A Method to Provide Accessibility for Visual Components to Vision Impaired

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Abstract

Non-textual graphical information (line graphs, bar charts, pie charts, etc.) are increasingly pervasive in digital scientific literatures and business reports   which enabling readers to easily acquire the nature of the underlying information [1]. These graphical components are commonly used to present data in an easy-to interpret way. Graphs are frequently used in economics, mathematics and other scientific subjects. In general term data visualization techniques are useless for blind people. Being unable to access graphical information easily is a major obstacle to blind people in pursuing a scientific study and careers [2].This paper suggests a method to extract implicit information of Bar chart, Pie chart, Line chart and math's graph components of an electronic document and present them to vision impaired users in audio format. The goal is to provide simple to use, efficient, and available presentation schemes for non textual which can help vision impaired users in comprehending form without needing any further devices or equipments. A software application has been developed based on this research. The output of 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 .The benefit of this approach is automatic providing the user with the message and knowledge that one would gain from viewing the chart.

Keywords: K**.** Vision Impaired, Bar Chart, Pie Chart, Line Chart, Function Graph, Text to Speech, GNUPLOT, GraphicReader.
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1. INTRODUCTION

This Graphics are widely used in newspapers, text books, web pages, metro maps, instruction manuals etc. They provide significant cognitive benefits over text. These graphical components have an important role in conveying, clarifying, and simplifying information [3]. The majority of information graphics that appear in formal reports, newspapers, and magazines are intended to convey a message or communicative intention [4].Unfortunately, graphics are not easily accessed by vision impaired people. In visual form, they are not accessible to vision impaired. Vision impaired people unable to learn about the processes involved in reading, analysing, and interpreting information presented in data visual graphs, tables and charts which are frequently used in math and science materials to present and summarize data. It is fair to say that lack of access to diagrams and other graphical content significantly limits educational and workplace opportunities for people with vision impairment as well as access to popular media. This is in contrast with textual content in which assistive technology have improved access [5]. Traditionally charts are used to display trends and relationship, and also can be used to communicate processes or display complicated data simply. These charts may be designed for the experts

trained users for data visualization or in popular media without complicated scientific reasoning [6]. Charts are typically intended to convey a message that is an important part of the document and this information generally not repeated in the article [7]. Thus people who are unable to see and understand this chart will lose important part of information.

Several approaches have been addressed the accessibility of chart using alternative methods. A number of projects have attempted to make graphic components accessible to vision impaired users by reproducing the image in an alternative medium, such as sound [8], touch [9] or a combination of the two [10][11].Viable alternatives include generation of a tactile graph, delivering the information in text, interaction with an audio graph, or a combination tactile/audio approach [12]. Non-textual components can be made accessible to the vision impaired in verbal description or audio format and Haptic(tactual) feedback. These techniques help to express the data being graphed in non visual ways. Synthesized speech and Braille are two common examples of conveying information through the auditory and tactile senses [2]. Current approaches have limitations such as the cost of translating into an accessible graphics format, use of expensive tactile graphics or expensive peripheral devices, or lack of congruence with the original visual graphic[5].Traditionally, graphs and diagrams are presented in Braille, or raised dots and lines on the swell-paper [13]. Tactile graphics are images that use raised surfaces and vision impaired user can feel them. They are used to convey non-textual information such as maps, paintings, graphs and diagrams. Tactile graphics can be seen as a subset of accessible images [14].

Several problems are associated with Braille and Tactile technique:

- Only a small proportion of blind people can use Braille, because reading it requires sufficient tactile sensitivity which all vision impaired do not have [15].

- Blind people can only get a rough idea about the content [13].

- Tactile diagrams are not durable. It is not easy to make changes to tactile diagrams.

- Reheating the swell paper could overcook the already raised parts and reduce the quality [16].

- In the method ,making graphs tactile Picture in Flash (PIAF)[21], the general shape of the graph can be understood by touching it carefully, but hardware is needed to generate tactile charts. Two main effective restriction factors in this method which must   be considered for tactile symbols in charts are :Discriminating ability and Searching ability [22]. Tactile symbols without these properties could not help to explore concepts of charts by vision impaired people.

In addition, Haptic feedback which is more useful for guidance and assisting users' navigation on the graphs is not efficient to present exact data values to the user. Moreover, if too much information is presented via Haptics, the narrow bandwidth can be easily overloaded [2]. Also it may take users some time to familiarize themselves with the new interface. The limitations of the force feedback devices also hinder users exploration on the graphs[18]. Vocalizing the form of the graph and individual data is useful as long as a screen reader is provided to interpret trends in the data, however, the shape of the chart has to be imagined in the user's mind[20].

In addition other methods have some limitation such as:

- Conveying data via sound pitch and 2-dimensional acoustics[19].It is difficult to convey data accurately with the acoustic method(non speech sound), and moreover, since acoustics are volatile, information can easily be misheard.

- The Interactive SIGHT (Summarizing Information GrapHics Textually) system provides visually impaired individuals with the high-level knowledge that one would gain from viewing. SIGHT uses image processing techniques to extract communicative signals from a chart, but it is still limited to present information of the bar chart within the WebPages [4].

2. METHODOLOGY

There are two categories for methods to present visual component to vision impaired:

- Passive (description tool):The user is presented with a representation of the entire visual part at one time, with limited user input.

- Active (exploration tool):The user can explore non textual part [23].

The offered method in this paper has been attempted to combine two mentioned categories. It means this method presents a completed description of illustration (passive) and provides navigation ability through various field of data to give user opportunity to explore and build a mental map of the visual components (active).

On the other hand, providing an alternative equivalent for inaccessible content is one of the primary ways authors can make their documents accessible to people with disabilities [18], providing a hierarchy of text equivalents can also convey the hierarchical structure of the graphic components [3]. The alternative content fulfills essentially the same function or purpose for users with disabilities as the primary content does for users without any disability. Text equivalents are always required for graphic information [3]. Therefore this research has focused to extract these text equivalents from graphic components where they are not provided by authors.

For implementation this method, accurate understanding of the ways in which non-textual parts benefit sighted people, together with the problems encountered when exploring them non-visually, are required [24]. Also understanding of nature, meaning and concepts and obtaining comprehensive information from graphics must be considered to present detailed descriptions. The factors which appear to affect graphical comprehension are the purposes for using graphs, task characteristics, discipline characteristics, the differences between presenting information visually and aurally, and how and what graphical parts are represented in the mind[25]?

Most significant benefits for readers of visual parts are reducing demands on short-term memory and gaining a quick overview [26] which have been considered in aural representation in this method.

In general term each chart structure contains two parts:

1. Text part including :the number and amount of each axis ticks, axis labels ,legends and title.

2. Image part including: graph body.[22].

To provide non textual graphical components accessibility to vision impaired users it is essential to obtain comprehensive information from image .In addition advanced techniques for the graphic understanding are needed [27].Since large quantities of data are presented in a graphic, thus efficient access strategies are required according to the tasks that users are trying to accomplish during navigation through information.

2.1 GraphicReader Software Application

GraphicReader is a software application which has been developed in order to provide real-time and independent access to the vast repository of information in the graphics (bar chart, line chart,

pie chart and math's graph), with automated image processing, math processing, decoding, and extracting information which these graphical components convey and emphasis. After extracting data as text, the system analyze them to generate XML format which is convertible to   audio format and   used to provide easy navigation ability to vision impaired people .The application integrates appropriate representation for information accessibility.

This main core is Visual Extraction Module (VEM) and regarding the charts structure contains two Sub-Modules:

1. Text data extraction by performing accurate Optical Character Recognition (OCR) .Before OCR some preparation steps must be done to clean the text background and enhance the text .Theses processing steps are:

- 90 degree rotate if aspect does not match layout

- Crop

- convert to grayscale

- enhance filter to clean background and remove noise

- text smoothing

- Sharpening

- saturation change

- alternate text smoothing via adaptive blur

After OCR , running Text Analyzing Module or Data Interpretation leads to gain access to chart title, axes labels, the number and value of ticks ,and number of slices.

2. Image data extraction contains graph digitization to provide data table .Data table is a table with two columns to shows amount of each dependent variable related to its independent variable.

After data extraction and data collection, XML generating Module generates XML code based on all collected data and considering the result of Data Interpretation Module. The availability of markup format for the description of a chart helps to concentrate on the development of presentation strategies which comprehensively expresses the original chart in audio format without needing further peripherals.

By completing XML code user is passively presented key statistical information about the presented chart. For users who do not need detailed description, an static description should be generated for a quick access.

Since any technique that aims to provide non-visual accessibility of charts needs to support the processes of mental model formation and manipulation, at this stage user can easily navigate the chart and has the benefit of both *passive* and *active* presentation .It means the user is guided by the system in navigating the content of the chart or can control the presentation by deciding what parts of the charts to focus on. The main important features of navigation ability in GraphicReader, are reducing the demands on memory and reassuring user to explore the chart meaning.

Thus depending on user navigation request which is send to system through user interface different classified data could be extracted from XML representation, converted to plain text and sent to TTS module to make audio representation.

In addition XML representation is converted to a .dat file and .gnu configuration file and sent to GNUPLOT module to generate accessible graphical component using classified data in XML representation. In fact this module is a feedback module and by comparing graphical component produced by GNUPLOT and original image, accuracy of system can be estimated and errors are found and corrected. Figure 1 illustrates the overall architecture of the GraphicReader access system.
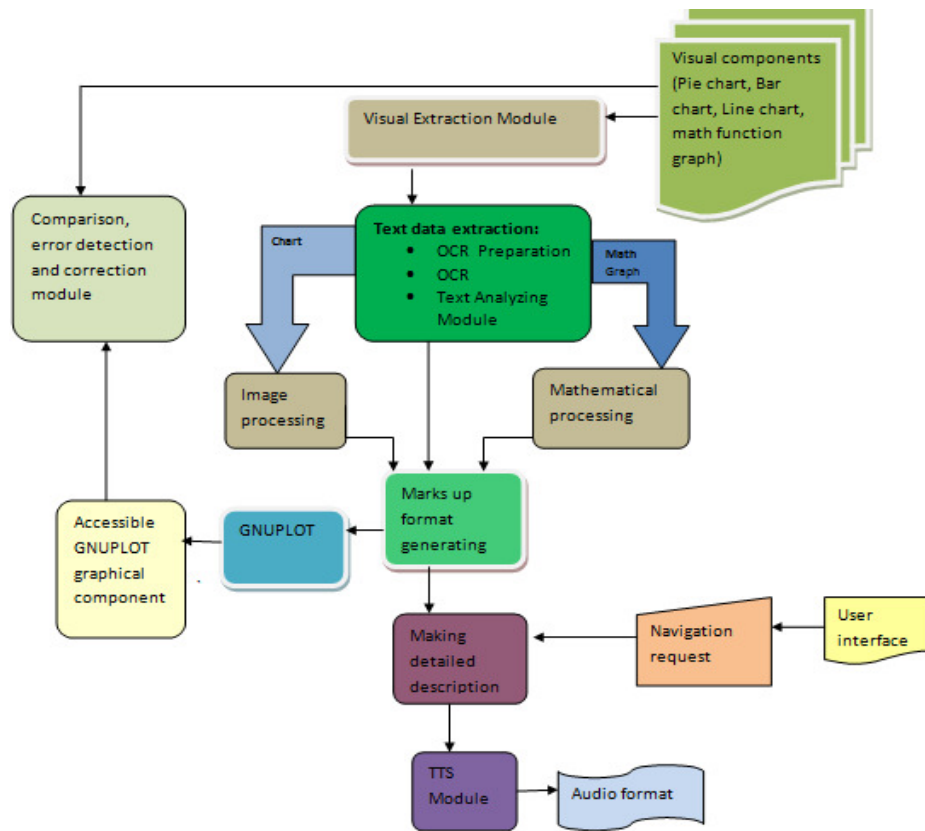
FIGURE 1: GraphicReader access system flowchart.

2.2 GNUPLOT

GNUPLOT is an open source command-line program that can generate two- and three-dimensional plots of functions, data, and data fits. It is frequently used for publication-quality graphics as well as education. One major accessibility benefit derived from GNUPLOT is encoded as plain text. Authors can create and edit it with a text-processor authoring tool. Plain text encoding also means that people may use relatively simple, text-based. This can help users with visual impairments, and can be used to supplement graphical rendering. GNUPLOT presents prepared, simple, text based and easy to use pattern to generate math's function graph, bar char and pie chart.

3. EXAMINED VISUAL COMPONENTS

3.1 Bar Chart

The Bar charts are one of the most commonly used visualization techniques and are often encountered daily, e.g. on newspapers, journals and magazines. Bar chart contains rectangles

which the height indicates the quantities of the corresponding variables. They usually show discrete and independent variables.

For a bar chart, the representation includes the number of bars in the graph, the labels of the axis, and information for each bar such as its label, the height of the bar. Some emphasized information implicit in bar chart are:

- The highest bar on the graph.

- The lowest bar on the graph

- Two bars which have the closest values.[16].

GraphicReader currently handles electronic images contain Bar chart produced with no overlapping characters. Also it hypothesizes standard placement of labels and axis headings. VEM for Bar chart contains several image processing steps such as OCR.

In order to extract vertical and horizontal axis labels and number of bars image must be sent to OCR engine.

Figure 2 illustrates   the sample of a bar chart which   indicates the   "Average Price of Advertisements of five different channels Grey scale mono graph ,image of vertical lines   and ,extracted text from OCR.
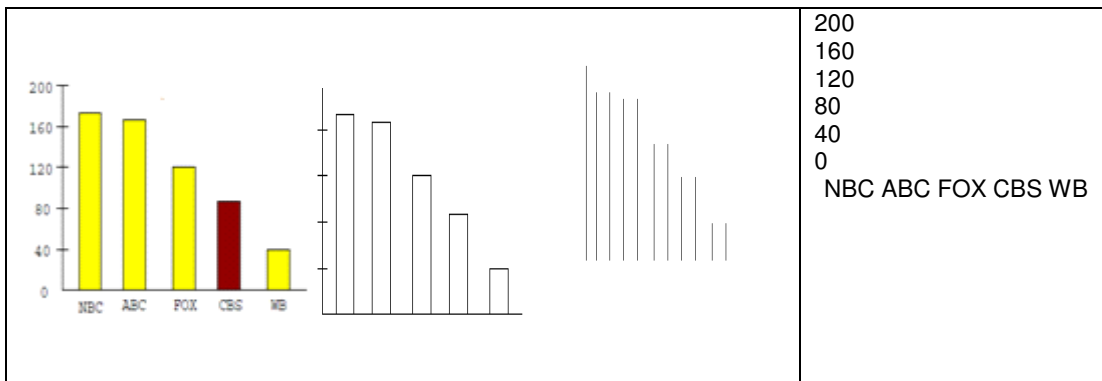
FIGURE 2: Sample of Bar chart, mono color image, vertical lines image, , OCR output.

Output Text file generated by OCR helps to recognize number of bars (in this example is five), labels of bars (NBC, ABC, FOX, CBS, WB) and scaling value on vertical axis(between 0 to 200 by step value 40). By converting the chart to grey scale mono graph, removing horizontal lines, splitting image of vertical lines to tiles and using histogram of each tile, number of black pixels in each bar has been obtained, the height of each bar can be calculated by comparison with vertical axis maximum value and its number of pixels. For example vertical axis has value 200 by 177 black pixels, thus the value of NBC bar by having 153 black pixels is 172 .Table1 shows relation between value of each bar and its number of black pixels.

Tile no	No of black pixels	Height of Bar
0	330	Vertical axis +NBC
1	153	NBC=200*153/177=172
2	147	ABC=2000*147/177=166
3	147	
4	106	FOX=200*106/177=120
5	106	
6	76	CBS=200*76/177=86
7	76	
8	34	WB=200*34/17=39
9	34	

TABLE 1: Height of bars in the sample bar chart

The following is XML codes generated by XML generating Module using data extraction from VEM:

<bar-chart>
<horizontal-axis-label>"Channel" </horizontal-axis-label>
<vertical-axis-label>"Millions of Dollars" </vertical-axis-label>
< vertical-axis-range >"0:200" < /vertical -axis-range >
<vertical-axis-tic>"40" </vertical-axis-tic>
<x,y>NBC,172</x,y>
<x,y>ABC,166</x,y>
<x,y>FOX,120</x,y>
<x,y>CBS,86</x,y>
<x,y><WB,39</x,y>
</bar-chart>

After XML generation, the system produces .gnu configuration file and .dat file to provide GNUPLOT package required files such as the following:

```
#Bar.gnu
reset
set output "bar.png"
set ylabel " Dollars"
set ytics "40"
set style fill solid
set term png truecolor
set xlabel "Channel"
set yrange [0:200 ]
set boxwidth 0.5
 plot "data.dat" using 1:3:xtic(2) with boxes
#Bar.dat
0   NBC   172
1   ABC   166
2   FOX   120
3   CBS    86
4   WB     39
```

Figure 3 shows an accessible image which is output result of GNUPLOT package. This image can be replaced by original image for more usage and getting more efficient and quicker results in terms of accessibility. Comparison this output image and inaccessible original input image has shown a little difference in value of bars height.
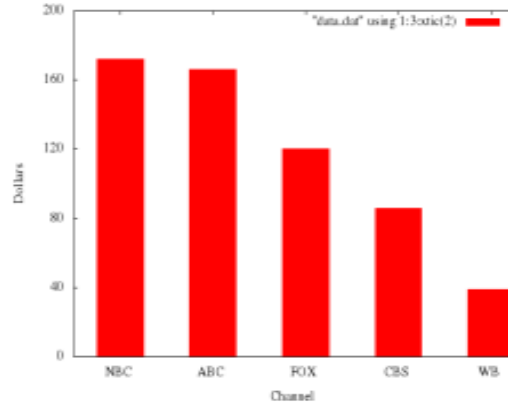
FIGURE 3: GNUPLOT output Bar chart.

3.2 Pie Chart

A pie chart is a circular chart divided into sectors, illustrating proportion. In a pie chart, the arc length of each sector (and consequently its central angle and area), is proportional to the quantity it represents [28] The symbols are the pie sectors. Each pie sector has to be matched with the variable via the legends. By the matching algorithm, the underlying data can be interpreted. VEM for pie chart supposes which legend information are in descending order.

Figure 4 illustrates the sample of a pie chart which indicates "Annual Market Share Analysis for three different products", extracted text from OCR and color histogram information extracted by image processing.

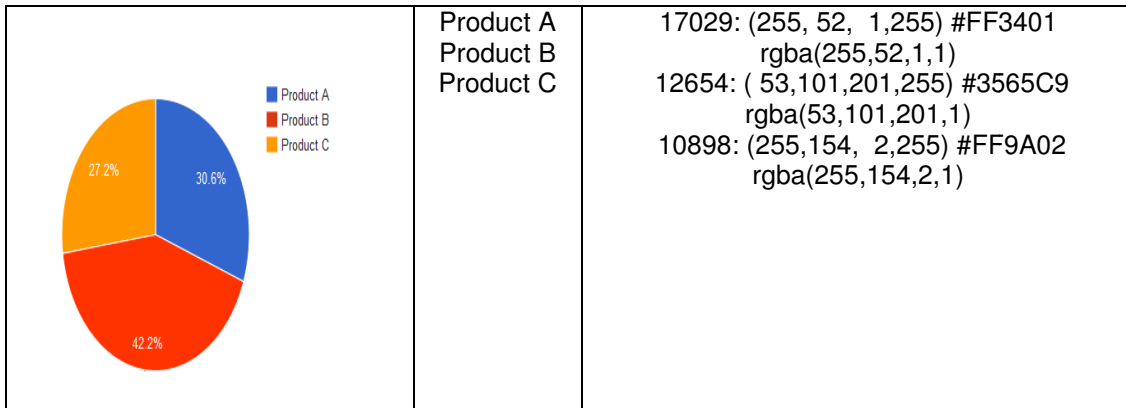|		

	Product A
	Product B
	Product C
		17029: (255, 52, 1,255) #FF3401
		rgba(255,52,1,1)
		12654: (53,101,201,255) #3565C9
		rgba(53,101,201,1)
		10898: (255,154, 2,255) #FF9A02
		rgba(255,154,2,1)

FIGURE4: Sample of Pie chart, OCR output, Histogram output.

As it is observed from histogram information the total number of colored pixels is 17029+12654+**1**0898=40581.Table 2 has shown the percentage of each product.

Slot	Percentage	Accuracy level
Product A	17029*100/40581=41.96%	99.4%
Product B	12654*100/40581=31%6.	98.7%
Product C	10898*100/40582=26.85%	98.7%

TABLE 2: Slots percentage of sample pie chart.

XML codes generated by Marks up Format Generating Module are as the following:

```
<pie-chart>
<title>" Annual Market Share Analysis for three different products"" </title>
<no of slots l>"3" </no of slots>
< slot-1 >"Product A,41.96%" < /slot-1 >
```

< slot-2 >"Product B,31%" < /slot-2 >
< slot-3 >"Product C,26.85%" < /slot-3 >
</pie-chart>

3.3 Line Chart

Line chart displays information as a series of data points connected by straight line segments [29]. It is a basic type of chart common in many fields. It is created by connecting a series of points that represent individual measurements with line segments. A line chart is often used to visualize a trend in data over intervals of time [30]. A line chart is typically drawn by two crossed lines, called axes. The horizontal axis is called the x-axis which represents the independent variable and the vertical axis is called the y-axis which *represents* the dependent variable. The line chart may contain additional lines drawn parallel to both axes which is called grid. Each axis indicates significant values with small marks, called ticks. A short description of the axis is label The chart overall description is title.

For line chart, Graph digitization is a process involves converting the pixels in the image of line chart to original (x, y) data values. Extracted original (x, y) data values from the image helps to generate digitizing data table [31].

Therefore graph digitization has two responsibility, First finding the position of pixels of the main graph in the image and   then   running mathematical function for all found pixels to assign a coordinate system to the pixels in the graph based upon the extracted scaling values, line chart image size ,and line chart origin point pixel position. Although the basic concept of converting the image pixel values to scaled values is straightforward, practical consideration such as specifying accurate origin point must be addressed.

- Finding graph pixels position process includes several image processing steps as the following :

    ➢ Resizing image to 640x480
    ➢ Removing all gridlines it is essential to discriminate grid lines from the axes.
    ➢ Obtaining graph image without axes and text by using color separation and color histogram information
    ➢ Conversion graph only image to grayscale
    ➢ Flipping image to move origin point from top left corner to bottom left corner
    ➢ Negation graph image
    ➢ Converting image to a text file including information of each pixel location
    ➢ Removing all black pixels information from text file .Remaining pixels are body graph pixels
    ➢ Sorting data in text file based on first column(x values)

- Conversion graph pixels position to original (x, y) data value   depends on finding origin point pixel position, obtaining X-ratio and Y-ratio. To approach this goal, following step must be done:
    ➢ Obtaining axes image without graph using color separation and color histogram information
    ➢ Removing axes ticks and axes labels and generating an image which contains only horizontal axe.
    ➢ Converting horizontal axe image to a text file including information of each pixel location in horizontal line
    ➢ Removing all white pixels information from text file related to horizontal axe
    ➢ Obtaining position of origin by finding Minimum X value and Maximum Y value.(which   Xo, Yo are origin coordinate values, and W,H are weight and height pixel sizes of image)
    Xo= Minimum_X_ value
    Yo=480- Maximum_ Y_ value
    W= Maximum_X_ value- Minimum_X_ value+1

> H= Maximum_Y_ value- Minimum_ value+1
> X-ratio=amount of X_ticks*number of X_ticks/W= Max-x-Scale /W
> Y-ratio=amount of Y_ticks*number of Y_ticks/H= Max-y-Scale /H

➢ Conversion pixel to data has been done using following formulae:
(which Xp,Yp are pixel position coordinate values, and X,Y are original value in chart)
X= (Xp –X`o)*X_ratio
Y= (Yp-Yo)*Y_ratio

➢ Converting X floating values to integer using function "floor(x)" as the following :
If x<0: then return int(x)-1
If x>0: then return int(x)
Function floor(x) is used except for last X value which is used "ceil(x)" function to convert to integer.
If x<0: then return int(x)
If x>0: then return int(x) +1
Converting Y floating values to integer using function round(y)

After performing all these processes , digitizing data table of different value for X ,Y has been generated and with presenting numerical data in the form of a line chart relative values ,relative ratios and interpretation of trends , can be understood instantly. Also it should be useful in addition X, Y, slope of the individual line between two adjacent points has been calculated and added to data table. It should be calculate from this formula:

$$\text{Slope\_i} = ((Y_i - Y_{i-1})/ (X_{i} - X_{i-1}))$$

Calculating slope between two points helps to provide better summary description for line chart trends using the following rules:

➢ If a line segment slopes upward from left to right, the slope is positive.
➢ If a line segment slopes downward from left to right, the slope is negative.
➢ If a line segment is horizontal, the slope is 0 (zero).
➢ If a line segment is vertical, the slope is undefined.

Most considerable factors which must be described in a line chart are as the following:
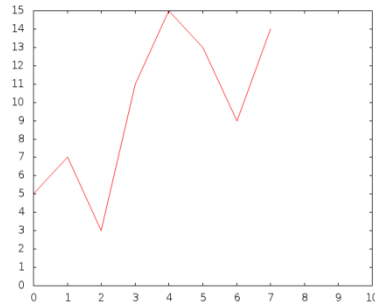
• Counting the number of lines.
• Identifying the line friction.
• Counting the number of bends on the line
• Counting the number of intersections

Table 3, indicates a table of original values which generate the sample line chart.

X	Y
0	5
1	7
2	3
3	11
4	15
5	13
6	9
7	14

TABLE 3: Original values of the sample line chart.

Figure 5 illustrates the sample line chart generated by above

FIGURE 5: The sample line chart .

The results of first VEM sub module are :
Data extracted Module 1:Max-x-Scale=10 ,Max-y-Scale=15
The result of second VEM sub module contain origin point pixel position and graph dimension
are: Xo=60 Yo=22 W=547 H=420

And finally table 4 shows the result of Graph Digitization before converting to integer values:

X	Y
0.18	5
1.05	6.92
2.10	3.035
3.16	10.96
4.03	14.85
5.09	12.89
6.14	9
6.98	13.98

TABLE 4: Data extracted from line chart by GraphicReader.

 The generated XML codes regarding extracted data table from sample line chart comes below:

```
<line-chart>
<title>" "</title>
<horizontal-axe-label>"X" </horizontal-axe-label>
<vertical-axe-label>"Y" </vertical-axe-label>
< horizontal-axe-range >" 0: 10" < /horizontal-axe-range >
< vertical-axe-range >" 0 : 15" < /vertical -axe-range >
< x_tick>"1"</x_tick>
< y_tick>"1"</y_tick>
<x0,y0>"0,5"</x0,y0>
<x1,y1><"1,7"></x1,y1>
……
<x7,y7><"7,14"></x7,y7>
<slope0>"2"<.slope0>
<slope1>"-4"<.slope1>
….
</line-chart>
```

The application provides users the opportunity to select several presentation options such as chart title, average point, maximum point, minimum point, start point, endpoint, or trend of the chart points. The user provides input to the navigation process through keyboard controls.

3.4 Graph of math's function
Graphs are visual presentation for math information and useful to illustrate qualitative information, which are sometimes even impossible to describe them .A graph is a picture that shows how sets

of data are related to each other. Generally structure framework of graph of the function contains two crossed axes which meet on origin point. The axes divide the plane into four quadrants. Scaled values are increased from left to right on horizontal axe and respectively from down to up on vertical axe. For describing graph of the function labels , scaled value and the range of each axes, where the function grows or decreases, where the maximums, the minimums and the flexes are and where the points of discontinuity are must be considered. Also following factors should be included in graph description [14][16].

- Meet points of the graph with axes: These points are obtained by assigning zero to "x "and finding "y "value and assigning zero to" y" and finding "x". This step requires solving the equation .For example one method for this purpose is using   :
  Quadratic Formula : ax2 + bx + c = 0 value of x is given by:

  $$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- Inflection point: The function is continuous at the point and the concavity of the graph changes at that point. This point is found by make the y", zero.

- Starting and ending points: These points are obtained by assigning minimum and maximum   values indicated on vertical axe to y   and finding x.

- Minimum and maximum points: These points are obtained by assigning zero to y' and finding x at this point :

  - If y ">0, then the point is maximum
  - If y "<0, then the point is minimum
  - If y"=0 ,then the point can be both or neither

- Shape: Regardless details, shape of graph function depends on function, so in most cases general shape of graph can be guessed by having function.   Some rules to find shape of graph are as the following:

  - If y=ax+b ,then the shape is a line
  - If y=ax2 + bx + c or quadratic functions   ,then shape of graph is parabola
  - If 'a' is positive, the graph will be 'U' shaped. If 'a' is negative, the graph will be 'n' shaped. The graph will always cross the y-axis at the point c (so c is the y intercept point).
  - If for an specific interval x2>x1 and y2>y1 ,or y'>0 ,then in this interval graph is increasing
  - If for an specific interval x2>x1 and y2<y1 ,or y'<0 ,then in this interval graph is decreasing
  - If for an specific interval y'=0,then in this interval graph is constant
  - If f(x)=f(-x) ,then graph has symmetry regarding y or even
  - If f(x)=-f(-x) ,then graph has symmetry regarding origin   or odd
  - If y">0 then graph is concave up
  - If y"<0 then graph is concave down

Figure 6 illustrates a sample for graph function using y=x^2+2*x as function formula.
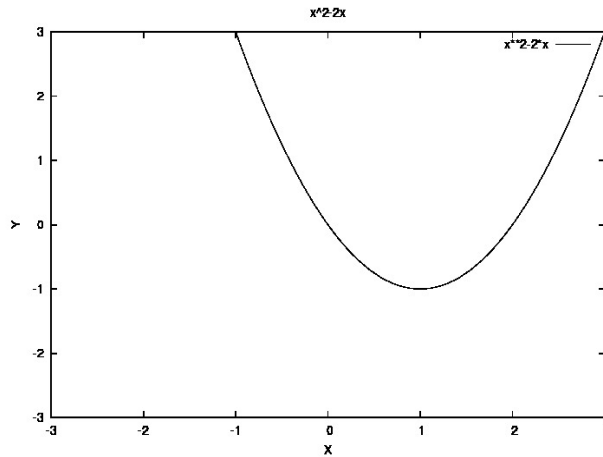
FIGURE 6. Sample of math's graph function sample.

Table 5 is the data table of above graph obtained from performing Data Digitization using mathematic processing.

X	Y
-3	15
-2	8
-1	3
0	0
1	-1
2	0
3	3

TABLE : function.   Extracted data from math's graph

XML codes are generated by GraphicReader using information extracted from mathematical analyzing.:

```
</graph>
<shape>"parabola"</shape>
<horizontal-axis-label>"X" </horizontal-axis-label>
<vertical-axis-label>"Y" </vertical-axis-label>
< horizontal-axis-range >"[-3:3]" < /horizontal-axis-range >
< vertical-axis-range >"[-3:3]" < /vertical -axis-range >
<horizontal-axis-tic>"1" </horizontal-axis-tic>
<vertical-axis-tic>"1" </vertical-axis-tic>
<equation>"x**2-2*x"</equation>
<vertical -intercept>"0,0"</vertical-intercept>
<horizontal-intercept>"0,0"</horizontal-intercept>
<horizontal-intercept>"2,0"</horizontal-intercept>
<starting -point>"-1,3"</starting -point>
<ending-point >"3,3"</ending-point>
/<minimum-point>"1,-1"</minimum-point>
</graph>
```

Description results of GraphicReader application using mathematical analyzing and data s
- Horizontal axis is labeled X and its range is between -3 to 3
- Vertical axis is labeled Y and its range is between -3 to 3
- Horizontal and vertical step value is 1
- This graph is plotted from the equation: y= x^2 -2x
- The graph is started from point (-1, 3) from top left quarter of plane until (3,3) located on top right   quarter of plane :

$$x^2 -2x=3 \rightarrow x=3 \quad x=-1$$

$$x^2-2x=-3 \rightarrow \text{no answer}$$

- Horizontal intercept occurs at   points 0,0 and 2,0(y=0)
- Vertical intercept occurs at point 0, 0 (x=0)
- Shape of graph is parabola and has minimum (a=1>0) value at (if y'=0$\rightarrow$ 2x-2=0, then x=1, y=-1) point (1,-1)

4.   COMAPRITIVE EVALUATION

 Comparison between this research method (using synthesis speech) and tactile representation for non textual components to vision impaired users shows that tactile representation requires manual preparation, a peripheral device and user training . Additionally, these original visual components must have some properties that may be transposed to a tactile representation thus limiting the possible attributes that may be included. For example;

- Pie charts must be enlarged to display the divisions of the circle. If numbers are shown, they should be preceded by the numeric indicator (number sign) regardless of whether the text is transcribed in literary or Nemeth (mathematics and science) code. The outline of the circle is tactually difficult to discern from the lines separating the divisions. A few of these lines may be stopped just short of the centre to avoid clutter. [34].

- Tactile representations for bar charts provide relative comparison of magnitude, not detailed, accurate values.

- Using tactile methods to access information in line charts provides presentation without measurement or scale. It may be difficult to differentiate between division lines that are close together.

- Tactile method for Math's graph only represents the shape of graph without any detail. Non-speech methods, when compared with synthesis speech, provides an overview of the data, as it can be delivered in a shorter time than synthetic speech. Encoding the data value in the pitch of a MIDI note is a common strategy used to represent relative values of numerical data. A user can scan the pie chart or math's graph to get an idea of the overall distribution of the data, without accessing to the exact values [33].

- Synthetic speech which is used in this research, delivers detailed information such as actual values and proportion to vision impaired users. It can be used to represent text labels and precise data values without cluttering the tactile image with Braille or raised letter components. However listening and comparing many values passively through speech alone can be laborious and time consuming, considering navigation through information and active representation solves the issue regarding sequential passive representation.

- Previous researches show accuracy for non speech audio method to transfer information of line chart is approximately 80%[12] and for virtual touch (Haptic) is between 85.56% and 94.07% [32]. This method utilized in this research showed an accuracy in conveying implicit data in line chart at approximately 98% and for pie charts, 98.7%.

5.   CONCLUSION AND FUTURE WORKS

This research, has designed a system to provide non-visual aural access to charts. The proposed approach has advantage of the ability to extract substantial information of charts from the image. Since the Visual Extraction Module assumes that it is dealing with a simple chart created by "GNUPLOT" and title position, axes ticks and, axes label locations must be in "GNUPLOT" forms, further work is required to extend this work to other charts layouts and digital formats. Issues remain with the user interaction and making the most appropriate and efficient description for effective communication of graphical information in documents to vision impaired

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