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Development of a Real-World Oriented Smartphone AR Supported Learning System for Seasonal Constellation Observation

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Abstract: In this paper, smartphone Augmented Reality (AR) and 2D contents were utilized to develop a system called the Real-World Oriented Smartphone AR Learning System (R-WOSARLS) for seasonal constellation observation, which based on planetarium contents in the planetarium of Nagoya City Science Museum for constellation learning. An experiment was conducted to evaluate the usefulness, usability, and users' satisfaction of our system. The results show that the R-WOSARLS is effective in improving the observation and learning of students and in enhancing their motivation to pursue seasonal constellation learning.

Keywords: augmented reality, smartphone, seasonal constellation, astronomy education

1. Introduction

The planetarium is a useful cognitive tool for people to learn about the night sky and astronomy concepts (Plummer, 2009). Seasonal Constellations are one of the key astronomy concepts that people see in their daily life. One of the popular astronomical concepts covered by projection learning programs in the planetarium of Nagoya City Science Museum (2014) is the seasonal constellation. Valuable and interesting information about constellations is shown and explained in an easy-to-understand format in these learning programs. However, the learning environment of a planetarium is still limited to virtual scenes, where learned can observe strained constellations, but there is a significant different between reality and the learners' imagination regarding constellations. However, naked eye observation of constellations in the starry sky is often restricted by time, geography and weather. Moreover, it is not easy for learners to identify the invisible constellations in the starry sky, compared to the Sun or Moon. Research has been conducted to study the development and usefulness of educational materials for constellation learning, using several approaches. Mouri et al. (2008) developed a web system for locating constellations in the starry sky based on the planisphere in a planetarium. However, learners who were taught in this learning environment still had a gap between real constellations in the sky and what they learned. For example, learners have no clear visual feeling of the elevation angle of constellations in the starry sky, even if they were provided the elevation angle information of a constellation. Kondo et al. (2005) utilized curator knowledge to develop a learning environment for learners to study and observe real constellations, such as how to identify stars or constellations in the sky with body scale guidance. However, this observation method is still limited by geography, weather, and time. Since AR technology can address these limitations (Tian et al., 2014), there are number of astronomy AR applications (Google Skymap, 2013), (Star walk, 2013), (Ura et al., 2012) and mobile system (Soga et al., 2011) for this purpose. The primary goal of these applications is to locate the stars and planets in the sky. However, these applications are not designed for teaching learners about seasonal constellations and they are unable to reach the educational goals of science regarding constellations. For example, there is no function to assist learners to observe and learn about seasonal constellations, such as the spring triangle. Secondly, there is no function for learners to understand the mechanisms of a seasonal constellation.

Finally, there are no suitable instructional strategies to specifically enable learners to engage actively in seasonal constellation observation with these applications.

In this research, smartphone AR and 2D contents were utilized to develop a system called the Real-World Oriented Smartphone AR Learning System (R-WOSARLS) for seasonal constellation observation, which can be applied to real constellation observations. The results of experiment showed that the system enhances learners' results regarding constellation observations. It was also highly motivating with regards to constellation observation.

2. System Interface

2.1 Learning Goal of Constellation Observation

The proposed system was developed as an educational tool to support seasonal constellation observation in a real world environment. The functions of the system are based on the planetarium content regarding constellations, from its projection program. The following contents are included on the topic of seasonal constellations:

(1) Observe constellation (Leo, Scorpius, Aqulia, Pegasus, Orion) to determine its azimuth and altitude in the real sky.

(2) Search and locate typical seasonal constellation (Leo, Scorpius, Aqulia, Pegasus, Orion) with body scale guidance in the starry sky.

(3) Observe spring constellations, summer constellations, autumn constellations and winter constellations, spring triangle, the summer triangle, autumn quadrangle, and winter triangle in the south starry sky.

(4) Observe typical season constellations (Leo, Scorpius, Aqulia, Pegasus, Orion) diurnal motion orbit over one day.

(5) Understand the mechanism of seasonal constellations from the universe's viewpoint.

The aim of the system is to assist learners to observe seasonal constellations in the south bright sky and achieve the specified learning goals regarding constellations under planetarium learning. The following system's interfaces were utilized to facilitate a real world oriented learning environment in order to achieve the learning goals of constellation observation.

2.2 System Interface

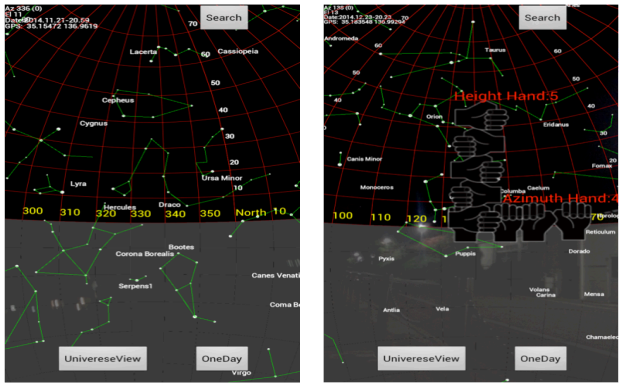

Figure 1. The AR view interface of R-WOSARLS (left), locating the constellation with hand images in AR view (right).

We developed the R-WOSARLS on the Google Android operating system using the Eclipse toolset, ADT, and the Android 2.1 Software Development Kit. The programming language is Java. The resulting application is supported by a range of smartphone and tablet devices that are compatible with Android 2.1 or higher. The entire AR view interface of the R-WOSARLS is shown in Figure 1 (left). The data section shows the orientation, angle of elevation of the mobile device, the GPS location, date and time. The horizon line, in combination with the lines of latitude and longitude, can

help learners locate and observe the constellation. An interactive interface was developed to recreate the planetarium interfaces regarding seasonal constellations. There are spring constellations, spring triangles, summer constellations, summer triangles, autumn constellations, autumn quadrangles, and winter constellations, and winter triangle options. Learners can choose any season, and the related seasonal constellation starry sky will be displayed in the AR view, as shown in Figure 2. In addition, constellations in AR view can be located with the hand images. For example, after learners choose one seasonal constellation, for example Leo, and click the "Search" button, the hand images will guide the learners to find the Leo constellation in AR view, as shown in Figure 1 (right). The "OneDay" functions in AR view assist learners to observe the one-day motion orbit of typical seasonal constellations in the starry sky. For example, learners will need only a few minutes to see the Leo constellation motion of rising in the east and setting in the west, as seen in Figure 3, this function assists learners to reach their relevant learning goals efficiently (4). Through the AR view function, learners can reach the constellation learning goals within the scope of science education. Furthermore, frequent use of the R-WOSARLS will allow learners to recreate the visual feelings of azimuth and elevation angle of constellations in the actual starry sky.

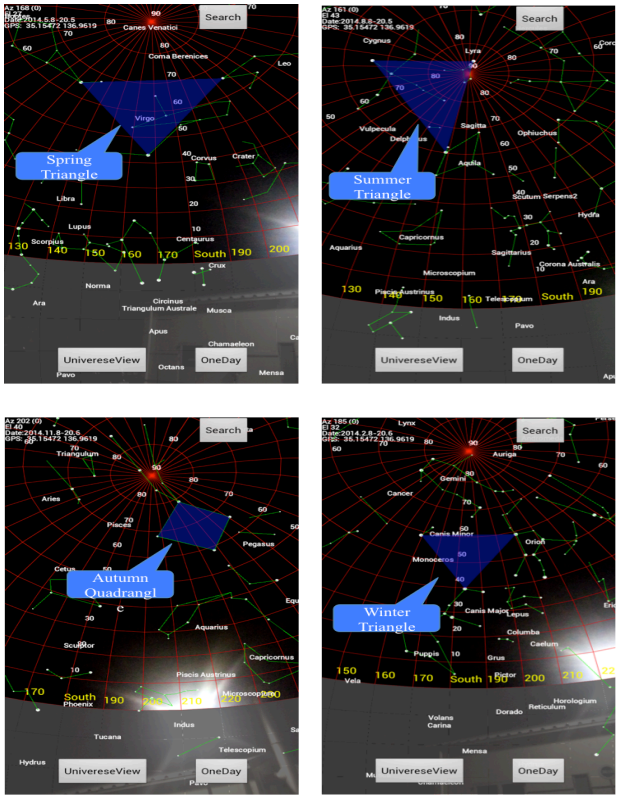

Figure 2. The seasonal constellation of the southern starry sky in spring (upper left), summer (upper right), autumn (down left), and winter (down right), in AR view.

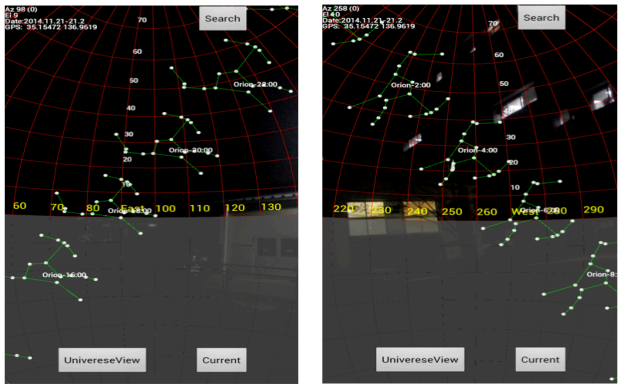

Figure 3. The AR Display of the orbit of Orion over one day in AR view.

A straightforward universe viewpoint interface was developed, in order to allow learners to study the seasonal constellation mechanisms more easily. When the users touched the "Universe View" button, they were presented with the "Universe View" interface as shown in Figure 4 (left). In fact, learners can see that the constellations of the south starry sky differ across the four seasons, because of the Earth's rotation and the fact that it completes a revolution around the Sun over a year. Therefore, from the universe's view, the four key stages of the Earth's revolution in orbit are spring, summer, autumn, and winter. Moreover, in each key stage, there are typical seasonal constellations, which are Leo (spring), Scorpius (summer), Pegasus (autumn), and Orion (winter). Using this view, learners can understand the position and relationship between the Earth and seasonal constellations with regards to orbit. In order to assist learners to understand the mechanism of seasonal constellations in the south starry sky, each stage provides image and text materials to explain this mechanism, based on the viewpoint of the observer. For example, when cycling through spring season's observation view, image materials about the mechanism of spring seasonal constellations will be displayed, as shown in the Figure 4 (right).

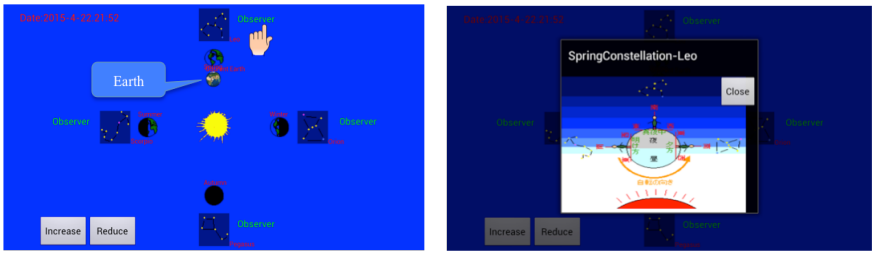

Figure 4. Clicking observer text (left), images of the mechanism of spring constellation–Leo (right).

3. Experiment and Evaluation

3.1 Experiment Design

Table 1: The questionnaire items about usefulness of R-WOSARLS.

No.	Contents
Q1	The grid lines in the AR view interface are helpful for understanding the azimuth and elevation angle of a typical seasonal constellation in the sky in real time.
Q2	The body scale (hand) search function in the system is helpful in searching for the targeted constellation in the real starry sky.
Q3	The function of "OneDay" in the system is helpful in observing the movement of a one-day orbit of typical seasonal constellation in the sky.
Q4	The function of "DisplaySeasonConstellationStarry" in the system is helpful in observing the seasonal constellations in the south starry sky.
Q5	The function of "Universe View" in the system is helpful in understanding the relationship of the Sun-Earth-seasonal constellation, and the mechanism of a typical seasonal constellation in different seasons from the universe's viewpoint.

Table 2: Questionnaire items about the usability and users' satisfaction of the R-WOSARLS

No.	Contents
Q6	It is easy for me to operate the system.
Q7	The interface was clear and easy to understand.
Q8	The response time of system is short when you are operating the system
Q9	It is interesting for me to use the system to observe season constellation.
Q10	The system is helpful to me in enhancing my motivation on season constellation.
Q11	I would like to use the same kind of system for astronomy learning in the future.

An experiment was conducted with 12 participants to confirm the usefulness and usability of the system. The 12 participants were undergraduate and graduate students with majors unrelated to astronomy, but they were confirmed as having an interest in observing seasonal constellations. The participants were requested to perform a series of constellation observational tasks during different times of the day. Example experiment scenes are shown in Figure 5.

After each task had been completed, the participants were given follow-up questions in order to assess the value of the R-WOSARLS. These questions are listed in Table 1. After completing all tasks and the relevant questions regarding the usefulness of the proposed system as listed in Table 2, participants were given six questions about its usability and their overall satisfaction.

Figure 5. Experimental scenes

3.2 Discussion and Result

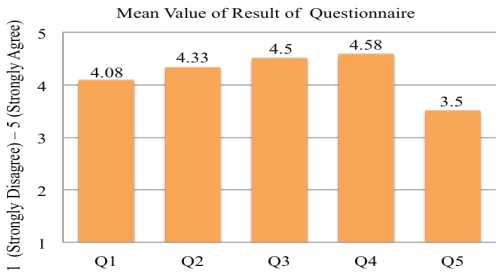

Figure 6. The result of usefulness questionnaire of R-WOSARLS.

The results of the survey pertaining to the usefulness of the proposed system are shown in Figure 6. The mean of questionnaire item Q1 was 4.08, showing that the users deemed the latitude and longitude lines in AR view to be useful in finding the azimuth and elevation angle of the constellation in the sky. Almost all of participants agreed that the body scale method was useful and more convenient to search for the targeted constellation. They would like to practice searching for the targeted constellation in the sky with their hands without the system. This is clear from the mean of 4.33 for Q2. Participants confirmed that the "OneDay" function was very useful in observing the targeted constellations one-day orbit in the sky (Q3). The mean of Q4 was 4.58, proving that the participants conclusively agreed that the "DisplaySeasonConstellationStarry" function was helpful in observing the seasonal constellation across different seasons. All the questionnaire items (Q1, Q2, Q3, and Q4) regarding the usefulness of the AR view had a mean above 4.00, which indicated that the AR view was very helpful to learners in observing the seasonal constellations, and provided a visual real-world learning experience. However, compared to the aforementioned AR view function, the mean of Q5 was only 3.50, since most participants considered that it was better to use a more intuitive interface and have more content to assist users in understanding the mechanisms of seasonal constellations. Based on this analysis and the experiment's results, it can be concluded that the proposed system is very useful for learners to observe seasonal constellations in a real-world environment.

In terms of the interface design, most of the users agreed that the system was easy to operate, with a mean value of 3.75 for Q6, as shown in Figure 7, In addition, the mean of 4.25 for Q8 showed that the response time when operating the system was brief and to the users' satisfaction, allowing the users to operate the system and complete their observational task. However, participants reported that the interface was not clear or easy for the users to understand, with a mean value of only 3.42 for Q7. During the interviews with the participants, it was reported that the size of the text should be larger and that a different set of colors would make the interface easier to use.

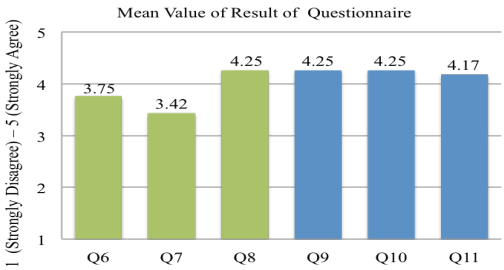

Figure 7. The usability and users' satisfaction of questionnaire result of the R-WOSARLS.

It was found that this system helped users enhance their motivation regarding seasonal constellations (Q10), as shown in Figure 7. 8 participants had limited knowledge about constellations. After they used the system to complete observational tasks, participants' knowledge on seasonal constellations was improved, and they thought the system was very interesting, with a mean value of 4.25 for Q9. In the future, the participants stated that they would prefer to use the same kind of AR learning system to observe other astronomy phenomena. In other words, the participants were satisfied with the R-WOSARLS and believed that such a system can increase their interest in astronomy.

3. Conclusion

In this paper, the utilization of smartphone AR technology and 2D content was described, with regards to the recreation of planetarium learning interfaces or contents for seasonal constellations, called the R-WOSARLS. The results of the conducted experiment revealed that the R-WOSARLS allowed learners to improve their knowledge and reach a set of seasonal constellation observation learning goals. Furthermore, it enhanced the motivation levels of the learners. For future work, improvements to the interface design of the system are planned, based on participants' comments in the experiment, in order to allow learners to more easily operate and understand the system interface. Our future challenges include the implementation of the R-WOSARLS in a secondary school science class to test the learning effects of the system.

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