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Review of Technology to Access Infographics for Visually Impaired

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ABSTRACT
Providing diagram accessibility to visually impaired is a challenging problem in the field of computer vision. Innovations in technology has brought noticeable change in the representation of data in variety of graphical formats and has special impact in visual communication. Unfortunately, technological solutions have not become rich enough to reach to visually impaired and the complexity of diagram accessibility remain as a challenging problem in the field of computer vision. Visually impaired face various challenges to access visual contents including information graphics(infographics). With assistive technologies, attempts have been made to access knowledge present inside infographics upto a certain level with its pros and cons. This paper outlines the challenges to access infographs by visually impaired and reviews tactile, non-speech, speech and hybrid technology based solutions available to make infographs accessible. The paper also includes suggestions to create accessible infographs.

Keywords: Accessibility, Assistive Technology, Infographics, Non-speech interface, Screen Readers, Visual Impairment.

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I. INTRODUCTION

Visual representation of data using maps, charts, graphs, flow diagrams, math equations etc. are common non-textual methods of conveying information and are much more effective than text. One of the categories to represent data, knowledge and complex information quickly and clearly is known as information graphics (infographics). Infographics represent data using visual elements that can help to simplify the information processing. According to the anatomy of infographics (Fig.1), there are three components of it; visual, content, and knowledge. Visuals consist of graphical elements like shapes and content consists of the information, facts / statistics [1,2]. The knowledge is a sort of insight that the infograph contains.

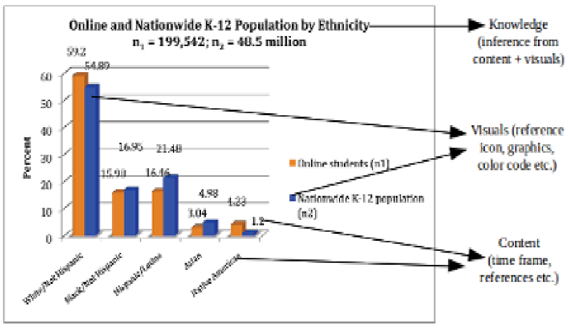


Fig.1 Anatomy of Infographs

With the fare increase of data, infographics are getting popularity. There are various types of infographics including Time-series data, Statistical distributions with histograms, bar charts, line graphs, flow map, Choropleth maps, pie chart, Cartogram, Node-link diagrams, adjacency diagrams, and Networking with: Force-directed layout, arc diagrams, and matrix view etc. But visualization techniques using infographics are almost useless for the Visually Impaired(VI). In the absence of vision, it is very difficult for them to understand the knowledge communicated through visual content. The reason may include the format barrier, language barrier, missing alternative text and description etc.. Inaccessible infograph is an important aspect that requires to address for the community which cannot see and face problem in processing visual contents including all types of infographs.

Many assistive technologies such as screen readers, tactile graphics, braille display have addressed issue upto certain level. But these technologies also have limitation to make infographics accessible according to the VI community.

This paper outlines the challenges faced by VI to access infographics and reviews the technology solutions available to make accessible infographics. The paper is organised as follows. Section 2 highlights the challenges to access infographics by VI, section 3 reviews the technology based solutions to access infographics, section 4 analyses the limitations of available technology solutions and adds suggestions towards improving the accessibility of infographics.

II. CHALLENGES IN ACCESSING INFOGRAPHICS BY VISUALLY IMPAIRED

Today, infographics are widely used for information visualization based on analysis of data sets. All the three components (visual, data and knowledge) of infographics together build the correct semantic to understand. Any one out of three cannot sufficiently give the correct knowledge of infographics. However, knowledge represented by infographics combines the data and description of visuals to get correct semantics. Sometimes, even for the sighted person it is difficult to infer the correct knowledge hidden in the infographs. In the absence of sight, the complexity increases and processing infographics presents significant challenges for VI. The literature stated various challenges to access the GUI elements and visual content presented in infographs for people with vision impairment:

- Processing data, legends, color information, orientation, relation between elements and languages symbols, increases cognitive load
- Representation of infograph creates possible barrier in accessing it [3].
- ➢ The pixel barrier that refers to the problem when the screen output is stored as a pixel map in the graphics memory and cannot be read by usual text-to-speech systems.
- ➢ The mouse barrier refers to the problem that blind users cannot handle the mouse or pointing device in an effective way as an input device; this is a psycho-metrical problem resulting in absence of feedback.
- ➢ The layout barrier caused by the use of layout features for syntactic and semantic analysis purposes.
- Presenting the actual semantics of the visual content to the VI is one of the critical challenges and must be addressed to make them accessible. In absence of visual feedback, it is difficult to prepare a mental modal required to understand the intended message of infographics.

All these challenges make infographics inaccessible and to access the visual content, either VI has to depend on sighted person or computer literacy is required to use various technology solutions.

III. TECHNOLOGY SOLUTIONS TO ACCESS INFOGRAPHICS

Visually impaired persons have very limited access to visual graphics and 2d diagrams. Most of the academic reading resources specially in the subjects of Science, Technology, Engineering and Mathematics(STEM) are inaccessible and it is very difficult for VI to carry out their study in such stream. Accessibility experts and researchers are actively working from past few decades towards to find feasible solutions to address these challenges. Over the decades, a number of non-visual interfaces have been introduced. These can be categorised as Haptic interfaces including tactile-graphics, Sonification as non-speech audio, Speech based Natural language Interface (NLI) and the Hybrid of all (Fig.2) [4].

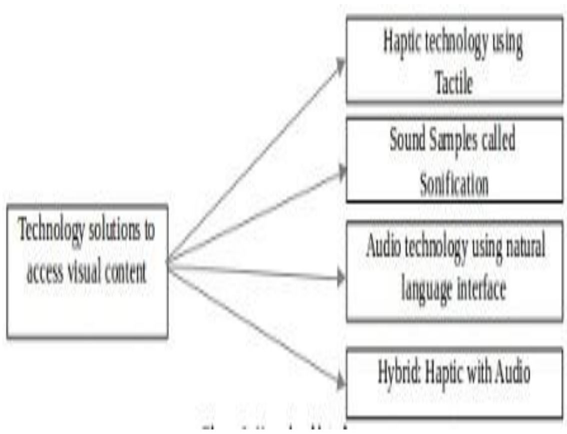


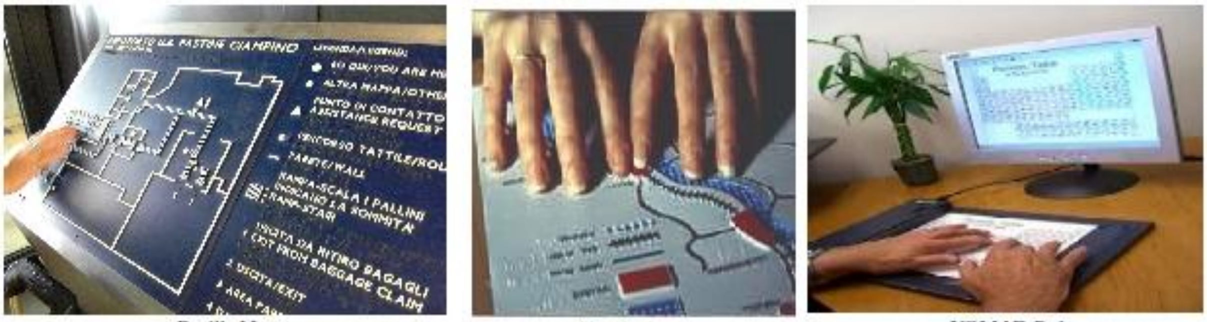
Fig.2 non-visual interfaces

3.1. Haptic technology using Tactile

Haptic technology using tactile is touch based feedback technology (Fig.3) that recreates the sense of touch by applying force, vibration or motion to the user. Trends have been included tactile, braille and other kinesthetic devices like vibration as haptic technologies. Vibrotactile, or vibration-based feedback is the most common form of feedback and is widely available on mobile phones and many tablets. Vacuum-formed(thermoformed), swell paper (micro-capsule paper) and embossed (e.g. produced on a braille printer) are common formats used for tactile-graphics. Earlier, the sensible technology PHANToM was introduced to access the visual content with speech synthesis [5]. Yu and Brewster [7]. In 1970s, first refreshable braille display was introduced to access the content on computer display and to read the labels and text available on charts, bar graphs and other information graphics. In the tactile section, NOMAD was used with a touch-sensitive pad on which raised-line graphics are placed [9]. NOMAD was extensively used to independently

described a system for presenting simple bar charts using a joystick with audio and evaluated it against tactile diagrams [6]. GraVVITAS presented accessible graphics using a multi-touch display with haptic feedback for the fingers provided by small vibrating motors, and audio feedback for navigation

learn about geography, geometry, biology, physics, physiology, electronics, astronomy, and subjects involving charts, graphs, diagrams or spatial concepts. In 2014, American printing house and Touch Graphics have collaboratively introduced Talking Tactile Tablet (TTT) and improved older Pen to describe probe for tactile graphics [10].



Braille Map Tactile map NOMAD Pad

Fig.3 Haptic technologies using Tactile

Kluas M. and Dominique B. have presented different approach by printing images using normal text Braille printers. The gray scale image was converted to edge image and then it was transformed into textual image. The textual image then converted to XML based Portable Embosser Format(PEF) [11].

3.2 Sound Samples called Sonification

Non-speech auditory interfaces including Sonification (also known as sound of vision) have long been used to describe the complex visual interfaces by using the corresponding wave file. They were initially used by VI to explore graphical interfaces having coordinated maps and tables, augmented with non-textual sounds. Different Sonification based framework like iSonic, SonArt and EdgeSonic have been found helpful to gain insight about data and to find patterns [12]. The Soundgraphs system allowed the presentation of line graphs in sound[13]. Here the time is mapped to the X-axis and pitch to the Y-axis. The shape of the graph can be heard as a rising or falling note playing over time. It allows listeners to get an overview by listening to all of the data very quickly. Properties of 2D and 3D objects and color based infographics have also been presented using Sonification. AudioGraf and ViewPlus were used hybrid approaches with an Sonification, audio-tactile and force feedback for creation/conversion and reading the selected part of visual content [6,14,15,16]. Franklin and Roberts have proposed many designs to present pie charts using Sonification technique [17].

3.3 Audio technology using natural language interface

Natural languages are richest systems of communication known to humankind. Natural language processing (NLP) techniques from artificial intelligence is mainly used to describe the charts and graphs. Speech is used as output medium for VI. Literature also included the use of natural language to present the information graphs to VI. In 2002, the TeDUB system was developed which automatically generated descriptions of certain classes of information graphics (electronic circuit diagrams, UML diagrams and architectural plans) and allow blind people to explore them independently [18]. Many researchers have taken this as base and extended it for greater accessibility of information graphs. iGraph-Lite system was introduced to provide short verbal descriptions of the information depicted in graphs and a way to also interact with this information [19]. Over a decade, teams under Sandra Carberry had started working to summaries information graphics such as bar-charts, line-graph textually. Experimental tool developed for that purpose is known as SIGHT (Summarizing Information GrapHics Textually). Further SIGHT has extended using different infographics like single/multi-color bar charts and line graph [20, 21, 22, 23].

Printed braille format with audio output is useful for blind as well as deaf blind. In many cases screen readers like NVDA and JAWS have been enhanced to read the textual image. Julius, Mike and Tompsett tried to describe the images available in web content. Resource Description Framework (RDF) and Web ontology language (OWL) were used to convey the meaningful description of an image [23].

3.4. Hybrid technology

Braille print with audio, tactile graph with audio, tactile with Sonification are few examples of hybrid techniques. All most every technology solution mentioned in previous sections belong to hybrid technology. The audio/touch method has been well tested and found to provide excellent accessibility. Based on audio/touch method, Voice And Touch diAGRAM (VATAGRAMS) was introduced as a tool to read, create, modify and share relationship based diagrams using sound and gestural touches for visually impaired users [25]. Many systems are developed which require human interaction to describe the visual content. DIAGRAM (Digital Image And Graphic Resources for Accessible Material) Center has developed a tool called Poet, an open source image description tool, that provides interface to author to add the description to visual content present in the DAISY format and to read by screen reader when image appears in document [26]. GraphicReader has been developed to provide real-time, independent access to the vast repository of information in the graphics (bar chart, line chart, pie chart and maths graph) generated by GNUPLOT tool, with automated image processing, math processing, decoding and extracting information from graphical components [27].

IV. DISCUSSION

Cognitive benefits including perception building, inference construction after compiling the types of data are the result of the feedback we get from our senses. In the absence of vision, assistive technologies like tactile, braille or speech output help in preparing a mental model of visuals and in inference generation. In case of infographics, as mentioned earlier, one element out of three i.e. visual, text and knowledge may not be sufficient for correct and complete inference generation. It requires to relate all three elements in correct manner and needs better cognitive skills with enough practice of accessing infographics using assistive technology. Though each of the technology solutions reviewed in previous section depends on the capability, limitations and experience, as well as the mood of user. But technology itself presents challenges while using it [7,8,18,28,29].

4.1 Challenges using technology solutions

- Challenges using haptic technologies with tactile:
  - With haptic tactile technology solutions users must have experience of diagram otherwise it is difficult to locate and relocate specific parts of infograph. Rich, spatially distributed nature of visual cues is not available during haptic perception.
  - In case of raised-line drawings blind observers can be confused and may need clarification as to what perspective it may represent. Wall and Brewster have also mentioned that the participants often confused of the Tactile mouse (VTPlayer) with output medium Braille, user couldn't hold the mouse traditionally (2 hands instead of one), and were disappointed by the small display and low resolution of the device[8].
  - Limited size and resolution of the tactile display area makes it difficult to use and to perform movements in a manner analogous to the role of visual information when a standard mouse is used.
  - Raised paper tactile representations are not utilized much. The reason behind is, because it needs for sighted assistance during production and a bulky, expensive, specialist equipment.
  - Refreshable braille displays presented only limited amounts of text at one time and cannot present graphics at all.
  - Braille print with audio output does not present the description of image, it just reads the text (if any) available on image. It gives accurate results only for black and white images with text and shapes.
- Non- speech based Sonification techniques:
  - With limited sound codes for symbols of Sonification, it is very difficult to present the correct semantics, color and layout information.
  - Sonification is difficult with all kinds of infographics. It is complicated to present model based infographics like UML, ER diagrams, shape and relation based diagrams using Sonification, because they have different way to present the information.
- Speech based output:
  - Screen reading software access is sequential and involves great exertion. It demands high memory to remember both the data and short cut keys. iGraph-LITE used a simple, yet powerful, template-based system that can be extended with little work, but at the same time, the complexity of the produced sentences is only just good enough.
  - Speech based output rely on sound which can decrease the users focus on listening to auditory environmental cues.

- Format of visual content (jpeg, png, gif etc.) is also a concern while accessing elements of infographics. SVG is the preferred format to work on infographics. Country like India, where number of languages exists, all most every technology solution present challenges to access information of infographics available in different Indian languages
- Another aspect that requires attention is the quality and quantity of description for visual content presented. On demand, precise and effective description should be included as alttext or long description.

Tactile solutions, Sonification and speech output based technology can be compared on metrics such as cost, usability and ease of use as in Table-1.

Assistive technology	**Cost** Low - less costly High - costly	**Usability** Low - less effective High - effective	**Ease of use** Easy - easy to use Complex - difficult to use
Tactile (touch based)	High	High	Easy
Non-speech based Sonification with sound codes and vibration	High	Low	Complex
Speech output based (screen reader)	Low	High	Easy
Haptic	High	High	Complex

Table1: Comparison of Assistive technologies

It is not being justified when tactile is compared with screen reader on the basis of cost. Because both have different approaches to access the knowledge inside the infographics. Tactile techniques involve hardware that increases the cost whereas screen readers are s/w based approach to access the infographics. Feedback provided by tactile devices gives a feel and helps to prepare mental model of chart or graph. That is very helpful in case of VI. Whereas audio feedback helps them to understand the message present with available elements. Due to cost factor of the haptic technologies including tactile printing of 2d/3d objects, users are unable to get the content easily. In India, IIT, Delhi and Saksham, India (NGO) are trying to find feasible solution to reduce the cost involved in printing tactile graphics with thermo-form and swell paper and helping VI and organizations to convert work related documents in the tactile based accessible format.

4.2 Creating accessible infographics

Creating accessible infographics should not be a rocket science for the creator of infographs. The best and most accessible option for infographics is to simply give text alternative to describe the hidden knowledge inside infograph. Most of infograph creation tools including OpenOfficedraw, Creatly, SmartArt, Conceptdraw provides options to add alttext for core elements such as caption, scale, axes labels, color codes etc. Other than the creator, the author of content also has provision to make infographs more accessible upto certain level. The solution is to mark up the content using native HTML elements such as headings, unordered lists, ordered lists, tables, etc., where appropriate and style the HTML accordingly using CSS to be visually appealing for sighted folks. Screen readers are very literal and tend to read out data with no particle words or punctuation. In many cases, VI users have tough time discerning if the data should be read as a series (10,20,30...) or a range (40 – 50). Using a CSS technique to position text off the screen, it's simple to add some particle words (such as "from" or "to") for screen reader users.

Though the paper discussed here the assistive technologies to access the visual content, but there are effective methods through which developer can create accessible diagrams while creating them. That can reduce the efforts of making the diagrams accessible while reading. The tools like GNUPLOT, Graphviz, GML are introduced to create accessible graphics for VI.

V. CONCLUSION

Visually impaired also have right to look for concise information that quickly conveys a complex concept or data relationship, or distills a large set of data or text into a small piece of information. The main focus of this study is to present various challenges faced by visually challenged while reading infographs using assistive technologies. Hybrid technology using audio-tactile are successfully used to provide the high-level knowledge that would gain by viewing infographics. Further, the challenges can be addressed to improve the accessibility of infographs. Computer mediated transcription can be automated and technology can be developed to process and bring out the message behind visual contents.

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