Implementation of Chart Creation Functionality in Voice-Based Report Generator for the Visually Impaired

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Abstract Being able to communicate information is important in the information society, and data visualization is an important way to do so, but there are limitations to software accessibility for the visually impaired. For the visually impaired who have difficulty creating charts, which are essential for information transfer and understanding, we implemented a voice report generator supporting various chart drawing. The system allows users to say the title, type, data, and labels of a chart, and then generates a chart based on this information. The system supports a variety of plot types, has a simple user interface, and can be operated using a Bluetooth remote control. We conducted an experiment to evaluate the usability of this system and found that it is a convenient and efficient system for generating reports without much difficulty for visually impaired people.

Keywords Creating chart · Voice recognition · Visually impaired

1 Introduction

In the information age, where we are inundated with vast amounts of information and intelligence is a competitive advantage, being able to communicate information effectively is a key competency. Visuals are an important source of information because they help people retain data and information more intensely than text [1]. Given the importance of visuals, data visualization is the most efficient way to understand the nature and meaning of data [2].

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Data visualization is a popular way to get things done. However, this is a blind spot for blind people, who need other senses, especially auditory information, to access visuals. They often need an assistant to help them use the software, or they find it difficult to use. To address these issues, previous research has implemented image embedding in a voice report generator that allows blind users to create reports independently [3]. However, there is a limitation that they cannot create charts to visualize data.

In this paper, based on the previous research, we implement the following chart creation functionalities to enable visually impaired individuals to produce high-quality reports:

(1) Visually impaired individuals can input the title, type, data, and labels of the chart they wish to create using voice commands.
(2) The created chart can be reviewed and changed by voice in the "Edit File" function.

2 Related Works

2.1 Existing Command-Based Reporting Services

LaTex: LaTex is a document preparation system primarily used for documents related to technology and science, and it is widely employed for publishing purposes [4]. It proves to be especially efficient when dealing with complex mathematical equations, references, indexes, and similar elements. Additionally, one of its advantages is that it is a command-based document editor, unlike Microsoft's Word, which means users do not waste time on design aspects. Consequently, users can concentrate more on the content of the document. However, since it is a command-based document preparation system, it comes with the drawback of requiring a considerable amount of time and effort for users to learn and use the commands effectively.

While it is widely used and certainly a useful system, it is difficult for the visually impaired to use because it is typed rather than spoken, and because it is command-based, which is difficult for blind people to use.

2.2 Previous Research

VTR4VI: VTR4VI is a speech-based report generation system designed to enable visually impaired individuals to independently create reports, serving as the initial precursor to this research [5]. Users input commands and content via speech, and the system utilizes speech-to-text (STT) technology to insert these inputs into the report. Reports created using the VTR4VI system are in HTML format, so the process

involves inserting appropriate tags based on voice commands and placing additional content within these tags.

VReport: VReport is an enhanced version built upon VTR4VI, with the addition of an image insertion feature, aiming to enable visually impaired individuals to create high-quality reports that can include images [3]. In VReport, users input commands and descriptions of images via voice. The text-to-image functionality then retrieves suitable images from search engines. Subsequently, the image captioning feature allows visually impaired users to listen to voice captions for several retrieved images and select the desired one for insertion into the report.

Despite the initial enhancement of the previous research, VTR4VI, VReport has a limitation of not being able to create charts. Considering the impact of data visualization, it can be concluded that adding chart creation functionality to VReport would be highly beneficial for visually impaired users of the system.

3 Design and Implementation of Chart Creation (Referred as VReport+)

In this paper's implementation of VReport+, additional functionality has been added to create and modify charts such as bar graphs, line graphs, pie charts, and more, all through voice commands. The main purpose of VReport+ is to create a chart in the report by entering the chart type, title, data values, and data labels by voice to create the chart, the values entered by voice are based on the LaTex commands. Considering the report is in html format, we implemented the JavaScript to create the chart in the body of the html code.

3.1 User Interface

Considering that the main target users of this system are visually impaired, the user interface of VReport+ is designed to be as simple as possible and to facilitate the use of assistive devices [6]. Therefore, the interface consisted of only buttons as shown in Fig. 1, and when a button is clicked, the button is read aloud using text-to-speech (TTS) technology.

3.2 System Operation Principle

Figure 2 shows how the system works. The system's operation can be categorized into four phases.

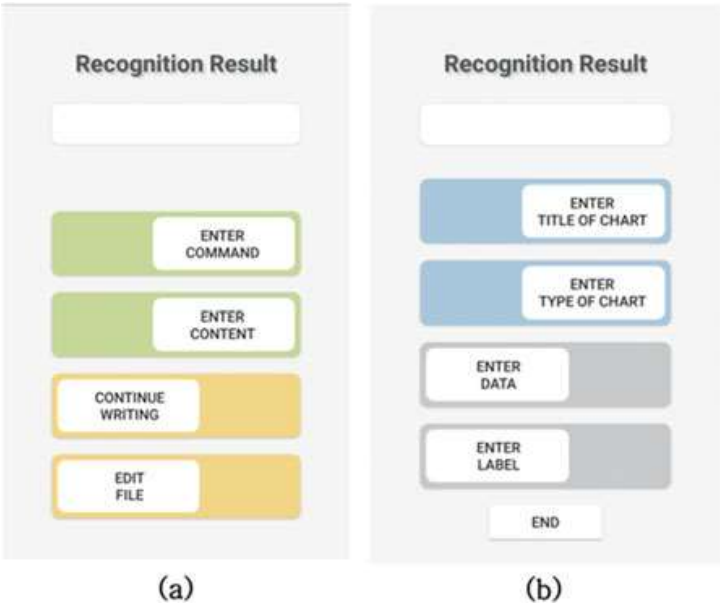


Fig. 1 User interface of VReport+. **a** Main, **b** adding chart

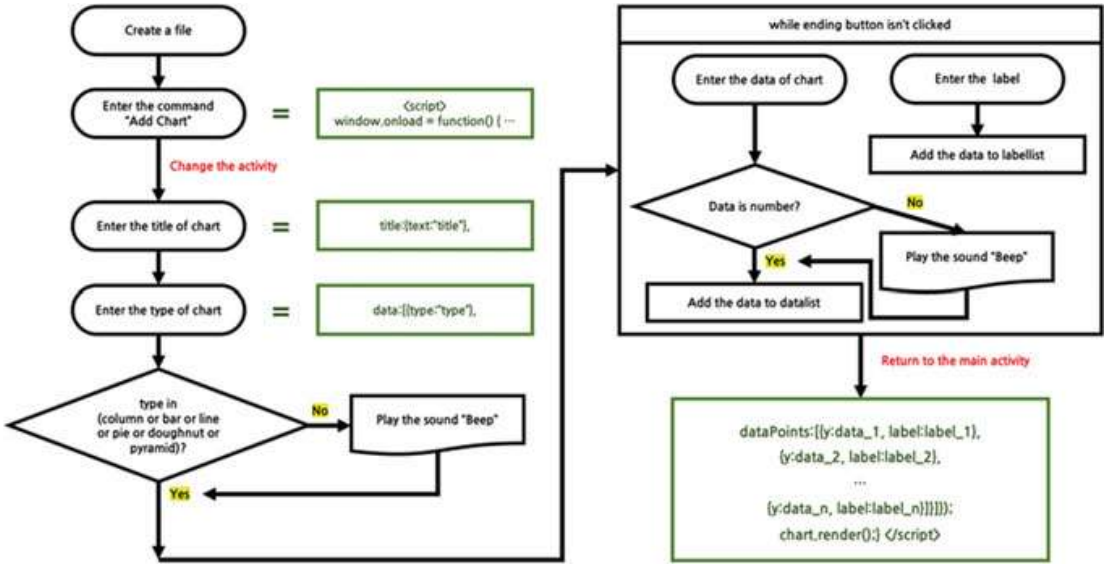


Fig. 2 Operation flow of the VReport+ system

Step (1) Enter the title of chart: To enter a title for the chart, click the 'ENTER TITLE OF CHART' button and then speak the title of the chart user wants to create. The title will be inserted into the 'title' section of the JavaScript code.

Step (2) Enter the type of chart: To create the desired type of chart, the user clicks on the 'ENTER TYPE OF CHART' button and speaks the desired diagram type. There are six types of diagrams that can be created: horizontal bar graph, vertical bar graph, line graph, pie graph, donut graph, and pyramid graph. Speaking the words 'ybar', 'xbar', 'line', 'pie', 'dounut', or 'pyramid' will generate a chart of that type.

If user says anything other than those six, the system will beep to indicate that it can't find the type of chart, and user can keep typing until it stops beeping.

Step (3) Enter the data and label: To insert data and label values, which are the core of the chart, user can click the 'ENTER DATA' button and speak the value of the data, and then click the 'ENTER LABEL' button and speak the label that corresponds to the data. However, to match the data with the label, the user must enter the label after entering the data.

When entering data values, the user must enter the data numerically. If the user enters a non-numeric value, the system sounds a 'beep' to indicate that an invalid value has been entered. As numbers are entered as data, the system adds them to the data list one by one.

In step 3, there are three possible cases:

1. The first is when the value entered as a data is not a number. This can happen when the system checks to see if the user is entering a label after entering normal data. If the system detects this situation, it treats the data as a zero to create the chart.
2. The second is when a user enters a valid value for a data value but does not enter a label for that data. This can be detected when the system checks to make sure that the user is not entering data consecutively. If it does, the system treats the label as 'blank' and lets you build the chart.
3. Finally, there is the case where both data and labels are entered correctly. In this case, the system will match the data and labels in the order they were entered to create a normal plot.

Step (4) End the creation of chart: When the user clicks the "END" button to end up charting, the chart is constructed from the values entered by voice in the previous step and written to the report. This is done in the head section of the HTML report, and the detailed implementation will be described in the next section.

3.3 Implementation of Chart Creation

To take into account that the reports generated by this system are in HTML format, the system creates a chart by writing JavaScript code in the head part of the HTML. Figures 3, 4, 5, and 6 show the behavior of the system and HTML for each scenario. However, the premise of all scenarios is that the data is 17 and the label is 'dog'. In addition, the variables dataCheck and labelCheck have a value of 1.

Scenario 1; the data has empty values, but the labels are entered correctly, i.e., the data has non-numeric values or no values, but the labels are all filled in correctly so that the total number of data is less than the total number of labels. As shown in Fig. 3, we can see that the algorithm fills the labels with zeros for the empty values and produces a normal plot.

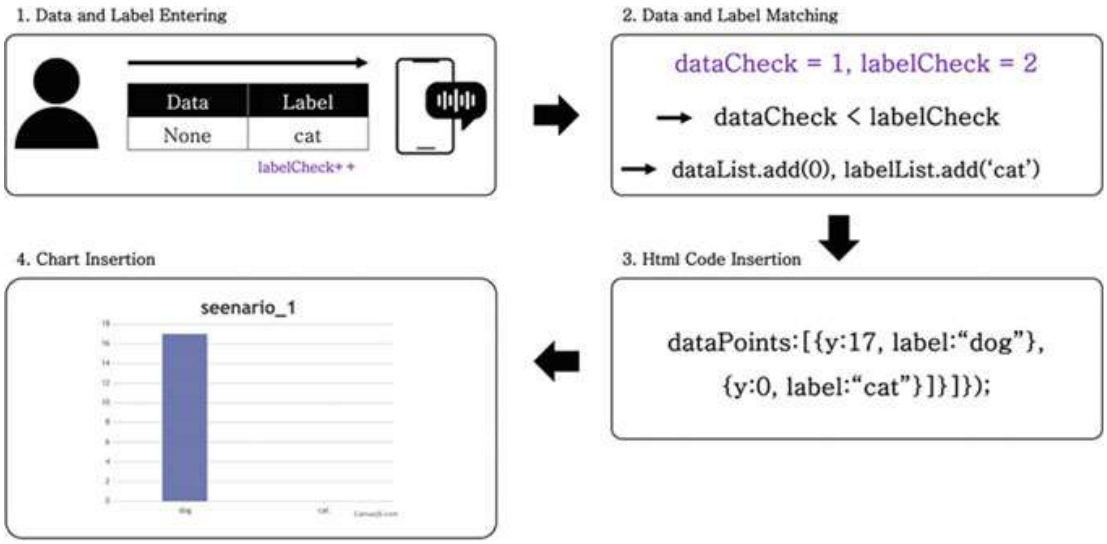


Fig. 3 Operation process of the VReport+ system for scenario 1

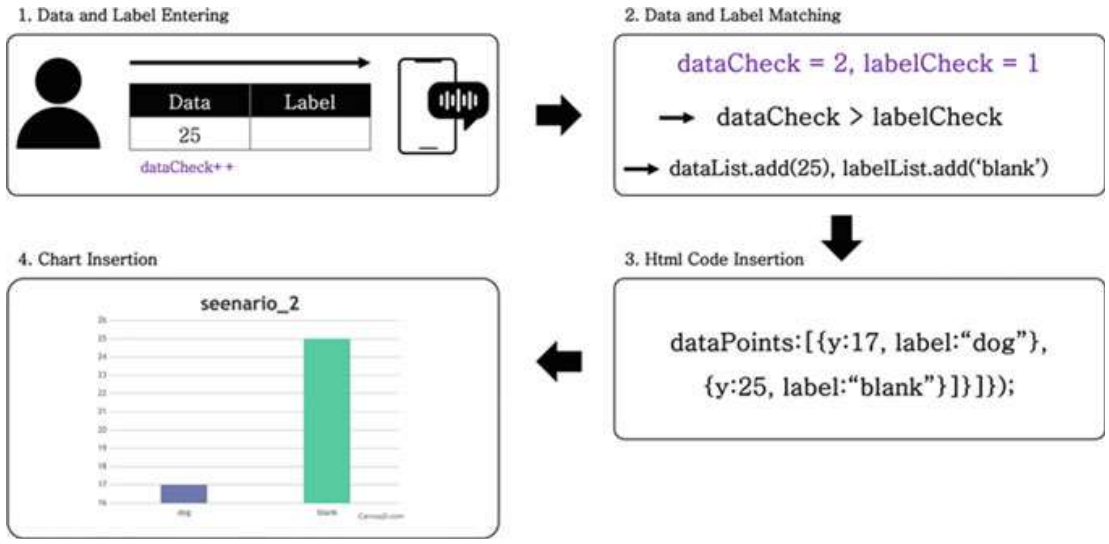


Fig. 4 Operation process of the VReport+ system for scenario 2

Scenario 2; the data is entered correctly, but there are blank strings in the labels, i.e., there are cases where no labels were entered, so the total number of labels is less than the total number of datas. As shown in Fig. 4, we can see that the algorithm fills the labels with the empty value 'blank', and then plots the chart as normal.

Scenario 3; data and labels are entered correctly. As shown in Fig. 5, we can see that the chart has been added without any problems.

Scenario 4; creating multiple charts. In this case, the system checks to see if the script code already exists. If the script code already exists, add only the code for charting within the existing script. As shown in Fig. 6, we can create more than one chart within the same report.

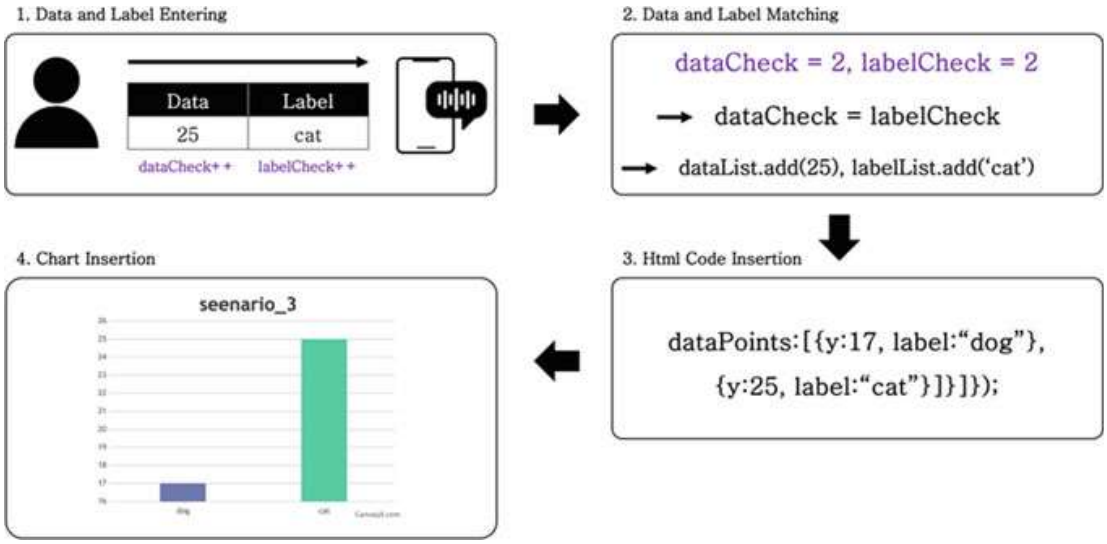
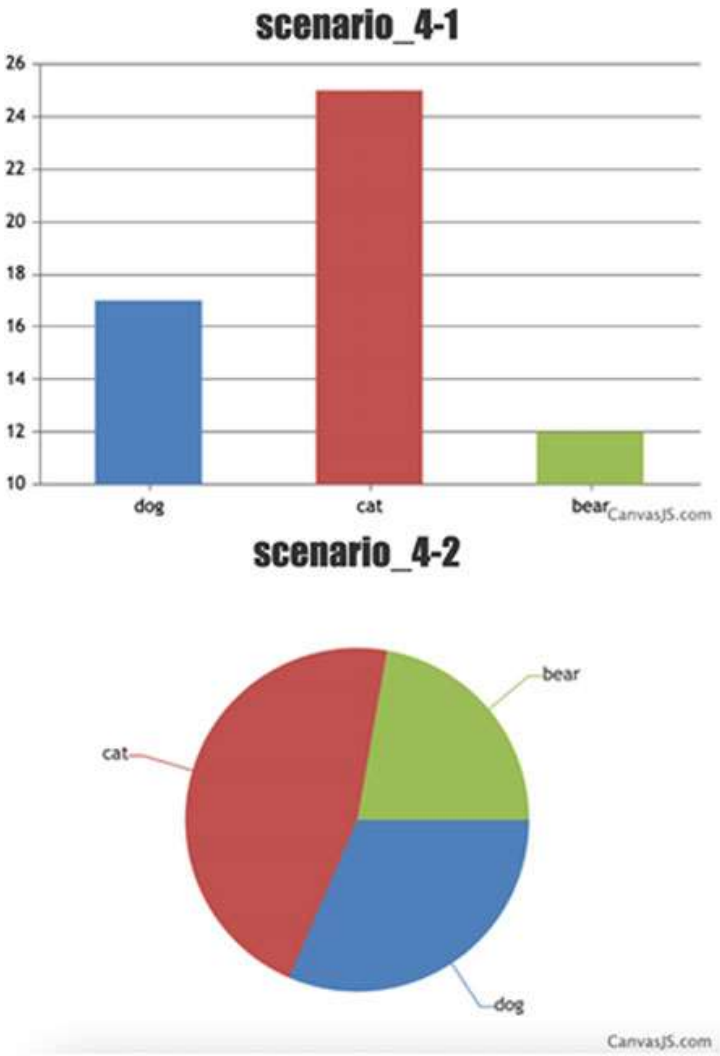


Fig. 5 Operation process of the VReport+ system for scenario 3

Fig. 6 Code for the chart and HTML report created in scenario 4



By verifying that scenarios 1 through 4 work, we can see that the system correctly creates chart in a variety of cases.

4 Evaluation

4.1 Usability Evaluation

Based on the goal of the system implemented in this paper, which is to enable blind people to efficiently add charts to reports, the usability evaluation aims to determine whether the goal is achieved. The evaluation aims to verify the effectiveness of the voice-based chart-plot feature. Therefore, we experiment with the time of the using system by blind and non-blind users.

Design of evaluation: The evaluation is conducted as a time difference between blind and non-blind. Therefore, we measure the amount of time a non-blind person spends using the creating chart function when blind and when non-blind to determine the effect of the difference in time. The criteria of the using system scenario during the evaluation are as follows. The first criteria is to create two charts. The second criteria is to create two charts with a minimum of five data points and a maximum of seven labels. The last criteria is to create a file and create a chart without using any other features of the system.

Result of evaluation: In this paper, the usability evaluation is conducted by the difference in the time spent using the system by blind and non-blind users, i.e., we focus on whether the system actually helps make the report more informative when used by blind users. The results of this experiment will be analyzed using a t-test, which checks for heterogeneity in the sample and determines if the results are statistically significant [7].

The time spent and the *p*-value of the *t*-test are shown in Table 1. The usage time is the average of the difference in time to create a chart between blind and non-blind users. Blind users took an average of 161.2 s to create a chart, while non-blind users took an average of 154 s. A t-test was performed on this and a *P*-value of 0.08 was obtained for an alpha value of 0.05, which is not statistically significant.

This means that being blind or not does not make a statistically significant difference. Therefore, we can confirm that visually impaired can use this system efficiently with similar performance to non-blind people.

Table 1 Usability evaluation results and corresponding *T*-test result

Time of adding chart (blind)	Time of adding chart (non-blind)	*P*-value
161.2 (s)	154 (s)	0.08

5 Conclusion

Focusing on the fact that visuals and data visualization can help convey information and improve comprehension, this paper implements a system to help blind people create charts by voice in reports. The user inputs the title, type, data, and label of the figure by voice, and the system adds the corresponding script code to the HTML report. Bars, lines, circles, pyramids, etc., can be created, and multiple charts also can be created. In addition, considering that the target users of this system are visually impaired, the user interface is as simple as possible and can be easily operated with a Bluetooth remote control, which is an assistive device.

Based on an experiment with 10 blindfolded people, the experimental results are significant in that the system is suitable for use by the visually impaired because it is easy to create charts with a few simple voice commands, and the blind can achieve similar performance to the non-blind without much difference.

Therefore, it can be seen that the charting function implemented in this paper is suitable for use by visually impaired people. The expectation of this thesis is that blind people can use this system to create charts and visuals in reports and produce quality reports.

In a follow-up study, we aim to implement math graphing and formula creation features not supported by this system. In addition, we would like to identify and improve practical improvements and limitations through usability evaluation with real blind people.

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