

# Microsoft Excel Charts<sup>TM</sup> Accessibility: An Affordable and Effective Solution

Siddhartha Gupta    Manshul V Belani    Dinesh Kaushal    M. Balakrishnan  
IIT Delhi\*            IIT Delhi\*            Sapiient            IIT Delhi\*  
gupta.sidharthasbs@gmail.com    manshulvbelani@gmail.com    dkaushal@sapiient.com    mbala@cse.iitd.ac.in

## Abstract

This paper describes an effort to make Microsoft Excel Charts- line, pie, bar/column, radar, scatter-accessible using NVDA screen reader. This solution fetches chart information- axis, axis title, series, trend line, chart title, chart area, plot area, legend, legend entry, legend key- using Excel Native APIs and presents the information for each element type as separate navigable object. User study results validate the usability of this solution.

## 1 Introduction and Motivation

Students in Science, Technology, Engineering and Mathematics (STEM) and non-STEM fields of education have to deal with a lot of quantitative data during their education. Not only that, a lot of such data is also produced by them as a part of some research, project or curriculum requirements. Charts are the most commonly used tools for representing such data. Microsoft Excel<sup>TM</sup> provides an easy to use interface for charts. Microsoft Excel supports 10 major categories of charts: Line, Pie, Bar, Area, Scatter, Stock, Surface, Radar and Combo (Available Chart Types, n.d.). Excel charts can be used by students in STEM branches or by professionals in their respective employment sector. However, this interface is not accessible to Visually Impaired (VI) Users. Lack of availability of affordable assistive solutions to this commonly used tool is a hindrance to many VI users.

In this paper, we propose a solution to improve the accessibility of charts in Microsoft Excel<sup>TM</sup>. This solution is based on the use of the native APIs of Excel. It does not depend upon any device other than a Windows based system and an open source screen reader, i.e. NVDA. Therefore it is an affordable solution which aims at making digitized charts and graphs accessible to the VI users. This solution can bring positive impact not only in education, but also in terms of employability of VI people. To sum up, in education charts are extensively used in domains like maths, economics, statistics or any field which relies on data representation. Similarly in employment charts are an important data visualization aid to users in managerial, banking, analytics and many other such positions.

## 2 Related Work

Different methods of presenting chart information have been researched.

Sonification relies on audio feedback. In this approach, different dimensions of sound are correlated with the data represented in the graph. For instance, the pitch of the sound could be used to represent increasing/decreasing trend of the data. However this approach is not applicable to charts like scatter or surface charts.

Similarly another approach focuses on using haptic feedback for conveying the information represented by charts. Haptic devices provide force feedback along different dimensions. Haptic cues can come in different forms of forces returned by the haptic device. Many researchers [(Jay, 2008); (C. Sjöström, 2003); (J. Fritz, 1999)] use a magnetic force to pull the user towards the needed virtual object. Virtual fixtures and vibrations [(P. Roth, 2002)], light force [(J. Fritz, 1999)] have also been used to provide haptic cues. However these systems mostly focus on simple line and bar charts. Also

difficulties like delimiting the graph space and maintaining contact with the graph are faced by the users while handling haptic feedbacks [(W. Yu, 2000)]. Additionally this requires special devices which further add to the cost.

The third approach used is textual representation of chart data. A commonly used way is to describe the chart textually in the alternative text attribute of excel charts which in turn is spoken by the screen reader. However this information has to be provided in a way that it is easily perceivable by a VI person. The major drawback in this approach is that it is inefficient and too verbose for the user. Another variant of this approach is auto summarization of chart data, BrailleR Project (Godfrey, 2012) provides summarized information based on the class type of a graph. However, it is not clear how will this solution behave if multiple series are plotted in a chart or if different class charts are plotted together on a chart.

ViewPlus Inc.'s IVEO(Gardner, 2005), a commercial product, converts graphical information to IVEO format, which are SVG files and have associated audio feedback. These files need to be printed using Embosser. The printed tactile file can then be placed on IVEO touchpad, on which a user can press on an object and hear the computer speak the audio feedback associated with that object. Another such product from ViewPlus, Audio Graphing Calculator (AGC) (Audio Graphing Calculator - ViewPlus, n.d.), describes the shape of the graph using audio tones and cues. It also provides option for tactile output of charts and graphs. However, both the products are quite expensive and have dependence on additional hardware. Another commercial device, Orion TI-84 Plus (Orbit Research, n.d.) makes graph accessible by providing speech output of graph coordinates or audio tones for graph.

Multimodal representation (I.A. Doush, 2009) uses a combination of one or more aforementioned approaches. For instance, haptic and audio clues are used by (I.A. Doush, 2009) to represent the chart. However as gathered from the user feedback, apart from the need for additional hardware, this approach has shortcomings like speed of navigation (I.A. Doush, 2010). Another tool MathTrax (NASA MathTrax Homepage, n.d.) relies on sonification and alternative text to represent charts and graphs.

One of the key objectives of open source movements like NVDA is affordability. Even the approaches described above that provide access to charts do not meet the criteria of affordability as they need special hardware as well as training to use them. The solution presented here is a simple enhancement that can be merged with NVDA and distributed as a part of it.

## 3 System Description

### 3.1 About NVDA

NVDA (Non Visual Desktop Access) is an open source screen reader for Windows based computers. It was developed by two blind developers - Michael Curren and James Teh in 2006. It runs on both 32-bit and 64-bit editions of Microsoft Windows XP or later. It has no additional hardware requirements beyond those of the operating system and requires around 50 MB of disk space. It is programmed in Python 2.7 and bundled with eSpeak, a free multi-lingual speech synthesizer (NVDA Features).

### 3.2 How NVDA Gathers Information

NVDA fetches information about GUI widgets, textual data, events, user interactions and OS events with the help of:

**Accessibility APIs:** These are special purpose APIs that provide information about the graphical widgets such as name, type/role, description, value, states, etc. Accessibility APIs also provide events to allow assistive technologies to monitor object's properties changes. Accessibility APIs include Microsoft Active Accessibility (MSAA), IAccessible2, Java Access Bridge and UI Automation.(Design Overview)

**Native APIs:** If application does not expose sufficient information via accessibility APIs but expose information via native APIs (not specific to accessibility) then these APIs can be used. For example, in Microsoft Excel™, information such as Font Name, Font Size, Color, Cell-coordinates can be retrieved by using COM (Component Object Model) APIs.(Design Overview)

**OS Functions:** Windows OS provides many functions to obtain system information and perform tasks. Information that can be obtained includes the class name of a window, the current foreground window, window location, process or thread ID. Tasks that can be performed include moving/clicking the mouse and sending key presses.(Design Overview)

## 4 Approach and Implementation

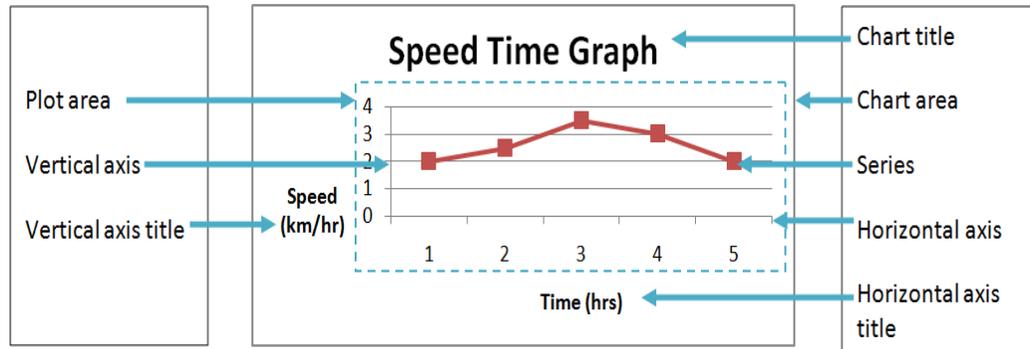
An Excel chart is composed of various element types including chart title, axes, series, legend, plot area, chart area. Not all element types are applicable to all chart types supported by excel. For instance axes chart element is not applicable to a pie chart. Different chart types and chart elements are listed in the excel enumerations xlChartType (XlChartType Enumeration (Excel)) and xlChartItem (XlChartItem Enumeration (Excel)) respectively. For a selected chart, information about chart elements-axis, axis title, series, trend line, chart title, chart area, plot area, legend, legend entry, legend key-is gathered using the excel chart COM object(Chart Object (Excel)). Further, each of these element types is modeled as a navigable/focusable object. That is, a class for each such element is implemented and is instantiated depending upon the selection event of that chart element. Within these classes, information for any related attributes particular to that chart element is also gathered using the excel chart COM object.

The Charts present in an excel sheet are listed in a dialog box, shown in Figure 1, and they can be easily selected by choosing a chart and pressing the Move to button. User interaction with charts, through arrow keys, triggers selection events. These events are handled by NVDA. Based on the currently selected chart element, appropriate accessible object for that element is created. This accessible object has attributes like name, state, role, description etc. which are filled by fetching the corresponding information from the Chart Object in Excel COM Model. Information pertaining to this accessible object is spoken by NVDA. Moreover, for each chart element, information specific to that element can be fetched by user using designated shortcut keys (nvaccess/nvda, n.d.)



**Fig. 1:** Elements List Dialog Box showing Charts Present in Excel Sheet.

For example, for each chart element in the line chart shown in Figure 2, classes used are discussed below:



**Fig. 2:** Navigable Elements of an Excel Chart

There are two axes in the line chart above: the Category (Horizontal Axis) and Value (Vertical Axis). These axes are represented by a single class named `ExcelChartElementAxis` (`nvda / source / NVDAObjects / window / excelChart.py`). In this class, axis group and type attributes are fetched using Excel chart COM Object. Similarly the axis titles are represented by a class named `ExcelChartElementAxisTitle`. In this class, axis titles are fetched.

Chart Area and Plot Area are represented by classes `ExcelChartElementChartArea` and `ExcelChartElementPlotArea` respectively. In these classes, extra applicable attributes like chart and plot heights, widths are gathered.

Series is represented by class `ExcelChartElementSeries`. In this class, values of data-points represented in the chart are gathered along with the increasing or decreasing trend information as compared to the previous data-point.

## 5 Unsupervised User Study

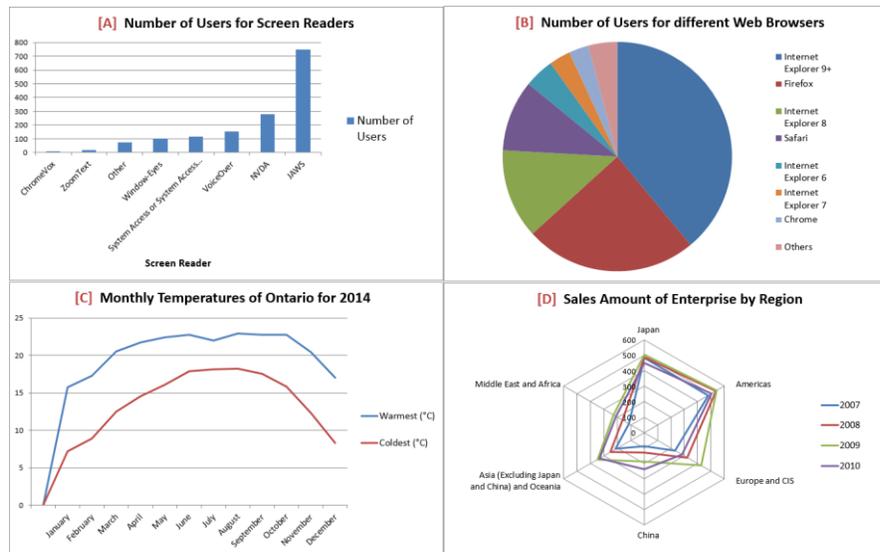
The user study was conducted with fourteen Visually Impaired users. As a part of this study, each user accessed Excel Charts (Column, Pie, Line and Scatter) using this solution and answered thirteen questions based on the given charts.

After performing the task, the users were asked to rate the solution based on certain parameters. Methodology, focus group and the parameters of evaluation are discussed in the sections below.

### 5.1 Methodology

An email, requesting users to participate in the user study, was sent to NVDA Users Mailing List (Other Community Sites, Blogs and Email Lists, n.d.) and VI Bankers in India (Visually Impaired Bankers Of India, n.d.). VI users willing to participate in this study were sent the Excel document containing charts and associated questions, instructions to use the solution and a questionnaire document for their feedback. They were further requested to mail the Excel task sheet and the questionnaire document back to us after performing the task. After performing the task, the users were asked to rate the solution based on the ease of accessibility, solution's impact on their productivity and also how did they manage to use Excel Charts earlier.

The Excel task sheet contained four independent charts: Column, Pie, Line and Radar as shown in Figure 3; and thirteen questions to be answered based on analysis of these charts. The questions tested understanding of data represented in the chart and statistical inferences drawn from analysis of the chart, such as Maximum, Minimum, Range and Trend of data representation (increasing, or decreasing).



**Fig. 3:** Charts Used in User Study: **[A]** Column Chart **[B]** Pie Chart **[C]** Line Chart **[D]** Radar Chart

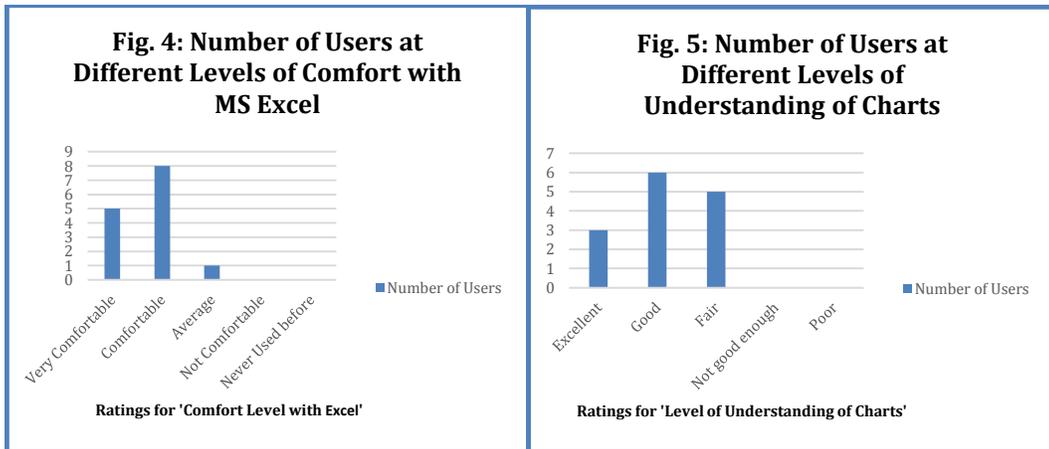
Bar Charts are similar to Column Charts except for difference in presentation. Therefore, accessibility of one implies that of the other. Similarly, Scatter and Line charts behave same in terms of accessibility. This is because, Line charts in Excel are collection of discrete points joined by line. Moreover, Combo Charts are a combination of two or more supported Excel charts. Therefore these charts were not considered separately.

## 5.2 Focus Group

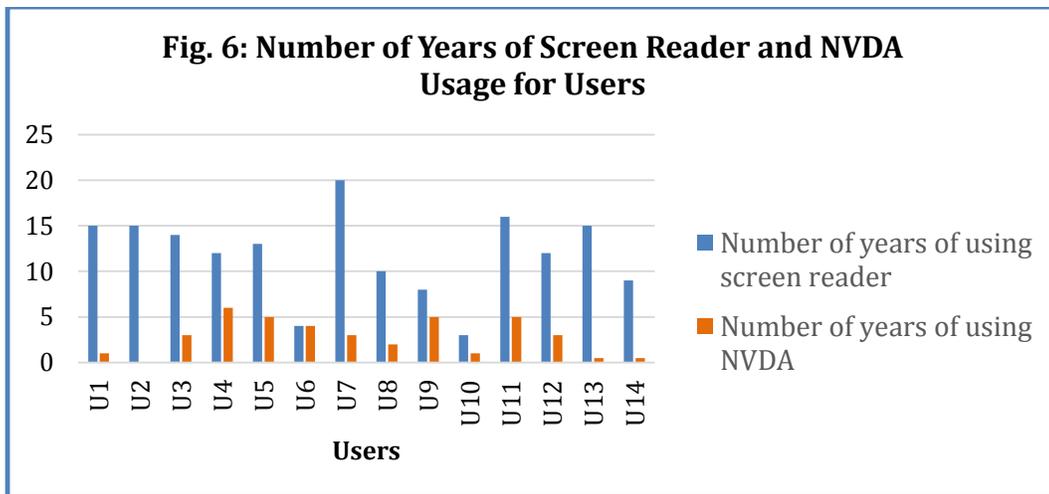
Fourteen VI users- eleven males and three females- participated in the study. These users were in the age group 16-54 years. Eleven employed users were having job profiles among Data Analyst, Accessibility Consultant, Sales Personnel, Lecturer, Bank Officer and Manager, Accountant, Engineer and Computer Administrator. While three users were undergraduate students with Mathematics as a common discipline.

Focus Group used Windows OS with versions 7 or later. Excel versions used were 2007 or later. Systems used for performing the task had RAM of 1 GB or more, while processors used had clock-speeds 1.60 GHz or more.

Comfort Level of Focus Group with MS Excel and Charts is shown in Figures 4 and 5. More than 92% of users rated their comfort levels with MS Excel as 'Comfortable' or 'Very Comfortable'. All users rated their understanding of charts as 'Fair' or better.



Screen reader usage and NVDA usage for Focus Group is represented in Figure 6. Screen reader usage of Focus Group, as gathered from their feedback, lies in range of 3 years to 20 years; while the average screen reader usage is 11.85 years. Similarly, NVDA usage of Focus Group, as gathered from their feedback, lies in range of 0 years to 6 years; while the average NVDA usage is 2.78 years.



### 5.3 Evaluation and Results

The effectiveness of this solution is evaluated based on the following parameters:

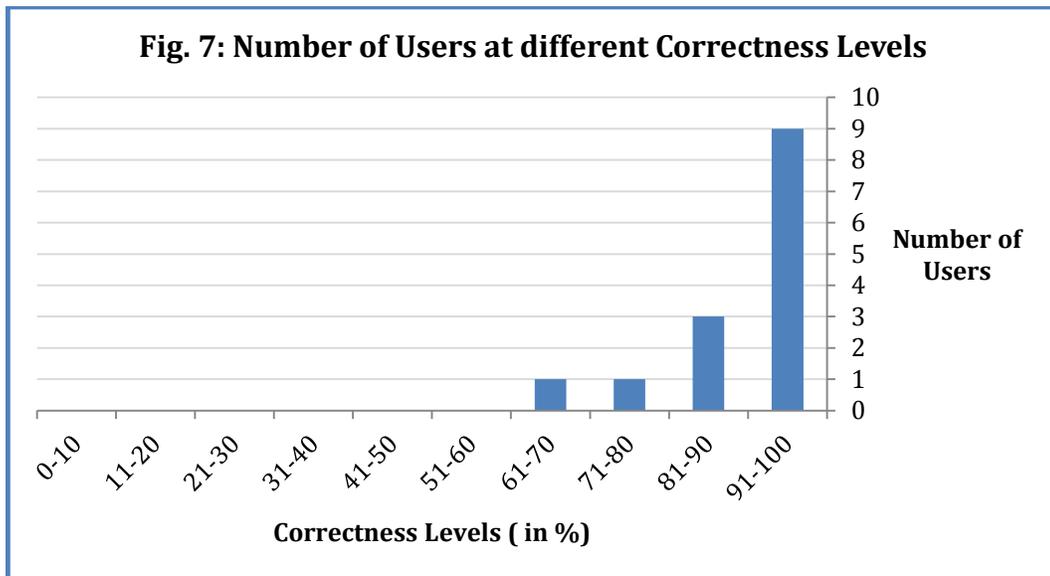
#### 5.3.1 Correctness

Correctness is measured as the percentage of number of correctly answered questions to the total number of questions asked in the task. That is,

$$Correctness = \frac{\text{Number of questions answered Correctly}}{\text{Total number of questions}} * 100$$

It was found during analysis of user study results that the first element of Line and Radar charts does not receive focus while navigation, hence this first element should be either blank or null. The Radar chart used in our study was not constructed using this knowledge and one of the questions based on radar chart was dependent on the data represented by this first element, the Total number of questions used for calculation of Correctness is taken as twelve instead of thirteen.

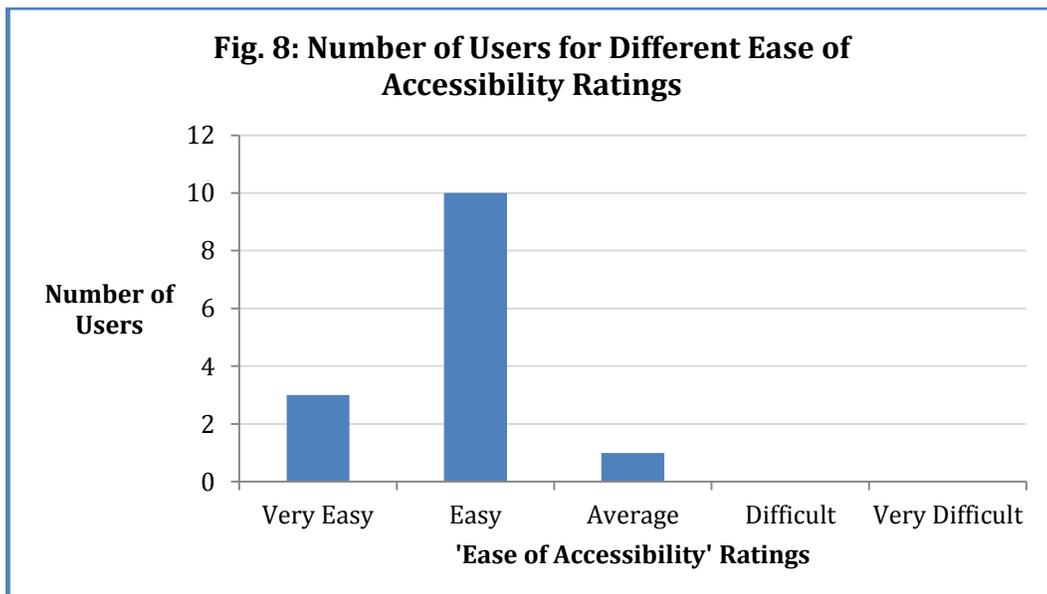
More than 85% of the users were able to answer the questions with more than 80% correctness as shown in Figure 7.



### 5.3.2 Ease of Accessibility

Ease of accessibility of this solution is calculated based on the user rating among the five options: Very Easy, Easy, Average, Difficult and Very Difficult.

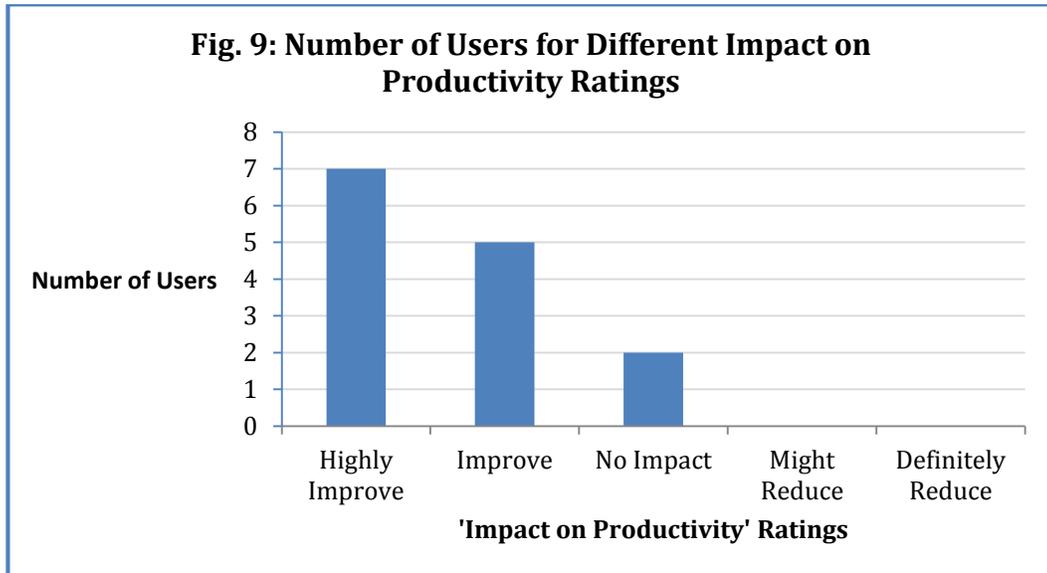
More than 92% of the users rated the solution as Easy or Very Easy to use as shown in Figure 8.



### 5.3.3 Impact on Productivity

Impact on Productivity of this solution is calculated based on the user rating among the five options: Highly improve productivity, Improve productivity to some extent, No impact on productivity, Might reduce productivity, Definitely reduce productivity.

More than 85% of the users rated that the solution will either 'Improve' or 'Highly Improve' their productivity as shown in the Figure 9.



### 5.3.4 Before and After Analysis

All fourteen users were able to independently complete the task using this solution. Earlier, 50% of these users took sighted help to perform tasks involving Excel charts while remaining never used Excel charts.

## 6 Conclusion and Future Work

Our solution makes six Excel Chart types accessible: Bar, Pie, Column, Line, Radar and Scatter. For these charts, the information about applicable chart elements are gathered and presented to the user. User Study results validate that the solution is effective and easy to use, as users were able to perform the task completely without any help; understand the data represented by the chart and draw inferences based on the data.

Through the analysis of user study results, we found that the first element of Line and Radar charts does not receive focus while navigation, hence the information pertaining to these elements is not spoken. Finding solution to this issue and making accessible the excel charts: surface, area and stock constitute our future work.

## 7 Acknowledgement

We acknowledge the contributions of Dr. Rohan Paul (Assistech Lab, IIT Delhi), Mr. Dipendra Manocha (Saksham Trust, Delhi), Mr. Vardhan Verma, Mr. Manish Agrawal (Sapient), Mr. Piyush Chanana (Assistech Lab, IIT Delhi). Mr. Dipendra Singh (IIT Delhi) and Mr. Siddharth (Assistech

Lab, IIT Delhi), for their guidance and motivation which helped us in this work. We would also like to thank Mrs. Suman Dogra (Saksham Trust, Delhi) for testing this solution and providing valuable feedback. We would also like to acknowledge the support provided by Hans Foundation, Centre for Internet and Society, Bangalore, National Association for the Blind, Delhi and Sapient Consulting. Our sincere gratitude goes to NVDA Developers – Mr. James Teh and Mr. Michael Curren, without whom this work couldn't be completed.

## 8 References

- Audio Graphing Calculator - ViewPlus*. (n.d.). Retrieved from <https://viewplus.com/product/audio-graphing-calculator/>
- Available Chart Types*. (n.d.). Retrieved 10 07, 2015, from Office: <https://support.office.com/en-in/article/Available-chart-types-a019c053-ba7f-4c46-a09a-82e17f3ee5be>
- C. Sjöström, e. a. (2003). Phantom-based haptic line graphics for blind persons. *Visual Impairment Research* 5, 13-32.
- Chart Object (Excel)*. (n.d.). Retrieved 10 07, 2015, from Office Dev Center: <https://msdn.microsoft.com/en-us/library/office/ff194426.aspx>
- Design Overview*. (n.d.). Retrieved 10 07, 2015, from NVDA Community: <http://community.nvda-project.org/wiki/DesignOverview#General>
- Gardner, J. A. (2005). The ViewPlus IVEO technology for universally usable graphical information.
- Godfrey, A. J. (2012). The BrailleR Project. *DEIMS*, (pp. 1-7).
- I.A. Doush, e. (2009). Making Microsoft Excel™ Accessible: Multimodal Presentation of Charts. *ASSETS*, (pp. 147-154). Pittsburgh, Pennsylvania, USA.
- I.A. Doush, e. (2010). Multimodal Presentation of Two-Dimensional Charts: An Investigation Using Open Office XML and Microsoft Excel. *ACM Transactions on Accessible Computing (TACCESS)*.
- I.A. Doush, e. (2010). Multimodal Presentation of Two-Dimensional Charts: An Investigation Using Open Office XML and Microsoft Excel. *ACM Transactions on Accessible Computing (TACCESS)*.
- J. Fritz, a. K. (1999). Design of a haptic data visualization system for people with visual impairments. *IEEE Trans. Rehab. Eng.*, 7, (pp. 372-384).
- Jay, C. e. (2008). Using haptic cues to aid nonvisual structure recognition, Article No. 8. *ACM TAP*, 5. *NASA MathTrax Homepage*. (n.d.). Retrieved from <http://prime.jsc.nasa.gov/mathtrax/nvaccess/nvda>.
- (n.d.). Retrieved from Github: <https://github.com/nvaccess/nvda/blob/master/source/NVDAObjects/window/excelChart.py>
- nvda / source / NVDAObjects / window / excelChart.py*. (n.d.). Retrieved 10 08, 2015, from Atlassian Bitbucket: [https://bitbucket.org/manish\\_agrawal/nvda/src](https://bitbucket.org/manish_agrawal/nvda/src)
- NVDA Features*. (n.d.). Retrieved 10 07, 2015, from NVAccess: <http://www.nvaccess.org/about/nvda-features/>
- Orbit Research*. (n.d.). Retrieved from [http://www.orbitresearch.com/orion-ti-84\\_details.php](http://www.orbitresearch.com/orion-ti-84_details.php)
- Other Community Sites, Blogs and Email Lists*. (n.d.). Retrieved from <https://github.com/nvaccess/nvda-community/wiki/Connect#english-users-mailing-list>
- P. Roth, e. a. (2002). A Comparison of 3 Nonvisual Methods for Presenting Scientific Graphs. *J. Visual Impairment and Blindness* 96.
- Visually Impaired Bankers Of India*. (n.d.). Retrieved from <http://groups.google.com/group/vib-india>
- W. Yu, e. a. (2000). Haptic Graphs for Blind Computer Users. In *Workshop on Haptic HCI* (pp. 41-51). Springer.
- XIChartItem Enumeration (Excel)*. (n.d.). Retrieved 10 07, 2015, from Office Dev Center: <https://msdn.microsoft.com/en-us/library/office/ff196373.aspx>
- XIChartType Enumeration (Excel)*. (n.d.). Retrieved 10 07, 2015, from Office Dev Center: <https://msdn.microsoft.com/EN-US/library/office/ff838409.aspx>

## 9 About the Authors:

**Siddhartha Gupta** is a Project Associate at IIT Delhi, Computer Science Department working as a software developer for NVDA Project. His areas of interest are Computer Vision and Machine Learning.

**Manshul V Belani** is a Project Associate at IIT Delhi, Computer Science Department working as a software developer for NVDA Project. Her areas of interest include Human Computer Interaction and Algorithm Design.

**Dinesh Kaushal** is managing NVDA India Project. He is a Senior Associate at Sapien. He has more than 10 years of experience in assistive technology development and accessibility implementation.

**M. Balakrishnan** is a Professor in the Department of Computer Science & Engineering at IIT Delhi. For the last 22 years, he is involved in teaching and research in the areas of digital systems design, electronic design automation and embedded systems. More recently the focus of his work has been in development of affordable assistive devices for visually impaired. He is involved in a number of projects that can enhance safe mobility as well as assist in education. His webpage is: [www.cse.iitd.ernet.in/~mbala/](http://www.cse.iitd.ernet.in/~mbala/)