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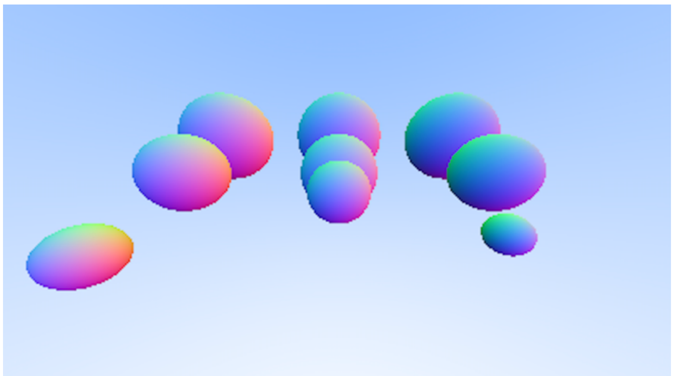
Ray Tracing Project

Task 1



Scene 1 with 9 spheres

The scene is composed with nine spheres in front of the camera. The camera's position is (0, 0, 0) and it looks into the screen along negative z-axis.

The positions and radius of the spheres

position: (0, 0.4, -1.4) radius: 0.3

position: (0, 0.1, -1) radius: 0.2

position: (0, 0, -0.6) radius: 0.1

position: (0.8, 0.4, -1.4) radius: 0.3

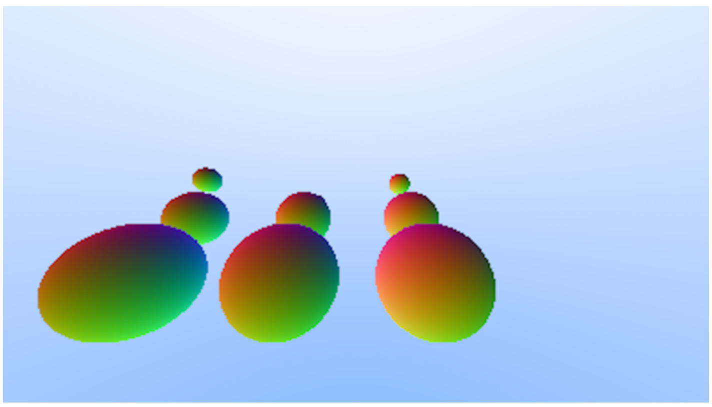
position: (0.8, 0.1, -1) radius: 0.2

position: (0.8, -0.2, -0.9) radius: 0.1

position: (-0.8, 0.4, -1.4) radius: 0.3

position: (-0.8, 0.1, -1) radius: 0.2

position: (-0.8, -0.2, -0.6) radius: 0.1



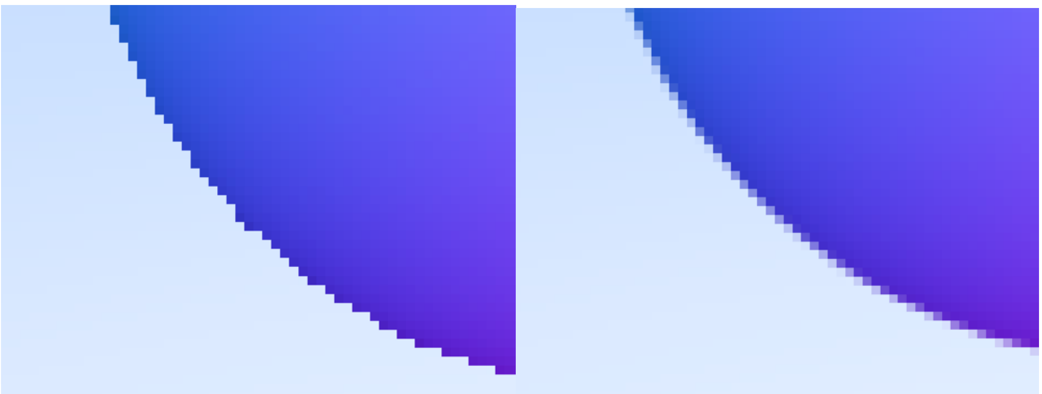
Scene 2 with 9 spheres from backside

In the scene 2, the same objects are observed from another position. The origin of the camera is (-0.4, 0, 2.5). The look-at position is along positive z axes this time. Hence, we see the scene from the backside.

Task 2

Before Antialiasing After Antialiasing

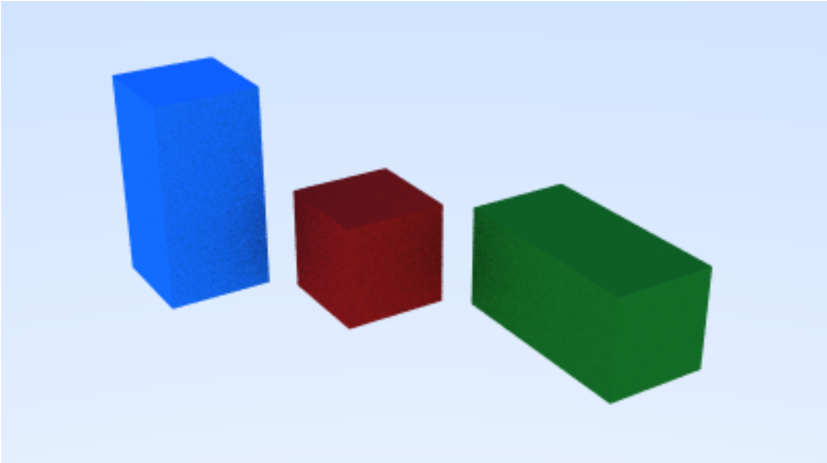
The seen with antialiasing is a better one because there are jaggies along edges for the seen with no antialiasing. On the other hand, the scene with antialiasing looks more real than the other one. When we zoom into the edge the difference is seen below.



Before Antialiasing After Antialiasing

Task 3

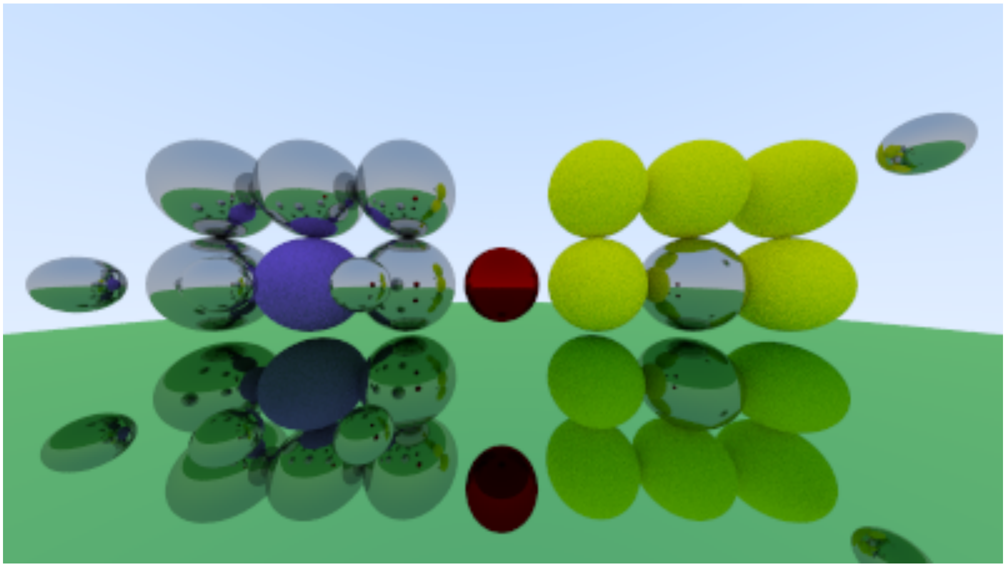
Rectangles are used to create cubes and boxes. There are three types of rectangle objects with different normal vectors. These are xy rectangle with a normal vector (0, 0, 1), xz rectangle with a normal vector (0, 1, 0) and yz rectangle with a normal vector (1, 0 0). The look from position of the camera is (5, 3, 2) and the look at position is (0.25, 0.25, -1).



Scene with a cube and two boxes

Task 4

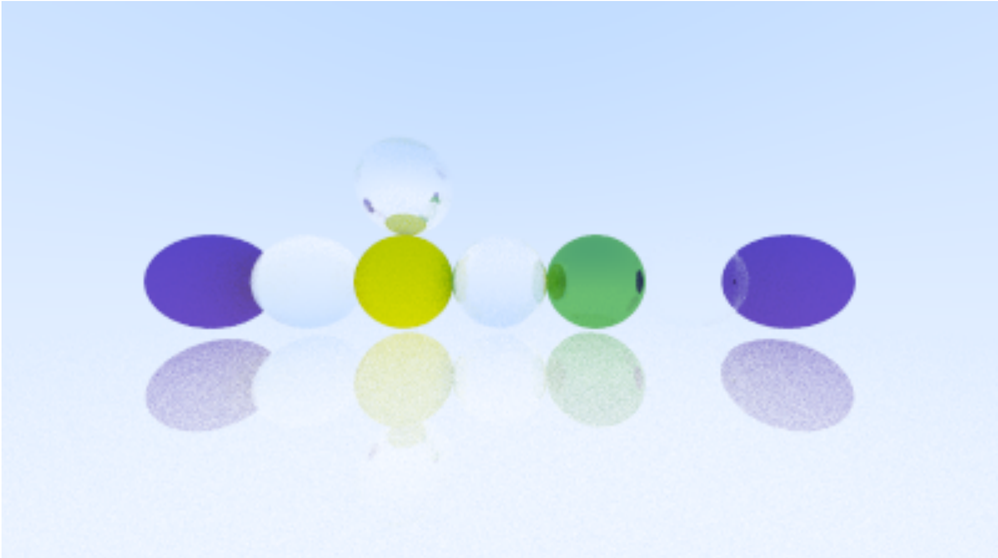
18 spheres are created in the scene. Two types of material are used metal and lambertian. Metal reflects the light perfectly. Lambertian is a diffuse material and reflects the light randomly. Lambertian Reflectance model is used to have a random reflection for lambertian.



Scene with different material spheres

There are also 3 different types of metal and 2 different types of diffuse objects. There are 10 white metal spheres which look like a mirror. There is one red metal sphere at the center and a huge metal green sphere at the bottom with a 100 radius. 17 reflection can be seen on the biggest sphere. There are 5 yellow lambertian spheres on the right and one purple lambertian sphere on the left surrounded by metal spheres.

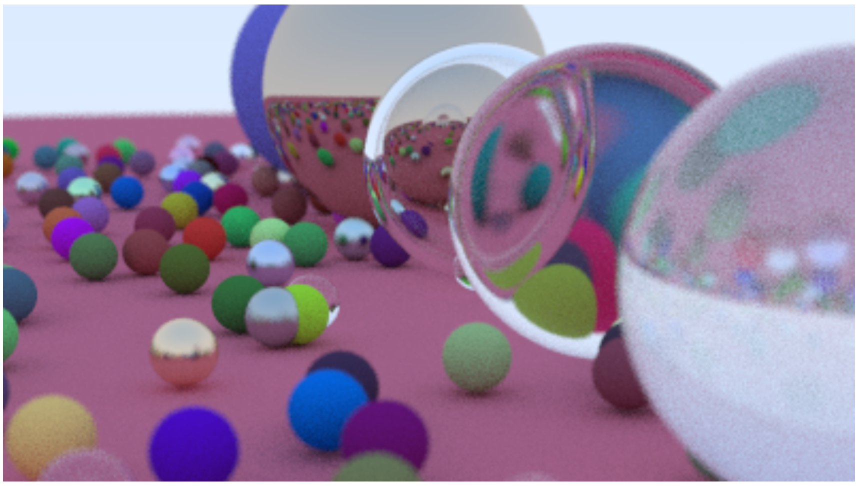
Task 5



Scene 1 with dielectric materials

There are some materials which are not neither completely opaque nor reflective. Dielectric materials do not reflect the light but refract it. They have their own index of refraction. For instance, ice has 1.31 index and diamond has 2.417. In the scene above, there are nine spheres. 8 of them are small sized with 0.5 radius and there is one at the bottom with 100 radius. The bottom one is a diamond sphere, so it does not reflect the light and it is not opaque. There are three opaque spheres, two of them are purple and one is yellow. There is one dielectric sphere on the top of yellow sphere. And, it has a 10 index of refraction. Hence, it looks like a mirror because of a high index of refraction.

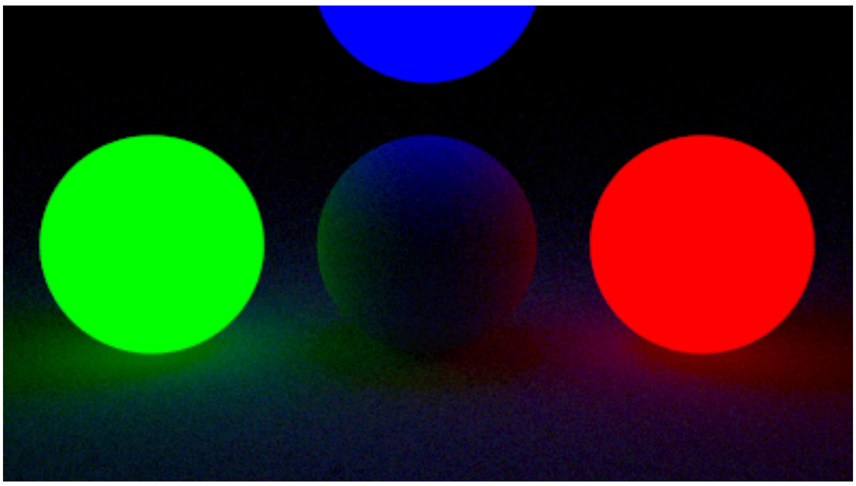
There is one sphere at the right of the scene, next to purple sphere. I called as airball because it has 1.01 index of refraction, so the light passes through it and looks like nothing is there. At the left of that sphere, there is one green metal sphere which reflects the light and we can see the reflection of purple sphere on the right corner. Finally, the sphere at the center consists of dielectric material as well with 2.417 index of refraction. Therefore, it looks more like diamond.



Scene 2 with dielectric materials

For scene 2, a random sphere generator is used to create spheres with random colors. And, five bigger spheres are created to observe their material attributes. There is one Lambertian sphere at the back and one metal sphere in front of it. The metal sphere reflects the light perfectly and we can see other balls' reflection. There are 3 dielectric spheres with different index of refractions. The one on the very right has 2.5 index, the one at the middle has 1.1 index and the one at the back has 0.9 index. We can compare metal sphere at the back and dielectric sphere at the middle in terms of how they reflect the light. As seen above, metal is reflecting perfectly but dielectric spheres do not. The one with 1.1 index looks like all colors are mixed on its surface which is very interesting to observe.

Task 6

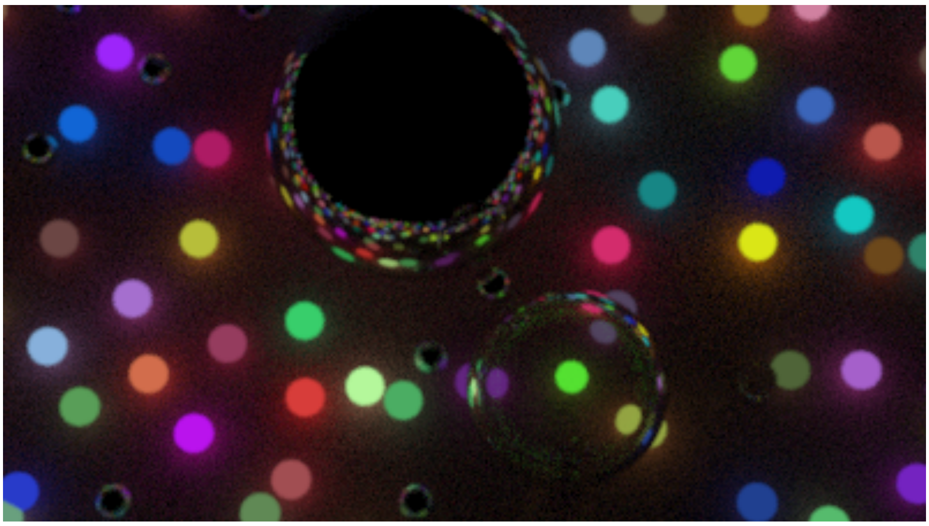


3 spheres emit different color of light

There are 5 spheres in the scene, two of them are lambertian, one is at the center and the other is at the bottom with a radius 1000, son the second one is more like a ground. Three spheres which emits lights are created in the positions red (-5, 2, 2), blue (0, 7, 2) and green (5, 2, 5). The center (0, 2, 2) and the camera's look at position is also (0, 2, 2). The look from position of the camera is (0, 8, -22).

Small spheres emit light and bigger dielectric spheres

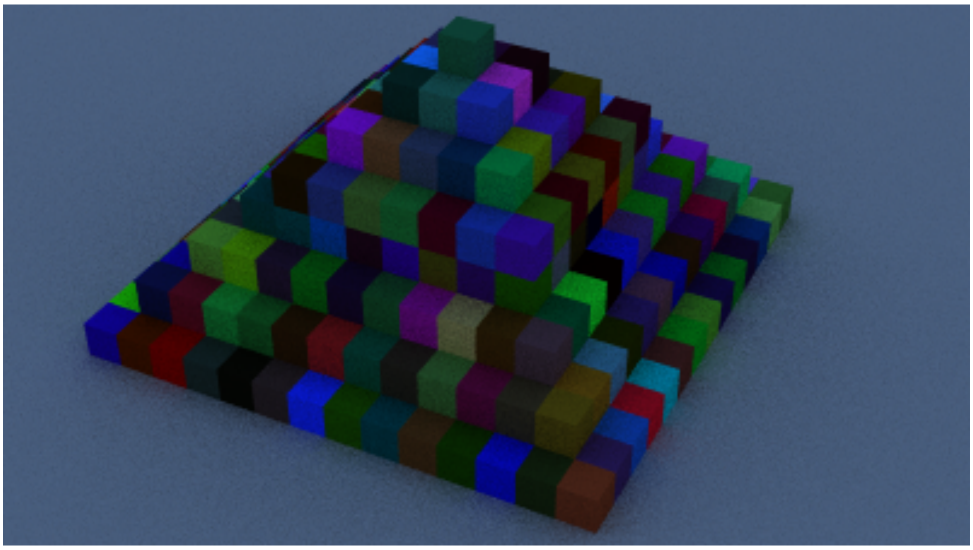
In task 5, small lambertian spheres were created randomly, this time I have used new material that diffuse light. There are some metal spheres as well, but most of them are spheres emit light. Although background is totally dark, light sources make the picture visible. The look from position of the camera is (13,2,3) and look at position is (0,0,0).



The same world with a different camera position

Now the look from position of the camera is (5,15,3). We are looking the scene from above.

Task 7



The Rainbow Pyramid

I created a pyramid consists of colorful cubes. Rendering of this scene took more than 70 minutes. I used three nested for loops to locate the cubes to create a pyramid. The look from position of camera is (6, 10, 12) and look at position is (0, 0, 0). The cubes located in the base are between (-3, 0.2, -3) and (3, 0.2, 3). There are 196 cubes at the bottom, one above 144 cubes and one above 100 cubes and so on.

Task 8

The approximate time complexity of ray tracing on models with triangles is O(b . p). However, it is possible to reach O(log(b) . p) complexity by optimization of the algorithm. Where b represents number of triangles in the scene and p represents the number of pixels on the image.

Preprocessing an image is regularizing of an existed image such as noise canceling. On the other hand, computing an image is creating the image from scratch by rasterization or ray tracing.

The critical parameters of a ray tracing algorithm for its performance are number of samples per pixel, the depth rate, the antialiasing algorithm, type or texture of models and number of pixels. Increasing number of samples per pixel or the number of pixel cause to last ray tracing algorithm longer.

The number of triangles is more important than the number of objects. Because some objects can be simple, and some can be very complex. Hence, I will consider the number of triangles to estimate the maximum rendering time per frame. If the resolution is 6000x6000 then there are 36×10^6 pixels in the scene. There are 5 million triangles to check intersection if we assume that checking 1 million triangles will take 0.00001 second in a supercomputer at Pixar. Then, the rendering time will be $36 \times 10^6 \times 5 \times 0.00001$ which is 1800 seconds. Hence, the approximate time will be 30 minutes with these assumptions.