Beyond a Visuocentric Way of a Visual Web Search Clustering Engine: The Sonification of WhatsOnWeb

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Abstract. It is widely accepted that spatial representation is processed by an amodal system. Recent studies show that blind subjects have a better motion ability than sighted people in performing spatial exploration guided only by auditory cues. The sonification method offers an effective tool able to transmit graphic information, overcoming the digital divide risen by a visuocentric modality in which contents are conveyed. We present a usability evaluation aiming at investigate the interaction differences between both blind and sighted users while surfing WhatsOnWeb, a search engine that displays the information by using graph-drawing methods on semantically clustered data. We compare the visual presentation of three different layouts with the sonificated ones, demonstrating both qualitatively and quantitatively that blind and sighted users perform with no significant differences the interaction. These results remark that the digital divide could be decreased by going beyond the visuocentric way of the commonly adopted visual content representation.

Keywords: Sonification, Information visualization, Accessibility, Usability.

1 Introduction

Many studies agree that the spatial representation of information is independent from the way in which the sensory inputs are displayed; in particular, some authors pointed out that blind subjects have a better performance in processing spatial auditory inputs than sighted people [1, 2]. Indeed, it has been highlighted that blind people show a motion ability in performing spatial exploration tasks guided by only natural acoustic cues, functionally equivalent to the visually guided way for sighted people [3].

Starting with these suggestions, an amodal system of spatial representation has been proposed, by explaining the involvement of the auditory, haptic, and kinesthetic information in the spatial mapping processing of blind people [4]. At the base of the spatial information elaboration process some different strategies lie, related to both nature of the information and different points of body references: allocentric vs egocentric. During the spatial orientation, totally or partially blind subjects show their preferences for a body-centered strategy, based on corporal references points, rather

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than for an allocentric strategy, often adopted in mental rotation and scanning tasks [5, 6]. Therefore, the nature of sound seems to be able to communicate the complexity of static or dynamic data representation, by keeping their inner relations unchanged [7].

In this work, we want to introduce a usability evaluation study of a sonificated version of a search clustering engine called WhatsOnWeb (WoW), an application tool based on new graph visualization algorithms, implemented at the Department of Computer Engineering (DIEI) of the University of Perugia [8]. WoW conveys the indexed dataset using graph-drawing methods on semantically clustered data [9]: the visuo-spatial data representation provides the whole information by conveying it in one single browseable page. By rebuilding the output in graphics mode, WoW's layouts provide what is conversely ordered in any Search Engines Report Page (SERP) where the query outputs are in a top-down hierarchical sequence, starting from the greatest ranking level website to the lowest in several results pages [10,11].

Unlike the operation of common search engines (e.g. Google and Yahoo), WoW does not use ranking as a hierarchical organization criterion of information, but it represents the information order even by a semantic association between data, making all the contents easily and simultaneously available and learnable. Moreover, the disappearance of browsing text - totally replaced by a gestaltic (synoptic) graphic one - allows an easy and quick use of the information by reducing accessibility barriers.

Just as Ivory, Yu, and Gronemyer [12] claimed, blind users took twice as long as sighted participants to explore search results, and three times as long to explore web pages. Those results show the gap that exists on the interaction with traditional search engines between blind people, who use screen readers to surf the Web, and sighted people. These considerations seem to suggest that accessibility is actually not enough: there is a strong necessity to implement search engines that are both accessible and usable. In this way, as Federici et al. pointed out [13], WoW overcomes the efficiency limitation of SERP search engines previously shown, since its structure overcomes the limitations of a top-down flat representation by introducing different ways to convey the spatial information.

2 What Is WhatsOnWeb

In order to redesign the WhatsOnWeb system accomplishing the accessibility and usability principles, we followed the user centered design (UCD) in accordance with the ISO 13407 "Human-centered design processes for interactive systems" [14]. First, we proceeded by decoupling the WOW algorithm and subsequently making an automatic accessibility analysis using the RAVEn Eclipse plugin provided by IBM [15], then we implemented the software code by accomplishing the Java Foundation Classes and the guidelines provided by Sun and IBM [16]. Specifically, a composite architecture was produced by allowing the vocalization function, considering both the use of screen readers and the need of an autonomous integrated synthesizer. Finally, an appropriate support to the navigation peripherals has been arranged: the navigation structure of WhatsOnWeb has been created as much independent as possible from the peripheral, considering the future aim of extending the system also to the Brain Computer Interfaces. Each graph has been organized by following different levels, using

cluster nodes - i.e. the semantic sets of results- with possibility of expansion and collapse by users click - i.e. deep level of information - and leaf nodes - i.e. the sites resulted from the research - as terminal constructs.

In a recent study conducted by Di Giacomo et al. (2008) [17] on a WhatsOnWeb prototype (http://whatsonweb.diei.unipg.it:8080/wow3.2/), the effectiveness and efficiency of the four different layouts implemented -TreeMap, Layered, Radial, and Orthogonal - were compared through a navigation task and a satisfaction questionnaire. Findings showed that 56% of people judged the TreeMap as the best graphic interface layout compared to the other ones. These results were confirmed by the opinions expressed by the participants in the satisfaction questionnaires. Following the experimental data on the TreeMap model, it has been developed the actual WoW prototype by adding a new layout called Spiral TreeMap (spiral tree organization) as a new visualization layout, where the most relevant node is set at the center of the screen and the less significant data are progressively set around. This organization in the process of being tested, together with sonification, should allow a significant improvement of the layout effectiveness and efficiency.

3 Sonification of WhatsOnWeb: Design and Implementation

Sonification is the "transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation" [18]. In most of the sonificated systems priority is usually given to the mapping of the sound attribution to data, but not to the interactivity with the user: in order to overcome this limit and to guarantee that the sonification represents both the interaction design and information, Zhao, Plaisant, and Shneiderman (2008) [19] provided the Action by Design Component (ADC) framework, a sonification model designed to permit an active and dynamic navigation into the interaction environment. For this reason, we chosen the ACD framework as a theoretical background for the sonification of WhatsOnWeb, in which the indexed data are organized by semantic correlations resulting in abstract information.

The sonification of WoW is combined with visual events describing both global and particular browsing information. While the global information is visualized after "search" action, the temporization technique provides to increase the intensity of each cluster. From the first to the last ranking organization result is guaranteed to the user through an overall overview of information which allows the first mental representation of the framework that users are going to browse. The complexity of the tone of each node is related with the complexity of its paraverbal information: for example, while browsing a cluster node, an harmonic chord will be executed suggesting the semantic links with the other peaks. A Low-latency (less than 100 ms) of short sounds have been used in order to grant a kind of active interaction in which sound information processing and keeping does not implicate a short term memory overload [20]. Moreover, WoW browsing is granted by the auditory reiterable feedback which provides spatial information in order to facilitate user orientation. Indeed, WoW provides to user a persistent signal which indicate his/her current position in the interface, as it happens in visual navigation. Spatial cues are uttered by a stereo-audio overview which simulates the position of selected nodes within a Cartesian coordinate plane;

the information identification and memorization is strengthened by a verbal feedback voiced by an integrated synthesizer. We implemented three different ways of sonification, by using the sound's volume, pitch, tone, blinking, and grid reference to transmit visual features in a univocal way. We tested three different sonification models. In the first one, VolumeSonification model, the Euclidean distance coding for a node compared to a significant reference is rendered through the sound volume level, whereas the panning is used to strengthen the node detection on the abscissas axis as absolute information. The second, BlinkAndPitchSonification, conveys spatial relations through an independent mapping of the two axes of the Cartesian plane (x, y) respectively with the frequency of the sound blinking together with panning, and with the note pitch. Finally, in order to optimize the graphic representation in terms of sound, the PanAndPitchSonification has been created solely considering the panning for the x axis and the pitch for the y axis.

4 Usability Evaluation of the Redesigned WoW

The experimental analysis of the reengineered and sonificated WoW software evaluated the usability of the different layouts: TreeMap, Layered Radial, and Spiral TreeMap.

Experimental Procedures. 1) The first phase investigates the usability of the sonificated WoW by an expert evaluation. Three experts, with more than five years of experience in the usability evaluation, assessed the software by the Nielsen's heuristic list [21]: a user scenario has been carried out in order to test each of the implemented layouts. In particular, the experts' tasks were to test the usability and the layout differences between the three models of sonification: PanAndPitch, PitchAndVolume, and BlinkAndPitch. The heuristic evaluation identified a small set of usability with a medium and high level of severity, suggesting us that it is necessary the redesign of the layout. Finally, all the evaluators suggested us to unify two of the sonification models - PanAndPitch and BlinkAndPitch - proposing a new model called PanAndPitchBlinking. The P&PB model conveys spatiality through the two axes of the Cartesian plane (x, y) by using the panning technique (x axis) and the note pitch (y axis) and it employs the blink effect to represent the rank order of each vertex. *2)* Following the expert analysis we fix the errors of the application and, then, we performed a usability test with two groups of participants: 4 totally blind users and 4 sighted users (mean age 28, equally distributed by sex). This phase of evaluation aims at investigate both the quality of users' interaction with the visual and sonificated WoW and the users' satisfaction. In order to achieve these evaluation goals, we used the Partial Concurrent Thinking Aloud (PCTA) [22] and the System Usability Scale (SUS) [23] questionary. Each user tested the WoW after a clear and essential description of the task and a preliminary exploration (lasting 3 min) of the layout. The experimental task, provided by a scenario, consisted in an exhaustive search of the meaning of the word "Armstrong" by using the WhatsOnWeb search engine. The keyboard navigation has been carried out by using either three typologies of layout -Radial, Layered e Spiral TreeMap- or the PanAndPitch Blinking sonification. At the end of the evaluation session, we interviewed all the subjects about their layout preferences and finally they were asked to complete the SUS survey.

Experimental Results. Problems identification during the PCTA protocols were collected and matched with the heuristic analysis of the first evaluation phase. All the subjects found 19 problems, 9 out of them are related to the visual performance and 11 to the auditory performance. The one-way ANOVA analysis, carried out by SPSS 18 on task completion times for each layout, shows no significant differences ($p>.05$) between the two groups and between the kind of layout - Layered layout (sighted M=50,25", blind M= 132,5), Spiral TreeMap layout (sighted M= 263,25", blind M= 236") - whereas significative difference was found on the Radial layout ($F_{(1,6)}=13,690$; $p<0.05$). The analysis of the SUS score shows no significant differences ($p>.01$) between the two participants' groups. Therefore, since these results highlight similar levels of efficacy, efficiency, and satisfaction between the two groups for both information presentation modalities, the sonificated modality and the visual modality performances seem to be homogeneous.

5 Conclusion

Thanks to a geometric spatial representation, WoW seems to make easier for a user the information manipulation and findability. A global homogeneity on the evaluation data shows that the use of WoW, or in general of a system that grants its accessibility, reduce the digital divide. Many accessibility and usability studies pointed out that subjects with visual disability are the main excluded from the ICTs because of the missing information concerning "not only just to text, but also to graphics, tables, and figures" that screen readers can not actually translate [24].

From the application point of view, WoW seems to be a versatile system that might be used not only for searching in the World Wide Web, but also for retrieving documents in smaller environments. Moreover, according to Anderson's theories which states that the human knowledge is organized through semantic categorizations [25], WoW, since clusterize information in semantic node, by emulating cognitive mental information processing, makes easier to all users achieve and elaborate ICT information. The indexed data representation way provided by WoW aims to optimize the effectiveness and efficiency of the interaction. Moreover, the information visualization techniques used to implement the architecture of WoW allow a remarkable reduction of the number of sensory controls necessary to perform and complete tasks. At the same time, the WoW system provides an extensible and device-independent architecture to lead the events through a two interaction states. The reduction of the number of events necessary to perform a searching task allows the user navigation through control systems and/or communication systems, such as Brain Computer Interfaces, eye-trackers, tongue controllers and speech/sound interfaces.

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