

Original Article

# An Overview of Accessibility to the Graphical Study Materials for Visually Impaired or Blind Students

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**Abstract** - Equal access to information is a basic right of all people. But blind or visually impaired students do not get this opportunity, as the graphical study materials have to be accessed with special methods and the adequate methodologies are yet to be implemented. Researchers are investigating this area to make available 100% accessibility to blind and visually impaired people. This paper discusses the existing methods provided to access graphical aids such as mathematical formulas, computer network diagrams, tables, and charts by blind and visually impaired students.

**Keywords** - accessibility, graphical study materials, computer network diagrams

## I. INTRODUCTION

Nowadays, a significant and rapid change has happened in delivering educational content. The internet and web-based instructional aids open vast opportunities for students to access information and self-learning. Most institutions and universities have started online courses for students around the world so that they can access the courses. But when the sighted students go with the advancements in online/e-learning, the vision-impaired or blind students are left behind due to the lack of accessibility for the information. The main reason for this problem is that the e-learning materials are vision-centric and include images, animations, and interactive media. So the visually impaired or blind students have no equal opportunity to access knowledge as sighted students. Recently, this problem has become a great concern as the gap is widening between the students who are blind or vision impaired and sighted. The term 'vision impaired' refers to a vision disability resulting in little vision [1], and the term 'blind' refers to being unable to see anything. Of the five body's sensory inputs, vision is the key sense used in learning [2]. Currently, vision impaired and blind people increasingly try to get an education in competitive areas in the marketplace. Considering this problem, the Cisco academy for vision-impaired (CAVI) has delivered the Cisco academy programs to blind and vision-impaired students since 2003 [3]. The Cisco curriculum is delivered using Flash and interactive

web pages suitable for sighted people. So when they focus on the vision impaired and blind people, several problems have to be addressed. The first problem is that the mathematical formulas and diagrams used in those programs, such as topology diagrams and network diagrams, are not accessible and cannot be explained to the students who have been blind since birth. The second problem is that the arrangement of frames and the lack of correct text equivalent buttons add to the complexity of the presented material. And there is no way of accessing the content of interactive sessions and finding the supporting text confusing and misleading [3].

As stated before, providing a complete reading system for the visually impaired and blind students is the biggest challenge that the program providers have faced. Two ways have been used when providing online courses for these students. Those are tactile methods and audio methods. In the tactile method, physically raised representations of characters on a flat surface are used to explain the content. And audio aids read the content to blind students, using tools that synthesize speech as output [4]. For online or e-learning course contents, the better option is the usage of audio aids to use tactile methods (Braille, etc.); a previous education on those methods is needed.

## II. LITERATURE SURVEY

It has been identified that most people said to be blind retain some residual vision. The Royal Blind Society of NSW notes that having 10% or less of the sight of a person who possesses their full sight is required for a person to be legally classified as blind [6]. According to this fact, Veal, Maj, and Makasaranondh have introduced a Dynamic Pattern System (DPS) for blind people with remaining vision attributes. Since the low vision students cannot read the configuration screens, DPS provides a sequence of screen patterns to represent alphanumeric characters. Each pattern represents an alphanumeric character, and the sequence of patterns represents a word. It is also described the topology diagrams using colored patterns [6].

DPS can make use of students remaining visual capacities by allowing them to choose their own sets of patterns to represent a character set [6]. DPS



system is an effective system for remote access internetworking students with low vision.


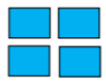
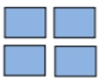




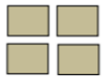


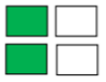
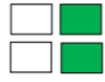







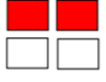

Item Name	Item Symbol	DPS 1st pattern Longer display time	DPS 2nd pattern Shorter display time
Router			
Switch			
PC			
Straight-through Ethernet Cable Right Direction (Green)			
Crossover Ethernet cable Left Direction (Red)			
Straight-through Ethernet Cable Lower Direction (Green)			
Crossover Ethernet cable Lower direction (Red)			

Fig. 1 A subset of possible DPS symbols for use in internetwork topology diagrams [6]

Several assistive devices are used to access information by visually impaired or blind students. One of the popular is DAISY digital talking book reader. DAISY (Digital Accessible Information System) is a format for Digital Talking Book and multimedia representation of a print publication [10]. This is more advanced than traditional book readers as it has the features of searching, placing a bookmark, navigating line by line, and adjusting the speed according to the user's preferences. But identifying the different components such as diagrams, mathematical formulas, images, charts, and tables and converting them to an audio format is still at the research level.

Information can reach the recipient in different formats. One of the popular formats is Portable Document Format (PDF). It has several features to make it popular for document viewing. It is page independent as it doesn't need to process the pages in order but can process only the needed page. And PDF viewers are platform free. But a scanned PDF is an image format, and due to that, assistive technologies such as screen readers are inaccessible to PDFs. By using the (Optical Character Recognition) OCR, PDFs have been scanned, and through a text extraction, it generates an editable text formatted document. To read a scanned document, it should be

tagged and reconstructed as another document that can be navigable and accessible by assistive technologies [14]. The open-source OCRopus for OCR is used for page segmentation, and it is one of the leading open-source document analysis systems with a modular and pluggable architecture [15]. The final output is in html Optical Character Recognition (hOCR). hOCR is a logical format for representing the output of the OCR system [14].

**A. Accessing Mathematical Formula**

Accessing mathematical formulas is a difficult task for blind students. To overcome this problem, Nazemi and Murray have introduced an application called MATHSPEAK. It accepts objects described in LaTeX and converts them to a linear format that can be vocalized. This application represents math formulas to blind students via text to speech (TTS). Most math expressions are displayed as images, not text, and those need to be re-render in a textual format. To do this, Mathematic Optical Character Recognition (MOCR) is used [5]. And then, the math formula should be converted to a linear model. To avoid the ambiguities in the audio output of the math formulas, some pre-processing techniques are needed before sending the Amsmath format of the linear math formula to TTS [4]. Presentation in (Mathematical Markup Language) MathML format is specific to mathematical information retrieval. This encodes the mathematical notation and meaning and is suitable for vocalization [11]. MathML is an XML application for describing mathematical notations by extracting their structure and content.


Math formula	Amsmath	Text format Before preparation	Text format After preparation
	<code>\frac{1}{\sqrt{2}+\frac{1}{\sqrt{2}+\frac{1}{\sqrt{2}+\dots}}}</code>	open bracket 1 close bracket ,over open bracket square root of 2 plus ,open bracket 1 close bracket over open bracket square root of 2 plus open bracket 1 over close bracket open bracket square root of 2 plus ,until to ,close bracket ,close bracket ,close bracket	1 over open bracket square root of 2 plus ,1 over open bracket square root of 2 plus 1 over open bracket square root of 2 plus ,until to ,close bracket ,close bracket ,close bracket

Fig. 2 Output of TTS after Amsmath and Pre-processing [4]

**B. Drawing Diagrams**

According to the research done by Murray and Armstrong [3], the visually impaired and blind people are provided remote laboratory access to follow Cisco Certified Network Associate (CCNA) programs. The lectures are recorded and made available as audio files on the project website. But explaining graphical information to blind people is the biggest challenge. So the methods they use now are creating textual descriptions for graphics/ diagrams and using a screen reader to read that description to the reader. And both Netlab and Packet Tracer tools are inaccessible to many visually impaired and blind students. So an accessible network simulator net sim is introduced to illustrate possible methodologies. It is based on Mac OS X Tiger, an operating system with an integrated screen reader called VoiceOver [8]. The screen reader (VoiceOver) keyboard shortcuts can access all user interfaces and network topology elements, and a clear description is given when it reads. It is impossible to handle the mouse movements to create communication links to connect two devices for the visually impaired and blind students. The keyboard shortcuts can access all user interfaces and provide a meaningful response when reading through VoiceOver. i Net Sim uses tables to place the device locations in the topology area and configure ports and links. These tables are used to navigate with speech prompts which can be operated through shortcut and cursor keys. i Net Sim successfully proved that network simulators might be accessible [7]. iNetSim is intended to replace Packet Tracer, allowing vision impaired and sighted students to complete CCNA level 2 [8].

**C. Table Content Identification and Description**

Nazemi, Murray, and McMeekin have introduced away [9] to explain the tables, as the structure is different from the other components. RAST and Voronoi methods are used to identify the boundary of the table. RAST is a developed algorithm which is having three steps. Those are finding the columns, finding the text lines, and determining the reading order. The voronoi algorithm identifies the connected components in the layout and divides the page into regions.

The table can be extracted as a separate individual component. That will be sent to the table cell recognition module to specify the number of columns and rows, column title, and cell position. The RAST will result in horizontal and vertical identifier lines indicated with yellow color, and by using these identifier lines, numbers of rows and columns can be identified. Cell positions can be identified by using the intersection points of these lines. A number of columns in the table can be identified using the number of vertical lines, and the number of rows can be identified using the number of horizontal lines. The table reader module extracts the information in the table and sorts them based on the columns or rows.

Several image processing techniques are used to access each cell using the intersection points. Morphology erodes and dilates techniques are used to find the row and column lines. Finally, the cropping technique and all intersection points table are segmented into cells.

(PK, PK)	Column Name	Description	Data Type	Size	Required	Default value
PK	CustomerID	Unique five-character code based on customer name.	Text	5	Yes	
	Company Name	Customer Company	Text	40	Yes	
	ContactName	Name of the person who should be contacted	Text	30		
	ContactTitle	Title of the contact person	Text	30		
	Address	Street or post-office box	Text	50	Yes	
	City	City name	Text	20	Yes	
	State	State Code	Text	2	Yes	
	Zip	Five digit zip code	Text	5	Yes	
	Phone	10 digit phone number	Text	15	Yes	
	Fax	Fax number	Text	15		
	Email	Customer email address	Text	20		

**Fig. 3 A sample table and its vertical and horizontal separator lines by morphology technique [9]**

All the found cell positions are tagged and sent to the OCR to extract textual data. This table reader has the navigation ability, and the user can interact with data.

**D. Chart Recognition**

For chart recognition, several techniques are used. The chart recognition module determines the chart type and uses image morphology. Using image morphology, the structure of the image can be studied. It compares each pixel in the image against its neighbors. If a pixel is white and surrounded by other white pixels, that is not the edge of the image. The process depends on defining a 'Structuring Element' or 'Kernel,' which defines what pixels are classed as 'neighbors' for each specific morphological method. The dilate operation returns the maximum value in the neighborhood. The erode operation returns the minimum value in the neighborhood. Use the composite program to overlap two dilate and erode images. Performing binarization, erode and dilate morphology, compositing erodes and dilate images, rotation and edge detection produce circle images from pie charts and nothing from line charts and bar charts. Distinguishing between bar and line chart is executed by eliminating horizontal lines from the image. In this stage, several vertical lines remain from the bar chart [9].

An application called GraphicReader has been developed to automate the presentation of the charts to visually impaired and blind students in detail. Using the Visual Extraction Module, data and the text are extracted. Then the extracted data will be generated.

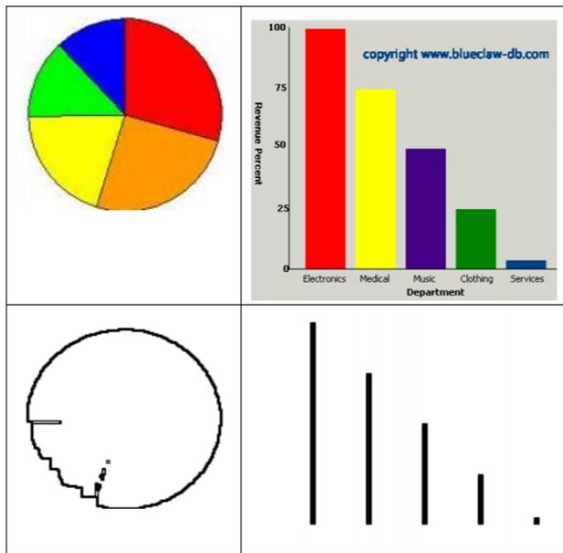


Fig. 4 Chart recognition based on morphology [9]

As in the Extensible Markup Language (XML) format, it has been done for pie charts, line charts, bar charts, and graphs of math functions. The output of the application is a textual summary of the graphic, including the core content of the hypothesized intended message of the graphic designer. The textual summary of the graphic is then conveyed to the user by Text to Speech software. This approach automatically provides the user with the message and knowledge that one would gain from viewing the chart [12].

### III. DISCUSSION

The researchers suggested methodologies for providing visually impaired and blind students with complete accessibility to the curriculum. Even though several methodologies and applications are developed to accomplish this task, the goal is not completely achieved, but to some extent. The scanned PDFs are converted to MathML, and the MATHSPEAK application can convert that to audio. Using this method, even a very complicated math formula can be understood by blind students. Here, to make the PDF document accessible to the assistive devices, OCRopus can be used. Since that is an open-source package, configurations can be made according to the scenario.

The low-vision students can use the DPS system, and the students who are blind (no residual vision) cannot use this system. And the currently used method to describe the topology and network diagrams is, creating separate descriptions for each diagram and reading that description using a TTS. That is a time-consuming and non-practical method. As the different types of charts have been identified and the details of those charts are presented in an explanatory manner to the blind students using audio outputs, there should be a method to explain the network and topology diagrams in detail to the blind students. iNetSim application is designed to draw

diagrams by the blind students themselves, and tables are used to get the communication links between two devices. But the descriptors (ASDescription) are missing. But most of the diagrams are not created using iNetSim but using Packet Tracer.

The best option to explain the diagrams is using automated audio files. It is low-cost and easily accessible to visually impaired and blind students. And DAISY talking book reader allows users to navigate through the content. The issues in this survey are user interaction and making the most suitable and efficient description for the graphical information for visually impaired and blind students. So it is better to consider creating a supportive application for DAISY talking book readers to read the diagrams (initially for the topology and network diagrams in CCNA students) by extracting each information in those. Image morphology methods can be used to identify the components in the diagrams.

### IV. CONCLUSION

According to the conducted review, it is clear that a plethora of researchers is on the track of attempting to provide equal accessibility to the visually impaired and blind students as ordinary students. And there are some other graphical aids such as images to be accessed by them. However, it is visible that the methodologies used in the discussed research are affordable to the students.

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