Subjective Evaluation of a Lunar-surface Browsing Tool Using Map-based AR

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Abstract: We have developed a browsing tool for visualizing information about the lunar surface that uses map-based AR (augmented reality) in which virtual objects are superimposed on an actual map, resulting in a tangible user interface. In particular, our browsing tool enables a user to learn about the exploration conducted during the Apollo 17 mission by using a map of the lunar surface with geographically embedded information. We conducted a preliminary experiment to investigate the practicality of this interface compared to a WIMP (window, icon, menu, pointer) interface. The results showed that the AR interface is suitable for learning about the lunar surface and that it is probably better for children than the WIMP interface.

Keywords: Map-based augmented reality, tangible user interface, learning environment, lunar surface, museum exhibition

Introduction

As the Earth's only natural satellite, the Moon is one of the most familiar astronomical objects. Scientific data about the lunar surface, collected during the NASA Apollo missions [1], is often used in science museum exhibits. Museums try to do education and enlightenment for their visitors mainly by exhibiting objects [2]. If the actual objects do not tolerate being exhibited or are not well suited for exhibition, replicas are used. Multimedia presentations and computer graphics are widely used for presenting various types of data from digital archives [3].

Interactivity is an important factor to consider when creating a learning environment that motivates visitors to learn. An environment based on a computer using the conventional WIMP (window, icon, menu, pointer) interface is not particularly well suited for public exhibits because not all visitors may be comfortable using a computer. An alternative interface is thus needed to facilitate control of the digital content being exhibited. Our group has taken a map-based augmented reality (AR) approach to providing such an interface [4]. Map-based AR enables geographically embedded information to be overlaid on an actual map. It creates a tangible user interface that supports interacting with virtual objects intuitively by enabling the user to manipulate physical objects corresponding to data elements [5–7].

Many AR systems have been targeted at education [e.g., 8–11]. Although these systems use AR technology to provide a tangible user interface, more systematic research (user studies, performance evaluations, etc.) must be carried out before map-based AR can be effectively used for a learning environment.

We have developed a lunar-surface browsing tool using map-based AR. With this tool, a user can learn about the exploration performed by the Apollo 17 astronauts by browsing geographically embedded information using “marker sticks,” as shown in Figure 1. A user can explore the Apollo 17 landing site, follow the paths taken by the astronauts in the lunar roving vehicle (rover), and study the extra-vehicular activities (EVAs) and scientific experiments [12], as shown in Figure 2. In this paper, we describe the lunar surface exploration system we constructed using our browsing tool and a preliminary user experiment.

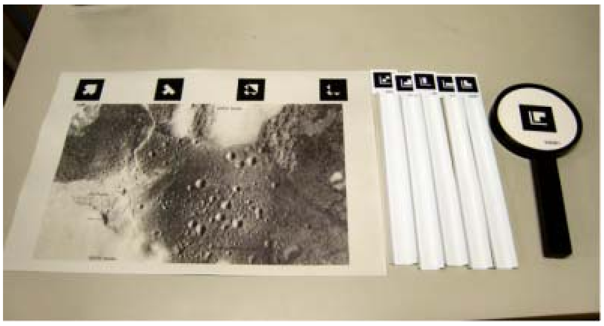


Figure 1. Lunar surface map and marker sticks

Figure 2. Lunar surface map and overlaid information

1. System

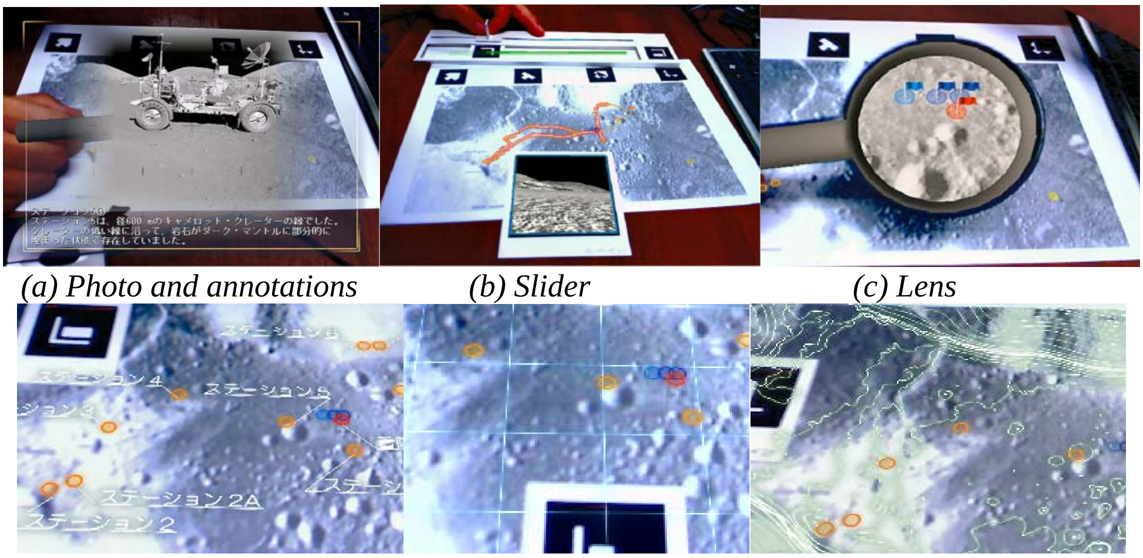
Our lunar surface-browsing tool presents the geographically embedded information or virtual objects superimposed onto the real map in video images. We assume that the browsing tool is used at a PC with a normal LCD monitor.

1.1 Components

The browsing tool is controlled with marker sticks. Two lens markers are used to provide zoom-in views of the lunar surface map. The user pans one of them over the map, reducing and increasing the zoom-in rate by changing the relative size of the lens marker in the video image. The other is used as a pointer to retrieve geographically embedded information by selecting a point of interest on the map. The geographical data for the EVAs are overlaid on the map when information markers are presented in the video image. The data include the rover’s route, the stations where it stopped, and the craters near the route. Transparent images of the elevation are overlaid on the map with contour lines or with a contour color map. Blue grids are overlaid on the map for presenting the scale of the EVA area. A miniature model of the rover is presented on the map, and it moves along the actual route. The view of the landscape from the rover’s viewpoint is presented in another window in the video image. As the rover moves along the route, the landscape changes to match the changing viewpoint. The position of the rover on the map is controlled with a slider. Presenting the view from the rover enables the user to view the landscape at various points along the route.

1.2 Operation

Examples of system operation are shown as snapshots in Figure 3. Figure 3 (a) shows an image of the rover and annotations about the geographic features at station 5 where the user points on the lunar surface map. Figure 3 (b) shows the slider and the landscape along the route from the egocentric viewpoint. The landscape is superimposed on the rover view marker in the video image. Figure 3 (c) shows the lunar surface relief magnified with the lens. The magnification varies with the relative size of the lens marker in the image. It depends on the distance to the lens marker from the camera that captures the video images. Figure 3 (d) indicates the names and places of the rover stations. Figure 3 (e) shows the grid pattern in which each line corresponds to 2km. Figure 3 (f) shows the contour lines of the lunar surface elevation.



(a) Photo and annotations *(b) Slider* *(c) Lens*

(d) Station names *(e) Grid Pattern* *(f) Contour lines*

Figure 3. Sample screenshots

The software for the browsing tool was installed on a PC equipped with a 2.6-GHz Pentium IV CPU, 512 MB of memory, and an nVidia GeForce FX5700 graphics card with 128 MB of video RAM. Video images were captured with a 640 x 480-pixel web camera. ARToolKit [13] was used as the image processing library for capturing the video images, detecting the square markers in the images, tracking the positions and orientations of the markers, and recognizing the patterns inside the markers.

2. Preliminary Evaluation

We subjectively evaluated our map-based AR system to investigate the usability of the browsing tool in comparison to a WIMP (window, icon, menu, and pointer)-based tool. A geographical navigation system, GMC [14], was used as the WIMP-based tool. Figure 4 shows examples of the tool utilization in the experiment.

2.1 Method

Nineteen undergraduate and graduate students, who were not astronomy majors, participated in the evaluation. They were instructed to use the system to become familiar with the lunar surface area explored by the crew of Apollo 17 and to subsequently evaluate the operation of the browsing tool by answering eight questions (Table 1) using a five-point scale. They were not given any particular task, but they were given as much time as they wanted to use the system.

One of the advantages of AR is viewpoint-based interaction in which virtual objects are presented to match the user's view. However, this requires attaching a camera to the user's head, which makes the scene view unstable due to head movement [15]. We therefore used an LCD monitor for the display, and the camera was placed next to the monitor on a table.

(a) WIMP *(b) Map-based AR*

Figure 4. The tool utilization in the experiment

2.2 Results and Discussion

The results of the subjective evaluation are plotted in Figure 5. The white and black bars indicate the average scores for a WIMP interface and our map-based AR interface, respectively. The error bars represent the standard deviation. Since the scores for all the questions for both interfaces were higher than 3, both should be suitable for learning about the lunar surface.

A dependent t-test was performed to identify the effect of the interface for each question. A statistically significant difference was found only for questions 1 ($t(18) = 3.77$, $p < 0.05$) and 5 ($t(18) = -2.28$, $p < 0.05$).

Table 1. Questions used for subjective evaluation

No.	Question
1	**Was the system easy to use?**
2	**Did the system give you an immersive feeling?**
3	**Were you able to look over the entire area explored by the crew of Apollo 17?**
4	**Was using the system for a long time tolerable?**
5	**Do you think children would be able to use the system?**
6	**Do you think people in general would be able to use the system?**
7	**Was manipulating the system enjoyable?**
8	**Do you think a group of people would be able to use the system?**

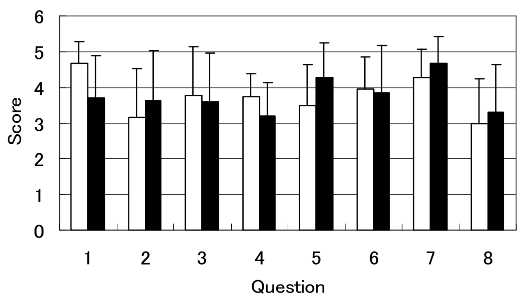


Figure 5. Results of subjective evaluation (white: WIMP; black: map-based AR)

The WIMP interface was considered to be easier to use (Q1) probably because it was more familiar. Four participants pointed out in their comments that experience is needed in order to become adept at using the marker sticks for the AR interface. However, as shown by the response to Q5, the AR interface was considered to be better for children. Six open-ended comments pointed out that children would probably enjoy manipulating the marker sticks as well as exploring the lunar surface. The comments were consistent with the score result in Q7, which had tendency that the map-based AR interface was more enjoyable than the WIMP interface.

The open-ended comments from the participants give us useful suggestions to clear the characteristics of the map-based AR interface. In the positive opinions, five participants commented on the intuitive interaction using the marker sticks, and three commented on a feeling of presence created by the manipulation of the sticks and map. These were interpreted as the benefits of the tangible user interface. In the negative opinions, two participants stated that there were too many marker sticks, and nine stated that the pointing to geographically embedded information was sometimes troublesome due to the density of points within the small map at which the information embedded. Three commented on occasional confusion about the locations of the information on the map. From these comments it would be necessary to make the lens pointing function smoother.

We expected the evaluation result that the real map would highly contribute to a feeling of presence or immersion in map-based AR. However, this did not work well for presenting the lunar surface relief, because the map was two dimensional.

3. Conclusion

We have developed a lunar-surface browsing tool using map-based AR for learning about the exploration conducted on the lunar surface during the Apollo 17 mission. It uses a printed map of the lunar surface that contains geographically embedded information. We incorporated the tool into a system and used it to conduct a preliminary evaluation in order to investigate the practicality of the browsing tool. The results showed that the AR interface is suitable for learning about the lunar surface and that it is probably better for children than the WIMP interface.

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