

Tactile Graphics in Braille Textbooks: The Development of a Tactile Graphics Creation Manual

KANEKO Takeshi

Department of Policy and Planning

OOUCHI Susumu

Department of Educational Support

Abstract: This paper presents practical guidelines for making Braille dots drawings in Japanese Braille textbooks. Braille textbooks prepared in line with ordinary textbooks include not only edited Braille texts but also pictorial cuts converted to tactile drawings. In the conversion, focus should be on the variety of pictorial cuts and development of tactually understandable drawings. Tactile drawings made by Braille dots account for a high percentage of tactile drawings used in Japanese Braille textbooks. The paper discusses the underlying theoretical principles and provides practical guidelines with examples for the production of these drawings. There are five principles as follows.

1) Selection criteria should be developed to choose appropriate pictorial cuts from original ordinary textbooks for the conversion to tactile drawings. Then, as for pictorial cuts not converted to tactile drawings, strategies should be considered such as the replacement of them with suitable text, and so on. 2) The restraints on preparation of Braille dots drawings, such as line type or length, should be considered. 3) As specific features of tactile and visual perception differ, it is necessary to establish criteria for making Braille dots drawings, such as determining the appropriate distance between components, and the number of components per unit area. 4) Braille dots drawings should be prepared, taking into consideration types of pictorial cuts in the textbook, particularly in terms of their shape. 5) Braille dots drawings should also be accompanied by detailed explanatory notes in Braille so that children/students will easily understand the tactile drawings.

Key Words: Tactile drawing, Braille dots drawings, practical guidelines, Braille textbooks, visual impairments

I. Introduction

Braille textbooks authored by the Ministry of Education, Culture, Sports, Science and Technology, in Japan (MEXT) and used in schools for the visually impaired are edited and translated into Braille based on original authorized textbooks. These textbooks include Braille texts translated from original textbooks as well as pictorial cuts converted to Braille dots drawings (Endnote 1) or vacuum-formed graphics (Endnote 2). In the classroom, children/students read Braille text and touch tactile drawings.

Our nationwide survey of how much tactile teaching materials are used in schools for the visually impaired¹⁴⁾, showed approximately 40-50% of respondent schools use almost all tactile drawings in Japanese language, social studies, mathematics, and science textbooks. If schools using two thirds or more of tactile drawings in textbooks are considered, about 50-60% of respondent schools may then be estimated to use tactile drawings in textbooks. The percentage is lower for tactile drawings in Japanese language, social studies, mathematics, and science textbooks at the junior high and high school levels, but

about 30-50% of respondent schools use two thirds or more of the tactile drawings in textbooks.

On the other hand, since original pictorial cuts are designed to be visually understandable, simply converting these pictorial cuts to tactual drawings in convexed format, in most cases will not bring about tactilely understandable pictorial cuts because of the nature of tactile perception. In addition, since original pictorial cuts are various, it is necessary to convert them to appropriate tactile drawings while adapting them to a tactile medium to ensure effective learning occurs. Furthermore, as most of the drawings in textbooks are Braille dots drawings that fundamentally only consist of dots, the conversion of pictorial cuts to tactile drawings, should take into consideration this nature of Braille dots drawings.

In addition, if children/students using Braille use textbooks other than Braille textbooks authored by MEXT, they need to be translated into Braille, and their pictorial cuts need to be converted to tactile drawings in an appropriate manner. Hence, as it is common to ask volunteer groups to translate Braille texts or tactile drawings, the most effective approach is to develop practical guidelines for the production of tactile drawings. In this case, the practical

guidelines should assume that any output is produced from Braille printers, rather than zinc plate-based printing (Endnote 3) used by Braille publishers.

Considering these problems, this paper aims to describe realistic and practical guidelines for the conversion of original pictorial cuts in ordinary textbooks to tactile drawings, in particular Braille dots drawings, which account for majority of these tactical drawings. In addition, the paper aims to identify the basic principles for preparing a more detailed new “*Manual for Making Tactile Graphics*” to address the issue of tactical drawings other than Braille dots drawings.

II. Overview

1. Guidelines for Conversion to Braille Dot Drawings

Braille drawings in MEXT authored Japanese language, social studies, mathematics, science, and English textbooks used at the elementary and junior high school levels are edited by several editorial board members in respective field/subject areas. How the editing process is done is disclosed in the “Braille Textbooks Editorial Guidelines”⁸⁾⁹⁾. The guidelines also describe the principles applied in the editing of pictorial cuts in the original textbooks. In addition to these editorial guidelines, a range of documents from both Japan and overseas describing practical guidelines for tactile drawings are available^{1) 2) 4) 7) 8) 9) 11) 12) 15) 16)}.

Relevant to the main theme of the paper, some of these guidelines mention important strategies for converting pictorial cuts to tactile drawings, while other do not describe such guidelines. As this paper aims to propose practical guidelines for converting pictorial cuts to tactile drawings, these need to be as comprehensive as possible, in the context of these documents as well. Some documents enumerate practical guidelines, but it is necessary to sort out problems in converting pictorial cuts of authorized textbooks to tactile drawings and describe a theoretical framework for these guidelines, rather than simply listing guidelines. By placing practical guidelines in a theoretical framework, it is possible to prevent overlooking important guidelines. In addition, for stakeholders directly engaging in conversion to tactile drawings, such as tactile drawing volunteers, it is necessary to suggest specific examples consistent with these practical guidelines.

In this context, the paper proposes some basic principles as the theoretical basis for converting textbook pictorial cuts to Braille dots drawings and explains the practical guidelines for producing Braille dots drawings within such a theoretical framework. In addition, by selecting actual pictorial cuts in original textbooks, the paper makes it possible to provide examples of ‘best practice’ approaches for conversion to Braille drawings. By doing so, the authors believe we will be able to obtain basic knowledge for the

preparation of a “*Manual for Making Tactile Graphics*,” as mentioned previously.

2. Basic Principles for Conversion to Braille Dot Drawings

In this paper, five basic principles are proposed:

1) Selection of pictorial cuts converted to tactile drawings: Since conversion of all pictorial cuts in original textbooks to tactile drawings is unnecessary or difficult, it is necessary to select only pictorial cuts considered necessary to convert to tactile drawings. In addition, those pictorial cuts not converted to tactile drawings should also be handled in an appropriate manner.

2) Restraints on conversion to Braille drawings: When tactile drawings are made in the form of Braille dots drawings that basically consist of dots only, there are some constraints in their creation to which editors should pay due attention.

3) Criteria for preparing Braille dots drawings: Based on the nature of tactile perception, Braille dots drawings should satisfy certain criteria, such as the degree of distance between components and the number of components per unit area. The nature of tactile perception also relates to the simplification of Braille dot drawings.

4) Creation of Braille dots drawings suitable to types of pictorial cuts: As pictorial cuts have various characteristics, this principle relates to how appropriate Braille dots drawings should be prepared to satisfy each of these various characteristics of pictorial cuts. Rather than suggesting guidelines for each of the various pictorial cuts, this paper advises that at first, pictorial cuts be sorted out based on the simplification of Braille dots drawings and the essential information that Braille dots drawings should deliver to readers.

5) Addition of detailed text information: In addition to ingenuity in preparing Braille dots drawings, this principle calls for the addition of detailed text information so readers will easily understand the drawings.

Based on the five principles outlined above, this paper now describes realistic and practical guidelines for the preparation of Braille dots drawings.

III. Guidelines for Making Braille Dots Drawings

1. Selection of pictorial cuts converted to tactile drawings

Some pictorial cuts from original textbooks do not include important information for readers simply because they form backdrops to the textbook or they are ornamental pictures, or photos.

In this context, rather than converting all pictorial cuts in the original textbooks, it is suggested to avoid converting pictorial cuts with less important information.

This strategy is actually employed when preparing Braille



Figure 1 Original Textbook: New Science 5, Part 1; Tokyo Shoseki; pp.1-3; 2002 edition

textbooks, and is mentioned in Braille textbook editorial guidelines for each subject^{8) 9)}. Similar strategies are also mentioned in APH (American Printing House for the Blind) (1997)¹⁾ and Sheppard, L. et al. (2000)¹⁶⁾.

On the other hand, even if pictorial cuts such as photos or complicated maps contain important information, in some cases it is difficult to convert them to tactile drawings. In these cases, rather than simply avoiding conversion to tactile drawings, it is suggested they be replaced by text information. This strategy is used in practice for Braille textbooks and a similar strategy is used by the American Printing House for the Blind (APH, 1997).

In addition, according to Braille editorial guidelines, if

it is difficult to replace pictorial cuts with text information, teachers are advised to teach using oral explanation, and models or large tactile maps. According to Sheppard et al. (2000)¹⁶⁾, teachers should demonstrate actual objects rather than tactile drawing, such as coils, if they are easier to comprehend.

Based on the aforementioned perspectives, it is appropriate to adopt the following strategies: (a) editors should avoid converting a pictorial cut to a tactile drawing if it does not include important information; (b) editors should replace a pictorial cut with text information only if it includes important information but is impossible or difficult to convert to a tactile drawing; and (c) if a pictorial cut

includes important information but is impossible to convert to tactile drawing or text information, teachers should teach using oral explanation, models, actual objects, large tactile maps and other teaching materials.

The following supplemental observations on strategies (a-c) are appropriate. Strategy (a) does not mean deleting pictorial cuts from original textbooks as much as possible, but rather calls for the conversion of original textbook's pictorial cuts from original textbooks as much as possible. As mentioned in APH (1997)¹⁾, as the skills of children/students to perceive tactile drawings are enhanced by touching tactile drawings, editors should actively insert tactile drawings into the textbooks of low-grade children to stimulate their perceptual response. In Strategy (b), when replacing pictorial cuts with text information, existing Braille textbooks either do so by taking advantage of texts accompanied with original photos or figure from the original textbook, or insert the information of photos or figures in the text. Concerning Strategy (c), if models or large tactile maps are unavailable, it is suggested that teachers prepare these resource materials themselves. Even if tactile drawings are available in Braille textbook, teachers should sometimes prepare and use tactile drawings or models to supplement tactile drawings.

In this context, based on existing Braille textbooks and Braille editorial guidelines, the following is an example of the selection of pictorial cuts for conversion to tactile drawings. A further example given is substituting text information for pictorial cuts not converted to tactile drawings. (see Figure 1)

On Pages 1-3 of the elementary school 5th grade science textbook, pictures of three children and a scenic photo (see top of Page 1) in the original textbook, as shown in Figure 1, have not been converted to tactile drawings or replaced with text information. This is because they do not include important information.

The illustration and photo at the bottom of Page 1 do include important information, but have been replaced with the following texts because of the difficulty involved in converting them to tactile drawings.

John: "From weather forecast on radio or TV program, we are able to know the weather tomorrow."

Mary: "Newspapers have a weather forecast column that includes precipitation probability and weekly forecast."

As for Pages 2-3 of the same textbook, pictorial cuts in the original textbook include important information, but have not been converted to tactile drawings. Instead, the information included in the pictorial cuts is inserted in the text as follows:

Forecasts of weather changes in newspapers or on TV programs include local weather, the nephogram of a weather satellite, and

precipitation information from the AMeDAS.

The nephogram shows cloud images based on data sent from a weather satellite. AMeDAS precipitation information is in a bar chart that shows automatically measured local precipitation on a 4-point scale ("small," "rather small," "rather large," and "large") on a map of the Japanese islands.

Figure 2 shows texts and pictures on Pages 8-9 of the elementary school level 1st Grade National Language textbooks. The text portion is translated to Braille as it is—"Would you read out a story?"— whilst the picture portion is converted to text data as follows:

Different Kinds of Stories

The Monkey and the Crab

Urashima and the Kingdom Beneath the Sea

Bremen Town Musicians

Three Little Pigs

Figure 3 shows a photo and the text of Page 4 of the elementary school level 3rd/4th grade Social Studies textbooks. The photo is omitted but is converted to text information, whilst taking advantage of the description in the original textbook that accompanies the photo. That is, "There is the same mark in a lot of different locations, such as a white bus body, a billboard of 'Kobe City Kobe-Eki-Mae Bicycle Parking Lot', and a manhole describing it as 'Kobe Rainwater.' What on earth are these kind of marks?" (Endnote 4)

2. Restraints on conversion to Braille drawings

There are various approaches for preparing tactile drawings, such as Braille dots drawings, vacuum-formed graphics, gluing down tactile materials, Stereo Copying, the raised writer approach, and UV-curable resin ink printing. They also have different and separate characteristics.⁶⁾

Among these approaches, essentially Braille dots drawings only consist of dots; their points, lines, and surfaces are composed only of dots (Endnote 5). This poses some constraints when preparing Braille dots drawings.

This section describes the types of dots actually used for Braille textbooks and Braille printers, and then describes their constraints. It describes the Braille printer, *ESA721 Ver. '95*, which is compatible with all Braille drawing software currently available in Japan, such as EDEL, Tenzukun, and BES (Endnote 6).

(1) Dot types

Braille dots drawings use several different kinds of dots. There are five to six dot types for Braille textbooks and one to three dot types for Braille printers (Endnote 7).

As an example of dots used in Braille textbooks, Table 1 shows the dot types and dot sizes used in junior high school



Figure 2 Original Textbook: National Language 1, Part 1; Mitsumura Tosho; pp.8-9; 2002 edition



Figure 3 Original Textbook: New Social Studies 3/4, Part 1; Tokyo Shoseki; (a portion of) pp.4; 2002 edition

level Science (Category 1) textbooks and those available for the Braille printer, *ESA721 Ver. '95*.

When comparing dot types between Braille textbooks and Braille printers, Braille printers do not have the very large and medium-small dots of Braille textbooks. Braille printers have almost the same dot sizes as large, medium and small dots used in Braille textbooks. Medium size

dots are the same size as Braille dots used for both Braille textbooks and Braille printers.

(2) Line width available

In the aforementioned example, Braille textbooks have five different dot sizes, while Braille printer *ESA721 Ver. '95* has three different dot sizes.

Table 1 Dot Sizes of Braille Textbooks and Braille Printers

a. Dot Types of Braille Textbooks (Junior High School level Science (Category 1 textbooks))

| Dot type* | Dot size Dot base diameter (mm) |
|--------------|------------------------------------|
| Very large | 2.7 |
| Large | 1.8 |
| Medium | 1.5 |
| Medium-small | 1.2 |
| Small | 0.8 |

*Unauthorized names applied for convenience by the authors

b. Dot Types for Braille Printer, *ESA721 Ver. '95*

| Dot type* | Dot size Dot base diameter (mm) |
|-----------|------------------------------------|
| Large | 1.7 |
| Medium | 1.5 |
| Small | 0.7 |

*Unauthorized names applied for convenience by the authors

In Braille dots drawings, the expression of dots, lines and surfaces is determined by a range of differing dot sizes.

In Braille dots drawings, lines, the most basic component of a drawing, are also expressed with a series of dots using small intervals in the form of a line. As a result, line width availability also depends on dot sizes. In the aforementioned example, there are five kinds of line width available for Braille textbooks and three types of line width available for the Braille printer, *ESA721 Ver. '95*.

Although five kinds of line width are available for Braille textbooks, it does not mean that all of these line widths are usable in a single drawing. Braille users are able to distinguish different line types by touching on multiple lines at the same time. However, since their tactile field is rather small, Braille users are not necessarily able to touch them at the same time, and in some situations, are unable to distinguish different line types. For this reason, line types in a single drawing should be limited to three or less line types.

(3) How to use dots

In the case of the aforementioned Braille textbooks, it appears that medium and medium to small dots are used for main lines. For example, junior high school level Science (1st Category) Braille textbooks have many examples using two dot types in a single drawing for different purposes. In a single drawing, medium to small dots are used for the vertical and horizontal axes of graphs, medium dots are used for graph lines and ground lines, and medium to small

dots are used for people, hand trucks, and other goods.

Large dots are partly used as lines, such as for highlighted arrows, and in most cases very large dots rather than lines are used as points, such as for points on graphs and city locations. If small dots express a line, they are often used as constituting auxiliary lines, such as leader lines. They are also used to form surface patterns, such as marking out a surface. If five dot types are available, editors may use them for different purposes as mentioned above.

On the other hand, only three dot types are available for the Braille printer, *ESA721 Ver. '95*.

In the case of Braille printers, the unavailability of medium to small dots used with medium dots to express a major line in Braille textbooks, poses significant constraints when expressing a line. For example, if attempting to use small dots for surface patterns and two line types for other major lines in a single drawing, editors have no choice but to use medium and large dots to express these two lines. However, large dots are too big to give refined expressions.

In addition, since the very large dots of Braille textbooks are unavailable for Braille printers, if points on a graph or city locations are expressed with a large dot, medium and small dots are only available for expressing lines.

In this way, a smaller range of expressions, such as points, lines, or surfaces, is available for Braille printers than for Braille textbooks. In this sense, editors need to exercise their ingenuity in expressing Braille dots drawings, taking into consideration these constraints.

(4) Line length

As lines are expressed with a series of dots in Braille dot drawings, editors face constraints in terms of line length available.

That is, for Braille textbooks, if taking the minimum length with three points, the distance between the center of the end point is 5mm for large dots, 4mm for medium dots, 3.8mm for medium to small dots, and 3mm for small dots. In contrast, for the Braille printer, *ESA721 Ver. '95* (Endnote 8), it is 5mm for large dots, 4mm for medium dots, and 3mm for small dots.

These facts also pose constraints on the expression of closed graphics. For example, a square requires a side of at least 3-4mm long.

3. Criteria on preparing Braille dots drawings

In general, if tactile drawings, including Braille dots drawings, are expressed by simply convexing the contours or boundaries of original pictorial cuts, in many cases Braille users may not tactilely understand the tactile drawings owing to the nature of tactile perception. Visually recognizable graphics are sometimes not tactilely recognizable because tactile perception has lower spatial acuity and narrower tactile field than visual perception. In

comparison, as the smallest tactile field is only as large as a fingertip, Braille users inevitably pick-up unnecessary information as long as it is located in the fingertip. Due to synergy effect of these factors, tactile perception of graphics is rather difficult.

In this context, all of the editorial guidelines for tactile drawings recommend avoiding complexity and making a graphic as simple as possible.

Then, what degree of complexity or simplicity is appropriate? What kind of criteria is desirable?

How large these numerical values should be for perceptible graphics is explained in terms of the complexity of a graphic from the orientation of two numerical values: (a) the distance between two components; and, (b) the number of components per unit area. In relation to the former numerical value, this section also presents an argument for how large a Braille dots drawing should be.

(1) Distance between components

If a distance between two adjacent components is smaller than a certain value, such a visually recognizable distance is tactilely imperceptible. This is because tactile perception has lower spatial acuity (i.e., lower resolution) than visual perception. The spatial acuity of tactile perception is measured with the value of two-point threshold, which varies among research projects, but stands at 2-3mm in the case of a finger distal pad.^{18) 19) 20)}

The following section explores the distance between two components by simplifying the argument as the distance of two parallel lines. In this case, if the distance between the two lines is smaller than a certain value, it is not recognized as two different lines, and Braille users sometimes perceive there to be no space between them. This numerical value ranges from 2 to 6mm, depending on research projects¹⁾ 2) 4) 11) 15) 16). Some of these projects discuss the values of the aforementioned two-point threshold on fingertips^{2) 11)}, while others do not. As these latter projects do not mention specific experiments, they probably argue the empirical values of tactile drawings users who actually touch two lines.

Amongst these projects, research projects that highlight 2mm as the two-point threshold^{11) 16)} encourage Braille editors to “create a distance at 2mm or more,” and “leave space at least 2mm wide,” respectively. Of the three projects calling for a 6mm distance^{1) 4) 15)}, two^{1) 15)} mention that less than a 6mm space between the two lines might lead to “difficulties of recognizing two lines,” or prevent Braille users from “easily distinguishing the two lines.” The last project⁴⁾ states that Braille users “tend to recognize them as a bold line.”

In this context, some researchers stress the problems involved. For example, a two-point threshold would have different values due to gaps in the discrimination abilities

of examinees as well as in experimental conditions. That is, sometimes different experimental equipment is used, or researchers ask examinees for the specific distance in which they certainly perceive two lines, or for the specific distance in which they perceive something other than one line^{5) 17)}. In addition, when measuring two-point thresholds, researchers generally use equipment such as slide gauges or compasses, and place them on the examinees’ fingers. On the other hand, when examinees touch two lines on tactile drawings, they put their fingers on the paper and move their fingers around. In the finger/hand rehabilitation field, the former approach is called “static discrimination,” while the latter is called “moving discrimination”, a procedure in which testing technicians put two points and move on the fingers of examinees¹⁰⁾. Some reports argue that examinees are normal if the value of moving discrimination is 2mm.³⁾

In fact, researchers should conduct experiment research by providing two lines with different intervals and asking examinees to detect the distance value in which they clearly identify them as two different lines. However, based on the arguments presented here, the authors tentatively suggest that the distance between two components should be at least 2mm.

(2) Size of Braille dots drawings

If line width is different, the distance between the edges of two lines will also vary, even if the graphic is the same size. This is because, if the distance between the two lines’ centers remains unchanged, the distance between the edges of the two lines is the distance between the centers of the two lines minus the width of the line.

Original textbooks usually utilize lines of 0.2mm wide. Pictorial cuts with a 1mm distance between the edges of two lines of 0.2 mm wide are also frequently seen in original textbooks. In this case, the distance between centers of these two lines is 1.2mm.

If attempting to convert this pictorial cut to a tactile drawing with medium to small dots, the distance between edges of two lines will be zero because the line width is 1.2mm (i.e., 1.2-1.2mm). If this is so, editors are unable to convert the original pictorial cut to tactile drawing at the same size.

If the standard value for the distance between edges of these two lines is 2mm—as mentioned earlier—the distance between the centers of the lines should be a minimum of 3.2mm (i.e., 2mm+1.2mm). For this reason, to convert the original pictorial cut to tactile drawing so that the standard value for the distance between two lines is satisfied, editors need to alter the size of pictorial cut. In this case, they need to expand the original pictorial cut by 2.7 times (i.e. 3.2mm/1.2mm) so that the distance between the line centers is 3.2mm.

In sum, if converting an original pictorial cut to Braille



Figure 4 Japanese atlas in junior high school social studies textbook on geography
(Original Textbook: Junior High Social Studies: Geography; Kyoiku-Shuppan; pp.51; 2002 edition)
 (The atlas is enlarged and turned so that it would fit one page of Braille textbook version. The size of one page is marked with dotted lines.)

dots drawing without changing the pictorial cut proportion, editors should identify the shortest distance between two lines on the original pictorial cut, measure the distance between centers of these two lines (a distance referred to as “a”), then calculate the numerical value of the line width of the tactile drawing plus the standard value (i.e., 2mm in this case)—this numerical value is referred to as ‘b’, and finally calculate ‘b’ divided by ‘a’. If the value (b/a) is greater than 1, editors may not convert the original pictorial cut to a Braille dots drawing without changing the graphic size. In this case, the necessary enlargement factor will depend on the numerical value of ‘b/a’.

As a specific example, this section explains how to convert the Japan Atlas used in junior high geography (Figure 4), to Braille dots drawing so that the atlas will fit a single page size in a Braille textbook.

The coastlines of Boso Peninsula, Miura Peninsula, and Izu Peninsula are used for the example (See Figure 6 and Figure 7). First, the lines used in the original atlas's coastlines are approximately 0.2mm in width. If the coastlines of Boso, Miura, and Izu Peninsulas are

converted to Braille dots drawings with 1.2mm-wide lines, Miura Peninsula will touch Boso Peninsula (Figure 5) and Tokyo Bay will no longer look like a bay. In fact, the shortest distance between the coastlines of Miura and Boso Peninsulas on the original atlas is 1.2 mm between the line centers. If 1.2mm-wide lines were used, the distance between the two lines would be zero. That is, without changing the atlas size, it is impossible to convert Boso, Miura and Izu Peninsulas to a Braille dots drawing in the same proportion as the original atlas.

As stated earlier, if the standard value for the distance between these two lines is 2mm, editors must enlarge the atlas by at least 2.7 times to express these three peninsulas in the same proportion as the original atlas by using 1.2mm lines.

If the original atlas shown in Figure 5 is enlarged 3.0 times, which is slightly larger than the 2.7 times, the resultant Braille dots drawing atlas is as shown in Figure 6.

If there is an upper limit for the graphic size of Braille dot drawings, and the necessary enlargement factor is unavailable, editors need to simplify or deform the original

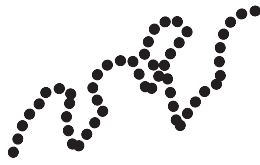


Figure 5 Braille drawings of three peninsulas (in full-size drawing)

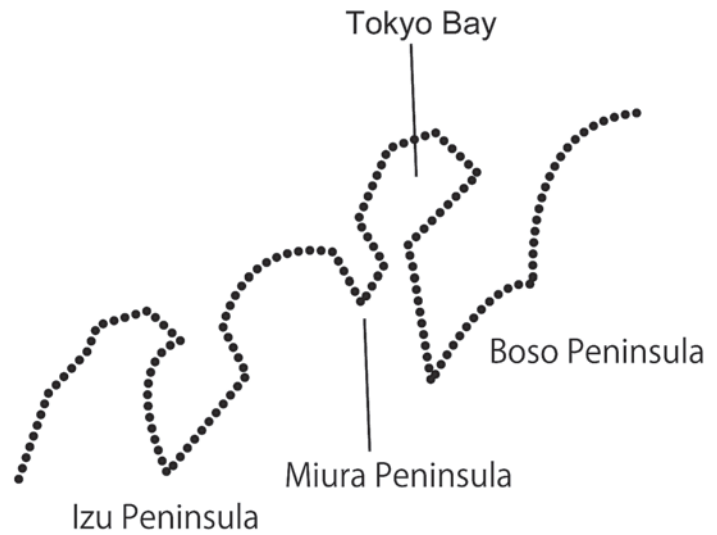


Figure 6 3-fold enlarged Braille drawings of three peninsulas (in full-size drawing)

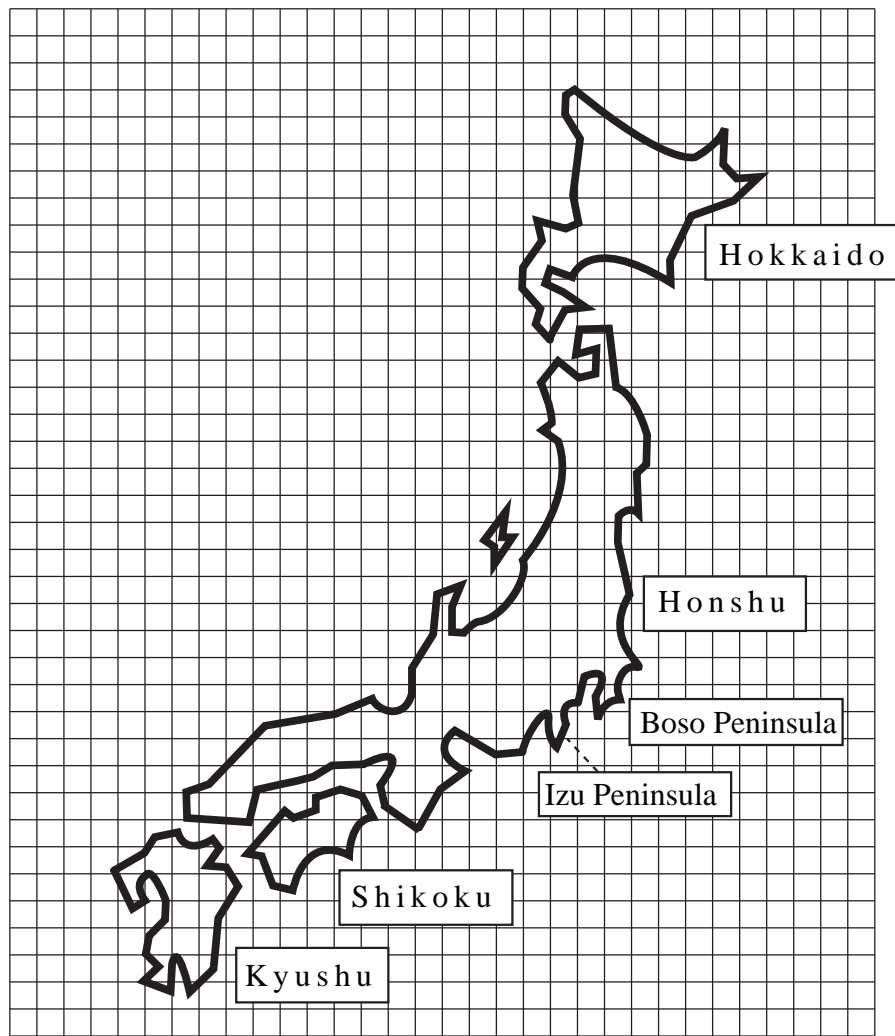


Figure 7 Braille drawings in the case of two components in 6x6mm grids
(The space among 4 islands Hokkaido, Honshu, Shikoku and Kyushu is larger than the original drawing so that it will stand at 2mm or longer.)

pictorial cuts.

(3) Number of components per unit area

The complexity of pictorial cuts is also measured by the number of components per unit area, such as the number of continuous lines and curves and the number of separated components.

If the number of components per unit area assumes a smaller value, the pictorial cut is simpler and less complicated. When making tactilely recognizable Braille dots drawings, how many components are appropriate per unit area?

Bris (2003)²⁾ recommends a 6 x 6mm grid should include only two tactile drawing components for each. As mentioned above, the number of components in this context includes the number of continuous components, such as continuous lines and curves. Bris (2003) insists on two components in a 6x6 mm grid for the following reasons: (a) a Braille letter plus a space with the next Braille letter would be almost equal to 6x6 mm; and (b) distinguishing Braille letters means distinguishing a pattern consisting of two elements, considered as two lines.

Further investigation is necessary to validate this criterion, as well as its theoretical base. However, it is an effective approach to create a certain sized grid as a unit area and to count the maximum number of components in the grids to quantify simplicity.

Figure 7 is an example of 6x6 mm grids and contour lines in the aforementioned Japanese atlas, based on above criteria, converted to Braille dots drawings to fit one page of a Braille textbook. In this case, some portions of the Japanese atlas, such as Miura Peninsula or Chita Peninsula, have necessarily been omitted. If editors intend to express these omitted portions, they need to convert them into Braille dot drawings by enlarging the portions.

4. Creation of Braille dots drawings suitable to types of pictorial cuts—simplification and essential information.

If editors intend to prepare a Braille dots drawings as simple as possible consistent with the abovementioned guidelines, it is important to omit less important information and to simplify the original pictorial cut so that important information is delivered to readers. For this purpose, editors need to identify what is essential information in the original pictorial cuts.

Simplification is not difficult if the original pictorial cut is less important in terms of its shape or may take a simpler shape. However, editors have a serious problem if the shape of the original pictorial cut is important. In this context, when converting to Braille dots drawing, it is useful to distinguish pictorial cuts in which their shape is important and those in which their shape is less important or is

acceptable in a simpler shape.

Hereinafter, by distinguishing these two cases, this section distinguishes pictorial cuts from the viewpoint of what kind of information should be delivered to readers, and then describes more practical guidelines for various pictorial cuts.

(1) Pictorial cuts in which shape is less important or is acceptable in a simpler shape

a. Graphs

Graphs, including bar graphs, line graphs, band graphs, and circle graphs, essentially express numerical values in relation to a certain topic in the form of a bar, line, band, or sector form. For this reason, in most cases original pictorial cuts are also relatively simple. In this situation, a tactile drawing should only express bars, lines, bands, or sector forms, which are also tactilely understandable.

If expressing these data in Braille dots drawings, editors should only pay attention to the following points: (a) describing vertical/horizontal axes of bar or line graphs in a weaker tone than data lines or bars; (b) simplifying numerical values on these axes; (c) expressing background grids of graphs by embossing on the inside of the paper (Endnote 9); and, (d) describing bars of bar graphs as a series of dots in a row to three rows. By doing so, the resultant tactile drawing will be tactilely recognizable, even if it takes a similar form to the original graph. However, if the original graph is a plate-like 3D graph, looks diagonally, is a plate-like circle graph, or is an oval-shaped circle graph, editors should convert it to a 2D rectangle or circular form to make it tactilely understandable.

The following are examples of circle and line graphs from elementary school level Social Studies textbooks (See Figures 8 and 9). In these examples, the oval-shaped circle graph has been converted to a circular form, while the line graph is expressed in the same manner as the original graph.

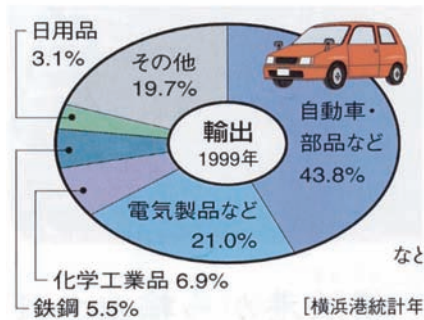
A problem occurs if multiple numerical values are provided in relation to a certain topic. In this case, editors may divide the graph to describe two or so numerical values for each of these graphs.

This strategy is also recommended in the elementary school level Social Studies chapter of the current Braille textbook editorial guidelines⁸⁾.

b. Schematic diagrams

Schematic diagrams graphically illustrate functions of a certain thing, configurations/interactions among various portions, or flow of goods or information. Rather than imitating the exact form of the original, schematic diagrams are often illustrated in a simplified or deformed manner. Some schematic diagrams illustrate intangible stuff as well.

To be more specific, examples of schematic diagrams include creature's organic functions diagrams, electrical

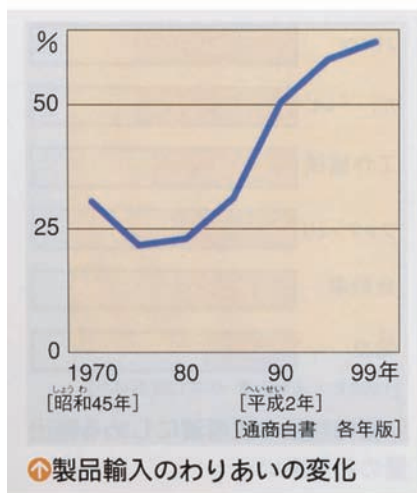


a. Original Textbook: New Social Studies 5, Part 1; Tokyo Shoseki; pp.87; 2002 edition
(The subject of the graph is 'Trading Goods in Yokohama Bay'.)

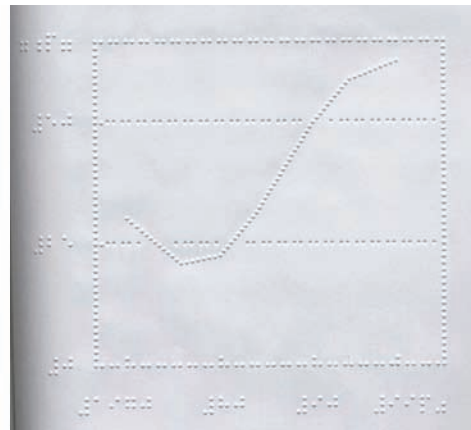


b. Braille Textbook: Visually Impaired Person's Elementary School 5-3; pp.171; 2002 edition

Figure 8 Braille drawing of circle graph (Elementary school social studies textbook for 5th graders)



a. Original Textbook: New Social Studies 5, Part 1; Tokyo Shoseki; pp.92; 2002 edition



b. Braille Textbook: Visually Impaired Person's Elementary School 5-3; pp.227; 2002 edition

Figure 9 Braille drawing of line graph (Elementary school social studies textbook for 5th graders)

diagrams for science, and flowcharts for social studies.

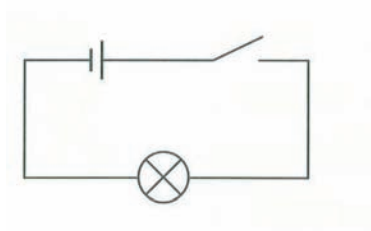
Schematic diagrams by definition essentially illustrate functions of a certain thing, configurations/interactions among various portions, or flow of goods or information. Their shapes are not necessarily an emulation of their originals. They may take a simpler shape as long as they accomplish their purpose.

Original pictorial cut has rather simple shape in some cases. Even if it takes complicated shape, schematic diagrams may get simplified or deformed in an easily understandable manner as long as they deliver essential

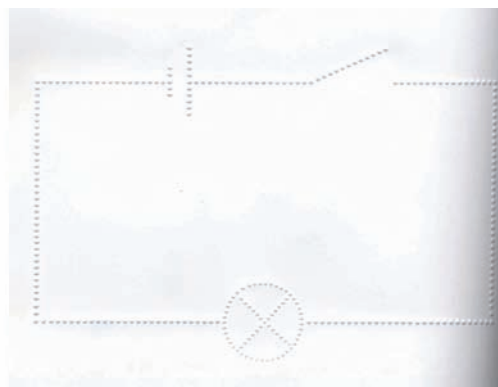
information.

Here is an example of an electrical circuit in the current Braille textbooks on science (see Figure 10). This example essentially illustrates how a battery, switch, bulb and electric wires are connected. Since the original pictorial cut is simple, this is an example of converting to Braille dots drawing as it is.

Then, although the original textbook illustrates a pictorial cut that looks similar to the real goods, here is an example of a pictorial cut that serves as a schematic diagram and is convertible to Braille dots drawing (see Figure 11). In this

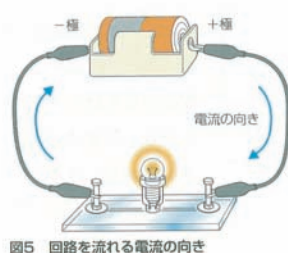


a. Original Textbook: Junior High School Science 1st category; Kyoiku-Shuppan; pp.84; 2002 edition

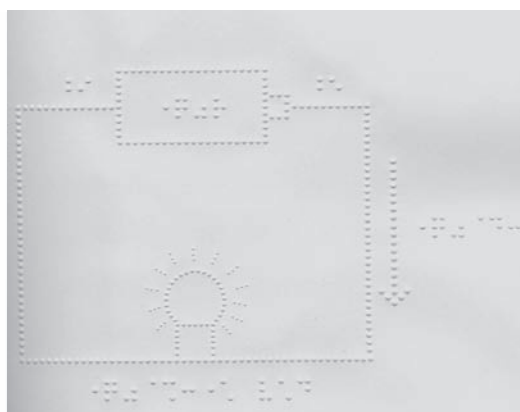


b. Braille Textbook: Visually Impaired Person's Junior High School Science 1st category; pp.112; 2002 edition

Figure 10 Braille drawing of electric circuits (Junior high school science 1st category textbook)



a. Original Textbook: Junior High School Science 1st category; Kyoiku-Shuppan; pp.83; 2002 edition



b. Braille Textbook: Visually Impaired Person's Junior High School Science 1st category; pp.107; 2002 edition

Figure 11 Braille drawing of electrical current direction (Junior high school science 1st category textbook)

example, the pictorial cut essentially illustrates direction of electric current, and the shape of actual battery, miniature bulb or conductive wires, as shown in the original pictorial cut, is not so important. For this reason, they are illustrated in a simplified manner in Braille dots drawing. In addition, this example appropriately deforms the shape of positive electrode because it essentially illustrates the electrical flow from positive electrode to negative electrode.

By the same token, if experimental tools or experimented plants/animals are shown in an explanatory drawing for science experiment, and their configuration or task flow is more important than their exact shapes, then this kind of explanatory drawing should be treated in the same manner

as schematic diagram. In the same manner, if a functional diagram of organs of living creature is able to get simplified as mentioned earlier, it is easily recognizable tactilely.

(2) Pictorial cuts in which their shape is important

a. Photos and pictures

Among photos or pictures of goods or animals/plants, there are ones in which their expressions are dependent on the shape of objects.

In this case, Braille dots drawings should express as similar shape as possible to original pictorial cuts.

Even in this case, if simplification is necessary, editors should simplify the pictorial cut, taking into consideration

essential information that should be delivered by the pictorial cut. For example, if a pictorial cut is designed to show a certain animal/plant species, it is necessary to put a priority on important characteristics that distinguish them from other species. If it is designed to depict a species group, for example insects in general, it is necessary to express their clear characteristics, such as three body sections (i.e., head, bosom and abdomen) and six legs attached to the bosom region.

b. Maps

Maps show actual landforms. The shape of coastal lines, river flow lines, and prefectural boundaries has meanings because it represents actual landforms.

On the other hand, if it has a complicated shape, tactile drawing of such map is not tactilely imperceptible.

As explained in the example of Braille dots drawing of Japanese atlas, if Braille users are supposed to understand the exact shape, proportion or positional relationship of Boso Peninsula, Miura Peninsula and Izu Peninsula, editors should pay due attentions to partially enlarging the atlas.

As explained earlier, if expression is necessary in a limited space, editors should omit minor information and depict rather rough information.

5. Addition of detailed text information

As explained above, editors should create Braille dots drawings in line with practical guidelines by simplifying the original pictorial cuts to deliver essential information to readers, taking into consideration the content of the original pictorial cuts. In addition, editors may offer text information on the Braille dots drawing before showing the Braille dots drawing.

In this relation, Japan Braille Library's Working Group on "Introduction to Tactile Drawings for translation into Braille" (1988) ¹²⁾ calls for editors to include the text information as follows.

- 1) Basic concepts that should be known to readers before they read the drawing
- 2) Overall layout of the drawing
- 3) Explanations on each portion of the drawing
- 4) Explanations on explanatory notes in Braille (If inserting Braille explanatory notes in the drawing, necessary text information is unable to get inserted as a whole and is replaced with its summary. In this case, commentary on the text information is necessary.)

Providing such information prior to Braille dots drawing would facilitate reader's understanding of the Braille dots drawing. In particular, this strategy is necessary because Braille users are facing difficulties in grasping overall drawing at once due to their tactile field much narrower than visual field of ordinary persons. In other words, providing

such text information prior to a drawing will compensate the limitations of tactile perception that only provides partial information and will facilitate understanding of the entire picture.

On the other hand, the current Braille textbooks do not include detailed text information to this extent. They include explanations on the marks in Braille dots drawings or explanatory notes in Braille (mentioned in above 4)) at best.

This is probably because Braille textbook editors assume that teachers would make explanations on Braille dots drawings in the classroom. However, more detailed text information would be necessary at least for children/students' self-study purposes.

Someone argue that Braille dots drawings would be unnecessary if text information explains Braille dots drawings. However, understanding from text information would be basically different from understanding by touching a Braille dots drawing.

In this relation, let us look at an example by referring to the said book ¹²⁾ and actual examples of the said textbook. For example, as to Braille dots drawing that illustrates how convex lens would work in junior high school level science category 1 textbook as shown in Figure 12, the following text information might be provided prior to the Braille dots drawing.

In this illustration, a convex lens is located vertically, and light comes from the left side, goes through the convex lens, and forms a focus on the right side.

The convex lens is divided to five sections. The lines represent how the light goes through each of these sections. How much the light is refracted is different among these sections. The light is refracted at a larger angle at the top and bottom sections. Refraction gets weaker at the second section from the top as well as the second section from the bottom. In the center section, the light is not refracted and goes straight.

For this reason, the light gathers at a certain point on the right side of the convex lens, forming the focus.

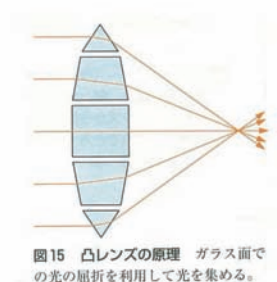
To enhance children/students' abilities of tactile drawing perception, the authors believe that children/students should read the text and touch Braille drawing by comparing between the text and the drawing.

IV. Discussion

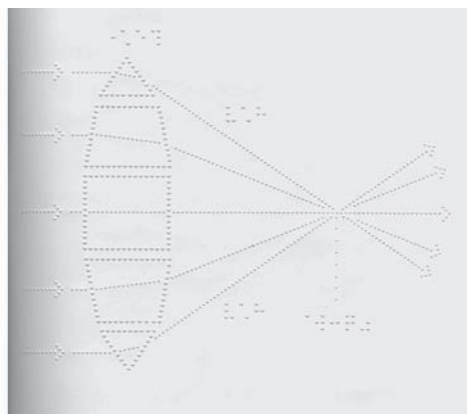
1. Conversion to tactile drawing in Braille dots drawing form

As explained earlier, Braille dots drawings are unique format because they basically consist of dots only. They have some limitations, such as line width or shortest line length, resulting from dot types available.

In particular, as three dot types are only available,



a. Original Textbook: Junior High School Science 1st category; Kyoiku-Shuppan; pp.9; 2002 edition



b. Braille Textbook: Visually Impaired Person's Junior High School Science 1st category; pp.79; 2002 edition

Figure 12 Example of adding detailed text information (Junior high school science 1st category textbook)

Braille printers provide much narrower expressions than Braille textbook publishers, which are capable of using approximately 5 dot types.

If editors use Braille printers, they need to exercise their ingenuity for expressions in textbooks. It is expected that manufacturers will develop Braille printers equipped with a wider variety of dot types.

Such Braille printers are necessary because teachers need to prepare Braille dots drawings as teaching aids of Braille textbooks, or to provide Braille dots drawings for Braille users commuting to ordinary classrooms, where such Braille dots drawings are not printed at Braille printing houses.

This paper (see III. 2. (2)) argues that a single drawing should have three line types at maximum because tactile field is smaller. This does not mean that three dot types are enough. As for line types, it is important to use three line types (out of five types) in an appropriate manner, taking into consideration dots used for surface patterns or location points.

In terms of improvement in Braille printers, some problems are pointed out in a research project that prepared computer-based Braille dots drawings in line with those on Braille textbooks and evaluated the output from Braille printer¹³⁾. One of the authors of this paper has worked on this research project. In this project, he prepared Braille dots drawings with Braille dots drawings creation software EDEL and Braille printer *ESA721 Ver. '95* mentioned earlier. Unlike Braille dots drawings on the textbook, he has found some problems: Dots are not neatly arranged in straight lines or curves; dots are not evenly distributed in some portions; and small dots are embossed higher than medium or large dots. In addition to the aforementioned

problems, the authors hope that these problems get solved.

2. Simplification in preparing Braille dots drawings

As criteria for creating Braille dots drawings, this paper points out the distance between two points and the number of components per unit area.

From the past research projects, the former should be 2mm-6mm, or at least 2mm, while the 6x6 mm unit area should include two components at maximum in terms of the latter, as explained earlier.

Further examinations will be necessary to check out feasibility of these criteria. However, as tactile drawings should be simple as much as possible, editors should follow more concrete guidelines, such as giving the distance between two lines as large as possible, and reducing the number of components per unit area as much as possible.

Simplification in line with these criteria does not mean that editors should simply satisfy these criteria. As mentioned earlier in this paper, editors should simplify pictorial cuts so that their essential information will get delivered to readers, taking into consideration importance of their shapes as well as characteristics of pictorial cuts, such as graphs, schematic diagrams, pictures, photos or maps.

3. Making appropriate Braille dots drawings suitable to types of pictorial cuts

Rather than explaining how to convert all types of pictorial cuts to appropriate Braille dots drawings, this paper only discusses a limited number of pictorial cut types, such as graphs, schematic diagrams, photos, pictures and maps. For example, this paper omits geometric figures in mathematics. In addition, schematic diagrams include

various pictorial cuts with different characteristics each other. It is important to suggest practical guidelines for converting each of these graphic types to Braille dots drawings in an appropriate manner, and further efforts are necessary to do so.

However, as stated above in this paper, rather than exhaustively suggesting how to convert various pictorial cuts to Braille dots drawings, it would be more effective to suggest concrete and practical guidelines by sorting out pictorial cuts based on importance of their shapes as well as the essential information that they should deliver to readers.

4. Education expertise in preparing Braille dots drawings

As for the current Braille textbooks, editorial board members are responsible for selecting which original textbook's pictorial cuts should be converted to Braille dots drawings. In addition, they also give instructions on which pictorial cuts would not be converted to Braille dots drawings and should be replaced with text information.

These selections and instructions cannot be done without knowledge on visual disabilities and each subject of school curriculum.

This paper has argued that pictorial cuts should be simplified so that their essential information would get delivered to readers. This task cannot be done either, without knowledge on such subject and the contents of their portions. This also holds true when adding detailed text information to Braille dots drawings.

An important matter is who should do these tasks when translating textbooks to Braille textbooks for Braille users commuting to ordinary classroom. Rather than simply depending on Braille creation volunteer groups, visually-impaired person's schools in local communities should play more active roles in these tasks, for example.

Endnote 1: Braille dots drawing means a graphic that consists of dotted lines or dot patterns and embossed with dots similar to Braille dots used on Braille-use sheets.

Endnote 2: In vacuum-formed graphics, original drawings are duplicated in the following manner: (a) producing a convex original plate; (b) heat-treating the original plate after putting a plastic sheet on it; (c) softening-up the sheet and extracting the air from inside to closely attach the original plate and the plastic sheet; (d) detaching the sheet from the original plate.

Endnote 3: Zinc plate printing means embossing dots on paper by embossing dots at the same location on two zinc plates, and then inserting Braille-use paper between these two zinc plates and applying pressure with a roller. When preparing Braille drawings in this manner, tools may be

used to manually emboss the dots onto the zinc plates. In addition, various types of dots are available, depending on the tools used. It is also possible to neatly prepare straight lines, curves, and surface patterns by adjusting embossed dots.

Endnote 4: Hereinafter, all Braille textbooks cited in this paper are the current 2002 version, as are all original textbooks corresponding to the Braille textbooks.

Endnote 5: Braille textbooks also include short lines as well as arrow-head-like combinations of short lines ("<" and ">") printable with the tools available at Braille printing houses.

Endnote 6: Another printer, NewESA721, that belongs to the same product series as ESA721 Ver.'95, is also compatible with Braille creation software. There is no difference in dot types and dot sizes.

Endnote 7: Different Braille textbooks use slightly different dot types. This is probably due to the differing dot types used by Braille textbook publishers and Braille dot creators.

Endnote 8: The Braille drawing creation software, EDEL, is capable of adjusting the distance between dots. The abovementioned data represent the distance between dots with the numerical values 6, 4, or 7 when EDEL is used for creating Braille dots drawings.

Endnote 9: "Embossing on the inside of paper" means embossing a dot on the opposite to the ordinary side of paper. Ordinary dots take a convex shape, but "embossing on the inside of paper" will yield hollow-like dots.

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