CS 6366 Computer Graphics

Final Project Report

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1. ***Title:***

   Environmental Mapping

2. ***Problem summary:***

   Why we choose & Problems we deal with:

   In our final project, we decide to choose a topic that we are interested in and would like to challenge in the field of Computer Graphics to research and study on it. After considering, we think the topic Environment Mapping is challengeable and also interesting for us.

   Although we have learned some basic techniques in Computer Graphics, we know some basic shading techniques like how to light, transform and texture the objects. However, the renderings are probably not quite what we envisioned. With the technique of Environment mapping, we can dramatically improve the images. This makes us made the decision to discover and resolve this problem.

   Details about Environmental Mapping:

   When we are doing with the graphics objects, we have following issues:

   a. Many objects are glossy or transparent
   b. Glossy/Transparent objects reflect the external world
   c. The world is refracted through transparent objects

   Thus, it is important to make the scene appear realistic. Because the precisely simulating of such phenomena is computationally costly and very comprehensive, it requires us to track the rays, find out where they collide and do some extra lighting computations. That is, the reflection mapping approach is more efficient than the classical ray tracing approach of computing the exact reflection by tracing a ray and following its optical path. Under this background, we have environment mapping, which is a very simple and powerful method to generate reflections. It assumes that everything surrounding an object is infinitely distant from the object, so it

simulates reflections by using the reflection vector to index a texture map infinitively. Environment mapping also gives rendered objects a chrome-like appearance.

3. *Description of work:*

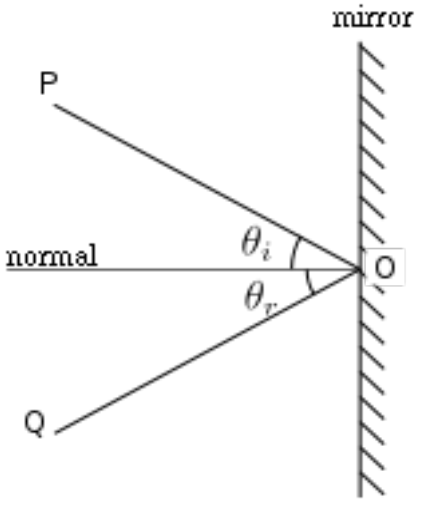
Procedures of our work:

During our project, we divided our works in some small parts and use the Control Variant Method to do different tests, so that we could control our tests easily. By doing so, we could easily detect which part we are doing is meeting problems and deal with the problem separately.

Implement reflection and refraction (most important and first place):

First of all, we tried to implement the main functions in our environmental mapping, which cover the reflective and refractive effects in our project. With the reflective effect we could reflect all the scenes and objects from the mirror-like object we implement. With the refractive effect we could refract the scenes and objects behind the object we implement. We are also able to change the refractive index.

Reflection:

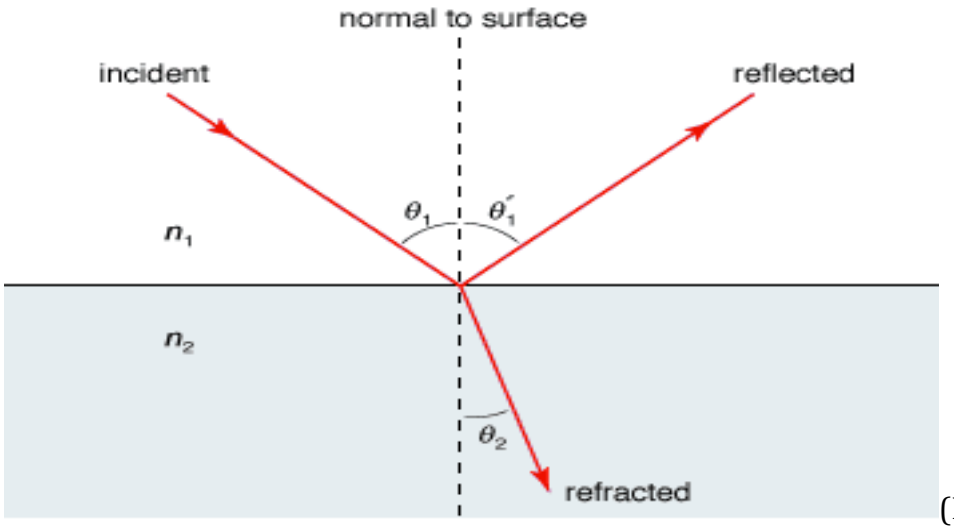


(P1)

With Normal perpendicular to the reflection side

- Θin=Θreflective
- Θin is the angle between light_in and normal
- Θreflective is the angle between light_re and normal

Refraction:



(P2)

From this picture, we could clearly observe the refracted light and the reflected light. From above, we have discussed the reflected light.

To calculate the relationship between incident angle and refracted angle, we need to introduce the *Snell's law.*

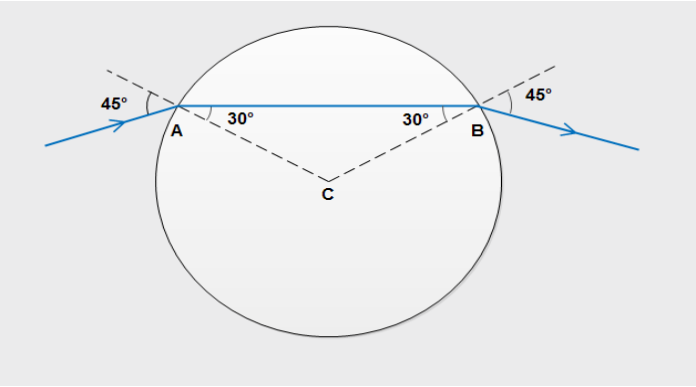
That is,

$$n_1 sin\theta_1 = n_2 sin\theta_2$$

$$\theta_1 \textit{ is the angle between incident light and normal}$$

$$\theta_2 \textit{ is the angle between normal and refracted light}$$

However, what we should notice here is, when we are refracting with an sphere object (e.g. sphere glass), the bottom and topside of the refractions in our sphere will be reversed with the real scene, this is because:



Thus, we could understand that what we see that refracted on the topside of the sphere is actually the lower side of the real scene behind the sphere.

In our working phase, we used different types of objects and different types

of materials to show the effects of reflection and refraction. The pictures will be showed in next part.

Implement different types of objects for observation, testing and comparison
Then, we did illustrate the Environment Mapping with different forms of objects like follows:

a. Cubic objects
b. Sphere objects (2048 polygons, which gives us a more obvious and clear vision of refraction)
c. Hebdomicontadissaedron (72 polygons, which shows reflection aesthetically)
d. Rock object
e. Cyborg object

Implement different types of environmental scenes:
After that, we inserted the environmental scenes with different topics, which could let us show our reflective and refractive effects effectively.
Although we only implemented several senses, that are “Mountain”, “Green Bay”, and “Sunset”, we have tested more than 20 different scenes with mostly of them are skyboxes, also some indoor scenes.
During the testing, we assured that our functions of reflection and refraction are successfully implemented.

Setting up with different types of materials with (amb, diff, spec and shininess):
After having the reflection and refraction effects, and implementing different types of objects and scenes to display our work. We inserted the material function in our work, which could let us change the different types of materials during our testing. We have searched many types of materials, like glass, plastic, ice, ruby, diamond, pearl, emerald and vacuum. All of them own different parameters for their Ambient, Diffuse, Specular and Shininess (We have implement the parameter Shininess as new parameter here). After comparison, we pick several typical materials to implement in our project. They are glass, emerald and ruby respectively.

Problems we met & how we dealt with them:

However, during the working phase of our project, we met some questions. One of them is that when we are implementing the scenes, the left and right sides were swapped. However, we found in our source codes, we implement the code which corresponding our photo dislocated.

One more question is that, when we are dealing with the scenes, it is hard to split a full scene into 6 sides of a box. That is, when we tried to take pictures even with a full-scene camera, the picture covers only the 360° scene, which means only 4 sides (front, back, left and right) covered, that's obviously not enough. So the scene could only be approximately combined with these cameras (if we could take picture like the street views in Google Maps, this problem would be solved).

Fortunately, as we have a very clear thinking and designed the processing steps of the project separately, none of the problems were too crucial to make us be stopped during the work, although they did cause some difficulties and made us think carefully about our solutions.

4. *Results:*

Problems we achieved

a. Reflection

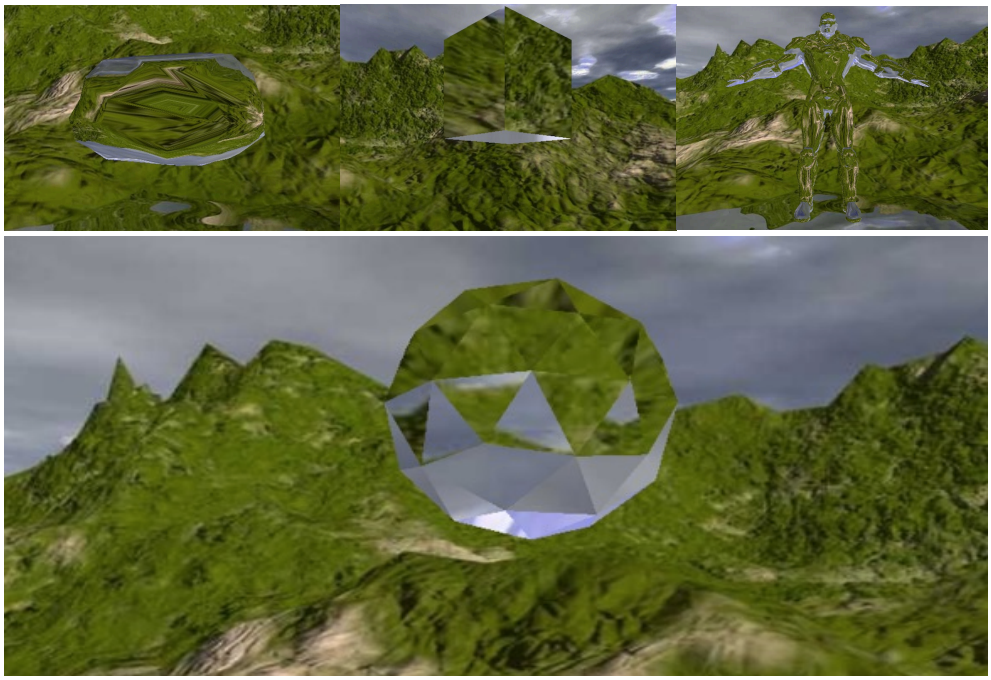
As we can see, the reflection effect is successfully implemented

b. *Refraction*

As we can see, the refraction effect is successfully implemented

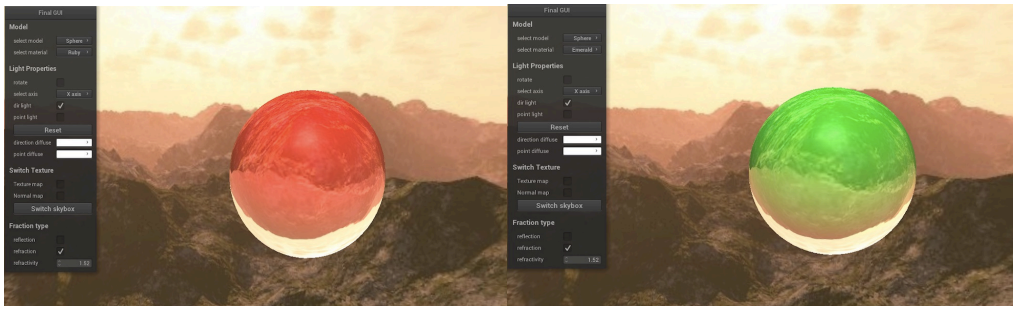
Here we need to notice that, with a cubic object, the refraction will not change the bottom and topside in the illustration. However, with sphere object, the top and bottom sides are reversed. This is because the definition of Snell's law.

c. *Objects*



Example of Different types of objects that display the effect

d. Materials



With Ruby and Emerald

Here we change the parameter of the ambient, diffuse, specular and shininess, so that different reflection/refraction effects will be displayed based on different types of objects we use.

5. *Analysis of work：*

From the designing phase of our work, we tried to set up our goals in a step-by-step way, we have split our project in many small parts, so that we could test if the current part we are doing is going well and so we can go further.

By doing our work, we have successfully solved the reflection and refraction problems, that are relevant about our project theme, environmental mapping. Besides this, to better understand and display our work, we have also added some additional influencing factors like different types of objects, scenes (skyboxes) and materials. With objects like cubic and sphere, we understand clearly why the refraction will display different scenes on different object. With different types of materials, we could observe the difference of refractions based on different refraction ratio of materials.

Generally, we think we have achieved our goal, with main effects reflection, refraction successfully implemented and other influencing factors successfully tested.

Reference:

P1: https://en.wikipedia.org/wiki/Reflection_(physics)

P2: https://en.wikipedia.org/wiki/Snell%27s_law

P3: https://www.okphysics.com/6-47-refraction-inside-a-transparent-sphere/

https://learnopengl.com/