Building Problem Spaces for Deaf and Hard of Hearing Students' Spatial Cognition in a Programming Language

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Abstract. It has been published that the mental faculty for handling languages influences the development of spatial cognition ability for deaf and hard of hearing students. To make measurements for their ability and extract the features, various kinds of methods that decrease the language effects have been tried. In this article, an experimental method is described that uses a programming language. The communication method using the simple language and the graphical interface may give us a convenient way for students' understanding questions and expressing their ideas. The software tool used in the research, Hyperlogo and its graphical interface, is described in the first half section. And then the experiments to which the tool is applied are shown.

Keywords: Spatial Cognition, Hyperlogo, Deaf and Hard of hearing, Communication tool, Programming Languages, Turtle graphics.

1 Introduction

Understanding the spatial cognition ability of handicapped children/students is important but rather difficult work. A large number of researches have being carried out on this subject [2]. In this study, deaf and hard of hearing students are focused. They are thought to may have language problems to express their cognition results.

Preceding researches, e.g. [3], have investigated the difference between hearing children and hard of hearing children about the spatial cognitions. According to his and related works, the difference is small for the task which is thought to be difficult to get the effect of language. But it is relatively large in the case of having close relation to the language. Nakano used the Japanese sign language for decreasing the language effects, and could figure out the development process of acquiring the ability of spatial cognition [5].

C. Stephanidis (Ed.): Universal Access in HCI, Part III, HCII 2009, LNCS 5616, pp. 167–175, 2009.

Deaf and hard of hearing students are said usually to have their difficulty of developing spoken and written languages' performance because of the disability of audio channel. Extracting the meaning of questions and expressing replies may depend on each respondent's language handling competence in the ordinary natural language.

Comparing with the natural languages, programming languages are said to have less expressional flexibility. But they surely have simple syntactic rules and clearly defined semantics. The comparative studies between natural languages and programming languages have been carried out, e.g. [6].

The authors expect to be able to decrease effects of the above competence difference if such programming languages can be used as a tool. They planed to use a programming language for studying the feasibility whether a simple artificial language can be applied to the problem. Programs can describe structures of the objects like mathematical formulae. A program is interpreted as a suitable media and can describe not only solving processes but results or answers.

Hyperlogo is a member of the Logo language family [1][4]. It is enhanced the mathematical characteristics. It might suite for describing both questions and answers formal. The graphical function can provide a convenient interface for utilizing visual information between the students and researchers.

2 The Graphics System of Hyperlogo

Hyperlogo is the language system which the authors designed and implemented for their research work [7][8]. The three-dimensional (3D) graphics is added to the Hyperlogo. The well known Turtle Graphics invented by Seymour Papert provides a simple and user-friendly interface to users. Graphical figures are drawn by a locus of turtle. So the authors used this framework to their system.

The turtle in this system is made by a computational object, i.e. the functional closure, that stores the location and posture information in it such as present place coordinates, heading direction, tilt angles of the body and drawing-pen status. The activity control of a turtle is performed by the message passing method to the objects.

2.1 The Local Coordinates World and the Global Coordinates World

Turtles' traditional commands such as forward, backward, left turn and right turn are issued based on the local view. That is the view from the turtle's front windscreen. For example, "right-turn 60" means to face rightward in the local coordinates of the turtle. On the contrary, the action result of the turtle appears in the global coordinates world (Fig.1). When a turtle moves forward from the present location to the new location in the virtual space, an observer who may be the same person with the command issuer sees the command's execution result through his local view.

A turtle can be interpreted as the mapping mechanism between the local coordinates world and the global coordinates world in Hyperlogo (Table 1). The authors introduced a number of commands in the global world. Users can use the commands of both worlds according to their control context.

If screenshots are necessary, please make sure that you are happy with the print quality before you send the files.

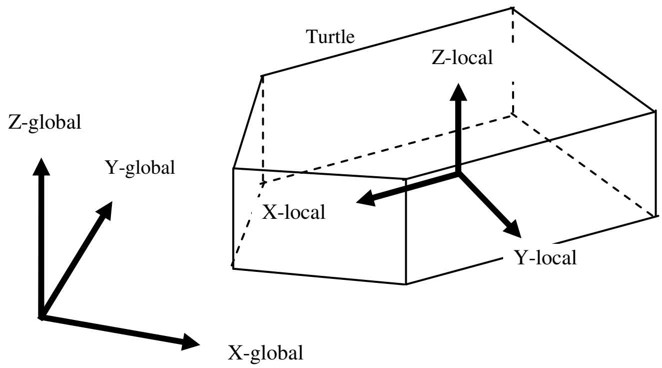

Fig. 1. Local coordinates and global coordinates

Table 1. Movement commands

<Local group>			
right <angle>	left <angle>	up <degree>	down <degree>
roll-cw <angle>	roll-cc <angle>		
<Global group>			
move <place>	roll-reset	head <target>	
north	south	east	west
northeast	northwest	southeast	southwest
<Common group>			
forward <steps>	backward <steps>	pen-up	pen-down

2.2 Architecture of the Turtle Graphics

The graphics of the system treats three-dimensional (3D) world. All figures are generated in the 3D virtual space. The traditional two-dimensional (2D) world is represented by the handling of view.

Fig.2 shows the schematic structure of the system.

World event controller. The controller accepts user's command and drives turtles. It places objects in the world, show them and changes the observation view angle of a user.

Coordinates transformation engine. The coordinates transformation engine consists mainly of;

- Rotation matrix procedures.
- Inversion matrix procedures.

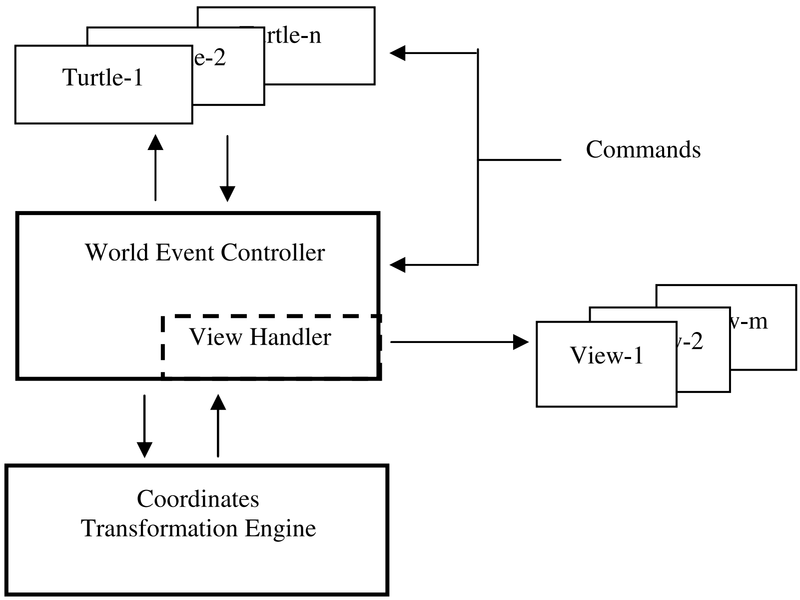

Fig. 2. Structure of the system

- Scaling vector procedures.
- Shift vector procedures.

Changes of a turtle's position are interpreted as a change of the angles of the local axes to the global coordinates.

The turtle's movement commands consist of two groups, commands based on the turtle's local coordinates such as "right-turn" and commands based on the global coordinates of the virtual world such as "head". Commands based on the global coordinates are converted to the movement action simply. Commands based on the local coordinates needs mapping to the displacement of the virtual world's coordinates. The coordinates transformation engine computes the change of the coordinate values. The matrix calculation is the main task of the engine.

View handler. The view handler draws figures projected to the 2D screen named the view, and then the figure is displayed on the display device.

2.3 Movements of a Turtle

Every movement is accumulated to the angle transformation matrix. Initial position, posture and the total angle transformation matrix provides the next position and posture.

[Total transformation matrix]
← [Transformation matrix of the present step]
* [Old total transformation matrix]
[New position and posture]

← [Initial position and posture]
* [Total transformation matrix]

Objects in the virtual world are expressed by the wireframe.

[Object] ← [[Line-1]
[Line-2]
…
[Line-n]]
[Line] ← [[Start point] [End point]]

User can retract the last input and restore the previous state by the rewind command. Issued commands by a user are recorded in sequence to a logging file. The file can be examined in the later analysis.

2.4 View Control

Users can change their view angle with the command and observe the drawn figure in a pane from practically any angles (Fig.3). For example, a view from the opposite side of a table can be drawn easily in the Jean Piaget's well known three mountains problem.

These commands are designed mainly for the expression assignments described at the next section (Table 2).

Table 2. Viewing commands

view-angle <x-rotation-angle> <y-rotation-angle> <z-rotation-angle>	
front-view	rear-view
right-side-view	left-side-view
top-view	bottom-view

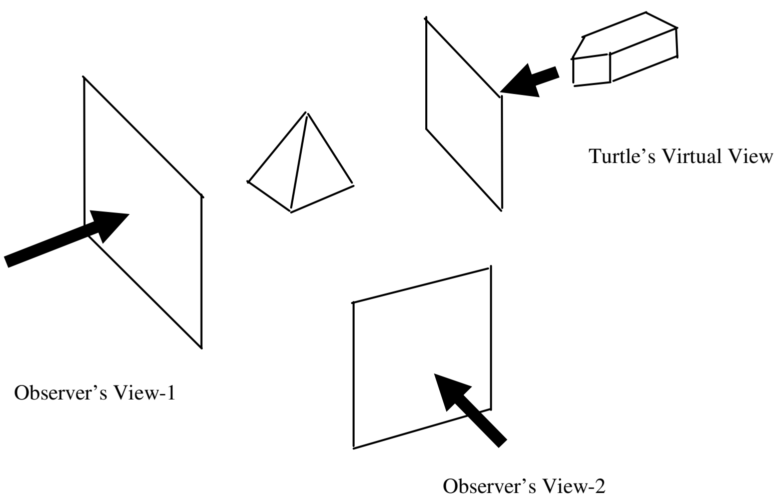

Fig. 3. Views of various angles

3 Assignments

Three groups of assignment are set up; understanding assignments, expression assignments and viewpoint assignments. The understanding assignments and the expression assignments are intended mainly to estimate the degree of the subjects about handling graphical figures. The viewpoint assignment is designed to investigate the decision strategy and kinds of information concerned with the coordinates.

1. Understanding assignments
Shows programs coded in Hyperlogo, and asks students the result figures that the programs will draw.

Fig.4 is an example of drawing a square object.

Problem- 1A. When you execute a program in the left box, what figure will you obtain? Draw it in the right box.

2. Expression assignments
Shows students figures and asks them to make programs that will draw similar figures. All commands that a student issues in the trial or building phase are logged to the file for analysis.

Fig.5 is an example of presented object on the display.

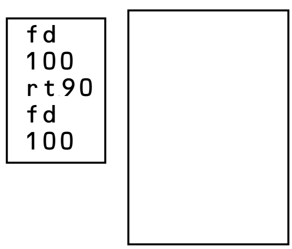

Fig. 4. An example of the understanding assignment problem

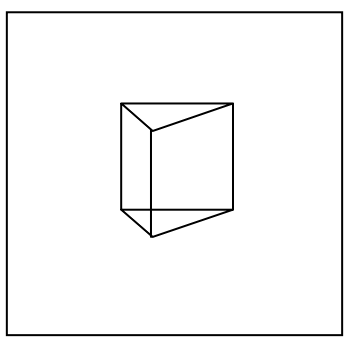

Fig. 5. An example of the presented figure

3. Viewpoint assignments
Shows a bird-eye view of the simple model area, in which some streets, crossings, some shops, mountain and pond are located. Asks students to drive a turtle from the given start point to destinations. The students' commands and their issue sequences including withdrawals are recorded entirely. Commands based on the local coordinates and commands based on the global coordinates in the situation are mainly examined.

Fig. 6 shows the model town map. It has the compass points, and a few landmark spots are located along the street. Every street intersects at right angles with each other except some crossings, so as to coincide with the compass directions. The mountain and the pond can be in sight at a certain places on the street.

Problem-2B. Observe a figure on the display. Make a sequence of commands that will draw the same figure. You can rotate and see it from the several view angles, front view, rear view, right-side view, left-side view, top view, bottom view and practically any angle you want. Try it on the computer freely to complete your answer. And then write the answer at every command on the sheet.

Problem-3C. This is a map of the Nowhere Town. You are asked to go on errands. Now you are at the start point on the map. Drive your car and drop by the places in order; Hamburger shop (H), Post office (P), Movie theater (T) and Station (S).

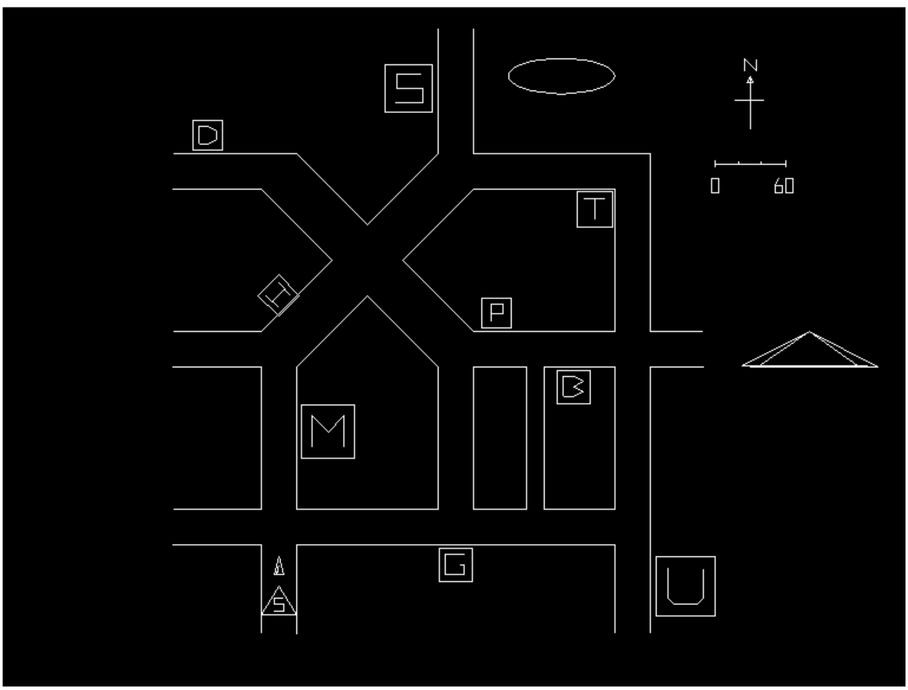

Fig. 6. The town map

4 Experiments

Experimental subjects. Six persons, made up of five university students and one non-student. Students are at the first-year and have attended the fundamental programming class. The other person is the same age and was given a special lecture about programming. All persons have difficulty in hearing.

Contents of the experiment

Understanding assignment	3 problems
Expression assignment	4 problems
Viewpoint assignment	1 problem

Experiment process

1. Brief explanation about the language characteristics and graphics
2. Brief explanation about the methods for controlling the Turtle
3. Understanding assignment test
4. Expression assignment test
5. Viewpoint assignment test

Results of the experiment. On the first two assignments, A few students became aware of the relation between the similarity of command's partial sequences and the similarity of drawn figures. Validity of using a programming language as a tool was verified.

On the viewpoint assignment, Table 3 is the five students' command history. The change-direction commands only are listed in the table. The corner ID column shows the sequence on the given route. The rows show student's trial at the same corner.

Table 3. Issue history of the rotation commands

Corner ID	A	B	C1	2	3	D1	2	3	E1	2	3
1 (R45)	right 45	right 45	right 60			right 30	right 45		right 45		
	right 10										
2 (R90)	right 60	right 45	right 30			right 90			left 50	right 50	right 80
	right 40	right 45	right 40						right 70		south
									left 50		
3 (L45)	left 45	left 45	left 45	right 40	left 40	left 105	left 30	left 45	east	east	
	left 20										
4 (L90)	left 90	left 90	left 90			left 90			north		
5 (L90)	left 90	left 90	left 90			left 90			west		
6 (R90)	right 90	right 90	right 90			right 90			north		

Three kind of keeping-track strategy are extracted; making modification one after another, cancel and retry, and using global information. Hypothesis of the change of the decision making can be read from the list. It was confirmed that the result of the assignment makes sense. The authors are expecting the comparison with the hearing students.

5 Conclusion

For spatial cognition studies of deaf and hard of hearing students, the spoken languages and the written languages were used at the early stage. And then the sign languages were put to use. The authors have been considering that programming languages are also the useful tool for the study.

Using a mathematical programming language has brought to decrease the expressional ambiguity. Providing information for the students seems to have been improved. It is also still remained whether these assignments suites better to examine the students' spatial cognition.

The study is still at the search phase at present. But the hypothesis from the limited results can be framed that a programming language is a useful medium of communication and measurement. This hypothesis is planned to be verified at the succeeding phase of the study. Increase the number of subjects and comparing with hearing people are required now.

The authors would like to express their thanks to the students who gave them the opportunity of the experiment.

Acknowledgments. This work was supported by Grant-in-Aid(No. 20500745) for Scientific Research(C) from Japan Society for the Promotion of Science(JSPS), Japan.

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