Enabling Customization of Discussion Forums for Blind Users

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Online discussion forums have become an integral component of news, entertainment, information, and video-streaming websites, where people all over the world actively engage in discussions on a wide range of topics including politics, sports, music, business, health, and world affairs. Yet, little is known about their usability for blind users, who aurally interact with the forum conversations using screen reader assistive technology. In an interview study, blind users stated that they often had an arduous and frustrating interaction experience while consuming conversation threads, mainly due to the highly redundant content and the absence of customization options to selectively view portions of the conversations. As an initial step towards addressing these usability concerns, we designed PView - a browser extension that enables blind users to customize the content of forum threads in real time as they interact with these threads. Specifically, PView allows the blind users to explicitly hide any post that is irrelevant to them, and then PView automatically detects and filters out all subsequent posts that are substantially similar to the hidden post in real time, before the users navigate to those portions of the thread. In a user study with blind participants, we observed that compared to the status quo, PView significantly improved the usability, workload, and satisfaction of the participants while interacting with the forums.

CCS Concepts: • **Human-centered computing** → **Accessibility technologies**; *Empirical studies in accessibility*.

Additional Key Words and Phrases: blind, screen reader, assistive technology, online discussion forum

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1 INTRODUCTION

The importance of online discussion forums has significantly increased in recent years [5, 35, 36, 53]. People all over the world use discussion forums, such as Reddit, Quora, and Stack Overflow, to share and seek information about a wide range of subjects [61, 65, 76]. Discussion forums have also been incorporated into a wide array of websites including news, entertainment, online education, video streaming, and social media, where people engage in conversations about politics, sports, science, and many other topics [32, 56, 70]. Given the rising importance of these forums, it is essential that they are accessible and usable for people of all abilities, including those who have severe visual impairments such as blind people.

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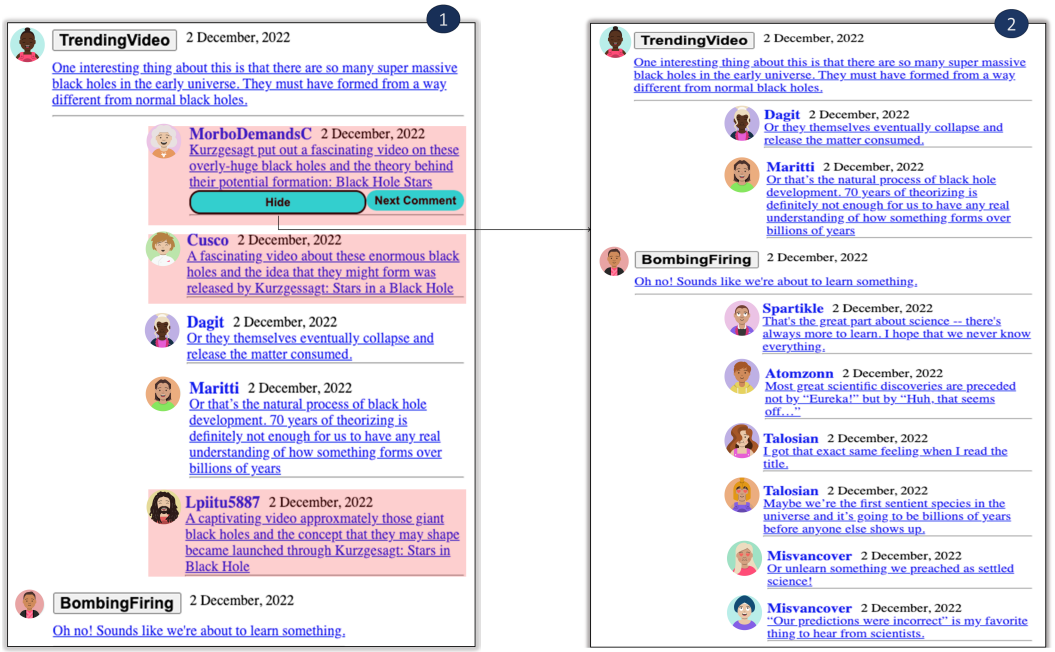


Fig. 1. Illustration of the proposed PView interface. Users can explicitly hide a particular post in a thread and in response PView automatically detects and hides all other posts which are substantially similar to that hidden post.

People with severe visual impairments including those who are blind predominantly use screen reader assistive technology (e.g., JAWS [60], VoiceOver [7], NVDA [51]) to interact with computer applications including online discussion forums. Screen readers narrate the content on the screen and allow users to navigate the content in a one-dimensional manner via a 'screen reader focus' (or cursor) driven by an assortment of keyboard shortcuts (e.g., 'H' for the next heading). This "press-and-listen" screen reader interaction has been shown to be the root cause of several usability issues for blind users in typical e-commerce web browsing activities such as shopping [31, 50, 58]. The impact of such one-dimensional aural interaction on the usability of online discussion forums however is still an unexplored research area.

To fill this knowledge gap, we conducted an interview study with 12 blind persons who regularly interacted with online discussion forums using screen readers. In the interview, all participants stated that it was tedious and frustrating to trudge through reams of text in discussion forums, mainly due to redundancy, high volume, and a lack of customization options. Specifically, the participants mentioned that the presence of multiple posts expressing the same idea or thought, acknowledgments (e.g., "thank you"), and comical digressions not only increased the amount of listening but also distracted them from the main topic of discussion. While such characteristics of forums can also affect sighted users, the extent of the impact on usability is likely to be disproportional, since, unlike sighted users, blind users cannot quickly *skim* through text via visual scans. To improve usability with the online forums, a majority of the participants suggested an alternative interface that could provide customization options for selectively viewing a fraction of the posts in threads, by filtering out posts that did not match their preferences.

Informed by the study feedback, we designed PView – an intelligent browser extension for online discussion forums (see Figure 1) that lets blind users filter out posts based on their personal preferences. Specifically, with PView, if a blind user chooses to explicitly hide any post, all other posts that are substantially similar to the hidden post are automatically detected and hidden in real-time. To detect similar posts, we used a BERT [24] based model fine-tuned on a custom dataset. This way, PView enables blind users to not only avoid redundant content as far as possible but also avoid irrelevant posts (e.g., trolls, hate speech) that are rife in loosely moderated online forums.

An evaluation of PView in a user study with blind participants showed significant improvements in the usability and the interaction workload compared to the status quo. In their qualitative feedback, the participants overwhelmingly stated that the proposed interface would motivate them to be more 'active' in online discussion forums than they are with the present web interface. In sum, this paper makes the following contributions.

- The findings of an interview study detailing the usability issues faced by blind screen reader users in online accessibility forums.
- A novel browser extension PView for online discussion forums that enables blind users to view only desired portions of the conversations through self-driven semi-automatic filtering of posts.
- The findings and insights from a user study evaluating PView against the status quo.

2 RELATED WORK

Our work closely relates to existing research on the following two topics: (i) Web interaction using screen readers; and (ii) Characteristics of online discussion forums.

2.1 Web Interaction using Screen Readers

Plenty of research has been done to understand the nature and challenges of screen reader interaction with web content [6, 11, 40, 42, 59, 62, 66]. One line of research in this regard has been to evaluate the accessibility of websites based on the well-known WCAG accessibility guidelines [20]. For instance, Solovieva et al. [62] measured the accessibility of various university websites and found that there were still many university websites that did not adequately meet the desired accessibility standards and therefore need substantial improvements in this regard. Many automatic accessibility checkers (e.g., WAVE [69], FAE [52] and axe DevTools [23]) have also been developed to assist developers in detecting and correcting accessibility issues in their websites [1, 17, 27, 28, 41].

Many studies have also been conducted to uncover and understand the pain points of blind screen reader users on the Web [8, 15, 40, 47, 66]. For example, Theofanos et al. [66] conducted a study with 16 blind participants to understand the relationship between accessibility and usability, and they found that it is crucial to include blind users in the design and testing process in order to create accessible and usable designs. Similarly, Lazar et al. [40] investigated the factors that frustrated blind screen reader users on the Web and their study unveiled several interaction issues. For instance, they found the keyboard-based screen reader navigation to be extremely limiting in that it required the users to remember a multitude of shortcuts and devise navigation strategies to do even basic web tasks that sighted users can do in a matter of few seconds. Their work has inspired many other studies which have also uncovered web accessibility and usability issues [43–45].

To address these accessibility and usability concerns, many solutions have also been proposed in the literature [10, 14, 46, 68]. Some of these works have focused on explicitly conveying the semantics of webpage content via alternative screen reader-friendly non-visual user interfaces such as dialog systems [9, 29] and third-party input devices [13, 63]. The speech assistant by Gadde et al. [29] allowed blind users to issue simple commands to obtain a quick overview of the current

webpage, and also provide commands for instantly moving the screen-reader focus to a specific segment on the webpage. Similarly, Ashok et al. [9] proposed a browsing assistant that automated web tasks for users via a spoken dialog. Specifically, with their assistant, the users could simply issue verbal commands for an assortment of web activities including screen reader navigation within a page, and the assistant automated these tasks on behalf of the users.

All the aforementioned studies and techniques have mostly focused on general webpage interaction and navigation, and as such have not considered the specific characteristics of online discussion forums in their designs. We, therefore, try to plug this usability gap in this paper.

2.2 Characteristics of Online Discussion Forums

The characteristics of online discussion forums slightly vary depending on their type. All discussion forums provide users with the ability to start a thread, reply to others' comments, view others' replies, and sort comments based on many aspects such as the time of posting and number of replies. Some of the well-known types of discussion forums online are course discussion forums, social media conversations, video-related discussions, and news article discussion forums. Online course discussion forums are mainly used to clarify students' doubts, reply to other student's doubts on the subject, and discuss any academic topic that mostly takes place at the student's level in terms of critical thinking on a subject [4, 25, 39, 48, 67]. This type of discussion forum is usually managed by an administrator (e.g., teaching assistants, instructors). Discussion forums can also be seen under each article on some of the news websites. This type of discussion forum is mainly used by people all over the world to express their opinions and also reply to other peoples' opinions on a particular news event or a topic. Unlike student course discussion forums, news discussion forums are often loosely moderated and sometimes even allow anonymous participation. E-commerce websites too have similar forums under each product, but that type of discussion, known as the review section, is usually tightly moderated and includes mechanisms to detect and filter out spurious reviews [2].

The anonymity and lax moderation in news and entertainment forums significantly influence the nature of conversations in these forums. Several prior investigations have shown the increased presence of vulgarity and trolling [22], rudeness in tone [19, 38, 55], sarcasm [3, 34, 37], and bias towards any person or political party [49, 54]. The increased presence of such content can significantly impact peoples' interaction experience depending on how sensitive they are towards such content. While sighted people have the privilege to visually skim through the content while avoiding objectionable content as much as positive, blind screen reader users on the other hand have no choice but to listen to such content. Therefore, there is a need for solutions that can assist blind users in avoiding such content on demand, thereby improving their user experience in such forums. We describe our solution PView next.

3 UNCOVERING NON-VISUAL USABILITY ISSUES IN DISCUSSION FORUMS

We conducted an IRB-approved interview study with 12 blind participants to understand the challenges they faced while foraging discussion forums.

3.1 Participants

We recruited 12 visually-impaired users (7 female, 5 male), with an average age of 47.75 (Median = 51.5, SD = 10.64, Range = 24-62). The inclusion criteria required the participants to be proficient in web screen reading and also familiar with one or more of the online discussion forums. All participants stated that they accessed a discussion forum at least once every week. Table 1 presents the participant demographics.

ID	Age	Gender	Age of Vision Loss	Occupation	Preferred Screen Reader	Forum Experience	Forum Usage (times/week)
P1	56	F	Age 5	Vendor	JAWS	4 years	1
P2	44	F	Since birth	Unemployed	VoiceOver	6 years	4-5
P3	52	F	Since birth	Self-employed	JAWS	3 years	6-7
P4	24	M	Age 6	Student	NVDA	7 years	7
P5	51	M	Since birth	Musician	JAWS	5 years	3-4
P6	42	F	Age 4	Unemployed	JAWS	6 years	4-5
P7	56	F	Age 2	Social worker	JAWS	3 years	3-4
P8	62	F	Since birth	Unemployed	NVDA	4 years	3
P9	53	M	Cannot remember	Self-employed	VoiceOver	5 years	5-7
P10	55	F	Cannot remember	Tutor	NVDA	5 years	3-4
P11	35	M	Since birth	Programmer	VoiceOver	10 years	2
P12	43	M	Age 5	Secretary	JAWS	1 year	2

Table 1. Demographics of blind participants in the interview study. All information was self-reported.

3.2 Interview Format

All interviews were conducted remotely via either phone or Skype. The interviews were semi-structured, with questions about the following two topics:

- General questions about discussion forum-related browsing habits. E.g., *On which websites do you typically interact with accessibility forums? How do you navigate conversation threads in forums? What information in the threads do you consider most important and typically spend more time on during navigation?*
- Usability challenges and counter navigation strategies while perusing discussion forum threads. E.g., *What frustrates you while navigating forums? How do you work around issues while navigating conversation threads?*

The participants were also asked to illustrate some of the usability issues to obtain a detailed understanding of the problems. All sessions were audio-recorded and also screen-captured (if applicable) after obtaining the participant's consent. The personal information of the participants were limited to those listed in Table 1. No identifiable information was retained after the interview. Each interview lasted about 30 to 45 minutes. The collected interview data was then qualitatively analyzed using an open coding technique [57], where we iteratively went over the user responses and identified key insights that reoccurred in the data.

3.3 Findings

Forum conversations in news article websites are popular. Almost all (10) participants indicated that they enjoyed perusing discussion forum threads attached to online news articles. These participants mentioned that in these forums, they could freely express their opinion anonymously and also hear what other people all over the world had to say about the topic of the news articles. Other than news discussion forums, there were also mentions of community question-answering

forums such as Reddit (4 participants) and video streaming-related forums such as those on YouTube (6 participants).

Linear navigation of forum threads is tedious. All participants stated that they had no choice but to listen to all the content in the threads one-by-one in most forums as there were no special shortcuts to quickly jump between the threads and also between just the contents of the posts. Half (6) of the participants explained that the sequential navigation included listening to the extraneous metadata information such as post author's name, time of posting, number of likes, and number of replies in addition to the post content. These participants stated that they preferred listening to mostly the content of the posts, and further mentioned that they paid attention to the other meta information only on rare occasions.

Preference for posts with positive sentiment. A majority (8) of the participants stated that they mostly preferred listening to the posts with an overall positive sentiment and an 'optimistic outlook'. This was best stated by the participant P4 - *"There is too much negativity in online discussions. I for one like to see positive comments. For example, I was looking at the comments for a video that I liked the other day, and saw that many people were unnecessarily criticizing the video for no good reason. I wished I could just filter these comments out."* The other participants too echoed P4 in that they wished there was a feature for removing negative comments that *"did not add any value to the conversations" (P8).*

Redundant content across posts is the major source of frustration. Almost all (11) participants mentioned that there was a lot of redundancy in online forum conversations. These participants mentioned that this redundancy significantly contributed to the tedium and frustration since they had to listen repeatedly to the same information as they navigated the conversations. The examples of redundant content given by the participants included acknowledgements (e.g., *thank you, ok, I agree*), emoji sequences, copy pastes from others' comments, and multiple postings of the same comments by the same author. To tackle redundancy, 8 participants suggested a 'filtering' feature that would enable them to hide redundant comments automatically. Participant P6 further mentioned that such a filtering option would help blind users listen to a more diverse set of opinions from the public in the same amount of time that they currently spend navigating forum conversations filled with redundant content.

No obvious strategy to cope with tedious sequential navigation. All participants mentioned that they did not know of any strategy to quickly skim through the comments in online discussion forums. A few (4) participants further noted that they couldn't fully exploit the diverse keyboard shortcuts supported by screen readers since all comments and metadata were in the textual format.

Summary. The interview study revealed several pain points of blind screen-reader users when they interacted with online discussion forums. From the study observations, it is clear that an alternative non-visual interface is needed that enables users to personalize the content in forum threads, so that they can quickly and comfortably scan through the posts in the conversations. Towards this, we designed and developed the PView prototype interface which is described next.

4 SYSTEM DESIGN

Figure 2 presents an architectural schematic illustrating the workflow of PView browser extension. When a webpage with a discussion forum is loaded in the web browser, PView automatically extracts all the threads by leveraging the extant CommentsMiner [64] algorithm and then stores the extracted information in Firebase[1] according to a well-defined schema. While listening to a post, if the user presses 'ENTER,' PView shows two buttons -'Hide' and 'Next Comment' right

[1] https://firebase.google.com/

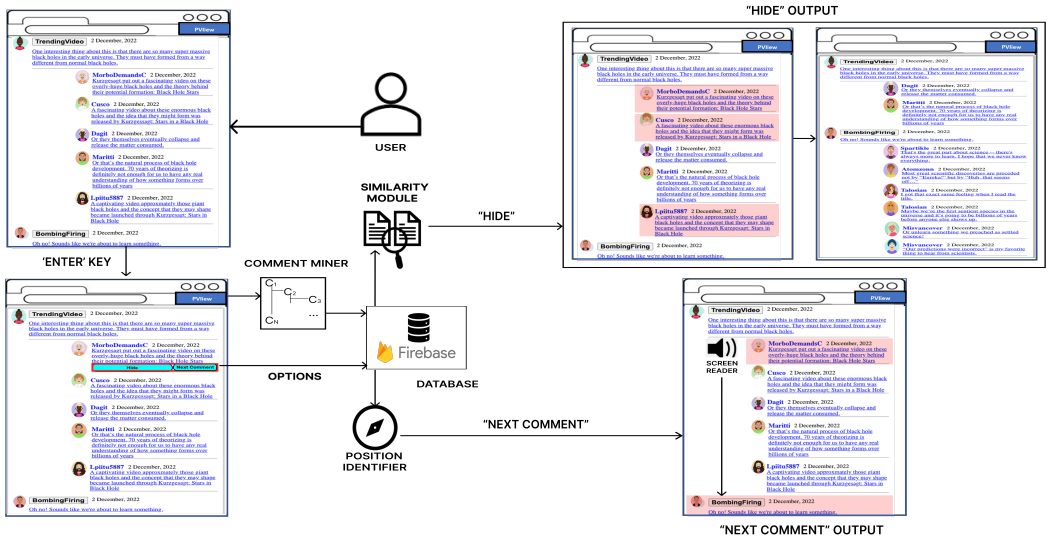


Fig. 2. Architectural schematic of PView.

below the post and automatically moves the screen reader focus to the 'Hide' button. If the user presses the 'Hide' button, PView identifies and removes all similar posts (including the current post) from the entire forum and moves the focus to the next unfiltered post. On the other hand, if the user presses the 'Next Comment' button, PView moves the screen reader focus to the beginning of the next thread by skipping all the remaining posts in the current thread. Given this quick access to the posts and threads, PView helps blind screen-reader users save significant time and effort by avoiding navigating through redundant/irrelevant threads and posts. We describe each component of PView next.

4.1 Discussion Forum Extraction

For this task, we leveraged the publicly available CommentsMiner [64] method due to its well-established efficacy. The primary objective of CommentsMiner is to determine the DOM pattern of the posts in the discussion forum threads and then extract all posts using this identified pattern. To determine the pattern, the method first generates a list of candidate patterns using the existing CMTreeMiner algorithm [21] and then identifies the most optimal pattern using a Winner Takes All (WTA) ranking approach [74]. Once the pattern is identified, CommentsMiner scans the DOM tree (using depth-first search) to find and extract all the subtrees matching the pattern, where each subtree corresponds to a post. The position of the subtrees, as well as ancestorship in the DOM, is then leveraged to rebuild the threads and hence the entire forum structure. In their evaluation, the authors of CommentsMiner observed that it had an accuracy of approximately 0.9. All extracted information from the discussion forum is directly stored sequentially in a single-table database. Two additional columns were added to the table in the database: i) an annotation field indicating whether a post was the beginning of a thread ('T') or simply a reply to other posts ('P'); and ii) a path field which stored the HTML xpaths of each post.

4.2 Real-time Customization and Quick Navigation

To support real-time customization and quick navigation of forum content, PView relies on the *Similarity Detector* and *Position identifier* modules.

4.2.1 Similarity Detector. This module is responsible for identifying all posts that are substantially similar to a given post based on their meanings. For example, if the given post is a simple "ok" message, then Similarity Detector will detect all other posts which are simple acknowledgments. Semantic similarity detection refers to determining the proximity of two sentences based on their intentions. To compare two posts, where each post may have multiple sentences, we first embedded the two posts using a fine-tuned BERT model [24] and then computed the cosine similarity between the two embeddings. If this cosine similarity score exceeded a pre-fixed threshold value (0.5 in our prototype), the two posts were considered similar.

To fine-tune the BERT model [24], we built a custom data corpus[2] and stored the trained parameters (i.e., the model) in an HDF5 file[3]. This file was then used by the Similarity Detector to generate post embeddings for computing semantic similarity scores between two posts. If a user chooses to hide a particular post, PView uses the Similar Detector to make pairwise comparisons between that post and all subsequent posts, and in the process detects all similar posts further down in the forum. These detected similar posts are then automatically removed by PView in real time before the user navigates down the threads. An evaluation of Similarity Detector on our custom test dataset[4] demonstrated a performance of 0.79 F1 score.

4.2.2 Position Identifier. The Position Identifier is responsible for determining the post that corresponds to the beginning of the next thread. To do this task, this module leverages the HTML xpath of the current post along with the annotation in the database ('T' or 'P' mentioned earlier) to determine the current thread in focus. Specifically, in the database table, the Position Identifier first identifies the row corresponding to the current post using its xpath information, and then locates the closest row (below the current post's row) that has the 'T' annotation. This row with the 'T' annotation corresponds to the post at the beginning of the next thread. The exact DOM node corresponding to this post can again be obtained from the XPath information available in the row. PView can then use this xpath to shift the screen reader focus (i.e., cursor location) to the next thread should the user request it by pressing the 'Next Comment' button in the PView interface.

4.3 User Interface

The user interface of PView (see Figure 1) is extremely simple by design. When the user's screen reader focus is on any post, the user can press the 'ENTER' key to access the two PView features, namely the 'Hide' button and the 'Next Comment' button. By default, PView moves the focus to the 'Hide' button. If the user does not wish to hear similar posts, the user can simply press ENTER to invoke the 'Hide' button, and PView forwards the selected post to the Similarity Detector. The Similarity Detector then detects all other similar posts and PView accordingly removes these posts from the webpage by internally manipulating the DOM. After filtering, PView automatically redirects the screen reader focus to the next post. If the user presses the 'Next Comment' button for a given post, the screen reader focus is automatically moved to the beginning of the next thread (if any). If there are no subsequent threads, PView simply produces an earcon signally at the end of the forum.

[2] https://github.com/accessodu/Discussion_Dataset/blob/main/dataset_train.csv
[3] https://docs.h5py.org/en/stable/
[4] https://github.com/accessodu/Discussion_Dataset/blob/main/dataset_test.csv

4.4 Engineering Details

We next describe the engineering challenges and effort involved in implementing the above modules as well as integrating them into a single PView browser extension.

4.4.1 Auto Extracting Discussion Forums from Websites. Extracting discussion forum threads and posts using the CommentsMiner algorithm was not straightforward, and it required preprocessing and post-processing steps. During pre-processing, we injected tags in specific locations of the target webpage and auto-assigned unique IDs to each webpage element. We also filtered out irrelevant nodes (ads, menus, quick links, forms) to ensure the practicality of the approach; without pruning, the CommentsMiner algorithm took too much time to execute, thereby 'freezing' the PView extension and making it unavailable for the blind users. During post-processing, we mapped the CommentsMiner output (i.e., DOM subtree patterns) to actual nodes in the webpage that corresponded to posts, then grouped the posts into threads based on parent-child relationships, next determined the order of posts in each thread and the order of threads based on DFS traversal order, and finally rebuilt the entire discussion forum structure internally for supporting the PView UI intended for blind screen reader users.

4.4.2 Backend Management of Discussion Forum Threads and Posts. For storing, maintaining, and retrieving the state of discussion forum threads (e.g., currently hidden posts, current similar posts, page location of threads, node XPaths, annotations, reply-to relationships) in real time, we coupled PView back-end with a Google Firebase database. This database was essential to support data consistency and navigation in the front-end UI of PView where users could manipulate the forum content according to their preferences.

4.4.3 Fine-tuning and Integration of Large Language Model to Detect Similar Posts. We fine-tuned the BERT language model for detecting similar comments instead of using the pre-trained model, since discussion forum texts authored by end users substantially deviate from the standard texts that are used for training large language models like BERT [45]. Specifically, language in discussion forums is more casual, grammar errors are ignored and sometimes deliberate (e.g., out-of-vocabulary words), and sentences are often ill-formed. So, we first built a custom dataset of discussion-forum posts and then used the publicly-available TensorFlow library and Keras API to fine-tune Bert using this custom dataset. Also, since the back-end architecture including the fine-tuned model was developed entirely in Python, we implemented a communication channel between the back-end (Python) and the front-end (Javascript) using the Flask API for exchanging information and ensuring smooth operation of the PView browser extension.

4.4.4 Auto-Detecting Next/Previous Threads. For supporting quick navigation between threads in the PView UI, we implemented a listener module to continuously monitor the current screen reader location (i.e., the current post/thread in focus), and also established a communication pipeline between the front end, the back end, and the custom Google Firebase database using the Google API and the Python Flask API. Specifically, the front end transmitted the current post text to the back end, which then queried the database to determine the current thread in focus. Depending on the user request (i.e., move to next/previous thread), the back-end once again queried the database to obtain the XPath of the node corresponding to the first post in the next/previous thread. Once the front end UI received this XPath from the backend, it used custom JavaScript functions to move the screen reader cursor to the post corresponding to the XPath.

4.4.5 Dynamically Generating UI for Accessible Tabbed Navigation of Forum Threads. Implementing modules in the back-end to dynamically generate the front-end UI was also a substantial engineering effort. We ensured that the created HTML elements in the UI were accessible with a screen reader,

by creating modules to inject appropriate WAI-ARIA labels and attributes following the WCAG guidelines. We also pre-processed the posts retrieved from the Firebase database to filter out distracting extraneous elements that carried no information. We further added inactive links to each post to facilitate the desired 'tab-key' navigation with a screen reader. All these modules were implemented using custom JavaScript functions.

4.4.6 Developing PView browser extension. To build PView as a functional Chrome browser extension, we followed the guidelines provided on the Google website[5]. We utilized the in-built Chrome API[6] to execute all tasks related to the Document Object Model (DOM) of a webpage. For example, we relied on JavaScript routines in the API to extract the entire webpage DOM and forward it to the back-end server for further processing.

5 EVALUATION

We conducted an IRB-approved interview study with 14 blind screen reader users to assess the effectiveness of PView in assisting users while they interact with discussion forums.

5.1 Participants

We recruited 14 visually-impaired users (6 female, 8 male), with an average age of 48.29 (Median = 49.5, SD = 9.14, Range = 28-62) via email lists and snowball sampling. As in the case of the interview study, the inclusion criteria required the participants to be proficient in web screen reading and also familiar with online discussion forums. We specifically required the participants to be proficient in the use of the JAWS screen reader since our study setup included only the Windows OS platform. To ensure external validity, there was no overlap between the participant groups in this study and the prior interview study. All participants stated that they accessed a discussion forum at least once every two weeks. Table 2 presents the participant demographics.

5.2 Design

In a within-subject experimental setup, we asked the participants to interact with discussion forums under the following three study conditions.

- **Screen Reader**: The baseline status-quo condition where the participants used their preferred screen readers to do the study task.
- **PView Hide**: The proposed solution where the users can leverage the only the *hide* feature of PView while they interact with the forum threads using their preferred screen readers to do the assigned task.
- **PView Full**: The proposed solution where the users can leverage both the features of PView while they interact with the forum threads using their preferred screen readers to do the assigned task.

The study task was to simply navigate the comment forums for up to 15 minutes while voicing out their experiences, issues, and preferences (i.e., we adopted the concurrent think-aloud protocol). We opted for this simple task to mimic realistic scenarios where most people typically just surf through news comment forums, while occasionally replying to some of the comments in the forum threads. Our choice of using news comment forums for the tasks directly stemmed from the findings of the earlier interview study that showed the widespread popularity of these forums. To mitigate the learning effect during the study, we selected the discussion forums from three different news articles on the Yahoo news aggregation website[7]. The assignment of these articles (thereby the

[5] https://developer.chrome.com/docs/extensions/mv3/architecture-overview/
[6] https://developer.chrome.com/docs/extensions/reference/
[7] www.yahoo.com

ID	Age	Gender	Age of Vision Loss	Occupation	Preferred Screen Reader	Forum Experience	Forum Usage (times/week)
P1	56	M	Since birth	Musician	JAWS	3 years	5
P2	54	F	Age 4	Unemployed	JAWS	6 years	4-5
P3	46	M	Age 5	Vendor	JAWS	4 years	1
P4	28	M	Age 3	Student	JAWS	8 years	6-7
P5	54	M	Age 4	Social worker	JAWS	6 years	4
P6	44	F	Cannot remember	Self-employed	JAWS	5 years	5
P7	62	F	Since birth	Unemployed	JAWS	3 years	3
P8	52	M	Since birth	Tutor	JAWS	5 years	4
P9	35	M	Cannot remember	Programmer	JAWS	7 years	3-4
P10	47	F	Since birth	Secretary	JAWS	4 year	4
P11	45	F	Since birth	Unemployed	JAWS	5 years	3
P12	43	M	Age 5	Vendor	JAWS	1 year	2
P13	52	M	Since birth	Unemployed	JAWS	5 years	1
P14	58	F	Cannot remember	Consultant	JAWS	8 years	5-7

Table 2. Demographics of blind participants in the PView evaluation study. All information was self-reported.

forum threads) to the conditions as well as the ordering of the conditions were counterbalanced using the standard Latin Square method [16]. We chose the forums from the same Yahoo website to ensure a fair comparison between the study conditions, by neutralizing the confounding effects of underlying HTML implementations of forums. Moreover, to mitigate the confounding impact of algorithm accuracy on the user interface evaluation, the forums selected were such that the accuracy of similarity detection in the threads was approximately the same (0.73 – 0.76 F1 score).

5.3 Apparatus

The study was conducted with a Lenovo ThinkPad laptop which had all the necessary software - Google Chrome browser, PView Chrome extension, JAWS screen reader, and the NVDA screen reader installed under the Microsoft Windows operating system. An external QWERTY desktop keyboard was also connected to the laptop as all participants mentioned that they were familiar with the standard keyboard during the recruitment process.

5.4 Procedure

The experimenter began the study by obtaining the participant's informed consent and explaining the objectives of the study to the participant. The experimenter then allowed the participant some practice time to become familiar with PView as well as customize the screen reader settings according to their preferences. This was done to ensure that the participant's comfort level with the study apparatus was more-or-less similar to that with their own computers at home. The experimenter then asked the participant to complete the study tasks according to the predetermined counterbalanced order. After each task, the experimenter administered the SUS and NASA-TLX questionnaires [18, 33] to obtain feedback regarding the usability and task workload respectively for

the corresponding study condition. At the end of the study, the experimenter collected subjective feedback from the participant via an exit interview. All conversations were in English and the participants were compensated for their time. Each study lasted about 1-1.5 hours.

5.5 Data Collection and Analysis

Other than the SUS and NASA-TLX responses, we also recorded the participants' *think-aloud* utterances while doing the tasks as well as their subjective feedback from exit interviews. The experimenter also noted down any peculiar screen reader behavior from the participants while doing the tasks in forums. We analyzed the SUS and TLX responses using standard descriptive and inferential statistical methods. For the textual data collected by transcribing the participants' utterances and subjective feedback as well as the experimenter's notes, we used qualitative analysis methods. Specifically, we used an open coding technique [57] to iteratively go over the textual data and identify key insights and themes recurring in the data. We detail our findings next.

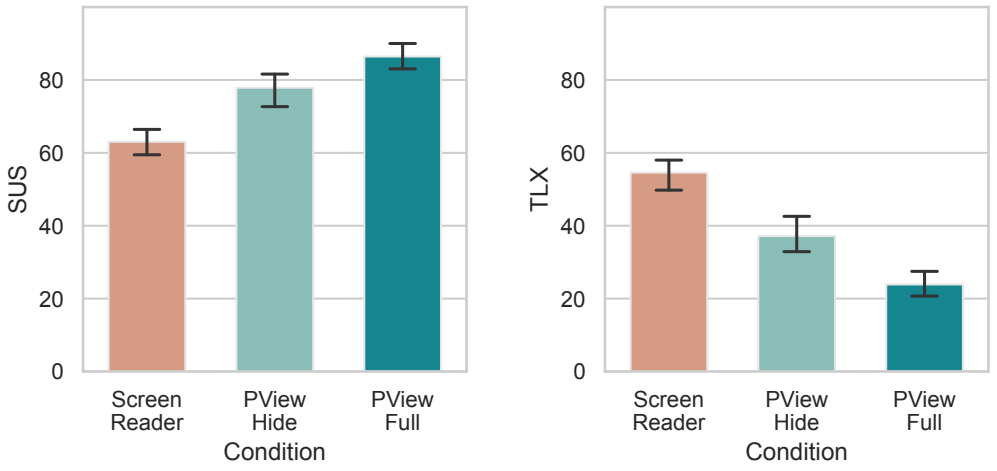
5.6 Results

5.6.1 Usability. As mentioned earlier, we measured usability via the SUS questionnaire [18]. This questionnaire requires the participants to respond to ten 5-point Likert scale questions (1-strongly disagree, 5-strongly agree), and the responses are combined into a score between 0 and 100, with higher SUS scores indicating better usability. The SUS score statistics for the three study conditions are shown in Figure 3a. As seen in the figure, the SUS scores for the PView conditions were significantly higher than the baseline status-quo screen reader condition. This difference in scores was also found to be statistically significant (one way ANOVA test, $F = 34.81$, $p < 0.001$). A post-hoc Tukey's HSD test showed that the difference in the SUS scores was statistically significant between all pairs of conditions: (i) *Screen Reader* vs. *PView Hide* - $Q = 7.38, p < 0.001$; (ii) *Screen Reader* vs. *PView Full* - $Q = 11.66, p < 0.001$; and (iii) *PView Hide* vs. *PView Full* - $Q = 4.27, p = 0.01$.

A deeper analysis revealed that the SUS Likert items responsible for the significant differences in scores between the conditions were question 1 (*I think I would like to use this system frequently*), question 3 (*I thought the system was easy to use*), and question 8 (*I found the system very cumbersome to use*) and question 9 (*I felt very confident using the system*). For these questions, the responses were overwhelmingly positive for the *PView Full* condition, reasonably positive for the *PView Hide* condition, and mostly negative for the *Screen Reader* condition. The trend was similar for other SUS Likert items as well, however, the difference in responses was not as pronounced as in case of the aforementioned four SUS Likert items.

5.6.2 Task Workload. We measured the interaction workload by leveraging the NASA-TLX questionnaire [33]. The TLX questionnaire comprises two parts. In the first part, the participants are asked to provide feedback in terms of absolute numbers in a hundred points range with 5-point steps for each of the following six subjective subscales: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. In the second part, the weights for the subscales are determined by letting the participants perform pairwise comparisons between the subscales based on their perceived importance. Like SUS, TLX also generates a score between 0 and 100 by combining the participants' responses from both parts of the questionnaire. However, unlike SUS, lower scores indicate better performance and reduced workload.

The TLX score statistics for the three study conditions are presented in Figure 3b. We observed a significant effect of the study conditions on the TLX scores (one way ANOVA test, $F = 47.25$, $p < 0.001$). Pairwise comparisons between conditions using the post-hoc Tukey's test revealed that the average TLS scores for the *PView Full* condition was significantly higher than both the *PView Hide* ($Q = 5.93$, $p < 0.001$) and the baseline *Screen Reader* conditions ($Q = 13.7$, $p < 0.001$). Even



(a) SUS (b) NASA-TLX

Fig. 3. Perceived usability (SUS) and task workload (NASA-TLX) for all three study conditions.

between *PView Full* and *PView Hide* conditions, the difference in TLX scores was found to be be statistically significant ($Q = 5.93$, $p < 0.001$).

A closer inspection of the individual responses to the TLX questions revealed that responses to the Mental Demand, Effort, and Frustration subscales contributed the most to the differences in the final TLX scores between the study conditions. The participants gave very high values (i.e., higher taskload) to these three subscales for the *Screen Reader* condition, whereas the values for the other two PView conditions were significantly lower. Between the *PView Full* and the *PView Hide* conditions, the Effort was the main discriminating subscale - the participants felt that their effort in *PView Hide* condition was much higher than in the *PView Full* condition. Other than Effort, the responses to the Temporal Demand subscale too exhibited a similar pattern where the participants specified slightly higher values for the *PView Hide* condition than for the *PView Full* condition.

5.6.3 User Interaction Behavior. From the qualitative analysis of the experimenter's notes, we identified a few peculiar interaction patterns that were common across multiple participants. In the *Screen Reader* condition, almost all (12) participants started the task by carefully listening to the first few posts in their entirety, before speeding up with quick shortcut presses after listening to only the first few words of the subsequent posts. Such an interaction behavior was almost non-existent in the *PView Full* condition. In the *PView Hide* condition, we did notice a few instances of such behavior mostly when the participants wanted to jump to the next thread from a post in the previous thread in a forum.

Another distinguishing pattern we observed between conditions was that a majority (8) of participants revisited many of the posts in the *Screen Reader* condition. In contrast, in the other two PView based conditions, the navigation was almost always linear, i.e., the participants did not go back to listen to a previously visited post. Also, in the *PView Full* and PView Hide conditions, all participants used the 'Hide' feature at least 5 times and 3 times respectively to filter out all posts that they did not want to listen while doing the corresponding tasks. Moreover, in the *PView Full* condition, all participants relied on the 'Next Comment' feature at least 2 times to directly jump to the subsequent threads.

5.6.4 Qualitative Feedback. The analysis of the participants' think-aloud utterances and subject feedback in exit interviews revealed many common thought patterns. Some of the notable ones are presented next.

'Boring' to repeatedly hear the same information. As in the case of the earlier interview study, almost all (13) participants stated in exit interviews that they did not like listening to posts that simply echoed other posts without adding much new information. This was also noticeable in the think-aloud utterances where the experimenter heard sentences like "again, the same thing", "can I move on to the next topic", "nothing new here", and "next, next" in the *Screen Reader* condition. Such utterances were significantly fewer in the *PView Full* and PView Hide conditions.

Nice to hear diverse opinions. Most (10) participants mentioned that they noticed a significant drop in redundancy while doing the tasks under the *PView Full* and PView Hide conditions. These participants expressed that it was a 'welcome change' in the 'positive' direction. Four of these participants further mentioned that such a change would motivate them to spend more time perusing forums and they also stated that it would encourage more participation of blind users in online forums. To quote *P6*:

> I noticed a clear difference as I went through the comments, they are not saying the exact same thing. This is not what I am used to, but I love it. With this, I don't have to rush through the comments by quickly pressing the DOWN key. I can take my time because I know what I hear next will be different from what I heard before. I can gather more information with this. This is a game-changer for folks like us.

Need for thread summaries and sentiment-based filtering. Six participants expressed a need for a 'summary' feature in PView that could provide them with a summary of any thread in the forum. These participants explained that such summaries would automatically 'collapse' redundant information in threads and thereby save considerable time and effort while navigating the forums. Also, as observed in the interview study, a sizeable chunk (5) of participants in this study too expressed a desire for a feature that could only show them the 'positive' posts in the threads.

Need to remember user preferences. More than half (8) of the participants suggested that PView should remember their preferences regarding posts in a forum, and then automatically apply these preferences in other forums, even across different websites. These participants mentioned that although they liked the idea of hiding posts in real-time, they did not want to hide the same type of posts each time they visited any forum.

6 DISCUSSION

The user study demonstrated the efficacy of PView in improving the user experience of blind screen-reader users in online discussion forums. However, the study also highlighted a few limitations and provided insights that collectively pave the way for future research in this area. Some of the notable ones are discussed next.

6.1 Limitations

One of the limitations of our work is that we evaluated PView with only the JAWS screen reader users. Although JAWS is the most popular screen reader, many blind users also use other screen readers such as NVDA and VoiceOver [71]. While PView conceptually is screen reader-agnostic and will therefore likely produce similar results in the case of other screen reader users, the evaluation must nonetheless be conducted to validate our hypotheses.

Another limitation of our work is that it is limited to the English language forums. In real-world scenarios, the language of discussion forums is usually dictated by geography, and in many cases,

the same forum threads have posts written in different languages. Extending our method to support multi-lingual forums is in the scope of our future work.

The third limitation of our prototype is that it only supports forum interaction on desktop and laptop computers. Studies have shown that people are increasingly accessing forums on smartphones [12, 30, 72, 75] and therefore we plan to adapt PView for smartphone usage. However, this adaptation is not straightforward given that smartphone web browsers do not support extensions. We will therefore explore alternative ways such as service apps to make PView available on smartphones.

Also, our work focused only on the 'consumption' aspect of forum interaction while largely ignoring the 'creation' aspect. Understanding the needs of blind screen reader users with respect to creating posts/inserting replies is tangential to our work and we plan to investigate this aspect as part of our subsequent research efforts.

Lastly, our evaluation only focused on the news discussion forums. While we expect many of our findings to be most applicable to other forums as well due to the similar underlying dialog structures (e.g., forums attached to videos on YouTube), we acknowledge that there is a possibility that some of our findings may not hold in certain types of discussion forums, e.g., community question answering forums[8], due to varying conversation styles and structures. Investigating this is the scope of future research.

6.2 Long Term Memory and Personalization

In the subjective feedback, many participants mentioned that it would be useful for PView to remember user preferences (i.e., the types of posts they chose to hide) so that these preferences can automatically be applied to subsequent interactions with other forums not only on the same website but also on other web sites. To provide this personalization support, we will need to address the following challenges. First, there are privacy challenges associated with securely storing and processing user interaction data. Second, the data format for storing and retrieving user preferences needs to be explored as it affects the efficiency and usability of user interaction. Lastly, the personalization approach should take into account the fact that user preferences may depend not only on the topic of the forum but also on the type of website housing the forum. We plan on addressing these challenges in our future work to include personalization support in PView.

6.3 Summarization and Sentiment-based Filtering

Also in the user study, many participants suggested two more features to be included in PView - thread summarization and sentiment-driven filtering. Fortunately, quite a few natural language models presently exist for both dialog summarization and sentiment analysis [26, 73], and we can easily integrate these models into our PView framework. However, designing the user interfaces for leveraging these features as well as delivering the outputs of these models, is a challenge that needs to be addressed before users can exploit these features in PView.

7 CONCLUSION

In this paper, we presented PView, an intelligent browser extension that enables blind users to customize discussion forums in real-time in order to improve usability, task load, and overall user experience. The design and development of PView were guided by the findings of an interview study with 12 blind participants who regularly interacted with online forums using screen readers. For providing the advertised features, PView leveraged state-of-the-art machine learning and natural language processing techniques such as CommentsMiner and BERT. In a user study with 14 blind screen reader users, we observed that compared to the status quo screen reader, PView significantly

[8] https://groups.io/g/jaws-users-list/topics

increased the usability and decreased the workload for these users while they interacted with discussion forums. The study also yielded many insights and suggestions that can potentially foster further research in this area, thereby continuing the efforts to bridge the web usability gap between sighted and blind users.

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A SUS QUESTIONNAIRE FOR MEASURING SYSTEM USABILITY

Statement	Response Options	Score
1. I think that I would like to use this system frequently.	1 (Strongly Disagree) to 5 (Strongly Agree)	(Response - 1)
2. I found the system unnecessarily complex.	1 (Strongly Agree) to 5 (Strongly Disagree)	(5 - Response)
3. I thought the system was easy to use.	1 (Strongly Disagree) to 5 (Strongly Agree)	(Response - 1)
4. I think that I would need the support of a technical person to be able to use this system.	1 (Strongly Agree) to 5 (Strongly Disagree)	(5 - Response)
5. I found the various functions in this system were well integrated.	1 (Strongly Disagree) to 5 (Strongly Agree)	(Response - 1)
6. I thought there was too much inconsistency in this system.	1 (Strongly Agree) to 5 (Strongly Disagree)	(5 - Response)
7. I would imagine that most people would learn to use this system very quickly.	1 (Strongly Disagree) to 5 (Strongly Agree)	(Response - 1)
8. I found the system very cumbersome to use.	1 (Strongly Agree) to 5 (Strongly Disagree)	(5 - Response)
9. I felt very confident using the system.	1 (Strongly Disagree) to 5 (Strongly Agree)	(Response - 1)
10. I needed to learn a lot of things before I could get going with this system.	1 (Strongly Agree) to 5 (Strongly Disagree)	(5 - Response)

Table 3. SUS Questionnaire [18]

The total SUS score is computed by adding the scores (i.e., last column in Table 3) for each statement, multiplying the sum by 2.5, and then dividing the product by 10, as shown in the equation below.

$$SUS = \frac{(\sum_1^{10} Score) \times 2.5}{10} \tag{1}$$

The SUS score is always number between 0 and 100, with higher scores indicating better usability.

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