Lighting Part 1

Computer Graphics - SET08116

EDINBURGH NAPIER UNIVERSITY

Outline

How do we representation colour?

How do we representation colour?

Modern computer graphics work in a 32-bit colour space.

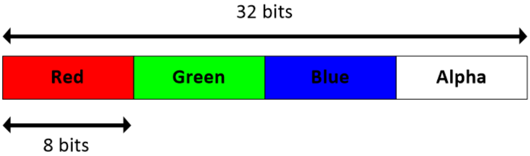
- Enables 16.7 million possible RGB colours
- It is estimated that the human eye can see 10 million colours

Typically, 4 colour values of 8-bits are used.

- Normally we consider Red, Green, Blue, and Alpha.
- We can have other definitions of colour.

We can work with different value representations:

- 0..255 is typical in desktop applications
- It is better for us to work from 0.0 to 1.0 (0% to 100%)



Working with Colour

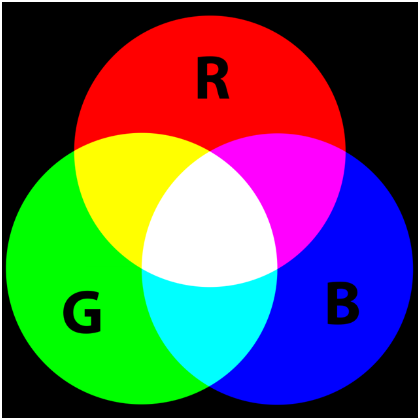
You should treat colour as a value you can work with. Consider it a 4-dimensional vector.

We can add colours together:

- Red + Green = Yellow
- (1.0, 0.0, 0.0) + (0.0, 1.0, 0.0) = (1.0, 1.0, 0.0)

We can also multiply colours together:

- Magenta * Yellow = Red
- (1.0, 0.0, 1.0) * (1.0, 1.0, 0.0) = (1.0, 1.0, 1.0)



Vertex Colours

Up to this point, we have been associating colours to our vertexes. Blending then occurs across surfaces based on the colours between two vertexes.

In OpenGL, we will follow the RGBA format for colour.

- Textures may be stored in other colour formats. We will use a library to convert.
- DirectX also allows other texture colour formats.

These colours can be used in our lighting calculations.

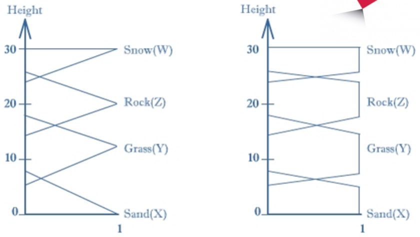
- We use colour for light and surfaces to calculate general colour
- We can also use textures to provide more detailed surface colour

Texture Blending

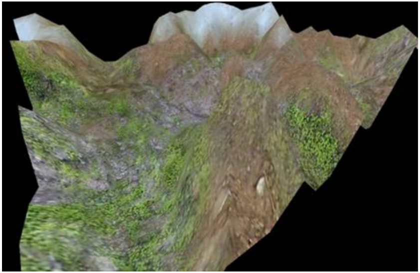
The ability to blend colours together in this manner proves to be very useful.

- Multi-texturing
- Terrain

We will revisit blending colours when discussing texturing and terrain.



A) Weight mapping scheme B) Normalized

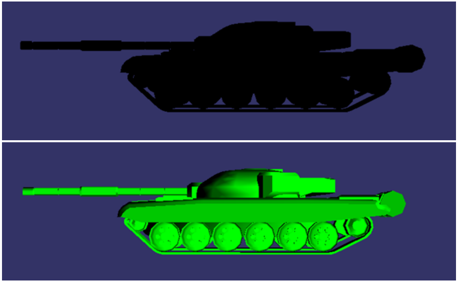


Why Lighting?

Colour isn't enough!

We use lighting to add the concept of depth and shape to our 3D scene.

- Unlit objects lack shape, and therefore appear flat and lacking detail.



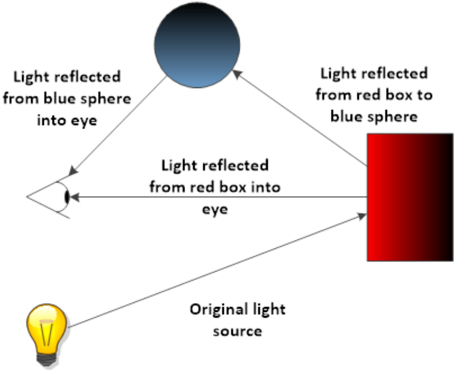
Lighting adds realism to our rendered objects.

- Specular detail
- Light reflection

How Lighting Works

From our point of view, light operates as rays interacting with objects. There are three main points to consider:

- Light is emitted by some form of light source. There are a number of different possible light sources.
- Light is reflected from the surfaces of objects within the scene
- Light reflected from surfaces is eventually absorbed by a sensor (e.g. the eye)



Materials

The rays of light are only one part of the equation when determining what the sensor absorbs.

Light itself has a colour. The colour of light is usually close to white in most circumstances, but not always.

Objects (or specifically their surfaces) themselves have a colour.

- The colour of an object's surface reflects a particular colour of light rather than absorbing it.

The colour of light that an object reflects is commonly described as its material.

- A surfaces material may have other properties, such as a texture.

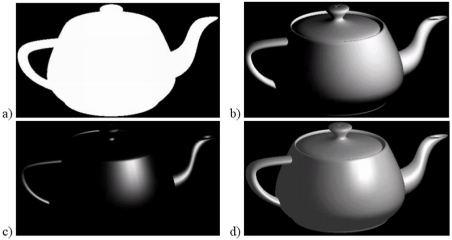
Main Lighting Types

Generally, an object has three lighting effects affecting it at any time.

- Ambient Light
- Diffuse Light
- Specular Light

The colour of an object is determined by combining these three lighting effects together.

- Plus any other effects



What is Ambient Light?

Ambient light is the simplest lighting type in a scene. It is a form of light that affects everything equally in a scene.

- It has no direction.
- It has no distance.
- Doesn't take into account which part of the object is being lit.

Outdoors, we typically think of daylight as an ambient light effect.

- Although the sun itself provides a directional light source.

Ambient Light Equation

The ambient lighting calculation is the simplest form:

$$\mathcal{D}\mathcal{A}$$

The ambient light of a particular vertex is just the ambient material colour of the object multiplied by the ambient light colour of the scene.

Lighting a Surface

Ambient light is a form of lighting that affects all geometry in a scene equally.

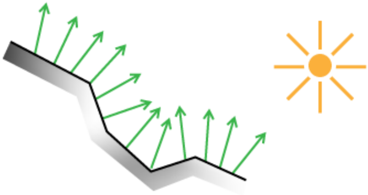
Therefore, ambient light still provides a 2D appearance to objects in the scene as everything appears flat.

Objects reflect light based on how their surfaces are aligned with the light source.

- Occluded objects / surfaces get no light
- Surfaces perpendicular to the light source get full light.

Working with Normals

We use the surface normal to determine how light interacts with a surface. We are essentially trying to determine how light reflects from the surface.



We will be covering in more detail how we calculate light in the theory lecture tomorrow.

Normals are very important throughout lighting calculations. They allow us to determine how light interacts with a particular surface.

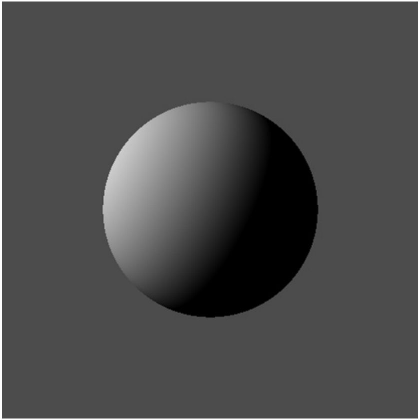
What is Diffuse Light?

Diffuse light is concerned with the direction that the light is travelling. It is the interaction of the light with the surface, helping to determine the colour of an individual surface.

Geometry facing a light source is lit.

Geometry not facing a light source is unlit.

An example of directional light source outside is the sun.



How does Diffuse Light Work?

Diffuse light is concerned with the light direction against the surface normal for the piece of geometry in question.

- If angle = 0 then full light
- If angle > 0 and $< \frac{\pi}{2}$ then shaded accordingly
- If angle $> \frac{\pi}{2}$ then unlit

Think about how this would work if you shone a light on a table.

Lambert's Cosine Law

The simplest method to calculate the diffuse light for a particular vertex is using Lambert's Cosine law. This works by realising the value of of the cosine of the angle:

- $\cos 0 = 1$
- $\cos \frac{\pi}{4} = \frac{1}{\sqrt{2}}$
- $\cos \frac{\pi}{2} = 0$

The graph of the cosine function illustrates why this is the case.

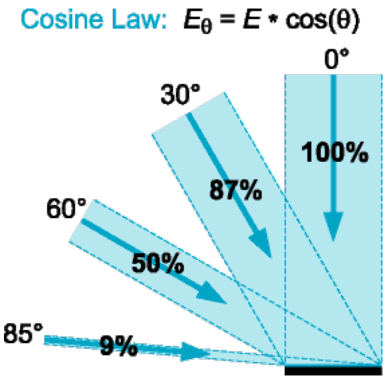


Fig. 6.3 Lambert's cosine law.

Diffuse Light Equation

Using Lambert's Cosine Law, we can define our diffuse lighting equation as follows:

$$\mathcal{DC}max(\mathbf{L} \cdot \mathbf{N}, 0)$$

Remember, the dot product of two vectors has a relationship to the cosine of the angle between them. Both the surface normal and the light vector are unit length, thus making the dot product equal the cosine of the angle between the two vectors.

We also need to transform the surface normal if the vertex itself has been transformed.

We always set the alpha of the diffuse calculation to 1. We have to set this as the calculation won't ensure this.

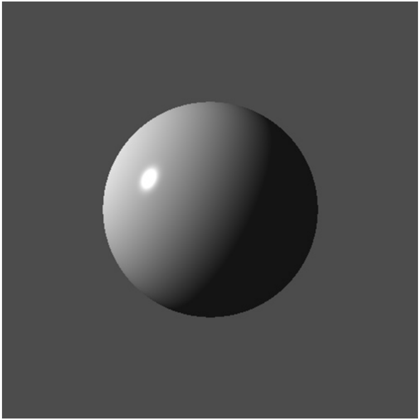
What is Specular Light?

Specular light refers to the point on the object where the light strikes in relation to the eye.

- Specular reflection.

Specular highlights provide a shiny look to an object's surface.

Specular highlights also indicate where the light is coming from.

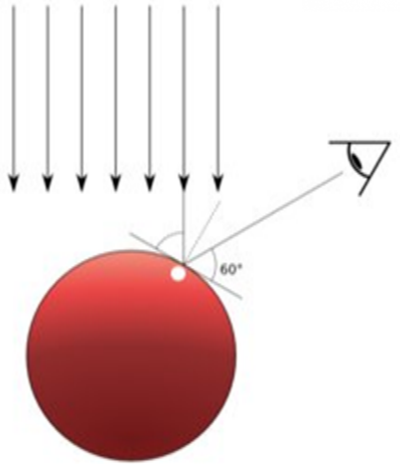


How does Specular Light Work?

Specular light is the most complex form of basic lighting. It requires three pieces of information:

- Light direction
- Surface normal
- Eye position

The calculated intensity of the specular light is based on the eye position.



Specular Light Equation

The specular lighting equation is the most complex of the three basic equations, although it does build on the diffuse light equation.

$$\mathbf{V} = \frac{e - p}{\|e - p\|}$$

$$\mathbf{H} = \frac{\mathbf{L} + \mathbf{V}}{\|\mathbf{L} + \mathbf{V}\|}$$

$$s = \mathcal{SD} \max\left(\mathbf{N} \cdot \mathbf{H}\right)^{shininess}$$

Other Lighting Types

Ambient, Diffuse, and Specular are considered the main environmental lighting types.

- Object materials usually deal with these three types

There are of course other lighting types which affect a scene:

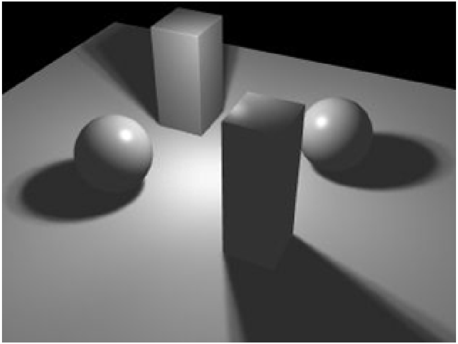
- Dynamic lighting
- Point lights
- Spot lights

Point Light

A point light is a light that emanates from a particular point in the scene.

We use the same equations, but calculate light vector based on vertex position and light position.

The distance to the light affects the intensity of the light on the object.

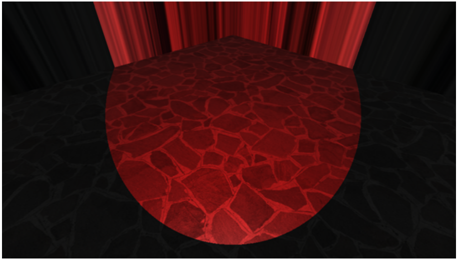


Spot Light

Spot lights also work using light position and distance. However, this time the direction of the light is also important.

Objects behind the spot light aren't lit.

A spot light therefore also has an angle associated with it. This acts as the beam width. Distance is also important.

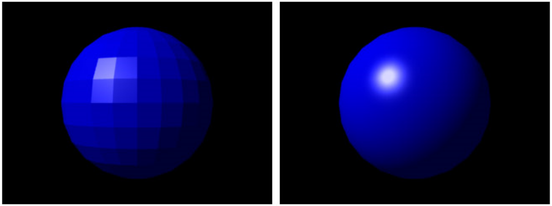


Phong Shading

Phong Shading is a popular per-pixel approach to performing lighting calculations.

Normals are interpolated across the surface of a polygon. Unlike per-vertex shading (Gouraud Shading as it is known), Phong shading is calculated on the fragment shader - the calculations are approximately the same however.

Phong shading provides a smoother shading look than Gouraud shading:



FLAT SHADING PHONG SHADING

Summary

From this lecture, you should now know about:

- Colour, and how we treat colour in our graphics applications
- The main types of lighting that we use in our scene:
  - Ambient light
  - Diffuse light
  - Specular light
- How we calculate the different light types
- Some other approaches to lighting that we can take:
  - Point lights
  - Spot lights
  - Phong Shading

Recommended Reading

Real-Time Rendering, Chapter 5.

Interactive Computer Graphics, Chapter 6.