An Empirical Study for Examining the Performance of Visually Impaired People in Recognizing Shapes through a Vibro-tactile Feedback

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ABSTRACT
In this paper, we present results of an empirical study for examining the performance of blind individuals in recognizing shapes through a vibro-tactile feedback. The suggested vibro-tactile system maps different shades of grey to one pattern low-frequencies tactical vibrations. Performance data is reported, including number of errors, and qualitative understanding of the displayed shapes.

Categories and Subject Descriptors
[H.5.2] [**User Interfaces**] Graphical user interfaces (GUI), Haptic I/O, User-centered design, User interface management systems

General Terms
Algorithms, Design, Human Factors, Languages

Keywords
Visually impaired people, vibro-tactile feedback, low-frequencies tactical vibrations

1. INTRODUCTION
An important accessibility drawback of current screen readers is the failure of individuals who are blind or visually-impaired to quickly get an overall sense of a webpage in terms of overall semantics, main message, structure, and interaction affordances [1]. Our work focuses on developing and evaluating a sensory substitution system based on a vibrotactile solution, cheap and efficient in noisy and public environments.

2. RELATED WORKS
Related works reviewed in this section are two-fold: first, we view previous researches on vibrotactile feedback technologies; second, we review some works leveraging the perception of layout and logical structures.

2.1. Vibrotactile Output
Many authors have proposed the attachment of vibrotactile actuators on users' body for working as mnemonic information [2]. Opticon is one of oldest systems that proposed a vibrotactile feedback [3]. Opticon translates the written word into a scanned display on the fingertips. Another interesting prototype designed for interactive tabletops has been proposed by [4], the prototype is represented by a device incorporates interactive haptics into tabletop interaction. A 2D tactile prototype has been suggested by [5] to train blind people for their independent mobility. The prototype is associated to a 2D tactile array (vibration array) which consists of 16 vibrating elements arranged in a 4×4 manner. UbiBraille is a vibrotactile reading device has been designed [6] that leverages the users' braille knowledge to read textual information. Another tactile prototype was suggested by [10]. As the user interacts with a graphics tablet, a tactile feedback is provided via a tactile matrix on a mouse. The main drawback of many proposed systems is that they need specific devices which cannot be integrated easily to handled devices.

2.2. Perception Of Document Layout And Logical Structures
Perceiving the 2D structure of web pages greatly improves navigation efficiency and memorization as it allows high level reading strategies [1]. A tactile web browser for hypertext documents has been proposed by [7]. This browser renders texts and graphics for visually impaired people on a tactile graphics display and supports also a vocal feedback. Tactos is a perceptual interaction system [8], which consists of a tactile simulator, a graphics tablet with a stylus and a computer. A structured participatory-based approach has been proposed by [9], this approach aims to develop targeted haptic sensations for purposes of web page exploration. All these mentioned approaches aim to give visually impaired people the ability for perceiving logical structures. In this paper, we contribute a vibrotactile framework, which features (1) on hardware level: cheap, little intrusive, plugged-in easily with handled devices, modular for adding easily and synchronically many tactile electronic components - piezoelectric vibrators, solenoids matrices, peltiers- in order to get a large, rich and useful tactile semantics; and (2) on software level: a graphical user interface, controlling wirelessly many parameters -vibration, amplitude, duration, rhythm, and repetition-, integrated easily with handled devices.

3. VIBROTACTILE FRAMEWORK
Our system "TactiNET" (Figure 1) provides one pattern vibrotactile feedback when the blind user touches the tablet. To achieve the desired system, we have designed an electronic circuit, which controls many micro-vibrators placed anywhere on the body. A Bluetooth connection with an android tablet allows controlling the actuators. An Android dedicated program on the tablet views an image on the screen and detects information about the user touches (X, Y, Time, and Pressure). The intensity of the light emitted by the tablet at touched points is then transmitted to the embedded device in order to control the tactile stimuli.

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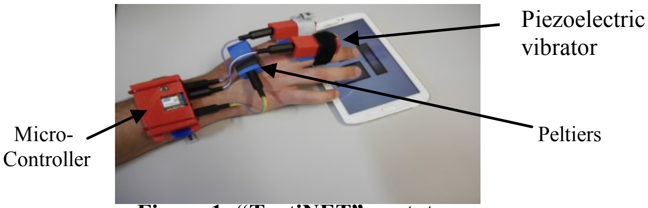

Figure 1: "TactiNET" prototype.

To validate our prototype and concepts of vibrotactile access to visual structures of web pages, we wanted first pretest our hypothesis: visually impaired people can explore and redraw simple grayscale shapes by using vibration motors.

4. PRE-TESTS PROTOCOL

We made experiments with 5 blind persons, each experiment consisted of: personal and technical questions, explanations of the test objective, a training task, and finally an evaluation task. The tested images (viewed on the tablet) contain some examples of expected results of web pages layout extraction, so success of distinguishing these shapes by blind users could be an indicator of their ability to distinguish web pages layouts. Figure 2 presents some images of evaluation phases.

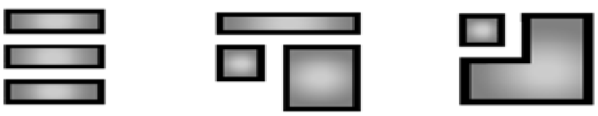

Figure 2: Images IDP1, IDP2, IDP3 (Evaluation Task).

Image IDP1 contains 3 rectangles with matched sizes and with vertical order, and the image IDP2 contains 3 rectangles with different sizes and many relations of directions, so testing these two images could indicate the ability of distinguishing sizes, and distinguishing relations of directions. Image IDP3 contains different shapes, so it could test the ability to distinguish different shapes in the same image. We created different transitions of gray scale for each shape to analyze the reaction through a continuous decreasing/increasing intensity generated by the micro-motor.
For each image in the evaluation task, we asked users to explore it and to answer for some questions (cf. in table 1, symbol ✓ represents a correct answer and the symbol X an incorrect one).

Table 1. Answers of questions for images IDP1, IDP2, IDP3

User-ID	ID0			ID1			ID2			ID3			ID4		
IDP	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Number shapes	✓	✓	X	✓	X	X	✓	X	✓	X	✓	✓	✓	✓	✓
sizes of shapes	X	X	X	X	X	X	✓	X	X	X	✓	✓	✓	✓	✓

At the end of the test, we asked each user to draw the recognized graphical patterns founded in each touched image (we used another tablet for redrawing). Some users could redraw forms nearly identical to original evaluation images. Figure 3 views the redrawing results of the user who answered successfully to all questions.

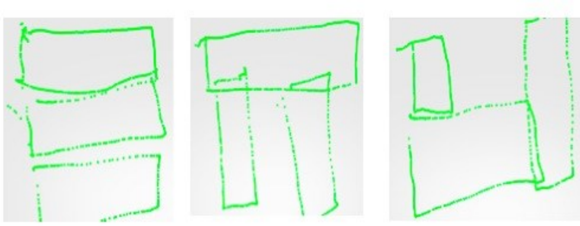

Figure 3. Results of redrawing images IDP1, IDP2, IDP3

5. ANALYSIS OF RESULTS

We notice from data in table 1 that the best performance is for the user with ID4, and this may be because this user is the youngest between others, and it could be because she was the only one who has already used touched devices (an iPhone, in her case working with VoiceOver), and this could be an indication that more training users more getting better results. Redrawing comparison with touched images can conclude: 1- ability of distinguishing sizes of shapes, because the degree of scaling between redrawn shapes is nearly equal to the degree of scaling between real shapes. 2- ability of distinguishing relations of directions (vertical order, left to, right to…), because relations of directions between redrawn shapes are nearly identical to relations of directions between real shapes.

6. CONCLUSION AND PERSPECTIVES

We have presented an embedded device dedicated for visually impaired people to explore simple grayscale shapes using vibrations. First results are promising: after a short training period, tested persons were able recognizing basic patterns. Many enhancements to be achieved such as increasing the number and quality of micro-vibrators, and more controlling frequencies and amplitudes.

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