Towards a Platform for Non-Visual Access of Web Pages on Touch Screen Devices

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Abstract. In this paper, we present results of an empirical study for examining the performance of sighted and blind individuals in discriminating ranges of frequencies. The suggested tactile vision substitution system is based on a vibro-tactile solution, portable, cheap and efficient in noisy and public environments. The system converts semi-automatically the visual structures of web pages into vibrating rectangular shapes presented on touch-screen mobile devices.

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 web page in terms of overall semantics, main message, structure, and interaction affordances [1]. Interpreting the layout of a document is often indispensable to understand its contents [10] [11] [12]. Sighted persons navigate the web pages first by scanning it quickly to get a global overview of the content structure (this process is called skimming) [13]. After that, they read the contents by following various reading paths [12] [13]. Our work focuses on developing and evaluating a sensory substitution system based on a vibro-tactile solution, cheap and efficient in noisy and public environments.

2 Related Works

Many authors have proposed the attachment of vibro-tactile actuators on users' body for working as mnemonic information [2]. Opticon is one of oldest systems that proposed a vibro-tactile 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 vibro-tactile reading device [6] that leverages the users' braille knowledge to read textual information. The main drawback of many proposed systems is that they are not oriented for web navigation; in addition, they need specific devices which cannot be integrated easily to nowadays handled devices.

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.

3 Vibro-Tactile Framework

Our system "TactiNET" (Figure 1) provides one pattern vibro-tactile feedback when the blind user touches a 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's touches (X, Y, Time, and Pressure). The gray level at touched points on the tablet is then transmitted to the embedded device in order to control the tactile stimuli.

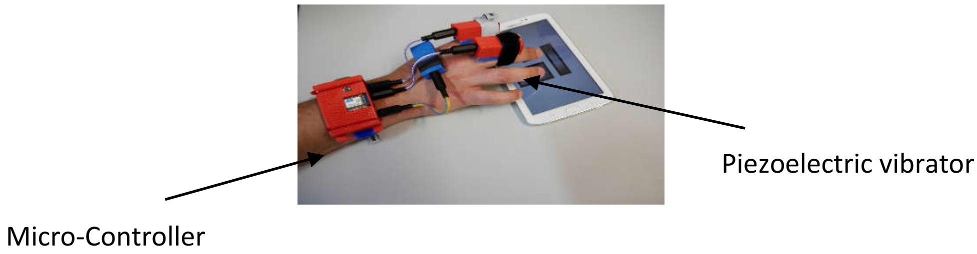

Fig. 1. TactiNET prototype.

A series of experiments validated our prototype and concepts of vibro-tactile access to visual structures of web pages [9]. First pre-tests validated our hypothesis: visually impaired people can explore and redraw simple grayscale shapes by using vibration motors [9]. The series of experiments described in this paper aims to select a range of frequencies most perceptible by sighted and visually impaired persons. These ranges of frequencies will be used in generating vibro-tactile feedbacks that represent contrasts of visual elements in web pages.

4 Pre-tests Protocol

38 sighted children (average 8.26 years) and 25 adults participated in the study. The 25 adult participants were composed of 20 sighted persons (average 29.8 years) and of 5 blind persons (average 57 years). Each participant had to navigate on the touch-screen, split in two equal-sized parts. They were asked whether the vibration feedbacks generated when touching the first part of the screen were identical to the vibration feedbacks generated when touching the second part of the screen. To run the experiments, two tablets of type Samsung GALAXY Tab 2 (10.1 inch) have been used. The first tablet, connected with the prototype device of TactiNET, is dedicated to the haptic exploration of the participant. The second tablet is dedicated to the experimenter to generate the various pattern of vibration sent to the first tablet. The two tablets are connected by a Bluetooth connection.

Participants navigate on the tablet by using the index of their preferred hand (left or right). The actuator to perceive the vibrations are placed on the non-preferred hand. The experimenter asked them a single question: « are the vibration feedbacks generated when navigating the left part equal to that generated when navigating the right part?"

Five frequencies have been chosen to be evaluated as reference frequencies: 101.5625Hz; 203.125Hz; 304.6875Hz; 406.25Hz; and 500Hz. Each value of these five reference frequencies have been evaluated with two conditions of amplitude variability V0 and V5. Variability V0 means that the amplitude value is always 255 for all the vibration feedbacks generated when the participant navigates any part of the tablet screen. Variability V5 means that the amplitude value is between 255 and 250 (255-5). When the variability V5 is activated, a random integer value between 0 and 5 will be generated for each touch on any part of the tablet screen. This random integer value will be subtracted from the maximum amplitude value 255. The objective of adding these two types of variability is evaluating the framework sensitivity in public or noisy environments. Using the framework in public environments or noisy situations (trains, buses, walking situations, etc.) might affect on the performance of the users. A simple change in the amplitude value could be a simulation of generating some noisy factors.

After selecting the reference frequency values, the values of non-reference frequencies to be compared with the reference values have been determined. Each reference frequency value was compared with values of 10 series (5 ascendants and 5 descendants) of non-reference frequencies. Each series consists of 13 successive values. The difference between every two successive values in the same series is 7.8125Hz (this value is due to hardware constraints in the device). The reference frequency value is the center value of each series. For each reference frequency, the experimenter starts the comparisons by the first value of an ascendant series. For each comparison between a reference frequency and a non-reference frequency, the experimenter asks the participant about the equality of generated vibrations. The answer is always either yes or no. When the participant supports two equal successive answers that are different from the first answer in the series, the experimenter stops the comparisons in the current series, and starts another comparison in the next series of the same type (ascendant or descendant). For the adult participants, all the reference frequencies and the amplitude variabilities have been evaluated.

To select the most perceptible ranges of frequencies, the perceptual threshold and the differential perceptual threshold for each reference frequency have been calculated. The perceptual threshold PTref for each reference frequency REF is the mean of the perceptual thresholds of its descendant series (5 descendant series) and the perceptual thresholds of its ascendant series (5 ascendant series).

$$PTref = (PTdescendant\text{-}series + PTascendant\text{-}series)/2$$

The perceptual threshold of descendant (or ascendant) series PTdescendant-series is the mean value of the perceptual thresholds of its 5 series (S1, S2, S3, S4 and S5).

$$PTdescendant\text{-}series = (PTS1 + PTS2 + PTS3 + PTS4 + PTS5)/5$$

The perceptual threshold of a series is the mean value of its successive values that have been compared with the reference frequency.

After measuring the perceptual threshold for each reference frequency for each participant. The perceptual threshold for each reference frequency for each group is calculated. The perceptual threshold for certain reference frequency (REF) for a group (G) is the average of perceptual thresholds of that reference frequency for all the group members (N members).

$$PTG,ref=(PTuser1,ref + PTuser2,ref + PTuser3,ref + ... + PTuserN,ref)/N$$

The differential perceptual threshold DT for each reference frequency REF is calculated by subtracting the perceptual threshold value from the value of the reference frequency:

$$DTref=|\ PTref - reference\ frequency|$$

The result is represented as an absolute value. For example, for the reference frequency 101.5625Hz, if the perceptual threshold is 99.01Hz, the differential perceptual threshold will be |101.5625 - 99.01|=2.5525Hz. The differential perceptual threshold indicates how the perceptual threshold is far or close of the reference frequency value.

5 Analysis of Results

The differential perceptual thresholds for each reference frequency have been calculated under two conditions: variability V0, and variability V5. The reference frequency 304.6875Hz has the smallest differential perceptual thresholds either with the variability V0 or with the variability V5. Figure 2 presents the mean and standard deviation values of differential perceptual thresholds for blind and sighted participants with two conditions of variability V0 and V5. It is noticeable that the reference frequency 304.6875Hz has the smallest differential perceptual thresholds either with the variability V0 or with the variability V5.

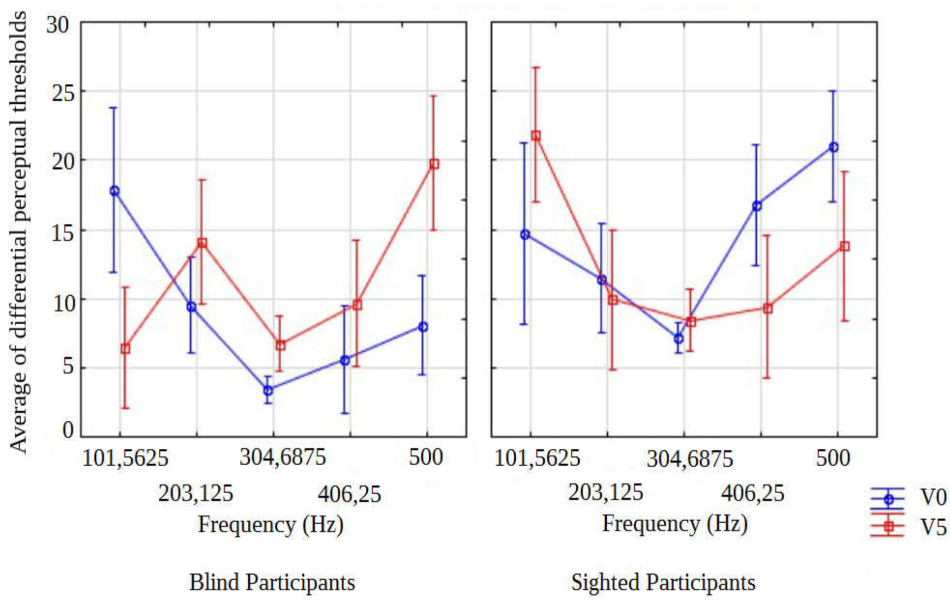

Fig. 2. Mean and standard deviation values of differential perceptual thresholds for adult sighted and blind participants with two conditions of variabilities V0 and V5.

An ANOVA statistical analysis has been calculated taking into account two types of variabilities, and the visual status of the participants (sighted or blind). The statistical analysis indicated an effect for changing the reference frequency: $F(4,28) = 3.58$, $p = 0.017$, $\alpha = 0.81$. An analysis post-hoc with the test of Bonferroni has indicated that the differential perceptual threshold for the reference value 304.6875 Hz is the least important comparing with other differential perceptual thresholds. This result means that "the differences in ranges of frequencies that are close to value 304.6875 Hz is more perceptible and discriminated than the differences in ranges of frequencies close to other tested reference frequencies".

An ANOVA analysis has been conducted to estimate the effect of the amplitude variability (V0 or V5) on the differential perceptual thresholds of adult participants. The analysis did not indicate any effect of the variability: $F(1,8) = 0.052$, $p = 0.83$, $\alpha=0.05$. This means that the simple amplitude variabilities do not affect on the performance of the adult participants. Another ANOVA analysis has been conducted to estimate the effect of the amplitude variabilities (V0 and V5) on the differential perceptual thresholds of children participants. The analysis did not indicate a significant effect of the variability: $F(1,36) = 2.02$, $p = 0.17$, $\alpha=0.028$. This means that the simple amplitude variabilities do not affect on the performance of the children participants. An ANOVA analysis indicated an effect of the type of the series (descendant or ascendant) on the differential perceptual thresholds: $F(1,36)=6.23$, $p=0.018$, $\alpha=0.68$. The average of differential perceptual thresholds in series of type descendant (=20.10Hz) is larger than the average of differential perceptual thresholds in series of type ascendant (=14.98). Another ANOVA analysis indicated an effect of the children age (group G1 and group G2) and the type of the series (descendant or ascendant) on the differential perceptual thresholds: $F(1,36)=10.16$, $p=0.0032$, $\alpha=0.87$.

6 Examples of applying the results

The proposed idea to achieve the mentioned objective is converting automatically the visual structures that represent the layout of a web page into a vibrating page. The vibrating page is represented on a touch-screen device using a graphical vibro-tactile language. This language is defined as a set of rules, principles, and recommendations for managing a non-visual interaction between the user and the navigated vibrating page. A vibrating page is a transformed format of a normal web page. It contains graphical geometrical symbols (forms) dedicated with vibro-tactile feedbacks. The vibro-tactile feedbacks are based on transforming the light contrasts into tactile vibrations. Figure 3 presents an example of a simple Graphical Vibro-Tactile Language (GVTL). The main basic graphical elements are geometrical forms, such polygons 1, 2, 3, 4, 5, and 6 in figure 3. These geometrical forms have different sizes (surfaces), lengths, widths, locations, and different spatial relations. A particular vibro-tactile feedback is dedicated for each shape. These vibro-tactile feedbacks could be varied in frequency, amplitude, waveform, and duration, such feedback signals 7, 8, 9, 10, 11, and 12 in figure 3. This simple GVTL could be used to represent a web page. Shapes may represent segments of HTML elements (paragraphs, images, other parts in a web page). Varieties in semantic meanings between the segments contents can be represented by different types of vibration.

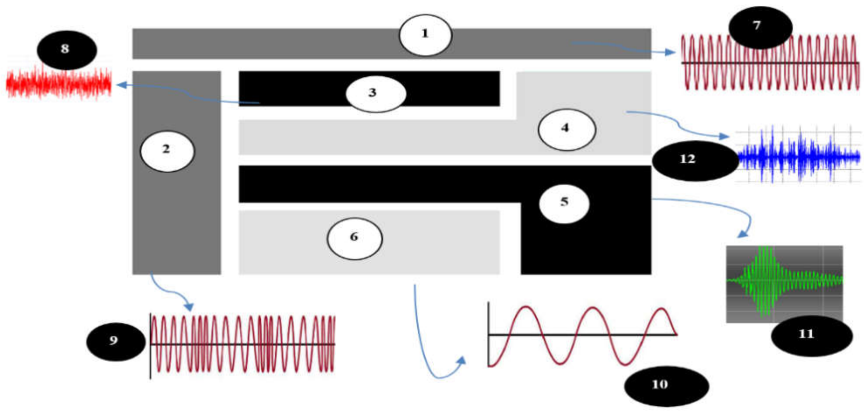

Fig. 3. An example of a simple graphical vibro-tactile language.

The proposed idea is based on a hypothesis that visually impaired persons can explore graphical geometrical shapes on a touch-screen mobile device, and they can perceive their varieties in size, form, spatial relations, and semantic contents by using vibro-tactile feedbacks. This proposed idea could be considered as a new non-visual navigation solution for exploiting the spatial two-dimension information of web page interfaces. This navigation approach may be equivalent to classical visual exploration of a document based on a luminosity vibration. In other words, the visual information presented on digital screens obtained by the visual scanning methods, may be obtained by a manual exploration strategy based on vibro-tactile interaction.

Depending on the conducted experiment, a set of ranges could be defined as following: F = {f: f∈[50 Hz, 550 Hz]}. Five ranges (R1, R2, R3, R4, R5) could be distinguished in this set:

- R1=[50 Hz, 150 Hz[, in case of choosing two frequencies from this range to represent two objects presented on the mobile device, the minimum difference between the two chosen values should be greater than 14.38 Hz. This difference value has been calculated depending on the data presented in table 2,
- R2=[150 Hz, 250 Hz[, the minimum difference between two chosen values from this range should be greater than 12.71 Hz,
- R3=[250 Hz, 350 Hz[, the minimum difference between two chosen values from this range should be greater than 6.27 Hz,
- R4=[350 Hz, 450 Hz[, the minimum difference between two chosen values from this range should be greater than 10.05 Hz,
- R5=[450 Hz, 550 Hz[, the minimum difference between two chosen values from this range should be greater than 15.07 Hz.

7 Conclusions and Perspectives

This experiment aimed to select the most perceptible ranges of reference frequencies with two types of amplitude variabilities. The results indicated that it is possible for participants to detect a very simple difference between frequencies close to the frequency 304.6875 Hz. This ability of discrimination is not identical for differences close to other frequencies such as 500 Hz. The results indicated that there is not a significant difference between the sighted and blind participants in perceiving the evaluated referential frequencies. Many enhancements to be achieved such as increasing the number and quality of micro-vibrators, and applying the obtained results on the designed framework.

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