Gloss Enhancement beyond Projector Performance using the Glare Illusion

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ABSTRACT

The glare illusion is a well-known illusory perception in which a region appears brighter than its actual luminance when surrounded by a gradation of luminance. We propose a method of enhancing gloss beyond projector performance using this glare illusion. The effectiveness of the proposed method is confirmed by comparing it with the proposed and conventional method.

1 INTRODUCTION

Spatial augmented reality (SAR) using a projector is attracting attention owing to the increasing prevalence of projection mapping and has been studied in various ways since Raskar proposed Shader Lamps [1]. Such SAR is capable of modifying the appearance of the target object with illumination projections.

Amano et al. [2] proposed a material appearance manipulation that emphasizes the glossiness of the target object by boosting contrast using SAR. However, the optically correct glossiness manipulation on a diffuse object surface is impossible due to the extremely high brightness of the specular illuminance. In this research, we explore a method of manipulating material appearance manipulation that gives realistic glossiness using illusory perception instead of optically correct manipulation.

One projection technique that based on the illusory perception is that of deformation lamps, proposed by Kawabe et al. [3], which induces motion perception by projecting temporally alternating edge enhancements. Akiyama et al. [4] proposed an algorithm to extend the controllable color gamut of manipulation using a projector system based on color constancy. Color constancy is the difference between the perceived and the actual color of an object caused by the color of environmental illuminations. By applying an optical illusion, these projection techniques realized the manipulation of perceptual appearance manipulations beyond the limitations of environmental lighting and hardware performance. Inspired by these perceptual approaches, we proposed a more realistic method of enhancing the glossiness by exploiting the glare illusion. Our algorithm generates shaded inducer surrounding specular part on the diffuse manipulation target. We also proposed a gloss enhancement for the natural scene with specular detection and morphology operation as shown in Fig. 12.

2 RELATED WORK

Tamura et al. [5] conducted a user study to confirm perceptual brightness under glare illusion conditions. They compared perceptual brightness using the three brightness profiles of Glow, Halo and Uniform, as shown in Fig. 1. In this study, a patch (visual angle of 3.4° with the inner circle) was placed in the center with the Inducer (visual angle of 9.0° with the outside circle) surrounds it. The intensity profile on the inducer is increasing toward the patch in the case of Glow and decreasing in the case of Halo. The intensity of the Uniform inducer is an averaged brightness of other patterns. These samples were presented on the display and compared with the Uniform of reference for the three types of intensity profiles. Through the experiments, they clarified that the brightness of Patch is perceived brightly in the order of Glow, Halo, Uniform. In addition, a binomial test revealed that the Glow intensity profile increases perceptual luminance significantly between 20 and 200 cd/m^2 and that the perceptual luminance increases by at least 30%. Other experimental results revealed that Halo is perceived to be brighter than Uniform, with a significant brightness increase. However, the increase in luminance is less than 20%.

In conclusion, their research revealed that the glare illusion is most effectively induced under the condition of Glow profile. As a pilot study, we conducted the same experiment using a conventional projector instead of a flat panel display and confirmed the effectiveness of the glare illusion on the projection display.

Fig. 1 Three kinds of brightness profiles
The left is Glow, the center is Halo, and the right is Uniform.

3 PROPOSED METHOD

We propose an effective method of glossiness enhancement by the overlay projection using the glare illusion. Our method generates a shading inducer on the manipulation target object with an image projection which modifies the illumination profiles to Glow. To confirm the effectiveness of our method, we conducted

a user study on the three types of projection: our proposed method; simple contrast enhancement; and uniform white illumination. The manipulation target object was a circle with surrounding area printed on the matte paper as shown in Fig. 2. The environmental illumination was the brightness of the room as a condition similar to [2]. To enhance the glossiness using the glare illusion, we prepared a projection pattern as shown on left of Fig. 3. The contrast enhancement implemented in [2] enhanced scene contrast using a tone curve. However, we simplify enhance contrast of the simple manipulation target with a white and black projection as shown in right of Fig. 3. Uniform white projection was used as a reference illumination condition.

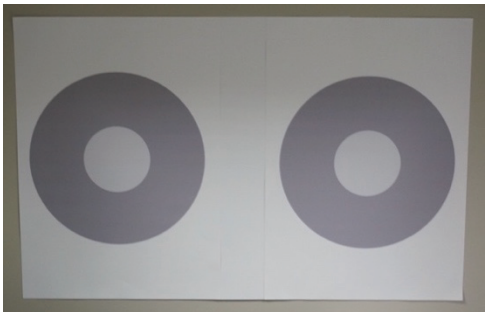

Fig. 2 The manipulation target
Patch and gray inducer are printed on each white paper.

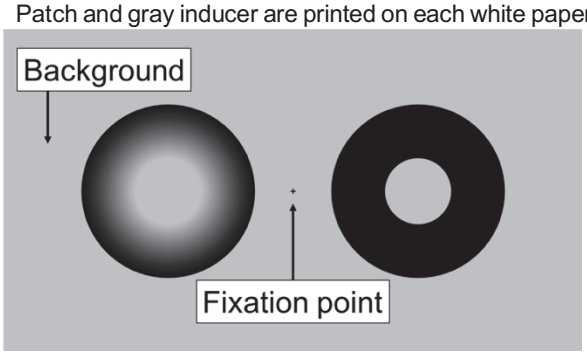

Fig. 3 Projection image example
The left is the brightness enhancement using glare illusion. The right is contrast emphasis.

4 EXPERIMENT 1

4.1 Experimental Method

In the experiment, the background area was lit uniformly by the projector. The left and right patches were given the same luminance to evaluate the difference in perceived brightness of the patch caused by the different luminance profiles of the inducers. Each pair from three types of projection (our proposed method, simple contrast enhancement, uniform projection) were projected on the both left and right manipulation target. However, it compared 6 positions including the exchange of right and left. The minimum radiance of the patch because of environmental illumination was 24 cd/m^2. The radiance of the stimulus was changed in 18 steps of 24, 29, 34, 39, 44, 54, 64, 74, 84, 94, 104, 114, 124, 134, 144, 164, 184, and 204 cd/m^2. With 6 pair comparisons and 18 radiance levels, there were 108 comparisons made in each experimental session.

Each experimental session began with the research participant starting at the fixation point for 3 minutes. After this, one of 108 stimuli (example shown in Fig. 3) was projected for 0.3 s and participants selected brightest side by pressing the right or left arrow on a keyboard. All stimuli are repeated once to increase the number of trials. Therefore, one session was composed of 216 trials (2 repeats × 6 positions × 18 luminance levels). A total of 4 sessions were conducted.

4.2 Experimental Environment

The research participants were eight normal vision aged from 22 to 23 years (seven men and one woman). A high resolution projector (SONY, VPL-VW245) was used. The projection range was adjusted to a size of 27 inches (596 × 335 mm). The distance between the projection plane and the research participant was 1340 mm. Each research participant sat in a chair and observed the target object with both eyes.

4.3 Result

In the experimental results shown in Fig. 4~6, the answer that the glare illusion was perceived brighter at any luminance significantly exceeded the chance rate (50%). The order of perceived brightness for three types of projection was glare illusion, followed by contrast enhancement, and lastly uniform projection. This result suggested that the brightness beyond the optical brightness was perceived. Therefore, it was suggested that gloss enhancement exceeding the projector performance could be realized.

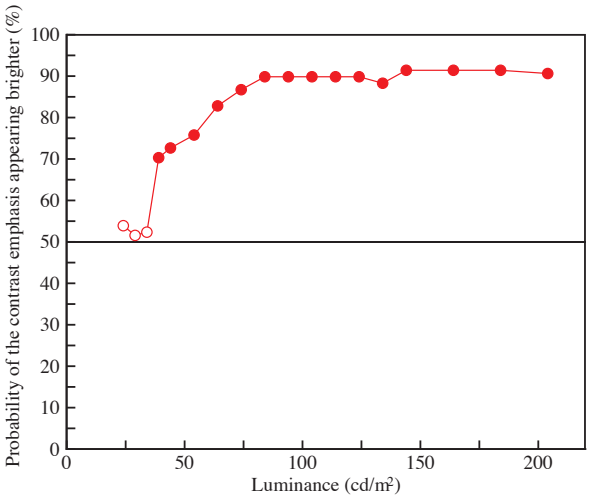

Fig. 4 The results of a pair comparison of uniform projection and contrast emphasis
The horizontal axis indicates the luminance of the center patch. Filled symbols indicate a significant difference from chance (50%). The vertical axis indicates the probability of contrast emphasis appearing brighter than uniform projection.

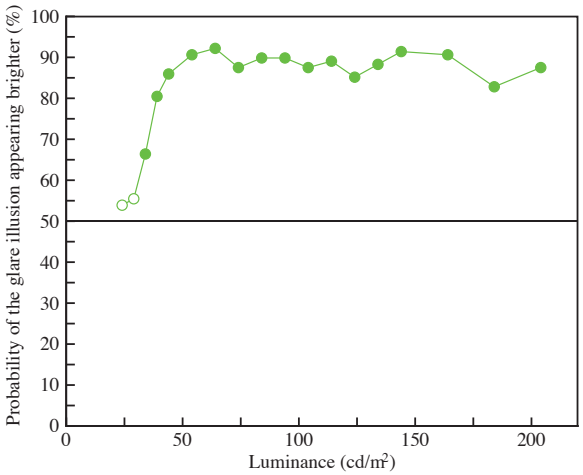

Fig. 5 The results of a pair comparison of brightness enhancement using the glare illusion and contrast emphasis

The vertical axis indicates the probability of brightness enhancement using the glare illusion appearing brighter than contrast emphasis.

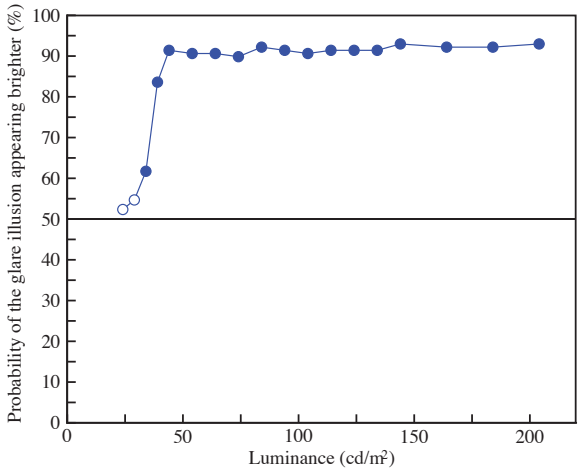

Fig. 6 The results of a pair comparison of brightness enhancement using the glare illusion and uniform projection

The vertical axis indicates the probability of brightness enhancement using the glare illusion appearing brighter than uniform projection.

5 APPLICARION TO GENERAL SCENES

We propose perceptual gloss enhancement by applying the glare illusion to gray images of general scenes (Fig. 7). The brightest part of the image was detected as the specular part and indicated with white regions in a binary image (Fig. 8). The rest of the part was painted with gray. Then, we generated gradation around specular parts (Fig. 9). These intensity profiles are the same as the glow pattern to induce glare illusion. For this gradation generation, we implemented recursive outline painting using morphological operations. For the non-specular part, we projected a weak uniform illumination to keep these parts visible.

The result of projection onto the printed image of Fig. 7 is shown in Fig. 10~12. These are the appearances taken by the camera at the time of projection.

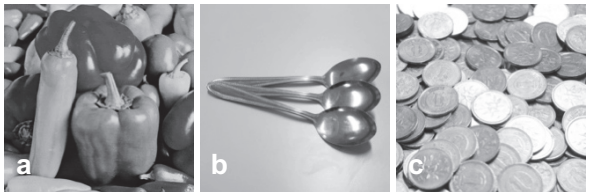

Fig. 7 Gray images of the general scene
(a)pepper (Standard test image dataset)
(b)Spoon (c)Coin

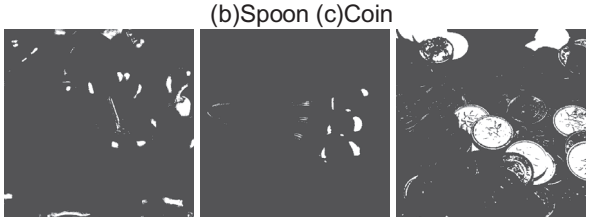

Fig. 8 Binary images (specular emphasis)

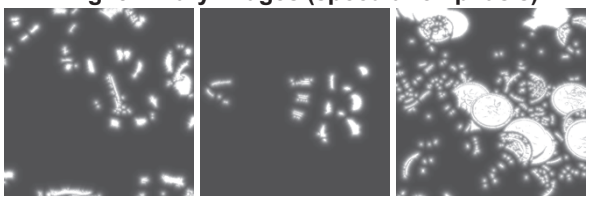

Fig. 9 Projection images (brightness enhancement using the glare illusion)

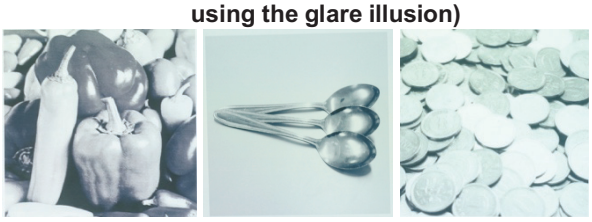

Fig. 10 Uniform projection

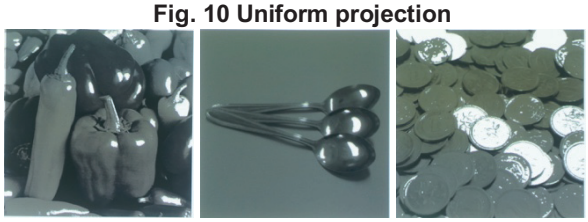

Fig. 11 Specular emphasis

Fig. 12 Gloss enhancement using the glare illusion

6 EXPERIMENT 2

6.1 Experimental Method

We evaluated the effectiveness of our proposed method in general scenes. We prepared 10 kinds of printed general scenes shown in Fig. 7 and Fig. 13 and placed the same scene printed gray images on the left and the right side. Then we applied a pair of three

projections: white projection (Fig. 10), specular emphasis (Fig. 11), and gloss enhancement using the glare illusion (Fig. 12). Therefore, it compared 6 positions including the exchange of right and left. The research participant answered which of the projection results felt brighter. For this evaluation, we adjusted the maximum pixel value of the projection to 5 levels of 195, 210, 225, 240, and 255. Therefore, one session was composed of 300 trials (10 samples × 6 positions × 5 levels). Research participants were 4 normal vision people aged from 23 to 24 years (4 males). The projection conditions were the same as in Section 4.2.

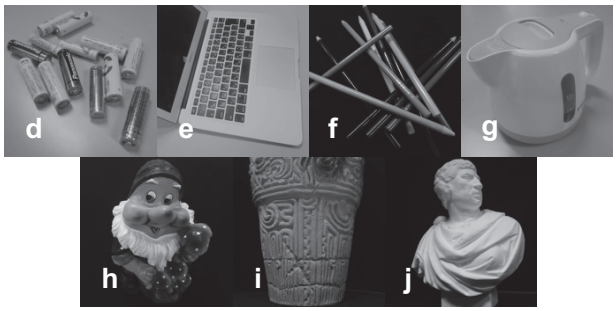

Fig. 13 The general scene for experiment
(d)Battery (e)PC (f)Pen (g)Pot (h)Dwarf
(i)Earthenware (j) Plaster figure

6.2 Result

Table 1 shows the average probabilities of all pixel values that the latter of white uniform projection and specular emphasis, white uniform projection and gloss enhancement applying glare illusion, and white uniform projection and gloss enhancement applying glare illusion are felt brighter.

The research participants answered that the proposed method was brighter than specular enhancement in all samples. However, there are samples where the proposed method is not effective. For example, the specular part of the spoon is inclined similar to the glare illusion. Therefore, further glossiness enhancement is difficult by the proposed method. On the other hand, Plaster figure, Dwarf, and Earthenware do not have a specular reflection. Therefore, we think the proposed method induced glare illusion, and it achieved effective glossiness enhancement more than the other projections.

7 CONCLUSIONS

In this paper, we proposed a method to enhance gloss using the glare illusion. We performed a subject experiment to show that images enhanced by this method are perceived as brighter than when processed by conventional contrast enhancement. As a result of this subject experiment, it was confirmed that the glare illusion was induced and perceived as brighter than the contrast enhancement. Therefore, it was suggested that gloss enhancement exceeding the performance of the projector could be realized.

Table 1 The probability that the latter felt brighter.

Scene	Uniform vs Specular [%]	Uniform vs Glare [%]	Specular vs Glare [%]
a. Pepper	33.3	**63.3**	**100.0**
b. Spoon	6.7	10.0	**100.0**
c. Coin	3.3	26.7	**100.0**
d. Battery	16.7	26.7	**100.0**
e. PC	10.0	33.3	**76.7**
f. Pen	10.0	46.7	**100.0**
g. Pot	6.7	33.3	**100.0**
h. Dwarf	60.0	**53.3**	**76.7**
i. Earthenware	10.0	**53.3**	**100.0**
j. Plaster figure	30.0	**66.7**	**100.0**

We confirmed that it was difficult to enhance glossiness for objects with the same inclination as the glare illusion. On the other hand, we confirmed that gloss enhancement was effective for non-glossy objects.

In the future, the number of the research participant will be increased. In addition, we want to statistically evaluate the proposed method and verify applicable targets.

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