

Adaptable Web-based user interfaces: methodology and practice

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Abstract This paper introduces a novel approach to the development of inclusive Web-based user interfaces. This approach, proposed as an alternative to the traditional design and development for the 'average' user, builds on concepts and principles of the Unified User Interfaces (U2I) methodology and aims at increased accessibility and usability through user interface adaptation to diverse users characteristics, including disability, expertise, preferences, etc.. The EAGER development toolkit, which facilitates Web developers in following the proposed approach in practice, is also introduced here. As a case study, the paper then describes the employment of EAGER in the development of a new fully functional Web portal for the European Design for All and e-Accessibility (EDeAN) network, proving the viability and consistency of the toolkit, as well as its ability to stand as a horizontal and efficient development aid. A number of complementary evaluation techniques were applied to EAGER and to the developed prototype portal, confirming the perceived benefits both for end-product users and Web developers.

Keywords: Web accessibility, Web usability, Design for All, User Interface Adaptation.

1 Introduction

The World Wide Web serves as an unprecedented resource for knowledge, communication, and data and services acquisition, and plays a key role in an increasing number of aspects of everyday life, including commerce, information, education and training, job searching and remote collaboration, entertainment, social participation, and interaction with public administrations. The Web, thanks to its universality and the evolving usefulness (if not necessity) of its content, holds an unprecedented potential of reaching an enormous number of individuals, a population of potential

Target population	User tasks	Context of use	Means of access
Language	Work	Home	Platform
Age	Socialisation	Office	(Public terminals, PCs and Laptops,
Background	Entertainment	School	PDA and smart phones)
Skills	Education	Car	Assistive Technology
Preferences	Surfing	Internet cafe	(screen readers, scanning)
Disability (blind, motor impaired, deaf, cognitive impaired)	Commerce Government	(light, noise, privacy, security, etc.)	Browser (Explorer, Netscape, Firefox)

Table 1: Dimensions of diversity (some examples).

users significantly characterised by diverse interaction skills, abilities, preferences, and access equipment (personal computers, mobile phones and other small display devices, web-TV, kiosks, assistive technology, etc.).

Admittedly, the design and development of Web applications and services that meet the needs and requirements of as many diverse users as possible is a difficult and demanding task. The vast majority of developers today, by "tradition" (if not as a compromise), insist on designing their artefacts for the typical or so-called "average" users, trusting this as the best solution to cater the needs of the broadest possible population. Unfortunately, this approach leads to excluding numerous categories of users, such as non-expert IT users, the very young or the elderly, people with disability, etc. [1]. However, specialised designs for one user group often constrain the capabilities of another still important group. As a result, developers, eventually pushed by social or market needs towards broadening their user base, are often required to further "improve" their artefacts so that these adhere to generalised (i.e., average - again) usability and accessibility guidelines. Ultimately, this way of practice, usually also accompanied by limited user testing, leads to end-products that fail to justify their underlying effort investments.

Contemporary users increasingly desire and expect the delivery of user interfaces (UIs) that are highly tailored to their own needs, and hardly compromise on rigid designs for some imaginary "average" users. To this end, the main challenge faced today by designers and developers of Web-based User Interfaces (WUI) is to elaborate and deploy approaches that can meet effectively, in various contexts, as many diverse needs and requirements as possible. An indicative list of dimensions of diversity to be considered are presented in figure 1.

Recent approaches to Universal Access and Design for All emphasise the central role of user interface adaptation towards satisfying, equally, the needs and requirements of diverse target user groups, including people with disability. Hereupon, the Unified User Interface (U2I) development methodology has been proposed in order to support the development life-cycle of user interfaces capable of adaptation behaviour [2]. So far however, adaptation has been explored mainly in the context of independent

applications. In the Web environment, adaptation techniques for have been applied mainly at the level of user agents (e.g., the AVANTI browser [3]). However, such approaches are limited by the fact that the user must have the actual product installed on the computer used to gain access to Web content.

This paper describes the *Unified Web Interfaces* (UWIs) method as an alternative approach to the design and development of Web-based applications. This novel method builds on well-established *Design for All principles* and on the *Unified User Interfaces* methodology. Furthermore, EAGER, an advanced toolkit, is described as a means to facilitate Web developers in following the proposed UWI method and create interfaces that conform to W3C accessibility guidelines, and which are able to adapt to the interaction modalities, metaphors and user interface elements most appropriate to each individual user, according to profile information based on user and context specific parameters.

2 Related Work

Previous related work mainly focuses on adaptation techniques for the Web include Alternative User Agents, Intermediary Agents and Self-adapting Web-based systems.

2.1 Alternative User Agents

To ensure seamless access to the Web, several approaches involved the development of special purpose user agents (web browsers). For instance, the AVANTI Web Browser [3], facilitates static and dynamic adaptations in order to adapt to the skills, desires and needs of each user including people with visual and motor disabilities. WebAdapter [5] is a Web agent that provides accessibility functionalities for blind, visual and physically impaired people. pwWebSpeak32¹ is a commercially available web agent designed and developed by SoundsLink for users who wish to access the Internet in a non-visual or combined auditory and visual way. Another special purpose agent has been proposed in Henricksen and Indulska [6], including sophisticated adaptation mechanisms to provide context-aware behavior and user interfaces.

In general, special purpose agents offer a very promising approach to web accessibility and usability. Special purpose agents can deliver a number of facilities that include alternative interaction modalities and UI elements, support for a number of assistive technologies and input output devices, as well as text to speech and speech recognition facilities. These agents offer the advantages of desktop-based processing together with the positive features of intermediary frameworks, acting themselves as a proxy between the Web and the user. However, these approaches are limited

¹<http://www.soundlinks.com/pwgen.htm>

by the fact that the user must have the actual product installed on the computer used to gain access to the Web. Therefore, these facilities must be either presented as commercial products or be embedded in existing mainstream Web browsers in order for the aforementioned benefits to reach their actual beneficiaries.

2.2 Intermediary Agents

Intermediary agents can be considered as filtering and transformation tools that build alternative versions of webpages based on disability category, user preferences, or heuristic rules. WebFace [4] constitutes an example intermediate agent supporting accessibility with respect to physical or perceptual disabilities, or combinations thereof. Web Adaption Technology² developed by IBM Research proposes a method of making Web pages accessible without requiring the use of assistive technologies. Several other intermediary frameworks are specifically designed for people with vision impairments, and focus on removing sticky user interface elements or on transforming them to exploitable elements by assistive technologies. More specifically, these frameworks transform a web page from a graphics-heavy and inaccessible version to a text-only version that is easily accessible by visually impaired users. Some of the most well-known systems in this category are the Personalizable Accessible Navigation [7], the Access Gateway system [8], the Textualise system³, the Accessibility Transformation Gateway [9], the IBM system described in Han et al. [10], BETSIE⁴, Crunch [11], Muffin⁵ and RabbIT⁶. Web-Based Intermediaries (WBI) [12], [13], [14] is a special dynamic framework that includes a Text-To-Speech service [15] supporting the speaking of the text of HTML pages during their displaying to end users. Web Page Transformation [16] is another framework that offers a webpage transformation algorithm to browse webpages on small devices.

Concluding, the concept of intermediary agents is considered as a very promising approach for enabling universal accessibility on the Web. However, practical experience has highlighted a number of issues that tend to reduce the universality of the approach. Many websites do not produce HTML code for each element appearing in a webpage. There are examples of websites where the rendered code is entirely in a client scripting language. Additionally, malformed HTML code tends to make these websites not readable by proxies (due to the issues arising in the process of parsing malformed documents). An ad hoc solution to this issue was the development of specialized filters for each website or portal parsed by an intermediary agent. However, the current situation of the Web is far

²<http://www.webadapt.org/>

³<http://aquinas.venus.co.uk/>

⁴<http://www.bbc.co.uk/education/betsie/>

⁵<http://muffin.doit.org>

⁶<http://rabbit-proxy.sourceforge.net>

from allowing a generic solution to this problem. Finally, the diversity of the target user population cannot be address by just "fixing" the rendered HTML output. Sometimes, there is a need to perform additional operations, such as replacement of interaction elements and modalities, in order to cope with a diverse target user population. This is clearly not supported by Intermediary Agents.

2.3 Self-adapting Web-based systems

In addition to intermediary agents, there are Web systems that encapsulate adaptation. E-Victor [17] is an eCommerce system that has been developed as a component based application. Components are grouped into services that offer functionality to application users (user services) or to other services (internal service). The E-Victor system supports alternative navigation, layout and user interaction components using the WebComposition Markup Language. Although this approach has important results, the use of a specific markup language reduces the advantage to be used as a general solution for Web development. Additionally, this approach focuses on a specific system, and does not present a generic framework to be potentially applied for the majority of websites or sites developed with a specific technology. Finally, E-Victor does not support accessibility adaptations.

In Taib and Ruiz [18], a finite state machine algorithm was proposed, which gathers information on the clicking styles of the user and categorizes them into predefined profiles during progress through the task. A default profile gets weighted by the modality used at each step of the navigation. Finally, the system applies predefined presentation templates for every step of the process, progressively adapting to the interaction style of the user. A visual profile (using mainly images) would receive a shorter description with many images, while a text profile would get only one image and a longer text. A multimedia profile would get a video description, a speech profile a spoken description and an iconic profile a digest style including bullet points and iconic information. This approach uses statistical values in order to choose among predefined patterns of interaction styles that fit to specific user interaction styles. Although this algorithm can derive conclusions about user presentation preferences (e.g., image style, text style) it can not infer interaction preferences. Additionally, this method supports only alternative information representation, and does not offer the means to be extended to support alternative interaction (input) dialogues.

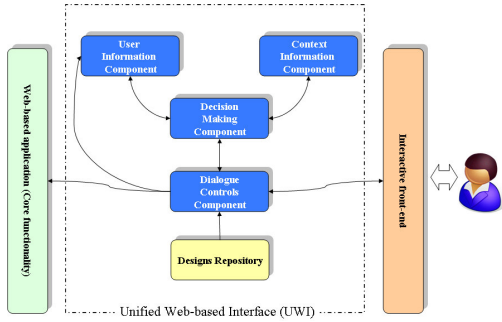


Figure 1: Architecture of Unified Web-based Interfaces (UWIs)

3 Towards Unified Web-based User Interfaces

This paper focuses on the design and development of Web-based Unified user interfaces (WUIs), and proposes a novel approach, based on Web portal technologies and UI adaptation techniques, to embed personalised accessibility and usability features deep into Web design. Endorsing a Design for All approach, the deployment of the Unified User Interface (U2I) methodology in the Web environment is proposed here for ensuring the delivery of automatic adaptation to diverse users and contexts of use. The Unified Web Interfaces (UWI) methodology is derived from the U2I architectural structure [2]. Figure 1 presents a general overview of the UWI architecture and the engaged communication channels. The basic components involved in the architecture are:

- The *User Information Component*: responsible for collecting and propagating user specific attributes.
- The *Context Information Component*: responsible for collecting and propagating attributes varying by the context of use.
- The *Decision Making Component*: in charge of the overall decision making regarding the conditional activation/deactivation of interaction elements.
- The *Designs Repository*: a repository of alternative design artefacts to be utilised by the Dialogue Controls Component.
- The *Dialogue Controls Component*: a repository of alternative interaction styles to be conditionally activated or deactivated to form the *Interactive front-end*, i.e., the adapted user interface.

Following the U2I architecture [2], the engaged communications channels are used for propagating the user and context specific parameters from the *User* and *Context Information Component* to the *Decision Making Component*. On the other hand, the *Decision Making Component* is responsible for propagating its decisions to the *Dialogue Controls Component* in order to inform about the activation or deactivation of interaction elements. The aforementioned communication channels are bidirectional in order for the *Decision Making Component* to be able to propagate decisions that may result into changes in the user or context specific parameters. The overall process leads to the activation of the appropriate interaction elements to be used for rendering the final interactive front-end.

3.1 User Information Component (UIC)

The UIC (see figure 2) acts as a server for collecting and providing information about user profiles. Each user profile contains attribute values automatically identified or specified by the user, both prior and during interaction. To collect such information during the interaction, a specific monitoring mechanism is used inside the UIC. The User Profiles Repository is a database of all users and the corresponding profile data records. On the other hand, the User Components Repository stores information regarding the conditional activation - deactivation of interactive elements per user as propagated by the DMC. To achieve bidirectional transmission of data, specialised Web Services and Logic are incorporated acting as a proxy class to the implementation underlying these two repositories. The Interaction Monitoring Module provides the mechanisms mentioned above for monitoring the interaction history of each user and inform accordingly the User Profiles Repository for future use. The data recorded by this module includes records of successful or unsuccessful completion of actions, the subjective preferences of navigation options, etc. The core element of the UIC is the Profiling Module, which is responsible for propagating User Profile information to the DMC, and additionally acts as an interface to the rest of the UWI components as well as to specialised profiling UI modules, such as:

- The *User Profiles Statistics UI module*, which presents statistics regarding the popularity of the various designs and settings available.
- *User Profile Selection UI module*, which enables the user to choose among predefined user profiles or to configure manually a new one.
- *User Profiles Administration UI module*, which allows site administrators to define predefined profiles and facilitate their main target user groups.

Figure 3 depicts an example of the attribute value based user profile model. Similar considerations hold for the CIC presented in the next

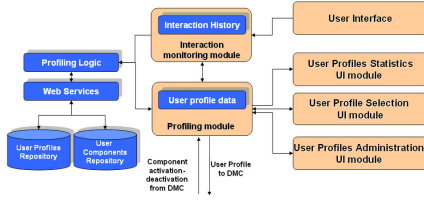


Figure 2: The User Information Component (UIC) architectural model

Parameters	Values				
Language	English	Greek			
Disability	None	Blind	Low vision	Color-blind	Motor-impaired
Web familiarity	Low	Moderate	High		

Figure 3: Example of a User Profile instance

section.

3.2 Context Information Component (CIC)

The CIC is intended to collect and propagate context attribute values (machine and environment) of two types: (a) (potentially) static, meaning unlikely to change during interaction, e.g., browser and peripheral equipment; and (b) variant, dynamically changing during interaction (e.g., due to environment noise, or the failure of particular equipment, etc.). A *Context Monitoring Module* that has the responsibility to monitor context changes and propagate this information to the *User Profiling Module* mentioned above. This module in turn enriches a *User Context Profile Repository* with these context specific attributes to be used in the process of decision making. Clearly, the attributes to be supported dynamically by CIC are quite limited, in WUIs, due to the current lack of methods for collecting such information from the client side.

3.3 Decision Making Component (DMC)

The DMC decides, in essence, when, why and how adaptation will occur. In other words, it entails the logic regarding the conditional activation and deactivation of alternative UI components according to user and usage attributes propagated by the UIC and the CIC. The core of this component consists of a number of implemented rules representing the design space of the user interface by mapping hierarchically various user attributes to appropriate alternative designs. For example, the decision logic for presenting links can be as follows:

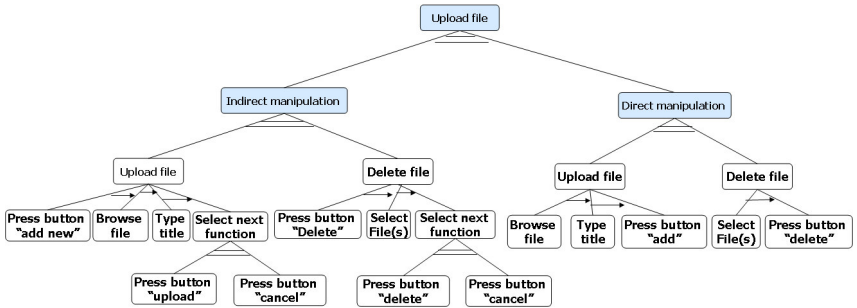


Figure 4: The polymorphic task hierarchy concept

- if *web knowledge* belongs to high, then use *coloured links*;
- if *web knowledge* belongs to moderate, then use *underlined links*;
- else use *push buttons*.

3.4 Dialogue Controls Component (DCC)

The role of DCC is to apply the interface adaptations decided by the DMC and structure the final front-end of the underlying application using the selected dialog components. More specifically, this component (i) provides the implementation of the alternative dialog components of a self-adapting interface in the form of dynamic libraries; (ii) moderates and administrates the alternative dialog components; and (iii) maintains a record of user interaction with alternative dialog components.

3.5 Designs Repository (DRE)

The DRE component is populated with designs of alternative dialogues controls in a form of abstract design and polymorphism. Polymorphic decomposition leads from an abstract design pattern to a concrete artefact. U2I design emphasises capturing abstract structures and patterns inherent in the interface design, enabling incremental specialisation towards the lower physical-level of interaction, and making therefore possible to introduce design alternatives as close as possible to physical design [2]. This makes it easier to introduce at any stage additional values of design parameters (e.g., considering new types users and contexts) without affecting the entire design space. Figure 4 depicts an example of polymorphic task hierarchy, illustrating how two alternative dialogue styles for an "upload file" task may be designed. Alternative decomposition "styles" are depicted in the upper part, and an exemplary polymorphic decomposition in the lower part.

In the depicted process, the following primary decisions need to be taken: (a) at which points of the task hierarchy polymorphism should be applied, based on the considered (combinations of) user- and usage-context- attributes; and (b) how different styles behave at run-time. This is performed by assigning to pair(s) of style (groups) design relationships. These decisions need to be documented in a design rationale that directly associates user- / usage-context- parameter values with the designed artefacts. As a minimum requirement, such a rationale should document [2]: related task, design targets leading to the introduction of the style, supported execution context, style properties and design relationships with competing styles.

4 The EAGER toolkit for Web developers

In order to facilitate Web developers in applying the proposed UWI method in practice, a prototype development toolkit, named EAGER⁷, was developed. EAGER is an advanced library of the core UWI architecture components: *User Information*, *Context Information*, *Decision Making*, *Dialogue Controls* (activation/deactivation), of the primitive UI elements with enriched attributes (e.g., buttons, links, radios, etc.), of the structural page elements (e.g., page templates, headers, footers, containers, etc.), and of the fundamental abstract interaction dialogues in multiple alternative styles (e.g., navigation, file uploaders, paging styles, text entry). The technologies that were used for the development of the EAGER toolkit include:

- Microsoft Visual C# .NET for the implementation of the UI modules.
- Microsoft Visual C# .NET and XML for Business Logic and Web Services.
- Microsoft SQL server 2000 for the database implementation.

For the development of EAGER, a number of UI elements were designed and implemented in polymorphic task hierarchies according to specific user and context parameters values. This phase provided input to the actual development process of EAGER, which involved the implementation of the alternative interaction elements and of the mechanisms for facilitating the dynamic activation - deactivation of interaction elements and modalities based on individual user interaction and accessibility preferences.

In brief, EAGER is an advanced library of: (a) core UWI architectural components; (b) primitive UI elements with enriched attributes, e.g., buttons, links and radios; (c) structural page elements, e.g., page templates,

⁷EAGER stands for "toolkit for Embedding Accessibility, Graceful transformation, and Ease of use into Web content Realisations".

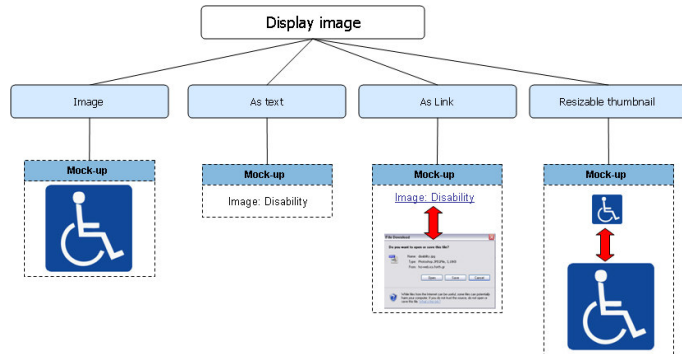


Figure 5: Image alternative representations

headers, footers and containers; and (d) fundamental abstract interaction dialogues in multiple alternative styles, e.g., navigation, file up-loaders, paging styles and text entry. The next subsections describe the types of adaptations supported by the EAGER.

4.1 Content-related alternative designs

Adaptation of content affects the content such as text, graphics or any other media type or data used or displayed by the application. This type of adaptation is most common on the Web. UWI supports adaptations, which automatically modify the presentation and conceived behavioural attributes of interactive elements.

An example of context-related adaptation concerns the presentation of images. Images appear usually as content of Web portals. Blind or low vision users are not interested in viewing images but only in reading the alternative text that describes the image. In order to facilitate blind and low vision users, two design alternatives were produced which are presented in figure 5.

The text presentation of the image simply does not present the image, but only a label with the prefix 'Image:' followed by the alternative text. The second representation, targeted to users with visual impairments, is same as the first with the difference that, instead of a label, a link is included that leads to the specific image giving the ability of saving the image. In particular, a blind user may not wish to view an image but may wish to save it to a disk and use it properly.

In addition to the above, another design was produced that can be selected as a preference by web portal users in which the images are represented as thumbnail bounding the size on the web page. A user who wishes to view the image in normal size may click on it.

In Table 2, the design rationale of the alternative images design is

Task: Display image				
Style:	Image	As text	As link	Resizable thumbnail
Targets:	-	Facilitate screen reader and low vision users in order not to be in difficulties with image viewing	Facilitate screen reader and low vision users in order not to be in difficulties with image viewing but with the capability to save or view an image	Viewing images in small size in order not to hold large size on the web page with the capability to enlarge the image to normal size when it is necessitated.
Parameters:	User(Default)	User (Blind or Low vision)	User (Blind or Low vision) and user preference)	User (preference)
Properties:	View image	Read image alternative text	Read image alternative text or and select linked named as the image alternative text to save or view the image	View image thumbnail and select it to view it in normal size
Relationships:	Exclusive	Exclusive	Exclusive	Exclusive

Table 2: Design rationale of the images alternatives.

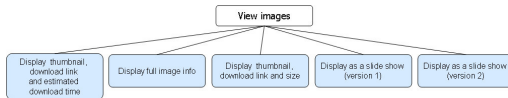


Figure 6: Images representations

presented.

Portals usually include lists of downloadable images. As presented in figure 6, five alternatives artefacts were designed according to user web expertise (table 3). For novice users, images are presented as thumbnails along with a link that downloads images and a description of the estimated time to download the image. For moderate users, the link is accompanied with the image size. Finally, images lists for expert user, consist of the link to download the image along with the image name, size and type.

In the three previous presentations (figure 7) the images appear thumbnails, along with information varying according to user web expertise. In the presentation that is shown in figure 7 (4), the user may view images in a greater size and navigate among them through the options "next" and "previous".

4.2 Layout-related alternative designs

Adaptation of layout changes the way information is presented to a user visually. This can be done to accommodate different types of displays or to satisfy preferences of aesthetic, cultural or other nature a user may have. The proposed framework supports layout adaptations, as long as it offers alternative templates layouts depending on screen resolution, disability

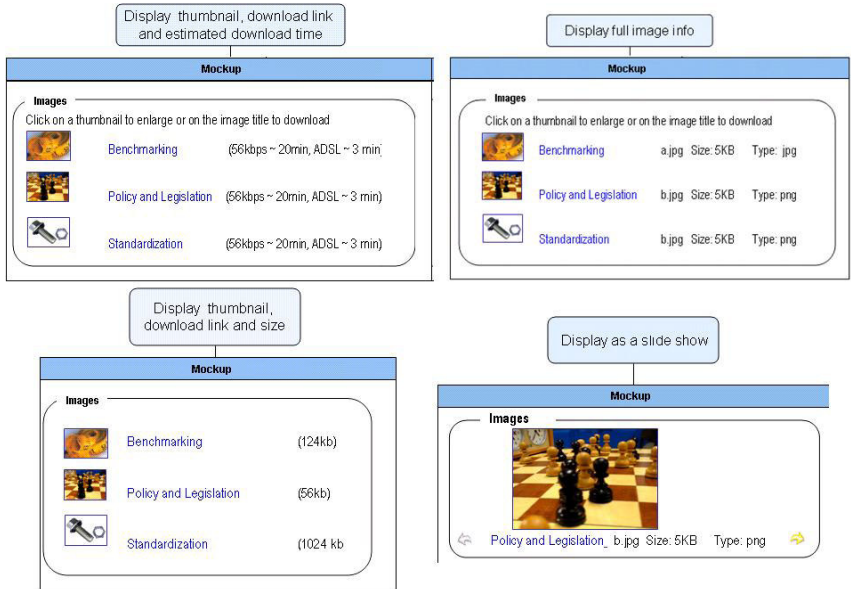


Figure 7: 1:Display thumbnail, download link and estimated download time, 2:Display full image info, 3:Display thumbnail, download link and size, 4:Display as slide show.

Task: View images				
Style:	Display thumbnail, download link and estimated download time	Display full image info	Display thumbnail, download link and size	Display as a slide show
Targets:	Usability flexibility	Usability flexibility	Usability flexibility	Usability flexibility
Parameters:	User (novice)	User (expert)	User (moderate)	User preferences
Properties:	-	-	-	-
Relationships:	Exclusive	Exclusive	Exclusive	Exclusive

Table 3: Design rationale of images representations.

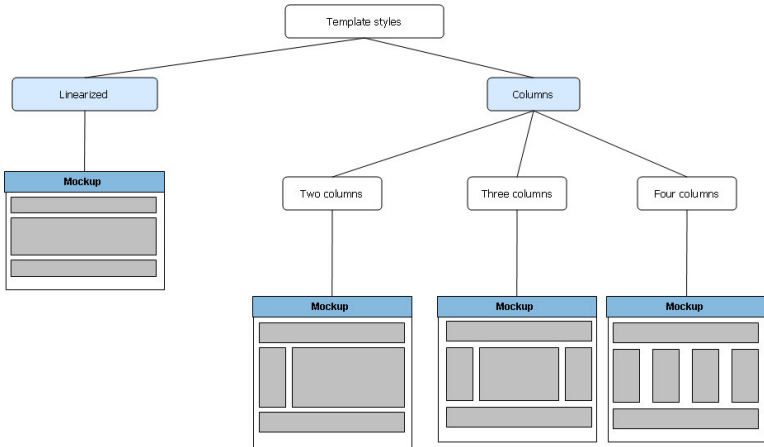


Figure 8: Template representation styles

Task: Template styles		
Style:	Linearized	Columns
Targets:	Accessibility, speed, naturalness, flexibility	Speed, flexibility, cover optimum screen size
Parameters:	User (Blind, Low vision)	User (No visual impairments)
Properties:	-	-
Relationships:	Exclusive	Exclusive

Table 4: Design rationale of the template styles.

etc.

A portal template generally maps to the generic scheme that incorporates the containers hosting contents. As presented in figure 8, two generic template styles were designed. The linearized template style contains all the containers (top navigation, content, bottom navigation) in a linear form. On the other hand, the columns template style has three alternative styles where top and bottom navigation are placed on the top and bottom positions, and the middle container is split in two, three or four columns respectively for the two, three, four columns template.

According to the design rationale presented in Table 4, the linearized template supports speed, naturalness and flexibility for blind or low vision users, whereas the columns templates sustain speed, flexibility and optimum screen size for users with no visual impairments. The alternative columns templates are intended to be used in order to support content flexibility.

Template size constitutes another significant aspect that is associated with the screen resolution in which the portal will be presented. According to [25], a web page has to be optimised for 1024x768 resolutions, but has

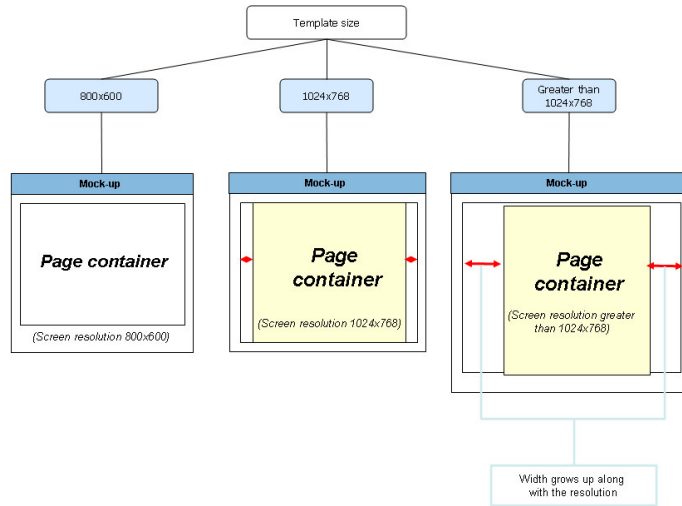


Figure 9: Template alternatives according to device resolution

	Task: Template styles		
Style:	800 x 600	1024 x 768	Greater than 1024 x 768
Targets:	Cover optimum screen size	Cover optimum screen size	Cover optimum screen size
Parameters:	Device resolution: 800 x 600	Device resolution: 1024 x 768	Device resolution: greater than 1024 x 768
Properties:	-	-	-
Relationships:	Exclusive	Exclusive	Exclusive

Table 5: Design rationale of the templates alternatives according to device resolution.

to stretch well for any resolution, from 800x600 to 1280x1024 using a liquid layout. As presented in figure 9 and Table 5, the template size may be resized according the device screen resolution in order to cover the optimum screen size.

When the resolution is 800x600, the template covers all the surface of the screen, whereas for 1024x768 resolutions the template has on its left and right sides a small unexploited area, in order to maximize the readability of the contents. For resolutions greater than 1024x768, the width of the empty area left and right of the template is increased according to screen resolution.

4.3 Navigation-related alternative designs

Adaptation of navigation adapts the navigational structure of a web application hiding or modifying links. Navigation constitutes one of the

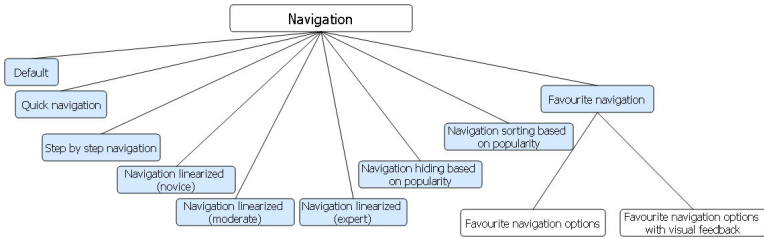


Figure 10: Navigation alternatives

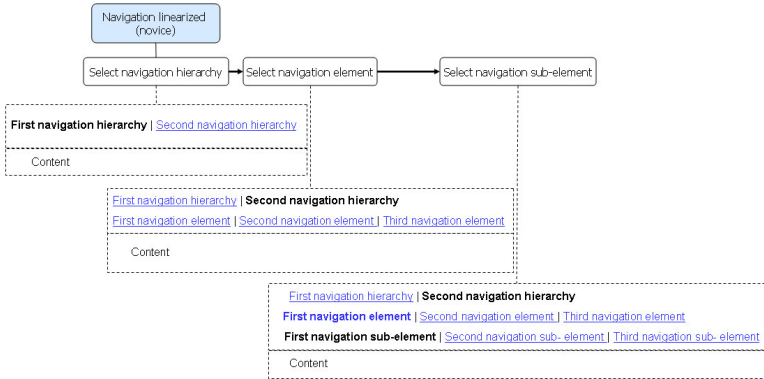


Figure 11: Navigation linearized (novice)

main mechanisms that a web portal user uses. Multiple alternatives of the navigation mechanism were designed in order to support individual user abilities and preferences. These are presented in figure 10.

The linearized navigation for novice users (see figure 11) offers a linear form for all the navigation links of the portal, and in parallel step by step navigation is supported. Initially, the user has to select among navigation hierarchies, next among entire navigation elements, and finally among navigation sub-elements. In each step, the previous hierarchy is available in order to navigate back to another navigation hierarchy or navigation element. This step by step navigation mechanism offers guided navigation to novice users with vision impairments, in order to enhance the accessibility, flexibility and usability of the portal.

The linear navigation targeted for moderate with visual impairments supports a linear form of the entire navigation of the portal. Initially, the user selects among navigation hierarchies and then the available navigation elements for the selected navigation hierarchy are presented, along with a navigation path through which the user may navigate back to the navigation hierarchy. Through this procedure the user has to scan limited

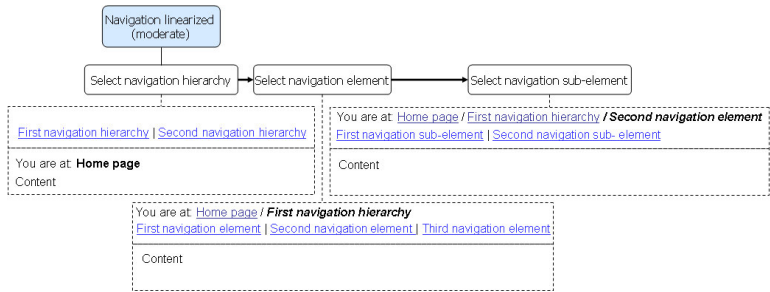


Figure 12: Navigation linearized (moderate)

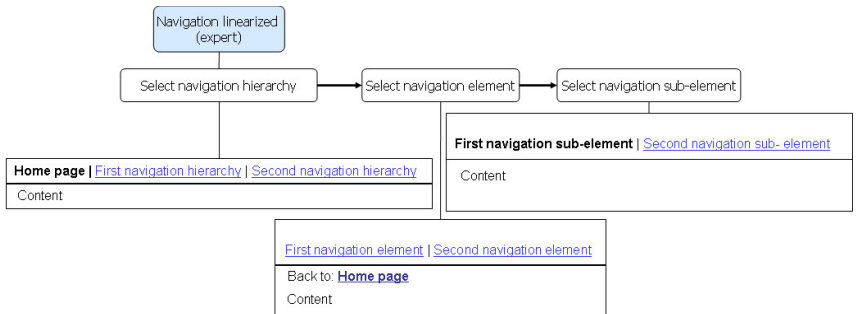


Figure 13: Navigation linearized (expert)

navigation options using the screen reader, is constantly informed about which page is being browsed, and always has an efficient way to navigate back to the navigation hierarchies thanks to the path mechanism (see figure 12).

The linear navigation for expert users with visual impairments resembles the linear navigation for moderate users, but without the path mechanism. In this way, the expert has the ability to navigate back to the navigation hierarchy, but is not notified about the web page browsed each time (see figure 13). In this way, the expert can browse through the navigation mechanism quickly, without having the screen reader always reading the path of the entire page.

4.4 Interaction-related alternative designs

Adaptation of user-interaction changes the way the user interacts with the application. An application might adapt offering a wizard based interface to less experienced users and a single page form to other users. UWI framework supports conditional activation and deactivation of multiple interaction modalities based on the user profile including alternative task

Task: Navigation			
Style:	Navigation linearized (novice)	Navigation linearized (moderate)	Navigation linearized (expert)
Targets:	Accessibility, flexibility, usability	Accessibility, flexibility, usability, limited reading by the screen reader	Accessibility, speed, flexibility, usability, limited reading by the screen reader
Parameters:	User (Blind or Low vision and novice web expertise)	User (Blind or Low vision and moderate web expertise)	User (Blind or Low vision and expert web expertise)
Properties:	Navigation hierarchy first, navigation element next (for desired navigation hierarchy), navigation sub-element next (for desired navigation element)	Navigation hierarchy first, navigation element next (for desired navigation hierarchy), navigation sub-element next (for desired navigation element)	Navigation hierarchy first, navigation element next (for desired navigation hierarchy), navigation sub-element next (for desired navigation element)
Relationships:	Exclusive	Exclusive	Exclusive

Table 6: Design rationale of the step by step navigation (novice, moderate, expert).

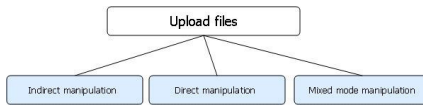


Figure 14: Upload files alternatives

structures, alternative syntactic paradigms, task simplification.

An example of interaction-related adaptation concerns file uploading. Uploading files constitutes a frequently used function for web users. As it is shown in figure 14 to 16, three alternative designs were produced targeted to expert, moderate and novice users in order to upload and delete files.

As it is shown in figure 15, a novice user in order to upload a file has to complete several simple steps; firstly, the user has to press the button 'add new', then the interface changes, and the user has to complete three simple steps, browse a file, type a title and push the button 'upload'. A progress bar with the file upload time appears. To delete an uploaded file, the user has to press the button 'delete' and then to check the files to delete and press again the 'delete' button. The described presentation is targeted to novice users, because it contains simple and detailed steps.

The direct manipulation alternative (figure 16 (1)) is designed for expert users. All the functions are provided in a single interface in order to be accessed by the user quickly and effectively. The user has only to browse a file, type a title and press the button 'add' in order to upload a file. On the other hand, in order to delete a file that has already been uploaded, the user has only to select the file or files and press button

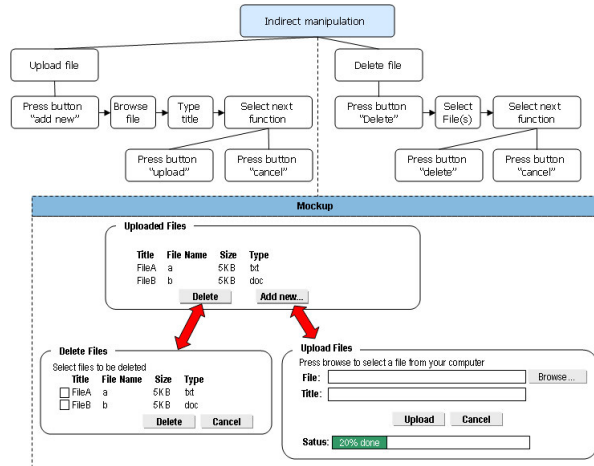


Figure 15: File upload (indirect manipulation)

	Task: Upload files		
Style:	Indirect manipulation	Direct manipulation	Mixed mode manipulation
Targets:	Simplicity, guided steps	Speed, effectiveness	Guides steps, effectiveness, usability
Parameters:	User (novice)	User (expert)	User (moderate)
Properties:	Upload file: Press button 'add new' first, browse file next, type title next, press button 'upload' Delete file: Press button 'delete' first, select file(s) next, press button 'delete'	Upload file: Browse file first, type title next, press button 'add delete file: Select file(s) first, press button 'delete' next	Upload file: Press button 'add new' first, browse file next, type title next, press button 'upload' Delete file: Select file(s) first, press button 'delete' next
Relationships:	Exclusive	Exclusive	Exclusive

Table 7: Design rationale of the upload files alternatives.

'delete'.

For moderate users, an intermediate design (between novice and expert user design, see figure 16 (2)) was prepared that includes two interfaces: one to upload files and another to view uploaded files and delete files that were uploaded by accident. The moderate user in order to upload a file has to press the button 'add', then automatically a second interface appears where the user browses a file, types a title and finally presses button 'upload'. A moderated user in order to delete a file uploaded by accident has only to check the file or files to be deleted and then to press the button 'Delete'.

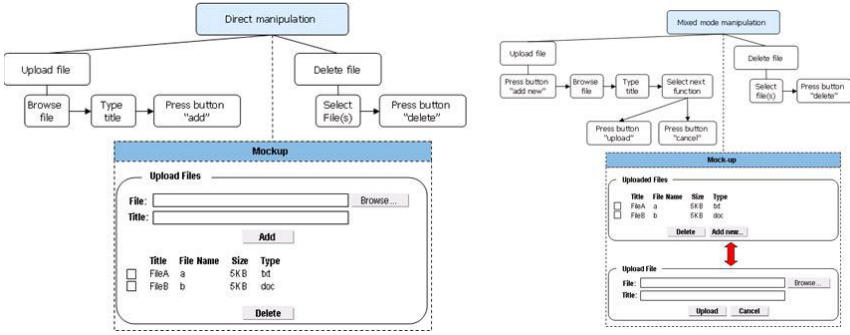


Figure 16: File upload 1: direct manipulation, 2: mixed mode manipulation

5 Case Study: A prototype developed by means of EAGER

As a proof-of-concept, a prototype portal was developed following the UWI methodology by means of the EAGER toolkit. In order to elucidate the benefits of EAGER, an already existing portal was selected and redeveloped from scratch. In this way, it was possible to identify and compare the advantages of using EAGER, both at the developer’s site, in terms of developer’s performance, as well as at the end-user site, in terms of perceived user-experience improvement. In particular, the original portal of the *European Design for All e-Accessibility Network (EDeAN)*, namely Hermes, was redesigned and reimplemented using the EAGER development framework.

The new portal disseminates information about the scope, objectives and outcomes of the EDeAN networking activities. Through the portal public area a number of facilities can be accessed such as information about EDeAN, resources from the Ariadne Resource Centre, news and announcements, frequently Asked Questions, statistics regarding the networking activities and surveys for collecting user feedback. The portal subscribed area is intended to support the actual networking activities, and therefore provides a number of communication and collaboration facilities.

The users of the portal have the option to access the portal settings and alter them in order to match their personal characteristics and the characteristics of the context of use. A number of parameters can be set, such as Language, Device and Display resolution, Assistive technology, Input Device, Disability and Web familiarity. Additionally, in order to allow users to quickly alter their settings, the quick settings option can be used, offering a number of predefined user profiles.

This section presents some examples of the resulting portal UIs using a number of alternative predefined profiles, in order to provide a quick overview of the possible transformation at the user's end. As a first example, activating the "Blind with no Assistive Technology and High Expertise" profile results in the interface presented in figure 17.

In this figure, the following adaptations are highlighted:

1. Text to Speech output is enabled for copying with the lack of assistive technologies. This adaptation is therefore used to mimic the functionality offered by screen readers.
2. Quick access links are presented on the top right and bottom right section of the page allowing blind users to quickly access the most important areas without the need to repeatedly scan the whole page
3. Section breaks are displayed on each page region allowing users with high expertise to skip page sections while navigating resulting to reduced navigation time
4. Images are displayed as text enabling blind users to access their alternative descriptions and furthermore reduce the portal loading time
5. Tables are linearised in order to provide meaningful information to blind users following the appropriate scheme for representing table data together with row and column information
6. Image Buttons are transformed to links enabling blind users to access links with their alternative image descriptions and furthermore reduce the portal loading time

General adaptations that affect the overall look and feel of the page include the linearization of templates, the absence of graphics, and the color scheme introduced (white background and black foreground).

Activating the "Motor Impaired, two Switches, Low Expertise" profile results in the layout presented in figure 18. In this figure, the following adaptations are highlighted:

1. Various quick access links are presented at the top and bottom of the page allowing in the case of motor impaired users to quickly access various parts of a page reducing the overall scanning effort.
2. Links are displayed as buttons for providing visual clues about the currently focused item
3. Section breaks are displayed on each page region allowing users with high expertise quickly skip through page sections.
4. Text boxes provide feedback on focus enabling users to quickly identify whether text insertion elements are focused.

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Accessibility options | Header | Footer | Members Entrance | Page content | Navigation help
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image: Acadie serves as a knowledge base on DIA, including the consolidated outcomes of the EDeAN discussion Groups, and any other means that can facilitate the application and implementation of DIA knowledge into effective work practices.
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To achieve optimum quality and configure the view of the portal you may select among the following options or from a list of predefined profiles:

image: Language Change 3 image: Assistive technology Change image: Disability Change	Language English Change Assistive technology Screen reader Change Disability Blind Change Skins Black skin Change	image: Device & display resolution Change image: Input device (s) Change image: Web familiarity Change	Device & display resolution 1280 x 1024 PC Change Input device (s) Keyboard & mouse Change Web familiarity High Change
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1st row 1st row : Policy and Legislation 1st row : 9
2nd row 2nd row : Standardisation 2nd row : 10
3rd row 3rd row : Best practice in DIA training 3rd row : 10
4th row 4th row : Technological development 4th row : 7
5th row 5th row : Benchmarking 5th row : 7
6th row 6th row : All members 6th row : 7
7th row 7th row : Dissemination 7th row : 4
8th row 8th row : EDeAN NCC Forum 8th row : 5
9th row 9th row : DIA@inclusion 9th row : 5
10th row 10th row : Moderators 10th row : 5
11th row 11th row : DAALLnet 11th row : 5

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1 [Back to \(Top | Footer Content\)](#)

[Top of the Page](#) | [Header](#) | [Footer](#) | [Members Entrance](#) | [Page content](#)

Figure 17: Blind with no Assistive Technology and High Expertise

5. An innovative software keyboard is provided for improving the poor text insertion rates of traditional QWERTY like virtual keyboards [23].
6. A window with the favorite navigation options is displayed providing access to novice users to their most commonly used navigation options.

Activating the "Colour Blind (Protanope) with Low Expertise" profile results in the interface presented in figure 18 Colour Blind (Protanope) with Low Expertise. In this figure, the following adaptations are highlighted:

1. Links are displayed with pink color while the page background is set to black. These transformations are made for supporting the appropriate background/foreground scheme (the one that maximizes contrast) for the selected color blindness.
2. Buttons use yellow color for background, red for border and black for text. This transformation is also employed for maximizing contrast and therefore making buttons easy to spot on the screen.
3. Charts are rendered using an appropriate color palette in order for color blind users to be able to distinguish chart data mainly because their separation is based on color coding.

The readers are encouraged to visit online the EDeAN⁸ portal for a hands-on experience of the adaptation/customisation behavior developed by the means of EAGER toolkit (Note: Some adaptation facilities supported by EAGER are only deployed in the restricted area of the EDeAN portal).

6 Evaluation - Validation

Following the development of the EDeAN portal, an evaluation of the EAGER generated outcomes (e.g., the prototype portal EDeAN) was conducted focusing on accessibility, as well as on user-experience in general. Accessibility issues were evaluated using the methodology that it is presented in subsection 4.1 according to W3C-WAI. The user-experience of the EDeAN prototype was evaluated using an innovative inspection tool (ORIENT) presented in detail in subsection 4.2.

6.1 Accessibility evaluation of UI elements

In order to evaluate all the outcomes of EAGER, the following decisions were taken after brainstorming with experienced accessibility evaluators:

⁸<http://www.edean.org>

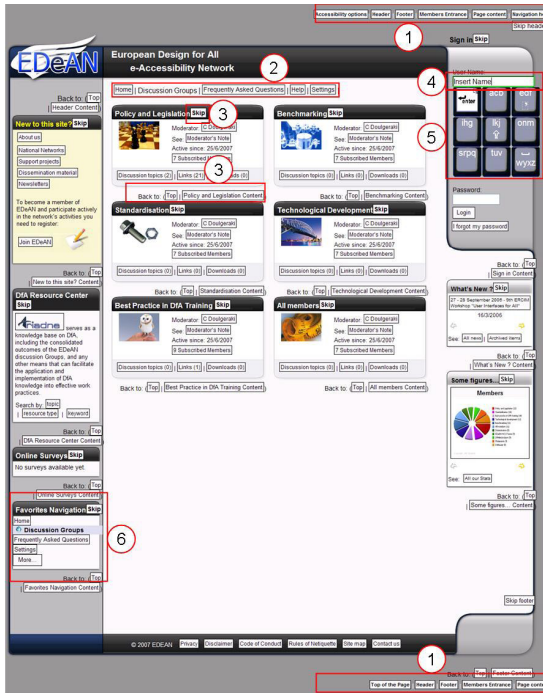


Figure 18: 1: Motor Impaired with two Switches and Low Expertise, 2: Colour Blind (Protanope) with Low Expertise

- All the autonomous user interface elements had to be evaluated in all the alternative styles externally from a portal using at least one evaluation accessibility tool checking for conformance with W3C Web Content Accessibility Guidelines (WCAG) and U.S. Section 508. Evaluating these elements in a portal's environment is particularly difficult due to the wide range of alternative UI elements combinations.
- All the user interface elements that are related to colour had to be evaluated in order to assess colour effectiveness.

Taking into account the above decisions, an exhaustive evaluation of all the UI elements was carried out using the Watchfire Bobby [24] tool that checks conformance with W3C Web Content Accessibility Guidelines (WCAG) and U.S. Section 508 in parallel. A report with the errors and warnings found was produced containing:

- Accessibility errors: seven(7) of Priority 1, twelve(12) of Priority 2, nine(9) of Priority 3 and
- Accessibility warnings: five(5) of Priority 1, six(6) of Priority 2, zero(0) of Priority 3.

For the errors that were identified, it was initially explored if it was possible to correct them. The errors that were correctable were corrected at once. For the rest of the errors, the accessibility level that the specific controls conform was noted. For the warning that were identified the same procedure as for errors was carried out.

For the user interface elements that are related to colours, W3C guidelines were followed. To conform to Web Content Accessibility Guidelines, foreground and background colour combinations should provide sufficient contrast when viewed by someone with low vision or colour blindness, or when viewed on a black and white screen. The formula suggested by the World Wide Web Consortium (W3C) to determine the brightness of a colour is: $((\text{Red value X } 299) + (\text{Green value X } 587) + (\text{Blue value X } 114)) / 1000$. In order to evaluate different colour combinations, the algorithm presented below was applied to background foreground colours for the UI elements that offer colour variety. For the UI elements that provide image output, the online tool Vischeck was used to transform output images to the corresponding images as seen by people with colour-blindness in order to evaluate them.

Finally, in order to identify if the portal is accessible to blind, low vision and motor-impaired users, confirming that it offers maximum accessibility for people with disability it was tested with various assistive technologies.

6.2 User-experience evaluation

In order to evaluate the EDeAN portal from the perspective of user-experience, and thereby validate EAGER, a special inspection tool named

Orient [19], and the underlying methodology [20] for assessing online services were used. The aforementioned evaluation methodology and tool, was applied to the fully functional prototype of the EDeAN portal.

The Orient tool was chosen as it provides a simple-to-use, quick and efficient way to simulate a user's reasoned action process and derive conclusions about the overall user-perceived quality of a system. The Orient inspection process is conducted in four phases by a multidisciplinary team of inspectors. The tool is composed of open-ended questionnaire forms that help individual inspectors make their user-orientation comments and assign positive or negative scores to these. The first phase is the preparation phase, where the objectives and limitations of the inspection are explored and the composition of the inspection team, both in terms of number and expertise, is envisaged. During the set-up phase, the team of inspectors identifies user groups for the given system, based on user goals, and lists the system functions. Also at this phase the conditions of use for each user group are laid down. The core phase of the evaluation follows, where each inspector follows a step-by-step procedure to assess the user-orientation of the system as a whole, and to investigate its individual functions. Finally, during the reporting phase, the inspection leader collects and summarises the results from individual forms, and if required, synthesises the final report, which contains both quantitative data (scores) and qualitative data (expert comments and proposals for improvement). A detailed example evaluation by means of the ORIENT tool is reported in [21].

As a result of the conducted evaluation, the individual rates achieved by the current (prototype) design of the EDeAN portal are more than satisfying (see Table 8). More specifically, for all three indicative user types inspected (blind, colour-blind and motor impaired) by a team of four inspectors including leader, the portal achieved high rates of availability-approachability (reflecting in a broad sense accessibility) and of quality of interaction (reflecting in a broad sense usability); in almost all cases the rates were above the acceptance borderline (zero value) and ranged from 1 and 3, which reflect slight to major examples of good UI design practices. Yet, as shown in the above qualitative evaluation data, there were few design cases identified which need to be reconsidered or slightly improved.

This assessment confirmed the expected benefits of EAGER both in terms of accessibility and usability of the final product, taking also into account various levels of user expertise.

7 Conclusions

This paper has presented the Unified Web-based User Interfaced, a novel approach to the development of Web-based user interfaces that is based on the Unified User Interfaces methodology. EAGER is a novel toolkit that

Overall quality of interaction experience

	First time		and novice users		Moderate users		Expert users				Total	
	V	U	A	Q	M	A	Q	M	A	Q		M
User Group "Color users"	0	1	1	1	0	2	2	0	0	2	0	0.81
User Group "Blind blind"	1	0	1	2	1	2	2	0	1	2	0	1.09
User Group "Motor impaired"	2	2	2	2	0	2	2	0	2	3	0	1.54
Total	1.00	1.00	1.33	1.66	0.33	2.00	2.00	0.00	1.00	2.33	0.00	1.146
			1.066				1.33			1.33		

Where:

V stands for Visibility.

U stands for Perceived usefulness & ease of use.

A stands for Availability & approachability.

Q stands for Quality of interaction experience.

M stands for Relationship maintainability.

Values from "-4" to "-3" are user-orientation catastrophes.

Values from "-3" to "-2" are major problems.

Values from "-2" to "-1" are minor problems.

Values from "-1" to "1" are cosmetic problems and/or examples of good practice.

Values from "1" to "2" are minor examples of good design solutions.

Values from "2" to "3" are major examples of good design solutions.

Values from "3" to "4" are best design solution example (maximal fit).

Table 8: Overview of the quality of user experience for three indicative types of users of the EDeAN prototype.

allows Web content developers to put in practice the proposed approach. The EAGER toolkit has been employed experimentally by the authors to develop a new portal for the European Design for All and e-Accessibility (EDeAN) network. In this context, several different modules were implemented, such as Special Interest Groups, Digital Library, Training courses, and a complete user profiling mechanism. This effort provided valuable feedback in a number of directions. In particular, the development of such a large scale application proved the viability and consistency of the toolkit and demonstrated its ability to stand as a horizontal and efficient development tool.

In the EDeAN portal case study, the correlation of the various alternative designs of UI elements to user and context related parameters (i.e., the automatic adaptation according to generic, predefined profiles) has been made on a normative basis. Therefore, the various designs used are not claimed to be optimal, and need to be further verified in the future, for example through feedback from user trials in real contexts. However, this work has made clear that the proposed approach allows embedding in Web-based applications such decision making logics and automatic adaptation facilities for the benefit of accessibility and better user experience. On the other hand, it has also proved that the proposed approach can produce Web applications that allow their users to select customise the designs according to their preferences or even Web applications that support automatic adaptations.

Another key feature of the UWI method, and consequently of the EAGER toolkit is its ability to be extended and include an unlimited number of alternative interaction modalities and elements. This process entails, mainly, the design and coding of the alternative interactions styles. Then, they can be easily incorporated in the existing toolkit, simply by modifying the decision logic for supporting their conditional activation and deactivation.

The new interaction elements can be in turn easily incorporated in the framework by adding the required decision logic for supporting their conditional activation and deactivation. For example, in order for the framework to be able to produce high quality results in a PDA, the first step to be followed is the evaluation of the existing interaction element in order to decide whether their output is sufficient for use with PDA devices. In the case this does not occur, new styles must be produced to facilitate the interaction and display requirement of a PDA. Additionally, whenever new functionality is required, the process for extending the framework to support new interaction elements must be applied. The overall process of decision making does not alter. The framework continues to operate with enriched decision logic applied whenever the context of use parameters specifies that a PDA device is used.

Moreover the complexity of the UI design effort is radically reduced due to the flexibility provided by the EAGER toolkit for designing interfaces at an abstract task-oriented level. Using EAGER, designers are not

required to be aware of the low level details introduced in representing interaction elements, but only of the high level structural representation of a task and its appropriate decomposition into sub tasks, each of which represents a basic UI and system function. On the other hand, the process of designing the actual front end of the application using a mark-up language is radically decreased in terms of time, due to the fact that developers initially have to select a radically increased number of interface components each of which represents a far more complex facility. Additionally, developers do not have to spend time for editing the presentation characteristics of the high level interaction element, due to the internal styling behaviour. Furthermore the incorporation of EAGER's higher level elements make a portal's code more usable, more readable and especially safe, due to the fact that each interaction component introduced by this framework is designed separately, developed and tested introducing a high level of code reuse, efficiency and safety. It is therefore clear that using a standard UI toolkit a monolithic interface is created, whereas using the EAGER toolkit dynamically adaptable and easily extendable interfaces are generated.

Overall, the method and toolkit presented in this paper for embedding accessibility, graceful transformation and ease of use for all in future and existing Web-based applications goes beyond traditional usability and accessibility approaches, in which Web content developers need to provide one single design well-optimised for various types of users.

References

- [1] Stephanidis, C. (Ed.), Salvendy, G., Akoumianakis, D., Bevan, N., Brewer, J., Emiliani, P.L., Galetsas, A., Haataja, S., Iakovidis, I., Jacko, J., Jenkins, P., Karshmer, A., Korn, P., Marcus, A., Murphy, H., Stary, C., Vanderheiden, G., Weber, G., & Ziegler, J. (1998) Toward an Information Society for All: An International R&D Agenda. *International Journal of Human-Computer Interaction*, 10 (2), 107-134.
- [2] Savidis, A., Stephanidis, C. (2004). Unified User Interface Design: Designing Universally Accessible Interactions. *International Journal of Interacting with Computers*, 16 (2), 243-270.
- [3] Stephanidis, C., Paramythis, A., Sfyraakis, M., Savidis, A. (2001). A Case Study in Unified User Interface Development: The AVANTI Web Browser. In *User Interfaces for All*, Stephanidis, C. (Ed), Lawrence Erlbaum, NJ, 525-568
- [4] Alexandraki, C., Paramythis, A., Maou, N., & Stephanidis, C. (2004). Web accessibility through adaptation. In *Proceedings of the*

9th International Conference on Computers Helping People with Special Needs (ICCHP 2004), Paris, France, 7 - 9 July (pp. 302 - 309). Berlin Heidelberg: Springer-Verlag.

- [5] Hermsdorf, D. 1998. WebAdapter: A Prototype of a WWW Browser with new Special Needs Adaptations. In the Proceedings of the XV IFIP World Computer Congress, Computers and Assistive Technology (ICCHP 98), eds. A. Edwards, A. Arato and W. Zagler, 151-160.
- [6] Henriksen, K. and Indulska, J. 2001. Adapting the Web Interface: An Adaptive Web Browser. In the Proceedings of the Australasian User Interface Conference 2001, volume 23, Number 5. Australian Computer Science Communications.
- [7] Iaccarino, G., Malandrino, D. and Scarano, V. 2006. Personalizable edge services for web accessibility. In the Proceedings of the 2006 international Cross-Disciplinary Workshop on Web Accessibility (W4a): Building the Mobile Web: Rediscovering Accessibility?, W4A, vol. 134., 23-32. New York, NY: ACM Press.
- [8] Brown, S. S. and Robinson P. 2001. A World Wide Web Mediator for Users with Low Vision. In the Proceedings of CHI 2001 Workshop No. 14 "Universal Design: Towards Universal Access in the Information Society".
- [9] Parmato B., Ferydiansyah R., Zeng X., Saptono A. and Sugiantara I. W. 2005. Accessibility Transformation Gateway. In the Proceedings of 38th Hawaii International Conference on System Sciences.
- [10] Han R., Bhagwat P., Lamaire R., Mummert T., Perret V. and Rubas J. 1998. Dynamic Adaptation in an Image Transcoding Proxy For Mobile Web Browsing. IEEE Personal Communications 5(4): 8 - 17.
- [11] Gupta, S. and Kaiser, G. 2005. Extracting content from accessible web pages. In W4A '05: Proceedings of the 2005 International Cross-Disciplinary Workshop on Web Accessibility (W4A), 26 - 30. New York, NY: ACM Press.
- [12] Barrett, R. and Maglio, P. 1998. Adaptive Communities and Web Places. In the Proceedings of the 2nd Workshop on Adaptive Hypertext and Hypermedia, HYPERTEXT 98.
- [13] Barrett, R. and Maglio, P. 1999a. Intermediaries: An approach to manipulating information streams. IBM Systems Journal 38(4): 629 - 641.
- [14] Barrett, R. and Maglio, P. 1999b. WebPlaces: Adding people to the Web. In the Proceedings of 8th International World Wide Web Conference. ACM Press.

- [15] Barra, M., Grieco, R., Malandrino, D., Negro, A. and Scarano, V. 2003. TextToSpeech: an heavy-weight Edge computing Service. In the Poster Proceedings of 12th International World Wide Web Conference. ACM Press.
- [16] Chen, Y., Xie, X., Ma, W.Y., Zhang, H.J. 2005. Adapting Web Pages for Small - Screen Devices. *IEEE Internet Computing* 9(1): 50 - 56.
- [17] Graef, G. 2000. Adaptation of Web-Applications Based on Automated User Behaviour Analysis. In the Proceedings of the Second Annual Conference on World Wide Web Applications (WWW 2000), 72 - 75.
- [18] Taib, R. and Ruiz, N. 2006. Multimodal Interaction Styles for Hypermedia Adaptation. In the Proceedings of the International Conference on Intelligent User Interfaces (IUI'06), 351 - 353.
- [19] Mourouzis, A., Antona, M., Kastrinaki, A., & Stephanidis, C. (2006). ORIENT: An Expert-based Tool for Assessing the User-orientation of eServices. In P. Cunningham and M. Cunningham (Eds.), *Exploiting the Knowledge Economy: Issues, Applications and Case Studies*, Proceedings of eChallenges e-2006 Conference, Barcelona, Spain, 25 - 27 October (pp. 443-450). Amsterdam, The Netherlands: IOS Press.
- [20] Antona, M., Mourouzis, A., & Stephanidis, C. (2007). Towards a Walkthrough Method for Universal Access Evaluation. In C. Stephanidis (Ed.), *Universal Access in HCI-PART I of the Proceedings of 4th International Conference on Universal Access in Human-Computer Interaction (UAHCI 2007-held as Part of HCI International 2007)*, Beijing, China, July 22-27 (pp. 325-334), LNCS 4554, Springer-Verlag, Berlin Heidelberg (ISBN: 978-3-540-73278-5).
- [21] Mourouzis, A., Antona, M., Boutsakis, E., Kastrinaki, A., & Stephanidis, C. (2006). User-orientation Evaluation Framework for eServices: Inspection tool and usage guidelines. FORTH-ICS Technical Report, TR-372.
- [22] Antona, M., Mourouzis, A., Kastrinaki, A., Boutsakis, E., & Stephanidis C. (2006) User-orientation inspection of ten European eServices: Results and lessons learned. FORTH-ICS Technical Report, TR-373.
- [23] Mourouzis, A., Boutsakis, E., Ntoa, S., Antona, M. & Stephanidis, C. (2007) An Accessible and Usable Soft Keyboard. In Volume 6 of the Proceedings the 12th International Conference on Human-Computer Interaction (HCI International 2007), LNCS 4555, Beijing, China, 22-27 July, (ISBN: 978-3-540-73280-8).
- [24] Watchfire Bobby Version 5.10.2.3.

- [25] Nielsen, J. (2006) Screen Resolution and Page Layout. Nielsen, J., Alertbox, Available electronically at: http://www.useit.com/alertbox/screen_resolution.html.