Evaluation of authenticity by perception-based rendering for a reflected image

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Abstract

This paper presents the results of subjective evaluations to investigate the authenticity of a reflected image captured at various positions on virtual object. We attribute correct reflection to visual equivalence by curvature and distortion of a surface. Here, the distortion is defined as magnification and displacement of reflected object. Using captured images and computer graphics, we attempt to confirm the sensitivity of an observer to magnification and displacement by conducting two sets of experiments. Upon conclusion of these experiments, we establish that the displacement component of the reflected image is more sensitive to the observer than that of magnification. In addition, these results suggest the importance in considering symmetrical or asymmetrical positioning of the reflection image in guaranteeing authenticity.

Introduction

In recent years, appreciation of augmented reality has been widely utilized in our life. For example, consumers can visually check the arrangement of the room by setting up furniture into desired positions in a virtual environment [1]. Also, designers can communicate how an accessory looks when worn by a particular individual, by overlaying accessories on an actual image even over the internet [2][3].

In these virtual simulations, it is important for the observer to give equivalent visual sense of perception between reproduced and real objects. To execute this simulation, exact shape and appearance of the material that constitute the object is required. This appearance invokes visual perception, which consists of diffusion, gloss and texture, and so on. Specifically, reflection is more important since the contrast of reflected image is highly related to the roughness of the surface of the reflective object.

These reflection images can be reproduced by using two-pass ray tracing between the environment and the eye position. Unfortunately, it has a detrimental weakness of high computational cost [4]. Instead of using ray-tracing technique, the environment mapping method is widely used, in which the image of the surrounding is attached to the surface of the object [5]-[7].

The image of the surrounding is captured by using a wide-angle camera situated at the position of the reflective object. We define this position as the ‘base position’ in this paper. The image captured at the base position can create the correct reflected image, since all light passing through the base point is recorded. However, with this technique, the image must be captured every time the position of the reflected image changed. In order to realize augmented reality from an arbitrary point in space, the image of the surrounding must be acquired at all positions. This constraint impedes the real time reproduction of environment mapping.

Therefore, we will evaluate the exactitude and robustness of the environment mapping by examining a series of reflected images that is captured at some distances from the base position. Since our brain understands that we are incapable of accurately interpreting the shape of the reflective surface, we assume there is some ambiguity in the image being reflected. In our experiment, we use a Utah Teapot as the reproducing object, and render a reflected image onto its surface. Subjective evaluations are performed to investigate authenticity of the reproduced image at various positions at which it was captured.

Related Works

In the real world, light is emitted in every direction. One part of the light incident to the surface of the object will reach their directly, whereas other light is reflected from other surrounding objects. Although there is a difference in the direct and indirect nature of the light, all the incident lights can be treated as a form of illumination. If we would like to use all visible light incidents to render some object, it is necessary to measure the radiance from every direction. Instead of this cumbersome measurement, a spherical image or environment mapping is useful in a realistic rendering. The radiance at each point on the spherical image indicates the amount of light arriving from each direction. For its exact reproduction, a wide-angle camera situated at the object’s position must capture the spherical image. This seems to be the constraint for the technique of environment mapping.

As one of the solution for this constraint, we paid attention to the Ramanayanan's research [8]. This research introduces the concept of visual equivalence for use of image fidelity in the field of computer graphics. Images are visually equivalent if they convey the same impression of the appearance of the scene, even if they are visibly different. To understand this phenomenon, they conducted a series of experiments that explore how an object geometry, material, and illumination can interact to provide information about its appearance. As a result of this psychophysical experiment, this research characterized some conditions under which two classes of transformations on illumination maps (blurring and warping) yield images that were visually equivalent to reference solutions.

Based on the conclusion of the above research, a misarrangement in an illumination map may be similarly permitted. Namely, we assume that perceptual visual equivalence can be realized even if the position of captured image is different from the base position. With this assumption, a real-time rendering of environment mapping can be applied in an augmented reality.

We therefore evaluate the influence of misarrangement in environment mapping with the following experiments.

Approach of Our Experiment

The light path of the reflection is shown in Figure 1. This light path obeys the rule of mirror reflection on a smooth surface. It is well known that the shape and position of reflected image vary depending on the surface curvature of the reflective object. Therefore, we can attribute correct reflection to visual equivalence of curvature and distortion on the surface. Here, the term of distortion includes both magnification and displacement components. Therefore we attempt two cases of experiments to identify the difference in sensitivity between magnification and displacement by observers.

For the case 1, two subjects of reflection are placed symmetrically away from the reflective object as shown in Figure 2(a). Conversely, for case 2, two subjects of reflection are placed asymmetrically away from the reflective object as shown in Figure 2(b). We proceed to evaluate the difference in sensitivity between the symmetrically and asymmetrically positioned objects by the observers.

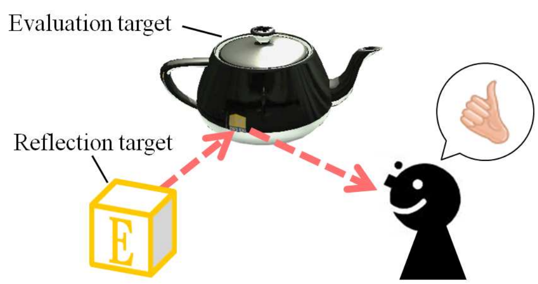
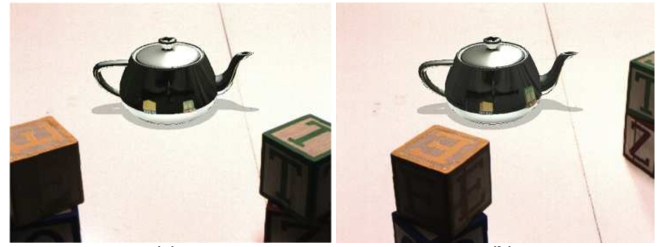


Figure 1. *Light path for reflection*



(a) ***(b)***

Figure 2.*The position of subject of reflection: (a) Symmetrically positioned (b) Asymmetrically position. These are rendered using surrounding images from the base position.*

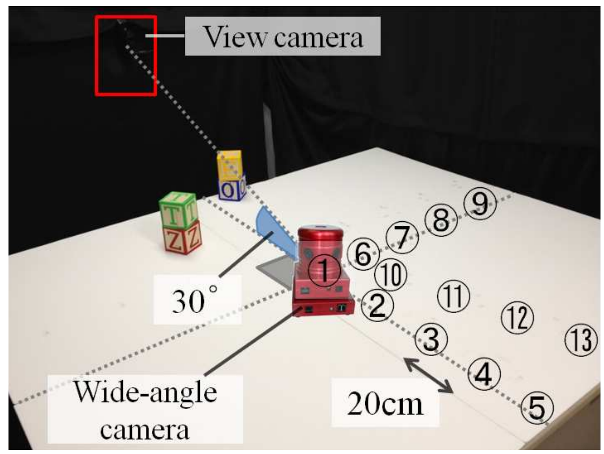
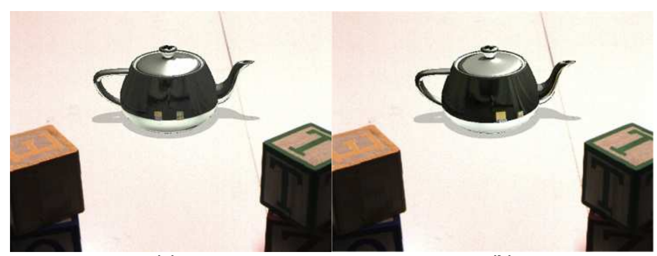


Figure 3. *Experiment layout to acquire images to be evaluated.*

Experiments

Our system to create evaluation images is shown in Figure 3. In this system, we use two cameras; the first one is a wide-angle camera (Point Grey Research Ladybug2, 1024×768) to acquire the surrounding images, and the second one is a view camera (Luminera LU175-SC-IC, 1280×1024) to acquire the image to be evaluated. Also, we use two sets of objects, the first objects are two pairs of child's blocks, and the second object is a Utah Teapot. Since the teapot is a virtual object in final image being evaluated, the wide-angle camera replaces the teapot in this experimental scene. The wide-angle camera captures the surrounding image around that position, and final evaluation image is created by synthesis of view camera image and the virtual teapot onto which the surrounding image is mapped. Here, it is noted that a child's block is rendered in the reflected image.

In the case 1 experiment, the wide-angle camera is positioned at circle 1(hereinafter called #1) to #9 as shown in Figure 3. Position #1 is the base position, and the incremental position from #2 to #5 simulates change in magnification of the object. The incremental change in position from #6 to #9 change both magnification and displacement of the object. To isolate the child's block from other surrounding objects, a black curtain is used to envelop the experimental booth. The example of final evaluation image in case 1 is shown in Figure 4.



(a) ***(b)***

Figure 4. *Sample of the captured images for evaluation in case 1: (a) At position #3; (b) At position #7.*

In case 2, the wide-angle camera is positioned at the position #1 through #13 as shown in Figure 3, where the position #1 is the base position. Although the positions #2 through #9 are at the same position as defined in case 1, the other reflected image at the positions defined in case 2 change both the magnification and the displacement. Therefore, we define the position #10 through #13 that only varies the magnification. Positions #10 through #13 are defined by the sum of the vector from two objects of reflection as shown in Figure 5. The example of the other images for evaluation in case 2 is shown in Figure 6.

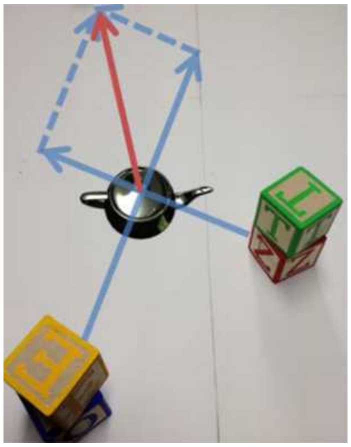
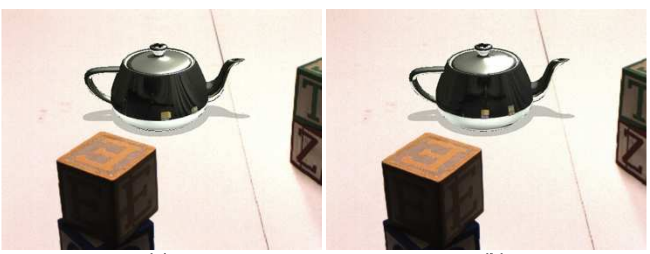


Figure 5. *Direction of the sum of the vector from two reflection targets*



(a) ***(b)***

Figure 6. *Sample of the captured images for evaluation in case 2; (a) At position #7 (b) At position #11.*

Figure 7 shows the layout of the subjective experimentation. We will use a 17-inch display (FlaxScan L551, EIZO) and the distance between the display and the observer is 3 times the height of the display. The observers subjectively score the authenticity of these reflected images in a scale of 1 to 5. The scale is defined as follows; 1 for not authentic; 2 for slightly authentic; 3 for somewhat authentic; 4 for almost authentic; 5 for very authentic. In addition, if observers reply 2 or less, we record the observer's comments about the evaluation image. All of the images are presented to each of the observers in random order, and total of 3 experiment cycles are performed. Overall, 10 males and females in their twenties participated in the experiment and all had normal or corrected-to-normal vision.

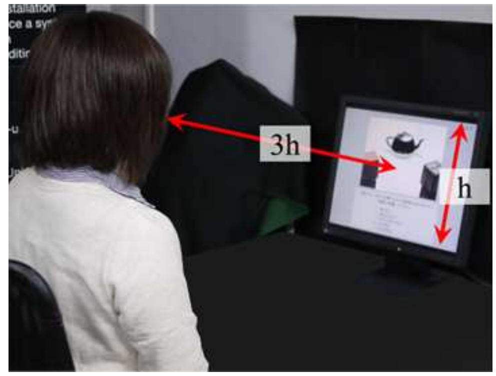


Figure 7. *Experimental environment of subjective evaluation*

Results and Discussion

From case 1, a typical result of subjective evaluation and an average of scores are shown in Figure 8 and Figure 9. The x-axis indicates the position of the image capture, and the y-axis indicates the subjective score of authenticity given for the images. Almost all observers assigned highest score at base position #1, and also assigned relatively high score at positions #2 to #4. The reflected images of these positions vary only by its magnification. Therefore, we assume that observers are relatively insensitive to the change in magnification when the reflected objects are positioned symmetrically from the observer. Only at position #5, almost all observers assigned a low score. From this, we derive that our ability to detect authenticity has some range, and extreme change in magnification draws attention to the error in artificial reflection even if the only change is its magnification. On the other hand, the positions #6 to #9 are assigned a low score by almost all observers. The changes in magnification and displacement are introduced in the reflected images at these positions. Comparing the result from positions #2 to #4, we can derive that displacement of the reflected image is more detectable than of its magnification.

From case 2, a typical result of subjective evaluation and an average of scores are shown in Figure 10 and Figure 11. Almost all observers assigned a relatively high score at positions #10 to #13. Only change in the reflected images of the positions #10 to #13 is the magnification. Therefore, we can assume that the observers are insensitive to the change in magnification component, when the reflected objects are positioned asymmetrically in the reflected image. Furthermore, the observers scored higher at positions #3 to #5 compared with positions #7 to #9, since positions #3 to #5 exhibits less change in displacement than positions #7 to #9. Only at position #6, almost all observers assigned a higher score than positions #2 and #10, since the asymmetrical placement of the reflected object at position #6 is emphasized as shown in Figure 12.

From the results of case 1 and case 2, we derive that the factor of displacement of the reflected image is more detectable than its magnification. In addition, these results suggest the importance in considering the positioning of the reflected objects, which can be symmetric or asymmetric from the view of the observer.

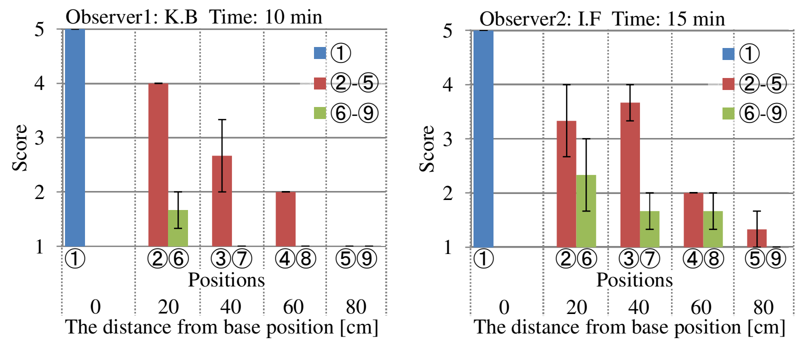


Figure 8*. Typical results of subjective evaluation in case 1*

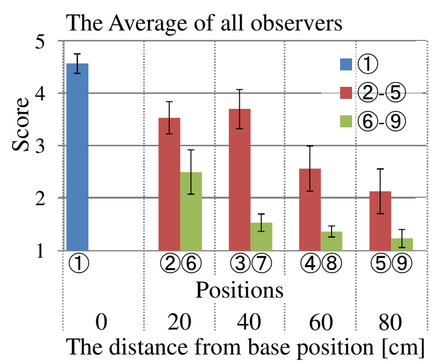


Figure 9*. Summary of subjective evaluation in case 1*

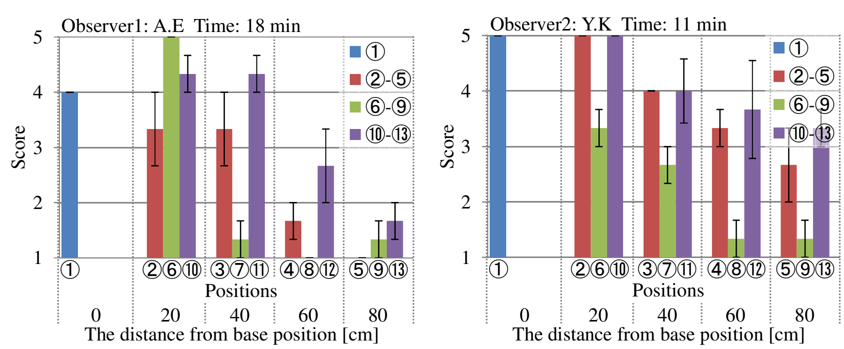


Figure 10*. Typical results of subjective evaluation in case 2*

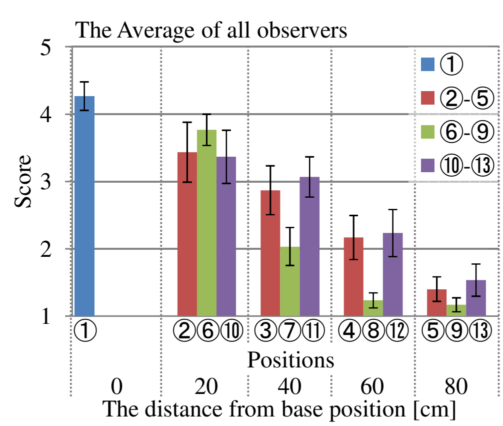
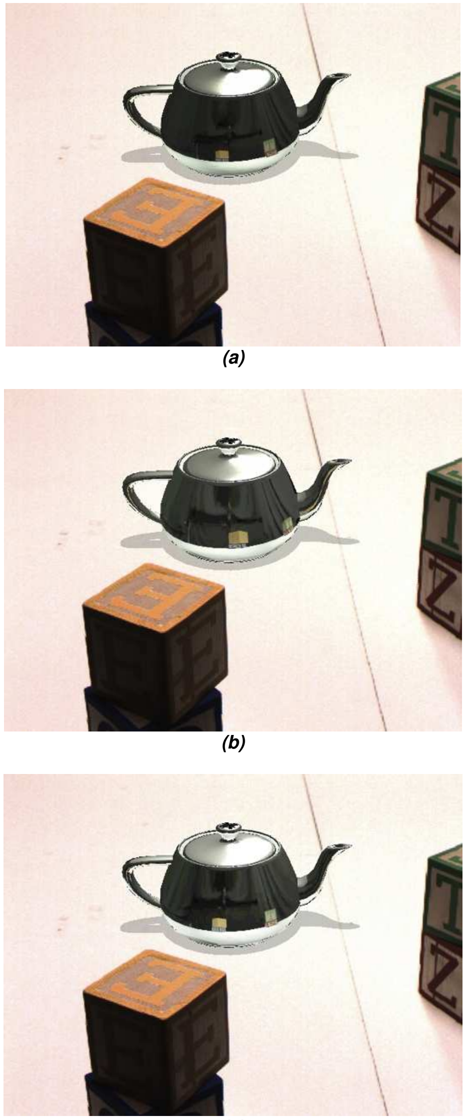


Figure 11*. Summary of subjective evaluation in case 2*



(a)

(b)

(c)

Figure 12*. Difference in evaluation images; (a) At position #2, (b) At position #6, (c) At position #10. The asymmetrical property of the reflected image at position #6 is emphasized when compared with positions #2 or #10.*

Conclusion

This paper presented the results of subjective evaluations to investigate the authenticity of a reflected image on virtual object, which is captured at various positions. We attributed correct reflection to visual equivalence by curvature and distortion of a surface. The overall distortion of the reflected image was modified by altering magnification and displacement components. Two sets of experiments were conducted to investigate the observer's sensitivity to magnification and displacement. For the first case, two objects of reflection were placed symmetrically from the reflective surface. For the second case, two objects of reflection were placed asymmetrically from the reflective surface. We positioned a wide-angle camera to acquire the surrounding images at incremental changes in positions in both experiments. One was the base position; others were the positions that incrementally altered only the magnification of the object; the others were positions that altered both magnification and displacement. As results of these experiments, we derived that the displacement component of the reflected image is more detectable to the observers than that of magnification. In addition, these results suggest the importance in considering the positioning of the reflection objects, which can be symmetric or asymmetric from the view of the observer.

In this paper, our experiments were based on specific reflected image involving only blocks and a black curtain, and derived the condition for producing a visually authentic reflected image. Utilizing visual attention, we have to investigate future opportunities on how incorrect reflected image can be virtually undetectable based on what we learned in this experiment. Specifically, we have to explore extracting the prominent features of the reflected images and transforming the surrounding images such that these reflected images are perceived as correct reflection. Therefore, we will endeavor on developing a system which is capable of real-time reflection rendering for augmented reality as the future work.

Acknowledgement

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