AN EMPHASIZED HIGHLIGHT MODEL OF METALLIC OBJECT ON CAVE SYSTEM IN CONSIDERATION OF CONTRAST AND PARALLAX

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ABSTRACT

Accurate rendering of a virtual scene in real time has been one of important issues for virtual reality (VR) technology. Specular reflection of light has been studied a long time, which is always seen on a metallic object and causes occasionally very strong brightness (highlight). Due to restriction of number of gradation of brightness (usually 256), maximum brightness and contrast ratio, the highlight is relatively weakly represented by displays and projectors. In addition, specular reflection will be take influence of binocular parallax and motion parallax, because it is light to reflect in a specific course.

Therefore in this paper, an emphasized highlight model of a metallic object on the CAVE system is proposed. Decreasing brightness slightly on neighbor area of highlighted area, the proposed method increases contrast ratio between the highlighted area and neighbor area. Furthermore, using features of CAVE, the proposed method also represents glance (blink). When a metallic object moves, the method alternatively represents images with highlight and without highlight for both eyes. Since the difference of images for both eyes influences binocular parallax and motion parallax, a userfeels glance more realistically.

Keywords: computer graphics, virtual reality, specullar reflection, motion parallax

1. INTRODUCTION

Accurate rendering of a virtual scene has been one of important issues for virtual reality (VR) technology. On the other hand, computation of rendering is usually restricted in real-time in order to keep viewer's immersive sense in the virtual world. Therefore development of more realistic rendering technique with fast computation is useful to VR technology.

This paper considers specullar reflection, which is always seen on a metallic object and causes occasionally very strong brightness (highlight). Due to restriction of number of gradation of brightness (usually 256), maximum brightness and contrast ratio, the highlight is relatively weakly represented by displays and projectors. Especially, VR scene tends to be relatively dark since projectors usually display apart large images. Consequently glare does not impress us in a virtual space as strongly as in our real world.

In addition, we watch a scene affected by binocular parallax and motion parallax whether we look at outside world with both eyes[1]. Namely watching surface with specular reflection is considered to be influenced by the both types of parallax, since the specular light to each eye is possibly different very much. Therefore, the difference should be discussed in order to make generated images more photorealistic, when we generate stereoscopic images with specular reflection.

This paper proposes an emphasized highlight model for a metallic object on the CAVE, which equips a multi-faced stereoscopic display VR system (see Fig.1). Decreasing brightness slightly on neighbor area of highlighted area, the proposed method increases contrast ratio of the highlighted area against neighbor area. The decrease of the brightness is as small as it impresses a user darker.

Also introducing features of the CAVE such as high-speed alternative switching of images for both eyes and tracking viewpoint and line of sight to image generation, the proposed system generates so different highlighted images for both eyes that the system provides us glance (blink) effectively, according to movement of target object. In typical case when a metallic object moves relatively against the line of sight, the proposed system represents highlighted image for an eye and non-highlighted images for another eye, according to position and relative velocity of the object. Since the representation is not fixed due to small difference of position and direction, more brilliant highlight can be provided to the virtual space.

With the intensification of contrast ratio of the highlighted area and the generation of different images with/without highlighted area, the proposed system can improve user's impression with respect to metallic objects.

2. EMPHASIZED HIGHLIGHT MODEL FOR STEREOSCOPIC DISPLAY SYSTEM

2.1 Overview

The proposed system achieves emphasized highlight by the two ways; intensification of contrast ratio of the highlighted area and the generation of different images with/without highlighted area. For both ways specification of the position of the highlighted area is necessary. Therefore, in the

Fig. 1: ChuoCAVE

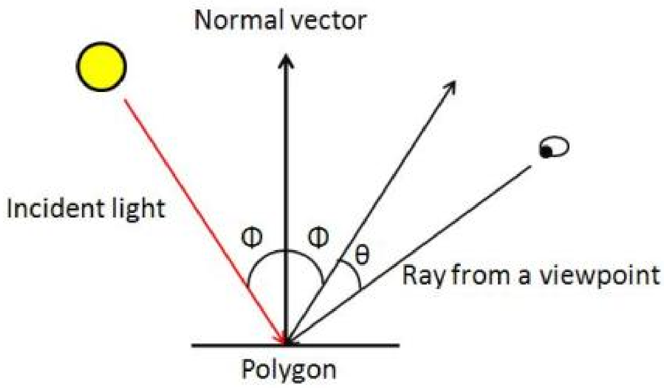

Fig. 2: Phong model

first place, the system detects the position of highlighted area through calculation of specular reflection at all polygons. Then, decreasing brightness at their neighbor area, the system intensify contrast ratio between the highlighted area and the neighbor area. Furthermore, considering position and relative velocity of the object having highlighted area, the system determines brightness of the highlighted area for each eye. Based on the determination, the system generates, displays and frequently switches images with increased/decreased highlight.

The proposed system assumes polygon model for shape description, which has information on position of three vertices, index to neighbor polygons (connectivity information) as well as diffuse/reflective coefficients. Here the Phong specular reflection model is introduced to calculation of highlight. Also, brightness (r, g, b) is assumed to range from $(0, 0, 0)$ to $(1, 1, 1)$. If some of r, g, b exceeds 1, then the value is truncated to 1.

2.2 Specification of position of highlighted area

Let I_r be brightness of an incident light, S be reflectivity of an object, n be a shininess factor, be angle between the incident light and the normal vector of the object, and be angle between the incident light and the ray from a viewpoint (see Fig.2). Then, specular brightness S_r is determined as follows by the Phong model[2]:

$$Sr = Ir \cdot S \cdot \cos^n(\ ) \tag{1}$$

The area is determined as highlighted area if sum of S_r and brightness of diffuse reflection exceeds $(1, 1, 1)$. Through the above calculation, the polygons having highlighted area are given. Then, neighbor polygons of the highlighted polygon are determined by the connectivity information (see Fig.3).

Let (R, G, B) be brightness at the neighbor area in RGB color space. Then, (H, L, S) in HLS color space is converted from (RGB) by the transformation formula[3]. Decreasing luminance L, the proposed system intensifies contrast ratio between highlighted area and its neighbor area, while hue and saturation hold. Reversely converting updated (HLS) to (R, G, B), we can determine brightness at the neighbor area in consideration of emphasis of the highlighted area. Since both of the conversion and reverse-conversion processes are simple calculation, the proposed emphasis does not harm real-time rendering on VR system.

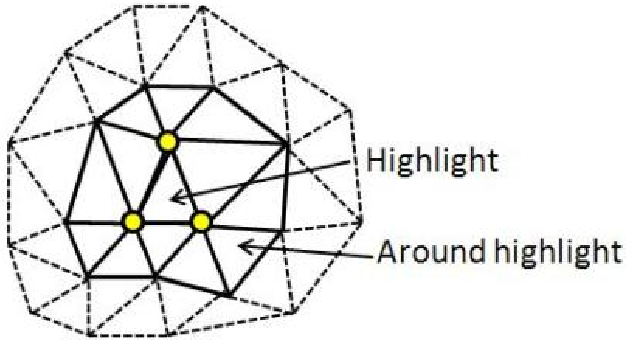

Fig. 3: The neighbor area of highlighted area

2.3 Switching images with/without highlighted brightness

The proposed system displays alternatively a set of CG images with/without highlighted brightness for both eyes according to a user's line of sight. Especially when the line of sight moves relatively from side to side, the highlighted area moves fast. Therefore, relative velocity of a target object to the line of sight is necessary to determine whether image should be switched or not.

Let O_t be a vector from viewpoint to an object, D_t be line of sight to central visual field before moving. Also let $O_{t+\ t}$ be a vector from viewpoint to an object, $D_{t+\ t}$ be line of sight to central visual field after moving (see Fig.4). Then, relative angle velocity ω can be determined as follows:

$$\omega = \frac{|\;_{t+\;t}\quad_{t}|}{t}, \tag{2}$$

where

$$_{t} = \cos^{-1}\left(\frac{\O_t \cdot D_t}{|O_t||D_t|}\right), \tag{3}$$

$$_{t+\;t} = \cos^{-1}\left(\frac{\O_{t+\;t} \cdot D_{t+\;t}}{|O_{t+\;t}||D_{t+\;t}|}\right). \tag{4}$$

If ω exceeds the given threshold, highlighted brightness is removed from either one of two images for both eyes. In the next steptime, the highlighted brightness is restored and alternatively the brightness is removed from the image for another eye. This switching images with/without highlight is executed every steptime. From some experiment (users' evaluation), this paper adopts the threshold angle velocity as 2π, and the steptime as 0.2 second.

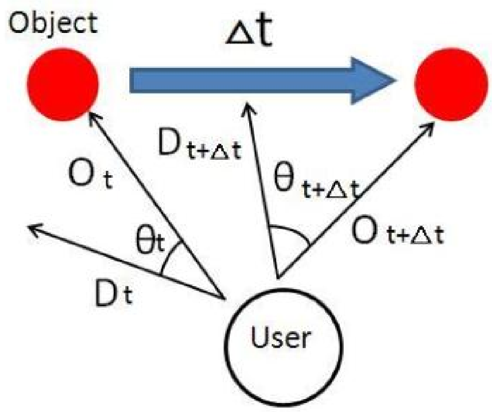

Fig. 4: Relative velocity of a target object to an user's line of sight

3. IMPLEMENTATION AND EVALUATION

3.1 Implementation

The proposed system is installed on the ChuoCAVE, which is CAVE-type VR system with three-faced stereoscopic screen, a mouse-like user interface WANDA, and tracking system of an operator 's viewpoint and WANDA[4]. Table 1 shows computational environment of the ChuoCAVE, and Fig.5 shows a snapshot when one of the authors manipulate the proposed system.

Table 1: Computational environment

CPU	Dual Core AMD opteron Processor 285
Memory	4.00GB RAM
Graphics card	NVIDIA Quadro FX 4500
OS	Microsoft Windows XP Professional

Fig. 5: 3D metallic cow on ChuoCAVE

3.2 Experiments

For example, a metallic cow with 5804 polygons having 2904 vertices and diffuse reflectivity $(r, g, b) = (0.7, 0.7, 0.7)$ is applied to the proposed system. Figures **??** and 7 show generated images from the left and right eyes, respectively. Difference of highlighted area between both eyes (viewpoint) is shown in the figures. Also Fig.8-11 show generated images on which brightness of the neighbor area of the highlighted area is decreased by the proposed system. On the system the highlighted areas are blinked by switching those images and alternative images without highlight, when the relative angle velocity exceeds the given threshold 2π.

3.3 Evaluation

For evaluation, 15 graduate/undergraduate computer engineering students used the proposed system on ChuoCAVE. 12 among 15 have knowledge on specular reflection.

In the first place, they watched a metallic cow displayed by the conventional method (not emphasized by the proposed system). Then, in order to identify appropriate decrease of brightness at the neighbor area, three cows were shown one by one, which have different reflectivity, A:(0.7, 0.7, 0.7), B:(0.5, 0.5, 0.5) and C:(0.3, 0.3, 0.3). For each case, brightness was decreased from 5% to 30% at the neighbor area. Questionnaire is first finding unnatural borderline and emphasized highlight. Table 2 shows the result. From the result, a certain correlation is seen between original brightness and appropriate decrease of brightness. Al-

Fig. 6: A metallic cow model for left eye

Fig. 7: A metallic cow model for right eye

Fig. 8: A metallic cow model reduced brightness 10% of the neighbor area of the highlighted area.

Fig. 9: A metallic cow model reduced brightness 10% of the neighbor area of the highlighted area.

Fig. 10: A metallic cow model reduced brightness 20% of the neighbor area of the highlighted area.

Fig. 11: A metallic cow model reduced brightness 25% of the neighbor area of the highlighted area.

though more detailed correlation should be investigated in future, the following experiment determines the ratio of decrease as the average of the above result for each reflectivity.

Table 2: Result of questionnaire about unnatural borderline and emphasized highlight

	5 %	10 %	15 %	20 %	25 %	30 %
(A) feel boundary line unnatural at first	0	1	5	6	2	1
(A) feel highlight emphasized	0	11	4	0	0	0
(B) feel boundary line unnatural at first	0	0	6	6	3	0
(B) feel highlight emphasized	0	5	10	0	0	0
(C) feel boundary line unnatural at first	0	1	1	3	8	2
(C) feel highlight emphasized	0	3	5	6	1	0

In the next step, the examinees manipulated the proposed system for the metallic cow shown in Figs.6-11 and compared with the result without the proposed emphasis. Questions are the follows.

(a) Feel the highlight more brightly.
(b) Feel the metallic object more metallically.
(c) Feel the highlight realistic when delete highlight switches. images with/without highlight

Table 3 shows scores about the comparison.

Table 3: Result of questionnaire about comparison without the proposed emphasis

	Definitely yes 7	6	5	No preference 4	3	2	Definitely no 1
(a)	6	8	1	0	0	0	0
(b)	5	5	4	1	0	0	0
(c)	8	0	4	2	1	0	0

Result (a) shows effectiveness of the intensification by the proposed system. Also (c) shows effectiveness of the switching images with/without highlight. (b) shows comprehensive evaluation of the proposed system. From the result, it is shown that the intensification achieves good performance while the switching does not so good. Score 0.854 of correlation coefficient between (a) and (b) also shows that the intensification plays an important role in the proposed emphasis. However, appropriate ratio of decrease of brightness should be carefully discussed. On the other hand, score 0.602 of correlation coefficient between (b) and (c) shows not so good performance. It is seen that the maximum score 7 for (c) is evaluated by the examinees who have the knowledge on specular reflection. This interesting grouping suggests that the knowledge on light reflection may influence impression on highlight. For reference, score 0.329 of correlation coefficient between (a) and (c) suggests that the intensification is independent from blink by the switching images.

4. CONCLUSION

In this paper, an emphasized highlight model for metallic objects is proposed, which is useful on CAVE type stereoscopic display system with head tracking. From the experiments on ChuoCAVE, the proposed system achieves appropriate emphasis of highlight. In future paper, more detailed investigation will be discussed, which determines appropriate thresholds seen in the proposed system. At that time, trade-off between effectiveness of emphasis and necessary computational performance should be deeply considered.

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