The Development of a Universal Design Tactile Graphics Production System BPLOT2

Mamoru Fujiyoshi[1], Akio Fujiyoshi[2], Nobuyuki Ohtake[3], Katsuhito Yamaguchi[4] and Yoshinori Teshima[5]

[1] Research Division, National Center for University Entrance Examinations
2-19-23 Komaba, Meguro, Tokyo, 153-8501 Japan
`fujiyosi@rd.dnc.ac.jp`
[2] Department of Computer and Information Sciences, Ibaraki University
4-12-1 Nakanarusawa, Hitachi, Ibaraki, 316-8511 Japan
`fujiyosi@mx.ibaraki.ac.jp`
[3] Research and Support Center on Higher Education for the Hearing and Visually Impaired, Tsukuba University of Technology
4-12-7 Kasuga, Tsukuba, Ibaraki, 305-0821 Japan
`ohtake@k.tsukuba-tech.ac.jp`
[4] Junior College Funabashi Campus, Nihon University
7-24-1 Narashinodai, Funabashi, Chiba, 274-8501 Japan
`eugene@gaea.jcn.nihon-u.ac.jp`
[5] Digital Manufacturing Research Center, National Institute of Advanced Industrial Science and Technology
1-2 Namiki, Tsukuba, Ibaraki, 305-8564 Japan
`yoshinori.teshima@aist.go.jp`

Abstract. We introduce a new universal design tactile graphics production system: BPLOT2. With BPLOT2, blind persons and sighted persons can share resources and cooperatively draw tactile graphics to be utilized in braille textbooks and teaching materials. Present tactile graphics design applications have only GUI (Graphical User Interface) with the need for mouse operations and thus are not usable by blind persons. Equally inconvenient, our self-supporting tactile graphics production system for the blind, BPLOT, has only CUI (Character User Interface), so BPLOT is not popular among the sighted. Therefore, we implemented GUI on BPLOT and realized universal design on BPLOT2.

Key words: universal design, visually impaired, tactile graphics, GUI

1   Introduction

For a long time, it was believed to be impossible for blind persons to produce tactile graphics by themselves. Now, it is possible with BPLOT [1]. BPLOT is the first tactile graphics production system for the blind that enables the blind to produce tactile graphics by themselves. BPLOT produces tactile graphics from a source text file written in our newly designed plotter control language for BPLOT. Because a source file for BPLOT is a text file, it is editable with

any text editors by any person who has learned the plotter control language. Therefore, BPLOT enables not only the sighted but also the blind to produce tactile graphics by themselves.

The recent development of computer software is going in the direction of enriching GUI (Graphical User Interface). Undoubtedly, the development of GUI has enhanced the usability and productivity of computer software for the sighted. For example, a sighted person can draw a picture on a computer screen very easily with painting software such as Microsoft Paint. For the blind, on the other hand, great efforts have been and are being devoted to improve the usability and productivity of computer software. Nishi and Fukuda [2] introduced graphic editor software for the blind utilizing a tactile pin display DotView (KGS Corporation). Kopeček and Ošlejšek [3] proposed a method of creating pictures for the blind by dialogue. We are looking forward to the development of these approaches.

Tactile graphics design applications have been available, such as BES4 [4], EDEL-plus [5] and Tiger Software Suite [6]. Like Microsoft Paint, these present tactile graphics design applications have sophisticated GUI and enable the sighted to produce tactile graphics easily. However, because of the necessity for mouse operations, the blind cannot use these applications by themselves.

In this paper, we introduce a new universal design tactile graphics production system, BPLOT2. With BPLOT2, blind persons and sighted persons can share resources and cooperatively draw tactile graphics to be utilized in braille textbooks and teaching materials. BPLOT has only CUI (Character User Interface) and cannot display the image of figures on the display. Moreover, users have to learn the plotter control language, so BPLOT is not popular among the sighted. We, therefore, developed BPLOT2 by adding GUI on BPLOT and realized universal design on BPLOT2.

This paper is organized as follows: In Section 2, the outline of BPLOT2 is explained; in Section 3, examples of figures produced with BPLOT2 are shown; in Section 4, quality of productions is evaluated; and in Section 5, a conclusion is drawn.

2   Outline of BPLOT2

2.1   The System

The system needs a braille printer and a PC which runs on Microsoft Windows or DOS. The software for BPLOT2 was developed with Borland C++. In order to obtain tactile graphics of high quality, we chose ESA721 (JTR Corporation) as a recommended output device.

ESA721 is a braille plotter printer that can produce tactile graphics with very high resolution: horizontally 73 dpi (dot/inch) and vertically 80 dpi. In comparison with ordinary braille printers (20dpi), the resolution of ESA721 is four times more precise. The print head of ESA721 has eight print pins: six normal-sized pins (1.4mm in diameter) and two additional pins (0.5mm and 1.8mm in diameter). The six normal-sized pins are used to print braille characters. The two

additional pins and the first pin of the six normal-sized ones are used to draw dotted lines.

BPLOT2 has four different execution modes: drawing mode, interactive design mode, test mode and help mode.

2.2   The Plotter Control Language

In order to design tactile graphics by text editors, we developed a plotter control language. The plotter control language is like a computer programming language which consists of plotter control commands. In Section 3, we see examples of figure-drawing programs written in the plotter control language.

The plotter control commands were mainly imported from ones formerly used to control vector-graphics printing devices. Each command consists of a command name and parameters. Basic figures such as a circle and a straight line can be described by a single command.

One of the biggest characteristics of BPLOT2 is that we can magnify and reduce the output tactile graphics with the same sense of touch because lines are drawn with the same dot pitch. The dot pitch and the pattern of a dotted line are specified in the parameters of a command.

A figure-drawing program starts with the "window" command. It defines the virtual coordinate space where figures are described, and relates the virtual coordinate space to the real coordinate space of a sheet of paper mounted on a braille printer.

For figures frequently used, we prepared commands to describe those figures in one line. For example, in plotting a flowchart we can use commands to describe a circle or ellipse as "terminal", a rectangle as "process", a diamond shape as "decision", and several kinds of arrows. A parabola, a hyperbola, a trigonometric function, an exponential function and a logarithmic function can also be described by a single command.

Graphs including complicated curves can be described by means of spline functions. In plotting graphs, the axis of coordinates can be described by a single command. To import a series of plotter control commands written in another file, we use the "paste" command. Figures like a beaker and a test tube can be prepared in advance, and we can use those parts to describe equipment in a laboratory. To put a braille caption in a figure, we use the "braille" command. NABCC (North American Braille Computer Code) and Japanese KANA code are supported. In a similar manner to a computer programming language, comments and macros can be used.

2.3   The Development of GUI

We developed GUI on BPLOT2 for the sighted. During interactive design mode, we can enter GUI mode. In GUI mode, a design sheet is displayed at the center of the PC display. A sighted person can put basic figures on a design sheet in the PC display. Fig. 1 is the screenshot of the PC display in GUI mode.
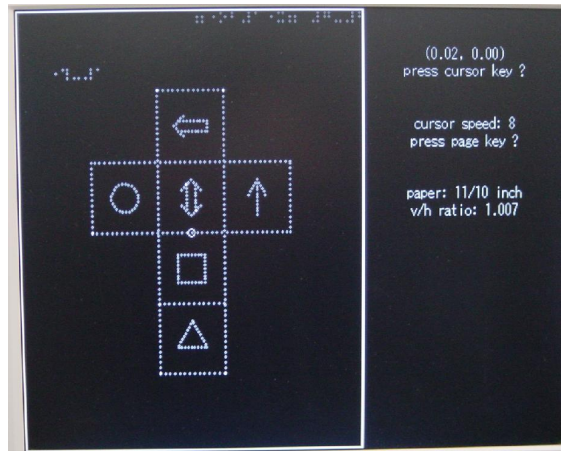
Fig. 1. Screenshot of GUI

The figure-drawing program corresponding to a design sheet is automatically generated and saved as a file.

3   Examples of Figures Produced with BPLOT2

Fig. 2 and Fig. 3 are examples of tactile graphics produced with BPLOT2. Fig. 2 is an unfolded cube as an example of a drawing constituted by basic figures. Fig. 3 is the graph of "labor force participation rate of Japanese women" as an example of the usage of the "spline" command used to draw complicated curves.

Program 1 and Program 2 are the figure-drawing programs for Fig. 2 and Fig. 3, respectively. The line numbers were added for the sake of readability.

Program 1 consists of 7 files with only 61 lines in total including comment and blank lines. The main module is to draw the whole figure, and six sub-modules are to draw componential figures drawn in the boxes. On line 5, the "aux" command is used to open a connection with a braille plotter printer ESA721. On line 6, "window 1 41 0 24" defines the range of coordinates on a sheet of paper; the range of a horizontal coordinate is from 1 to 41, and the range of vertical coordinate is from 0 to 24. On line 7, the "braille" command is used to print braille characters, where "5 22" means the coordinates to print them. On line 9, the "window" command is used again, and the range of coordinates is re-defined. On line 10, the "dot" command is used to set the size of dots to be printed, where 0 is the small dot, 1 the medium dot, and 2 the large dot. On line 11, the "box" command is used to draw a box, where the first two parameters "0 0" means the coordinates of the center, "2" the width, "8" the height, and "3" the length of intervals between dots. Similarly, on line 12, "box 0 0 2 8 3" draws a box. On line 13, the "line" command is used to draw a line from (-2,-4) to (2,-4) whose intervals between dots is 3mm. On line 15, the "paste" command is
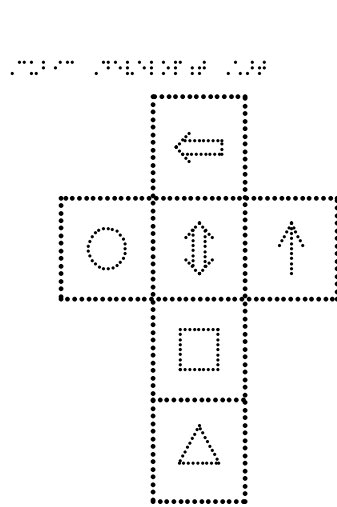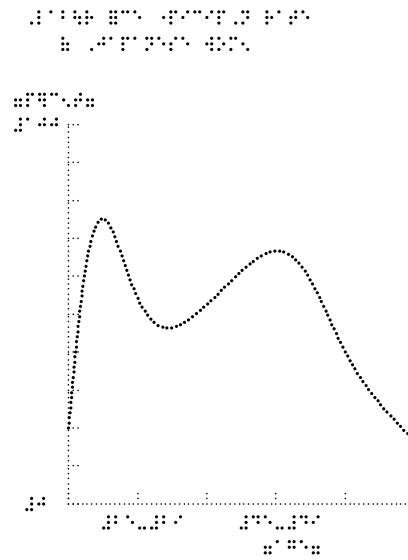
Fig. 2. Unfolded Cube

Fig. 3. Labor Force Participation Rate

used to draw a figure defined in a separate file, where "fig2_c.txt" is a file name, "-4 2" the coordinates, and "1 1" the magnification ratios of the horizontal and the vertical. On line 17, the "rotate" command is used to rotate the coordinates defined by the "window" command, where "1" means validity of the command, "0 0" the coordinates of the center of rotation, and "90" the angle of rotation. If the first parameter is "0", then the command is invalid. On line 29, "ff" means the end of page.

Program 2 consists of 32 lines. On line 8, the "origin" command is used to reset the origin of coordinates to (-6.5, -8). On line 11 and 12, the "xaxis" command and the "yaxis" command are used to draw the horizontal axis and the vertical axis. On line 23, the "spline" command is used to draw a spline interpolation curve which goes along six points specified from line 24 to line 29. "9999" on line 30 means the end of data.

4 Quality of Productions

To evaluate the quality of productions of BPLOT2, we compared productions from the following three tactile graphics production systems: BPLOT2, EDEL-plus and BES4. These three are the computerized tactile graphics production systems used in Japan to produce braille textbooks and braille test booklets. Among them, BPLOT2 is the only system for the blind to produce tactile graphics by themselves. These three systems utilize the same braille printer ESA721.

We had the three systems to produce the four tactile graphics shown in Fig. 2, Fig. 3, Fig. 4 and Fig. 5. We measured embossing time of each graphics.

Program 1. Figure-Drawing Program for Fig. 2

1	/* main module fig2.txt	1	/// module fig2_a.txt
2	Cubic Development Chart	2	aux
3	*/	3	dot 1
4		4	arrow 0 -1 0 1 30 1 0 2
5	aux		
6	window 1 41 0 24	1	/// module fig2_b.txt
7	braille 5 22 ,Cubic ,Development ,Chart	2	aux
8		3	dot 1
9	window -10.4 10.4 -12.5 12.5	4	box 0 0 0.8 0.8 2
10	dot 2		
11	box 0 0 2 8 3	1	/// module fig2_c.txt
12	box 0 2 6 2 3	2	aux
13	line -2 -4 2 -4 3	3	dot 1
14		4	circle 0 0 0.8 0 360 2
15	paste fig2_c.txt -4 2 1 1		
16		1	/// module fig2_d1.txt
17	rotate 1 0 0 90	2	aux
18	paste fig2_d1.txt 0 6 1 1	3	dot 1
19	rotate 0 0 0 0	4	line -0.27 0.717 -0.27 -1 2
20		5	line -0.27 -1 0.27 -1 2
21	paste fig2_d2.txt 0 2 1 1	6	line 0.27 -1 0.27 0.717 2
22		7	dart 0 1 90 0 45 0.9 0 2
23	paste fig2_a.txt 4 2 1 1		
24		1	/// module fig2_d2.txt
25	paste fig2_b.txt 0 -2 1 1	2	aux
26		3	dot 1
27	paste fig2_t.txt 0 -6 1 1	4	line -0.27 0.717 -0.27 -0.717 2
28		5	line 0.27 -0.717 0.27 0.717 2
29	ff // formfeed	6	dart 0 1 90 0 45 0.9 0 2
30		7	dart 0 -1 -90 0 -45 0.9 0 2
31	/// end of main module		
		1	/// module fig2_t.txt
		2	aux
		3	dot 1
		4	polygon 3 0 0 1 2

Although the total embossing time of BPLOT2 and BES4 were same, they were about 1.7 times faster than that of EDEL-plus. This difference may be caused by their embossing procedure. BPLOT2 and BES4 are drawing basic figures in due order. EDEL, on the other hand, generates dotted image of figures in memory first and embosses one line at a time from the top to the bottom of paper.

The quality of productions of tactile figures of BPLOT2 and BES4 were a little better than that of EDEL-plus because of the difference of embossing procedure.

Program 2. Figure-Drawing Program for Fig. 3

|			
1	// Labor force participation rate	17	
2	aux	18	braille 1.5 -0.5 #be-#bi
3	window 1 41 0 24	19	braille 7.5 -0.5 #de-#di
4	braille 5 23 ,Lab—r =ce "picip,n rate	20	braille 7.5 -1.5 7age7
5	braille 8 22 (,Japanese wom5	21	
6		22	dot 1
7	window -10.4 10.4 -12.5 12.5	23	spline 0 15 0 15 2 0 0 2
8	origin -6.5 -8	24	0 3 // point 1
9		25	1.8 11 // point 2
10	dot 0	26	4 7 // point 3
11	xaxis 0 15 3 2 2	27	9 10 // point 4
12	yaxis 0 15 1.5 2 2	28	12 6 // point 5
13		29	15 2.5 // point 6
14	braille -2.3 16.2 7p}c5t7	30	9999 0 // end of data
15	braille -2.3 15.2 #ajj	31	
16	braille -1.8 0.2 #j	32	ff // formfeed
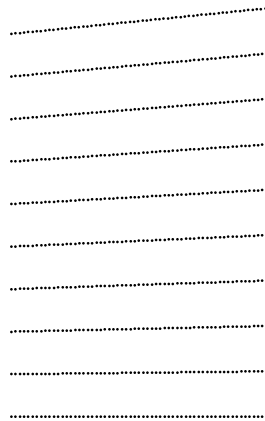
Fig. 4. Inclined lines
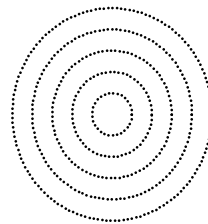
Fig. 5. Concentric Circles

5   Conclusion

The universal design of BPLOT2 enables the blind and the sighted to share resources and cooperatively draw tactile graphics. Since tactile proofreading by a blind person is necessary to ensure the quality of tactile graphics, a system which enables a blind person to proofread and revise tactile graphics was strongly requested. With BPLOT2, a blind person can edit a figure-drawing program generated from a design sheet drawn by a sighted person with GUI mode of BPLOT2. Likewise, a design sheet generated from a figure-drawing program formerly made by a blind person can be revised by a sighted person with GUI mode of BPLOT2.

Actually, BPLOT2 has been utilized to produce all tactile graphics of braille format tests for the National Admission Test for Law Schools and some tactile graphics for the National Center Test for University Admissions in Japan. Examples are shown in Fig. 6 and Fig. 7.
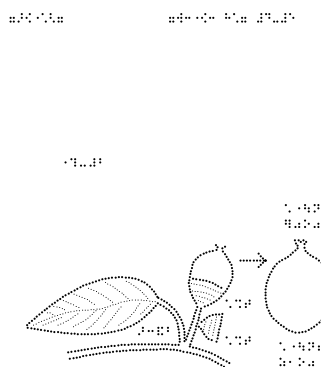
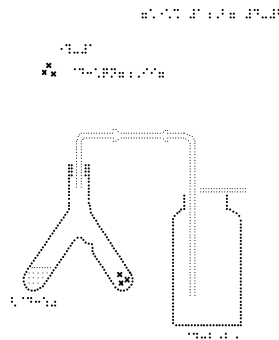**Fig. 6.** (Biology) Morphologic Characteristics of Acorn

Fig. 7. (Chemistry) An Equipment of Chemistry (Forked Test Tube and Gas collecting Bottle)

We think figure-drawing programs are superb in reusability and circulation because they are text files. We are preparing public domain figure-drawing programs usable for classes in mathematics, chemistry and physics.

Recently, the development of tactile graphic displays for the PC is remarkable. GUI is useful not only for the sighted but also for the blind. We want to offer GUI to the blind so that they can make use of a tactile graphic display in the near future.

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