CSE 252A: Reflectance Again

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1 Reflectance

For a diffuse surface, the BRDF is a constant ρ_d (light goes out equally in all directions). We call this constant the **albedo**. When we model BRDFs in computer vision, we often model them as constants for simplicity.

Note that the incoming (light source) direction ω_i still matters because of foreshortening:

$$L_r = \rho_d(\mathbf{N} \cdot \omega_i)$$

where $\mathbf{N}$ is of course the surface normal.

The other common BRDF is the mirror (specular) BRDF, where when light comes in, it goes out in *one* direction, the mirror direction, instead of all directions. The mirror direction ω_o is just the incoming direction ω_i reflected across the surface normal $\mathbf{N}$. (ω_o, ω_i, and $\mathbf{N}$ lie in the same plane.)

An example of a BRDF in-between diffuse and mirror BRDFs is the *rough specular BRDF*. A rough specular surface reflects light in a lobe according to the distribution of its microfacets.

We can measure BRDFs by putting objects in a measurement system (e.g. a gonioreflectometer) and sampling reflectance values. It's just digital signal processing, where we want to obtain samples for lots of different incoming and outgoing directions. Of course, this is fundamentally expensive because we need a lot of samples to reconstruct a four-dimensional function.

2 Lights

For the following cases, we assume a diffuse surface (as is commonly done in computer vision).

2.1 Nearby Point Source

For a patch lit by a nearby point source, the emitted radiance (same in all directions) at $\mathbf{x}$ is

$$L = \rho_d(\mathbf{x}) \frac{1}{\|\mathbf{s} - \mathbf{x}\|^2} \left(\mathbf{N}(\mathbf{x}) \cdot \frac{\mathbf{s} - \mathbf{x}}{\|\mathbf{s} - \mathbf{x}\|} \right)$$

where ρ_d is the diffuse albedo, s is the point light location, and $\mathbf{N}$ is the unit surface normal.

This is just the diffuse reflectance model with an additional quadratic attenuation factor.

2.2 Distant Point Source

Now, outgoing radiance L is equal to $\rho_d(\mathbf{x})\mathbf{N}(x) \cdot \mathbf{S}(\mathbf{x}) \cdot$ (intensity of light source). $\mathbf{S}(\mathbf{x})$ is the unit direction to the light source, which is about the same for all points since the light source is far away.

2.3 (Aside: Diffuse Lighting at Infinity)

For a light source at infinity, incident directions lie as a function on a sphere. **Spherical harmonics** form a natural basis for functions on a sphere, meaning a function on a sphere can be represented as a weighted sum of spherical harmonics of different orders (where order translates to frequency).

Thus, we can view diffuse lighting as a sum of spherical harmonics coming in from different directions, and since the lighting is diffuse we don't really need to worry about high-frequency information i.e. the high-order basis functions. This is analogous to Fourier transforms, except instead of sines and cosines of different frequencies we have spherical harmonics of different orders.

3 Photometric Stereo

We want to reconstruct 3D shape from image cues. One example of a cue is shading.

- **Shape-from-shading** uses a single image as a cue. This is often not practical, since it requires knowledge about the direction of the light source and the BRDF. Nevertheless, a lot of modern machine learning approaches perform shape-from-shading (infer things from single images).
- **Photometric stereo** uses multiple images with the same viewpoint[1] but different lighting.

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[1] No alignment necessary!