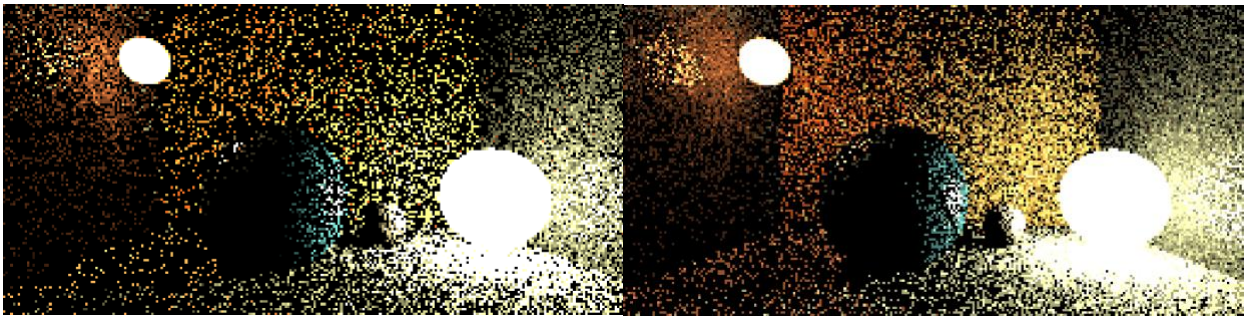
Variance Reduction Techniques

All 3 techniques are implemented in the sampleDirection method which sets the direction and probability of the sample. Which variance reduction technique is used is controlled by the VR_MODE flag at the top of the code.

Cosine Weighted Hemisphere Sampling

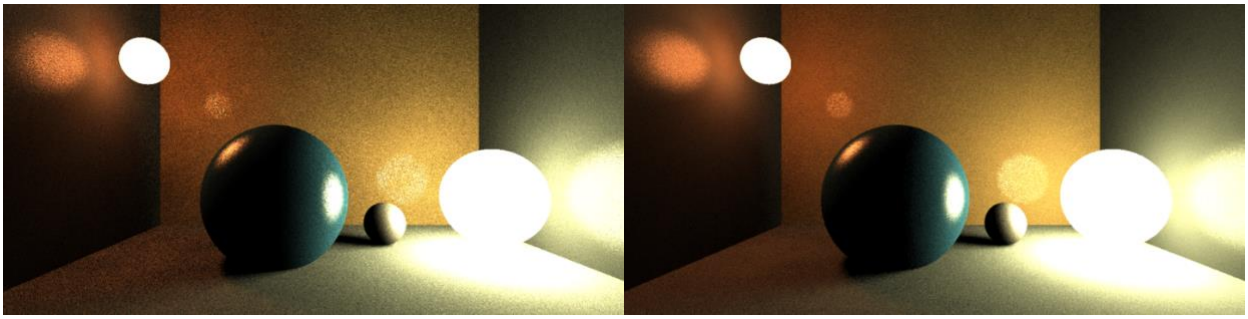
This is a form of importance sampling where the distribution sampled from is proportional to the geometric term in the rendering equation integral. In our implementation, we generate theta and phi for the spherical coordinates derived from the pdf (probability distribution function) proportional to cos of angle with z-axis of unit sphere, and then convert to Euclidean coordinates aligned with the hit normal. We also set the probability of ray which is dependent on the cos of the angle between the generated direction and the normal.

Demonstrating variance reduction by comparing with standard uniform sampling at 256 x 128 resolution after 20 samples. Note how the cosine weighted one has converged much more:



Standard Uniform Sampling *Cosine Weighted Sampling*

Demonstrating that there is no bias by showing that it converges to same pixel colors as standard uniform sampling at 1024 x 512 resolution after 1000 samples:

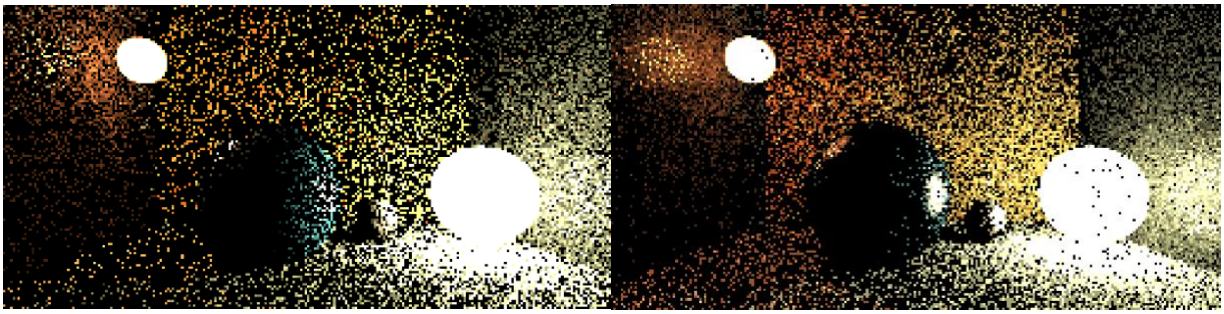


Standard Uniform Sampling *Cosine Weighted Sampling*

Phong BRDF Sampling

This is another form of importance sampling, where the distribution sampled from is based on the physically correct Phong BRDF. It's hard to sample the diffuse and specular term at the same time, so we use another uniform sample to determine if we are sampling the specular or diffuse term and use the pdfs based on the Phong equations accordingly. I also try to set the probabilities based on the pdf equations but something seems off since the pixels get darker with more samples.

Demonstrating variance reduction by comparing with standard uniform sampling at 256 x 128 resolution after 20 samples. Note how the Phong BRDF sampled one has converged much more:

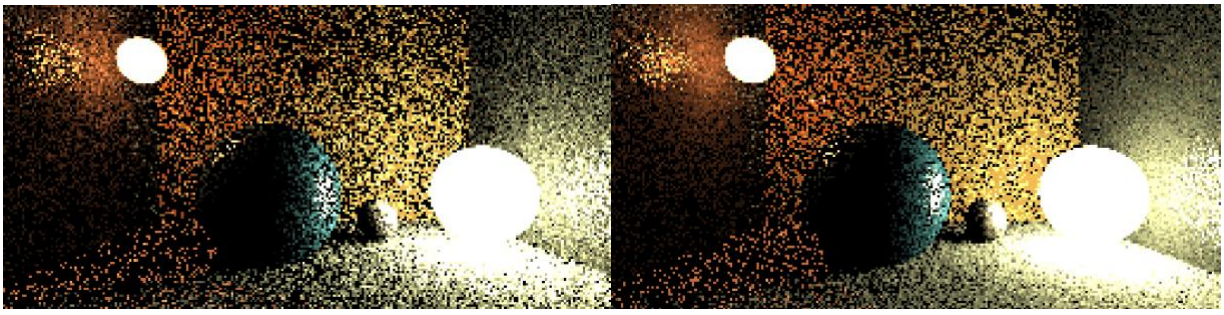


Standard Uniform Sampling *Phong BRDF Sampling*

Halton Pattern Uniform Sampling

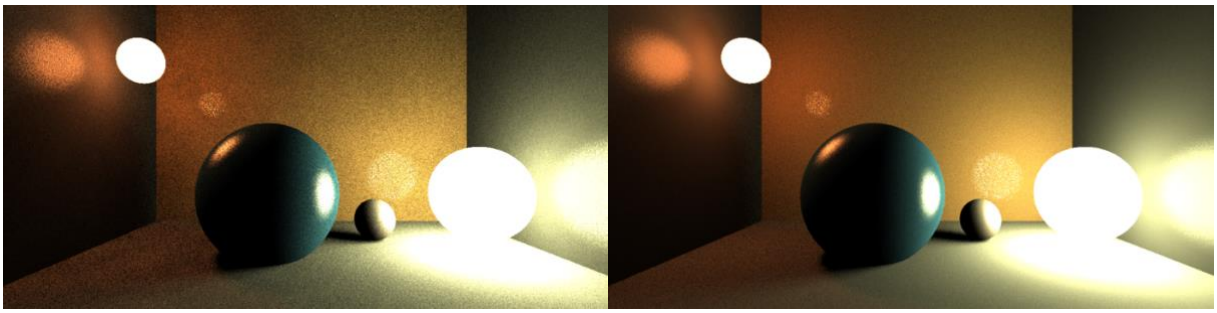
This is a form of uniform sampling that aims to be more evenly placed than random samples by using the Halton pattern. In our implementation, we create a halton function that uses the dimensionIndex and the sampleIndex to generate a Halton sample based on a fairly standard implementation, using a prime lookup function to find a suitable prime base. We then use the same equations as the uniform sample generation to generate the theta and phi coordinates for the direction vector and convert them to Euclidean coordinates.

Demonstrating variance reduction by comparing with standard uniform sampling at 256 x 128 resolution after 50 samples. Note how the Halton pattern one has converged more, most evident on the side walls:



Standard Uniform Sampling *Halton Uniform Sampling*

Demonstrating that there is no bias by showing that it converges to same pixel colors as standard uniform sampling at 1024 x 512 resolution after 1000 samples:



Standard Uniform Sampling

Halton Uniform Sampling