Université Pierre et Marie Curie

IG3D
Travaux sur Machine Encadrés

Compte Rendu

Mario Viti
mario.viti@etu.upmc.fr

8 mai 2017

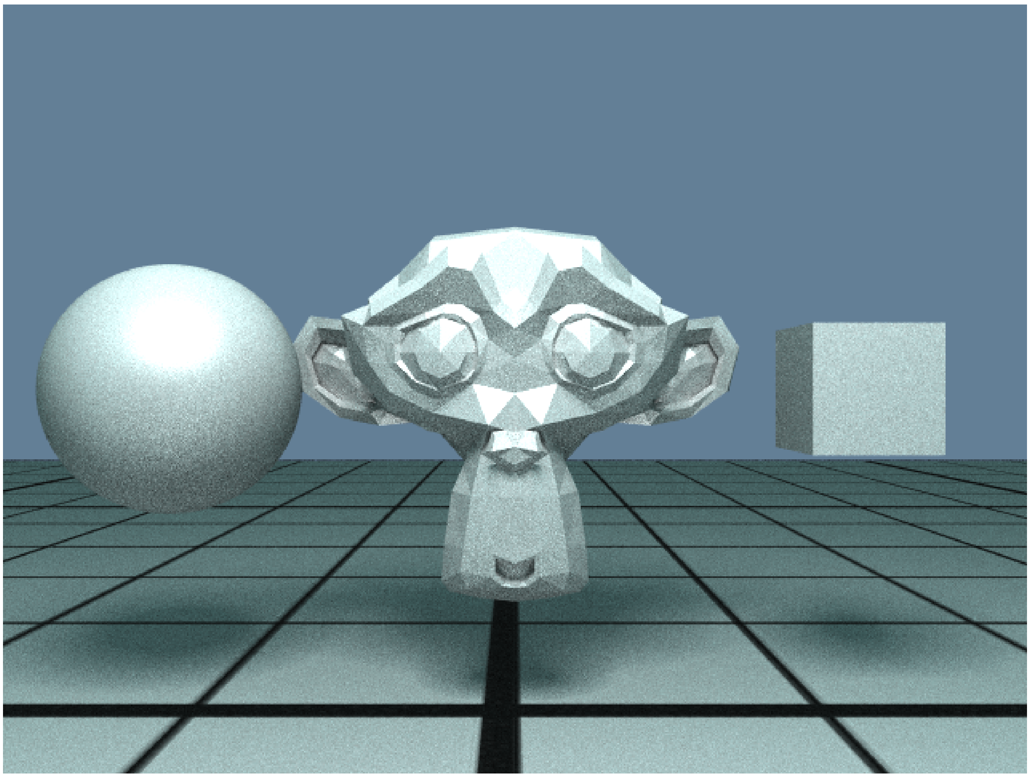

FIGURE 1 – An example of objects rendered with pathtracing.

0.1 Path Tracing

This project was focused on developing a path tracer. This techinque can render photorealistic images by approximating the bidirectional reflectance distribution function or BRDF. This function is defined recurively so it is natural to implement it as a recursive function as long as recursion depth is not eccessive.

$$L(p, \omega_{out}) = L_e(p, \omega_{out}) \int_{\omega_{in} \in H(p,n)} L(p, \omega_{in})) * brdf(p, \omega_{in}, \omega_{out})(n \cdot \omega_{in}) d\omega_{in}$$

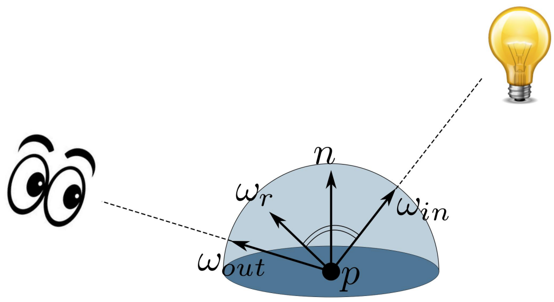

FIGURE 2 – a schematic representation of BRDF in a point p, there are several BRDFs depending on the material.

0.2 Materials

0.2.1 Diffuse Material

The diffuse contribution is calculated as $(n \cdot \omega_{in})$ which models shading according to the light sources. This material approximate the ambient contribution of the BRDF by using Montecarlo sampling. A refinemet to weith the contribution with the solid angle Ω as a coefficent to simulate color dimming or color solarization depenfing on the distance from the light source and the size of the light source. When the light source is spherical, it's easy to calculate the solid angle on an emisphere. With r being the ray of the light source, D the distance from p to the light source.

$$\Omega = 4\pi(\frac{r}{D})^2$$

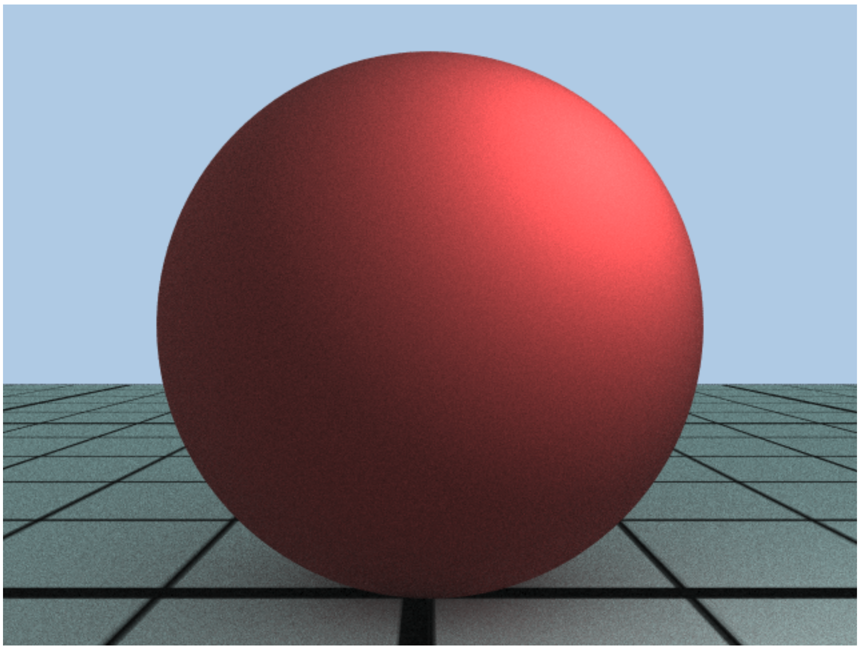

Figure 3 – Sphere with diffuse material.

0.2.2 Diffuse Specural Material

This method adds a specular term to the BRDF diffuse. By making use of $(\omega_{out} \cdot \omega_{in})$ it models the effect of reflected light towards the viewer. This effect can result in solarization of the material in certain points of the surface.

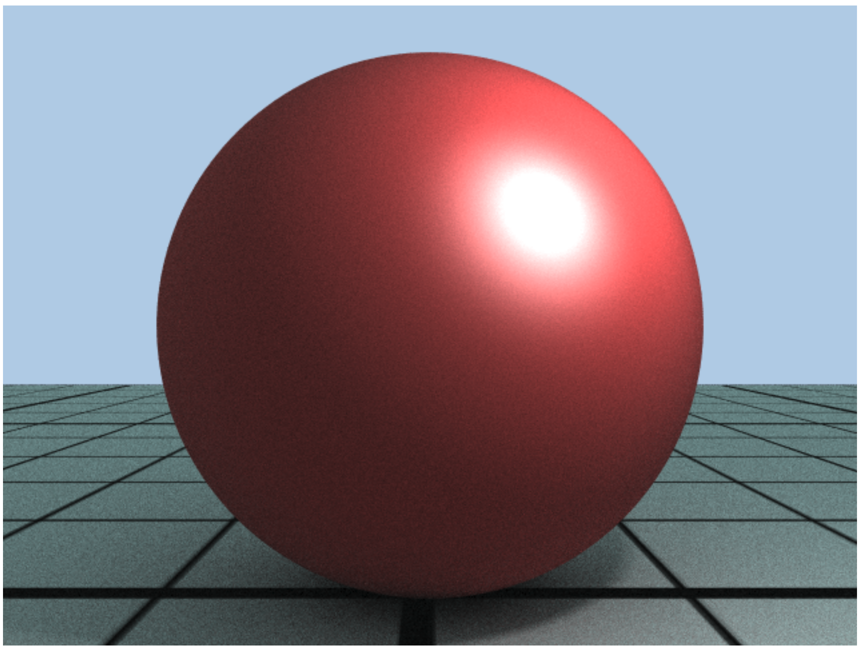

Figure 4 – Sphere with specular material.

0.2.3 Reflective Material

This material simulate a perfect mirror, only perfect reflection are calculated. In addition a tint can be used to simulate mirrors of various colors.

The reflected ray is calculated as a mirrored image of ω_{out} with respect to the normal n.

$$\omega_{refl} = \omega_{out} - 2n(\omega_{out}\dot{n})$$

FIGURE 5 – Sphere with perfect mirror material, to henance the effect it reflects a backgroung image wrapped around a scenario sphere, with depth of field the backgroung is isolated fromt the central object.

0.2.4 Transparent Material

The BRDF of this material is completely different from the previous. To render different thickess of the transparent object we calculate the refracted ray by means of the *Snell-Descartes* law.

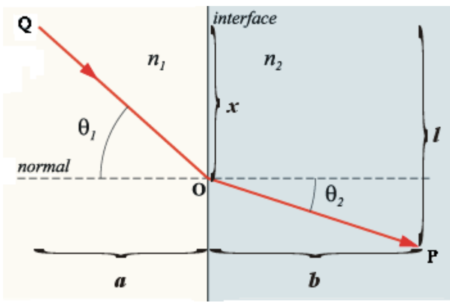

FIGURE 6 – Diagram representin refraction of a ray passing from a medium to another by *Snell-Descartes* law.

The index of refraction or IOR express this differece in thicknes of 2 media whe take an indicative media ratio as $IOR = \frac{sin\theta_1}{sin\theta_2}$ with θ_1 being the incident angle of the light source and the normal to the surface in medium 1 and θ_2 the resulting angle of refraction in medium 2, IOR is usually denoted as $\eta 1$ and $\eta 2$ respecively. In optics, the *refractive index* or *index of refraction* η of a material is than a dimensionless number that describes how light propagates through 2 media. A transparent objects emits 2 component, a refracted and a reflected ray originating from the same point. The resulting BRDF is than :

$$BRDF_{refl}(\omega_{out}) = \alpha BRDF(\omega_{refr}(ior)) + (1 - \alpha)BRDF(\omega_{refr})$$

1

The refracted ray is computed geometrically as follows :

$$\omega_{refr} = \frac{\eta_1}{\eta_2} * (-\omega_{out}) + (\frac{\eta_1}{\eta_2} cos\theta_1 - \sqrt{1 - sin\theta_1})n$$

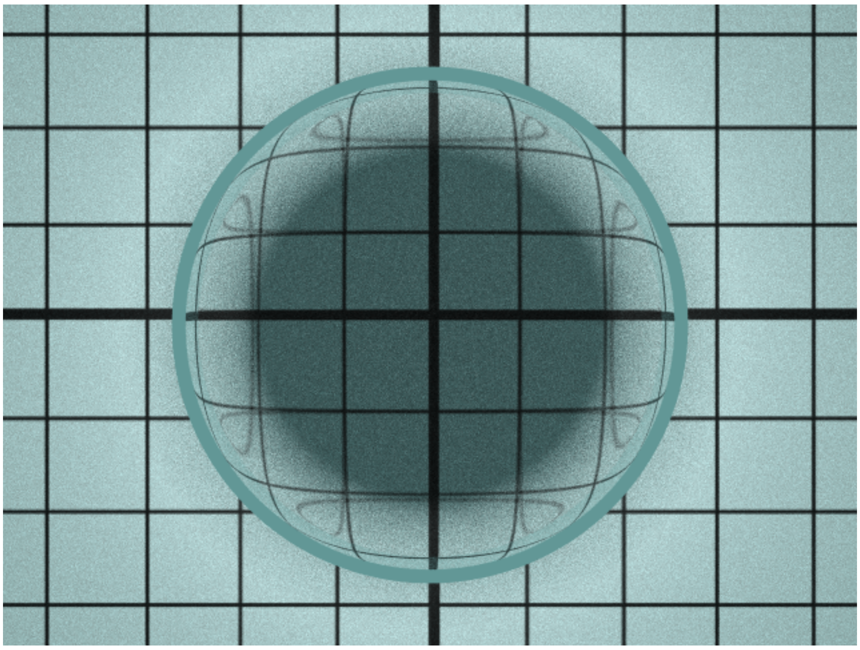

FIGURE 7 – IOR bigger than 1. Ring caused by total internal refreaction.

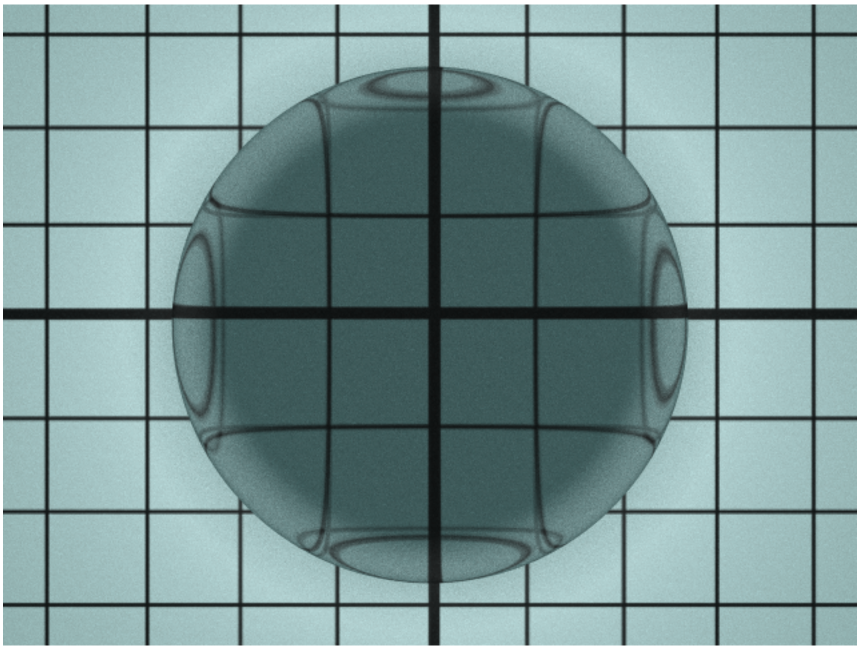

FIGURE 8 – IOR smaller than 1.

0.2.5 Ambient Occlusion

Ambient occlusion effect comes as a side effect of the path tracing implementation, even if no light is present in the scene objects close togheter shade each other, the montecalrlo sampling of diffuse material gives this effect of smooth ambiental light.

1. α is usually calculated by applying Fersnell equation or Schlick's approximation (not implemented).

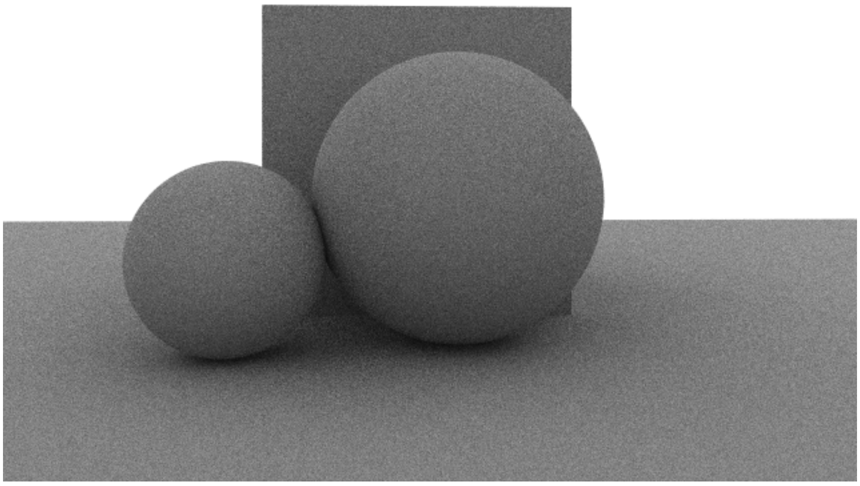

FIGURE 9 – Objects shading each other.

0.3 Effects

0.3.1 Texture Projection

Dependinf on the geometry it's possible to project a rectangular image on a manifold surface.

To be projected onto a smooth surface an image has to be sampled : however, mapping from $\mathbb{F}\times\mathbb{F}\times\mathbb{F} \rightarrow \mathbb{N}\times\mathbb{N}$ may lead to aliasing. To avoid or limit aliasing Antialiasing filters or AA techniques are applied, like bilinear filtering (Fig 12).

0.3.2 Anti Aliasing

Montecarlo sampling introduces noise due to the randomess of the method, a way around this is to sample multiple times the same pixel wich will randomly calculate portions of the $BRDF$. A positive side effect to sampling with an high number of sample per pixel or *SPP* is indirect coloring or color bleeding (Fig 13) (Fig 14) .

Another positive side effect is that the projection of a smooth curve on a grid results in a stepwise function, by using more samples per pixel, the curve will result smoother thanks to the montecarlo approximation of the integral of the curve (and therefore curve color).

The downside of this method is that computational time scales linearly with the number of *SPP*.

0.3.3 Depth of Field

Depth of field can be achieved by simulating a thin lens camera model.

With this effect it's possible to render in focus out ouf focus object depending on the distance to the focal plane. A fixed focal plane can have different dof depending on the *aperture* values measured in $f/$ (Fig 15), known as the focal ratio between the f or focal lenght and the *aperture* diameter.

A smaller $f/$ will introduce stronger blur when objects are not aligned with the focal plane (Fig 17) while a smaller aperture and an higher $f/$ will have less blurring effect (Fig 16).

In real settings depth of field is allways present when taking photos, whilst it takes extra effort to be modeled in rendering.

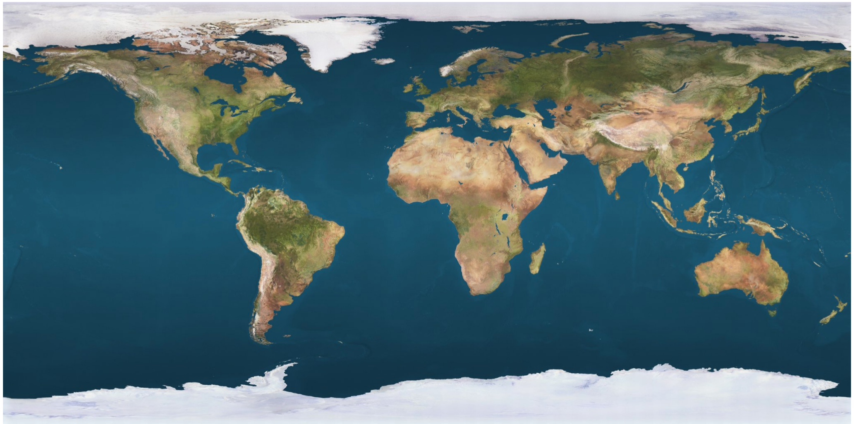

FIGURE 10 – Original Texture.

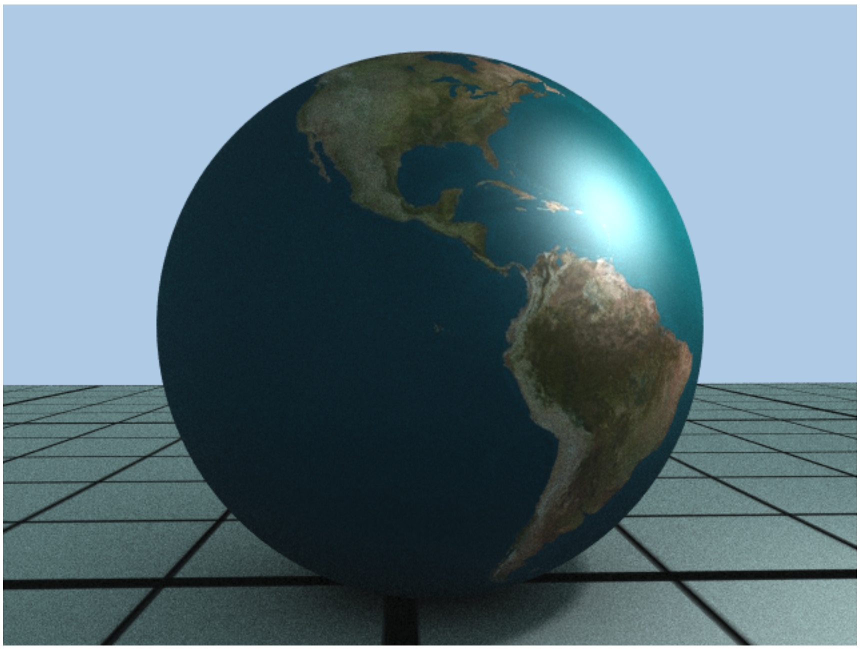

FIGURE 11 – Projection on a sphere of the original Texture.

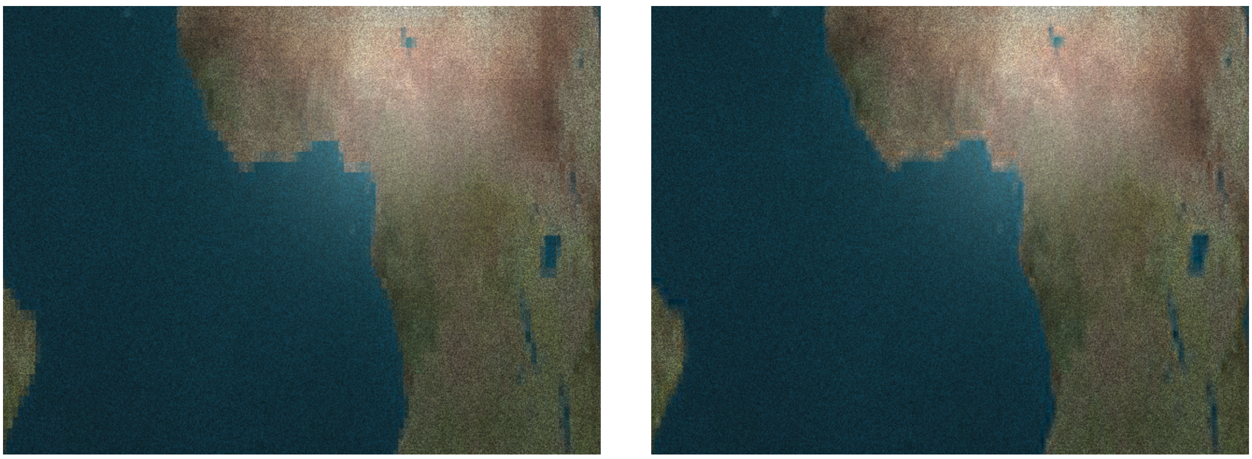

FIGURE 12 – Difference between AA bilinear filter off and on.

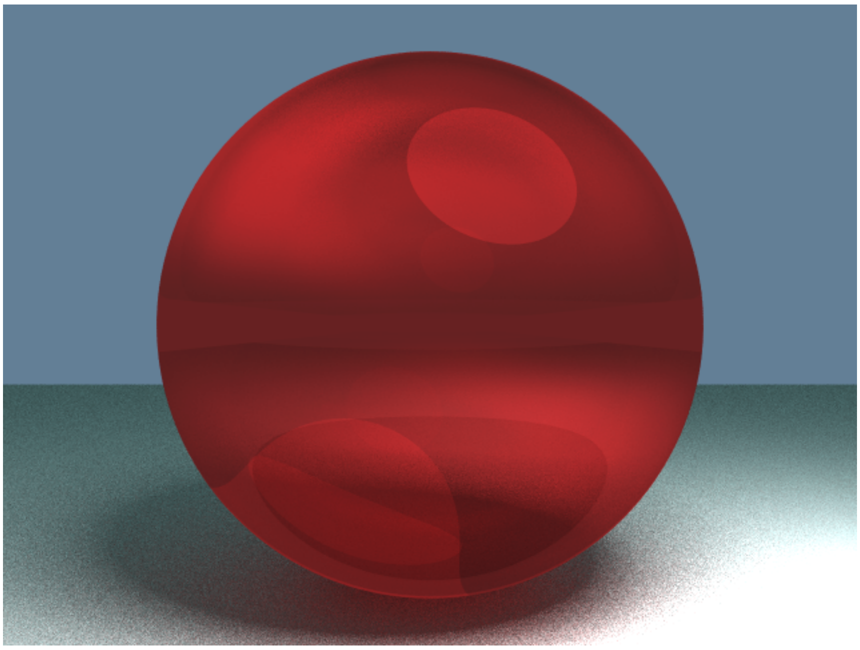

FIGURE 13 – 64 *SPP*.

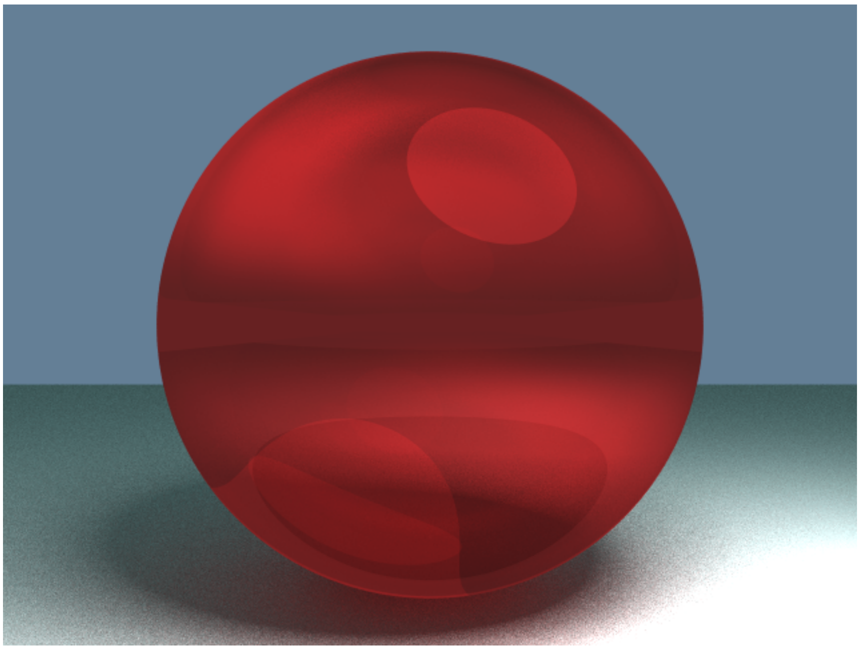

FIGURE 14 – 128 *SPP*.

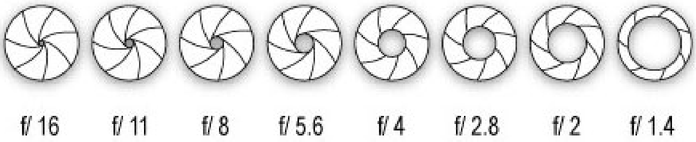

FIGURE 15 – aperture scale representation.

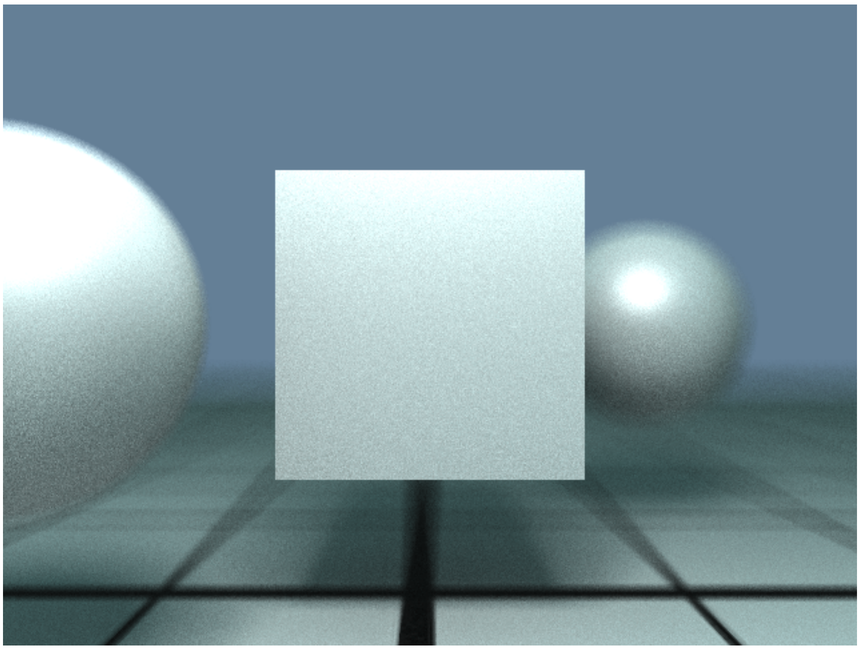

FIGURE 16 – a high $f/$ or stop.

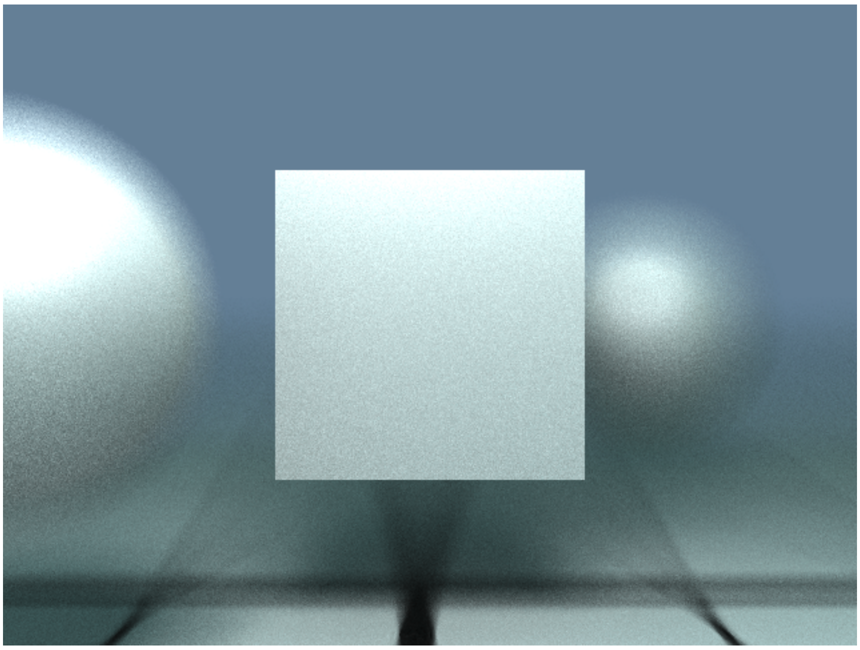

FIGURE 17 – a low $f/$ or stop.