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ORIGINAL ARTICLE

Assessing the Usability of Real-Time Urdu Braille Applications: A Comprehensive Evaluation

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ABSTRACT

Visual impairment encompasses both partial and complete loss of vision. Smart devices serve as efficient tools for assisting individuals with such impairments, empowering them to overcome their disabilities and improve their quality of life. Braille stands out as a widely adopted communication method among those with visual impairments. Touchscreen smart devices offer the ability to receive Braille input and promptly convert it into spoken language. However, many existing systems rely on input methods linked to specific locations, presenting challenges for visually impaired users. This study introduces a touchscreen-based Braille input method that remains accessible regardless of position, specifically designed for individuals with visual impairments. The aim is to minimize user effort by necessitating only taps on the relevant dots for each character. Through this interface, individuals with visual impairments can input Grade 1 and contract Grade 2 Urdu characters by tapping anywhere on the screen. Evaluation metrics such as efficiency, accuracy, error rate, and user satisfaction were employed to assess the user experience with the proposed interface.

Keywords: *visually impaired; smart devices; Urdu braille; mobile applications; usability; accessibility research*

Author`s Contribution

[1,2,3] Data analysis, interpretation, and manuscript writing, Active participation in data collection
[1,4] Conception, synthesis, and planning of research. Interpretation and discussion

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INTRODUCTION

Visual Impairment refers to individuals experiencing either complete blindness or irrecoverable low vision. Statistics reveal that 89% of visually impaired individuals reside in less developed countries, with women constituting 55% of this population. [1]. Braille, a language designed explicitly for individuals with visual impairments, employs combinations of six-dot patterns for communication. Initially, Braille was read and written using simple slate and a stylus. Six-dot patterns serve as the foundation for reading and writing in Braille, with words formed by selectively activating and deactivating specific dots. According to a survey conducted in 2017, 1.12 million people in Pakistan were declared blind and 1.09 million had significant visual loss out of a total population of 207.7 million [2]. The population of Azad Jammu and Kashmir is 4.05 million, with 8.08 percent of the population being disabled. Amongst these, 2.89 percent of the population has disabilities associated with vision problems [3]. To become an efficacious part of society, a visually impaired person must be educated and well-trained. For this purpose, in the 17th and 18th centuries, the idea of using a sense of touch was explored for reading and writing. In 1821 Louis Braille introduced a method named "Braille" that was composed of six dots. These dots are arranged in a 3×2 matrix and the combination of different raised dots makes a letter. This language is popular worldwide, and it has been used as a standard language for visually impaired people [4]. At first, Braille had been read and written using slate and a stylus. With the continuous growth in the number of Braille user's different devices like; Pitch Braille writer (1899), Stainsby Brailler (1903), Foundation Brailler (1932), Light Brailler (1950), Perkins Brailler (1951) and Braille Embosser (1960) were invented [5], [6], [7]. With the advancements in technology various touchscreen-based applications like TapTapSee [8], BeMyEyes [9], BeSpecular [10], KNFBReader [11], Color Teller [12], Text to Speech Synthesizer [13], [14], [15], etc. were introduced to facilitate visually challenged people, so that they can carry out routine tasks without impediments. But Braille to natural language conversion using touchscreen-based devices is still a challenge.

Braille to natural language conversion using computer technologies is important for the education of individuals with visual impairment. There are two main input methods: scanning handwritten Braille sheets for translation using image processing techniques, and directly inputting Braille via touchscreen devices. Different applications like Braille Touch [16], Braille Tap [17], Braille Enter [18], Braille Type [19], Edge Braille [20], etc., are available for Braille to English language conversion. Along with the benefits of using touchscreen devices, visually impaired people also face certain challenges related to the Braille input method. In [21] A thorough survey of existing schemes revealed common usability issues encountered by the visually impaired. The findings highlight some prevalent concerns: the necessity of using both hands for Braille text entry, privacy issues [22], finding location-specific buttons on the screen [23], gesture memorization [24], double tap, triple tap [17], and insufficient feedback [16]. In another study, the authors designed a solution for resolving these problems [25]. Study results were utilized to create an enhanced touchscreen-based solution aimed at improving touchscreen device usability and converting Braille into Urdu using real-time applications. The major objective of this study is to propose an improved position-free accessible touchscreen-based Braille input method for Urdu Braille writing and its usability evaluation.

In the rest of the paper, Section 2 offers a concise overview of the background and related work. Section 3 outlines the materials and methods, Section 4 presents a thorough analysis of the results and practical observations. Finally, conclusions and future directions are discussed in Section 5.

LITERATURE REVIEW

Visual impairment is a term that is used to describe visual loss, whether it is complete or partial. The prevalence of visual impairment in low- to middle-income countries is estimated at four times higher than in higher-income ones [1]. Enormous initiatives are required to evaluate the impact of disease on people and communities. Recent improvements in quantitative indicators to measure the quality of life, living standards, disease's financial impact, and treatments have enabled us not only to calculate the burden of disease but also to help enhance public health research. Communication tools using the sense of touch were designed in the early 1500s to improve the standard of living of people with visual impairments. Progressing from secret codes (1500s), carved woods (1600s), embossed printing (1700), and tactile systems (1800), finally, Braille was invented by Louis Braille in 1821. In the earlier versions of Braille, further advancements were made and now Braille is used as a standard language for visually challenged people worldwide. Braille is written on paper by punching dots and read by moving the fingers over the raised dots. Braille cells are represented by a combination of six dot patterns composed of 32 matrixes [26]. Many researchers are working on Braille to natural language conversion. Most of the recent work is on English language and in these methods, handwritten Braille sheets are scanned and then those sheets are converted into different languages. In a work done by Fahiem et al, scanned Braille images were collected and converted into Urdu using the deterministic Turing machine. For translating the Urdu script, a web-based Urdu-Braille Translator for visually impaired parents was created [27]. Limited studies have targeted Braille to Urdu language conversion and no study was found for Urdu braille conversion using touch screen-based input.

NavTap keyboard for mobile devices was designed by Guerreiro et al. in 2008. In these visually impaired users give text input using up, down, left, and right gestures. The overall user experience with these devices was positive, but the only issue was that this application requires the use of both hands [17]. Another application, No-Look Notes was designed using eight pie-menu on the screen. Visually impaired users must select an option to enter specific text. Scrolling the menu again and again was tiring for the users [28]. Similarly, VBraille was designed to comfort visually impaired users. In this scheme, the touch screen was divided into three rows and two columns and visually impaired users had to navigate among them to write a text. Tactile feedback was provided, which was beneficial to both people with visual and hearing impairments. However, gliding fingers all over the screen to achieve a specific goal was not liked by the users [29]. To alleviate these issues, TypeIn Braille was introduced, allowing visually impaired users to activate and deactivate dots with single and multi-touch. Several other gestures were used to carry out other operations. The burden of remembering many gestures was tiresome for visually impaired users [22].

In 2012, Mobile Brailler, an improved version of TypeIn Braille, was released. This application allowed visually impaired users to input data using one finger, split tap, two fingers, thumb-typing, and the nine-digit method [30]. This was yet another unfriendly interface. Braille calculators were created for visually impaired people to help them solve mathematical problems. In this application, the screen was divided into six sections and users must navigate to find the position of a specific character. Finding screen-specific text was difficult for visually impaired people [31]. Perkinput, a touchscreen-based Braille input system, was introduced in 2014. This method makes use of input finger detection technology (IFD). When the finger was moved across this interface, a finger-tracking algorithm was used to determine the finger's reference point. Users can write text with a single tap, double tap, or triple tap, which is not suitable for them [32].

In 2015, Edge Braille [20] and Braille Easy [33] were developed to meet the educational needs of visually impaired users. Edge Braille works by moving the fingers along the screen's edges, whereas Braille Easy activates and deactivates Braille dots with different taps. These techniques result in slower system performance.

This study aims to develop an enhanced position-free text entry interface designed for visually impaired users. The application developed for this study converts Braille to Grade 1 and contracted Urdu offering both converted text and audio feedback. The study involved gathering an improved dataset covering Grade 1 and Grade 2 Urdu alphabets, followed by a usability study for evaluation. Furthermore, a comparative analysis was conducted, contrasting the newly developed touchscreen-based application with the existing ones utilized in previous research endeavors.

RESEARCH METHODOLOGY

Initially, Braille Urdu Grade 1 and contracted Braille data set was collected using a simple touchscreen-based interface. Study participants were requested to input a minimum of 5 samples for each Braille Urdu Character. Following the collection of Braille samples, anomalies were manually removed from the dataset. Subsequently, the dataset was utilized for training using deep learning algorithms. Drawing from insights gleaned from existing literature, an enhanced interface was developed employing the trained models for Braille-to-text conversion.

For usability assessment, visually impaired students and teachers from the Special Education School actively participated in the study. The study encompassed a total of 25 participants, with 23 of them being visually impaired and the remaining two serving as sighted teachers instructing Braille. The age range of participants spanned from 8 years to 45 years. In Special Education Schools slate and stylus were the primary tools used for reading and writing Braille. Before commencing the usability study, consent was obtained from relevant authorities. Participants were provided with a comprehensive explanation of the application's functionality before initiating the survey. Additionally, each participant was afforded the opportunity to familiarize themselves with the application before undergoing usability testing. This preparatory training proved highly beneficial in fostering participants' confidence in the application.

This study aimed to identify the challenges visually impaired individuals faced when utilizing the proposed interface. To enhance the overall user experience, real-time data was gathered to gauge the performance and satisfaction levels of visually impaired users with regard to this application.

In this design, users have the freedom to tap anywhere on the screen, as illustrated in Figure 1. Initially, we employed this application solely for collecting Grade-1 and contracted Urdu Braille samples. Subsequently, this dataset was utilized for Braille to natural language conversion through deep learning techniques.

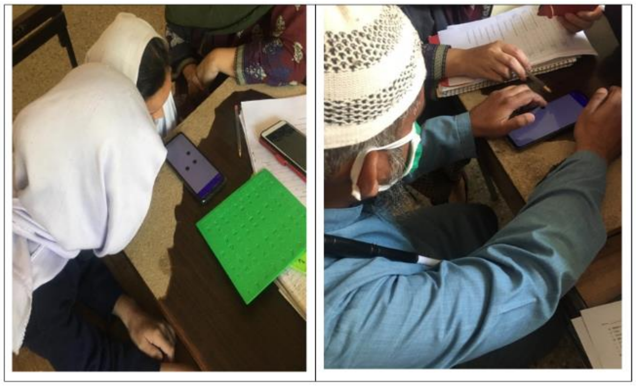

Figure 1. Visually Impaired users writing Braille using the BRETS interface.

When a user enters some characters by tapping the screen both text and voice feedback is provided.

RESULTS AND DISCUSSION

Table.1. shows a Paired t-test analysis of the number of words entered per minute and several errors that arrived during that time. The first pair represents words entered per minute using Grade 1 during 1st and 2nd sessions. Similarly, the second pair represents the number of words entered using contracted Grade 2 Urdu Braille during the 1st and 2nd sessions. The P-value determines whether the mean of the two variables is statistically significant. The null hypothesis of no average difference was rejected because the values of all the tests were less than 0.05. The average number of words and number of errors submitted in both sessions were found to be significantly different. It is evident from the results that the number of words entered per minute increased in the second session while the number of errors decreased significantly.

Table 1. t-Test: Paired two samples for means (Number of Words and Number of Errors)

Comparisons	Df	t Stat	P-Value
S1UG1 vs S2UG1	26	-9.35	<0.0001
S1UG2 vs S2UG2	26	-9.92	<0.0001
S1ErUG1 vs S2ErUG1	26	7.83	<0.0001
S1ErUG2 vs S2ErUG2	26	8.76	<0.0001

ANOVA for WPM

The following hypotheses were developed to determine whether the difference in results between the two sessions was significant or not.

Hypothesis 1

Null Hypothesis: The average number of words is not different for each subject in the first session.

Alternative Hypothesis: The average number of words is different for each subject in the first session.

Hypothesis 2

Null Hypothesis: The average number of words is not different for each subject in the second session.

Alternative Hypothesis: The average number of words is different for each subject in the second session.

Table.2. shows that the P-values of the test were less than 0.05 in both cases, indicating that the null hypothesis of no difference should be rejected. As a result, it was determined that the average number of words differed between the first and second sessions. Due to the rejection of the null hypothesis of ANOVA, Tukey post hoc analysis was used to determine which pairs have significantly different numbers of average words. The detailed results of this test are provided below.

Table 2. Analysis of variance (ANOVA) for Number of Words

Session 1					
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**
Between Groups	18.41	4	4.60	4.316	0.003
Within Groups	138.67	130	1.07		
Total	157.08	134			

Session 2					
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**
Between Groups	37.88	4	9.47	11.78	<0.0001
Within Groups	104.52	130	0.80		
Total	142.4	134			

Tukey Test for WPM

Table.3. show the difference as well as their respective p-values for the first and second sessions. Because the P-values are less than 0.05, so it evidences that the P-values representing the average difference in the corresponding pair are significant.

Table 3. Tukey HSD test words (Session 1 and Session 2)

Pairs	difference	Lower CI (95%)	Upper CI (95%)	P-values
S1UG2-S1UG1	-0.407	-1.185	0.370	0.597
S2UG2-S2UG1	-1.074	-1.749	-0.399	**<0.0001**

The following hypotheses were developed to determine whether or not the difference in errors is significant.

Hypothesis 1

Null Hypothesis: The average number of errors is not different for each subject in the first session.

Alternative Hypothesis: The average number of errors is different for each subject in the first session.

Hypothesis 2

Null Hypothesis: The average number of errors is not different for each subject in the second session.

Alternative Hypothesis: The average number of errors is different for each subject in the second session.

The P-values of the test are less than 0.05 in both cases, indicating that the null hypothesis of no difference is rejected. As shown in Table 4. The average number of errors was different between the first and the second session.

Table 4. Analysis of variance (ANOVA) for errors

Session 1					
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**
Between Groups	30.03	4	7.51	11.39	**<0.0001**
Within Groups	85.70	130	0.66		
Total	115.73	134			

Session 2					
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**
Between Groups	14.55	4	3.64	9.054	**<0.0001**
Within Groups	52.22	130	0.40		
Total	66.77	134			

Because the null hypothesis of ANOVA was rejected, a post hoc test was used to determine which pairs had significantly different average errors. The results of the tests are listed below.

Tukey Test for Errors

The difference and their respective p-values for the first and second sessions are shown in the Tables below. The bold p-values indicate the average difference in the respective pair is significant, as these values are less than 0.05, as we can see in Table 5.

Table 5. Tukey HSD test error (Session 1 and Session 2)

Pairs	Difference	Lower CI (95%)	Upper CI 95%)	P-values
S1ErUG2-S1ErUG1	-1.222	-1.834	-0.611	**<0.0001**
S2UG2-S2UG1	-0.963	-1.440	-0.486	**<0.0001**

Results showed that the BRETS interface is user-friendly and less stressful for visually impaired people as shown in Figure 2.

This interface requires visually impaired users to only tap active dots of the specific Braille character anywhere on the screen, making input simple and removing the burden from visually impaired users while entering Braille. According to the usability survey results, this interface is easier to use than previous interfaces, as evidenced by the larger number of words entered per minute. Furthermore, post-questionnaire results demonstrated that this application places the least burden on visually impaired users. It provides position-free text entry methods with no additional tapping to deactivate the dots, making it quick and user-friendly. It solves the problem of gesture memorization while also providing the most options with few gestures.

CONCLUSION

Differently-abled people are valuable members of society. Even with disabilities they often strive to cope with all the hurdles they face in their life. Braille is primarily used for written communication by visually impaired people. Braille has been written with a slate and a stylus. However, as technology advances in all areas of life, various techniques have been proposed to read and write Braille using electronic devices. Using touchscreen devices, a visually impaired user can enter Braille dots by following a predefined pattern.

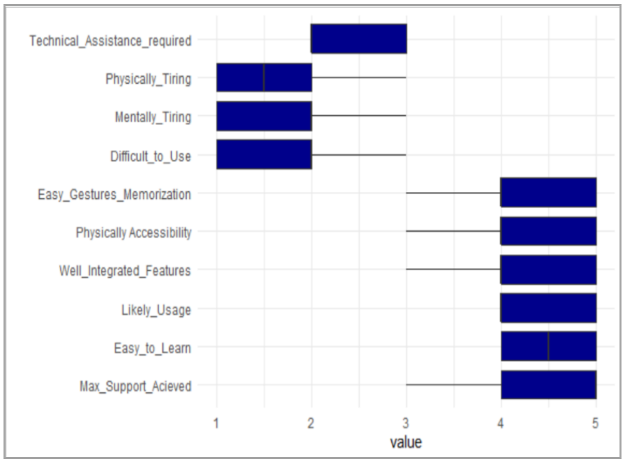

Figure 2. Acquired level of satisfaction from the visually impaired users

Differently-abled people are valuable members of society. Even with disabilities they often strive to cope with all the hurdles they face in their life. Braille is primarily used for written communication by visually impaired people. Braille has been written with a slate and a stylus. However, as technology advances in all areas of life, various techniques have been proposed to read and write Braille using electronic devices. Using touchscreen devices, a visually impaired user can enter Braille dots by following a predefined pattern.

The goal of this research was to design a position-free interface that can assist the visually impaired with Braille writing. Braille dataset was collected for Grade 1 Urdu and contracted Grade 2 Urdu. Deep learning models were used for Braille to natural language conversion. These models were then converted to lighter models that work well with Android touch screens. Visually impaired users can easily write Braille with audio feedback using this interface.

The results showed that on average 14 wpm can be written using the BRETS interface. Currently, this application supports Grade 1 Urdu and contracted Urdu. In the future, it is planned to support more languages as well as the inclusion of error correction features for identifying syntax and semantic errors.

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