A4: Shadows, Reflection & Refraction

一、概述

1.目 标：

（1）实现阴影
（2）实现镜面反射材质
（3）实现透明折射材质

2.知识点介绍：

实现以上目标使用的主要是光线追踪技术。通过递归调用光线追踪函数，从新的交点处发射新的射线，并检测场景中所有物体寻找交点。

（1）阴影实现：得到摄像机和物体的交点 A 后，从该交点 A 出发，向每个 Light 方向发射射线，如果射线在 Light 的位置和交点 A 之间和其他物体相交，那么该 A 点的最终颜色不受该 Light 的影响。但是要注意射线的起点应该稍微偏离表面，防止与自身相交。

（2）镜面反射/折射材质实现：在材质中有 reflective Color 属性，如果这个值不为 0 就代表需要反射。实现反射的主要方法是得到摄像机和物体的交点 A 后，从 A 点出发，向*镜面反射方向*发射射线并检测与场景中所有物体的交点。根据给出的 Bounces 值，多次递归调用 traceRay 函数，可以进行多次反射。透明折射也类似，只是换成了 transparent Color 属性和向*折射方向*发射射线。

二、实现细节

1. 阴影实现：

```
if (scene->getGroup ()->intersect (ray, hit, tmin)) {
        Vec3f point = hit.getIntersectionPoint ();
        Vec3f n = hit.getNormal ();
        for (int i = 0; i < scene->getNumLights (); i++) {
            Vec3f lightColor, lightDir;    float distanceToLight;
            scene->getLight (i)->
            getIllumination (point, lightDir, lightColor, distanceToLight);
            lightDir.Normalize ();
            if (shadows) {
                Vec3f origin = point + n * 0.1f;
                Ray toLight = Ray (origin, lightDir);    Hit m_hit;
                //再从交点处，向光源发射一条射线
                bool isShaded = InShadow (toLight, m_hit, distanceToLight);
                RayTree::AddShadowSegment (toLight, 0, m_hit.getT ());
                if (isShaded)continue;//忽略此光源的影响
            }
            //可计算的光源的影响
            color += hit.getMaterial ()->Shade (ray, hit, lightDir, lightColor);
        }
        color += (ambient * hit.getMaterial ()->getDiffuseColor ());
}
```

判断是否在阴影中：

```
bool RayTracer::InShadow (Ray &ray,Hit& hit,float dis) const {
    hit = Hit (FLT_MAX, NULL, Vec3f (0, 0, 0));
    bool intersect= scene->getGroup ()->intersect (ray, hit, EPSILON);
    //对于directional light，只要和别的物体相交就是阴影
    //对于point light，到交点的距离超过了到point light的距离，还是没有阴影的
    if (hit.getT () > dis)intersect = false;
    return intersect;
}
```

2.镜面反射实现：

```
if (bounces < 0) return Vec3f (0, 0, 0);
Vec3f reflectiveColor = hit.getMaterial ()->getReflectiveColor ();
        if (bounces && (reflectiveColor != Vec3f (0, 0, 0))){
            Vec3f mirror = mirrorDirection (n, ray.getDirection ());
            Ray r = Ray (point, mirror);            Hit tmp_h;
            //递归，终止条件是bounces<0
            Vec3f v =traceRay(r,EPSILON,bounces-1,indexOfRefraction,weight,tmp_h);
            RayTree::AddReflectedSegment (r, 0, tmp_h.getT ());
            Vec3f reflection = reflectiveColor * v; //反射系数*得到的反射颜色
            color += reflection;
        }
```

计算镜面反射的方向：

```
Vec3f RayTracer::mirrorDirection (const Vec3f &normal, const Vec3f &incoming) {
    Vec3f v = incoming - 2 *normal.Dot3(incoming) * normal;
    v.Normalize ();
    return v;
}
```

3.透明折射实现：

```
Vec3f transparentColor = hit.getMaterial ()->getTransparentColor ();
        if (indexOfRefraction && (transparentColor != Vec3f (0, 0, 0))){
            bool inside = ray.getDirection ().Dot3 (n) > 0;
            float new_index = hit.getMaterial ()->getIndexOfRefraction ();
             if (inside == 1) {//如果在内部
                new_index = 1;//indexOfRefraction置为1
                n = -1 * n;//法线取反 }
            Vec3f r_dir;
            if (transmittedDirection (n, ray.getDirection (),
            indexOfRefraction, new_index, r_dir)) {
                Ray r = Ray (point, r_dir);    Hit tmp_h;
            //递归，终止条件是bounces<0
                Vec3f v = traceRay (r, EPSILON, bounces - 1,
                          new_index, weight,tmp_h);
                    Vec3f refraction = transparentColor * v;
```

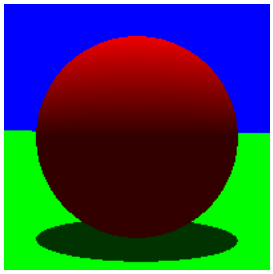
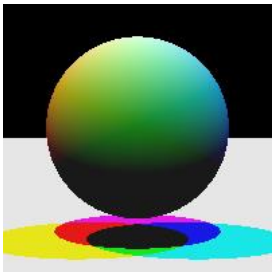
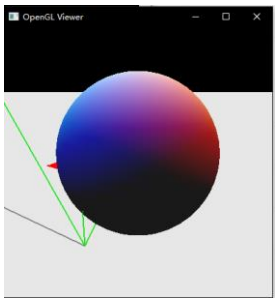
```
                color += refraction;
            }
        }
```

计算折射方向：

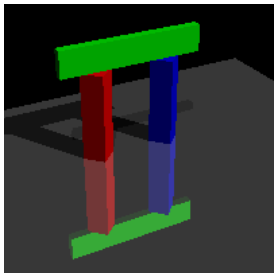
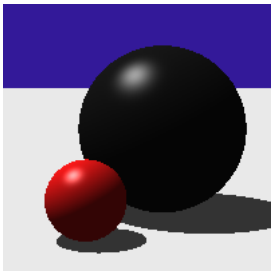
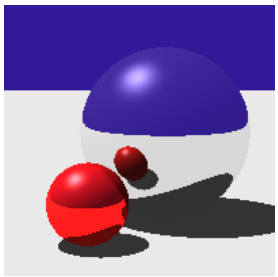
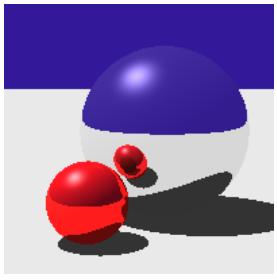
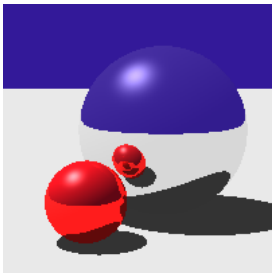
```
bool RayTracer::transmittedDirection (const Vec3f &normal, const Vec3f &incoming,
    float index_i, float index_t, Vec3f &transmitted) {
    if (fabs (index_t) < EPSILON) return false;
    float d = normal.Dot3(incoming);
    float x = index_i / index_t;
    float r = 1 - x * x * (1 - d * d);
    if (r < 0) return false;
    r = sqrt (r);
    transmitted = x * (incoming - d * normal) - r * normal;
    transmitted.Normalize ();
    return true;
}
```

三、结果展示

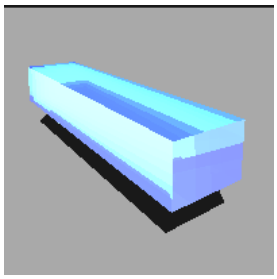
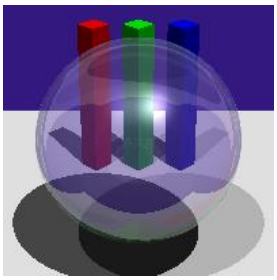
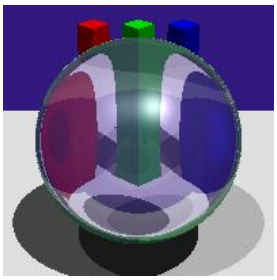
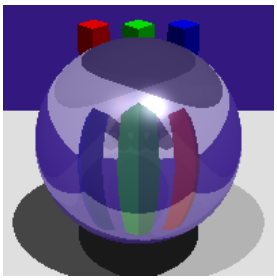
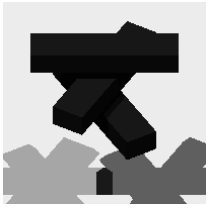
1.阴影测试:

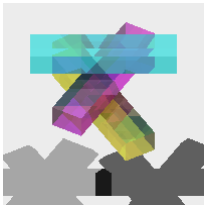
2.反射测试:

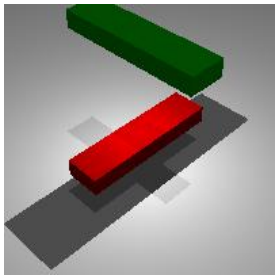
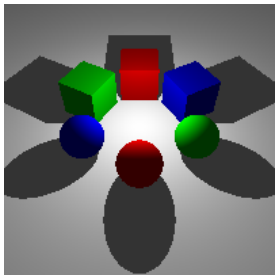
3.折射测试：

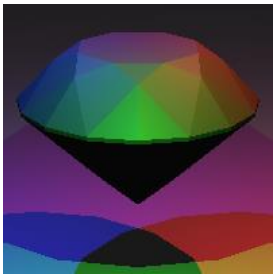
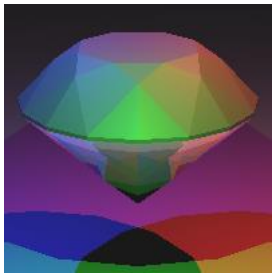




4.Point Light 测试：


5.faceted_gem 测试：

四、心得体会

通过光线追踪的技术可以得到很好的效果，加上点光源、阴影、反射、折射之后整个场景更加接近现实。