Accessible Web Browser Interface Design for Users with Low Vision

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We are studying user interface (UI) features that would be helpful to users with moderate to severe low vision and have developed a novel web browser front end that we believe will enhance efficiency and accessibility of the web to this large and growing population. The UI incorporates well-accepted principles and empirical knowledge from vision and rehabilitation sciences that go far beyond simple screen magnification. With an emphasis on simplicity and ease of use, the UI is designed so that once configured, no adjustments will be needed, regardless of what document the user is viewing. The UI will allow users simultaneous access to both the global features of web documents as the author intended, along with enlarged text tailored to the user's needs; this will allow access to all web pages without requiring that sites have special markup or authoring.

INTRODUCTION

The Internet and in particular the World Wide Web, are increasing availability of information for everyone with access to them, but they especially have the potential to improve the lives of visually impaired persons, perhaps more than any other technological development in history. Personal correspondence, banking and personal finance, shopping, and general access to information are but a few of the functions that are incrementally enhanced by the web for visually able people. For people with severe visual impairment, however, the impact of the web is far more profound. For the first time in history, people with severe visual disability can potentially perform these essential tasks of daily living without the assistance of a sighted person. The psychological benefit of being able to handle one's finances privately and independently, of being able to read and write private correspondence, of being able to read a newspaper independently, and of being able to shop privately, discreetly, and independently, cannot be underestimated. It is an enormously empowering and equalizing experience for the visually impaired person.

Most human interaction with the web takes place through the use of a *browser*, a software program that interprets structured documents containing embedded tags called markup. Some years ago, the browser was thought to be a specialized application that simply provided users with access to the web; nowadays, however, the browser appears to be posing a challenge to the desktop as the basic medium of user interaction. For example, Google is offering and promoting an office suite called Google Apps (http://www.google.com/a/) that runs over the web (either through a corporate intranet web server or via the wide-area internet), and is thought to be a potential threat to the dominance of the venerable Microsoft Office suite. It is accessed through a browser. Many popular email applications such as Outlook Express, Thunderbird, and Gmail, are web applications. Anticipating the future is the plan of Xcerion.com to offer a complete XML-based operating system called XIOS (see http://xcerion.com), which also would be accessed completely through the web browser and would not require in any substantive sense, any other underlying local operating system at all. The increasing trend away from desktop applications and toward web applications is the result of higher bandwidth and increasingly reliable internet access, relative ease of maintaining software for a single (web-based) platform, and the increasing sophistication of interactive features using technologies such as AJAX (Asynchronous Javascript and XML).

Ironically, while convenient access to the web is now quite good for those who are blind, by using browsers in conjunction with screen readers such as JAWS and WindowEyes, or text-only browers like Lynx in combination with speech programs like EmacSpeak, the web, and structured documents in general, remain *less* accessible for those with moderate and severe low vision. Development of web technology for low vision has lagged behind that for blind users for several reasons. First, the blind community has had a much stronger political voice throughout the world. Most people with low vision are older, have become visually impaired late in life, and are reluctant to identify themselves as visually impaired, no less join a group that advocates for their rights. Blind users on the other hand, have a clear, unified voice within the disability community. Blindness organizations have rallied and brought lawsuits that pressure governments to enforce laws such as the U.S.'s Americans with Disabilities Act, that promote accessibility of web and Internet technologies. Even though such laws protect people with low vision too, there are few if any organizations that represent the political voice of those with low vision, and as a result, the general public tends to equate visual disability with blindness. This is generally true worldwide (Oslo Workshop on Low Vision, 2005).

Second, developers of web technologies also tend to treat all visually disabled people, monolithically, as blind people. Sun Microsystem's Java and Microsoft's Accessibility Applications Programming Interfaces, and indeed most computer software accessibility standards, address accessibility for visually impaired people as if all visually impaired people had *no* vision. This is probably in part due to a lack of understanding of what low vision is, and possibly also in part due to a prevalent belief, dating back to the last century (Goodrich & Bailey, 2000), that those with partial sight should learn to accomplish tasks without vision, in order to take advantage of tools and techniques developed for blind people, and in order to prepare for the eventual possibility of losing all vision. Tools and techniques for blind persons are indeed inclusive in the sense that the entire continuum of visually impaired people can in principle use them. But for those with even very low vision, performing tasks visually is nearly always preferred and more efficiently accomplished, when it is possible to do so.

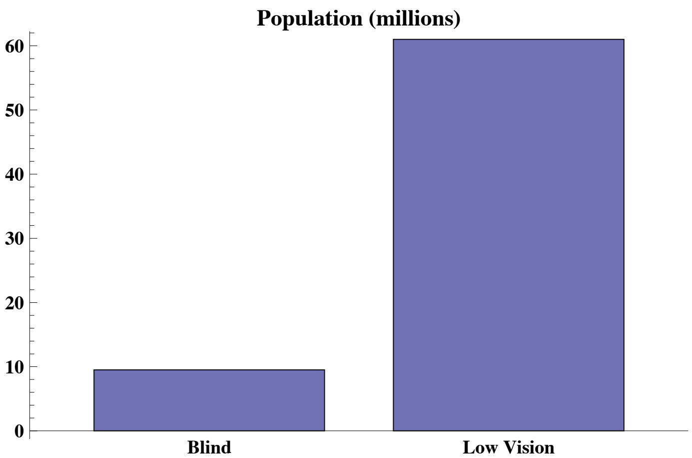

Figure 1 : Number of people worldwide who are blind or have uncorrectable low vision, based on World Health Organization (Resnikoff et al., 2004) data with reasonable assumptions (World Health Organization, 1996). Blindness is here defined as inability to use or potentially use vision to accomplish tasks of daily living, while low vision is defined as visual acuity less than 20/60 (in the better eye) or visual field extent.

A final reason why web technology for low vision has lagged behind that for blind people is that producing an effective interface for low vision is a more difficult task for the software designer. The range of best-corrected visual acuities, for example, that a useful low vision web browser would need to address is about 20/60 to 20/1000, a size range spanning over 1.2 log units. Providing a single visual interface for users that will accommodate such a large range of required sizes is very difficult. In contrast, the interface for all blind users is the same, requiring all visual display to be translated to some form of auditory information. Understandably, software designers find providing accessibility to blind persons a conceptually simpler task.

It should be noted that while most attention in computer accessibility has been directed towards making computers accessible to blind people, the number of people with low vision (many of whom also meet the criteria for various legal definitions of blindness) is far greater than the number who are blind and cannot use vision, a fact that is starkly portrayed in **Figure 1**. Accessibility is, of course, important to provide to both populations, but relatively little effort has addressed *visual* accessibility for low vision.

REVIEW

Previous attempts at enhancing web accessibility for low vision have been of four types: options within standard browsers, specialized browsers or plug-ins to standard browsers, desktop accessibility tools, and accessible markup and special authoring solutions. Each of these will now be reviewed briefly.

1) **Standard browsers**, including Microsoft Internet Explorer, Netscape, Mozilla, Firefox and Opera, all include accessibility features such as the ability to alter fonts and font sizes, colors, and zoom; the ability to remove images; and the ability to ignore site-specific style sheet information or substitute ones' own style sheet. However, such enhancements are still of limited usefulness, due to the diversity of web pages in cyberspace. Since each site is authored with different colors, backgrounds, font sizes (often expressed in absolute units), the user often needs to customize the display for each site visited, a tiresome and painstaking task. In addition, removing or replacing style information drastically alters the layout of the page relative to what the author intended. Thus accessibility features in these browsers work, but they are inconvenient and do not allow the user to see the page as the author intended it.

2) **Specialized browsers** (and plug-ins to standard browsers) for low vision, such as Ion Systems' WebEyes, IBM's Home Page Reader, Productivity Works' pwWebSpeak, and JBliss Imaging Systems' PnC Net, generally provide much more convenient and direct access to enhancements that make web pages more accessible to users with low vision. However, they too suffer from the same drawback as the appropriately-configured standard browser, in that each site the user visits may require a different configuration. In addition, as with standard browsers configured with user's style changes, the user with low vision is presented with the page not as the original web author intended it, but in some altered fashion, making it difficult to use standard features like navigation bars, or to communicate with a sighted person about the location of page elements on the display. If web authors tested their pages with these nonstandard browsers, they might take into account how the page appears when magnified or with altered colors, but this is rarely done.

3) **Desktop programs**, like Freedom Scientific's MAGic, AISquared's ZoomText, and Dolphin's Lunar Magnifier, provide screen magnification and a high degree of convenience and configurability, mostly available through keystrokes, for all or most programs on the user's machine, and not just the web. A big advantage of such solutions (over even the proposed browser) is that investing in learning one such program serves to enhance access to all desktop software *on the host operating system*. However, such programs cost hundreds of dollars (not including upgrades), which may be affordable to some consumers, but beyond the reach of many older users with low vision who may be living on social security and/or other disability benefits. Because these programs utilize low level operating system calls to access the screen buffer and cursor hardware, compatibility issues arise with greater frequency than for most software. Furthermore, these solutions are operating system specific, and are available only for a single platform (generally Windows). Finally, such programs are complex, difficult to learn, and may require training and extensive practice to use effectively. They tend to be used more by intelligent and edu-

cated visually-impaired consumers who lose vision while fairly young, rather than the average low vision consumer, who over the next decade will lose their vision after becoming dependent on the household computer as a standard appliance.

4) **Accessible markup and other authoring solutions** are probably the most ubiquitous accessibility solution for low vision. Unlike the other attempts, these are designed into the web site itself, rather than implemented on the user's machine. This category includes text-only web sites, the technique of stylesheet switching, and accessible authoring. Text-only sites, of course, require maintenance of parallel versions of web sites, an expense that few web sites are willing to bear. Those that do, often do not maintain completely up-to-date text versions. Stylesheet switching allows users to select from a pallette of options that may include several different text sizes and color schemes, all implemented through Cascading Style Sheets (CSS; or through another stylesheet technology such as eXtensible Stylesheet Language—XSL).

Accessible authoring means following good practices *in document markup*, that allow accessible browsers and other special software to provide information in a way that visually impaired users can access. A simple and common example is the use of the ALT tag in HTML to provide descriptive text to accompany images. Such good practices are detailed in a number of books (Clark, 2003; Paciello, 2000; Thatcher, 2002) and embodied in recommendations developed by the World Wide web Consortium's (W3C) web Accessibility Initiative (World Wide web Consortium, 2008). More elaborate systems that rely on cooperation between special annotations that are embedded in the authored site and software that runs on the user's machine are also possible (Asakawa, 2000).

Accessible authoring of structured documents can certainly enhance accessibility, but it is unrealistic as a universal solution, both because of the limited types of enhancements that are possible to accomplish with markup languages like HTML, and more importantly because it is virtually impossible to enlist the cooperation of the authors of billions of web pages and persuade them to author their sites in an accessible way. Indeed, a recent survey by the U.K.'s Disability Rights Commission (Disability Rights Commision, 2004) found that 81% of publicly accessibile web sites used by the British public failed to meet even the lowest priority checkpoints of the WAI's web Content Accessibility Guidelines, even though those sites are mandated to be accessible by the U.K.'s Disability Discrimination Act.

The technology proposed here, embodied in a Mozilla Firefox extension called LowBrowse™, addresses all of the problems described above. It relies on no annotation, markup, or special authoring of web documents. The user will be able to view the page as the original web author intended, albeit at a resolution limited by his or her visual disorder. It will run the same way on all popular operating systems.

NEW CONTRIBUTION

The novelty of the approach proposed here is largely limited to enhancing information that is in the form of text, either visibly rendered text, or hidden text such as ALT text. Images are handled through conventional image zooming. Enhancements for viewing graphic material are also important to provide, but the core part of the solution described here enhances text accessibility. To understand how requires some background about how users with low vision read.

Figure 2 is a summary of well-established and current thinking about the relationship between text size and reading speed in low vision that should be helpful in understanding the rationale for the transcoded reading frame concept. Both normally- and partially-sighted people can read at text sizes close to their word acuity limit (the smallest letter size for reading words; A_n and A_l for normal and low vision, respectively), but only very slowly. This activity is sometimes called spot reading (Whittaker & Lovie-Kitchin, 1993). The smallest text size at which people can read comfortably and at their maximum speed, is called the critical print size (Mansfield et al., 1993; Mansfield et al., 1996), as represented on **Figure 2** by C_n and C_l. The ratio of a given fluently readable text size to the word acuity limit A, is called the acuity reserve. Fluent reading generally requires an acuity reserve (Whittaker & Lovie-Kitchin, 1993) of at least about 2.5, and possibly significantly more for some people with low vision who may have more gradually

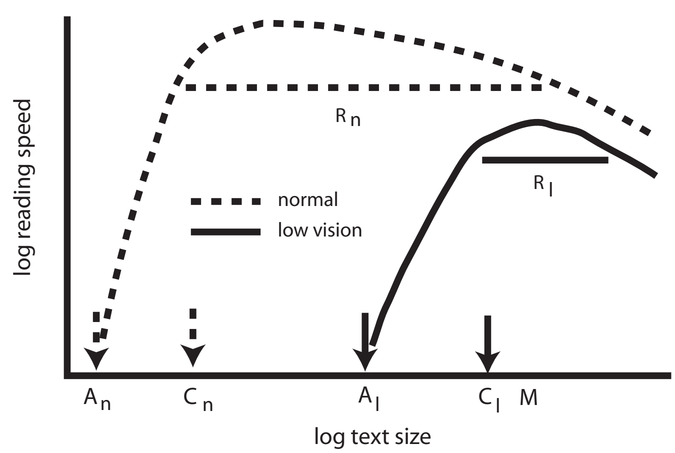

Figure 2: A_n and A_l represent word acuity limits for normal and low vision respectively. C_n and C_l are critical print size for normal and low vision. R_n and R_l are ranges of text sizes that can be read at or close to maximum speed.

rising slopes as text size increases from A_l.

As **Figure 2** illustrates, normally-sighted readers can read a very large (about 2 log units; Legge et al., 1985) range of text sizes (Rn) at or near their maximum speed. Despite a slow decline from peak speed with increasing size, their performance declines significantly only with very large text sizes (Legge et al., 1985). Practically, this means that readers with normal vision can efficiently read a large range of text sizes without adjusting the magnification (zoom) of the display. Those with low vision, on the other hand, are restricted to a much smaller range of text sizes (R_l), both because their acuity limit (A_l) is greater, and because many of the same factors that diminish reading efficiency at very large text sizes for normally-sighted readers affect low vision readers as well. This means that, unlike able-sighted readers, readers with low vision must continually adjust display magnification in order to bring text size on the retina into their smaller range of readable sizes—a cumbersome process that reduces reading efficiency**.** Additionally, high levels of magnification result in reduced field of view, and restricted field strongly reduces reading performance on computer displays (Beckmann et al., 1996; Harland, et al., 1998). In terms of interface design, this means that for most efficient reading, the user with low vision should always be presented with text of a single size—that size at which he or she can read most efficiently (which generally corresponds to the critical print size). Low-Browse™ accomplishes this and other enhancements through transcoding of Web pages within the browser. This feature has the most promise for increasing efficiency of the user's experience, for it eliminates the need to change magnification while reading. Regardless of text size on the authored web page, the user will always be presented with text at a size that is large enough to read, but not so large as to reduce reading efficiency unnecessarily. In comparison, screen magnifiers such as ZoomText magnify the screen image uniformly, so that the user continually needs to adjust the magnification depending on the initial (unmagnified) size of the particular text.

The bulk of the literature on low vision reading, and the rationale discussed thus far in this paper, focus on reading of continuous text. With the increasing importance of nonsequential reading and processing of mixed visual media on the web, however, other important aspects of reading and visual processing need to be considered in low vision browser design. In particular, for effective processing of Web pages, the user must be able to appreciate the *global view* of the page, both in order to navigate the page and to be able to target likely locations for an object of search.

The LowBrowse™ technology addresses this problem by optimally allocating the screen real estate to a single line of enlarged text, along with a global frame for navigation and to provide spatial context. Since the cursor is in the global frame showing the location of the text being read in the upper frame, the user always has a good idea of where on the original page layout the text being read is locate even if s/he cannot resolve all the details of the page..

The architecture underlying LowBrowse™ utilizes a transcoding design that intercepts the document (e.g. one using HTML) being requested on its way to the browser's rendering engine, analyzes it, alters it it, and then renders it for the user in two ways in two distinct windows, as pictured in Figure 3. The browser's display is divided into two regions: a top frame for reading, and a bottom "global" frame for navigating and appreciating global layout. Both frames are independently capable of rendering the document. The size of the reading frame and all aspects of font and color contrast of the text in the top frame are configurable, but in general, once the user has found optimal settings such as font, and top frame size, they will likely keep it that way. Note that the large text in the reading frame is not merely a magnified image of the pixels making up the text in the global frame. It is the rendering of a translation of the source document that is tailored to the visually impaired user's particular needs. In this way, LowBrowse™, using XSLT technology, *changes the markup and re-authors* the text in a manner that enhances readability once the text is rendered in the reading frame.

It is assumed that the user, while not being able to read the small text in the lower global frame, can still visually locate important features such as images, clumps of text, links, and navigation bars, and can point to them with a large cursor. This global frame is normally presented with no magnification, but if the user requires some magnification even to locate the gross features of the page, magnification can be increased in the global frame. While the user with low vision cannot resolve as much of the global frame as a user with normal vision, they can still appreciate much of the basic structure and organization of the page from this view. Zoom capability will be provided for the global frame so that the user can select the level of magnification that will best allow them to locate gross features of the page being viewed, but it is expected that this facility will be used only rarely, once a minimal magnification factor has been selected. Magnifying the global frame too much, of course, will diminish its usefulness for appreciation of global features of the page.

Using a large cursor in the global frame, but reading from the reading frame, the user can explore the page and read portions of the text corresponding to the cursor location. When the cursor hovers over text, that text is displayed in the reading

Figure 3: Basic LowBrowse™ view. The top "reading" frame is for reading text, while the bottom "global" frame shows the page as its author intended it to be viewed. The reading frame uses a single size font of the user's choice, with configurable reading frame size, font size, colors, contrast and letter spacing. Display of subsequent parts of the text being pointed to, beyond what fits in the reading frame (in this case "a leading non-profit...") are elicited by pressing the down-arrow key.

frame, at a comfortable color, size, font and letter spacing. (Notice in Figure 3 that the text under the cursor in the global frame is not only small, it is also presented in a different font and color scheme than the high contrast, tailored text in the reading frame.) If the text string is too long to fit within a single line of the reading frame, the string is broken, and successive portions of the string are elicited, by means of the down-arrow key press, so that the reader can key through the entire screen at his or her own pace, a practice that has been shown to enhance reading performance with sequential word presentation (Arditi, 1999). This single line presentation technique also eliminates the need for the user to find the beginning of the next line, which is known to reduce reading efficiency (Beckmann & Legge, 1996) and is a notorious problem for users of video magnifiers and hand magnifiers, as well as users of magnification software such as ZoomText and MAGic.

DISCUSSION

The unusual arrangement of the LowBrowse™ interface, in which the user must look back and forth between the reading frame and the global frame, does require dividing attention between the two frames, though not necessarily simultaneously. However, since information in the reading frame changes contingent on location of the cursor in the global frame, we suspect that users can easily learn to associate information in the two frames together, not unlike the association of location of a mouse on a mouse pad with cursor location on the screen. Indeed there are many successful examples of this kind of serial division of attention in vision rehabilitation, including the bioptic telescope used in driving and the video magnifier used in reading. Peli (2001) has termed this type of activity “vision multiplexing.”

While font, color, and letter spacing are adapted for best legibility in the transcoding prior to presentation in the reading frame, some aspects of the coding are purposely unchanged and preserved, for their signal or semantic value. For example, if the user is reading text that represents a clickable link, that text will be displayed, underlined and in blue in the reading frame, to signify to the user that this text is a hyperlink. Similarly, italic and boldface markings are preserved because they signify emphasis.

The usefulness for the low vision user, of having *all* text presented at the same *readable* size using the same font, color contrast, spacing etc. that the reader is comfortable with, *regardless of which page is being viewed,* and *without having to navigate to the next line,* cannot be emphasized enough. There is no technology presently available that provides this facility to users with low vision.

ACKNOWLEDGEMENT

This work was supported by NIH grants EY015192 and EY017583.

REFERENCES

Arditi, A. (1999). Elicited sequential presentation in low vision reading. *Vision Research, 39*, 4412-4418.

Asakawa, C., & Takagi, H. (2000). *Annotation-based transcoding for nonvisual web access.* Paper presented at the ASSETS 2000: The Fourth International ACM Conference on Assistive Technologies.

Beckmann, P. J., & Legge, G. E. (1996). Psychophysics of reading - XIV. The page navigation problem in using magnifiers. *Vision Research, 36*(22), 3723-3733.

Bruggeman, H., & Legge, G. E. (2002). Psychophysics of Reading-XIX. Hypertext search and retrieval with low vision. *Proceedings of the IEEE, 90*(1), 94-102.

Clark, J. (2003). *Building Accessible Websites*. Indianapolis, IN: New Riders Publishing.

Goodrich, G. L., & Bailey, I. L. (2000). A history of the field of vision rehabilitation from the perspective of low vision. In B. Silverstone,
M. A. Lang, B. P. Rosenthal & E. E. Faye (Eds.), *The Lighthouse handbook on vision impairment and vision rehabilitation* (Vol.
2, pp. 675-715). New York: Oxford University Press.

Harland, S., Legge, G. E., & Luebker, A. (1998). Psychophysics of reading. XVII. Low-vision performance with four types of electronically magnified text. *Optometry and Vision Science, 75*(3), 183-190.

Legge, G. E., Rubin, G. S., Pelli, D. G., & Schleske,
M. M. (1985). Psychophysics of reading - II. Low Vision. *Vision Research, 25*(2), 253
266.

Mansfield, J. S., Legge, G. E., & Bane, M. C. (1996). Psychophysics of reading \X\V: Font effects in normal and low vision. *Investigative Ophthalmology and Visual Science, 37*(8), 1492-1501.

Oslo Workshop on Low Vision. (2005). *Toward a reduction in the global impact of low vision.* Oslo, Norway: International Society for Low-vision Research and Rehabilitation.

Paciello, M. G. (2000). *Web Accessibility for People with Disabilities.* Lawrence, KA: CMP Books.

Peli, E. A unique approach to low vision. (2001). *Optometry, 72*(2), 128-130.

Resnikoff, S., Pascolini, D., Etya'ale, D., & Kocur, I. (2004). Global data on visual impairment in the year 2002. *Bulletin of the World Health Organization, 82*, 844-851.

Whittaker, S. G., & Lovie-Kitchin, J. (1993). Visual requirements for reading. *Optometry and Vision Science, 70*(1), 54-65.

World Health Organization. (1996). *Low vision care for the elderly.* Paper presented at the Workshop of WHO/PBL/96.57, Madrid.

World Wide Web Consortium. (2008). Web Accessibility Initiative. from http://www.w3c.org/WAI