

Development of Tactile Graphics Production Software for Three-Dimensional Projections

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Abstract. In this paper, we introduce tactile graphics production software for three-dimensional projections. A blind person can use this software without assistance from the sighted and produce tactile graphics of three-dimensional projections. With this software, we want to study the limitation of tactile recognition of projections and improve the guidelines of teaching projections.

Keywords: tactile graphics, the blind, three-dimensional projections, universal design.

1 Introduction

Tactile graphics production software for three-dimensional projections is developed for the blind. A blind person can use this software without assistance from the sighted and produce tactile graphics of three-dimensional projections. The software supports various types of projections such as orthographic projection, oblique projection, and perspective projection. Once required parameters are inputted to the software, tactile graphics of three-dimensional projections will be printed by a braille plotter printer.

Although the concepts of topological space and Euclidean space are learnable through tactile sense (haptic perception) and auditory sense, it is considered

that it is almost impossible for the congenitally blind and the early blind to acquire the concept of projections because of a lack of experience in seeing light and shadow [2,3,4]. However, there might be possibility that the concept of projections becomes learnable for them when a person starts abstract thinking around age 11 or 12 years.

This study presents tactile graphics production software for three-dimensional projections that is usable by a blind person. A blind person can obtain tactile graphics of various types of projections from any preferable viewpoint. The software enables the blind to study the concept of projections by themselves. Obviously, the tactile recognition of projections is much harder than the visual recognition of projections. We want to study the limitation of tactile recognition of projections and improve the guidelines of teaching projections.

2 Development of Bplot 3D

Tactile graphics production software for three-dimensional projections Bplot 3D is developed.

2.1 Outline of Bplot 3D

Since we want to make Bplot 3D to be usable by a blind person without assistance from the sighted, it is developed as a preprocessor of the universal design tactile graphics production system Bplot2 [1].

A user gives Bplot 3D a series of commands to produce tactile graphics of a three-dimensional projection by specifying a type of projection, a viewpoint, and a projection plane. Commands are written in a text file using our newly designed control language for Bplot 3D. Because a command file for Bplot 3D is a text file, it is editable with any text editors by any person who has learned the control language. Therefore, Bplot 3D can be used by both the sighted and the blind.

The software supports various types of projections. In general, projections are classified into two categories, namely, 'parallel projection' and 'perspective projection'. Moreover, 'parallel projection' are divided into 'orthographic projection' and 'oblique projection'. In parallel projection, the projection rays from the object to the projection plane are parallel to each other. Orthographic projection is a type of parallel projection where the view direction is orthogonal to the projection plane. On the other hand, oblique projection is a type of parallel projection where the view direction is not orthogonal to the projection plane. In perspective projection, the projection rays are not parallel to each other but they are emerging from the viewpoint.

2.2 Commands for Bplot 3D

To distinguish three-dimensional commands from ordinal commands of Bplot2, every three-dimensional command starts from '3'.

(1) Projection Type: A type of projections needs to be specified prior to the other commands. For orthographic projection, the command is ‘3orthographic’. For oblique projection, the command is ‘3oblique depth theta’. The parameters ‘depth’ and ‘theta’ specify the fraction of depth versus width, and the angle from the horizontal direction to the depth direction. For perspective projection, the command is ‘3perspective’.

(2) Viewpoint: A viewpoint is specified with the command ‘3viewpoint x0 y0 z0’. Instead of the coordinates, a viewpoint can be specified as a directional vector by the command ‘3direction theta phi’ for parallel projection.

(3) Wireframe: The wireframe of a figure is specified with the following commands. To define a plot, we use the command ‘3plot x0 y0 z0’. The command ‘3plot’ has three parameters for the coordinates of point ‘x0 y0 z0’. To define a line segment, we use the command ‘3line x0 y0 z0 x1 y1 z1 DotPitch’. The command ‘3line’ has seven parameters for the coordinates of start point ‘x0 y0 z0’, the coordinates of end point ‘x1 y1 z1’, and the dot pitch. To define connected line segments, we use the command ‘3bline’. The command ‘3bline’ specifies the dot pitch, the coordinates of start point, middle points, and end point, as follows:

```
3bline DotPitch
@x1 y1 z1
@x2 y2 z2
@x3 y3 z3
@...
@...
@...
@xn yn zn
@9999 0 0
```

On the last line, ‘9999 0 0’ means the end of command. We can also define a curve line with the command ‘3spline’.

(4) Macros: We can define macros for three-dimensional commands by using the command ‘3define identifier replacement_string_list’. The command ‘3define’ replaces ‘identifier’ into ‘replacement_string_list’ prior to the other three-dimensional commands. For the readability of three-dimensional commands, we can write parameters by identifiers instead of numerics.

2.3 An Example of Produced Three-Dimensional Projections

The following is an example of a command file to produce an oblique projection in Fig. 1. The command file ‘File 3D’ describes a wire frame of a cube that has the center as the origin and sides of length 6. The type of projection and the viewpoint are also described in the file. When ‘File 3D’ is inputted to Bplot 3D, the command file for Bplot2 ‘File 2D’ is obtained. From ‘File 2D’, Bplot2 can produce tactile graphics with a braille plotter printer.

On line 5 and 6 in ‘File 3D’, a type of projection and a viewpoint are specified. These lines are commented out in ‘File 2D’. On lines 8-10 and 50-51 in ‘File 3D’,

File 3D

```

1: /* Wire Frame of Cube
2:   by Oblique Projection
3: */
4:
5: 3oblique 0.67 45
6: 3viewport 0 -10 0
7:
8: 3define dotpitch1 2.2
9: 3define dotpitch0 4.0
10: 3define end_of_data 9999 0 0
11:
12: define small 0
13: define middle 1
14: define large 2
15:
16: /// visible lines
17:
18: dot middle
19: 3bline dotpitch1
20:   -3.0 -3.0 3.0
21:   3.0 -3.0 3.0
22:   3.0 3.0 3.0
23:   -3.0 3.0 3.0
24:   -3.0 -3.0 3.0
25:   end_of_data
26:
27: 3bline dotpitch1
28:   -3.0 -3.0 3.0
29:   -3.0 -3.0 -3.0
30:   3.0 -3.0 -3.0
31:   3.0 -3.0 3.0
32:   end_of_data
33:
34: 3bline dotpitch1
35:   3.0 -3.0 -3.0
36:   3.0 3.0 -3.0
37:   3.0 3.0 3.0
38:   end_of_data
39:
40: /// hidden lines
41:
42: dot small
43:
44: 3bline dotpitch0
45:   -3.0 -3.0 -3.0
46:   -3.0 3.0 -3.0
47:   3.0 3.0 -3.0
48:   end_of_data
49:
50: 3define point0 -3.0 3.0 -3.0
51: 3define point1 -3.0 3.0 3.0
52: 3line point0 point1 dotpitch0
53:
54: ///
55:
56: ff // formfeed

```

File 2D

```

1: /* Wire Frame of Cube
2:   by Oblique Projection
3: */
4:
5: //3D oblique projection (0.67, 0.25Pi)
6: //3D viewpoint (0.00, -10.00, 0.00)
7:
8: //3D defined dotpitch1 2.2 in rec. 1
9: //3D defined dotpitch0 4.0 in rec. 2
10: //3D defined end_of_data 9999 0 0 in rec. 3
11:
12: define small 0
13: define middle 1
14: define large 2
15:
16: /// visible lines
17:
18: dot middle
19: bline 2.200 //3D 5 points
20:   -4.421 1.579 //3D point 1
21:   1.579 1.579 //3D point 2
22:   4.421 4.421 //3D point 3
23:   -1.579 4.421 //3D point 4
24:   -4.421 1.579 //3D point 5
25:   9999 0 //3D end_of_data
26:
27: bline 2.200 //3D 4 points
28:   -4.421 1.579 //3D point 1
29:   -4.421 -4.421 //3D point 2
30:   1.579 -4.421 //3D point 3
31:   1.579 1.579 //3D point 4
32:   9999 0 //3D end_of_data
33:
34: bline 2.200 //3D 3 points
35:   1.579 -4.421 //3D point 1
36:   4.421 -1.579 //3D point 2
37:   4.421 4.421 //3D point 3
38:   9999 0 //3D end_of_data
39:
40: /// hidden lines
41:
42: dot small
43:
44: bline 4.000 //3D 3 points
45:   -4.421 -4.421 //3D point 1
46:   -1.579 -1.579 //3D point 2
47:   4.421 -1.579 //3D point 3
48:   9999 0 //3D end_of_data
49:
50: //3D defined point0 -3.0 3.0 -3.0 in rec. 4
51: //3D defined point1 -3.0 3.0 3.0 in rec. 5
52: line -1.579 -1.579 -1.579 4.421 4.000 //3D
53:
54: ///
55:
56: ff // formfeed

```

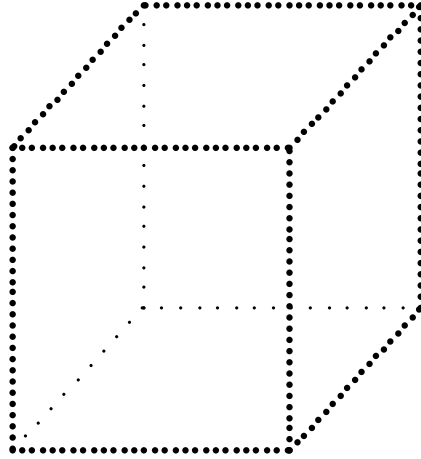


Fig. 1. Oblique projection of a cube

macros are defined. Parameters of other commands are specified by identifiers instead of numerics. These lines are commented out in 'File 2D'. On lines 12-14 in 'File 3D', there is the command 'define'. Since this command is not a three-dimensional command, Bplot 3D does not touch it. On line 18 and 42 in 'File 3D' and 'File 2D', the size of dots of dotted lines is specified with the command 'dot'. On lines 16-38 in 'File 3D' and 'File 2D', the wire frame of a cube on the visible side is defined. On lines 40-52 in 'File 3D' and 'File 2D', the wire frame on the hidden side is defined. On line 56 in 'File 3D' and 'File 2D', the command 'ff' means the end of page.

3 Experimental Evaluation

In order to evaluate the usefulness of Bplot 3D, an experiment was conducted to study which type of projection is suitable for blind students to recognize shapes of three-dimensional objects.

As experimental materials, we prepared tactile graphics of projections of four kinds of geometric solids (cube, cuboid, cylinder, and tetrahedron) by the following drawing methods: (1) development view, (2) front view of orthographic projection, (3) oblique projection without hidden lines, (4) oblique projection with hidden lines, and (5) perspective projection with hidden lines. An example of five tactile graphics of a cube is shown in Fig. 2.

Each figure was embossed on a sheet of braille-printer paper. The visible lines of wire frames were drawn by thick dotted lines (dot size 1.5mm in diameter and dot pitch 2.2mm) and hidden lines were delineated by thin lines (dot size 0.8mm in diameter and dot pitch 4.0mm).

Subjects were eight totally blind students in a high school for the blind. Their age ranged from 16 to 17 years old. They were classified into two subject groups:

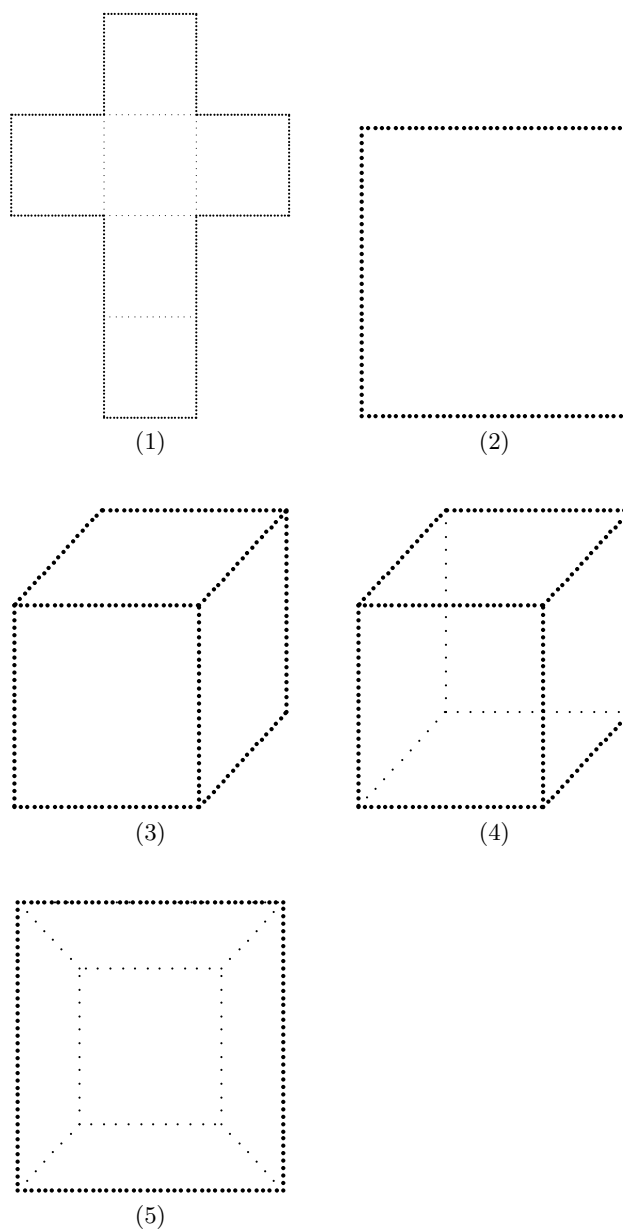


Fig. 2. Tactile graphics of a cube by the five drawing methods

the early blind and the late blind. In the early blind group, they suffered visual impairments before 5 years old. In the late blind group, they suffered visual impairments from 6 to 11 years old.

The subjects were asked to successfully observe tactile graphics of one of the four geometric solids by one of the five drawing methods. Simultaneously, they

were required to rank the five drawing methods. The task was repeated for the four geometric solids, respectively.

As a result of the experiment, we found that blind students prefer development view as the best drawing method. Oblique projections with and without hidden lines are at the second and third, and front view of orthographic projection and perspective projection are at the fourth and fifth. From the result of analysis of variance and Scheffe's comparison, the ranks of the five drawing methods were significant for all four geometric solids.

We also found that subjects in the late blind group recognized the concept of projection better than subjects in the early blind group through discussion with them. However, we could not find significant differences between two subject groups because the number of subjects was too small.

4 Conclusion

Tactile graphics production software for three-dimensional projections Bplot 3D was developed for the blind. Bplot 3D was implemented as a preprocessor of the universal design tactile graphics production system Bplot2 [1]. Both the blind and the sighted can produce tactile graphics of projections easily.

As a result of the experiment, we noticed that it is not easy for the blind to recognize projections. However, the study of projection is necessary in natural sciences for higher education [2,3,4,5].

To know the limitation of tactile recognition of projections and to improve the guidelines of teaching projections, we need further studies.

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