A Web Design Framework for Improved Accessibility for People with Disabilities (WDFAD)

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ABSTRACT
Information and Communication Technology (ICT) such as the World Wide Web (WWW) has increasingly become embedded in everyday life and is progressively becoming indispensable for public, business, personal efficiency or even improvement of livelihoods [1]. Web users including People with Disabilities (PWDs) can conveniently undertake a number of tasks that would otherwise be difficult or impossible. But many Web applications such as e-learning, e-commerce and e-government are not accessible to PWDs including the blind. Through Web accessibility guidelines, Web developers can develop Web applications that are accessible to PWDs. However, majority of the available accessibility guidelines are difficult to integrate into existing developer workflows and rarely offer specific suggestions that are developer oriented. In this paper, we propose a Web Design Framework for Improved Accessibility for People with Disabilities (WDFAD). The WDFAD provides precise guidelines on how to develop Web applications that are accessible to PWDs particularly the blind. These are packaged according to the three components of Web applications namely; content, navigation and user interface. Using constructs of the Non Functional Requirements (NFR) Framework, Web accessibility design objectives are represented as primary goals and sub goals. The primary goals represent the high level accessibility design objectives, while the sub goals represent the requirements that need to be met in the Web development process in order to meet each primary goal. WDFAD also illustrates the overlaps between the process of meeting each primary goal. This unveils the optimal ways of achieving Web accessibility during Web design. The precise nature of WDFAD and its packaging according to the main components of Web applications makes Web accessibility requirements potentially easier to understand and apply by Web developers. Web Developers prefer precise and familiar tools due to their busy work life and daily interface and expression in formal instructions. In addition, the global versus local classification of Web accessibility requirements in WDFAD modularizes the web accessibility guidelines hence making them easier to understand, apply and update.

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D.3.3 [**Design**]: Requirements-*analysis, design, framework.*

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Design, Human Factors, Theory, Standardization

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Web Accessibility, People with disabilities, Blind, Requirements, Web design framework.

1. INTRODUCTION

Information and Communication Technology (ICT) such as the World Wide Web (WWW) has increasingly become embedded in everyday life and is progressively becoming indispensable for public, business, personal efficiency or even improvement of livelihoods [1]. Web users including People with Disabilities (PWDs) can conveniently undertake a number of tasks that would otherwise be difficult or impossible. Examples of tasks undertaken by Web users include; e-learning, e- research, e-news, e-commerce and e-government. However for PWDs, these tasks are only possible on Web Applications designed to be accessible to such group of users. An accessible Web application is one that is sufficiently flexible to be used by all people including those using assistive technologies such as; screen readers, voice browsers and Braille displays [2].

Some groups, governments and organizations have developed Web accessibility guidelines that Web developers can use. Such guidelines provide Web accessibility requirements and techniques for designing accessible Web applications. But many Web applications such as search engines, news portals, research repositories, e-commerce and e-government applications are not accessible to PWDs including the blind [3], [4], [5],[6], [7]. Examples of the major guidelines include Web Content Accessibility Guidelines version 1.0 and draft 2.0 and Section 508 of the US Government Rehabilitation Act.

Most of the available guidelines offer quantifiable rules but Web developers often fail to implement them effectively [8]. One of the reasons given for this gap is that most of the available accessibility guidelines are difficult to integrate into existing developer workflows and rarely offer specific suggestions that are developer oriented [9]. Bigham and Ladner [9] counseled that Web developers would be more likely to create accessible applications if they are given specific suggestions on how to do so. There fore there is need for approaches providing specific suggestions that are developer oriented on how to develop Web

applications that are accessible to all users including PWDs. The proposed framework (a Web Design Framework for Improved Accessibility for People with Disabilities (WDFAD) provides developer oriented guidelines on how to develop Web applications that are accessible to people with disabilities particularly the blind. This is based on the three components of Web applications namely; content, navigation and user interface. The components are interrelated to; content accessibility, navigational accessibility and user interface accessibility design to form the three design activities of WDFAD. The design activities are represented as the primary goals of Web accessibility. On the other hand, the specific Web accessibility requirements that can make each Web component accessible are represented as the sub goals. The relationship between the primary goals in relation to the sub goals is shown, and the critical sub goals (requirements) identified. More so suggestions on the general application of WDFAD to improve Web accessibility are given. The rest of the paper is organized as follows; Web application components and Web accessibility, assistive technology, summary justification for the Web accessibility requirements, Web design framework for improved accessibility for people with disabilities, conclusion and future work.

2. WEB APPLICATION COMPONENTS AND WEB ACCESSIBILITY

A Web application is an application in which all or some parts are downloaded from the Web each time it runs. Opening a Web page may cause the execution of code in the Web server as well as in the HTML page [10]. A Web application has three components namely; content, navigation and user interface [11].

The content of a document refers to information conveyed to the user through natural language, images, sounds, movies or animations [12]. Web content includes text, images, video and audio files. Content is accessible if it can be viewed or accessed by all users including PWDs [11]. Viewing is concerned with the format of the content such as text form or audio form while access is concerned with the structure in which the content is presented that is how a document is logically organized for example by chapter, with an introduction and table of contents [12]. Due to lack of sight, the blind rely on the audio medium to perform a number of tasks including Web access. Hence they can only benefit from content that is primarily in audio form or that can be converted into the same.

On the other hand, Web navigation is the method of getting around a given page, or moving within the website and on to other Web pages. A Web application's navigation system is accessible if Web users with disabilities can perform all the navigational tasks with ease. The blind also rely on audio to perform navigational tasks. Hence for Web navigation to be usable to such users, the navigation steps and representative objects should be intuitive to the audio user with out loss of efficiency and effectiveness.

The user interface of a Web application refers to the objects or elements that the end user perceives and interacts with. This covers the way in which navigational objects are represented, which interface objects activate navigation, the way in which multimedia interface objects are synchronized, which interface transformations take place and the presentation of tasks that require users to input information (e.g. to fill out a survey form, to purchase software or to request information [11], [13]. An accessible user interface is one where all the perceptible and interactive tasks of a Web application can be understood, perceived and utilized successfully by PWDs. There fore for the user interface of Web applications to be accessible to the blind, it should cater for the access needs of non-visual users.

There is a close relationship between navigation, content and user interface. Several of the issues that influence content accessibility also influence navigation. For example, if you don't provide text equivalents for images that are links, then people using screen readers or text browsers will not be able to navigate the site. Similarly, if the alt text for image map hot spots (<area> tags) is missing then navigation of the site is definitely broken for people who are blind [13]. On the other hand, a number of navigational objects are also user interface objects (what the user perceives and interacts with on a page) such as links, tree controls, indices and headings. There fore the accessibility of each of the components complements the accessibility of the other components. This fact is further supported by the demonstrations in table 1 and 2 and figure 2.

At the general level, a Web application is accessible to PWDs such as the blind if it has accessible content, accessible navigation as well as an accessible user interface. Web accessibility standards and various researchers on Web accessibility for the blind have established that certain Web design considerations can make the Web accessible to PWDs and the blind in particular. Most notable of these include; text only version of entire website [14], [15], text alternative for every visual element [12], [16], [14], [11], synchronized text alternatives for synchronized video accompanied by interaction [17], meaningful content structure in the source code [14], [15], provision for skip navigation [8], [11], Descriptive titles for web pages/links and headings in relation to their purpose [17], dividing long pieces of content into sections with section headings [17], making Web pages appear and operate in predictable ways [17], helping users avoid and correct input mistakes [17], design for device independence [17], a accessible tables (data and layout) [12], [11],[20],[18] accessible frames or no frame content [11], [15], [19] presentation of form based content in a logical sequence [14], [11] testing the application with keyboard only access [12], use or conversion to standard document formats [12] and expansion of abbreviations and acronyms the first time they appear on a page [19].

However it is yet to be known how the given Web accessibility design requirements relate to the different components of Web applications. Table 1 shows a classification of the requirements according to the three components of Web applications. The classification was based on the earlier description of what comprises content, navigation and user interface in a Web application context in section 2. The purpose of the classification is to bring to light the relationship between Web; content, navigation and the user interface in relation to Web accessibility for PWDs such as the blind.

Table 1. A classification of the Web Accessibility Requirements for the Blind according to the three components of Web applications

Web Accessibility Requirements for the Blind	Affected Web Component if not met during design		
	Content	**Navigation**	**User Interface**
Text only version of entire website	yes	yes	yes
Text alternative for every visual element	yes	Yes	yes
Synchronized text alternatives for synchronized video accompanied by interaction	no	no	yes
Meaningful content structure in the source code	yes	yes	yes
Provision skip navigation	no	yes	no
Descriptive titles for web pages, links and headings in relation to their purpose	no	yes	yes
Divide long pieces of content into sections with section headings	no	yes	yes
Make Web pages appear and operate in predictable ways	no	yes	yes
Help users avoid and correct input mistakes	yes	no	yes
Design for device independence	yes	yes	yes
Accessible tables	yes	yes	no
Accessible frames or no frame content	no	yes	yes
Presentation of form based content in a logical sequence	no	no	yes
Test the application with keyboard only access	no	yes	yes
Use or convert documents into standard formats	yes	no	Yes
Expand abbreviations and acronyms the first time they appear on a page	yes	no	no

Having seen WHAT is required to make each Web application component accessible to the blind, the next section gives a summary justification as to why each requirement is necessary for the accessibility of each Web component. But first the assistive technology used by the blind to access the web is introduced.

3. ASSISTIVE TECHNOLOGY

Assistive Technology (AT) is the software or hardware specifically designed to support people with disabilities in carrying out daily activities [16], [20]. Our interest in this research is the assistive technology for the visually impaired particularly the blind.

The goal of visual assistive technology for the blind is to provide equivalent sight substitution mechanisms for computer and Web access. The blind require non-visual alternatives for traditionally visual tasks [16]. Examples of assistive technologies for the blind include: Braille terminals, sensory keyboards, screen readers and voice browsers.

Websites designed without accessibility in mind pose challenges to blind users such as interpretation and display of images and videos; efficient navigation and interpretation of web-based tables, frames and forms [14], [3] and [8].

Table 2 gives a summary justification as to why each requirement given in table 1 is necessary for the accessibility of the Web components. The summary also provides the relevancy of the requirements to assistive technologies used by the blind.

4. SUMMARY JUSTIFICATION FOR THE WEB ACCESSIBILITY REQUIREMENTS

This section presents a table summarizing the justification as to why each requirement is necessary for the accessibility of each Web component. The purpose of this presentation is to make known the contribution of each Web accessibility requirement to the Web usage experience of PWDs particularly the blind.

Table 2: Summary Justification for the Web accessibility Requirements of Web Components.

Requirement	Justification		
	Content	**Navigation**	**User Interface**
Text only version of entire website	ATs can only read & relay content in text form	ATs can only read & relay navigational elements in text form	ATs can only perceive and relay intelligibly interface elements in text form
Text alternative for every visual element	ATs can only read and relay content in text form	ATs can only read and relay navigational elements in text form	ATs can only relay intelligibly interface elements in text form
Synchronized text alternatives for synchronized video	Not applicable	Not applicable	Users can synchronously perform associated interactive tasks
Meaningful content	Adds a layer of	Time saving with	Time saving with user

structure in the source code	meaning enhancing ATs to read & interpret documents to users	navigation. ATs read Web pages in serial order	interface tasks. ATs ‚read' Web pages in serial order
Accessible Tables (data and layout)	ATs need to know which cell has header or title info for any given data cell	ATs need to relay lay out tables into a usable form for the user	Not Applicable
Accessible frames or no frame content (see end of table for definition)	Not applicable	Facilitates frame identificati on and navigation with ATs.	Facilitates frame identification and access to its elements by ATs.
Presentation of form based content in a logical sequence	Not applicable	Not applicable	Helps ATs understand & relay forms & their elements in usable formats
Use or convert documents into standard formats	Makes documents compatible with ATs	Not Applicable	Makes documents perceivable with ATs
Expand abbreviations and acronyms the first time they appear	Enables ATs to provide their full meaning to users	Not Applicable	Not Applicable
Provision for skip navigation	Not Applicable	Users can skip certain content e.g. adverts to main content	Not Applicable
Descriptive titles for web pages, links &headings in relation to their purpose	Not Applicable	For quicker user orientation within the site	Users can more quickly identify the parts they need
Divide long pieces of content into sections with section headings	Not Applicable	Users can move from heading to heading, to find quickly content of interest	Users will know when they have moved from one section to another & the purpose of each section
Make Web pages appear and operate in predictable ways	Not Applicable	Users can quickly form a mental image of the site	Having mental image of the site makes web pages easy to use
Help users avoid and correct input mistakes	Users will be able to supply the required information	Not Applicable	Interactive components will be more user friendly
Design for device independence	Makes pages compatible with ATs	Makes pages compatible with ATs	Makes pages compatible with ATs
Test application with keyboard only access	Not Applicable	Keyboard is the primary navigationa l device for the blind	Keyboard is the primary input device for the blind

Note 1: *HTML frames allow designers to present documents in multiple views as a way to keep certain information visible, while other sections are scrolled or replaced. An accessible frame is one with meaningful; title, name attributes and titles for all the frame pages.*

Table 2 shows that the major outcome of making content, navigation and user interface accessible to the blind is better performance of assistive technologies used by the blind to access the Web. This in turn should result into a more satisfying Web experience for the blind.

5. WEB DESIGN FRAMEWORK FOR IMPROVED ACCESSIBILITY FOR PEOPLE WITH DISABILITIES (WDFAD)

The Web Design Framework for Improved Accessibility for People with Disabilities (WDFAD) is an approach for developing Web applications that are accessible to all users including PWDs. This is based on the three components of Web applications namely; content, navigation and user interface.

The aim of WDFAD is to present Web accessibility design requirements into a developer oriented format. WDFAD uses the constructs of Non-Functional Requirements (NFR) Framework [21], to package the Web accessibility requirements for the blind (presented in table 1) into developer oriented accessibility guidelines. The NFR framework supports the requirements engineering process with components such as goals, decisions and rationale. It treats non-functional requirements as goals to be achieved during the process of system development [20], [22]. Our attraction to NFR framework was due to its modeling constructs namely; goal decomposition, design trade off analysis, design decisions rationalization (justification), goal evaluation, ability to identify critical goals as well the fact that accessibility is a non-functional requirement.

In WDFAD, content accessibility, navigational accessibility and user interface accessibility of Web applications are classified as the primary goals of Web accessibility. These are interrelated to the three components of Web applications namely: content,

navigation and user interface. The Web accessibility requirements that can make each Web component accessible are classified as the sub goals of Web accessibility. Justification is given as to why each sub goal is important for the accessibility of each Web component, the relationships between the primary goals and sub goals are illustrated and the critical sub goals identified.

The primary Web accessibility goals represent the high level accessibility design objectives of Web applications namely content, navigation and user interface accessibility. These are interrelated to the three components of Web applications as shown in figure 1. Each primary goal is then decomposed into sub goals. The sub goals represent the requirements that need to be met in the Web development process in order to make each Web component (content, navigation and user interface) accessible to all users including the blind. Table 2 further justifies the importance of the interrelationship between the primary goals and the sub goals. Additionally, critical sub goals are identified that is those that are shared by all the primary goals as illustrated in figure 2.

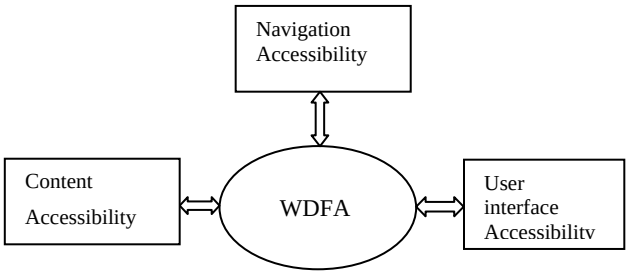

Figure 1: Primary goals of Web Accessibility for PWDs

Figure 1 shows three primary goals of the Web Design Framework for improved Accessibility for PWDs (WDFAD) that is; content, navigation and user interface accessibility. These represent the high level Web accessibility design objectives for making the Web accessible to all users including PWDs such as the blind.

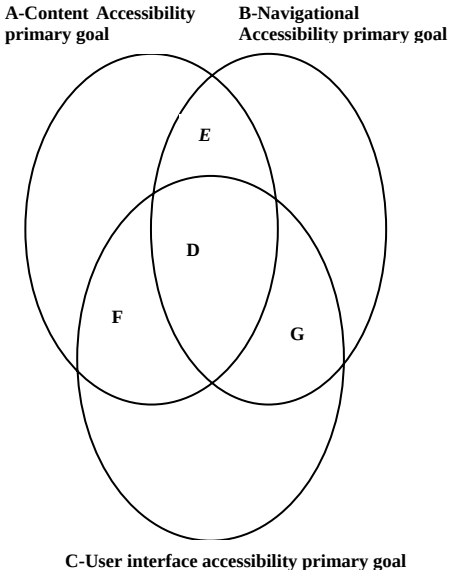

Figure 2: The Relationship between Web accessibility Requirements and Components of Web Applications

Key for Figure 2:

Set A- Content accessibility primary goal

{Text only version, Text alternative for visual elements, Meaningful content structure in the source code, Expand abbreviations and acronyms the first time they appear on a page, Use standard document formats, Accessible tables (data), Design for device independence, Help users avoid and correct input mistakes }

Set B- Navigational accessibility primary goal

{Text only version, Text alternative for visual elements, Meaningful content structure in the source code, Accessible tables (lay out), Accessible frames or no frame content, Test application with keyboard only access, Provision for skip navigation, Descriptive titles/names for web pages/links and headings in relation to their purpose, Divide long pieces of content into sections with section headings, Make Web pages appear and operate in predictable ways, Design for device independence}

Set C- User Interface accessibility primary goal

{Text only version, Text alternative for visual elements, Synchronized text alternatives for synchronized video, Meaningful content structure in the source code, Accessible frames or no frame content, Presentation of form based content in a logical sequence, Use of standard document formats, Test application with keyboard only access, Descriptive titles/names for web page/ links and headings in relation to their purpose, Divide long pieces of content into sections with section headings, Make Web pages appear and operate in predictable ways, Design for device independence, Help users avoid and correct input mistakes }

Set D- Sub goals shared by Content, Navigation and User Interface (A∩B∩C)

{Text only version, Text alternative for visual elements, Meaningful content structure in the source code, Design for device independence}

Set E- Sub goals shared by Content and Navigation (A∩B)

{Accessible tables (data and lay out)}

Set F - Sub goals shared by User Interface and Content (A∩C**)**

{Use standard document formats, Help users avoid and correct input mistakes}

Set G - Sub goals shared by Navigation and User Interface (B∩C**)**

{Accessible frames or no frame content, Test application with keyboard only access, Descriptive titles/names for web pages/ links and headings in relation to their purpose, Divide long pieces of content into sections with section headings, Make Web pages appear and operate in predictable ways}

The union of all the sub goals for all the primary goals (AUBUC) includes:

{Text only version, Text alternative for visual elements, Synchronized text alternatives for synchronized video, Meaningful content structure in the source code, Expand abbreviations and acronyms the first time they appear on a page, Use standard document formats, Accessible tables, Accessible frames or no frame content, Presentation of form based content in a logical sequence, Provision for skip navigation, Expand abbreviations and acronyms the first time they appear, Descriptive titles/names for web pages/ links and headings in relation to their purpose, Divide long pieces of content into sections with section headings, Make Web pages appear and operate in predictable ways, Design for device independence, Help users avoid and correct input mistakes}

5.1 Description and Discussion of WDFAD (Figure 2)

The Web Design Framework for Improved Accessibility for People with Disabilities (WDFAD) is represented in figure 2 as a Venn diagram with three sets that is A, B and C. Each set corresponds to a primary goal and contains the related sub goals for Web accessibility for the blind as the members. The primary goals represent the high level Web accessibility design objectives namely; content accessibility (A), navigational accessibility (B) and user interface accessibility (C). Members of each set are given in the key following figure 2.

The sub goals on the other hand, represent WHAT needs to be done (Web accessibility requirements) to achieve the primary goals. Some of the sub goals are members of all the three sets represented by $A \cap B \cap C$ (D). Others members belong to two of the three sets namely: A∩B (E)**,** A∩C (F) and $B \cap C$ *(G*). The members of these groups are also given in the key in accordance with table 1.

User interface accessibility set (C) has the most members that is thirteen out of sixteen (|C|=13) and also has the most unique members that is those that are not members in other sets (|C-B-A|= 2). Navigation follows user interface with eleven members (|B|=11) and has one unique member (|B- A- C| =1). Content accessibility set (A) has the least members (|A|=8) and also has one unique member (|A-B-C|= 1).

This description makes user interface a 'super primary goal'. If the sub goals are translated into design demands, user interface demands more, and content the least attention. This is related to the recent refocus of the Web (Web 2.0) to more interactive pages than static ones. In response, Web accessibility is also being refocused. Notably the Web Content Accessibility Guidelines version 2.0 draft (WCAG 2.0 draft) has incorporated many interactivity guidelines and techniques [17].

In terms of the overlap of the design requirements, four out of sixteen design requirements cut across the three components. These requirements are the most critical given that if they are not met , the accessibility of both components is affected. On a two by two group basis, navigation and user interface share the most requirements which makes the two more closely linked ($|A \cap B \cap C| + (|B \cap C| = 5)$).

Other important observations are that there are more shared sub goals (global goals) than individual ones (local sub goals) among the three primary goals of Web accessibility. That is the cardinality of the sum of D, E, F and G is greater than that of A, B and C minus all their intersection sets. Precisely, this can be represented as: $|D|+|E|+|F|+|G| > |((A- A \cap B \cap C- A \cap B- A \cap C)+(B-A \cap B \cap C-B \cap C-C \cap A)+(C- A \cap B \cap C-C \cap B-C \cap A|))$. The shared sub goals represent the critical accessibility requirements that need urgent attention. If the critical requirements are not met during the design of a Web application, all the three components of a Web application or two of the three will not be accessible to the blind. This is opposed to the non critical requirements which if not met, only one component's accessibility will be affected.

The precise nature of WDFAD and its packaging according to the main components of Web applications could make Web accessibility guidelines easier to understand and apply by Web developers. Web developers like all software developers prefer precise and familiar tools. Preciseness is important because developers are used to communicating in formal instructions. On the other hand, development tools building on or related to existing concepts/tools can get easily assimilated given the demanding work life of developers.

In addition, the global versus local classification of Web accessibility requirements in WDFAD modularizes the guidelines hence making them easier to understand, apply and update.

Existing guidelines such as WCAG could be simplified by categorizing it into global (content, navigation and user interface), global (content and navigation), global (content and user interface) and global (navigation and user interface). Another related classification could be according to the types of disabilities that affect a person's use of the Web.

CONCLUSION AND FUTURE WORK

Information and Communication Technology (ICT) such as the World Wide Web (WWW) has increasingly become embedded in everyday life for work, business and social activities. But many Web applications are not accessible to PWDs including the blind although it is possible to make such applications accessible. Majority of the available accessibility guidelines are not tailored to developer work flows and rarely offer specific suggestions that are developer oriented.

In this paper we have presented a Web Design Framework for Improved Accessibility for People with Disabilities (WDFAD). The WDFAD provides precise guidelines on how to develop Web applications that are accessible to PWDs particularly the blind. These are packaged according to the three components of Web applications namely; content, navigation and user interface. Using constructs of the Non Functional Requirements (NFR) Framework, Web accessibility design objectives are represented as primary goals and sub goals. WDFAD also illustrates the overlaps between the process of meeting each web accessibility goal and how to work around the overlaps for better and fast results. The precise nature of WDFAD and its packaging according to the main components of Web applications makes Web accessibility requirements potentially easier to understand and apply by Web developers. Developers including Web developers prefer precise and familiar tools due to their busy

work life and daily interface and expression in formal instructions. The classification of the guidelines into global and local Web accessibility requirements modularizes the guidelines further making them easier to understand, apply and update.

Future work will validate the framework on Web developers.

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