A Proposal for an Automated Method to Produce Embossed Graphics for Blind Persons

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Abstract. The aim of this paper is to provide examples illustrating the conditions for effectively functionalizing the "method of converting graphics into a form that can be perceived using senses other than sight" in the field of HCI. Specifically, it is shown that advantages that method are fully achieved with the implementation of a prototype embossed graphics output function for the statistical analysis software R. In attempting to generate automated tactile graphics from the output of any kind of graphics software, the strategy described below will be useful: a. To investigate whether the intermediate graphics format used in the relevant software consists of primitive vector format drawing commands and character printing commands that handle characters as codes, and b. If the latter conditions are fulfilled, to perform conversion to tactile graphics at the stage of graphics data expressed as that intermediate format.

Keywords: blind person, embossed graphics, vector format.

1 The State of the Art

Among sighted persons, communicative expressions are often performed using graphical representations as well as by using words. There are significant constraints on making good use of such graphical representations for blind persons. For expressions using words, there are established methods for expressing the words themselves as a braille transcription or by having them read out by voice. Effective methods of communication are being explored on the basis of such methods. On the other hand, standard methods have not been established for graphical representations, and there are limitations on the ability to make use of such representations. In what follows, methods of presenting graphical representations for blind persons that have a particularly notable relationship to Human-Computer Interaction (HCI) are described, and their advantages and disadvantages are summarized.

1.1 The Method of Translating Graphics to Explanatory Sentences

As a substitute for graphics, sentence-based explanations are generated that interpret the content depicted by the graphics. This method has been widely used both for

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braille transcriptions and for reading out by voice. Particularly for reading books [1], this method is almost only one available. A typical example within the HCI context is to provide explanatory sentences to a graphics object using the ALT attribute in the HTML specification [2]. To provide an audio description to a movie also falls under this method [3].

An advantage of this method is in using the same media to convert graphics to a medium used for presentation by words (braille or voice). In addition, the mental workload imposed on the user (the blind person) is sufficiently low if appropriate explanations are provided.

A first disadvantage is that human intervention is necessary to generate the explanatory sentences. Primarily, this is a limitation that results from only humans being able to judge what is intended by a picture (recent developments in image recognition are mitigating this limitation). A more basic problem is that the function graphics perform in a document cannot be recognized without understanding the context in which they are used. For example, when a picture of a national flag appears in a document, whether the flag's design is being discussed or if it is used as an icon to represent the country that uses the flag can be grasped after understanding the context in which the picture is used.

The disadvantage of human intervention necessarily results in a second disadvantage: the impossibility of providing on-the-fly accessibility to graphical representations. This problem may be not severe in a classical form of assistance for blind persons involving the provision of previously prepared static content as material transcribed in braille or read by voice. However, it is a critical limitation in HCI, which is characterized by the dynamic generation of content. Recent services that use cloud sourcing [4] are showing hints of how to solve this problem, but this does not eliminate this limitation.

A third disadvantage with this method is that it is difficult to convey an object that is effectively represented to the user graphically. Typical examples are details of trends represented by line graphs and complex topography represented by maps.

1.2 The Method of Transcribing Values Represented in Graphics into Characters

For graphics that are intended to show values intuitively (e.g., graphs and charts) there is a method for transcribing the values (numerical values) represented in the graphics into characters using a tabular format.

A first advantage of this method is that it can show values exactly (in some cases it will be more exact than the source graphics). Therefore, it is often used for content with strict requirements (e.g., an examination questionnaire transcribed into braille).

Next, a second advantage is that, if sufficient numerical data values are supplied, this method can be applied to dynamically generating content on-the-fly. This means that the human intervention necessary for the method of translating graphics to explanatory sentences is not required.

A first disadvantage of this method is its lack of the intuitive understandability of the visual presentation of graphics (which is often a reason to use graphical representation). With supplied numerical data, the user must reconstruct the information intended in the graphics, so the mental workload is relatively heavy.

A second disadvantage is that, as in Method 1 (the method of translating graphics to explanatory sentences), it is difficult to convey an object that is effectively represented to the user graphically.

A third disadvantage is that it is not applicable to graphical representations that cannot be shown by the extraction of numerical values (such as pictures and nearly all maps).

1.3 The Method of Converting Graphics into a Form that can be Perceived Using Senses other than Sight

This is a method involving converting a two-dimensional representation shown as graphics into another form (generally tactile graphics) that can be perceived using senses other than sight (practically the sense of touch) with a one-to-one conversion. It is generally used for graphics for which the two-dimensional layout is critically significant (e.g., maps). For output, braille embossers that have a function of embossing graphics and swellpaper are widely used. There have also been attempts to implement and apply presentation using a refreshable two-dimensional braille display. In addition to using the sense of touch, there have been attempts to represent curved lines on graphs using audible tones [5-6].

A first advantage of this method is that it can represent an object that is effectively represented graphically as-is. Although it cannot be assumed that presentation via the sense of touch has the same intuitive perceptibility as that of the sense of sight, there is a high value in representing an object represented as graphics as-is. Compared to the former two methods, being able to reproduce the details of a trend represented by a line graph and complicated topography represented by a map is a critical advantage.

A second advantage is that on-the-fly generation of tactile graphics is possible if machine-understandable data used to render the source graphics is supplied. As an attempt to make good use of this advantage, there have been studies and developments to realize automated tactile map creation systems [7-8] intended to be equal to online map viewing services (e.g., Google Maps [9]).

A third advantage results from the two above advantages: namely that a blind person can take direct part in activities which require the use of graphics. Such activities are innumerable. One typical example is exploratory study using statistical methods: that is, to investigate relationships among data plotted as various forms of charts.

A disadvantage of this method is that it is difficult to realize the same intuitiveness and lucidity for the sense of touch as well as for the sense of sight. For example, to convert a national flag icon used to represent a country into a tactile graphic would only degrade the speed of understanding: the name of the country should be written instead of the tactile graphic. Color representation such as that used in normal graphical representation is not available in tactile graphics. Therefore, this method should be applied for uses in which a one-to-one conversion can derive high utility (e.g. graphs and maps).

A second disadvantage is that the requirement for the second advantage, the supply of machine-understandable data that is used to render the source graphics, is severely limited at present. Thus, many studies [10] and developments that aim to realize this method (the method of converting graphics into a form that is perceptible using senses other than sight) are being implemented that attempt to recognize rendered graphics (bitmap data) then convert them to tactile graphics. In such approach using machine recognition, it is difficult to ensure the practical utility of the fully automated conversion.

In particular, it is difficult to recognize characters contained in graphics as a string rather than an image: in tactile graphics, characters contained in the source graphics must not appear as glyphs but as transcribed braille characters. Therefore, these studies have concentrated on the development of authoring software for sighted persons that furnishes tactile graphics [11].

As a result, the third advantage of this method, that a blind person can take direct part in activities that require the use of graphics, is not being sufficiently realized.

2 Scope of this Work

The aim of this paper is to provide examples illustrating the conditions for effectively functionalizing the third method, which has a high affinity with HCI from among the three methods described above. Specifically, it will be shown that the three advantages of the third method are fully achieved with the implementation of a prototype tactile graphics output function for the statistical analysis software R's graphics output. R [12] is widely recognized and utilized as advanced statistical analysis software. Thus, to achieve access to its graphics output function would be very useful to realize an environment in which a blind person can take on an active role in exploratory study using statistical methods.

The BrailleR project, conducted by Jonathan R. Godfrey, is a case of research and development focusing on such potential of R. This project can be summarized as an attempt to provide textual information to a blind user in conjunction with a graph, [13] and therefore it falls under Method 2 (the method of transcribing values represented in graphics into characters). With respect to the BrailleR project, the present research has the merits of being able to represent an object which is effectively represented as graphics as-is (e.g., trends of line graphs and distributions of boxplots), and of being able to comprehensively support R's graphics output. Moreover, with respect to the research aim of generating tactile graphs from raw numeric data, the present research is useful in making good use of the various graphical representations that are supported by R (e.g., line graphs, boxplots, candle charts and so on).

3 Implementation of the Prototype

R outputs various plots to computer monitors and files in many image formats using a mechanism called GRdevice. Graphics data is first rendered within R by many graphics functions using a common intermediate format. The production of final output data is handled by drivers that support the respective output formats after reading this intermediate format data. The list of supported image formats includes not only bitmap formats such as PNG and JPEG but also vector formats such as PostScript and SVG. Therefore, a vector format is used at the stage of the intermediate format. Letters in a graphic are expressed not by sets of vector data that represent glyphs but by character codes.

There are differences in the supported drawing commands among the various vector image formats. Therefore, at the stage of the intermediate format, only primitive drawing commands which are supported by all vector image formats must be used. The principal commands used in R's intermediate format are limited to a command to draw any straight line and a command to draw any arc of a circle. To implement automated tactile graphics output for R's graphics output, major tasks are to create line drawing functions that correspond to these two drawing commands and to print characters appropriately.

The present research is currently being carried out to develop software to generate tactile graphics from data described using the PicTeX format [14].

The PicTeX format is one of R's supported vector image formats. This approach was chosen for the following reasons: the drawing commands used in the PicTeX format have nothing in addition to R's intermediate format, so they are substantially the same; the set of drawing commands in the PicTeX format is highly human-readable, and debugging in the software development is easily done; and because it would be troublesome to maintain consistency with all of R's program code in the case of integration in R as one of the drivers that supports all the output formats.

The Ruby programming language was used to develop the software. Using Ruby enables it to run on a multi-platform basis similar to R. Tactile graphics are output by the ESA721 (Ver'95) [15] braille embosser, which is widely used in Japan. Therefore, this software produces tactile graphics as embossed graphics.

Special care is needed to transcribe characters in graphics generated by R into braille in tactile graphics. There are often problems in simply transcribing characters in graphics into braille, such as a set of braille characters lying on top of another object or running over the edge of the paper. This reasons for this are because: in general, a braille character occupies a larger space than a character in the source graphics; and braille is specifically used as horizontal writing, so the method of rotating a character string vertically or obliquely (such methods are often used in graphics) cannot be used.

Therefore, in the present research, a labeling approach was adopted. Strings of characters in graphics are assigned labels from “a” to “z” according to their order of appearance. In the tactile graphics, only these one-character labels are printed on the respective points where the original strings would be positioned. A list showing pairs of the respective labels and strings is printed on another sheet of paper. Referring to this list, users can understand what string is represented by the label in the tactile graphic.

4 Results

Examples of embossed graphics output are shown in the next figures. Fig. 1 is a line graph plotted by R, showing monthly average temperatures in Tokyo in 2012. The same data output as an embossed graphic is shown in Fig. 2. Braille labels are marked with corresponding block letters.

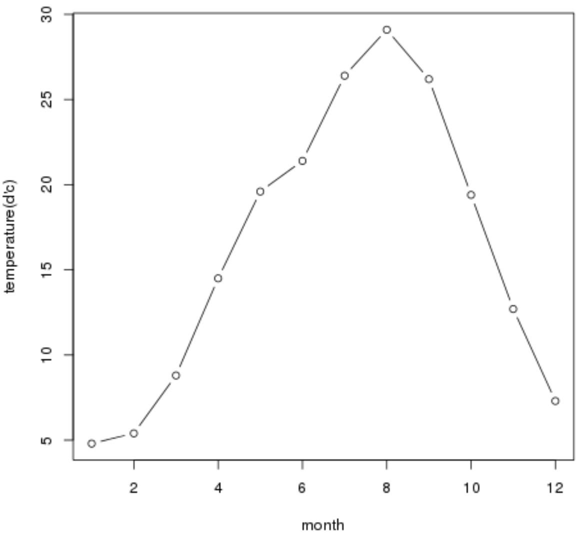

Fig. 1. An example of a line graph plotted by R

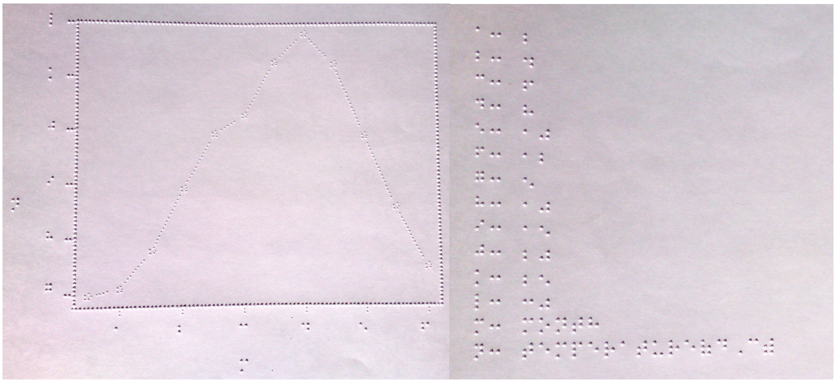

Fig. 2. An embossed graphic of Fig. 1. (left) and its listing sheet (right) produced by the developed software.

As discussed above, the present research focuses not only on graphs, but also on any graphics that would be effective when converted to tactile graphics, and thus aims to realize a comprehensive conversion system for R’s graphics output. An enhanced GIS data processing package has been developed for R, so it is often used to process map data. Fig. 3 is a map of Japan rendered by R using GIS data. The same data output as an embossed graphic is shown in Fig. 4.

Fig. 3. An example of a map rendered by R

Fig. 4. An embossed graphic of Fig. 3's bitmap data converted by Tenka

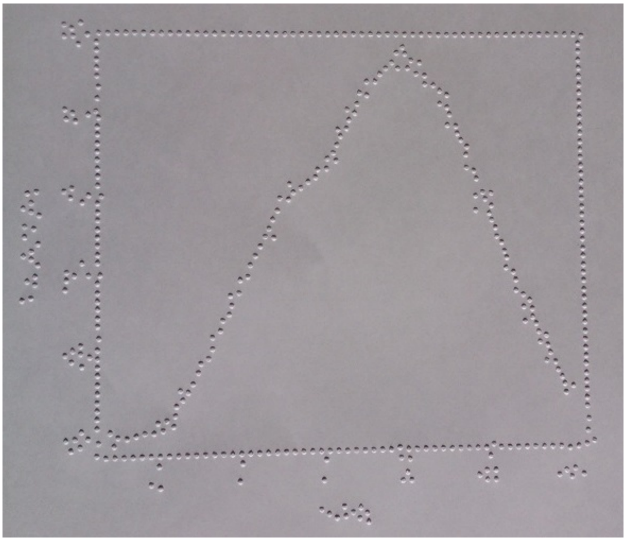

Fig. 5. An embossed graphic of Fig. 1's bitmap data converted by Tenka

Fig. 5 is an embossed graphic of Fig. 1's bitmap data (png format) using the software called Tenka [16] which is aimed to convert bitmap files for ESA721's drawing software Edel.

It is remarkable that not only pointing circles are collapsed but also letters are degraded unrecognizable.

5 Conclusion

A prototype system for generating tactile graphics output that can be applied in practical use has been developed targeting R's graphics output. It is anticipated that this method can realize the three advantages of Method 3 to a high level.

Such a result can be obtained because the second disadvantage of Method 3 can be avoided using R's intermediate graphics format. For instance, it can be anticipated that the results would be unsuccessful if an approach were adopted involving conversion from a bitmap that is the final output of one of R's drivers. The lines appearing in the graphics would become obscure and, in particular, there would be a severe limitation on processing text strings such as Fig. 5.

The results of the present research indicate that, in attempting to generate automated tactile graphics from the output of any kind of graphics software, the strategy described below will be useful.

1. To investigate whether the intermediate graphics format used in the relevant software consists of primitive vector format drawing commands and character printing commands that handle characters as codes.
2. If the latter conditions are fulfilled, to perform conversion to tactile graphics at the stage of graphics data expressed as that intermediate format.

6 Future Tasks

Broadly speaking, there are two kinds of future tasks:

1. The task of inspecting this approach's general utility

The present study specifically targeted the combination of R and its PicTex output, but implementation and verification should be performed for other R's output format or software.

2. R-specific tasks

The present research has focused on R because it was assumed that realizing access to its graphics output would be important in realizing an environment in which a blind person can take an active role in exploratory study using statistical methods. It is necessary to investigate whether blind persons really can effectively carry out exploratory study using statistical methods with tactile graphics.

In the course of the software development, the possibility of a blind person being able to draw an arbitrary figure will be discovered if appropriate drawing functions are defined. It is worth investigating the possibility of developing R as a form of drawing software for blind persons.

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