Representation of Texture using Integrating Shading, Inter-reflection and Highlight in Mixed Reality

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ABSTRACT

This paper proposes a method to keep temporal and optical consistency in mixed reality. Its approach is based on two related works: a method of shading with estimated lighting condition and a method of representing inter-reflection by means of sphere mapping. These two methods were not able to achieve real-time processing. Applying parallel processing with GPU to calculating color of each vertex, the proposed method realizes to process these two methods for each frame in real-time. Furthermore, this paper proposes to make a highlight map of the spherical mirror image to represent saturated highlight and a spread of highlight. Integrating shading, inter-reflection and highlight, this paper achieves to represent better texture of the virtual object.

1. INTRODUCTION

Mixed reality is an attractive and exciting way to superimpose virtual object in a real environment for various applications. One of applications of mixed reality is a layout simulator of interior of the real-world room. Using this application, users can superimpose virtual furniture in a real room to discuss the layout of the room before they buy it. Considering this type of application, in mixed reality it is important to keep three types of consistency: geometrical consistency, temporal consistency and optical consistency. This paper proposes a method to represent better texture of the virtual object reflected in the real-world scene. This approach is based on two related works. These works are aimed at increasing optical consistency in mixed reality. Yasumuro et al. have proposed the method to represent shading to the virtual object with estimated lighting condition with a spherical mirror [1]. Manabe et al. have proposed the method to represent inter-reflection of the virtual objects by means of sphere mapping with a spherical mirror [2]. These are excellent methods to keep optical consistency and represent the texture of the virtual object with real-world information, but these methods couldn't achieve real-time processing because of their high computational costs. In this paper, to keep temporal consistency, parallel processing is applied to these two methods. And these methods cannot represent saturated highlights and a spread of the highlight of the virtual object. So this paper proposes to make highlight map of a spherical mirror image in order to achieve to represent better texture of the virtual object.
2. RELATED WORKS

2.1 Representation of Shading with estimated lighting condition

Yasumuro et al. have proposed the method to represent shading to the virtual object with lighting conditions that are estimated with a spherical mirror. Their method is able to reflect virtual objects in change of the real-world lighting condition. Figure 1 shows a 3D marker which they use. This marker consists of 2D markers and a spherical mirror to acquire real-world information. In their method, the first step is to detect a marker from a captured image. On the assumption spherical mirror is on the marker, the spherical mirror image is extracted from the image. The next step is to divide the spherical mirror image into several areas, and to sample each area as one source of light. They regarded the mean value of the pixel values in each part as a color of the light source, and the vector of light source in each divided area is calculated with a normal vector of center in each divided area and viewing vector. Finally shading of the virtual object is represented by calculating a color of the virtual object according to lambert reflectance model (Figure 2).

![Figure 1: 3D marker which consists of 2D markers and a spherical mirror to acquire real-world information](image1)

![Figure 2: Example of result image that represents shading of the virtual objects with the method proposed by Yasumuro [1]](image2)
2.2 Representation of Inter-reflection by means of sphere mapping

Manabe et al. have proposed the method to represent inter-reflection of the virtual objects by means of sphere mapping with a spherical mirror. They also use the 3D marker shown in figure 1. The method is also able to reflect a virtual object in change of the real-world lighting condition. In the method, the first step is to detect a marker from captured image and to acquire real-world information from the spherical mirror on the marker. The next step is to apply sphere mapping to a virtual object with a spherical mirror image as an environmental map. Sphere mapping that is one of texture mapping techniques is able to represent inter-reflection by means of mapping a real-world scene to the virtual object. Debevec et al. had proposed a method that achieved sphere mapping to a virtual object with a spherical mirror, but their method have to put a spherical mirror on an optical axis of the camera [3]. Improving it, Manabe et al. applied rotating matrix to the optical axis. So their method was able to put spherical mirror at any point.

Figure 3: Example of result image that represents inter-reflection of the virtual object with the method proposed by Manabe [2]

2.3 The problem of processing speed of two related works

Yasumuro and Manabe have proposed the excellent methods that achieve to represent texture of a virtual object, but their methods are high calculation costs. In other words, they are not able to achieve real-time processing. Table 1 shows a processing time of their methods. All the results were rendered at a resolution of 640x480 pixels on an Intel Core i7-2600 at 3.40GHz with 4GB memory. These processes have to calculate a color of a virtual object for each vertex with every flame. The table shows that the methods cannot achieve real-time processing. This is because of high computational cost of each vertex color. In this paper, to achieve real-time processing, parallel processing is applied with graphics processing unit (GPU) to calculation for each vertex of the virtual object. Moreover these two methods are integrated to enhance representation of texture of the virtual object.

Table 1: A processing speed of the two methods. A method to represent shading is proposed by Yasumuro, and a method to represent inter-reflection is proposed by Manabe.

<table>
<thead>
<tr>
<th>Vertex</th>
<th>Shading [Hz]</th>
<th>Inter-reflection [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1178</td>
<td>12.37</td>
<td>15.42</td>
</tr>
<tr>
<td>2630</td>
<td>6.110</td>
<td>6.461</td>
</tr>
<tr>
<td>5462</td>
<td>3.317</td>
<td>2.959</td>
</tr>
</tbody>
</table>
3.4 The problem of mixing shading and inter-reflection

If shading and inter-reflection are simply mixed, it is not able to represent correct texture of the virtual object. This is because of saturated highlights and a spread of highlight. If an image is captured of the real-world scene with RGB camera, pixels have saturated value in highlight area. Figure 4 shows the case of it. In order to keep consistency in mixed reality, saturated highlights of the virtual object have to be represented. If shading and inter-reflection are simply added, however, it is not able to represent saturated highlights of the virtual object. This is caused by a limited range of the camera. On the other hand, there is a method that regards pixels that have values more than the threshold as saturated highlights. Adopting this method, it is not able to represent a spread of the highlight. Figure 5 shows the results of these two approaches. Left image is shows a case of simply adding two factors. In this case, highlights are not represented correctly because the range of camera is limited and highlights are low pixel value. Right image is shows a case of regarding pixels that have values more than the threshold as saturated highlights. In this case, a spread of highlight is not represented correctly. This paper proposes the method in which highlight map is created by Phong’s reflection model and saturated highlights and a spread of the highlight are represented.

![Figure 4: Parts of the high saturated value because of highlights](image)

![Figure 5: Examples of integrating shading and inter-reflection. Left is shows a case of simply adding two factors. Right shows a case regarding pixels that have values more than the threshold as saturated highlights. These two approaches are not able to represent saturated highlight and a spread of the highlight.](image)
3. PROPOSED METHODS

3.1 Highlight map

To represent saturated highlight and a spread of highlight on a virtual object, this paper proposes to make a highlight map from a spherical mirror image. This paper supposes that spherical mirror is located in an infinity distant place and a viewing vector is parallel to an optical axis of the camera. In Phong’s reflection model specular reflection is the strongest provided eye vector agrees with camera’s optical axis. In Phong’s reflection model, a spread of the highlight is calculated by $\cos^n \theta$ with angle $\theta$ and specular rate $n$. The spread of the highlight is represented by means of smoothing filter with $\cos^n \theta$ applies to a binary image that is made from the spherical mirror image. Figure 6 shows the steps of making a highlight map. The first step is to make a binary image of the spherical image according to a suitable threshold. The next step is to apply smoothing filter with $\cos^n \theta$ to the binary image to represent a spread of the highlight on the virtual object. The last step is to associate the highlight map with each vertex of the virtual object by means of sphere mapping.

3.2 Integrating shading, inter-reflection and highlight

Applying parallel processing with GPU to calculating color for each vertex, this paper achieves real-time processing. Figure 7 shows the processing steps of the proposed method. The first step is to detect a marker from a captured image and to acquire real-world information from the region of spherical mirror on the marker. The next step is to estimate positions of light source and calculate shading based on Lambert reflectance model. Then an environmental map is acquired and a highlight map is made from the spherical mirror image. The environmental map and the highlight map are associated to the virtual object by means of sphere mapping. The last step is to integrate these three factors to determine a color of the virtual object. The proposed method is able to achieve real-time processing every frame.

![Figure 6: The making steps of a highlight map](image)

![Figure 7: Processing steps of the proposed method](image)
4. RESULTS

All the results were rendered at a resolution of 640x480 pixels on an Intel Core i7-2600 at 3.40GHz with 4GB of memory. NVIDIA GeForce GTX 460 with 1GB video memory is used as graphics card. The rendering framework is developed in C. OpenGL and GLSL are used as graphics API, and ARToolKit and OpenCV are used as libraries.

Table 2 shows the processing speed with GPU. The result shows that the calculation using GPU additionally is faster than the calculation using CPU only. Table 3 shows the processing speed of proposed method that integrates shading, inter-reflection and highlight. In the case of making highlight map, the proposed method achieves real-time processing. Figure 8 shows an output image of the method proposed in this paper. The image shows that the proposed method is able to represent better texture of the virtual object.

Table 2: Processing speed of the two methods with GPU

<table>
<thead>
<tr>
<th>Vertex</th>
<th>Shading [Hz]</th>
<th>Inter-reflection [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1178</td>
<td>176.3</td>
<td>182.1</td>
</tr>
<tr>
<td>2630</td>
<td>102.4</td>
<td>104.5</td>
</tr>
<tr>
<td>5462</td>
<td>53.64</td>
<td>56.43</td>
</tr>
</tbody>
</table>

Table 3: Processing speed of proposed method that integrates shading, inter-reflection and highlight. The proposed method achieves real-time processing and represents a better texture of the virtual object.

<table>
<thead>
<tr>
<th>Vertex</th>
<th>Processing Speed [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1178</td>
<td>170.3</td>
</tr>
<tr>
<td>2630</td>
<td>102.1</td>
</tr>
<tr>
<td>5462</td>
<td>50.70</td>
</tr>
</tbody>
</table>

Figure 8: This figure shows the result of the proposed method. Making highlight map of the spherical mirror image and integrating shading, inter-reflection and it, brown-out highlights and a spread of highlight are represented.
5. CONCLUSION AND FUTURE WORK

This paper proposed the method to keep temporal consistency and optical consistency in mixed reality and it is able to represent better texture of the virtual object reflected in the real-world scene. Applying parallel processing with GPU to calculating color for each vertex, real-time processing has been achieved. Moreover, highlight map is made from the spherical mirror image, and the proposed method has achieved to represent saturated highlights and a spread of the highlight on the virtual object.

In future work, a camera that has high dynamic range (HDR) will be used to acquire real-world information and an error of lighting positions and inter-reflection caused by miss-registration will be reduced.

REFERENCES


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