Exercises Computer Graphics

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Exercise: Material Properties and Lighting

Subject of this exercise is the definition of material properties for scene objects with OpenGL. Furthermore, the definition of light sources and their parameters is explained.

A scene object's colour perceived by a viewer depends on two factors:

1. The properties of light, which is introduced into the scene by its light sources
2. The way, this light is reflected from the object's surface towards the viewer based on the material properties

Moreover, OpenGL allows light to be emitted from an object. It originates from the object and is unaffected by any light source. Regarding the reflectance of light at object surfaces, OpenGL distinguishes between three components, i.e. ambient, diffuse and specular:

- The **ambient** component describes light, which has been scattered in the scene, so that its direction cannot be determined (background light).
- **Diffuse** light comes from one direction and is scattered as soon as it hits a surface.
- **Specular** light comes from a particular direction and is reflected from a surface to a preferred direction. E.g. shiny metal has a high specular component.

Definition of Light Sources

OpenGL allows definition of up to 8 different light sources with their properties, such as colour, position, direction. The OpenGL command for this is

void **glLight**{if}[v](GLenum *light*, GLenum *pname*, TYPE *param*)

light defines the light source and can be one GL_LIGHT0, GL_LIGHT1, ..., or GL_LIGHT7
pname means the light characteristic, which is set by the command (see below)
param indicates the values, to which the characteristic is set

The following *pname* values are available in order to set light characteristics:

GL_AMBIENT	ambient RGBA intensity of light
GL_DIFFUSE	diffuse RGBA intensity of light
GL_SPECULAR	specular RGBA intensity of light
GL_POSITION	(x, y, z, w) position of light source; if w=1.0: positional light source positioned at (x,y,z) emitting light in any direction; if w = 0.0: directional light

	source (infinitey far away emitting light along the direction vector (x,y,z))
GL_SPOT_DIRECTION	(x, y, z) direction vector of spotlight
GL_SPOT_EXPONENT	spotlight exponent
GL_SPOT_CUTOFF	spotlight cutoff angle
GL_CONSTANT_ATTENUATION, GL_LINEAR_ATTENUATION, GL_QUADRATIC_ATTENUATION	attenuation factors

The following example code demonstrates the definition of two light sources:

```
GLfloat light0_ambient[] = {0.0, 0.0, 0.0, 1.0};
GLfloat light0_diffuse[] = {1.0, 1.0, 1.0, 1.0};
GLfloat light0_specular[] = {1.0, 1.0, 1.0, 1.0};
GLfloat light0_position[] = {1.0, 1.0, 1.0, 0.0};
GLfloat light1_diffuse[] = {0.0, 1.0, 0.0, 1.0};
GLfloat light1_position[] = {-1.0, 1.0, 1.0, 0.0};

glLightfv(GL_LIGHT0, GL_AMBIENT, light0_ambient);
glLightfv(GL_LIGHT0, GL_DIFFUSE, light0_diffuse);
glLightfv(GL_LIGHT0, GL_SPECULAR, light0_specular);
glLightfv(GL_LIGHT0, GL_POSITION, light0_position);

glLightfv(GL_LIGHT1, GL_DIFFUSE, light1_diffuse);
glLightfv(GL_LIGHT1, GL_POSITION, light1_position);

glEnable(GL_LIGHTING);
glEnable(GL_LIGHT0);
glEnable(GL_LIGHT1);
```

As can be derived from the example, lighting mode has to be enabled using the **glEnable**() command. Otherwise no lighting calculations are performed and the current color is simply mapped to the object. Furthermore, each light source has to be "switched on" by the glEnable() command.

Definition of a Spot Light

A spotlight is a positional light source emitting light with the shape of a cone. There are three parameters, which may be defined. First, the spotligt's direction vector with the glLight() parameter GL_SPOT_DIRECTION. E.g. the default (0.0, 0.0, -1.0) specifies a spotlight direction along the negative z-axis. Note: Geometrical characteristics of light sources, position and direction, are transformed by the modelview matrix stack and stored in eye coordinates. Thus, a light source, that remains fixed as to the world coordinate system, is defined by setting its position after whatever viewing and/or modeling transformations are used. Second, the width of the cone by the GL_SPOT_CUTOFF parameter. E.g. the command

```
glLightf(GL_LIGHT0, GL_SPOT_CUTOFF, 45.0)
```

specifies an angle of 45.0 degrees between the cone's center axis and its edge. The third

paramter, GL_SPOT_EXPONENT, controls the manner, in which the light intensity is attenuated from the center of the cone towards its edge.

Material Properties

Material poperties are set by

void **glMaterial**{if}[v](GLenum *face*, GLenum *pname*, TYPE *param*)

The *face* parameter specifies, which face of the object (front, back) the material definitions should be applied to. It can be GL_FRONT, GL_BACK and GL_FRONT_AND_BACK. The specific material property is identified by *pname* and the desired value is set via *param*. The following parameters are available:

GL_AMBIENT	ambient color of material
GL_DIFFUSE	diffuse colour of material
GL_AMBIENT_AND_DIFFUSE	ambient and diffuse colour of material
GL_SPECULAR	specular colour of material
GL_SHININESS	specular exponent
GL_EMISSION	emissive colour of material
GL_COLOR_INDEXES	ambient, diffuse and specular color indices

The following source code demonstrates the use of the command:

```
GLfloat mat_specular[] = {1.0, 1.0, 1.0, 1.0);
GLfloat shininess[] = {100.0};
glMaterialfv(GL_FRONT, GL_SPECULAR, ma_tspecular);
glMaterialfv(GL_FRONT, GL_SHININESS, shininess);
```

The material properties are set to specular reflection with high shininess. Fig. 1 shows an example image with 5 spheres. The OpenGL command glEnable(GL_COLOR_MATERIAL) sets a state, in which the object colour is calculated by a mixture of the material properties and the base colour, set by glColour(). If only material properties should be tracked, GL_COLOR_MATERIAL should not be enabled.

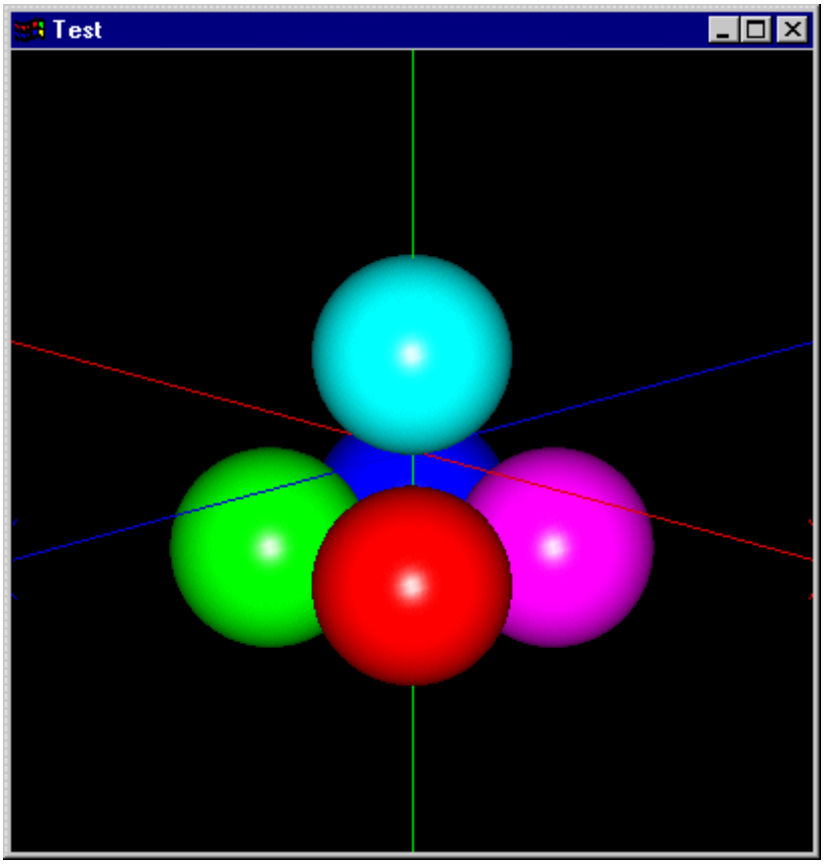

Fig. 1: Example of 5 spheres rendered with high shininess and specular reflection.

Preparation

1. Recapture your knowledge of lighting and shading.
2. Make yourself familiar with the OpenGL graphics standard.
3. Answer the following questions:
   Which three kinds of light sources are distinguished in OpenGL? What are their parameters, the user has to specify?
   Describe two different approaches to give a white sphere a green appearance.
   What has to be specified in order to make a sphere look metallic?
   In which manner (geometry) is a specular reflection modeled in OpenGL?

Exercises

1. Define and render a scene with two spheres and a single point-light source. Define material and lighting parameters such, that one sphere is perceived as consisting of light-gray reflecting metal and the other as of red chalk. Place the viewer suitably.
2. Define a spotlight such, that a bright spot may be perceived on one of the speres.
3. Define and render a solar system, consisting of a sun and several planets. Light is emitted exclusively from the sun.
4. (Optional) Animate your solar system.