DEVELOPMENT OF TEXTUAL INVENTORY TO SOLVE THE PROBLEMS FACED BY BLIND PERSONS REGARDING DIAGRAMS WHEN USING SCREEN READER SOFTWARE

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ABSTRACT: *The current paper is an attempt to investigate and design a solution for the problems of visually impaired persons, when they are confronted with diagrams in the text. Data is collected online from 50 blind computer users through Likert scale questionnaire containing 20 close ended questions. The study highlights the importance and limitations of the traditional and modern resources of diagram reading. The research puts an effort to design a method, including the development of textual inventory, which incorporates any computer software for the assistance of visually impaired computer users for the comprehension of diagrams. Several descriptions of selected diagrams are tested with the blind students to gather the common vocabulary which may assist computer programmers to design a solution that supports diagram description for screen readers. There are 10 blind respondents of which 50% are totally satisfied with the descriptions of all diagrams, and 30% did only one or two mistakes in understanding the same.*

1 INTRODUCTION

In the modern era the assistive technologies are not much efficient for the blind computer users as it is among the sighted viewers. With respect to diagram interpretation for the visually challenged persons the assistive technology is far behind than the level of satisfaction. There are three ways of accessing diagrams: aural, visual and haptic.

Diagrams are more active to trigger up the entire idea of a concept with just one image than the lengthy text. Hence the researcher tries to develop an inventory for computer programmers to assist blind computer users with the aural description of the images to make them enable analyzing the diagrams after experimentation. A method for assistance of visually impaired users is designed in this study, for description of diagrams commonly occurring in the standard texts. Section 2 of this paper outlines the literature. Methodology is described in Section 3. The section 4 describes experimentation and analyses of the experiments. Interpretation of data and discussion is given in Section 5. Last section tells the conclusion of this study.

2 REVIEW OF THE RELATED LITERATURE

In the work of [1], [2] and [3] importance of diagrams and graphs is supported better than the text in carrying a stronger effect on the human minds.

A long boring report has negative impacts on reader's mind, as it takes much time for reading. Another study shows that graphs along with visual content are more appealing than text without graphs. Captions and description are also important for understanding of a diagram or graph [3].

Diagrams are of various types, these are numerous in number. These diagrams are always modified according to the nature of the text. Few of the diagrams are as under: Pictographs, circles or pie graphs, coordinate graphs, histograms, line plots, stem and leaf plots or box plots.

People with ordinary visual abilities enjoy more means of information than people with visual impairment. Because a large material is available through print media which is inaccessible for blind people. Blind people use audio and haptic technologies to access graphical information [4,5,6] [7].

Braille is the oldest haptic technology for blind users. Electronic means of information are more recent than Braille such as tape recordings and latterly computer-generated synthesized speech [6].

There exist two ways of accessing graphs: manual and electronic. Manual ways of accessing graphs are raised line (drawing boards), tactile images, build up displays, vacuum forming method, Braille graphics, embossed paper displays.

Manual ways of accessing graphs are useful and cheap. But these most of the time make blind computer users dependent of their sighted counterparts. As these are to be made manually so these are time consuming and tactile production cannot meet the target of ultimately advancing higher education demands. More over the raised dotted lines distract blind persons.

Electronic ways of accessing graphs entails computer that are equipped with screen reading software tools [8]. Examples of screen readers are: Jaws For Windows, Windows Bridge, Voice Over, Nvda, Windows Eyes.

Despite of the availability of the screen readers there are certain limitations side by side. Screen readers do not read diagram well [9] [10]. In fact few of them don't even read aloud the present diagram in the text. Screen readers are much expensive. The serious limitation is that the software designers, generally, do not acknowledge the problems of the blind computer users to meet the needs of the blind persons in designing the assistive technologies. The last but not the least limitation is that the audience of blind persons are unaware and least interested in raising and highlighting their needs and requirements to the computer programmers.

3 METHODOLOGY

3.1 Overall Design

The current research starts with a survey from the real users of proposed design, and expands to the descriptive design of the study because descriptive design deals with the phenomenon present in the world hence it was suitable for the current research. It aims to develop a linguistic inventory for computer programmers which assists blind computer users to access graphs through computer. In the research, the data collection was required at two levels. At first data is collected through questionnaire by blind computer users and secondly through descriptive checklist an experimental design of the study which is dealt later on.

3.2 Pilot Testing

Before conducting this study a pilot study was designed to check the validity of audio graphs and its importance with respect to the competency level of the students. A pilot study is a small-scale of the proposed procedures, and methods. Gass and Mackeys explains "pilot testing can help avoid costly and time consuming problems during the data collection procedure as the loss of valuable, potentially useful and often irreplaceable data" [11]. A pilot study is important way of checking feasibility and usefulness of the data collection and method helps in making necessary changes before they are used with the final 50 research respondents.

3.3 Population

The population for the present research is of two types. At first level blind computer users at University level in all over the Pakistan. At second level type of population is again the blind computer users at university level in Lahore.

3.4 Sample

The sample chosen for the current research is 50 blind computer users for the level first data collection. The other sample for the second level data collection is 10 blind university students.

3.5 Instrument

In the present research two data collection tools have been used:

3.5.1 Likert Scale Questionnaire

A tool is designed on likert scale which consisted of 20 items. And the respondents are required to select one out of five options for each statement. As {**SA**=strongly agree, **A**=agree, **N**=neutral, **DA**=disagree, **SD**=strongly disagree}.

3.5.2 Checklist

A checklist entailing description of graphs to assist computer programmers to design such programs which describe diagrams (as circle, square, rectangle, triangle, transducers, automata flow charts, network diagramming etc) for the blind students.

3.6 Methodology for survey:

This section describes the methodology used for the survey from the blind computer users.

3.6.1 Purpose of the survey research

The researcher intends to gather data from the visually impaired students regarding limited access of diagram reading by screen readers.

3.6.2 Procedure:

For the purpose of data collection, researcher have conducted an online survey to check the diagrammatic accessibility by screen readers. Researcher have distributed 200 questionnaires online. For questionnaire distribution, Researcher have used personal mailing and Skype IDs of the students and online PBCL group for special persons.

3.7 Methodology for experimental Research Work

We conduct a session prototype session with the blind users for understanding their difficulties, and to note down the related vocabulary that can help them in understanding the diagram. In this session, we discussed different diagrams with visually impaired students, starting from the simpler one and ending on a relatively complex diagram.

3.7.1 Purpose:

Basic purpose of this session is to identify the vocabulary of specific diagrams for visually impaired person. The vocabulary collections help us to narrate the diagrams for blind users in such a way that they can easily understand the diagram through understandable narration.

3.7.2 Methodology for data collection

For the purpose of data collection regarding description of the diagrams, an experimental research was conducted in order to see the validity of the description so that a useful inventory could be developed for the computer programmers to assist visually challenged students with respect to diagram reading, which is the ultimate purpose of this work. The description was read aloud to the respondents i.e. blind students of undergrad and graduate programs at college and university level. Only those institutes were selected for data collection as these are considered well facilitated for the blind students.

3.7.3 Procedure:

The diagrams on which we worked to extract vocabulary in 2-4 sessions for each group separately are shown in the next section (Experimentation and Analyses) where the whole procedure is elaborated. Students were asked to draw the described diagrams by any means to check the suitability of the descriptions of the diagrams. They drew diagrams on the sand tray.

4 EXPERIMENTATION AND ANALYSES

4.1 Experimental setup

There are following diagrams on which we worked to extract vocabulary in 2-4 sessions for each group separately. Students were asked to draw the described diagrams by any means to check whether the descriptions of the diagrams is easily comprehendible for the blind readers. They drew the diagrams on the sand tray.

Example 1

In Figure 1, there is a Venn diagram containing two circles side by side having same size. Some part of both circle areas is overlapping; picture orientation is horizontal; and mode is landscape.

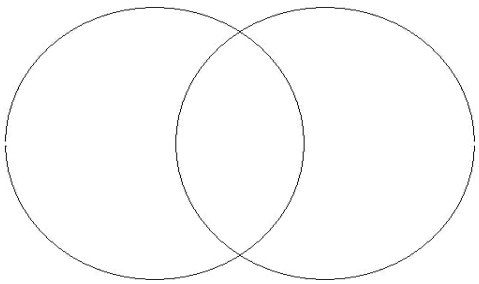

Figure 1: Venn Diagram Example

We analyze the following things:

- We should tell diagram specific name.
- We should tell picture orientation: Vertical or Horizontal. No other orientation.
- We should tell the overlapping area size, e.g. half of circle, quarter, radius full and radius 50%.
- We should tell the layout mode i.e. Landscape or Portrait.

Example 2

In Figure 2 there is a diagram having three circles like as triangle corners. Two circles are at the top level and having slightly distance from each other (no overlapping area) name as q1 and q2. The third circle is below of first two circles and

in the mid of above circles name as q3. There is an arrow (bending arrow) from q1 to q2, anther arrow from q2 to q3 and last arrow form q3 to q2. All these arrows are bending arrows.

We analyze the following things:

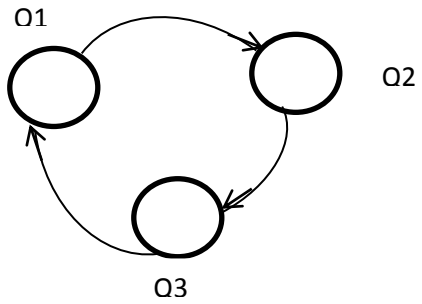

Figure 2: Diagram with Circles and Arrows

- Naming of circles is necessary.
- Orientation of circles must be told to blind person.
- We should tell arrow direction with cap.

Example 3

In Figure 3 there is a diagram having three circles like as triangle corners. Two circles are at the top level and having slightly distance from each other (no overlapping area) name as q0 and q1. The third circle is below of first two circles name as q2 and exact below to the q0. Third circle q2 is a double circle means circle inside circle. Third circle is treated as a final state. There is an arrow (straight arrow) from q0 to q1 and another arrow (straight arrow) from q2 to q1.

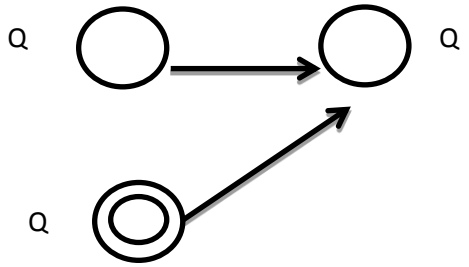

Figure 3: Diagram with Circles, Double Circle and Arrows

We analyze the following things:

- Naming of circles is necessary.
- Orientation of circles must be told to blind person.
- We should tell arrow direction with cap.

Example 4

Figure 4 explains the flowchart diagram. There is a rectangle consider as a starting state, below this rectangle there is a diamond (Diamond is like a trill rectangle). There is an arrow from rectangle to diamond (arrow direction is downward). There is another diamond below above diamond and arrow form above diamond to below diamond. There is a rectangle below this diamond and arrow cap from diamond to rectangle and this rectangle is known as finishing state. There are two other rectangles, one is right of first diamond and other rectangle is right of second diamond and arrow direction is from diamond to rectangle.

We analyze the following things:

- Sequence of shapes should be told to blind person.
- No. of shapes in whole diagram should be told to blind person.

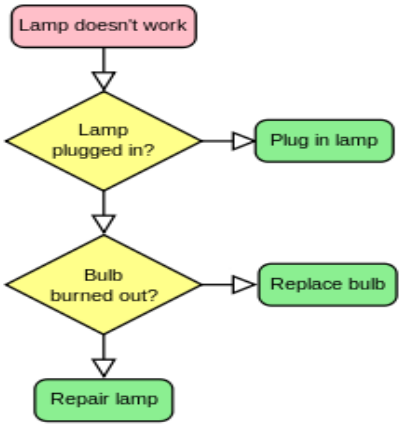

Figure 2: Flow Diagram Example

Example 5

Figure 5 is a hierarchical diagram. All shapes in this diagram are rectangles. There is a rectangle consider as a root (center point) and in the middle of the page. There are two child of

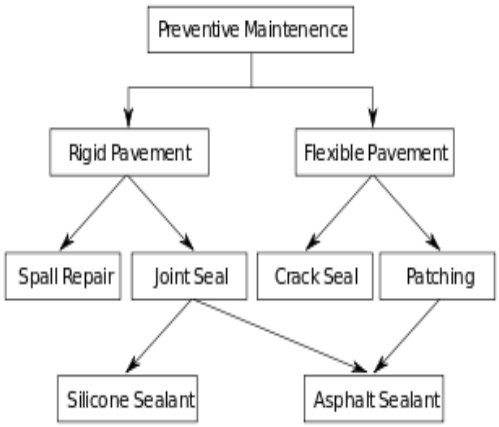

Figure 3: Hierarchical Organization Example

root and arrow head direction is from root to child (downward) and so on each of these children have two, two children.

We analyze the following things:

- Tell about child and root concept.
- Direction should be told first i.e. network diagram, flow chart etc.
- Naming conventions should be used.
- There are some multilevel details like hyperlink, so we should discuss or tell to blind person about complex words or diagrams for better understanding by using previous knowledge of blind.

4.2 Outcome of the experimentation

The general findings of the research support the description of the said diagrams. 50% respondents were totally satisfied

with the descriptions of all the diagrams. They did not face any kind of problem regarding the descriptions. Merely 30% of all the respondents were a bit confused hence they misunderstood one or two things overall. It was due to their background knowledge with respect to language. But they too conceptualized the thing correctly after the clarification given by the researcher. The rest of the 20% respondents faced the problems of drawing the diagrams, but they too could guessed the diagrams to the extent of 70%.

The above findings show the validity of the diagrams' description which ultimately becomes the part of linguistic inventory. There was not the description of a single diagram which completely detracted the respondents. Though it is limited to a small proportion of blind community yet they are capable enough to represent the entire population because their selection has been done on the basis of computer experience from various educational levels which would serve the purpose in making an inventory for computer programmers to let the blind computer users access diagrams through its possible description.

5 DATA ANALYSIS AND DISCUSSION

Figure 6 summarizes the overall responses against each question. Complete table of responses from blind users is provided in the Appendix of this paper.

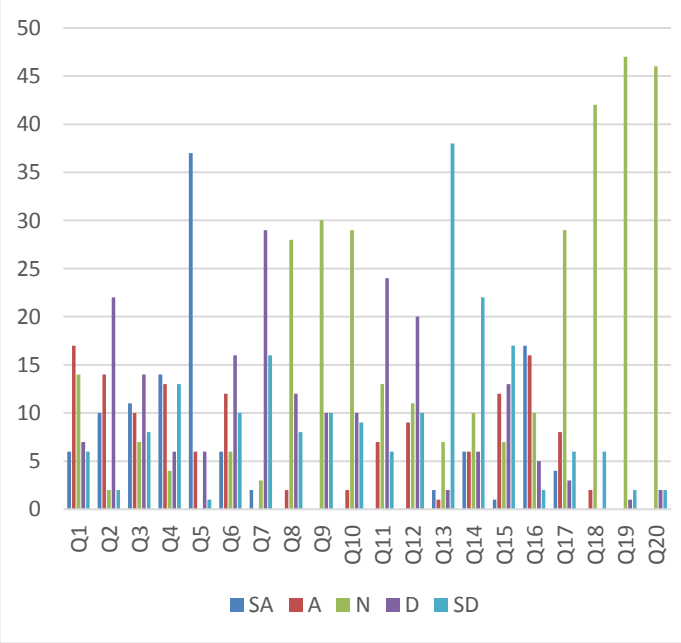

Figure 6: Overall Responses: SA(Strongly Agree), A(Agree), N(Neutral), D(Disagree), SD(Strongly Disagree)

Through responses of the audience the majority claims that tactile images are still efficient than screen images. It is due to this fact that most of the people do not know about the computer images. Another factor could be its cost and availability of more equipped technology. The other finding denotes that Braille is a major issue for blind people because results show that most of the people claim that Braille is not as much accessible as computerized data. The old method of accessing text among blind students i.e. Braille is still prevailing side by side the computer assistive technology. It is because much of blind learners are not familiar with the latest technology and screen reading software. Two factors are the cause of the prevailing of traditional ways of learning for the blind users: lack of awareness of the blind population and limitations of screen readers.

The other major finding of the collected data is the lack of awareness of emerging technologies. It is not easy to switch from current version to the newer one because there is a huge difference in current and subsequent versions. It means that technology is updating in not so comprehendible manner for the blind users. It is not possible to use the subsequent version with the prevailing commands and methods.

Most of the blind computer users use only JAWS as a screen reader. This shows that other screen readers are not experienced yet due to their unavailability, cost factor and no knowledge and the resource person. Less than enough blind people know about other existing screen reading software: Windows Bridge, Voice Over.

Since the blind computer users rely on the keyboard, a major flaw with respect to screen readers is found that most of the functions are inaccessible due to mouse centered commands. As general findings showed that screen readers read the text in a linear fashion hence they remain unable to read the diagrams by using specific shortcut commands from the keyboard.

No screen reader is fully equipped with respect to diagram reading even at basic level. As far as the programmers' role in developing such software to assist blind computer users is concerned we find that they may not realize about the difficulties and needs of blind computer users, especially with respect to diagram reading. The existing latest screen readers are not efficient in describing the diagrams within the text. Rather they do not even name the read or unread diagrams for the blinds.

One can conclude after reading the above findings that screen readers are not available in our country and few of them which are available are still far away from assisting the visually challenged learners in reading the diagrams.

5.2 Outcome

The general findings of this research supports the need of narration of the diagrams. 50% respondents were totally satisfied with the proposed descriptions of all the diagrams. They did not face any kind of problem regarding the narrations. 30% of all the respondents were a bit confused hence they misunderstood one or two things overall. It was due to their background knowledge with respect to the language. But they too conceptualized the diagram correctly after the clarification given by the researcher. The rest of the 20% respondents faced the problems of drawing the diagrams, but they too could guess the diagrams to the extent of 70%.

The above findings show the validity and usefulness of the diagrams' description which ultimately becomes the part of linguistic inventory. There was not the description of a single diagram which completely detracted the respondents. Though it is limited to a small proportion of blind community yet they are capable enough to represent the entire population because their selection has been done on the basis of computer experience from various educational levels which would serve the purpose in making an inventory for computer

programmers to assist the blind computer users access diagrams through its possible narration.

6 CONCLUSION

After the findings and analysis of the results researcher came to know about certain factors: both, tactile and oral ways of accessing diagram were discussed in the literature review with respect to their limitations. The study concludes that former way is best suited at school level, but it does not meet the demanding challenges of increasing electronic sources of learning for university students. After revealing the fact, the software developers need to update their technologies, {screen readers with respect to diagram reading} in the light of the present study. As several diagrams descriptions were tested with the blind students to gather the common vocabulary which may assist computer programmers to design diagram supportive screen readers. Further studies should be conducted on the topic of image translation, to eliminate the barriers for blind students.

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APPENDIX:

Complete table of responses from the blind users.

Q#	Question	SA	A	N	D	SD
1	Tactile images are efficient than auditory/spoken/sound images?	12% (6)	**34% (17)**	28% (14)	14% (7)	12% (6)
2	Text is well comprehended by touch sense than auditory?	20% (10)	28% (14)	4% (2)	**44% (22)**	4% (2)
3	Diagram is well comprehended by touch sense than auditory?	22% (11)	20% (10)	14% (7)	**28% (14)**	16% (8)
4	Tactile images are easily accessible than screen images?	**28% (14)**	26% (13)	8% (4)	12% (6)	26% (13)
5	Screen readers/narrators are expensive?	**74% (37)**	12% (6)	-	12% (6)	2% (1)
6	Programmers keep in view the diagram reading issue during the development of screen readers?	12% (6)	24% (12)	12% (6)	**32% (16)**	20% (10)
7	JAWS read the diagram well?	4% (2)	-	6% (3)	**58% (29)**	32% (16)
8	VOICE OVER reads the diagram well?	-	4% (2)	**56% (28)**	24% (12)	16% (8)
9	WINDOWS BRIDGE reads the diagram well?	-	-	**60% (30)**	20% (10)	20% (10)
10	Any other screen reader reads the diagram well?	-	4% (2)	**58% (29)**	20% (10)	18% (9)
11	Screen readers read name of the shape of the diagram?	-	14% (7)	26% (13)	**48% (24)**	12% (6)
12	Screen reader reads the basic diagram (square, circle, rectangle, triangle)?	-	18% (9)	22% (11)	**40% (20)**	20% (10)
13	Screen readers read complicated diagram (automata, network and flow diagram, hierarchy chart etc.)?	4% (2)	2% (1)	14% (7)	4% (2)	**76% (38)**
14	Screen readers mention the read or unread diagrams?	12% (6)	12% (6)	20% (10)	12% (6)	**44% (22)**
15	Screen readers have shortcut keyboard commands for diagram reading?	2% (1)	24% (12)	14% (7)	26% (13)	**34% (17)**
16	JAWS is equipped with OCR?	**34% (17)**	32% (16)	20% (10)	10% (5)	4% (2)
17	NVDA is equipped with OCR?	8% (4)	16% (8)	**58% (29)**	6% (3)	12% (6)
18	VOICE OVER is equipped with OCR?	-	4% (2)	**84% (42)**	-	12% (6)
19	WINDOWS BRIDGE is equipped with OCR?	-	-	**94% (47)**	2% (1)	4% (2)
20	Any other screen reader is equipped with OCR?	-	-	**92% (46)**	4% (2)	4% (2)