In *The Universal Access Handbook*. C. Stephanidis (Ed). Boca Raton, FL: CRC Press. Pp 38-1 – 38-18.

Accessing the Web

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Abstract: The World Wide Web offers much for those able to access its content. Limitations of visual, motor, language, or cognitive abilities, however, pose serious barriers to access. The W3C has provided guidelines for Web developers and browser functionality designed to enable access. Despite this, significant numbers of pages remain inaccessible or unusable by people with disabilities. Moreover, the advent of Web 2.0 threatens to create new accessibility problems. This chapter will discuss various challenges and solutions to making the Web accessible to all.

Keywords:

World Wide Web, Web technologies, Web 2.0, disabilities, aging, accessibility

1. Introduction and Background

The World Wide Web (Web) is the single largest repository of electronic information, art, and digital culture in the world. This gives it a special significance when it comes to governmental participation, shopping, entertainment, health-care, social networking, and economic issues such as employment and service. In short, a more independent life for many can begin with successful Web access.

> *"For me being online is everything. It's my hi-fi, my source of income, my supermarket, my telephone. It's my way in."*

This quote, taken from a blind user, sums up the sentiments experienced when talking with many disabled users, and drives home the importance of Web accessibility in the context of independent living. Most services, both governmental and private, and nearly all significant information resources now have Web interfaces. Access to these interfaces vastly extends the understanding and effective reach of both able and disabled users.

Two key attributes contribute to the impact of this technology. First, the information is distributed over probably hundreds of millions of servers but accessible from any user's computer anywhere in the world. Second, the information is digital and generally represented in such a way that it can be transformed into different formats to be used more effectively by people with disabilities. These two attributes give the Web its universal appeal and importance. The flattening of the global economy is also driving the Web to become a universal medium for commerce. Competing effectively in most economic sectors now requires a viable Web presence. With the ability to buy anything from anywhere, from the specialist baker in a foreign country, to the pizza delivery company at the end of the street, the accessibility of services has major implications for business on both a local and global scale.

The Web allows companies to reach beyond their normal local orbits and be relevant to distant communities, and it is for this reason that governments and participation in political activity and government services is also increasing. Reaching distant communities, communities which may not have otherwise participated has a knock on effect for health, wellbeing, and social participation. Indeed, participation in all these areas is enhanced when the Web is introduced, even when that participation is on a geographically local scale. From setting up neighborhood watch sites to local service information for healthcare, the Web is becoming just another way of communicating, exchanging, and informing audiences both locally and globally. While the rapid rise of the Web has left digital ethnographers and social anthropologists at something of a loss as to its exact nature, one thing is certain – the Web provides a tele-presence into shops, communities, and entertainment, both local and at a distance, that users would never have otherwise experienced. This is important for everybody, but especially important for communities of people who would otherwise be barred from full participation in these activities. These communities include those whose disabilities hinder their efforts to find employment, to interact more fully with society at large, and to freely use technology without assistance. However, with the growth of the Web, and a move to more thought and communication based activities (the emerging knowledge economy), there is the very real possibility of disabled people finding productive, fulfilling, and socially empowering lives because of Web access. While the point has not yet been reached where Web access is required by able-bodied people for daily living, it is probably not that far away. For disabled people, however, that threshold may have already been crossed.

This chapter discusses issues related to universal access for users with disabilities. Although the lion's share of attention in accessibility has been directed at users with vision disabilities, a number of people with other disabilities have difficulties accessing the Web. This Chapter considers issues related to hearing loss, motor impairment, cognitive disability and aging as they relate to Web access. This latter population, older adults, presents some very interesting issues of Web access due to the fact that in many cases there are multiple sources of disability. Thus, the discussion of older adults can be viewed as a window on topics of combined disability. Although not specifically discussed in this chapter, the number of people who experience disability with Web access is not limited to those with permanent disability. Many people, as a result of injury, face temporary disability that will cause them to experience one or more of the issues discussed in this chapter.

Following the presentation of needs of disabled users, this chapter describes some solutions. Guidelines to address Web accessibility are described, followed by discussions of new and emerging technologies that contribute to universal access to the Web.

2. Universal Access to the Web

Universal Access within the context of Web accessibility aims to help people with disabilities to perceive, understand, navigate, interact, and contribute to the Web. Disabled Web 'surfers' may use intermediate technologies to gain access to Web and computer functionality. In general, technology such as magnifiers and screen readers or specialized keyboards exist to provide access to any software on the computer. Such technology is not always required for the Web, however, since some accessibility features are incorporated directly into Web document standards and Web browser features.

There are millions of people who have disabilities that affect their use of the Web. Currently most Web sites have accessibility barriers that make it difficult or impossible for many people with disabilities to use them (Petrie et al. 2004). Usability is considered as critical to universal access. Therefore, this chapter explores technologies that not only meet the minimum requirements for Web accessibility, but also those that can help provide an effective browsing experience. In this spirit, technologies that often go beyond requirements specified by Web access guidelines are considered.

2.1 Vision

Globally, in 2002 more than 161 million people were visually impaired, of whom 124 million had low vision and 37 million were blind. However, refractive error as a cause of visual impairment was not included, which implies that the actual global magnitude of visual impairment is greater (World Health Organisation 2004). Worldwide, for each blind person, an average of 3.4 people have low vision, with country and regional variation ranging from 2.4 to 5.5. These figures - the first global estimates since the early 1990s - are the best current estimates of the global burden of visual impairment and are the result of new studies carried out in nearly all World Health Organization [1] regions, which have substantially updated the epidemiological data. For instance, of 878 million Europeans, 3 million are blind, 13 million have low vision, and 16 million are visually impaired (World Health Organisation 2004). This represents 4% of the total European population and 7% of the global population of people with visual impairments. However, these figures appear likely to change significantly. Indeed, based on the 1990 census, both figures are rising in developed countries due to an aging population. More than 82% of all people who are blind are 50 years of age and older, although older adults represent only 19% of

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[1] By the 10th Revision of the of the WHO International Statistical Classification of Diseases, Injuries and Causes of Death, low vision is defined as visual acuity of less then 6/18, but equal to or better than 3/60, or corresponding visual field loss to less than 20 degrees, in the better eye with best possible correction. Blindness is defined as visual acuity of less than 3/60, or corresponding visual field loss to less than 10 degrees, in the better eye with best possible correction. Visual impairment includes low vision as well as blindness.

the world's population. Therefore, technology to afford visually impaired users access to resources is becoming increasingly important as the global population becomes proportionally older. Chapter ++ “Sensory impairments” of this Handbook offers a more detailed discussion of vision-related problems.

Visual impairment is the most addressed disability in the Web accessibility spectrum. It is a challenging area because it requires the visual interaction model, and the HTML structure created to support this model, to be moved into a predominantly serial interaction paradigm. To bridge this gap, assistive technologies have been created for differing levels of visual impairment from low vision to profound blindness. These range from color manipulation software (Wakita and Shimamura 2005)[2], through browser magnification and legibility enhancing systems (Richards and Hanson 2004), to specialist browsing systems (Ramakrishnan, Stent and Yang 2004), finishing with applications for the most extreme cases of blindness, those to audibly read the screen (JAWS 2006). These screen-readers address text to speech translations by audibly reading documents, top-left to bottom-right, through a text-to-speech synthesizer. This is acceptable in most instances, as the screen reader also translates the focused user event handler (such as a toolbar or menu system), and so the application’s normal user event mechanisms can be used for interaction by a visually impaired user. Screen readers are discussed in details in Chapter ++ “Screen Readers” of this Handbook.

Initial attempts at screen reading , based on ‘screen scraping’, simply read the screen in a left to right, top to bottom order, often shuffling elements from semantically distinct regions that just happened to be adjacent to one another). As the visual complexity of Web pages increased these screen-readers become inadequate because of the reliance of Web documents on context, linking, and deeper document structure to convey information in a useful way. Because of this, Web browsers and Web page readers for visually impaired users have evolved to access this deeper document structure, directly examining the structured page source or the browser's internal representation of that source, the Document Object Model (DOM). By examining the role being played by portions of the text, it was hoped that more complex meanings (associated with style, color, etc.) could be derived. However, when interacting with complex Web documents these readers, although better than screen scrapers, still do not capture enough of the document structure to provide the visually impaired user a browsing experience as rich and meaningful as that available to a sighted user.

To fully support these users a better understanding of the perception of information by visually impaired users must be gained, reflecting genuine perceptual and cognitive processes rather than simply rely on a straightforward application of existing technology. This understanding may be limited to audio only processes or may eventually extend to novel cross–modal interactions that relate to Web accessibility and the display of Web documents for visually impaired users, such as haptics. There is a wealth of still to be discovered knowledge pertaining to Web accessibility, transcoding, cross-modal interaction, and perceptual analysis, and its study may result in a set of novel tools and techniques to inform the transformation process.

In summary, many visually disabled users consider the Web to be a primary source for information, employment and entertainment (Jacobs et al. 2005). Indeed, from questioning and contact with many blind users we have discovered that the importance of the Web cannot be over-estimated.

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[2] For color blind users.

2.2 Hearing

Significant hearing loss impacts a large number of people   Demographic surveys indicate that nearly 10% of the population experiences significant hearing loss, but the numbers increase sharply with age.   The number is less than 2% for children under 17 years of age, but as high as 29% for adults over the age of 65 (Holt, Hotto and Cole 1994; NIDCD; RNID). Chapter ++ "Sensory impairments" of this Handbook discusses hearing-related problems in details.

The WAI guidelines state that alternative formats should be provided for sounds or spoken Web content. The largely visual nature of the Web has, in many ways, proven advantageous for people who are deaf or hard of hearing. The Web provides visual access to information and services and communication applications such as instant messaging, e-mail, and video transmission of chats have enabled deaf and hard of hearing people to more easily interact with others.

As Web content becomes increasingly reliant on an audio channel, however, new barriers are presented to users who have a hearing loss. Even deaf or hard of hearing individuals who are skilled lipreaders cannot understand material that is presented in the form of a voiceover or with the face of the speaker partially obscured, poorly lit, or presented at a low frame rate.

The current explosion of interest in internet games and virtual worlds is an excellent example of environments in which increasingly sophisticated technology has the effect of increasingly disenfranchising users with disabilities. Consider that early forms of games and virtual worlds were text based. Now those have been replaced by sophisticated visual "worlds" with accompanying auditory effects. In many cases, critical information is only presented via sound. Users who do not have access to this information will be unable to participate in the game or interact fully in the virtual world. While some sounds might be considered the audio equivalent of eye-candy – musical soundtracks, for example, that primarily enhance emotional impact – equal access dictates that deaf and hard of hearing users be given at least an indication of the presence of such ‘ear-candy’.

Sound events can be appealingly presented in visual form in many cases. Alerting sounds and off-screen events can be visually represented by images (Kimball 2007). Such images not only make events accessible, but can represent fun multimedia alternatives, particularly in game environments (Trewin et al. 2008). Speech, however, must be represented by other means. Captioning is most commonly used to provide a visual representation of speech.

Captioning. Most people are familiar with subtitles that are used in foreign films to provide language translations. Captioning is similar in purpose. With captioning, speech is transcribed and the text is displayed onscreen, synchronized with the video and audio (at the level of individual sentences or phrases). Ideally, sound events (such as music, alerts, or environmental sounds) are indicated in the captions so that the deaf or hard of hearing person is aware of these events and can respond to them as needed. Captions can be open (meaning that they are always visible) or closed (meaning that they can be turned on and off as controlled by standard Web media applications).

A number of options exist for Web content providers to caption material (see Core Techniques for Web Content Accessibility Guidelines 1.0, 2000; National Center for Accessible Multimedia). An issue that often arises is whether to provide verbatim captioning or captioning at a reading level directed at the average reading level of deaf and hard of hearing users. To understand this issue, it is necessary to realize that the age at which a hearing loss is acquired has a number of important implications for a person’s ultimate language skill. Many find it surprising that hearing loss at a young age often makes it difficult to acquire skilled reading (for detailed discussions of the issues involved, see Conrad 1979; see also Chapter "Sign Language in the Interface: Access for Deaf Signers" of the current Volume). Nevertheless, the most generally accepted approach to captioning is to provide a verbatim transcript (Hanson 2007).

Signing. Sign languages are commonly used in deaf communities worldwide (Padden and Humphries 1988). Contrary to many expectations, there is not one common sign language throughout the world. Rather, there exist a number of sign languages, including a distinctly different British Sign Language (BSL), American Sign Language (ASL), and Australian Sign Language (Auslan), despite the commonalities of English across these geographies. For individuals who use sign language, a signed interface may be appropriate for websites. Sign language interfaces are considered in depth by Huenerfauth and Hanson (see Chapter "Sign Language in the Interface: Access for Deaf Signers" of the current Volume), so in the present discussion we will highlight only specific issues that impact Web access.

In contrast to captioning, which generally seeks to present speech and sound visually, sign language interfaces are typically promoted as a way of making written Web content accessible to sign language users who may lack the reading proficiency needed to understand the text on a website (see Chapter "Sign Language in the Interface: Access for Deaf Signers" of the current Volume; Kennaway et al. 2007). Often this is the case on websites or applications intended for deaf children who might not yet have acquired reading skills, but it may be considered appropriate for other websites to ensure equal access for sign language users.

Video chats, vBlogs, and video in e-mail are excellent examples of Web applications that allow signers to easily communicate. These Web applications have been enabled by the growing prevalence of high speed networks combined with new video compression technologies. While natural sign language using video is ideal from the standpoint of the signing user, its use may be better suited for communication applications than for language translations of print in websites. While video of a person signing will present the highest quality of signing, it still requires substantial local storage or high speed links to stream remote content. Once captured, it also tends to be quite difficult to edit as the corresponding text content changes, making it costly to maintain over time. Some sites use video effectively, such as the British Deaf Association[3]. The number of such sites is limited, however.

The inflexibility of video has prompted research on the use of signing avatars. These avatars provide an animated depiction of human signers. The goal of avatar technology is to one day have avatars that can automatically translate text into a native sign language. A glimpse of the future of avatar technology can be seen in the ASL signing avatar demonstrated on DeafWorld.com[4]. For now, human intervention is required to generate such high quality signing by avatars. Avatars that rely solely on machine 'translations' are limited to providing sign renderings of print that follow the text word for word, rather than being translations into a native sign language having fundamentally different syntax. A current research focus is on natural language translation, with a deep understanding of linguistics providing the rules for machine translation needed for avatars to display native sign languages (see Chapter "Sign Language in the Interface: Access for Deaf Signers" of the current Volume; Kennaway et al. 2007).

2.3 Motor Skills

Many people with motor impairments rely heavily on the Web to provide access to services and opportunities they would otherwise be unable to use independently. They form a very diverse group (see Chapter ++ "Motor Impairments and Universal Access" of this Handbook), but share

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[3] http://bda.org.uk/index.php

a number of core Web access requirements. The most prevalent causes of motor impairment are musculoskeletal disorders, including arthritis, and carpal tunnel syndrome. Worldwide, an estimated 9-27% of the population is affected to some degree by a musculoskeletal disorder (Huisstede et al. 2006).

The prevalence of physical impairment in the population is rising. This is partly due to demographic changes in the population – as the population ages, people are more likely to acquire some limitation in physical abilities (Lethbridge-Çejku, Rose and Vickerie 2006). It is also partly due to improvements in health care. More people are able to survive traumatic events such as stroke or brain injury. These may give rise to severe physical impairments, depending on the part of the brain that has been damaged. The prevalence of Parkinson's Disease is expected to double in the next 25 years, fueled by the aging of the population (Dorsey et al. 2007). Improvements in antenatal care are also leading to a rise in the prevalence of cerebral palsy (Krigger 2006; Odding et al. 2006).

Devices. Most individuals use both a keyboard and a mouse to access the Web, and people with limited dexterity are no different. Some people use a keyboard but no pointing device, and rely on key commands to control Web browsers and navigate pages. Some use speech commands to browse the Web. Others have a method of pointing and selecting a position on the screen, but no keyboard. For example, they may point by eye gaze and make selections by dwelling on a target. They enter text by clicking letters on a software keyboard on the screen (an on-screen keyboard), which are then sent to the browser by the keyboard software. Most on-screen keyboards also incorporate word prediction capabilities, where the user can select a predicted word with a single

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[4] http://www.deafworld.com/videos/?vid=80L2Xc0K8Jg
See also http://www.vcom3d.com/vault_files/forest_asl/

action (see also Chapter ++ “Virtual Mouse and Keyboards for Text Entry” of this Handbook). An enormous variety of inventive solutions are employed by those who find that the keyboard and mouse do not meet their needs (see examples in Alliance for Technology Access 2004). Individuals with very limited motion can use one or two binary signals generated by a physical switch, tongue switch, EMG sensor or other device, and can control a computer by scanning through the available options (manually or automatically) and selecting the items of interest. A switch user will typically control a Web browser indirectly through keystrokes entered on a scanning on-screen keyboard (see also Chapter ++ “Automatic Hierarchical Scanning for Windows Applications” of this Handbook).

Given the diversity of solutions used by this population, it is very important that Web pages be designed for device independence, without the assumption that the user has both a pointing device and a keyboard. The W3C WAI guidelines provide recommendations for achieving this (Caldwell et al. 2006; Chisholm et al. 2001). For example, it is recommended that pages should not use event handlers that are triggered only by mouse events, because this makes them inaccessible to a keyboard-only or speech-only user.

Because all of these input techniques can provide text input, the standard approach to providing universal access is to ensure that browsers and Web sites can be accessed and controlled via keystrokes. This provides a basic level of access, but can be very inefficient (Schrepp 2006). For example, a switch user must repeatedly scan through the letters of her keyboard to the ‘tab’ key, and each ‘tab’ key press advances her just one step through the set of browser options. For low bandwidth users, a specialized browser can provide far more efficient and effective keystroke-based access (Mankoff et al. 2002). Mankoff et al (2002) also identified several useful transcoding techniques for supporting low bandwidth input, including the addition of links to support backwards and forwards navigation at each paragraph break, other links for skipping unwanted sections, and specialized form widgets with built-in scanning capabilities.

Input Rate. One study of mouse users with mild to moderate motor impairments (Trewin and Pain 1999) found that selecting on-screen items typically took 2-3 times as long for this group as for a comparison group with no impairment, even with error correction time excluded. On the Web, every link selection may require considerable time and effort. Indeed, one major study of Web accessibility found that the usability problems most frequently reported by people with physical impairments were lack of clarity in site navigation mechanisms, and confusing page layout (Disability Rights Commission 2004). This finding probably reflects the high cost of taking a wrong path and the effort required to navigate around a page.

Typing speed is also affected. While a speed of 30-40 words per minute is normal for average QWERTY typists (Starner 2004), a keyboard user with a movement disorder might type at around 10 words per minute. An eye-gaze typist might produce 1-15 words per minute (Majaranta and Räihä 2002). For a scanning on-screen keyboard user, 1-5 words per minute is not unusual (Brewster, Raty and Kortekangas 1996).

To accommodate slower typing rates, Web pages can be made more usable by reducing the amount of free text entry to a minimum, providing pre-selected defaults wherever possible, and allowing the user to request extra time to fill in information on forms that have a time-out. These design guidelines go beyond the provisions of the W3C's WAI and UAAG guidelines, but have already been identified as being helpful for mobile web users, who also have slower input rates, higher error rates, and a higher cost of navigation errors than desktop users (Rabin and McCathieNevile 2006; Trewin 2006). Many mobile Web devices do not have a pointing device, and so support for keyboard navigation is also important for this community. Researchers are actively working to incorporate this core capability into Web 2.0 technologies (Schwerdtfeger and Gunderson 2006).

Dexterity Demands. Physical impairments affect movement in many different ways. If movement is painful, tiring, or difficult to control, then the level of dexterity demanded by a Web site will have a significant effect on the usability of that site. A further contributing factor is that techniques such as speech, eye gaze pointing, or EMG can be inherently error prone or difficult to control. People with severe motor impairments are often pioneers in the use of such technologies, at a stage when they are not robust or reliable enough to become more generally popular.

The design features described previously that minimize the typing required on a Web page can help to minimize the physical demands of interacting with a page. Web designers can also assist by providing error recovery mechanisms such as confirmation dialogs for irreversible actions. If a user has typed a password wrongly several times (being unable to check what they have typed) a response that does not lock the user's account is obviously preferable.

In the Disability Rights Commission study described earlier, the third most common Web site problem reported by people with physical impairments was small text and graphics (Disability Rights Commission 2004), which would be difficult to select. Although there has been research into mechanisms for making pointing and clicking on small targets easier (Grossman and Balakrishnan 2005; Worden et al. 1997), there is little operating system or browser support currently available. Making clicking physically easier, therefore, means making the targets larger. While browsers do provide the ability to enlarge text, other non-text clickable objects such as arrows for expanding sections of tree views often cannot be made larger except by magnifying the whole page. This introduces extra navigation actions and makes it more difficult to understand the context of the Web page as a whole. Cascading menus also introduce significant motor demands, because they require the user to follow a specific path in order to follow through the desired sequence of sub-menus. The longer a continuous action sequence must be maintained, the more likely it is for movement disorders such as jerks or spasms to disrupt it.

Many users of pointing devices would benefit tremendously from having the ability to specify a minimum target size at the browser level, in a similar way to choosing a preferred font size. Web pages should therefore be designed to accommodate changes to the way that basic clickable elements are drawn, in addition to font size changes.

In summary, there will always be great diversity in the assistive solutions used by individuals with physical impairments, and the speed and accuracy with which they are able to control the browser. However, they share a need for Web pages that are designed for device independence, with minimal dexterity demands, clear navigation mechanisms, and error recovery mechanisms. A good universal design should optimize both ease of keyboard access and ease of direct selection.

2.4 Cognition

The term cognitive disability covers a broad range of different issues. These can include learning disabilities (such as dyslexia), memory, attention, problem-solving, mental illness, intellectual abilities, processing of sensory information, and more (Newell et al. 2007). Within each class of ability, the level of impairment will also vary, making this a very ill-defined category. Related issues are discussed in details in Chapter ++ “Cognitive Disabilities” of this Handbook.

Compared with other disability areas, the topic of cognition has received little attention (Bohman

2004; Jiwnani 2001). Perhaps this is due to the widely differing needs of users in this population. Perhaps it is due to an assumption that the numbers of people with cognitive disabilities are few, a perception that will likely change with recent attention to autism spectrum disorder (Rice 2007) and traumatic brain injury (CDC 2006). Perhaps it is due to assumptions that people with cognitive impairments will not use the Web. Perhaps it is due to a lack of activism on the part of members of this demographic in demanding access. Whatever the reason or combination of reasons, the fact remains that many individuals with a cognitive limitation do wish to have fuller access to the Web. Many even have successful, professional careers for which Web access is required. Web authors should assume that their target audience *will* include people with cognitive impairments.

Extensions to current Web accessibility guidelines have been suggested to improve access for some groups of users with cognitive impairments (Poulson and Nicolle 2004). Many of the Web access barriers reported by people with cognitive impairments are familiar to all users, but felt more acutely by this group. Many design guidelines aimed at improving cognitive accessibility are basic techniques for effective communication. It is not surprising, then, that sites that design for this group can be more effective for everyone (Nielsen 2005).

A number of methods for supporting users with cognitive limitations can be implemented. Among these are navigational supports, reduced distractions, memory supports, and provision of text-to-speech. More specifics as to how Web design can aid in the usability of Web pages by people with cognitive disabilities are considered here:

- Web pages, and the process of navigating the Web, can be complex, but there are steps that authors can take to reduce this complexity and make Web sites more accessible to people who have difficulty with complex multi-step tasks. According to the WAI guidelines, the most accessible sites are those that use consistent navigation mechanisms, and keep to commonly used navigation conventions. Clearly structuring the information on the page is also helpful.

- Spatial ability, situation awareness, and the ability to focus and concentrate on a specific task are all important cognitive skills for effective Web navigation (Small et al. 2005). For some individuals, it can be very difficult to maintain the necessary level of awareness and focus. Animated elements on Web pages are a common source of irritation to many users, but the impact on usability for an easily distractible person can be profound.
- Memory is also an issue in Web navigation. It is easy for anyone to get lost in the sheer vastness the Web, unable to remember or figure out where they are, how they got there, and how to get to where they want to be. For sites that incorporate lengthy tasks with multiple steps, context information such as 'Step 2 of 4" can help to keep users oriented. In hierarchically structured sites, the use of "breadcrumbs" to show position in the site's page tree can also help.
- The **Back** button, although the most common means of returning to recently viewed pages, uses a stack-based model that makes entire branches of the recent history unavailable. Many users rely heavily on going back, but do not understand this model well. History and bookmark mechanisms that use text labels, and search mechanisms that require accurate spelling, can also cause navigation difficulties (Harrysson, Svensk and Johansson 2004). Supplementing the text labels with icons or page thumbnails can be very effective in promoting recognition in history and bookmark lists. Much mainstream research is devoted to investigating ways to support Web navigation, with suggestions including graphical history representations, and alternative back and history mechanisms

(Ayers and Stasko 1995; Cockburn et al. 2003).

- Many Web sites require users to register, and log on with a user ID and password in order to access their personal account information. Remembering all of these passwords can be difficult, and so browser tools that offer to remember previously typed IDs and passwords are very useful for people with memory limitations.

Given the wide variety of issues that fall under the category of cognition, space does not permit a complete discussion of all the issues and how the types of techniques mentioned here might apply. To give some sense of how these solutions work with specific users, two populations are discussed: users with developmental disabilities and those with dyslexia.

Developmental disabilities (such as Down syndrome or autism spectrum disorders) clearly impact a person's ability to utilize the Web. Clicking links and browser controls such as page up and page down appear to be of relatively little problem to this user group, while entering urls presents great difficulty (Harryson, Svensk and Johansson 2004). On individual pages, consistent page navigation, content supported by images, and structured browsing that guides users through a more limited number of selections is important (Brewer 2005; Sevilla et al. 2007). Users with developmental disabilities also can benefit from text to speech technologies that read Web content aloud and from pages that have relatively little content viewable at one time to reduce distractions (Richards and Hanson 2004).

Dyslexia is a neurological problem that impacts language. It can take many forms, of which the most commonly known is difficulty with reading and writing (Dyslexia Research Institute 2007; National Center for Learning Disabilities 2007; Shaywitz et al 1998). Not surprisingly, dyslexic users can benefit from having the ability to listen to the content of Web pages be read aloud. A number of design issues also can serve to make websites more usable for dyslexic children and adults, including providing memory supports and text options such as color contrast, font size, and spacing between words and lines of text (Elkind 1998; Vassallo 2003; *Web Design for Dyslexic Users*). The importance of providing the ability for individual users to make changes for their own needs is highlighted in research with this population, showing great individual variability, for example, in the font options when using software that allows them to adapt pages to their own needs (Gregor and Newell 2000; Hanson et al. 2005).

2.5 Aging

Contrary to conventional wisdom, many older adults are eager to utilize current computer technologies, with access to the Web being considered key (Czaja and Lee 2007; Fox 2004). Age-related issues for access to technology are discussed in Chapter ++ "Age Related Difference in the Interface Design Process" of this Handbook".

Older adults face challenges in accessing the Web. These challenges come from two sources. The first challenge for older adults is that many are novice computer users (Newell et al. 2006). With respect to the Web, problems arise due to confusing terminology and a bewildering array of options on the interface of conventional browsers. Various attempts, some commercial, have been made to make Web tasks easier for novice users. Some older adults, however, are retired from jobs or still hold jobs that require the use of the Web; many others have simply used it for their own personal interests for many years. A number of organizations worldwide, such as *SeniorNet* in the United States and *Old Kids* in China, help novice users get started with computers and get connected online (Xie 2006). In this same spirit, software applications geared specifically for the older adult have been devised, particularly with novice users in mind (Caring Family 2007; ElderMail 2007; Generations on Line 2006; Newell et al. 2006). Although there is currently a digital divide between those over 70 and other age groups in terms of Web use, demographics suggest that this divide will shrink in the coming years. Today, older adults over age 70 continue to use the Web less often than other age groups, but as the baby boomers become this older generation, the numbers of skilled Web users is expected to surge, creating what has been called a "silver Tsunami" (Fox 2001).

The second challenge for older Web users comes from the fact that nearly all older adults have some declines that impact computer use (if only the fact that multi-focal glasses must be worn to read content on the screen and these glasses typically are not well suited to reading text on a typically positioned display). Declines of vision, hearing, dexterity, and cognition are common. Previous discussions in this chapter suggest how some of these declines will impact older users. The complexity of Web technologies, particularly some of the emerging "Web 2.0" technologies, pose particular challenges for novice older users (Chadwick-Dias, Bergel and Tullis 2007; Zajicek 2007). While navigating the Web and dealing with new social interactions and dynamically changing content appears almost effortless for younger users, the cognitive declines typical of older adults (Czaja and Lee 2007) make the learning and use of such technologies difficult. Older adults typically read content more carefully, and read more of it before initiating an action compared to younger users (Tullis 2007). They are also less likely to utilize new collaborative technologies such as blogs and wikis, and are less likely to download newer media types such as videos and music.

Perceptual difficulties with vision and hearing are also problematic. With sound and video becoming more prominent on the Web, older users can benefit from captioning provided for users with hearing loss. Declining vision, however, is most often discussed by older users as a problem. Reduced acuity, color perception, and contrast discrimination accompany normal aging (Faye and Stappenbeck 2000; Parker and Scharff 1998). These declines lead to difficulties in reading small text, text that is closely surrounded by other visual elements, and text that has complex font styles or lowered contrast due to poor color choices on pages. Web design guidelines for older adults stress the use of larger fonts, high contrast (black on white or white on black) and increased spacing between text elements (NIA 2002). Some of the necessary adaptations are built-in to conventional browsers (such as Internet Explorer, Firefox, Opera, and Safari), although they are typically accessed via multiple levels of menus and complex dialog boxes, making it difficult for older adults to find and utilize these features (Sa-nga-ngam and Kurniawan 2007). Although older adults wish to use their available vision as much as possible for browsing, speech is often helpful in augmenting their reading. Potential problems with understanding synthetic speech (Czaja and Lee 2007) and long messages (Zajicek 2003), exacerbated by faulty memories and erroneous models of navigation, (Hanson, Richards and Lee 2007; Zajicek, 2001, 2003) suggest that speech, while useful, will not ensure the needs of older users are met.

In addition to these perceptual problems, older users may have difficulty using a mouse and keyboard due to illnesses or injuries that limit dexterity. There is evidence that older adults use different movement strategies than younger adults, with lower peak velocities, and many sub movements, and that fine positioning over a target is a particularly difficult for this group (Keates and Trewin 2005). Many would be well served by having larger targets on the screen that would not only make clicking easier, but would also make seeing the targets easier.

As declines for older people are often in more than one area, their combination can make accessibility more challenging than for users with a single disability. Consider, for example, an older adult who has both low vision and hand tremors. Finding assistive devices for magnification, speech, and mouse correction that work well together may be difficult (as these devices are not tested together) to impossible (the devices make conflicting demands on underlying system resources). Interestingly, despite this tendency to have multiple limitations, older adults do not tend to view themselves as ‘disabled’. This fact is critical in understanding that this population is less likely than their younger counterparts to use special devices, such as assistive input technologies described above. Particularly among novice users, there is a tendency to view problems as due to their own lack of understanding of the technology. This rarely leads to the realization that nonstandard software and hardware is available and can make computers easier to use. As such, older users will be more likely to struggle with standard technology.

2.6 Web Accessibility Guidelines

Web accessibility depends on diverse aspects of Web development and interaction technologies working together, including Web software (tools), Web developers (people) and content (e.g., font and color choices, element sizes, layout, etc.). The W3C Web Accessibility Initiative (WAI)[5] recognizes these difficulties and provides guidelines for each of these interdependent components: (i) Authoring Tool Accessibility Guidelines (ATAG) which address software used to create Web sites (Treviranus et al. 2000, 2004); (ii) Web Content Accessibility Guidelines (WCAG WG 2006) which address the information in a Web site, including text, images, forms, sounds, and so on (Caldwell 2008; Chisholm, Vanderheiden and Jacobs 2001); and (iii) User Agent Accessibility Guidelines (UAAG) which address Web browsers and media players, and their relationships to assistive technologies (Jacobs, Gunderson and Hansen 2002). There are other organizations that have also produced guidelines (e.g., IBM, RNIB, AFB, Macromedia,

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[5] Web Accessibility Initiative (WAI). Retrieved December 15, 2007 from http://www.w3.org/WAI/

etc.), but the WAI guidelines integrate many of the key points of the others.

Of these issues addressed by guidelines, the ones for creating accessible Web pages (WCAG) tend to be the most widely known. There is however, no homogeneous set of guidelines that designers can easily follow. In the Web accessibility field there are also other best practice efforts (Craven and Bophy 2003, Engelen et al. 1999) which mainly focus on creating tools to ensure accessibility through means such as validation, transformation and website repair. Validation tools analyze pages against accessibility guidelines and return a report or a rating (Chisholm and Kasday 2005; McCathieNevile and Abou-Zahra 2005). Repair tools, in addition to validation, try to repair the identified problems (Chisholm and Kasday 2005). Although there has been extensive work in the development of validation, repair and transformation tools, automation is still limited. While it is likely that there are certain accessibility problems for which solutions cannot be fully automated (e.g., checking the quality of alternative text provided for images), those solutions that can be automated are still hindered by the complexity of Web content analysis and the incompleteness of available transformation technologies.

2.7 Individual Coping Strategies

To overcome problems not yet addressed by tools and technologies, many disabled users use inventive coping strategies to enhance their performance when interacting with the Web. These strategies are often aimed at dealing with complex and inappropriately marked-up pages and aim to make 'bad' web pages 'good' by applying previously successful strategies. Coping strategies are more successful when the user is experienced, but are often complicated and only partially successful in many cases.

These strategies can be grouped into two types: specific strategies - based on the users' experience of interacting with a particular Web-page; and generic strategies - applicable to most

Web-pages. As an example of the former, some visually disabled users count the number of Tabs in order to skip things at the top of the Google results pages. Others use Ctrl+F to search for the text “similar pages” which enables them to find the first result. Examples of the latter often involve techniques for moving to the top or bottom of any page. Not surprisingly, users often indicate that they do not like pages that frequently change their structure, and prefer pages that are stable such as Google. This is mainly because users cannot apply familiar strategies when pages dynamically change structure. Both strategy types can also be used to train novice users to better cope with complex pages which are quite common on the Web. Such strategies, typically based on the design of particular pages, tend to cause users to return to just a handful of sites, however, with new sites being visited only when necessary (Yesilada et al. 2007). This means that nearly all the Web, including the so called 'long-tail' (Brynjolfsson, Hu and Smith 2003), is off-limits to the majority of visually impaired users.

3. Web Technology

This section presents a survey of current Web technology, focusing primarily on aspects that have impacted Web accessibility. Following this is a consideration of where the Web appears to be going and the accessibility challenges and opportunities likely associated with emerging Web technologies.

3.1 Existing Web Technologies and Accessibility

The Web has gone through a remarkable evolution from its beginnings in 1990. The first Web sites were extremely simple, consisting of little more than trivially formatted text, links, and an occasional image or two. Pages were “marked up” using a simple language, the Hypertext Markup Language or HTML, and links to other pages were included as simple references according to the Universal Resource Locator (URL) scheme. Tooling was also simple – a basic text editor and command-line FTP client were sufficient for the creation and publication of Web content.

Early Evolution. The initial exponential growth of the Web was powered, in part, by the fact that people could learn how to create Web pages by copying the work of others. It was generally a simple matter to "view source" and see how someone had achieved a certain layout or effect. The underlying markup could then be copied, forming the basis for new work. This had the effect of making Web design patterns, both good ones and bad ones, somewhat "viral", spreading through the population of content creators much like a virus spreads through a population of people (or, more recently, computers).

Unfortunately, bad design patterns, once established, had a tendency to persist. An example of a bad pattern still common today can be found in the use of tables to control page layout. The earliest Web pages consisted of simple text separated by headings and further separated into paragraphs. A richer page model soon evolved that had a navigation bar (with links to other sections of the site) and an area showing the content for the current section. The navigation bar was often implemented as a column in an HTML table. Of course, some HTML tables were used (some might say *properly* used) for assembling data into semantically meaningful rows and columns. But many were used merely for layout. This is not a problem for normally sighted users, since the two uses are clearly and visibly different. But for visually impaired users it is not at all clear how a screen reader should read table content – should the columns dominate with the links inside a column being read as a related set, or should the rows dominate with column headings and associated data being read in pairs (e.g., "temperature, 70 degrees, humidity, 80%")?

Separating Content and Presentation. Originally, HTML included presentation directives within the content itself. This conjugation of content and presentation style proved to be problematic for maintaining the device independence of the language. The desire to maintain device independence is closely linked with Web pages becoming increasingly accessible, since the mechanisms allowing remapping of content to different devices goes a long way towards allowing it to be mapped to different interaction modalities on any given device. This separation of content and presentation style is achieved through a confluence of two technologies: HTML and Cascading Style-Sheets (CSS) and lately their XML equivalents, XHTML (see 'XHTML and XForms', later in this section) and XSL Transformations (XSLT). In this model, the HTML file contains the content and the style file (CSS or XSLT) contains the presentation directives. Both files are transmitted separately to the client and assembled by the browser into the Document Object Model tree on which the browser's final rendering is based. In this way both authors and readers can independently attach styles (e.g., fonts, colors, and spacing) to HTML documents. The CSS language is human readable and writable, and expresses style in common desktop publishing terminology. One of the fundamental features of CSS is that style sheets cascade; authors can attach a preferred style sheet, while the reader can provide a personal style sheet to further modify the final presentation.

Malformed Content. Another result of being able to easily copy and adapt others' content was that somewhat malformed HTML came to dominate the Web. If a page worked well enough to be seen in the user's browser it was good enough to copy and modify. The errors thus propagated were generally not catastrophic (if they were the page wouldn't have rendered well enough in the first place to warrant copying). A typical error might just be a failure to match beginning and ending tags. But the effect of these errors in the aggregate was that browsers needed to be forgiving – employing heuristics to make reasonable inferences about the authors' intentions – or most content simply could not be rendered. And the effect of the browser's being forgiving was that more and more errors were injected into the world wide collection of Web content, since they were not detected by the casual page author whose only test consisted of seeing whether their browser showed the page the way they intended. Even the *tools* that soon became available to simplify the creation of HTML were often guilty of generating malformed content. In the end, one estimate is that something in excess of 9 out of 10 existing Web pages came to contain one or more HTML errors (Richards and Hanson 2004).

While browser developers might have the resources to unscramble most malformed HTML, creators of accessibility technology may not. This generally suppresses the development of Web accessibility technology. It also makes potentially attractive architectures, such as content transcoding by an intermediary server, exceedingly difficult since all the heuristics needed by a browser to cope with syntactically incorrect markup need to be replicated in the intermediary. One reaction to this problem has been the creation of stricter standards such as XHTML which are enforced by the browser (see below).

Rich Data Types. Early Web content had only a few data types. There was, principally, text, marked up using simple HTML. There were also images, generally encoded using either the GIF or JPEG formats. Text could be transformed for accessibility purposes (barring some of the difficulties mentioned above) rather easily. Images could be magnified as well since the formats were well known and rather straightforward. The situation now is much more complex. A wide range of "objects", such as Java applets and Flash movies, can be and often are embedded in Web pages. Little can be done to make most of these objects more accessible. They display their content however they do it, and no access to their underlying "model" is provided to support content transformations (although this is changing somewhat in the case of Flash for example). Since these technologies offer a richer “palette” to the creative Web designer, the resulting objects have typically proven to be quite complex, requiring good vision to see their parts and fine motor control to interact with them. Finally, the Web user’s overall task has become more complicated since the relevant runtime support for these data types must be downloaded and installed in each browser that is used. While this can be easy enough, there are cases where a skilled support staff must be engaged to find and install the necessary software. For disabled users, this can pose a formidable barrier.

Dynamic Content. Early Web content was static. It was composed by an author as part of a page and rendered by a Web browser. The only things a user could do was read the content, follow links to other pages, and submit simple forms back to the server. Starting with the introduction of JavaScript, however, Web content started to become much more dynamic. Content in forms could be checked for correctness and completeness prior to submission. New content could be revealed on the page based on user actions without server involvement. In general, this dynamism yielded richer and more compelling user experiences. But it also made the job of creating accessibility transformations much more difficult. Consider, for example, the not uncommon case of Web page content being a mix of static elements and dynamic script-driven content. Since the scripts are invoked in response to browser events (such as onLoad) or user events (such as onClick) the content is often created *in parallel* with or *after* the static content has been interpreted and represented in the browser’s internal DOM. Browser-side accessibility transformations (such as that found in Web page readers for the visually impaired) typically operate on the DOM. If the content is static, the code providing the transformation can be structured with the assumption that transformations can be applied to a DOM that is not changing. If the content is dynamic, the code must be structured to work on incomplete and changing DOMs. Complicating matters, the events signaled to this code by current browsers are not always complete and correct. As a result, it is not always clear when a DOM has been fully built either following initial page load or in response to a DOM-changing user event. The increasing use of "Web 2.0" technologies, such as Asynchronous JavaScript and XML (AJAX, see below), will only make these problems more vexing. Indeed, it is sometimes necessary to annotate the DOM with markers to indicate what has been transformed in a prior pass (Richards et al. 2007). This allows for touchup of incompletely transformed DOM sections when a user action indicates that section of the document to now be of interest. Going forward, it will be important to develop a set of patterns making dynamic Web 2.0 content more accessible.

Breakdown of Browser Navigation Models. The basic mechanics of Web navigation are confusing for many, especially for those with an imperfect understanding of how Web technologies work or those with some cognitive disability. As discussed above, many people have trouble comprehending the (hidden) stack model that maintains the browser's within-session page history. To make matters worse, this complex model is increasingly being violated by the implementation techniques underlying various forms of dynamic and session-dependent Web content. As a result, the browser's back button no longer reliably moves the user back through visited pages. Clicking it may now bring up a question about reposting form data. In other cases (e.g., in some Web portal frameworks) clicking the back button causes either nothing to happen or the working context to be completely abandoned (sometimes requiring the user to log back in). A similar problem has come to plague the primary means of between-session navigation – bookmarks. Bookmarks no longer reliably link to a specific page if that page data is dynamically generated based on session data. The recently articulated *REST* model (Fielding

2000), in addition to simplifying the notion of a Web service, has the desirable attribute that back button and bookmark behaviors are more predictable.

Transcoding. Many approaches attempt to influence Web content authors to create more accessible pages. As previously discussed in this Chapter, these approaches include guidelines, automated validation, and best practices. They all rely, however, on authors being concerned enough about accessibility to follow them. Problems still exist with poorly built and old pages, and so solutions that aim to change bad content to good content have been developed. These solutions are known collectively as 'transcoding' techniques.

As typically defined, transcoding is a technology used to adapt Web content so it can be viewed on any of the increasingly diverse set of devices found in today's market. Transcoding in this context normally involves syntactic changes (Hori, Kondoh and Ono 2000) or semantic rearrangements and chunking (Myers 2005). However, both normally rely, to some extent, on *annotations* of the Web page itself (Asakawa and Takagi 2000). The goal of annotations for Web content transcoding is to provide better support for assistive technologies, and thus for disabled users and users of small screen devices. However, annotation is expensive for content authors, because each page must be annotated with information regarding its structural context. This information must be applied to each page manually before the transcoding can work. Of course some systems exist that attempt to transcode pages based on annotations being automatically included in pages (normally from database driven sites with templates for page creation), but these often rely on bespoke technologies and solutions are only appropriate for one site.

Semantic transcoding aims to overcome some of the problems of using bespoke systems and technology. Using this approach, a page's encoded semantics provide the information needed to correctly infer the page's internal structure and purpose, thereby allowing the page's content to be presented in a different form that is fully meaning preserving. For the time being, however, such approaches are limited to pages built in accordance with a known template, greatly easing the analysis and transformation chore.

Each of these types of transcoding is fraught with problems. This is especially the case when sighted users and visually impaired users wish to use the same page. Automatic transcoding based on removing parts of the page results in too much information loss and manual annotation is nearly impossible when applied to dynamic websites (let alone the entirety of the Web). Most systems use their own bespoke proxy-servers or client side interfaces, and these systems require a greater setup cost in terms of user time. In practice, existing transcoding systems lean towards solving the problems of one user group and so destroy the content / structure / context for other non-target groups.

3.2 Emerging Web Technologies and Accessibility

Web evolution shows no signs of slowing down. While it is very difficult to make predictions about the future of the Web, a few clear trends are starting to emerge.

XHTML and XForms. The lax enforcement of HTML syntax has served as an impetus for the creation of XHTML (http://www.w3.org/TR/xhtml11). If a page is declared as containing XHTML, the syntax is checked by the browser and errors are simply signaled; no attempt is made to correct them. This makes the browser simpler and should, over time, increase the ratio of well-formed to malformed pages. Both effects would make the job of content transformation, including content transformation performed by an intermediary, much easier. Unfortunately, XHTML adoption has lagged with browsers either implementing only a portion of it or providing full error checking only if requested by the user. It remains to be seen whether the accessibility advantages associated with this technology will be realized.

XForms has arisen, in part, to provide a cleaner separation between client side data and appearance. This is a variation on the model-view separation long advocated within software engineering. In general, such a separation should make accessibility transformations more straightforward, since only the view portion of the Web page needs to be modified. Indeed, one of the primary implementers of the XForms standard are mobile device manufacturers who face the challenge (related to accessibility) of providing a semantically correct re-rendering of page content originally developed for much more capable devices.

Web 2.0. A loose cluster of concepts is gaining currency under the banner of "Web 2.0" (O'Reilly 2005). Some of these concepts fall in the space of collaborative content and information development (e.g., wikis, blogs, and content tagging). Others fall in the area of content utilization (e.g., RSS and Atom, data remixing and"mashups"). Others represent new business models for Web applications and services. Still others are best thought of as newer Web programming models providing some combination of lighter-weight application development (e.g., through the use of dynamic scripting languages), more open application development (e.g., harnessing the talents of a loose confederation of developers), or richer user experiences (e.g., using AJAX for in-place data-driven updating of Web pages without a page reload). It is worth noting that this latter set of concepts poses the greatest challenge to Web accessibility going forward. This can be exemplified considering the potential impact of open-source development on Web accessibility. Unless the governance model underlying this development has explicitly embraced Web accessibility, it is unlikely that individual contributors will ensure each new feature is accessible (although a good example of an open-source development project with sustained focus on accessibility is provided by Mozilla, *Mozilla* *accessibility*[6]). Additionally, as has been mentioned above, the dynamic, data-driven application model associated with AJAX makes DOM based accessibility transformations more difficult. Time will tell which of these concepts will come to dominate the future Web. It is clear, however, that Web accessibility will require ongoing efforts by standards bodies, tool builders, and content developers.

Semantic Web. The vision of the Semantic Web, as articulated by Tim Berners-Lee (1999), is of a Web in which resources are accessible not only to humans, but also to automated processes. The automation of tasks depends on elevating the status of the web from machine-readable to something called machine-understandable. The key idea is to have data on the web defined and linked in such a way that its meaning is explicitly interpretable by software processes rather than just being implicitly interpretable by humans. To realize this vision, it will be necessary to annotate Web resources with metadata (i.e., data describing the resource's content and nature). Such metadata will, however, be of limited value to automated processes, unless they share a common understanding as to their meaning. This sharing of meaning will be achieved partly through the use of ontologies. An ontology, defined using the new W3C language *OWL*, is a collection of shared terms that can be communicated between both people and applications. A reasoning engine can then make inferences about the relationships between items within an ontology and support queries over collections of items.

The Semantic Web is a vision that will take years to come to fruition. There are aspects of this vision that promise a more accessible future. First, increased machine processing may eliminate much of the tedium now associated with finding Web content. For a sense of what we may expect, compare the current difficulty of maintaining a useful set of bookmarks (which tend to

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[6] Mozilla accessibility. Available at: http://www.mozilla.org/access/

rapidly age into a useless jumble of often broken links) with the ease of conducting a Google search to find just what one needs in the moment of need. Of course, this barely hints at what might happen when information finding is guided not just by keywords and patterns of inter-page links but by a partial *understanding* of the meaning of the distributed content (and when search occurs not just for fractions of a second but for the hours and days we might anticipate in a future world of long-running software agents). A second benefit for Web accessibility may well derive from a greatly expanded use of metadata allowing to transform content more meaningfully. Recalling the example of the use of tables to control page layout, tables annotated with their purpose (layout vs. data structuring) would allow a screen reader to behave more sensibly than is possible now. In the case of a table used for page layout, the screen reader could vocalize the navigation bar links as a coherent set (treating the column as primary). In the case of a table used for data aggregation, it could read the column names and associated data values together (treating the row as primary).

Widgets. The last emerging Web technology to be discussed points beyond the current world of generic browsers making explicit requests of discreet servers to a world of highly customized information gadgets delivering fresh information in glanceable ambient displays. Various so-called "widget" runtimes are now becoming available to make this possible. These include operating-specific runtimes (such as the desktop environments provided by Apple and Microsoft) and cross-platform runtimes (such as the widget environments from Google, Yahoo, and Mozilla). Widgets are relatively easy to build, tending to be both small (from a coding perspective) and familiar (using a standard set of browser technologies such as HTML, XML, CSS, and JavaScript). While widgets can often run *in* a browser, they more typically run *free* of the browser and without any unneeded browser interface apparatus. At the time of this volume, thousands of widgets are already available for download. Of course, the proliferation of widgets may lead to a confusing set of non-standard interface techniques and require the user to laboriously manage an ever growing widget collection. However, widgets may provide the ability to create purpose built information environments perfectly suited for a person's preferences and abilities. For example, a not too distant future can be anticipated in which a severely motor impaired individual using a scanning interface could efficiently control a custom-built information display rather than a complex generic browser.

4. Conclusions

The World Wide Web is a vital resource for people with disabilities. But even with well-motivated regulations and a growing set of relevant standards, Web accessibility remains a challenge. In part this is because there are no good ways of automatically transforming all existing Web content to meet the diverse needs of people with widely varying vision, hearing, motor, cognitive, and age-related disabilities. This situation will improve over time through both increased developer awareness and the utilization of new technologies. As more content becomes better structured, and as more metadata and semantic information is added, it can be expected that more people will take full advantage of the Web.

There is no 'catch-all' solution to providing accessibility to Web based resources for disabled users. Each disability requires a different set of base access technologies and the flexibility for those technologies to be personalized by the end-user.

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