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Methods and Techniques of Adaptive Web Accessibility for the Blind and Visually Impaired

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Abstract

Massive volumes of information shared on the web together with linked open data initiatives and exabytes of data generated through social networks frequently disorientates and confuses web users in their everyday interaction. Additionally, web users constitute a highly heterogeneous entities with different needs and requirements. Considering this, user adaptive software systems have been developed as a new application approach to ease the interaction between users and web information with the intent to bridge the gap between such presentation and navigational pitfalls. The user adaptive interaction is especially useful when considering a marginalized group such as blind and visually impaired users. This paper attempts at providing an overview of a state-of-the-art survey concerning adaptive interaction between users and web information space with special emphasis on exploiting methods and techniques for adaptive web accessibility for blind and visually impaired people. Likewise, the exploration of possibilities of new methods and techniques for user adapted interaction for blind and visually impaired is highly required in order to alleviate the accessibility according to Web Content Accessibility Guidelines (WCAG). Recent studies indicate that even when the guidelines are implemented on web information systems, there is little indication that people with disabilities will gain better accessibility. To address these issues, we introduce various visual and auditory approaches to extend such adaptive methods and techniques for blind and visually impaired.

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1. Introduction

The World Wide Web (WWW) during the 25 years of its existence, provides information and services to a continuously expanding groups of users. Its fast, stable and unceasing enlargement contributes to the shaping of our information- based society. Volumes of data shared on web sites every day, linked open data initiative together with exabytes of data generated through social networks, may disorientate and confuse users, who adversely, constitute a heterogeneous and navigationally idiosyncratic entirety with different needs and requirements. In this aspect, user adaptive software systems appear as a new application approach, which concerns the interaction adaptation between users and web information space. This is made possible through explicit user model comprised of user knowledge, goals, interests, and other features that enables such systems to distinguish among different users (Brusilovsky & Maybury, 2002).

This paper attempts a state-of-the-art survey on the adaptation of interaction between users and a web information space. Special emphasis is provided on exploiting methods and techniques for adaptive web accessibility for blind and visually impaired people. Likewise, the exploration of possibilities of new methods and techniques for user adapted interaction for blind and visually impaired is highly required in order to alleviate the accessibility according to Web Content Accessibility Guidelines (WCAG). Recent studies indicate that even when the guidelines are implemented on web information systems, there is little indication that people with disabilities will have better accessibility (Power, Freire, Petrie, & Swallow, 2012). In relation to this, we outline some possible solutions through various methods and techniques for adaptive navigation support as well as adaptive content presentation for blind and visually impaired.

The rest of the paper is organized as follows: section 2 outlines the current methods and techniques that are used for providing adaptation of interaction to general users; section 3 presents some general conditions and criteria related to web accessibility for blind and visually impaired; section 4 elaborates various methods and techniques that can benefit the blind and visually impaired in relation to adaptive accessibility; and section 5 concludes this paper with some outlined future directions.

2. Background Research

Delivering adaptive web accessibility refers to the process of adapting to user's behavior based on a model built from user's goals, knowledge and preferences and exploiting this to enhance user browsing experience. The concept of adaptivity is usually referred to the process of selection and presentation of content done by the system, according to a particular user interest (Kobsa, 2004). A more clear and extensive definition of adaptive interaction through Adaptive Hypermedia Systems (AHS) was given by Brusilovsky (1996), which defines them as systems that mirror some features of the user in the user model and employs this model to adapt various visible aspects of the system to the user. We extend this proportion between system, user context, and adaptation in the form of user modeling adaptation loop (Brusilovsky, 2001) as depicted in Fig. 1.

The illustration shows that the system initially collects data about the user, then processes those, and finally results in adaptation. The collected data about every user profile is used to build a model which in turn generates adapted content. The model usually involves user's degree of knowledge about a particular concept which is used to determine the extent and level of adaptation (DeBra et al, 2003). This degree of knowledge is built using a metric which maps user activities to that particular concept. This user model, which describes the information, knowledge, preferences and other relevant aspect about the user, is needed because it allows extracting and expressing conclusions based on the above mentioned user characteristics (Martins, 2008). All of the above depicted processes are possible through various *methods* and *techniques*.

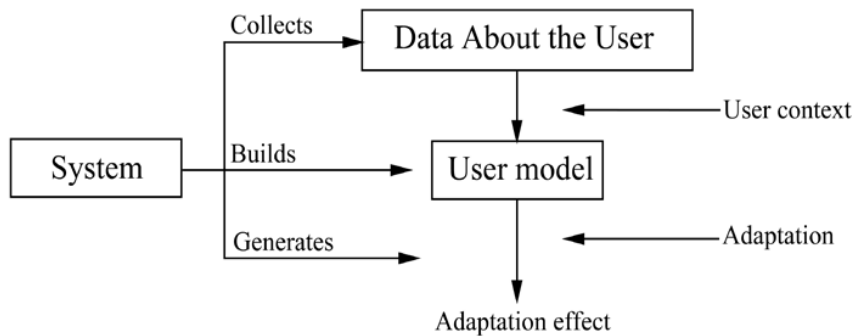


Fig. 1. Adaptation process through a user context model.

In this paper, by *adaptation method* we refer to a generalized and abstracted approach of adaptation (Brusilovsky, 2001). This usually represents a description of what the adaptation should do rather than how to do it. The implementation of a single method can be done in various ways. On the other hand, by *adaptation techniques*, we refer to a specific approach towards a particular method for delivering adaptation in user adaptive systems. These techniques are part of the implementation process of user adaptive software systems. Each adaptation technique is characterized by specific knowledge representation, modeling and adaptation algorithm (Brusilovsky & Maybury, 2002).

There also exist two distinctive adaptation levels based on where the adaptation is accomplished, such as the adaptation on the level of the content, known as content-level adaptation, and the adaptation on links, recognized as link-level adaptation. The former is known as *Adaptive Presentation* and the latter is accepted as *Adaptive Navigation Support*.

2.1. Adaptive presentation

The main idea behind adaptive presentation is adapting the content of an information space that is accessed by a particular user, related to the existing knowledge base and other user characteristics, goals and preferences. For example, let us consider the web as information space being visited by an experienced user. In this case a very thorough, detailed and deeper information will be presented due to the nature of the visitor. This is done because the user already knows its "interaction space" and what he is looking for is a more detailed and thorough result about a particular topic that is of a more interest to him. To the novice visitors, on the other hand, who happen to visit the space for the first time with no prior knowledge of it, the adaptive presentation tends to offer guidance toward the information they seek.

There are three generalized adaptive presentation methods (Knutov et al., 2009; DeBra et al., 2013) as outlined below:

- *Additional, comparison and required explanations* where the system provides additional information to the user if the system considers it necessary based on some prior rules derived from user model. The system tends to provide extra explanation for the visited content based on the previous visited concept, which is similar to the current one that the user is visiting. Sometimes the system tends to give further explanations if it considers that it is required for acquiring further concepts from the knowledge base, thus making adaptation more effective.
- *Explanation variations* represents manipulation of information fragments. This method is used in systems such as AHA! (Brusilovsky, 2001) and GALE (Knutov et al., 2009) with conditional inclusion of objects.
- *Sorting* as a method is used in cases where ordering of pages or fragments is required.

There exist several techniques for adaptive presentation that are summarized in Brusilovsky (1996) as:

- *Insertion, removal and alteration of fragments* which deals with how a piece of information, mostly limited to text, can be presented within a particular information space (i.e., a page). These pieces of text are usually called fragments, which can be inserted in a certain position as well as can be removed from within a page when a condition that meets specific rules is fulfilled. Alteration, on the other hand, represents a technique of storing different presentations for the same concept. Here the system stores different variants of the same concept that will be presented to different users. A typical example of alteration is fragment coloring (Kobsa et al, 2001) where for each particular user certain elements of the presentation may be marked out, such as relevant, irrelevant or too demanding for users.
- *Insertion, removal and alteration of pages* are the simplest techniques for adaptive presentation. The same approach applies as above, except that in here, we have more coarse grained elements for presentation, which are pages. In other words, instead of fragments, different variants of the same page with different presentations of the content can be shown to the visitor. Page-based adaptation does not scale up well when complex adaptation process is performed, especially when different page aspects must be adapted in different ways. (Bunt, Careni & Conati, 2007).
- *Strechtexts* represent a technique of showing a new content hidden within a text in the form of links. For example if a user clicks the stretchtext content, a new small window opens presenting new sets of content related to the clicked concept (Cannataro, 2001; Hothi, 1998).
- *Sorting and dimming* of fragments is technique of presenting the same set of information to all users and sorting them from the most to the least relevant fragment. Dimming, on the other hand, represents a technique of deemphasizing a certain fragment in order to indicate a fragment that is not important to the user but he can visit it if he prefers (Hothi & Hall, 1998).

2.2. Adaptive Navigation Support

The main concern of adaptive navigation support is dealing with extensive link structure and adapting it to user preferences. This type of adaptation guides users toward interesting and relevant information while on the other hand keeps him away from non-interesting and non-relevant information without obstructing their overall navigation freedom.

Several navigation support methods are identified such as:

- *Guidance* represents an adaptive navigation support method where users preliminarily have a goal to reach and the system suggests the path how to reach that goal. The path is consisted of several hyperdocuments which represent a possible or the only way of reaching the desired goal. Navigation guidance can be local or global. Whilst global guidance suggests a path to the user within information space as a whole, local guidance performs that successively link by link (Brusilovsky, 1996).
- *Orientation support* offers a link structure to the user allowing him navigation on that structure. If a complete structure of links is presented, the orientation support is considered global, while if partial links structure is shown to the user, then the orientation is local (Brusilovsky, 2001). Usually, orientation support is done by indicating a certain color where the user is located; links that are preferable to visit are shown in another color and links that should be avoided are shown in a more contrasted color. A typical example is seen in ELM-ART system (Weber & Specht, 1997).
- *Managing personalized views* is a method of creating a personal hypermedia repository for each particular user. This is often known as personalization, where a specific link structure consisted of pages presents the goal required by the user.

Identified techniques for adaptive navigation support are summarized as:

- *Direct guidance* deals with presenting the next best navigation choice to the user that will take him to the desired goal in a more efficient way.

- *Adaptive link sorting* considers sorting of the links based on their relevance, i.e., the most relevant links are placed higher in links structure hierarchy and vice versa.
- *Link manipulation* includes link hiding, link removal and link disabling. Link hiding as the word indicates hides the link from the user in order not to follow the same considering it as non-relevant. Link removal completely removes the link from general link structure prepared for the visitor. This is not always possible especially in the case when the link is placed in middle of the text. Finally, link disabling is a process of removing the link functionality and the click over the text does not follow other link structures. (DeBra & Calvi, 1998).
- *Adaptive link annotation* enriches the link with additional information and comments, which inform the user with the current condition of outbound links. Annotation of links can be done in textual form or in the forms of textual clouds or by using various icons.
- *Link generation* creates new relationships between pages and page fragments that are typically inexistent when the link structure was designed. The difference among classic link annotation, sorting and hiding, link generation actually creates new, previously non-existent links on a page.
- *Map adaptation* represents a rearrangement of content and link structure of a web site by which an adaptation effect is achieved. This is possible by using other adaptive navigation support techniques such as: link removal, link annotations, link promotion and demotion (Perkowitz & Etzioni, 2000). Link promotion is the technique of putting the link higher in the link structure’s hierarchy based on its relevance. Link demotion is pushing the links position deeper in the structure if it is irrelevant to the user.

Based on the above mentioned methods and techniques for delivering adaptive web accessibility, several technologies have been developed (Brusilovsky, 2001). The complete taxonomy of adaptive technologies is illustrated in Fig. 2.

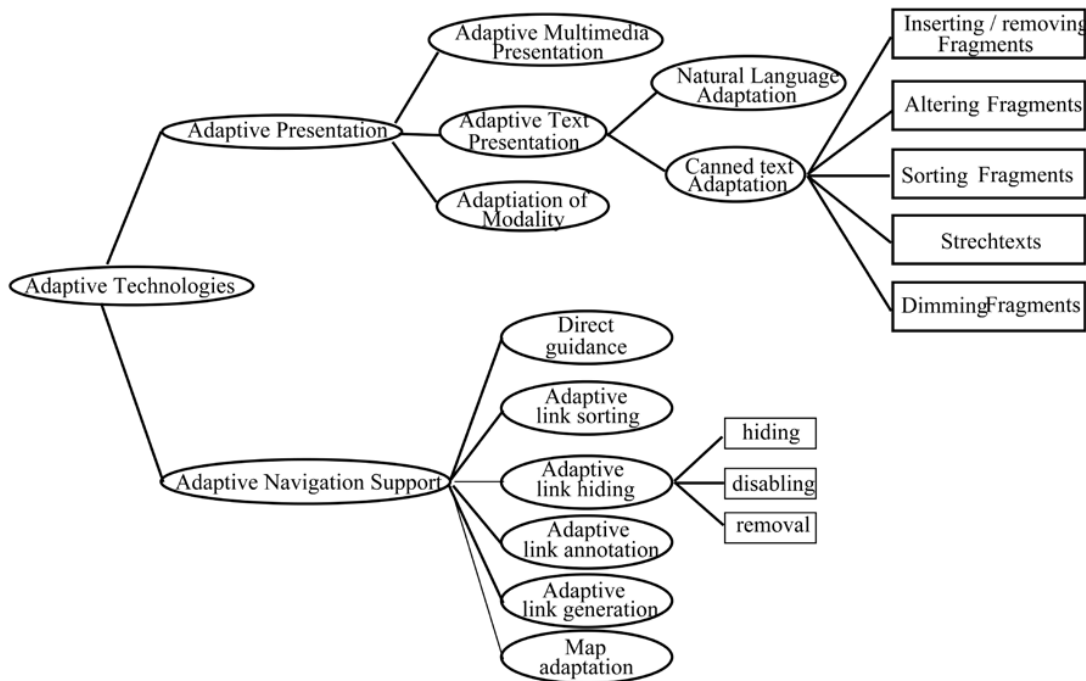


Fig. 2. Types of Adaptation technologies (Brusilovsky, 2001)

3. Web Accessibility Issues for the Blind and Visually Impaired

Even when web pages comply with Web Content Accessibility Guidelines (WCAG), blind and visually impaired users still face navigational problems (Power et al., 2012). Many studies conclude that for blind and visually impaired users, software solutions do not a priori guarantee digital content accessibility, hence many aspects need to be considered including the cultural ones (Ferati et al., 2014).

Navigation on the web through a screen reader for the blind is sequential by nature, although the web offers parallel and increasingly non-sequential content. For example, blind users do not extensively use the mouse when using the computer, instead they rely heavily in keyboard navigation which works better with specialized screen reader programs. In order to have a better analysis and understanding, we have considered the conditions of the blind and visually impaired separately. This is done for practical reasons considering that they are necessitated by different conditions and thus imply different requirements.

Web accessibility issues affecting blind users are mainly identified by Leporini and Paterno (2008), which include:

- *Lack of page context:* Users tend to lose the overall navigational context considering that they visit and read small portions of text within the page. Some tendencies to overcome this obstacle is through semantic web and semantic annotations of the context of page elements (Fernandes, 2006; Semaan, 2013).
- *Information overload due to excessive sequential reading:* Static portions of the web documents are often overloaded with links, frames, headers, menus and footer elements which obstruct the reading process. In order to reach to the desired information, many unnecessary chunks of data have to be passed, thus mechanisms that facilitate the identification of precise parts within the page are required. A possible solution that addresses this issue is, either through the use of concurrent speech methods which allows blind users to find information more quickly (Guerreiro & Gonçalves, 2014), or through skimming (i.e., grasping the tip of the information in order to quickly determine its content) (Ahmed et al., 2012).

Considering the visually impaired users, the following design aspects are found obtrusive:

- *Content serialization:* Typically all content blocks are presented (serialized) in a sequential order without considering the design aspects and relative positioning within hyperdocuments.
- *Navigation by special keyboard commands:* Visually impaired users prefer conducting their navigation through specialized keys which ensures them quick access to required information. Thus, ensuring keyboard functionalities is required either through specific functionality in reading software or as a special tag within hyperdocument. One such approach is seen in the study conducted by Puzis et al. (2012) in which through a particular predictive model, an appropriate and relevant set of actions for a specific browsing state is generated. Users may then choose between those actions through specific keys.
- *Difference in information conveyance between visual layouts and those afforded by aural perception:* Often for users with no sight issues, secondary information is given to them so they can identify it immediately (left or right menu bars, special headers, etc). It is important that such information should be presented in an accessible way for the visually impaired as well. One such approach, especially for graphs and tables, is seen in MultiVis Project (Kildal & Brewster, 2007) where haptics and non-speech sounds are used for making visualizations of data.

Understanding these issues represents a necessary step towards conceptualizing and developing approaches and techniques to provide successful adaptive interaction to the blind and visually impaired. Approaches and techniques for the discussed issues are proposed in the following section.

4. Approaches for Providing Adaptive Interaction to Blind and Visually Impaired

For sighted users there are myriad of adaptation techniques starting from content adaptation up to adaptive navigation support through information space. However, serious presentation and navigation pitfalls occur when adaptation is targeted for the blind and visual impaired users. Although various methods and techniques are used to deliver web accessible content for the blind and visually impaired people, generic and one-size-fits-all approach does not yield satisfactory results. Consequently, a specific adaptation techniques should be applied in order to achieve an adaptation specifically addressed to the blind and visually impaired. Based on various degrees of user blindness and impairment, specific solutions should be recommended and presented. For example, various content can be colored, zoomed, inverted, altered or presented in auditory form based on the type of content user searches, tools it uses or distance of the field of view from the screen.

Despite the above mentioned constraints, five adaptation techniques are identified based on the issues discussed in section 3. Four of them belong to adaptive presentation techniques and one falls within adaptive navigation support. The identified adaptation techniques that can substantially benefit the blind and visually impaired are summarized as follows:

- **Adaptive Multimedia Presentation:** involves displaying the multimedia content in a more accessible way suitable to user's preferences such as recognizing particular multimedia content in a specific context and presenting it to the user (Chitaro & Ranon, 2007). This would involve, for example, image transformation, sizing or zooming/unzooming.
- **Canned Multimedia Presentation:** has to do with techniques such as insertion, removal, hiding, disabling and filtering of multimedia content based on user navigation patterns.
- **Canned Text Presentation:** mainly involves techniques related to text manipulation and transformation such as: insertion or removal of text fragments, text alteration, text filtering, text fragment contrast transformation and visual text amplification.
- **Adaptation of Modality:** comprises mainly non-visual alternative techniques that facilitate the content accessibility including voice narrators and other auditory adaptations for content navigation.
- **Adaptive auditory link serialization:** involves serialized link manipulation, serialized link guidance, link generation, and link annotation. Serialization of links involves auralization techniques like: audemes (Ferati et al, 2012), earcons (Brewster, 1998), etc. For instance, this techniques can be represented by playing non-speech sounds every time the user stumbles on a piece of content that requires extra user attention.

The complete list of adaptation methods and techniques for each accessibility issue together with their requirement, motivation and target audience is given as in Table 1.

Table 1. Comprehensive table of adaptive methods and techniques for blind and visually impaired.

Web Accessibility Issue	Adaptation Technique	Adaptation Technology	Requirement	Motivation	Target
Lack of Page Context	Adaptive Multimedia Presentation	Adaptive Image Annotation	Displaying images and multimedia content within a page in an easy and identifiable way.	Avoiding the loss of overall navigational context.	Blind
		Adaptive Multimedia Annotation			
Information Overload from Sequential	Adaptation of Modality	Voice Narrators	Quick skipping of unnecessary portions of page contents and reaching the main relevant	Facilitating the identification of meaningful parts within	Blind
		Auralization			

Reading		Techniques	content.	web pages	
Information Overload from Sequential Reading (Contd.)	Adaptive auditory link serialization	(Audemes, Earcons etc.)	Enabling auditory techniques to quickly identify serialized links and their relevance.	Facilitating the identification of meaningful parts within web pages	Blind
		Alteration techniques			
Content Serialization	Canned Text Presentation	Filtering Contrast transformation Visual text amplification	Emphasizing the design aspects and relative positioning of content within web pages.	Facilitating the identification of relevant content location within web page	Visually Impaired
Navigation by Special Keyboard Commands	Adaptive Auditory Link Serialization	Serialized link guidance, Serialized link generation, Link annotation	Enabling specific keyboard functionalities within voice narrator software to present set of relevant links	Facilitation for quick and effective web navigation.	Blind / Visually Impaired
Difference Between Visual Layouts and Aural Perception	Canned Multimedia Presentation Canned Text Presentation	Fragment manipulation Strechtexts Fragment Sorting and Dimming	Enabling additional and comprehensive information for visually impaired within the content	Finding relevant information within web pages more easily.	Visually Impaired

5. Conclusion and Future Work

This paper provides an overview of a state-of-the-art concerning adaptive interaction between users and web information space with special focus on exploring methods and techniques for adaptive web accessibility for the blind and visually impaired. Addressing the problem of web accessibility for the blind and visually impaired users requires a priory analysis of issues that need to be addressed in order to ensure an effective web accessibility. After thorough analysis of the issues, five adaptation techniques were proposed together with fifteen proprietary technologies.

The future work should be focused around the following aspects:

- Implementing a prototype that addresses the requirements and motivations given in Table 1. Many modules of the above mentioned adaptation technologies are already implemented and are on the testing phase.
- Testing the compliance of the adaptation technologies given in this paper with WCAG recommendations. This would involve further research in identifying the increase of the level of accessibility when applying adaptation techniques proposed in this study.
- Usability testing and evaluation of the prototype. This would involve testing with blind and visually impaired users in order to assess the effectiveness of adaptation methods discussed in this paper.

We consider that the above mentioned identified methods and techniques provide a potential to increase the web accessibility for blind and visually impaired and consequently lower the digital gap for this category of users.

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