Real world appearance visualization using a multi-screen projection system and pre-filtered environment map

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(a) σ= **1** **(b)** σ= **101** **(c)** σ= **301** **(d)** σ= **501**

Figure 1: Results of manipulated appearance of a mirror finished bell by our method. We project a pre-filtered environment map (right) generated by applying gaussian filters with different σ which represents surface roughness, to a large multi-screen. As increasing σ, the glossiness of the bell decreased shown on the left and the center of (a) to (d).

ABSTRACT

In this paper, we build a real-world appearance visualization environment using a multi-screen projection system to manipulate an object's material properties such as specular reflection in the real world. To achieve this goal, we apply a spacial filter to an omnidirectional environment map, then projected onto a large multi-screen system. By manipulating the kernel of the filter, the visibility of the real objects on the mirror surface placed in the center of the system significantly changed. Because our system exploits the reflection of objects in a real-world, it is possible to immediately change the appearance of the objects as the displayed environment map changes. This enables artists to design the appearance, interactively.

CCS CONCEPTS

• **Computing methodologies** → *Mixed / augmented reality*.

KEYWORDS

computer graphics, interactive, real world, appearance

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1 INTRODUCTION

It has become more common to design the appearance of products using computer graphics[1], however, there is a slight difference between rendered images in a virtual world and actual products in the real world. While projection mapping can manipulate the appearance of an object in the real world, it is limited to modifying only the color. In this paper, we have developed a real-world appearance visualization environment using a multi-screen projection system to manipulate an object's appearance, including the glossiness of the mirror finished surface. This method aims to visualize material properties on objects with any glossy appearance by using appropriately computed environment maps. The results of our system are shown in Fig. 1.

2 OUR METHOD

To achieve the appearance of the visualization system, our basic strategy relies on environment map pre-filtering [2], which is known as a method for the real-time rendering of glossy surfaces in the computer graphics domain within a virtual world. To mimic the glossy reflection, the technique applies low-pass filtering to an omnidirectional environment map and applied on a mirror surface. In this research, we also utilize a mirror surface object,

but in the real world. By manipulating an omnidirectional lighting environment, it is possible to modify the appearance of the object.

2.1 Pre-filtered environment mapping for diffuse and specular control

To control the diffuse reflection, we firstly apply the cosine term convolution to the environmental map $L_i(\vec{\omega}_i)$, where $\vec{\omega}_i$ represents an incident light direction. Then, we multiply arbitrary diffuse coefficient k_d to obtain the diffuse component I_d of the given normal direction $\vec{n}$ as:

$$I_d(\vec{n}) = \int_{\Omega^+} k_d L_i(\vec{\omega}_i)(\omega_i \cdot \vec{n}) d\vec{\omega}_i. \quad (1)$$

We also apply the Gaussian G of an arbitrary σ which aims to control the roughness of a glossy surface. Theoretically, the specular component I_s can be described in following equation as:

$$I_s(\vec{n}) = \int k_s L_i(\vec{\omega}_i) G(\sigma, \vec{\omega}_i - \vec{n}) d\vec{\omega}_i, \quad (2)$$

Finally, the pre-filtered environment map $I(\vec{n})$ can be obtained as $I = I_d + I_s$.

2.2 Environmental map cropping

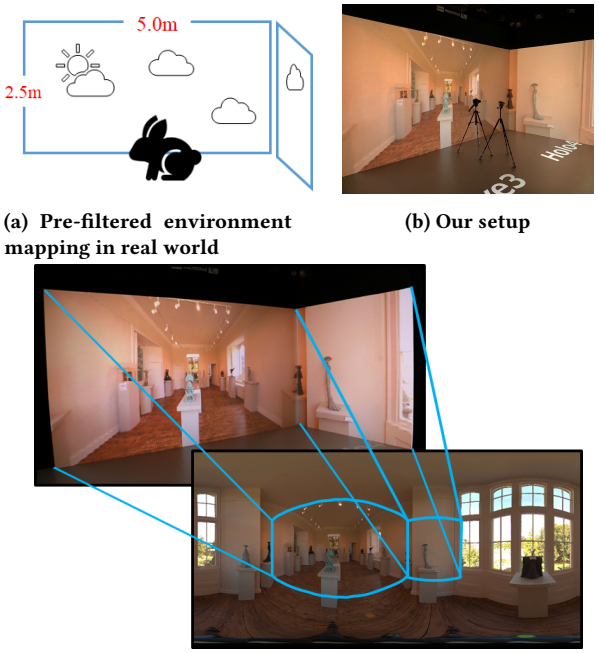
Instead of using a pre-filtered environment map in a virtual space in a graphics manner, we use a large-size multi-screen projection system shown in Fig. 2(a) and (b) to realize a real-world appearance visualization. Unlike in an ideal virtual space, however, the multi-screen is not fully omnidirectional surrounded. Thus, it is necessary to extract portion of images from the fully omnidirectional map to be projected onto the multi-screen. Figure 2(c) shows an illustration of the cropping process from a fully omnidirectional environment map. In our case, the screen sizes are approximately $5 \times 2.5 \times 2.5$ [m] as shown in Fig. 2(a). We assume that a target object is to be placed at the center of the stage, thus, the field of view is calculated to be 126.8[deg] for the front view and 53.2[deg] for the side view. As a result, the total field of view is 180[deg] which satisfies the coverage of the reflection direction to visualize object appearance.

3 EXPERIMENT AND RESULT

We placed a mirror-finished object (a table-top bell) at the center and projected pre-filtered environment map to the multi-screen. Figure 1 shows the result of our system under different values of σ applied. In each subfigure, the generated pre-filtered environment maps are on the right, and the captured photo and its close-up of the object under the illumination are shown on the left and the center. It is obvious that when the value of σ increases, the object appears to tend to be less glossy. Note that the appearance of the object can be immediately manipulated once the projected image changes. Also, the viewpoint can also be changed without any modification or computation, thus, there is no inconsistency in terms of binocular disparity when a stereo image is projected as a pre-filtered environment map. These are the advantages of our work.

4 CONCLUSION

In this paper, we showed the ability to manipulate an object's appearance in a real world by applying the pre-filtered environment map technique which is previously used in a virtual world. Our method is capable of updating specular roughness in real-time. This technique potentially be applied in various fields, such as cross-reality (XR) applications in entertainment, as well as in the appearance design process in product design. These are the future works of our work.



(a) Pre-filtered environment mapping in real world

(b) Our setup

(c) Environment map cropping

Figure 2: Setup of this method. We project a pre-filtered environment mapping to a large-size multi-projection system (a) and (b). The appearance of a mirror-finished object placed on the center of the screen can be manipulated by controlling the projected pre-filtered environment map. The environment map is necessary to be cropped as shown in (c) due to the limited omnidirectional coverage of the multi-screen.

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