Graphics Programming HW5 Report

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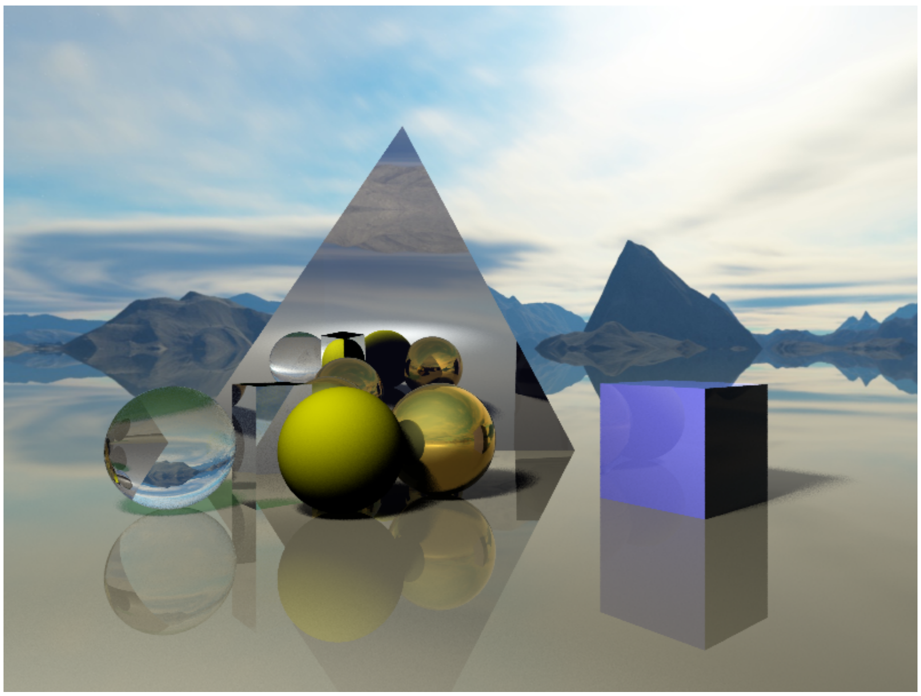

Figure 1: **Final result**. This is the result after implementing both mandatory and optional requirements. Dielectric glass material and soft shadowing technique are applied.

1 Baseline Implementation

I implement all the required features 1-(a) to (f) in the homework specification. This includes:

1. Implementation of (real-time) ray tracing on the fragment shader. Default environmental props, *i.e.*spheres, boxes triangular mirror and the plane are drawn.

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2. Colorization of props by Phong illumination model.
3. Implementation of (hard) shadows made by default point light sources using additional shadow ray casting.
4. Implementation of recursive reflection and provide various light scattering model, *e.g.*perfect specular (basic), Lambert (diffuse) scattering, specular scattering.
5. Skybox cubemap for environment map.
6. Fresnel effect is added for perfect specular and normal specular model. I don't think Lambert scattering model is well suited for Fresnel effect, so it is omitted.

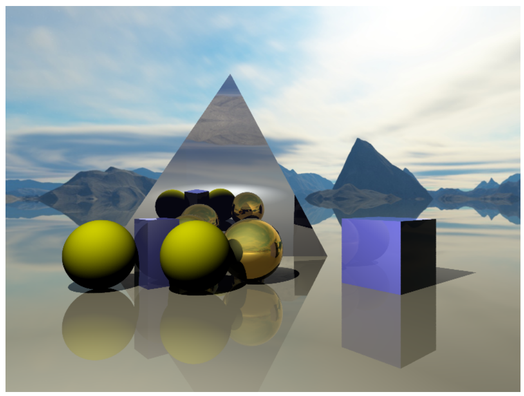


Figure 2: **After finishing the baseline implementation**.

2 Optional Implementation

I implement *two* of the optional features. Namely, *dielectric material* and *soft shadowing from area light sources*.

2.1 Dielectric Material

Dielectric material is implemented as specified. Dielectric material is capable of both reflecting and refracting the input light ray. Reflection probability is obtained by applying Fresnel effect. This material property is approximated with Schlick's method.

$$R_0 \coloneqq R(0) = \left(\frac{1-\eta}{1+\eta}\right)^2, \quad R(\theta) = R_0 + (1-R_0)(1-\cos\theta)^5. \tag{1}$$

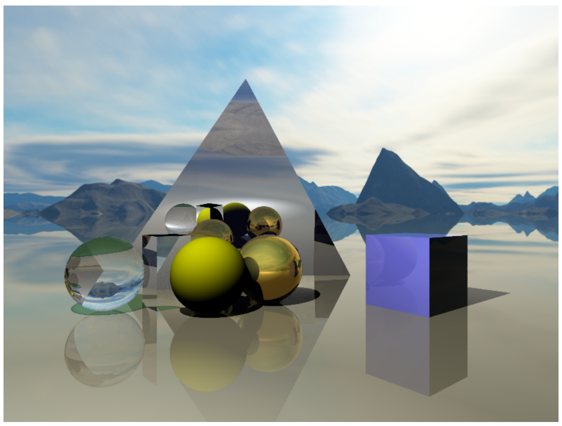
Reflected ray always follows perfect mirror reflection and refracted ray has direction according to the Snell's law. Shadow of the dielectric material is evaluated as an attenuation coefficient that is evaluated, again, by Schlick's approximation to Fresnel effect. This time, $1-$(shadow attenuation) is used instead of albedo.

Finally, transmittance of a ray cast on a dielectric material is evaluated with Beer-Lambert law. Assuming a homogeneous material, complex integrals in Beer-Lambert law is reduced to a simple exponential,

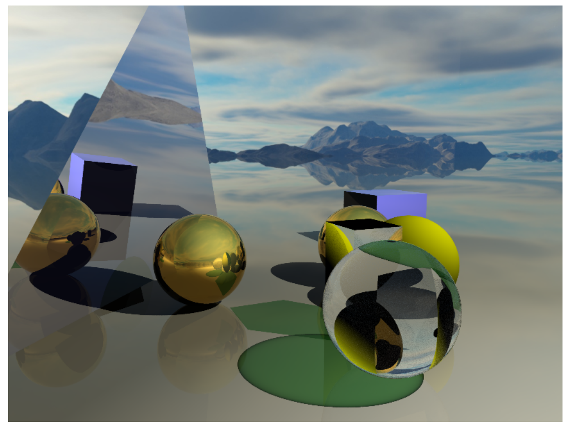
$$T = \kappa e^{-\kappa t}, \tag{2}$$

where κ denotes the extinction constant of the material and t is the distance the ray travelled inside the object.

For demo, the leftmost sphere and the leftmost AABB are given a dielectric glass material.



(a) Front view.



(b) Side view.

Figure 3: **Dielectric material**. One can clearly see in figure 3b that the shadows shed by dielectric material differ from that of other reflective materials. To generate more realistic scene, shadow rays are allowed to transmit through two different dielectric object. Two shadows from different dielectric objects are darkened when overlapped, but do not become fully opaque.

2.2 Area Light and Soft Shadow

Area light is implemented to have a simple triangular shape. Light direction is sampled per every Phong lighting procedure and shadow calculation by uniform sampling on the light triangle. Uniformly sampled points on a given triangle $\triangle ABC$ can be obtain from two uniform random variables $x_1, x_2 \sim \mathcal{U}[0,1]$, according to [1].

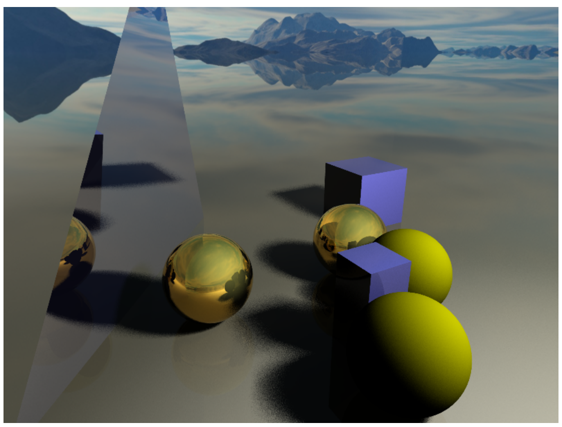
$$P = (1 - \sqrt{x_1})A + \sqrt{x_1}(1 - x_2)B + x_2\sqrt{x_1}C. \tag{3}$$

By increasing the number of sampled rays per pixel, I am able to attain realistic soft shadows.

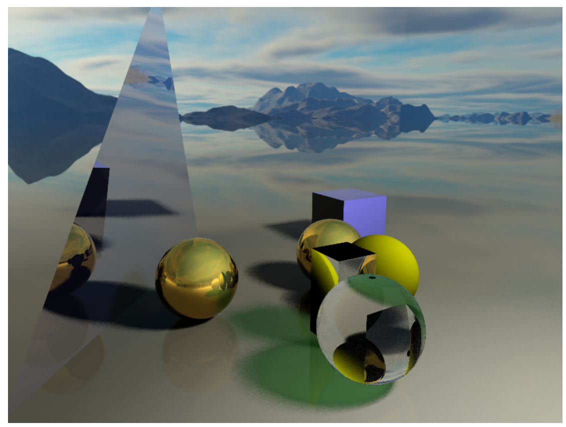
For demo, the point light at $(3, 5, 3)$ which contributes to the shadows in the baseline scene is replaced by a triangular area light $\triangle(2, 5, 3)(4, 5, 3)(3, 5, 4.7)$. The result can be seen in figure 4.

References

[1] R. Osada, T. Funkhouser, B. Chazelle, and D. Dobkin. Shape distributions. *ACM Transaction on Graphics*, 21(4):807–832, 2002.



(a) On baseline model.



(b) Soft shadow on dielectric materials.

Figure 4: **Soft shadow by area light**. Figure 4a shows the effect of area lighting on the baseline model. Figure 4b shows that the both optional features contribute independently to the realism of the rendered scene.