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Light Energy Design Influence to Caustic Effect of 3D Transparent Objects

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Abstract: ***This research makes a software which can produce reflective and transparent object. Reflective object will modeled can reflect another object surrounding it. And transparent object will modeled can produce caustic effect, that's rays which refract in one area. So that area will appear brighter than area surround it. The transparent objects in this research are ball, cube, tube, cube. The result that using software Delphi 7 dan OpenGL is showing up caustic effect of transparent object. Using backward ray tracing and photon mapping, this research will compare the caustic effect of 3D transparent objects according to light energy design.***

Keywords: transparent, ray tracing, photon mapping.

1. Introduction

Today computer graphics is used in many aspects, rendering method for making realistic pictures advances. One of rendering method that often uses is ray tracing. By ray tracing method, rendering picture result is according to the original because it shows up the reflecting effect such as ambient, diffuse dan specular. Ray tracing method is distinguished as forward ray tracing and backward ray tracing. Forward ray tracing is browsing light which is emitted from light source, and backward ray tracing is browsing light which emitted from camera or eye. Forward ray tracing method can results the picture using caustic effect but it needs long time for rendering because of so many lights emission from light source and not all of the lights hit object or forward to camera. Because of that, it needs backward ray tracing. The software for visualization is OpenGL and Delphi 7.

2. Reflection and Refraction of Light

2.1 Reflection of Light

Rays coming on an object's surface will be reflected at an angle equal to the normal in the subject field. Overview of beam coming and reflected ray can be seen in Figure 1. In simple terms it can be said with equal angle between $\vec{L}$ and $\vec{N}$, the angle between the $\vec{N}$ and $\vec{R}$.

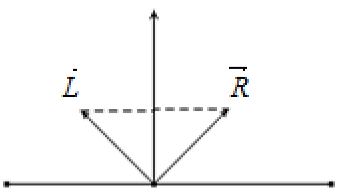

Figure 1: Formation Reflected Ray

To find the direction of the reflected beam can be formulated (Whitted, 1998) as in equation 1.

$$\vec{R} = 2\vec{N}(\vec{N}\bullet\vec{L}) - \vec{L} \qquad (1)$$

With, $\vec{R}$ *= reflected light,*

$\vec{N}$ *= normal,*

$\vec{L}$ *= negation of light coming.*

2.2 Refraction of Light

Rays on the transparent objects will be refracted. Results of refraction depends on the density of the material object. Refracted ray is calculated by reference to the normal vector of the object as shown in Figure 2. The beam b from the medium one, the speed is c1 and forming the angle of incidence θ1 of the normal line, on and pass an object with two medium, the speed of light in the medium two are c2 and refraction angle formed between the reflected normal light is θ2, the Snell's law (Halliday, 1960) is expressed in the following equation:

$$\frac{\sin(\theta 1)}{c1} = \frac{\sin(\theta 2)}{c2} \qquad (2)$$

c is 1:n so the term can be writtens

$$\sin(\theta 1) * n1 = \sin(\theta 2) * n2 \qquad (3)$$

θ1 and *θ2* = angle of incidence and angle of reflection,
c1 and *c2* = speed of light in the medium of origin and destination,
n1 and *n2* = the refractive index of the medium of origin and destination ray.

To find the direction of the rays that have been refracted (d), as shown in Figure 2 is obtained by the equation as the following equation:

$$d = \delta c + (1-\delta)(-U_n) \qquad (4)$$

$$\delta = \frac{1}{\sqrt{\frac{c1^2}{c2^2} * \| c \|^2 - \| c + U_n \|^2}} \qquad (5)$$

$$c = \frac{b}{\| b \bullet U_n \|} \tag{6}$$

with, d = reflected ray,

δ = the distance between the light refracted by the normal line,
Un = normal field,
c1 = speed of the medium 1,
c2 = on medium speed 2, and
b = light that comes on an object surface.

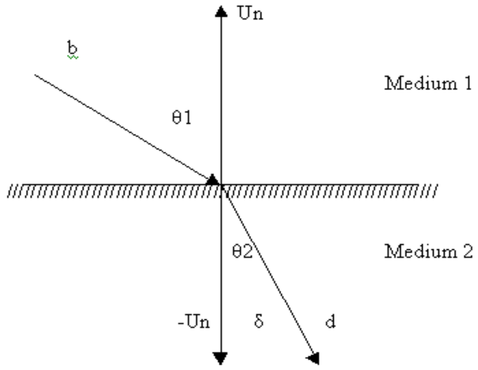

Figure 2: Refraction rays of medium 1

3. Photon Mapping and Backward Ray Tracing

Rays kept bumping into objects hit position and intensity of light. If you hit a transparent object, the light will be refracted. Refracted ray direction is calculated by using the theory of the refraction of light, ie light Snell's law and the search continued until crashing into objects that are not transparent. Mapping results can be seen in Figure 4.

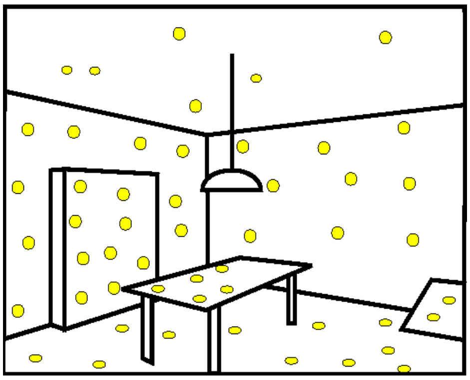

Figure 4: Mapping the beam on the object surface

Effect of reflected light collection modeled using photon mapping algorithm. The effect appeared with the rays is turned so that eventually crashed at a point adjacent, or even a lot of the refracted rays to the same point.

Photon mapping storing photons in the photon map of emitting point subjected to light, while the backward ray tracing is a method to trace the rays emitted from the camera or the eyes.

3.1 Photon Mapping

The basic principle of photon mapping is a store of light emitted from the light source to the photon map (Tin-Tin et al, 2005). Stored only light rays that hit the object is not transparent and is a result of the refraction of light by a transparent object. Beam ray tracing is done for each light source. Type of light emission is used to emit light in all directions from a central point, ie the point position of the light source. Overview ray emission can be seen in Figure 3.

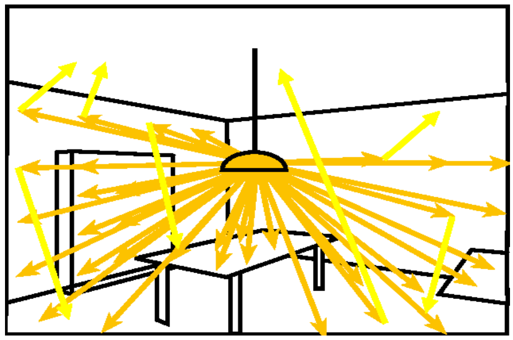

Figure 3: Shooting rays from the light source

Once the forward ray tracing process is complete, then proceed with the second phase by using backward ray tracing algorithm. Picture of photon mapping in the backward calculation ray tracing can be seen in Figure 5.

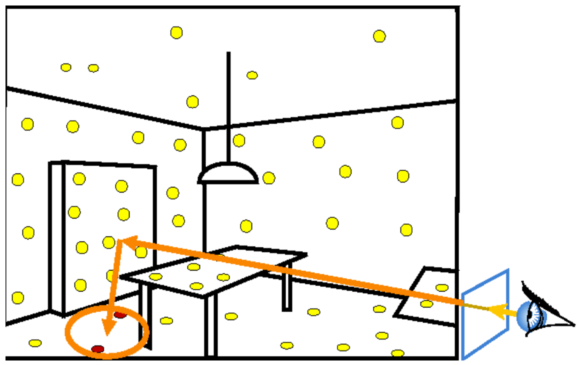

Figure 5: Backward ray tracing with photon mapping

The data structure used to store the beam is kd-tree data structure (k-dimensional tree) to get the render time. Photon data is broken down by position, the division was based on one axis (X, Y or Z) (Tin-Tin et al, 2005). The model of the effect of the bias shown in the following quation

3.2 Backward Ray Tracing

$$c = \frac{1}{r^2} \sum_{i=1}^{M} (\max(\bar{n} \bullet \bar{l}_i, 0) * k_d * color + \max(\bar{n} \bullet \bar{h}_i, 0)^a * k_s * color) * energy_i \tag{8}$$

with,
c = the effect of the bias light collection at the point P,
r = radius of the sphere S,
M = number of photons that are found in the sphere S,

$\bar{n}$ = *Normal vector at point P,*

$\bar{l}_i$ = *Negation photon direction i,*

$\bar{h}_i$ = *Vector of the direction of refraction with sightings photon direction i,*
a = exponent specular sharpness,
kd = coefficient of diffuse,
ks = coefficient of specular,
color = color of the surface at the point P,
energyi = photon energy level i, and
max (a, b) = back to the maximum value of a and b (Cheah, 1996).

While the algorithm is used as follows:
1. for each light source
2. find the direction of the beam
3. looking for a hit-ray point with all objects
4. If the object crashing
5. If on the reflective object
6. find light reflections
7. The plot of the beam reflected parameters
8. If on the transparent object
9. looking refractive beam
10. The plot of the refractive beam parameters

3.3 Analysis of Research

The results of rendering images generated by photon mapping rendering speed difference as shown in Table 1 and Table 2.

Table 1: Table Render Speed Scene Two ball in milliseconds

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Average
40108	39768	39828	39587	39757	39747	39346	39597	39717.25

Table 2: Table Render Speed Sceneone cube in milliseconds

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Rata-rata
16073	16023	16013	16063	16053	16023	16073	16013	16041.75

From Table 1 and Table 2 can be seen at the scene rendering time difference which contains a cube and two balls. Where the difference in the average rendering time is 23675.5 ms.

The trial of the software that was created by using Delphi 7 and OpenGL aims to determine whether it is appropriate output. For testing, the data - the data is organized as follows:

- Position Camera (0,300,900), view (0,300,0)
- Position Camera (0,300,900), view (0,300,0)
- The color combination of pink background set with 0.3, 0.3 and blue green 0.3, yellow 1.0
- Lamp with ambient coefficient (0.5, 0.5, 0.5), diffuse and specular coefficient (0.8 0.8 0.8). Lights are put in the position (0, 19, 0). Energies 20.
- Flat Field with normal (0, 1, 0), the distance from the plane y = -5 0. For ambient coefficient 0.7, 0.2 diffuse, specular 0.8, reflectivity and transparency 0 0,
- Scale folder (the square footage of the real world is represented by each unit area of the illumination map) on a horizontal plane is 2.

With the data - the data mentioned above, it is obtained as shown in figure 6 and 7.

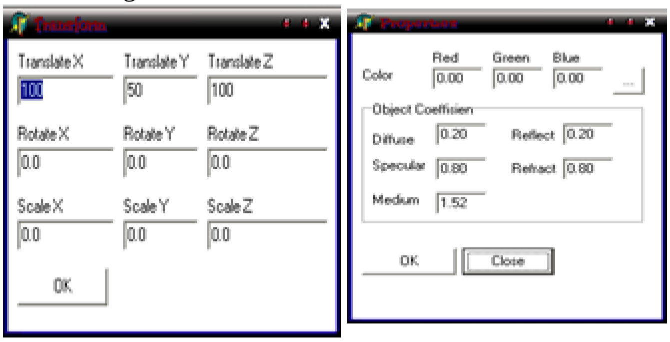

Figure 6: Properties cylinder

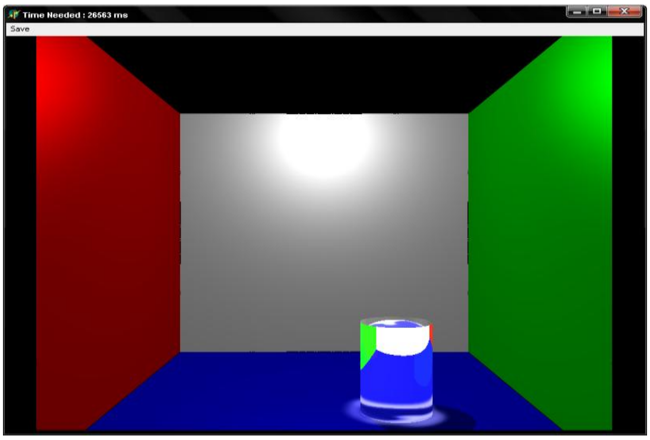

Figure 7: Caustic effect too broad area

The white area indicates the refracted ray collection accumulate so that the area light. Light-colored areas seem too broad and rectangular shaped. This happens because the energy that accumulates too big and maps quadrangular If divider energy enlarged it will look like in figure 8.

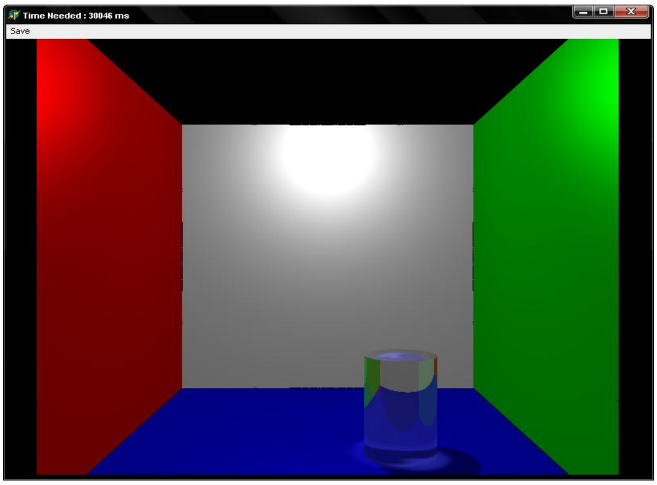

Figure 8: Caustic effect narrowing region

From the picture above effects found caustic. The resulting weakened yet looks better because the area caustic effect not too large and not too quadrangular.

4. Conclusion

From the results of experiments that have been performed and evaluation described in the test tried before it can be the following conclusions:

1. Objects are modeled invisibility not only managed to reveal another object is behind but also produces caustic effects such as which is expected.
2. Caustic effect produced only capable of producing the white effect, rather than in accordance with the color of the object is transparent. this matter because that is not mapped according to intensity but the energy.

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