Point Clouds & 3D Modeling
Practical Assignment

Rendering

The objective of this assignment is to write a Python program which renders a shaded image using a simple *normal* image. The following packages are recommended: PIL, math, numpy.

How to submit your assignment for evaluation?
Please send to tamy.boubekeur@telecom-paristech.fr, within one week after the lecture date, an email entitled [MVA][NPM][TP4] LASTNAME FIRSTNAME and containing a link to a single zip archive named LASTNAME_FIRSTNAME.zip. This archive should contain a file MVA_NPM_TP_4.py (your implementation) and a file report.pdf (1 to 2 pages) discussing and illustrating what you implemented. One should be able to try your implementation by entering python MVA_NPM_TP_4.py in the command line.

I. Image loading and display

For this assignment, we will make use of the file normal.png (see the course website). This file is an image of a scanned point cloud, where each pixel stores a local estimate of the normal vector at the pixel location. Based on this normal vector, we will compute a per-pixel color response later. We consider that the X and Y coordinates in image space correspond to the X and Y coordinates in 3D space, and that the camera is located along the Z axis.

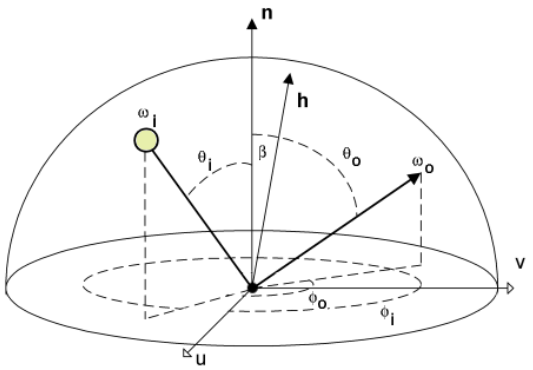
a. Load normal.png in an Image object (normalImage)
b. Display normalImage (using Python)
c. Store the image in a file called render.png

II. Diffuse shading

We recall the rendering equation:

$$L_o(\omega_o) = L_e(\omega_o) + \int_0^{2\pi}\int_0^{\pi} L_i(\omega_i) f(\omega_i, \omega_o) \cos\theta_i d\theta_i d\phi_i$$

This equation can be visually interpreted as follow:



- ω_i is the incoming light direction,
- ω_o is the outgoing direction e.g., the final sensor (camera) direction for direct lighting scenarios,
- n is the surface normal vector,
- L stands for the radiance measure,
- h is the *halfvector* i.e., the spherical average of ω_i and ω_o: $h = \frac{\omega_i+\omega_o}{\|\omega_i+\omega_o\|}$

For each pixel of the image, we now want to replace its value by the diffuse color response, using the Lambert BRDF:

$$f^d(\omega_i, \omega_o) = \frac{k^d \cdot albedo}{\pi}$$

a. Define a simple Material model (using a set of global variables or an object) in the form of an *albedo* RGB value and a *diffuse coefficient* k^d.
b. Define a lighting environment composed of a set of point light sources (again using a set of global variables or encapsulating the LightSource concept in an object), each point light source being defined by a 3D *position*, an RGB *color* value and an *intensity*. Start with a single point light source located at coordinates [0, 1, 1].
c. Implement a function def shade (normalImage) which renders an image using your Material and LightSource models, together with the scene's geometry defined solely by the per-pixel normal input normalImage.

III. Specular Materials

We now want to enrich our shading function with a more evolved reflection model, able to reproduce specular light reflections.

a. To do so, implement the *Blinn-Phong* BRDF:

$$f^s(\omega_i, \omega_o) = k^s(n.\omega_h)^S$$

With:

- k^s the *specular coefficient*,
- S the *shininess coefficient*.

Use both f^d and f^s by summing their contribution, for each light source.

b. Finally, we want to replace our specular BRDF by a *physically-based microfacet* model taking the general form a the *Cook-Torrance* BRDF:

$$f^s(\omega_i, \omega_o) = \frac{D(\omega_h)F(\omega_i, \omega_h)G(\omega_i, \omega_o, \omega_h)}{4(n \cdot \omega_i)(n \cdot \omega_o)}$$

This BRDF should be controlled by a *roughness* value α and a (theoretically binary) *metallic* property β characterizing the conductor/insulator nature of the material, together with a specular RGB color (derived from the Fresnel index). You will use the *GGX normal distribution function* as D, the *Schlick* approximation to the *Smith* model for G and the spherical gaussian variant of the *Schlick Fresnel* approximation for F. You can refer to the *Unreal Engine Real Time Shading reference white* paper by Karis (page 2 and 3) for details.