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Development of real-world oriented mobile constellation learning environment using gaze pointing

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Abstract: We developed a real-world oriented mobile constellation learning environment. Learners point at a target constellation by gazing through a cylinder with a gyro-sensor, which can display information related to the constellation. The system has a learning function. Through experimentation, we evaluated the learning environment to assess its learning effects.

Keywords: Mobile function, constellation learning, gyro sensor, gaze pointing

1.Introduction

Two methods are used currently by astronomy beginners to learn star names or constellations: observing and learning stars under the actual night sky, and observing and learning them under a virtual starry sky using a domed projection in a planetarium.
In the former method under an actual night sky, astronomy beginners must identify stars on a star chart or a star observation support tool as those in the real night sky to obtain astronomical information about a target star. Star charts and star observation support tools are indeed useful tools, but beginners must repeatedly shift their gaze between the night sky and the tool when identifying a star in the real night sky. In contrast, the method of observing and learning stars under a virtual starry sky using a domed projection in a planetarium requires costly and large facilities, usually entire buildings, and presents problems such as a lack of interactivity because activities must proceed to meet a schedule. Moreover, a projector is placed in the center of the dome, and seats for spectators are arranged around it. Consequently, astronomy beginners see strained constellations which differ from those in the real night sky; a large gap remains between reality and the astronomy beginner's imagination.
As just described, astronomy beginners often encounter stress when performing star observation. That stress can deter them from becoming interested in astronomy.
Consequently, our laboratory has conducted studies for star search support and astronomy learning support. We have developed a "constellation learning support environment incorporating finger pointing actions"[1][2][3]. By pointing at a target constellation in the real world, it presents information about the constellation on the system using text and sound. It facilitates the instruction of star names without identifying stars and reduces stress related to star observation. It also answers queries related to respective stars by detecting a pointed star with a magnetic position sensor worn on a fingertip and presents the answers with text and sound. Learners answer a question by pointing at a star in the real night sky. These features lead learners to match a learned star and a real star more quickly when looking up at the real night sky.

Nonetheless, the system presented in previous reports requires AC power and imposes location constraints that hinder their use in the real night sky because they use a magnetic position sensor. Their exercise functions also appear to be insufficient.

Nakajima and others developed a star observation support system using wearable augmented reality technology [4]. This method performs head tracking with a gyro-sensor and superimposes and displays a projected image of a starry sky along with information about constellations on the HMD with video see-through type augmented reality. Although this system supports constellation observation, it is confined to added information: it has no learning support function such as an exercise function.

"DS hoshizora-navi", a star navigation system functioning on DS produced recently by Nintendo [5] runs planetarium software on a Nintendo DS. When holding a DS with an additional orientation sensor module up to the night sky, it displays constellations in that direction on the display screen. This method requires learners to identify stars by comparing the real night sky with a screen display on the DS. It is particularly difficult under circumstances in which only a single star is visible among the clouds. Moreover, the DS hoshizora-navi is not equipped with learning support functions such as an exercise function.

Google Sky Map, which is operable on a mobile terminal equipped with Android, can do the same things that the DS hoshizora-navi does, but it also is not equipped with learning support functions such as the exercise function.

This paper therefore presents a proposal of a real-world oriented mobile constellation learning support environment. It can use the actual night sky as learning content in the open air and is available for mobile use with exercise functions. We also describe results of evaluation experiments.

2. Proposed system

This section explains the proposed system, which enables mobile units to be used based on an existing system. The explanation also addresses constellation exercise functions.

2.1 Use of a gyro-sensor

As described previously, the existing system uses a magnetic position sensor to identify the direction in which a learner points. The magnetic position sensor obtains a position coordinate treating a magnetic field generator (transmitter) as the origin and calculates a direction vector to a target star based on the difference between those position vectors by placing a magnetic position sensor in the positions of a fingertip and eyes, respectively. However, such sensors present the following problems: when using the system to determine the reference direction, calibration must be done. Furthermore, preparation for using the system is troublesome.

The method presented herein uses an orientation gyro-sensor to identify the gaze direction. The gyro-sensor is operated on 9[V] AC power, but it is also operable using dry-cell batteries. The gyro-sensor can obtain three axial rotation angles, Roll, Pitch, and Yaw. Of those, Roll is not used for this study because it represents values of change in twisting actions of the gyro-sensor. The direction in which a learner points is obtainable from the gyro-sensor output value.

Based on the consideration above, improvement of operational aspects is expected because calibration operations are not required in the existing system, nor is improvement of location constraints.

2.2 Gaze pointing

We use the device depicted in Figure 1 as the gaze pointing interface for this study. It is a device with a gyro-sensor attached to a cylinder. The mechanism of the released system was to point at the night sky holding a sensor with the hands. However, because evaluation

experiments for the released system revealed physical fatigue resulting from gaze pointing actions, we reviewed the interface. The interface proposed this time has a specification to observe constellations in the night sky with a cylinder, which is the same action as peering at the night sky through a telescope. An advantage is that it has higher pointing accuracy for constellations than pointing at constellations by finger with magnetic position sensor. Particularly when the night sky is obscured by clouds and when constellations are difficult to view, looking at the night sky with a cylinder simplifies location of a target constellation compared to searching for a target constellation using gaze pointing.

Figure 1 Gaze pointing interface device.

2.3 Expansion of exercise functions

The existing system has the following constellation exercise functions:

- Constellation layout
- Zodiacal constellations
- Star positions

It is possible to learn the composition and position of constellations using the existing system. However, the system is insufficient for constellation learning functions because it is impossible to learn the relation between constellations and the shape of constellations. This study constructs the following functions:

- Constellation mythology exercise function
- Constellation line-drawing function

(1) Constellation mythology exercise function

This gives an opportunity to learn in the real night sky in relation to a constellation myth and a constellation. It also enables learning of the positional relations of constellation that appear in myths. Learners can get a better understanding of the constellation shape using not constellation lines but constellation pictures.

(2) Constellation line-drawing function

Constellation line-drawing is a function enabling learners to draw straight lines and marks among given stars. A learner points at stars using gaze pointing actions. This function enables learners to draw an original constellation. It is an effective method particularly for younger people to foster an interest in astronomy. In the future, a function to learn constellation lines can be imagined as the following: the system presents a question about constellation lines; a learner draws constellation lines to be corrected in the real night sky; and the system matches the drawing with the correct answer.

3.System configuration

This section presents a description of the system configuration based on the proposed system.

3.1. Interface configuration

The system uses the interface shown in Figure 2 below.

The gyro-sensor communicates serially to the PC. Data are transferred in real time.

The Wii remote controller uses only a button function when operating the constellation mythological exercise function and the constellation line-drawing function. It communicates with the PC via Bluetooth.

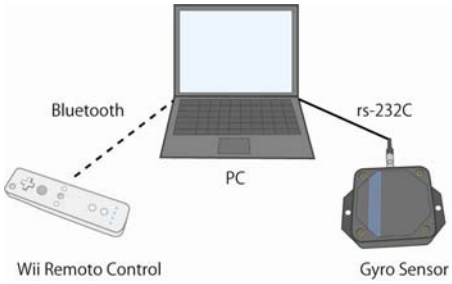

Figure 2 Interface configuration.

3.2. System configuration

Figure 3 presents the system workflow. When a learner points at a constellation using the gaze pointing interface, sensor data are transferred to the PC. After the transfer has been completed, the system analyzes the direction in which a learner is pointing. Then information related to the night sky around the indicated position is given to the learner through the system screen display.

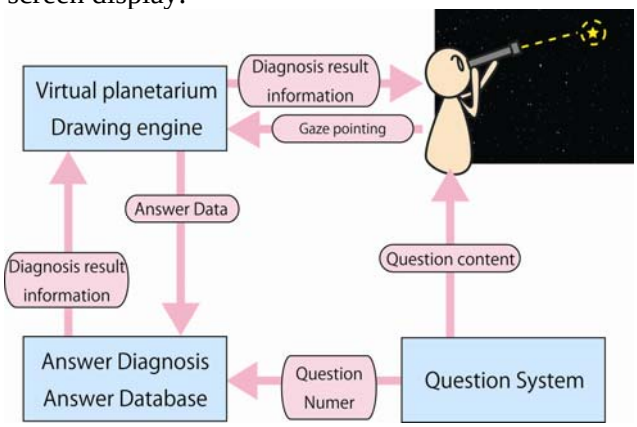

Figure 3 System workflow

For exercise functions, a learner selects an item to learn from the self-exercise panel. In the question system, the content of the question that was selected by the learner is displayed with text and voice. Simultaneously, the question system sends the question number to the answer search engine. The learner selects a star ahead of the gaze with the gaze pointing drawing function. The drawing engine sends star information that is selected by the learner to the answer-correcting engine as answer data. The answer-correcting engine corrects the answer with an answer database according to questions and sends the result to the drawing engine. Based on the diagnosis result, the drawing engine shows a message on virtual planetarium. The diagnosis result is informed by displaying the image in the virtual planetarium. In addition, when the answer is correct, the learner is informed of the next question, or that all answers were correct, with dialogue and sounds. The user is also informed with dialogue and sound accordingly if the answer is not correct.

3.3. Constellation mythological exercise function

The constellation mythological exercise function is a function to set questions about constellations composing constellation myths. The constructed system has realized the

constellation mythological exercise function on the theme of myths about Cassiopeia, Andromeda, Cetus, and Perseus.

This exercise function displays one scene of a myth with text according to the order of the myth story, as well as presentation by voice. Subsequently, the system instructs a learner to answer about the constellation appearing in the scene. The learner answers the question by finding the relevant constellation from the real night sky and marking a star in the constellation on the virtual planetarium by gaze pointing with the Wii remote controller button.

Then, the system judges the learner's answer. When the answer is correct, the system superimposes and displays the constellation picture on the virtual planetarium, proceeds to the next scene and displays it with text, and encourages the learner to answer about the constellation appearing next. The same question is presented repeatedly until the correct answer is given if the learner's answer is not correct.

The screen scene of the constellation mythological exercise function is portrayed in the left picture of Figure 4.

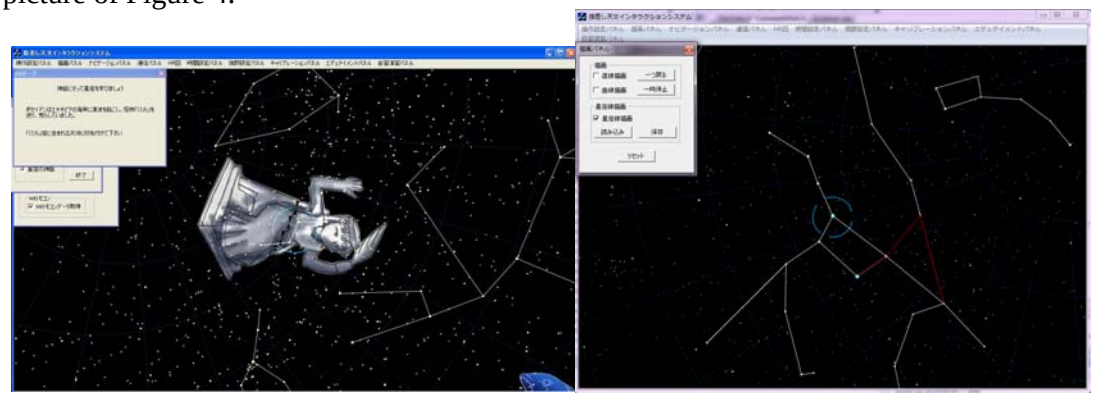

Figure 4 Scenes of the learning environment (Left: Constellation mythological exercise, Right: Constellation line-drawing function.)

3.4. Constellation line-drawing function

Constellation line drawing is a function that enables learners to draw straight lines and marks among selected stars. Right picture of Figure 4 presents the screen structure in the constellation line drawing. It is operated as a drawing method using the following procedures:

(1) Point at the starting point of a constellation line (star).
(2) When pressing the Wii remote controller button, the selected point turns red. Point at the next constellation while keeping the button pressed.
(3) After pointing, when releasing the button, constellation lines are displayed at two pointing points.

To draw more constellation lines, repeat procedures (1)–(3). Constellation lines can be stored as data; data saving is possible with the data output function and the data read function.

4.Experiment

4.1. Purposes

We verified the usefulness of the constellation mythological exercise by comparing the following support effects: learning outdoors with the constellation mythological exercise in the system and learning indoors with a book of constellation mythology. We also conducted a questionnaire survey to examine the usefulness and problems in the interface.

4.2. Method

Subjects of this experiment were nine students. First, we asked them to fill in a questionnaire sheet to assess their knowledge of constellations. Then we explained the method of this experiment. Before the experiment, we also asked subjects to use the system freely for a few minutes to become accustomed to its operation.

As Figure 5 shows, Experimental group learned with the constellation mythological exercise in the system. Control group did so using a book of constellation mythology.

Then the subjects orally explained a constellation myth under the real night sky as a recall test. If subjects cannot find some of the constellations, they are allowed to use navigation function. The navigation function is the function that guides a learner to a target constellation in the real sky. The navigation function is supported by the system by inheriting that of the previous learning environment[3]. We counted instances of navigation function usage for seeking constellations in the system. Thereby, we verified the learning effects of associating constellation mythology with constellations in the actual night sky.

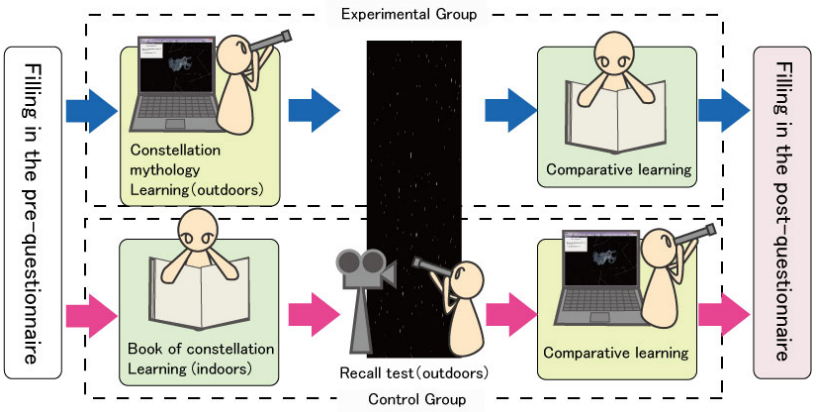

Figure 5 Flow of the evaluation experiment.

In the recall test, seven keywords comprising the story were prescribed in terms of the constellation myth. It was identified whether or not those keywords were included in the explained contents by the subjects.

After finishing recall test, both group exchanged their learning method. Experimental group experienced indoor learning with book of constellation and control group experienced outdoor learning with the system. Therefore, subjects in both groups were able to compare both learning methods and to evaluate system usability and usefulness. We implemented a post-questionnaire survey to determine the system usability. We asked respondents to evaluate questions (1)–(5) using a five-item scale and to fill in comments freely in answer columns of questions (6) and (7).

(1) Sense of physical fatigue
(2) Sense of mental fatigue
(3) Usability of the gaze pointing interface
(4) Usability of the Wii remote controller
(5) Whether constellation mythological exercises are fun?
(6) Advantages of learning with the book
(7) Advantages of learning with the system

4.3. Results and study

First, we conducted a pre-questionnaire survey to elicit astronomical knowledge. Results revealed that the number of constellations that subjects knew were fewer than five; subjects were almost entirely beginners of constellation learning. Furthermore, most subjects had

read between zero and five myths in constellation mythology. Taken together, their responses indicate that they were not very familiar with constellation mythology.
Next, we describe an evaluation experiment for the constellation mythological exercise. Table 1 below displays the number of wrong answers in constellation mythology and the number of times the navigation was used. The frequency of use of the navigation indicates that the constellation mythological exercise can be learned by associating constellation mythology with constellations under the real night sky. However, when particularly addressing learning of constellation mythology, the usefulness of the constellation mythology exercise is not well established.

Table 1 Results of constellation mythological exercises

Learning with the system	Subject	A	B	C	D	E
	The number of wrong answers in constellation mythology	1	3	3	1	1
	Times navigation was used	1	0	0	0	6
Learning with the book	Subject	E	F	G	H	
	The number of wrong answers in constellation mythology	4	0	0	0	
	Times navigation was used	2	8	4	4	

One reason might be the abundance of information in the book. In particular, visual information from illustrations strongly affects the learning of subjects in the control group. Another reason could be that subjects in the experimental group were unable to concentrate on the constellation mythological exercise because they were compelled to learn constellation mythology along with the position of constellations. Also, subjects might be unable to concentrate on the constellation mythology exercise, because it was outdoor learning in the cold winter night.

Table 2 Results of the questionnaire about usability and usefulness (Number of subjects of each score)

Score (1:Poor, 2:bad, 3:Fair, 4:good, 5:Excellent)	**1**	**2**	**3**	**4**	**5**
Sense of physical fatigue	1	5	0	1	2
Sense of mental fatigue	0	2	3	2	2
Usability of the gaze pointing interface	1	0	5	2	1
Usability of the Wii remote controller	0	2	3	2	2
Constellation mythological exercise function	0	1	2	4	2

Next, we present results in the questionnaire items. Answers varied throughout the whole questionnaire. However, regarding physical fatigue, scores of three and less accounted for the majority of responses, which is attributable to the burden on holding the gaze pointing interface during the exercises. We received an overall evaluation that they enjoyed the constellation mythological exercise function.
Finally, we introduce the freely described comments in Tables 3 and 4.

Table 3 Advantages of using the system

Easy to take in because of ability to identify constellations under the real sky.
Easy to grasp the constellation positions.
Pleasure felt when finding stars.
Easy to remember because a sense of distance, positional relations, and brightness can be experienced.
Learning by searching stars under the real sky is fresher and therefore easier to retain in memory than learning by reading.
I can actually see the real thing. Enjoyable.
It seems practicable continuously because it uses the real night sky.
Easy to remember as an experience because it is learning while watching the real night sky.
It can be experienced. Pleasure of searching.
I can understand the positional relations of the real starry sky.

The advantages of using the system are shown in Table 3. Many comments related to advantages of the system were the following: the pleasure of learning while watching the actual night sky; and information, such as the position of constellations, and myths remain in memory. Making learning fun engenders increased desire to learn. Therefore, using the system affects learning.

By contrast, advantages of learning with the book were listed as shown in Table 4: feeling less fatigue because pointing actions are not required; information sources are plentiful; learning at their own pace. The system includes problems such as not being able to concentrate on learning because it requires pointing actions. In addition, the system necessitates expanded information because the book has advantages attributable to its abundance of information sources.

Table 4 Advantages of learning with the book

Less exhaustive because it does not involve physical body movements.
It has pictures.
The text has abundant information. It is meaty in content.
Easy to understand because it has illustrations.
I can re-read the text any time I want to.
Not tiring. Warm. Shorter than the system in terms of learning hours.
Unaffected by weather conditions.
I cannot take it in because I work very hard at pointing. I can concentrate on a story.
I can read it in my own way. I can turn back to sentences I like.

5.Conclusions

This study replaced a magnetic position sensor used in previous studies with a gyro-sensor to make this system mobile. Using the system examined in previous studies, we constructed a movable constellation learning support environment.

We evaluated the system by comparing experimental group with control group. The result indicated that the learning by the system is appropriate to learn the positional relations of the real starry sky. By contrast, the result also indicated that the learning by the book is appropriate to learn the story of the constellation myths. Probably, the best way to learn constellation totally is to learn it by using both the system and the book. The system and the book can make up for disadvantages each other.

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