*, and *right-of*,
- **Step 2:** Evaluating metric relations: *far* and *near*,
- **Step 3:** Evaluating topological relations: *disjoint*, *adjacent-to*, *intersection*, and *inclusion*.

Note that when evaluating spatial relations, on-screen objects are distinguished using two dedicated auditory signals, i.e., a different audio signal is activated when touching each object (similarly to distinguishing objects in a doublet, such as with Experiments 1 and 2).

Similarly to Experiments 1 and 2, each of the above steps (1, 2, and 3) is conducted in 4 main phases:

- **Phase 1:** Mapping (correspondence) between embossed paper and vibrating screen tactile perceptions,

- **Phase 2:** Distinguishing between spatial relations,
- **Phase 3:** Identifying spatial relations (with multiple choices),
- **Phase 4:** Recognizing spatial relations (without multiple choices).

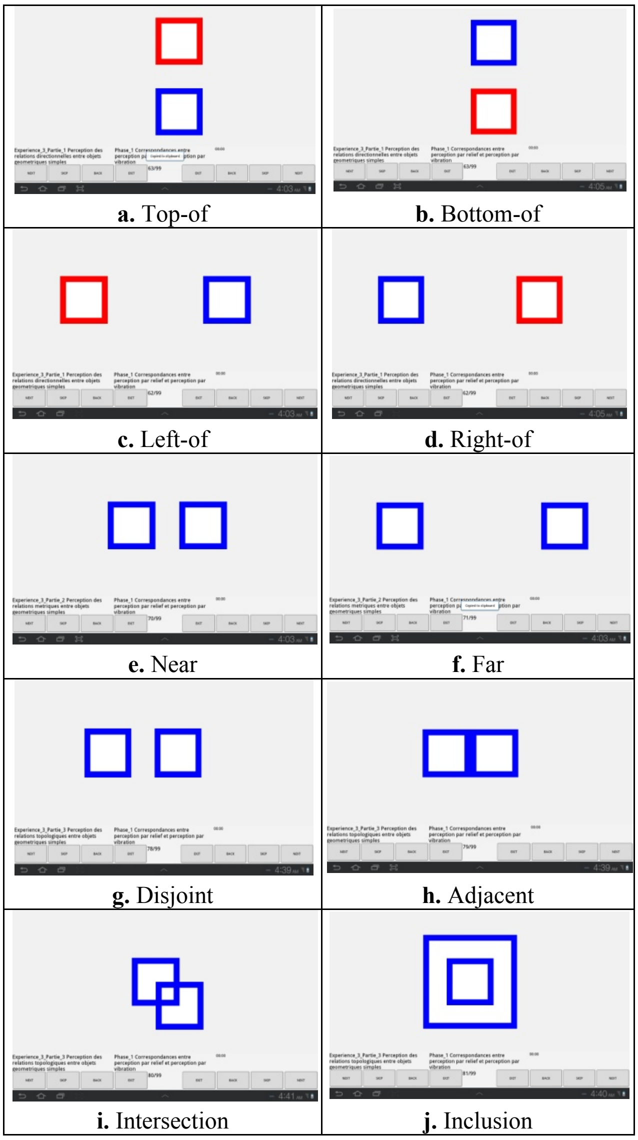


Fig.5. Prototype snapshots of spatial relations used in Experiment 3.

V. EXPERIMENTAL RESULTS

A. Prototype System

We have developed a prototype system, implementing our *EVIAC* experimental protocol on a mobile computer tablet (Samsung Galaxy Tab 10.1) with an Android operating system. The prototype implements all experiments, phases, and steps, following the guidelines provided in Section 5.

The prototype consists of 2 main application modules: i) the user (*tester*) interface, and ii) the *coordinator* interface, each designed to run on an Android-based system, connected together via a synchronized wireless link. On one hand, the *tester* interface is manipulated by the test subject. It provides the *tester* with contour (edge)-images (e.g., basic shapes and geometric objects) to be perceived, displayed on the computer tablet vibrating touch screen. In addition, the user interface records the hand movements of the *tester* while touching contour-based images (to be analyzed and exploited later, namely to allow user feedback in dynamically adapting images to the *tester's* visual deficiency, cf. Section 4). On the other hand, the *coordinator* interface allows administering the test: acquiring *tester* profile data in the beginning, and then allowing to navigate between experimental test phases, while recording *tester* answers as well as test phases execution time.

B.6.2. Preliminary Results

We conducted preliminary experiments on normal blindfolded candidates to test the feasibility of our proposal. Eight testers were chosen: 6 male and 2 female, aged between 21 and 30 years old, all of whom are familiar with personal computers and computer tablets. The test was coordinated by the paper's authors. In the following, we present the results obtained when conducting Experiment 1 of *EVIAC* (i.e., recognizing basic shapes). Remaining results (concerning Experiments 2 and 3) are ongoing, and will be published shortly.

Figures 6 and 7 present the number of correct results, presented in terms of number of testers, when performing phases 1 to 4 of Experiment 1.

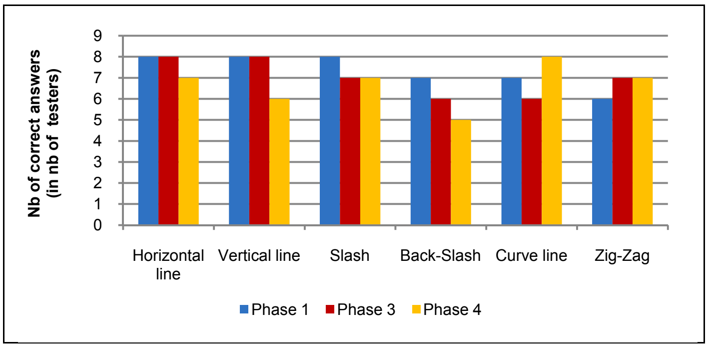


Fig. 6. Number of correct results, presented in terms of number of testers, when conducting phases 1, 3, and 4 of EVIAC's Experiment 1.

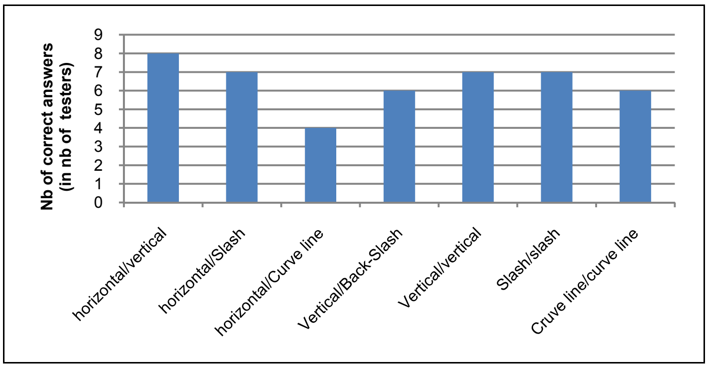
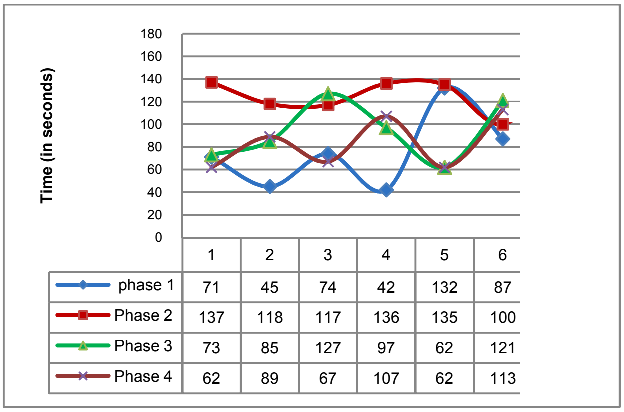


Fig. 7. Number of correct results, presented in terms of number of testers, when conducting phase 2 of EVIAC's Experiment 1.

In phase 1 (learning phase: mapping between embossed paper and vibrating screen tactile perceptions, cf. Figure 6), at least 6 (75%) of the 8 testers were able to effectively establish the correct correspondences between basic shapes presented on a vibrating touch screen and those on embossed paper, by correctly identifying the shapes on both mediums. However, most testers failed to identify the zigzag line. In phase 2 (distinguishing between basic shapes with multiple choices, cf. Figure 7), at least 6 (75%) out of 8 testers were able to correctly distinguish most basic shapes, except with the curved-line which was only distinguished by 4 testers (50%). The results of phase 3 (distinguishing between basic shapes with multiple choices) and phase 4 (recognizing basic shapes respectively - without multiple choices) are similar to those of phase 1, where at least 6 (75%) of the 8 testers were able to correctly recognize the basic shapes. Yet, Most testers failed to identify the zigzag line.

To summarize, we can conclude, based on the preliminary tests conducted here, that basic shapes such as: the horizontal line, the vertical line, and the sloping line seem accessible for more than 75% percent of blindfolded testers. However, more complicated shapes such as: the zigzag line and the curved line seem relatively difficult to recognize (by at least 50% of the testers).



	1	2	3	4	5	6
phase 1	71	45	74	42	132	87
Phase 2	137	118	117	136	135	100
Phase 3	73	85	127	97	62	121
Phase 4	62	89	67	107	62	113

Fig. 8. Time results per tester.

We also conducted timing experiments in order to highlight the average time required by a *tester* to recognize a basic shape. Results are presented in Figure 8. On one hand, the average time (for all testers and shapes) to recognize a given shape is equal to 1 min 24s, which seems feasible in practical scenarios (such as when reading a path on a digital map for instance). On the other hand, one can realize that phase 2 (distinguishing between basic shapes) is generally more time consuming than phases 1, 2 and 3 for most testers. This could be because phase 2 requires twice as much effort as the others, i.e., identifying 2 shapes (in a doublet) instead of 1, in order to establish (or not) the correspondence (and discriminate) between shapes.

VI. CONCLUSION

In this paper, we presented a new promising technological alternative based on vibrating screens to provide better understanding of digital image contours. Our approach opens various perspectives that would allow blind people to apprehend and play new roles in many life situations (navigating indoors and outdoors, understanding digital image contents, etc.). We presented here the adopted experimental protocol as well as the set of preliminary tests conducted on blindfolded people to validate the core of our approach. It is true that our study remains in its early stage but we are really confident about its accuracy and expressive power.

It is worthy to note that we are currently conducting several other tests to extend and cover a larger number of testers and profiles, namely: blindfolded users, low-vision users, as well as totally blind candidates. Also, we are currently studying the effects of learning (as in learning the shapes in EVIAC's phase 1) on result performance of testers in consequent phases. In addition, we aim to evaluate the time performance of testers in order to identify the possible effects of information overload and fatigue when geometric shapes and images become more complex. Note that an online version of our prototype system will be soon available online.

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