Frontiers of Web Site Evolution

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Abstract

Large-scale software systems must continuously evolve to respond to shifting business requirements. Many Web sites can already be classified as legacy systems, given their age, size, and complexity. As with older legacy systems, these "new" legacy systems represent significant institutional value. However, leveraging this value is challenging. In many ways, a Web site contains many of the features of a traditional software system, and yet possesses several unique features of its own. Consequently, Web site evolution represents a rich research area that builds upon traditional software maintenance & evolution, but extends it in new directions as well. This paper presents an overview of the field of Web site evolution, its unique challenges, and discusses selected research frontiers in the area, focusing on accessibility issues in particular.

Keywords: Web site evolution, accessibility, visually impaired, hearing impaired, software maintenance, legacy systems, mobile devices

1. Introduction

Software engineering rarely involves totally new "green field" development because most organizations have substantial legacy systems that they build upon and extend over time. The legacy systems represent significant institutional assets that can be reused as the system evolves over time to meet changing requirements and new business challenges.

When the World Wide Web (WWW) was first introduced in the early 1990's, one of its goals was aimed at accessing information across the Internet in a consistent way [7]. Since the first WWW Wizard Workshop in 1994, "older" Web sites are now passing nearly 15 years on the Net. During this one and half decades, Web sites have moved from supplementary mechanisms for communication to become an integral part of most organization's infrastructure; from passively disseminating information to include a wide variety user interactive activities.

As yesterday's Web sites become today's legacy systems, they have experienced many of the afflictions that many traditional complex software systems had and start showing some of the characteristics of typical legacy systems. For example, they have experienced incremental and crisis-driven maintenance, they were developed in (now) obsolete programming languages, they have brittle interfaces, and they run on old hardware platforms. As the Web sites become more complex, so do the maintenance become increasingly problematic. The situation that some unique features of Web sites systems differ from traditional software systems exacerbates the already complex maintenance and evolution tasks. As Web sites age, it is necessary to examine how they can be maintained and evolved in a discipline manner. This is the focus of the Web Site Evolution (WSE) research community.

1.1 Web Site Evolution

Developing a Web site poses many of the same challenges that developing a traditional software system does, in terms of the identifiable technical activities such as requirements, design, construction, testing, and maintenance & evolution. However, Web sites are also unique in several aspects. For example, they encompass files, programs, and databases [4]; they are often developed by people who may lack of a formal computer science or software engineering background; and they are often implemented in more than one languages.

As software ages, the task of maintaining it becomes more complex and more expensive. Poor design, unstructured programming methods, and crisis-driven maintenance can contribute to poor code quality, which in turn affects understanding. Better understanding of a program aids in common activities such as performing corrective maintenance, system reengineering, and keeping documentation current. To minimize the likelihood of introducing errors during the change process, the software engineer must understand the system sufficiently well so that changes made to the source code have predictable consequences. But such understanding is difficult to recover from a legacy system after several years of operation. In the current atmosphere of accelerated schedules, years are reduced to months or even weeks [46].

Web sites are the prime example of a modern system destined to be the legacy system of tomorrow. Indeed, several Web sites can already be classified as legacy systems, given their age, size, and complexity [46]. In the past, the subject system might have been a monolithic, mainframe-based payment processing system written in COBOL. Or it might have been a two-tier client/server system written in C/C++. For a Web application, there is a much richer range of implementation languages, heterogeneous development environments [4], and both client-side and server-side processes. All these and other factors make Web sites more difficult to understand, and hence more difficult to evolve in a disciplined manner.

The existing software maintenance and evolution knowledge and techniques are challenged by these unique WSE problems. Warren et al [56][55] have studied and analyzed the evolution of a number of Web sites of different types and sizes. They collected metrics and structural information of these Web sites, and showed that the Web sites have been undergone Lehman's laws [28] of continuous software evolution. However, there is also widespread consensus that Web sites exhibit a unique pattern of evolution, more akin to complete replacement in a very short timeframe, than incremental updates that traditional legacy systems undergo.

1.2 The WSE Series of Events

The premier conference that focuses on the disciplined evolution of large-scale Web sites is the *IEEE International Symposium on Web Site Evolution* (WSE) [23]. Since its inauguration in 1999 [43], the WSE series of events has provided a forum for researchers and practitioners to present original work on subjects related to Web sites evolution. Year 2008 marks WSE's 10th anniversary. Broadly speaking, for the past nine years, WSE have covered the two complementary aspects of Web site evolution [11]: the manner in which Web applications and related design and development techniques are evolving, and how existing Web applications can be maintained and evolved in a manner consistent with established software engineering principles.

The topics and themes of the past WSE events have reflected these aspects of Web site evolution, and highlighted some of the trends for the future. Some of the selected topics that have been discussed at WSE include analysis [26][15], architecture [37][41][16], testing [40][32][36][39], reliability and security [51][30], Web enabling legacy systems[31][38][17], and migrating Web applications to mobile devices [48].

Web Enabling Legacy Systems

At the start of WSE in 1999, Web enabling legacy systems was one of the key focus areas [44]. During this migration process, legacy systems are augmented with new capabilities, which increase the complexity of maintenance and evolution tasks. Some of the examples when dealing with Web enabling legacy systems included migration strategies [31], accessing legacy application via the Internet [38][17], and migrating to multilingual Web site [49][50]. As Web sites evolve from static content providers to more dynamic and interactive forms, offering a variety of services, migrating existing applications to Web services have become more apparent. Some of the issues of migrating to Web services are addressed in [47][29].

Migrating Web Applications to Mobile Devices

From software evolution history point of view, if we could regard the migration from traditional software systems to Web-based applications as the first big thing in evolution era, then migrating Web-based applications to mobile devices is the next big thing. More recently at WSE, the Web-based application itself can be considered the legacy (source) systems, and then the new (target) system is a mobile phone or other similar platform. This phenomenon is supported by the ever increasing computing power and sophisticated operating systems on mobile devices (e.g., PDAs and cell phones).

Migrating Web applications to mobile devices faces many unique challenges. Some of the factors that need to be considered include context-awareness, device and network heterogeneity issues, power consumptions, memory capacity, and connectivity. Different mobile devices often provide different functionalities and have different CPU speeds, memory capacities, and power [20]. This means that an application created for one platform may or may not run on a different device. One device may have a GPS and Wi-Fi connection while another device has neither.

Software also plays a part in differences between devices. One device such as Nokia's N95 may provide developer support for Java and C++ while another device such as Apple's iPhone only supports JavaScript and AJAX for developers. Just as devices are different, so are the networks that support them.

One of the earlier papers that address the issues of accessing Web sites from mobile devices was by Tilley, Toeter, and Wong [48]. Due to the restrictions of mobile devices, such as smaller screen size and limited network connectivity, existing Web sites may require significant evolution to support the mobile clients. They tested three different mobile devices (Apple Newton, the Compaq iPAQ, and WAP-enabled cell phones) and identified some of the issues in accessing Web sites from these mobile devices. For example, some of the Web sites are not set up for mobile access (therefore, the content rendered poorly). There are also some issues such as application availability issues, screen resolution and network bandwidth. They also pointed out that there are clear similar challenges of providing content that is accessible to both mobile devices and traditional Web browsers, and the challenges of providing content in multiple languages.

1.3 Outline of the Paper

The rest of the paper is organized as follows: Section 2 provides an overview of accessibility in the context of Web site evolution. Sections 3 and 4 focus on two areas of accessibility that have the potential to greatly impact a large number of users: accessibility for the visually impaired, and accessibility for the hearing impaired, respectively. Finally, Section 5 summarizes the paper and comments on some of the possible future research areas on the frontiers of Web site evolution.

2. Web Accessibility

As Web sites have advanced from passive, supplementary mechanisms for communication to become a primary and indispensable component of most organization's infrastructure and personal life, Web sites have finally begun to address the challenge of being a truly a universal communication vehicle [7]. This pervasive computing phenomenon implies that Web sites should provide a comparable experience to diverse users, irrespective of their national languages, physical abilities, or computing platforms [46]. The theme *Access for All* addressed this issue at WSE 2001 [45].

Accessibility is one of the prominent research topics facing WSE community. Web accessibility refers to how people with disabilities can perceive, understand, navigate, and interact with the Web, and that they can contribute to the Web. It also refers to making Web sites accessible to older population with changing abilities due to aging [3]. Web accessibility encompasses a variety of concerns ranging from societal, political, ecumenical, technical, to individual, physical, and intellectual [10]. Figure 1 identifies four groups of disabilities (visual, hearing, cognitive, and motor), leading to 15 possible combinations of disability issues.

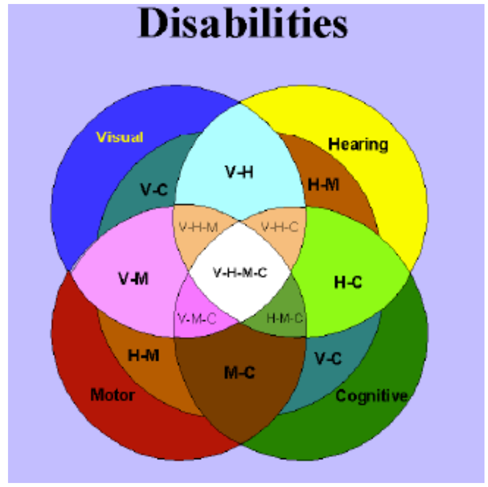

Figure 1: Venn diagram of disabilities [18]

Some of the representative issues of accessibility that have been addressed at WSE include maintaining the consistency of content and structure among Web sites of different languages [50], maintaining Web access for disabled people [8][5][14], and accessing Web sites from mobile devices [48]. Studying the issues of Web accessibility can provide a guideline for both Web developers and maintainers to better serve the greater good [6].

People with disabilities comprise a significant portion of the population, and Web sites should provide adequate and universal access to their resources. Figure 2 shows the 1996/1997 Disability Follow-up to the Family Resources Survey performed by the UK government in order to help plan welfare support for disabled people. The figure shows the prevalence of capability loss, where the overlapping circles indicate the population that has capability loss in multiple categories.

As majority of Web sites are considered either partially or totally inaccessible to people with disabilities. Some efforts have been put forth to address this problem. The World Wide Web Consortium (W3C) launched the Web Accessibility Initiative (WAI) in 1997 to provide guidelines as the international standard for Web accessibility [3] and its set of guidelines [57] (12 as the time of this writing). These guidelines receive government support from various countries. For example, US Section 508 of the Rehabilitation Act [59] requires access to electronic and information technology procured by Federal agencies. Section 508 §1194.22 established 15 accessibility standards for Web-based Intranet and Internet information and applications to which federal agencies must adhere when designing Web sites. Other countries have similar directives, such as the Stanca Act" in Italy [27].

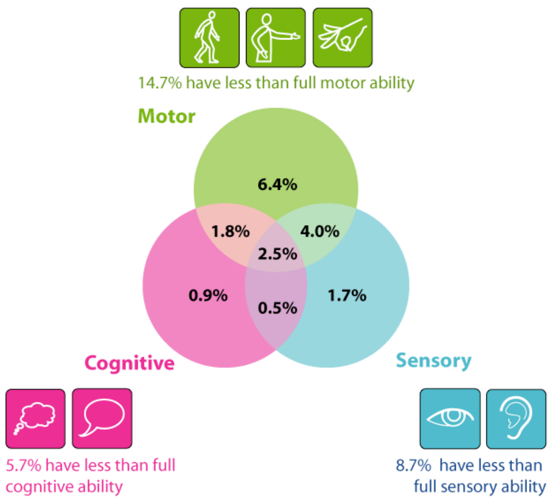

Figure 2: Prevalence of capability loss [1]

The research in Web accessibility addresses a vast area that encompasses several different components of Web development, deployment, and interaction with end users. These components include Web content, user agents, assistive technology, developers, authoring tools, and evaluation tools [3]. Technologies such as screen readers, visual enhancers, sign language translations, and on-screen or virtual keyboards have greatly enhanced the experience for disabled people using the Web. Nevertheless, there is a great amount of research that remains to fulfill the original of the Web to provide access for all. The next two sections discuss two of these areas: accessibility for the visually impaired, and accessibility for the hearing impaired.

3. Accessibility for the Visually Impaired

Being visually impaired does not necessarily imply legal blindness. It could also be being far-sighted (difficulty in reading close and small-font text), color blind, or limited fields of vision (e.g., cones). This means that issues related to visual accessibility are far-reaching. Therefore, evolving Web sites to be more accessible to this type of user is critically important.

One of the common practices to address Web accessibility for the visually impaired is through specialized user agents, such as screen readers and Braille displays. Screen readers are programs that "read aloud" the Web sites so visual impaired people can "listen to" instead of "look at" the Web sites. Screen-readers process all the text and text content associated with graphic elements on the Web site. However, screen-readers cannot interpret pictures and other graphical content. For example, there is little they can do with Flash objects unless the developer has taken care to provide an alternate media translation.

Braille displays are devices that receive data from screen-reading software and output it as Braille. They are not as common as screen readers, in part because they are specialized devices; screen readers and text magnifiers are often built-in to the operating system. This unfamiliarity often leads developers to ignore the importance that such devices can have to a significant portion of their users.

3.1 Current Research

One of the leading commercial screen-readers is JAWS® (Job Access With Sound) for Windows [24]. JAWS has a multi-lingual software speech synthesizer, and also outputs to refreshable Braille displays. In the open source community, Emacspeak [2] is a speech interface that allows visually impaired user to interact independently with computer by translating text to voice data. It works with Linux operating systems and provides support for the IBM ViaVoice speech engine. IBM Home Page Reader[1] (HPR) 3.04, launched in January 2005 [21][19], is another talking browser that can read text on a Web page, embedded descriptions of the charts, graphs, photos, and captions, and it can interpret popular multimedia and video files. VoiceOver that is included in Mac OS X V10.5 Leopard is a screen-reader and also supports a variety of refreshable Braille displays.

The use of XML (Extensible Markup Language) has extended to the domain of markup information for speech synthesizers. This extension is VoiceXML (Voice Extensible Markup Language). VoiceXML enables applications to read the Web pages to users and understand users' spoken responses through speech recognition software, e.g., IBM's *ViaVoice*[2]. The use of VoiceXML enables visual impaired people to access Web sites by reading the Web pages.VoiceXML2.0 is now part of W3C's recommendation [53].

Another voice related technology for visually impaired people is CallXML [13], which is created and supported by Voxeo [54]. CallXML creates phone-to-Web applications that allow users to retrieve Web content via phone, and to interact with Web based services using complex spoken commands [13]. CallXML provides telephone access to Web-based content for visual impaired people.

[1] IBM withdrew *Home Page Reader V3* in March 2008.

[2] IBM sold *ViaVoice* to Nuance in 2003.

While most current Web sites are highly visual and are designed for being "looked at" and communicate between a user and the Web site by "visual channel" (e.g., interface, content, page layout, orientation, navigation), visually impaired people cannot rely on the visual channel to use a Web site. To better support the interaction with a Web site, Bolchini *et al*. [9] posited that interactive applications should be mainly "aural" rather than "visual", and they defined some of the requirements for aural Web sites, such as information architecture requirements, page navigation requirements, and interaction requirements.

The development and deployment of Web accessibility and validation tools have greatly accelerated the improvement of Web accessibility. To better help Web site designers to grasp the weak points in their page, and to visualize how accessible or inaccessible of different areas are, in addition to those existing tools to analyzing the XHTML syntax of pages (e.g., *alt* tag for image) to comply with accessibility regulation and guidelines, Takagi *et al* [42] developed a Web accessibility designer (aDesigner), which visualizes visual impaired users' usability of a Web site. For example, aDesigner can visualize reaching time to each part of the page; indicate accessible or inaccessible areas; and present the text information extracted or generated by standard voice browser.

3.2 Future Challenges

Many achievements have been made for improving Web accessibility for visually impaired people. For example, some of the areas that people have been working on include the use of access technologies (e.g., screen-reader, refreshable Braille display, voice browsers), Web accessibility testing and validation (e.g., IBM Rational Policy Tester Accessibility Edition [35], who bought Bobby in 2007). However, many challenges remain. This section identifies a few challenges facing Web accessibility for visually impaired people in the context of Web site evolution.

Evolving Existing Web Sites to Aural Web Sites

Aural Web sites are those developed to optimize their accessibility for visually impaired people. Typically, visually impaired people rely on the screen-reader to read through Web pages text descriptive elements back to them. However, some elements on the Web pages are not textual in nature, such as buttons, tables, and images. It is the Web site authors' responsibility to use proper metadata to each element to make the Web site as accessible as possible. However, as discussed in a previous section, one of the differences between traditional software and Web applications is that people who have little formal computer science or software engineering training often develop Web sites. Those Web developers may have little knowledge of, or leave out by convenience, these accessibility features of a Web site, such as metadata for non-text elements. Over the time, it makes it difficult for the Web site maintainers to add these metadata later and make the Web site more accessible.

Like any other traditional software reengineering tasks, reengineering existing Web sites to become more accessible Web site for visually impaired people is difficult and costly. The challenges remain in finding the techniques and tools for the accessibility improvement of existing Web sites with the goal of immunizing the alteration of original code. IBM's "Social Accessibility Project" demonstrates part of the efforts towards this goal. The Social Accessibility Project was launched in July 2008. It is a service that aims to make Web pages more accessible for screen-readers, hence, people with disabilities, without changing any existing content [22]. The goal is to make Web pages more accessible to people with disabilities. Currently, the Social Accessibility Project focuses on screen-reader (e.g., JAWS) users using Internet Explore and Firefox plug-in. It is expected in the future the project will be expanded to other types of disabilities, such as hearing impaired people and people with motor problems.

Break the Sequential Browsing Order

Like books and newspapers, Web sites are a two-dimensional media. Meaning, the contents layout is arranged in a way from top to bottom, from left to right. The behavior that people browse a Web site usually doesn't follow the visual clue (or orientation) provided by the media – they scan skip and go to the points where they are interested. However for visually impaired people, they rely on the screen-readers to help them with the information on the Web. They are forced to follow the sequence that the Web provides, even that means they are not interested in the content.

The challenge is how to help visually impaired people not only to "read" the Web sites, but to also have the same efficient Web browsing experience as other people have. In other words, to help visually impaired people to reduce Reaching Time needed by listening to the most relevant content on the Web.

Cesarano *et al* [14] proposed two different approaches for dynamically, on-the-fly transforming Web pages into aural Web pages. Their approaches are based on the structural analysis of the HTML source code and content summarization algorithms. They overcome the deficient of visual impaired people are forced to listen to the page in a sequential manner (from top to bottom, from left to right by screen-readers). Along the same direction, Cesarano *et al* also pointed out that it is desirable to allow visual impaired users to reach certain contents faster than the other. The possible solution they proposed was to automatic generation of intra-page links redirecting to the most relevant page concepts.

4. Accessibility for the Hearing Impaired

Hearing impaired people face different obstacles from those who are visually, cognitively, or otherwise physically impaired. Hence, different technologies are needed to help to improve Web sites accessibility for them. Visual enhancers and screen-readers are useful to visual impaired; people who are cognitive impaired require navigational devices or tools to traverse through the sites, whereas people with physical impairments must use head pointers with on-screen keyboards. People with hearing impairments require tools to provide either text or signed languages for the audio information on the Web.

A common misconception of Web accessibility for hearing impaired people is that textual material, such as closed captioning of video and audio material, is an effective substitute for signed language. However, simple text may result in severe loss of context, idiomatic usage, and general culture nuances due to the way the language is structured. This is made worse for the rhythm when music is involved. Therefore, sign language is a more effective means to convey the information on the Web for hearing impaired people. Simply doing voice-to-text cannot provide a well-rounded Web experience for hearing impaired people. Providing sign language of audio and video material, such as from YouTube, is the ultimate goal, but it is also very challenging.

American Sign Language (ASL) is the language used by the majority of hearing impaired people in the United States and Canada. ASL has its own structure, which encompasses a grammatical sequence, idioms, and vocabulary, resulting in its own language. ASL structure consists of various phonemes, including palm orientation, movement, location, and non-manual markers (e.g., facial expressions and body gestures), which are combined in usage in order to convey a word or a phrase. To understand or to interpret signed languages, all phonemes of the language must be understood and interpreted as a whole entity.

4.1 Current Research

Previous work in Web accessibility, in relation to those who are deaf or hard of hearing, generally deduced that content that included audio should have appropriate annotations in order to be interpreted. While this has been the standard for those who develop Web sites following the W3C or Section 508 standards, this is not necessarily the case for the average user who may post their own contents, such as videos, blogs, and sound effects on to Web sites (e.g., YouTube [58]). Therefore, generating material that is inaccessible by a group of people with hearing deficiencies is a wide-spread (and growing) problem.

Closed Captioning (CC) the Web video is the first step towards video-sign language translation [33]. ProjectReadOn [34] lets user to submit a video (URL) and request caption. DoSub allows users to subtitle a posted video clip (on the user selected frames) in multiple languages. With a similar tool called BubblePly [12], users can add text to videos.

Avatars have been used for the purpose of signed languages. One such implementation in VCom3D [52] includes a pre-programmed signed story performed by an avatar that utilizes all of the ASL phonemes and facial expressions. This implementation of an avatar is generally used for the purpose of educating deaf children and persons who study signed languages. Avatars have been currently used on the Web to animate the form of the human body. This animated approach of sign language indicates a flexible means to mimic human behavior.

4.2 Future Challenges

Challenges in creating a more accessible Web for those who have hearing difficulties include [33]: audio extraction for randomly posted content, signed language implementation from the audio extraction, and rendering audio.

Audio Extraction

The majority of videos posted on the Internet by end users do not have CC, therefore, additional remedies for extracting speech need to be adopted. Although voice recognition devices are currently available, certain limitations make it difficult to extract information. Some limitations of voice recognition devices include extracting speech from external audio, and deciphering between individual accents.

Noises may mistakenly be interpreted, resulting in incorrect or garbled output. The question of a controlled environment becomes imperative to audio extraction, and the likelihood of segmenting the cacophony in an end-user posting from pertinent content becomes an issue.

Another challenge faced when attempting audio extraction is how to segment music: the lyrics, the instruments, and the rhythmic portions are all integral parts of an entire musical piece. It is an active area of research to examine how these segments could be extracted as one, how they could be segmented as parts, and what devices or algorithms may be used for this purpose.

Sign Language Automation

An accurate sign language interpretation requires the correct structure of sign language, which differs from English. To structure the syntax of the signs appropriately is a difficult task, as different scenarios may have a different sequence of words. The conception of how the words are combined in altering contexts is a challenge when attempting to automate sign language, as the sign may result in a contrasting interpretation from the original intent. The question is how can to overcome the relation of signs in varied concepts. The probabilistic methods of natural language processing need to be investigated with sign languages. These methods may be used to determine when signs are used in a given circumstance.

Rendering Audio

Rendering audio content has been applied via closed captioning devices. CC devices are generally commissioned by organizations, however is not readily considered by the average user who adds sound effects, songs, or video content. Moreover, CC is insufficient in relaying information such as the rhythmic structure of a songs which are effectively conveyed in the signing of songs, other lost audio material exist in sound effects, and therefore eliminates access to certain elements of the web.

The concern raised is whether or not a tool is viable for interpreting the information that is presented on the Web. Also, how to interpret the sound in a manner that is meaningful for those who are deaf, is a problem that needs resolution.

Additionally, the users of the Web need to be educated about appropriately annotating content, and meeting Web standards, to ensure that no user is left without the availability of information.

5. Summary

Web site evolution is an engaging research area that is both broad and deep. As the technology changes, the specifics of the problem change [25], but the underlying fundamentals do not. Of the many interesting areas that fall under the WSE rubric, accessibility is a topic that represents the frontier of research and practice.

For example, so-called "Web 2.0" sites employ AJAX to encourage a rich user interface and dynamic interaction. Unfortunately the interfaces are not always compatible with accessibility devices. The dilemma being faced is how to incorporate, or adopt a remedy that can facilitate the accessibility functionality, or permit the accessibility devices seamlessly.

Lest one think that these issues need not be of personal concern, for example if you do not currently suffer from such disabilities, it has often been said that we are lucky to be "currently abled"; the march of time often imposes accessibility constraints on all of us. Our physical skills may devolve in their capabilities, but the Web sites evolve in their capabilities. It is up to the community to ensure that the increased capabilities always keep the experience of all users in mind at all times. After all, this was the original intent of the Web, and it should remain so as it evolves over time.

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