Compatible 2D Table Navigation System for Visually Impaired Users

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Abstract
Complex data comprehension is a hard task for visually impaired people due to the lack of viable supporting tools. We designed a web-based interactive navigation system to enable visually impaired people to explore data tables on common mobile touch devices. Users can grasp overview and query detailed information through zooming in and out of a table. We also elaborated to make interactions simple and consistent with the mainstream mobile screen readers to minimize the users' cognitive burden.

Author Keywords
Visually Impaired Users; Tabular Data; Mobile Devices

CCS Concepts
•**Human-centered computing** → **Accessibility;** *Accessibility systems and tools;*

Introduction
In comprehending complex data, charts are often a good option. They can filter out unnecessary noisy details to discover the underlying core insight. Also, charts as an external cognition can reduce cognitive workload for retention. Visually impaired people, however, often cannot access the charts and have to perform filtering, retention, and comprehension tasks under tremendous cognitive pressure. To alleviate this gap, we introduce an interface for blind users

that can navigate 2D numerical tables on standard mobile touch devices.

Background

Although there are several assistive tools designed to resolve the gap, many of them remain inaccessible due to impractical costs of adoption. For example, some tools may require special, often expensive, devices. Other tools may require users to learn a broad set of new interactions that are inconsistent with those of everyday devices. For this reason, communities of blind people tend to adopt only a few number of assistive tools, one of which is a screen reader provided in mobile touch devices.

Through our pilot observation, we have found that few blind people encounter complex numerical data in everyday lives, and most blind people do not have the motivation to understand them. Even for a complicated task like finding patterns in a sequence of 50 numbers, many relied solely on their memory. Some people tried to use other tools such as braille display or cellular phones, but they were not effective enough since they only provide sequential access to the data.

Therefore, we concluded that there are still needs for tools that are consistent with and accessible from standard touch devices, which can serve the following three objectives:

- O1. The tool provides an overview of data
- O2. The tool can filter out unnecessary details
- O3. The tool reduces the cost of retention

Design

In this section, we discuss how the design objectives lead to the design decisions of the interface. Figure 1 illustrates an overview of the interface.

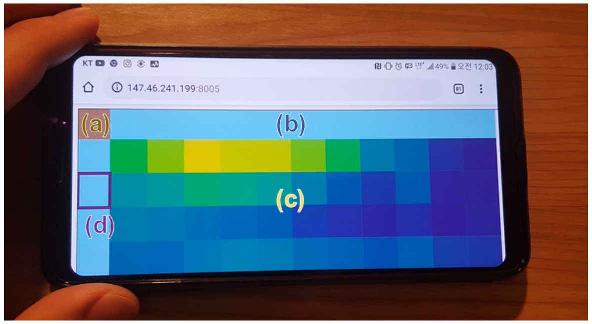

Figure 1: The interface consists of a grid of rectangular cells. There are four types of components: (a) a meta cell, (b) header cells, (c) data cells, and (d) a cursor.

Compatibility and Consistency

To make an interface that is compatible with standard mobile devices and consistent with the mainstream screen readers, we adopted the following design components:

- **Grid** The most frequent type of structured data that blind people encounter is of the tabular form. Also, the grid layout is simple enough for them to explore.
- **Virtual Cursor** Major screen readers, such as TalkBack of Android, use a virtual cursor to address the difficulty of placing a finger at an exact position.
- **Simple Interaction** Standard, medium-sized mobile devices are inappropriate for complex interactions. We tried to minimize unnecessary complications, such as interactions involving three or more fingers.

Overview and Filtering

Brushing over the whole area with a single fingertip can be a tedious task. To deliver a clear overview with minimum user interactions, the tabular view can be scaled down to a

	Default Mode		Reversed Mode	
Cell Type	*Primary*	*Secondary*	*Primary*	*Secondary*
Header	Label	Melody	Melody	Label
Data	Value	Pitch	Pitch	Value

Table 1: Primary and secondary information retrieved from each type of cell, depending on the navigation mode. *Label* indicates the name of the column or row, and *Value* indicates the actual number written in a cell. *Pitch* is determined by relative rank in the range of given data, ranging from 220Hz (A3) to 1760Hz (A6). *Melody* is a sequence of pitches in the row or column, played in order.

Interaction	Semantic
Single-tap	Retrieve primary data.
Double-tap	Retrieve secondary data.
Swipe	Move the cursor to an adjacent cell.
Swipe (2 fingers)	Lock the navigation area to the current row or column.
Drag (2 fingers)	Move the zoom window.
Zoom (2 fingers)	Adjust the size of zoom window.
Swipe (3 fingers)	Change the navigation mode.

Table 2: A set of available interactions and their semantic.

tiny size. If rows or columns get too small, they are binned to guarantee a reasonable cell size (e.g., cells are merged). Besides, zooming out can also assist people with low vision (e.g., blurred sight or tunnel vision) grasp context.

Reducing Retention Cost
For the interface to serve as an external cognition tool, users should be able to retrieve necessary data quickly. In our system, there are two types of data in each cell: descriptive and auditory. Users can decide which type of data is considered primary by changing the navigation mode of the system. Once the navigation mode is set, they can swipe over the cells to speedily retrieve the desired information. Table 1 shows the detail.

Use Cases

Suppose a blind user has a table with monthly sales data of four companies, which is shown in figure 1. The user first wants to find out which company has the highest average sales. Then, the user wants to find the maximum monthly sales of that company. Possible interactions are shown in table 2.

To identify the most productive company, a user can zoom out and explore the whole distribution, or alternatively, scan the melodies of each row and column. For the given situation, the user can easily decide that the first company is the most productive, and the maximum value is roughly in the middle of the row.

Now the user can limit the navigation area to the first row and start searching around in the middle. With primary information of data cells set to *Value*, the user can quickly find the maximum value.

Conclusion

In this study, we introduced a web-based 2D table exploration tool designed for visually impaired people. In order to cover users who are not used to dealing with complex data, we focused on developing an interface that is compatible and consistent with existing mobile devices. We claim that our interface can serve to reduce the gap between sighted and unsighted people in terms of complex data comprehension.

The following are possible future work.

Direct conversion from charts

On the web, simple charts as pie charts, bar charts, and line charts often miss proper text alternatives and exclude visually impaired users. Our system can be extended to import data directly from the charts. Even the scatter plots could be approximated to a density map.

Interaction Scheme for Low Vision

Both groups of people with total blindness and low vision can benefit from using our interface. However, depending on the group characteristics, features that are considered crucial may differ. In later works, interactions can be designed separately so that the most important features are the easiest to use.

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