ATU PRESS

An AI-Powered Model of Information Retrieval System for Visually Impaired Library Users

Azam Najafgholinejad (iD)∗

Assistant Professor, Information, and Artificial Intelligence Research Group, National library and archives of I.R. Tehran, Iran

Abstract

Purpose: This study presents a user interface model for library websites tailored to visually impaired (VI) users, leveraging the potential of artificial intelligence (AI).

Method: Through exploratory observation of 33 visually impaired users performing three real tasks on library websites, key factors affecting usability were identified. Data collection involved formal usability testing combined with the think-aloud protocol. The interfaces of four prominent Iranian library websites were analyzed. Content analysis supported by MAXQDA software was used to interpret the data, and Cohen's kappa coefficient was employed to measure inter-coder reliability.

Findings: The main findings of this study revealed that a logical webpage structure and clear descriptive headings have the most significant impact on usability. Additionally, inconsistent labeling, search and results presentation complexity, lack of interface customization options, and technical challenges were identified as major accessibility barriers for visually impaired users. AI-based solutions such as automatic error correction, intelligent voice assistants, AI-powered question answering, result clustering, smart filtering, text and image processing, summarization, and interface personalization were proposed to enhance the user experience. Overall, by integrating user feedback and cutting-edge AI technologies, libraries can create more inclusive digital environments that cater effectively to the needs of visually impaired patrons,

setting a precedent for future developments in accessible information retrieval systems.

Conclusion: Improving library website usability for visually impaired users requires a nuanced understanding of their specific needs. This research contributes by identifying underexplored AI-based strategies that can significantly enhance accessibility and user satisfaction. Future studies should assess the long-term effectiveness of these approaches and explore additional enhancements.

Keywords: User Interface, Library Websites, Visually Impaired Users, Artificial Intelligence, AI, Usability

Introduction

Advancements of Information and communication technology (ICT) has introduced various technologies designed to assist disabled individuals including those who are visually impaired (VI). Adaptive technology has become critical in the academic lives of VI users. A wide range of constantly evolving assistive or adaptive technology devices enables VI students to perform sight-related tasks independently. These devices include screen magnifiers, screen readers (used to read textual information), voice recognition software (used to simulate the keyboard), alternative pointing devices (used to simulate mouse pointing and button activation), optical scanners, optical magnifiers, note-taking devices and technology that produces large print, Braille or speech (King and Coetzee, 2018), Virtual Butler (perceiving through demotic sensors and users' requests and answers) (Fiol-Roig, 2009), Dot smartwatch (serving as a Braille smartwatch for converting email or message texts into Braille), Robot gloves (a wearable gadget for identifying and moving objects) (Park and Kim, 2018) FingerReaders (capable of scanning texts, identifying words, and converting them into voice messages) (Shilkrot et al., 2014), SmartCane (providing face identification and GPS guiding for VI in the outdoor environment) (Narayani et al., 2021), Be My Eyes (connecting the blind people with sighted volunteers through video calls for assistance), Glasses for disabled access to technology (a wearable gadget equipped with a sensor for orientation and Bluetooth capability for transferring data to mobile phones and computers), Digital Signage (guiding disabled individuals to access the campus and displaying textual guides through texts or audios), and Smart mobile phones (providing features such as calls, motion controls, touch feedback, display magnifier, large text, contrast, reverse color, display brightness, shortcuts, and virtual assistance). E-readers are also among the technologies that can assist disabled individuals capable by capturing images of book pages and analyzing texts through Optical Character Recognition (OCR). These devices identify images and read the text aloud (Harum et al., 2021). Additionally, the Daisy Player is a device that presents books in audio format maintaining the same structure, lines, and paragraphs as the printed version, allowing for search functionality (Sarmadi, 2016). Some of these technologies are only used in developed countries while others are utilized in less developed countries .

Along with all these technologies, Artificial intelligence (AI) serves as a tool that helps to create an enjoyable experience for users. To foster

improved interaction between AI and the user interfaces (UI), experts in user interface design must treat AI as an important variable during the interface design process. Technologies such as recommendation systems, user interface customization, dialog user interfaces based on Natural Language Processing (NLP), voice assistants, and cognition services based on machine vision for image comprehension and description are among the technologies that have unfortunately been overlooked in the design of library user interfaces. In this research, we focus on integrating artificial intelligence (AI) solutions into library information retrieval systems to not only enhance accessibility but to fundamentally improve user interaction and efficiency for VI users .

According to the World Health Organization (2021) globally, at least 2.2 billion people have a near or distance vision impairment. In at least 1 billion of these cases, vision impairment could have been prevented or is yet to be addressed. Statistics released by Iranian official organizations (Iran's Statistical Yearbook 2020, 2021) revealed that the State Welfare Organization of Iran provides support to over 206 thousand VI individuals. Consequently, it seems essential that library websites be meticulously designed to ensure accessibility and usability for this demographic.

With regard to the importance of this topic, the current research endeavors to formulate a model for UIs of library websites based on the experiences of VI users. Considering the importance of AI in improving the usability of user interfaces, this research also seeks to provide solutions for enhancing library websites' usability through the utilization of AI capabilities. Achieving these goals requires knowing the factors affecting the usability of library websites for VI users so that technological solutions based on AI can be proposed according to these factors. Therefore, this research addresses the following key questions:
- What are the factors affecting usability of OPAC (Online Public Access Catalog) digital libraries, and virtual reference services UIs in studied libraries based on the experience of visually impaired users?
- What is the user interface model of library websites that aligns with the experiences of visually impaired users based on the potential of AI?

Literature Review
Several studies have been conducted based on the experiences of VI users in the context of libraries and the web, including Turner (2003), Lazar et al. (2007), Buzzi et al. (2004), Chandrashekar (2010), Sahib et al. (2012), Xie et al. (2014), Yoon et al. (2016), Tomlinson (2016), Babu and Xie

(2017), Mulliken (2019), Dermody and Majekodunmi (2011). Not much literature has been found on intelligent user interfaces for VI users. Here are some cases that have benefited from artificial intelligence solutions in some way. Abdnikoyipour (2011) investigated and designed smart user interfaces with the aim at accelerating access to the information needed by VI users. She presented an agent-based approach to the problem of search personalization using intelligence, learning and goal-oriented capabilities, and finally a framework was designed to compare systems capable of reviewing those designed for the VI users. Felix et al. (2018) proposed a smart personal AI assistant for VI people using AI, machine learning, image and text recognition. The idea is implemented through an Android mobile app that focuses on voice assistant, image recognition, currency recognition, e-book, chatbots, etc. The app is capable to assist using voice command to recognize objects in the surrounding, to perform text analysis to recognize text in the hard copy documents and convert a printed or electronic book into an audio format using natural language. Marvin (2020) introduced DAVID a digital assistant application aimed at help the VI in recognizing text on real-world objects and provide audio feedback in real-time. It utilizes voice user interface technology such as speech recognition and speech synthesis as the means of interaction through voice input. Shera et al. (2021) conducted a study to reduce the cognitive effort required for interface navigation by identifying the accessibility issues according to the user's mental model. The study evaluated the accessibility of smartphone screens to solve organizational, presentation, and behavioral (OPB) problems of using mobile applications. Usability evaluation of an application was conducted and validated with a specific focus on Blind and Visually Impaired (BVI) user experience. A total of 56 BVI participants were included in the evaluation. Overall, four tasks to assess organization, avoidance of redundant information, serialization of content, and style and text presentation were assigned to the selected participants for a newly developed smartphone application. Ethnography, task completion within a specific time, and system usability scale (SUS) techniques were used for analysis and post-task evaluation. The results showed that the organization of the application was 100% effective for both BVI participants. Overall, this study indicated that application reduced the severity of OPB problems, offering higher usability with increased satisfaction level and enhanced effectiveness and efficiency for BVI users. Hence, this study provides design and development guidelines based on a practical evaluation to overcome the smartphone application

accessibility problems faced by BVI users. Walle et al. (2022) analyzed recent research work and achievements performed in the domain of AI-based and vision-based systems for helping blind and visually impaired people (BVIP). They started by highlighting the recent and tremendous importance that AI has acquired following the use of convolutional neural networks (CNN) and their ability to solve image classification tasks efficiently. Then, they concentrate their investigations on the use of CNN or related methods in a vision-based system for helping BVIP. They analyzed the existing surveys, and studied current work (a selection of 30 case studies) using several dimensions such as acquired data, learned models, and human–computer interfaces. They compared different approaches, and concluded by analyzing future trends in this domain. Abhishek et al. (2022) provided an insight into the implementation of assistive technology software that employs voice recognition technologies to aid the visually impaired in accessing computer applications and the internet. The software can also detect and rectify spelling and grammatical errors in content depending on the context of the entire phrase using an artificial intelligence-powered writing assistant called GingerIt. Kumar et al. (2023) focused on more than 30 research papers that are available on the topic of AI solutions for the visually impaired and reviewed them. The paper covers the research paper, the technology used, the solutions offered, and their solutions. Some recommendations are also provided based on the limitations found in the different papers.

Reviewing the literature suggests that technology interventions play a pivotal role in helping users with vision impairments tackle the challenges they face due to their disabilities. Also, smart assisting technologies can actively be adjusted according to the conditions of individuals and the environments. Therefore, reviewing works of literature on these issues, and providing solutions for enhancement can contribute to establishing an intellectual foundation and inspire action in this particular field of study.

Method

The research was employed a qualitative method. In this research, through the exploratory observation of 33 VI users engaged in real tasks (3 tasks) on library websites, the factors affecting the usability of the websites were identified. The data were collected using the formal usability testing and think aloud protocol. Users were observed while using a library website and performing defined tasks, verbally expressed their thoughts, feelings and opinions about their interaction experience. The observation process

was conducted online using screen recording applications like Fastone and Ocam. Routine tasks, such as like searching for a specific source (searching the book "Embezzlement and Money Laundering" written by "Narges Soltani"), locating and using the source (Finding any digital resource about "Saadi Garden" and proceeding to the step of using the full text of the resource), and communicating with the librarians (asking the librarian) were defined for VI users in libraries' websites' UI. The users were observed while using each library website and performing the defined tasks. At the same time, using the think-aloud protocol, they expressed their thoughts, feelings, and opinions about their experiences aloud. Participants were asked to describe what they were doing and what prompted a particular action. In other words, while performing the tasks, the user would say out loud every problem they encountered and everything they thought.

The research population consisted of visually impaired users who selected using a purposeful and snowball sampling method (users with university education). The minimum conditions required for the sample community were:

- Visually impaired and blind users who can understand the basic concepts of the Internet and the Web.

- Users who can interact with the screen without assistance using a keyboard, mouse, or assistive technology, including a screen reader software.

- Users should have minimum search experience in search engines and library websites to retrieve information.

Demographic data revealed that approximately 50% of the participants had a degree in higher education and more than 80% of them were employed or students at a university. Most of the participants (78.8%) primarily accessed their required sources from the web, using libraries less frequently.

In this research, the UI of several distinguished libraries in Iran were studied, including the National Library and Archives of Iran, Organization of Libraries, Museums and Documents Center of Astan Quds Razavi; Library, Museum and Document Center Islamic Consultative Assembly and the Central Library and Document Center of Tehran University were studied as prominent, famous and important libraries in the country. The research population selected through snowball sampling from different provinces of Iran and by introducing the visually impaired users themselves with respect to recognizing each other.

To analyze the research data (Think-aloud protocol data), content analysis (categorizing and grouping the codes) and coding scheme were employed. MAXQDA software facilitated this process. The transcripts were read at least three times and recoded several times, and were continuously expanded and revised, resulting in 651 final codes. Another researcher participated in the content analysis to confirm the validity of the data. Cohen's kappa was calculated to assess agreement between two coders. Thus, in addition to the researcher, three transcribed texts were coded by another researcher and the agreement coefficient of the two researchers was calculated. Cohen's Kappa index value was 0.693, which indicating fair agreement between two coders.

Findings

Participants from four library websites undertook the predefined routine tasks. In this research, only the data obtained from the think-aloud protocol while performing the tasks are analyzed and presented to answer the research questions.

Q1: What are the factors affecting usability of OPAC (Online Public Access Catalog) digital libraries, and virtual reference services UIs in studied libraries based on the experience of visually impaired users?

To answer this question, transcripts of 33 participants were investigated. Each script was divided into categories based on their topics, resulting in 651 final codes distributed across 5 categories. The identified points and their frequency in each of the 33 scripts are summarized in Table 1.

Table 1. Important Factors of Usability of Library Websites

Categories	Sub-categories	Frequency of Codes	Total
The organization and structure of the pages	Logical division and descriptive headings	116	273
	Labeling elements	57	
	alternative text and Image Descriptions	24	
	Prioritization of Relevant Content (backup links):	6	
	Technical Challenges	11	
	Dynamic content	8	

	Expected functions	27	
	Security barriers	24	
Challenges in Search and Information retrieval	Complexity of the search process	14	64
	Displaying retrieved resources	17	
	search results Organization	31	
	Access to sources	2	
Systemic messages	Error messages	22	46
	Task confirmation messages	24	
User-centricity	Users' requirements and independence	19	263
	Users' perception	12	
	Cognitive overload	12	
	navigation strategies	51	
	User Customization and Support	43	
	User Perceptions and Experiences	16	
	User Uncertainty and Inefficiency	71	
	User Skills and the Impact of Environment	39	
User interface compatibility	Interface Consistency and Integrity	26	26
total		651	

Table 1 indicates that 273 codes out of 651 total codes are dedicated to the organization and structure of the pages. User-centricity and search and information retrieval are respectively other categories with the most frequency. The subsequent section provides more detailed explanations for each category.

- The Organization and Structure of The Pages

Logical division and descriptive headings: A prevalent theme in user feedback was the need for clear and logical page structure. Participants consistently expressed frustration with the absence of well-defined headings and divisions, particularly on search result pages. This lack of organization made content discovery arduous and unsatisfying. Moreover, inconsistent and non-standard presentation of information, such as the use of non-standard tables for search results, exacerbated these issues. To enhance user experience, researchers emphasized the importance of establishing distinct page sections using clear and descriptive headings.

Incorporating landmarks and providing informative page titles were also identified as crucial elements for improving overall page structure and navigation.

Labeling elements: Another significant issue highlighted by participants was the lack of appropriate labels for user interface elements. Search boxes, registration forms, and other input fields often lacked clear labels, causing confusion and hindering user interaction. Inconsistent labeling of links and buttons further compounded the problem, forcing users to rely on trial and error to determine functionality. These findings underscore the critical role of effective labeling in ensuring accessibility and usability.

Alternative Text and Image Descriptions: Participants emphasized the critical role of alternative text (alt text) in providing essential information about non-textual elements to visually impaired users. Insufficient or absent alt text significantly impacted user experience.

Prioritization of Relevant Content (backup links): Users expressed frustration with excessive, unnecessary elements, and irrelevant links, particularly on search result pages. The inappropriate structure of backup links, requiring users to listen to numerous unwanted options, led to disengagement and abandonment of the page. Not being able to skip unnecessary content cause difficulty for users to navigate the page.

Technical Challenges: Technical issues such as coding errors, inconsistent page layouts across browsers, and dynamic content updates presented additional barriers for blind users. Screen reader compatibility and the management of moving content were specifically highlighted as areas requiring improvement.

Dynamic Content: Participants highlighted challenges associated with dynamic content, including issues with screen reader behavior, page focus, and the pace of content updates. Difficulties in pausing and controlling the flow of dynamic content were also reported.

Expected functions: Expected functionalities of page elements, such as the behavior of skip-to-content links and buttons, were identified as areas requiring improvement. Users expressed frustration with the unpredictability of these elements.

Security Barriers: The use of CAPTCHAs posed significant challenges for blind users. These visual tests hindered access to registration, purchasing, and other essential online services, limiting user independence.

- Challenges in Search and Information Retrieval
Complexity of the search process: Users encountered significant difficulties in navigating and understanding search processes within the examined websites. The complexity of advanced search features, including numerous combo boxes and their unclear functions, hindered effective search. Additionally, the placement of search buttons often required excessive user effort.

Displaying retrieved resources: Regarding search results, participants emphasized the importance of clear presentation formats, such as well-structured tables, to facilitate navigation. The absence of meaningful text descriptions for non-textual content, like scanned images or documents, significantly impacted the ability of blind users to understand and utilize search results.

Search result organization: This sub-category underlines the appropriate organization of search results in the form of headings or well-designed tables that align with the common navigation mechanism for tables.

Access to sources: In terms of accessing retrieved resources, users encountered obstacles, particularly with inaccessible PDFs. These challenges underscore the need for improved search functionality and accessible resource formats to enhance user experience for blind individuals.

- Systemic Messages: This category has been divided into two sub-categories which are error messages and task confirmation messages.
Error messages: This section focuses on the role of system-generated messages in the user experience. Error messages that fail to provide clear guidance or are not adequately announced by screen readers pose significant challenges.

Task confirmation messages: Additionally, the lack of confirmation messages for completed actions, such as adding items to a digital library cart, can lead to user uncertainty. Ineffective communication during online chat interactions further highlights the need for improved system messaging.

- User-Centricity: Use-centricity category is divided into sub-categories which are as follows:
User Requirements and Independence: Participants emphasized the importance of tailoring library services to meet the specific needs of visually impaired (VI) users. This includes providing accessible research

tools, facilitating communication with library staff, and offering services comparable to those available to sighted patrons. A strong desire for independence was evident among participants, who expressed frustration with reliance on others for tasks such as solving CAPTCHAs or navigating complex websites. Moreover, soft wares like DotWalker, Nvision AI, InstaReader, Google OCR, Kurzweil, and Google Lookout used by VI users were mentioned in this category.

Users' perception: Participants often reported a preference for general web search engines over library websites due to perceived accessibility and consistency issues. Additionally, some of the participants also emphasized the disappointing experiences with libraries.

Cognitive overload: Some of the participants pointed out the redundant information and excessive screen reader output contributed to cognitive overload.

Navigation Strategies: Blind users employ a variety of strategies to navigate library websites. Common techniques include the use of keyboard shortcuts (e.g., headings, buttons, and links) to efficiently traverse page content. Understanding these strategies is crucial for designing intuitive and accessible interfaces.

User Customization and Support: Participants emphasized the need for customizable interfaces, including options for text enlargement, font adjustments, and high contrast displays. Additionally, the provision of comprehensive help and guidance features, such as audio tutorials and virtual assistants, was seen as essential.

User Perceptions and Experiences: Many users reported difficulties in navigating library websites due to complex layouts and inconsistent information architecture. The absence of clear page structure and reliance on visual cues hindered user experience. Furthermore, users expressed frustration with CAPTCHAs and other security measures that presented insurmountable barriers.

User Uncertainty and Inefficiency: Users frequently expressed uncertainty regarding the outcomes of their actions while navigating websites. This lack of confidence was often attributed to insufficient information, such as missing alternative text for images, which prevented users from understanding available resources. Inefficient page structures, characterized by excessive text and poorly organized content, contributed to increased task completion times.

User Skills and the Impact of Environment: Participants highlighted the varying levels of digital literacy among visually impaired

users. While some users demonstrated proficiency in navigation techniques, others encountered challenges with tasks like accurate password entry. The study also underscored the influence of cultural attitudes and societal support on the user experience. Participants emphasized the importance of inclusive design principles and supportive policies in empowering visually impaired individuals.

- User Interface Compatibility

Interface Consistency and Integrity: Participants emphasized the importance of maintaining consistent and predictable website behavior. Synchronization issues between websites and screen reader software were identified as significant barriers to accessibility. Additionally, users expressed a need for simplified page designs and avoidance of rapid layout changes to enhance usability. The choice of language and terminology within the interface also impacted user experience. Ambiguous or misleading labels hindered navigation and increased user confusion.

Q2: What is the user interface model of library websites that aligns with the experiences of visually impaired users based on the potential of AI?

The proposed model is grounded in data collected from visually impaired (VI) users with a high level of technological proficiency to formulate a model for library websites. Here are some points that should be mentioned for the presented model:

- The extracted data for developing a model in this study was extracted from Iran's famous and big libraries which are generally accessible, although with some usability challenges. Thus, to make library websites accessible and usable, it is crucial to adhere to official accessibility standards.

- The yellow oval shapes in the presented model depict the solutions that AI can offer for improving the accessibility and usability of library websites (Figure 1).
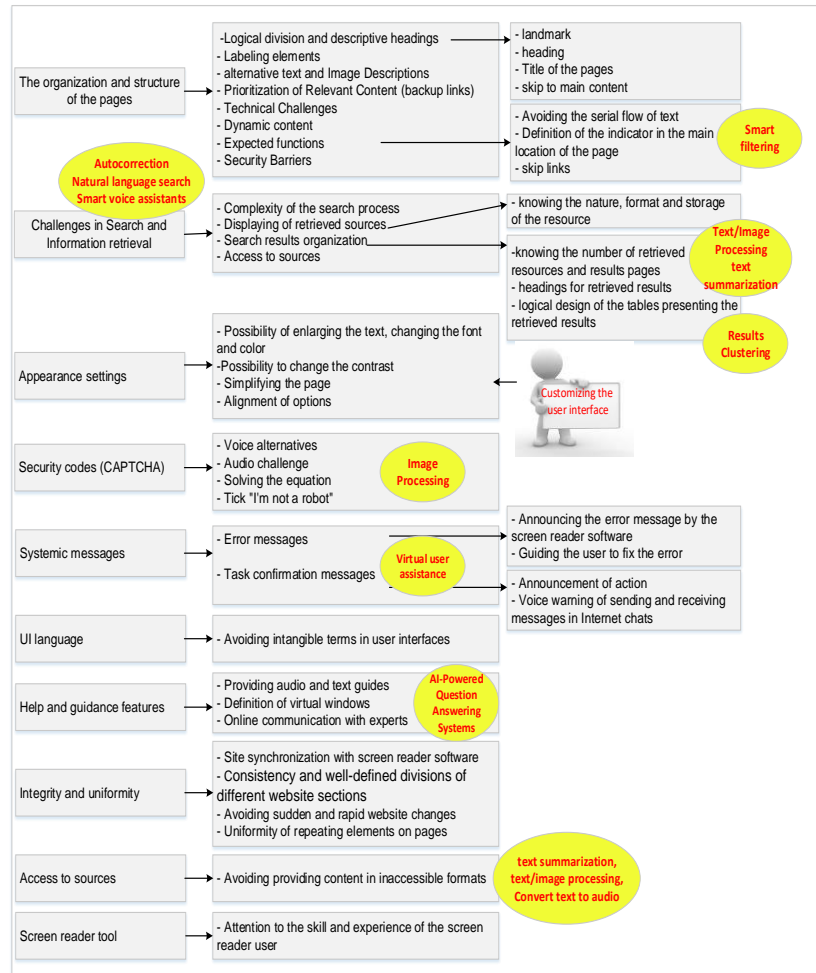
Figure 1. The Proposed Model for Usable Library Websites

4 Discussion

The analysis yielded 651 primary codes categorized into five themes, with "logical division and descriptive headings" emerging as a dominant factor influencing website usability for visually impaired users. Participants consistently emphasized the need for clear page structures and informative headings to facilitate navigation. While many studied websites incorporated headings, their effectiveness in guiding users was often limited. This finding aligns with previous research by Babu and Xie (2017), Yoon et al (2016), and Mulliken (2018), which highlighted the critical role of headings in enhancing accessibility.

Examples of exemplary practice can be observed in the library services of the Canadian National Institution for the Blind (CNIB) and the Royal National Institute of Blind People (RNIB), where logical page divisions and well-defined headings are effectively implemented. However, the study also revealed inconsistencies in page title clarity, indicating a need for further improvement in this area.

A significant barrier to accessibility identified in this study was the inconsistent and often absent use of tags and labels for webpage elements. Previous research by Babu and Xie (2017), Xie et al. (2014), and Lazar et al. (2007) corroborates these findings, emphasizing the critical role of descriptive tags in enhancing user experience. The importance of alternative text (alt text) for non-textual content cannot be overstated. Shimomura et al. (2010) highlighted the limitations of auditory perception compared to visual perception, underscoring the need for effective textual descriptions. Tomlinson (2016), Lazar et al. (2007), and Babu and Xie (2017) also emphasized the detrimental impact of missing alt text on accessibility.

Excessive and irrelevant links significantly impaired the user experience. Participants reported difficulty in differentiating essential content from supplementary content, often resulting in wasted time and effort. Prioritizing primary content by using clear link hierarchies and the use of "skip to main content" links is crucial. Additionally, the dynamic nature of web content, coupled with inconsistent screen reader behavior, exacerbated the navigation challenges. Coding errors, page refresh inconsistencies, and incompatible browser rendering affected the website's accessibility. The unpredictable behavior of dynamic content, such as banners and auto-updating content, further hindered user interaction. These issues, in conjunction with CAPTCHAs, imposed substantial barriers to independent navigation for blind users. These findings align with previous research by Chandrashekar (2010), Leporini et al. (2004), Lazar et al. (2007), Xie et al. (2014), and Shimomura et al. (2010), which emphasized the importance of clear link structures, effective use of alternative text, and the negative impact of technical issues on user experience.

Participants identified search complexity as a significant barrier, citing convoluted search interfaces, numerous unnecessary options, and poorly placed search elements. These findings align with previous research by Yoon et al. (2016) and Leporini et al (2004), who emphasized the need for intuitive and efficient search processes. Effective organization and

presentation of search results were also highlighted. Users expressed difficulty in identifying and accessing desired information on results pages. Byerley and Chambers (2001), Lazar et al. (2007), Yoon et al. (2016), and Buzzi et al. (2004) similarly reported challenges related to the formatting of results, table structures, and the absence of clear headings. In contrast, websites like the Accessibility Library Celia (Finland), RNIB (UK), the British Library, the National Library of Australia, and Library and Archives Canada demonstrated effective practices in organizing search results.

These findings underscore the importance of user-centered design in search functionality and result presentation to enhance accessibility for visually impaired users.

Participants emphasized the need for customizable interfaces, including options to adjust page size, color, and font. Additionally, the eliminating CAPTCHAs in favor of alternative authentication methods was strongly advocated. Error messages should provide clear guidance, and system feedback should be timely and informative. To enhance user autonomy, the provision of audio cues and alternative input methods is essential. Excessive screen reader output and information overload should be mitigated through careful interface design. These findings align with previous research by Lazar et al. (2007), Shimomura et al. (2010), and Sahib et al. (2012), which highlights the importance of user-centered design, effective error handling, and the reduction of cognitive load for visually impaired users.

Participants reported significant difficulties in navigating library websites due to complex structures, inconsistent layouts, and a lack of clear information hierarchy. These issues often led to user frustration and abandonment of search tasks. Chandrashekar (2010) supports this finding, emphasizing the cognitive burden caused by information overload.

The ability to efficiently locate and access information was hindered by factors such as poorly structured search results, limited customization options, and technical challenges related to screen reader compatibility. Users highlighted the importance of clear headings, logical page flow, and predictable interactions in enhancing the overall user experience. Moreover, the study revealed variations in user skills and experience, which influenced their ability to navigate complex websites. Turner (2003) emphasized the correlation between assistive technology proficiency and user performance.

Participants identified several key areas impacting the user experience

for visually impaired individuals. Inconsistent and ambiguous language within website navigation posed challenges. Additionally, the lack of clear guidance and support features hindered user's autonomy. Ensuring consistency in website design, including synchronization with screen reader software, was deemed crucial. Participants emphasized the need for well-structured content, avoiding sudden layout changes, and providing clear visual cues through alternative text.

The accessibility of library resources, particularly PDFs, emerged as a significant issue. Users reported difficulty in accessing and understanding information presented in non-textual formats. Tomlinson (2016), Dermody and Majekodunmi (2011) also emphasized the inaccessible PDFs (scanned images) as one of the main difficulties faced by VI users. The study also highlighted the influence of various user factors, including screen reader experience and familiarity with assistive technologies, on overall website usability. Chandrashekar (2010) also believes the users' education, experience, and comfort in using SRs along with awareness of available options, settings, and commands, were identified as essential factors influencing users' perception of accessibility. Turner (2003) concluded that the type of assistive technology used affects the search processes, with more advanced tools offering a more flexible approach for users in conducting searches.

According to the proposed model, the following AI-based solutions are suggested for the VI users on library websites. While most of the suggested solutions may not be currently available in library systems, they are ready for implementation.

Auto Correction: One critical area for improvement identified in the study was the need for robust auto-correction capabilities. The frequent occurrence of spelling errors and the sensitivity of library databases to spaces highlighted the necessity for such a feature. Implementing an AI-driven auto-correction system could significantly enhance user experience for all patrons, including those with visual impairments. Abishak's (2022) research provides a valuable foundation for developing this solution.

Smart Voice Assistants: The potential of voice assistants, such as Siri, Alexa, Google Assistant, and Cortana, to enhance accessibility for visually impaired library users is significant. By enabling voice-based interaction, these technologies can simplify navigation and information retrieval. The concept of a virtual assistant acting as a user guide within the library website, as explored by Marvin (2020), holds promise for improving user experience. Some specific functionalities that a voice

assistant could provide within the library context are searching for books, placing holds, or accessing account information.

Results Clustering: Participants highlighted the challenge of navigating through extensive and unstructured search results. Employing clustering techniques to group similar results could significantly enhance user experience. This approach, as explored by Ferworn et al. (2002), enables users to gain an overview of the results before delving into specific items. By organizing search results into thematic clusters, users can more efficiently identify relevant information. This strategy aligns with the broader goal of providing a structured and intuitive search interface for visually impaired users.

Smart Filtering: To enhance user experience, the implementation of smart filtering mechanisms is essential. By analyzing user behavior and preferences, redundant information, such as repetitive headers and footers, can be filtered out, reducing cognitive load. This approach, supported by research from Yesilada et al. (2007), prioritizes user needs and streamlines information presentation.

AI-Powered Question Answering Systems: The integration of advanced question-answering systems, such as ChatGPT, into library websites offers significant potential for enhancing user experience. By providing immediate and informative responses to user queries, these AI-driven tools can streamline the information seeking process.

Text and Image Processing/ Image Description: To enhance accessibility, digital libraries must prioritize the conversion of non-textual content into accessible formats. Implementing image-to-text conversion technologies, such as Optical Character Recognition (OCR), is crucial. Leveraging AI-driven image analysis, including object detection and image captioning, can further enrich the user experience. Google's "Show and Tell" algorithm exemplifies the potential of AI in generating descriptive text for images. By providing accurate and detailed image descriptions, libraries can empower visually impaired users to access and comprehend visual information effectively. This aligns with the findings of Felix et al. (2018) regarding the importance of text conversion to improve accessibility.

Text Summarization: To address the challenges faced by visually impaired users in processing lengthy text content, AI-powered text summarization tools can be integrated into library systems. Additionally, providing audio descriptions for charts and graphs can significantly to improve data accessibility. These features can contribute to a more

inclusive and user-friendly experience for all library patrons.

Natural Language Processing and Semantic Search: The integration of natural language processing (NLP) and semantic search technologies offers significant potential for improving information retrieval within libraries. These advancements enable search engines to understand the user's intent behind queries, even if phrased in natural language. By analyzing the context and meaning of user queries, NLP-powered search engines can deliver more relevant and comprehensive results. Examples like Bing's integration with OpenAI's ChatGPT and Phind.com demonstrate the potential of AI in search. Research by Wahabi et al. (2021) further supports the notion that neural networks can enhance the efficiency and accuracy of information retrieval processes. Implementing these technologies can empower users, particularly those with visual impairments, to formulate complex search queries and navigate library resources more effectively.

User Interface Customization and AI Integration: To effectively accommodate the diverse needs of all users, including those with visual impairments, library websites must offer robust customization options. Features such as font size adjustment, color contrast modification, and dark mode are essential. Additionally, integrating voice input capabilities, similar to those offered by platforms like Nevisalive, can significantly enhance accessibility. In addition, new feedback mechanisms can be integrated to continuously gather user input, thereby facilitating ongoing improvements to the interface design.

While AI-driven technologies hold immense potential for improving user experience, careful consideration must be given to the costs and benefits of implementation. Factors such as user demand, available resources, and the potential return on investment should be evaluated to determine the optimal level of AI integration.

Specifically, the model incorporates supervised machine learning algorithms for tasks such as auto-correction and result clustering, as well as unsupervised learning to capture behavioral patterns. Additionally, Natural Language Processing (NLP) techniques are employed to analyze user queries semantically, enabling context analysis and enhancing the match between user intent and library resources. The model can design with a modular and scalable architecture that facilitates easy updates and integration with external systems. Detailed diagrams (e.g., data flow diagrams, system architecture schematics) can be added to clearly illustrate the data ingestion, processing, and retrieval processes along with strategies

for efficient indexing and caching.

In order to thoroughly assess the system's effectiveness, we can define a set of quantitative performance metrics including Precision, Recall, and F1-score, as well as qualitative metrics based on user satisfaction surveys.

It is essential to prioritize ethical considerations in the development and deployment of AI systems to ensure fairness, transparency, and trust. Addressing bias mitigation is crucial, as AI algorithms can inadvertently perpetuate existing biases present in training data. Implementing robust measures to detect and correct these biases during both training and deployment phases can significantly enhance the reliability of the system.

Furthermore, data privacy and security must be safeguarded through comprehensive protocols. Encryption methods, advanced user authentication mechanisms, and strict adherence to international data protection standards are necessary to protect sensitive information and maintain user trust.

By integrating these ethical practices into AI development, organizations can create systems that not only perform effectively but also align with societal values and legal requirements. It is highly recommended that such considerations be actively implemented to promote responsible AI innovation.

Conclusion

To optimize library website usability for visually impaired users, a deep understanding of their specific needs and challenges is essential. In light of the findings, this study advocates for a strategic shift in the design and development of library websites toward a more inclusive, user-centered approach. Rather than merely addressing technical compliance, institutions should embed accessibility as a foundational principle in digital library services. This requires the integration of intelligent systems that can adapt to diverse user needs, particularly those of visually impaired individuals. AI-powered functionalities—when implemented thoughtfully—can bridge longstanding usability gaps by personalizing navigation, simplifying content presentation, and improving information retrieval processes .

Equally important is the institutional commitment to continuous engagement with end-users through participatory design practices and feedback mechanisms. Accessibility should not be perceived as a one-time technical fix but rather as an evolving goal that requires interdisciplinary collaboration, periodic evaluation, and ethical stewardship. By aligning

accessibility initiatives with broader organizational strategies—such as digital transformation, user experience optimization, and equity in access to information—libraries can become more responsive, resilient, and equitable in serving all patrons, including those with visual impairments.

Future research should explore the long-term impact of these strategies, while also identifying additional areas for improvement.

This study is the first of its kind in Iran to explore the user interfaces of library websites for individuals with visual impairments. By integrating advanced AI techniques and adhering to rigorous usability and ethical standards, the proposed model not only addresses existing challenges but also introduces novel solutions that significantly improve the accessibility and performance of library information retrieval systems. The study was conducted on a limited number of websites, and therefore cannot encompass all aspects that are representative of a library system. Additionally, the study focused solely on users with visual impairments, lacking a control group of sighted users to compare results between the two groups. Furthermore, the participants were predominantly university-educated, which may limit the generalizability of the findings to the tasks and issues faced by ordinary users. Future research should also include comparative studies involving both visually impaired and sighted users to comprehensively evaluate the differing usability challenges and benefits of AI-driven interfaces across diverse user groups. Furthermore, it is recommended that studies expand beyond visual impairments to investigate the impact of intelligent and adaptive user interfaces on various disability groups, thereby promoting more inclusive services. Additionally, exploring the ethical dimensions, user perceptions regarding privacy and data security, and trust in AI-powered library systems is crucial for designing transparent and reliable tools that foster greater user satisfaction and trust. Nevertheless, this study can serve as a catalyst and a complement to future research in the field of AI-driven user interfaces for individuals with disabilities.

CONFLICT OF INTEREST: The authors declare that they have no conflicts of interest regarding the publication of this manuscript.

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