Directional and Positional Lights

Lecture 18

Robb T. Koether

Hampden-Sydney College

Wed, Oct 9, 2019

Outline

Outline

Light Sources

Definition (Directional iight source)

A directional light source is "at infinity" in a specific direction. Thus, the light vector is the same for all vertices.

Definition (Positional light source)

A positional light source is at a finite point in space. Thus, the light vector varies from one vertex to another.

Light Sources

Definition (Directional iight source)

A directional light source is "at infinity" in a specific direction. Thus, the light vector is the same for all vertices.

Definition (Positional light source)

A positional light source is at a finite point in space. Thus, the light vector varies from one vertex to another.

- A directional light source is defined by a vector (**`vec4`** with $w = 0$).

Light Sources

Definition (Directional iight source)

A directional light source is "at infinity" in a specific direction. Thus, the light vector is the same for all vertices.

Definition (Positional light source)

A positional light source is at a finite point in space. Thus, the light vector varies from one vertex to another.

- A directional light source is defined by a vector (**`vec4`** with $w = 0$).
- A positional light source is defined by a point (**`vec4`** with $w = 1$).

Light Sources

Definition (Directional iight source)

A directional light source is "at infinity" in a specific direction. Thus, the light vector is the same for all vertices.

Definition (Positional light source)

A positional light source is at a finite point in space. Thus, the light vector varies from one vertex to another.

- A directional light source is defined by a vector (**`vec4`** with $w = 0$).
- A positional light source is defined by a point (**`vec4`** with $w = 1$).
- However, in practice, we use **`vec3`** and either treat it as constant or variable.

Light Sources

- Which is more efficient, directional or positional?

Light Sources

- Which is more efficient, directional or positional?
- Which is more realistic, directional or positional?

Light Sources

- Which is more efficient, directional or positional?
- Which is more realistic, directional or positional?
- Which is more important, efficiency or realism?

Outline

Directional Light Sources

- If the light source is directional, then the direction of the light source is given by a (unit) vector **L**.
- Then for every vertex, if **N** is the (unit) normal vector at that vertex, then the intensity of the diffuse light is

$$(\mathbf{N} \cdot \mathbf{L}) * \text{diffuse}.$$

- Added to the ambient light, we compute the shade as

$$\text{vColor} * (\text{ambient} + (\mathbf{N} \cdot \mathbf{L}) * \text{diffuse}).$$

Outline

Positional Light Sources

- Positional light sources are more complicated.
- Let L be the position of the light source, in world coordinates.
- Let P be the position of the vertex, in world coordinates.
- Then the light vector is

$$\mathbf{L} = \text{normalize}(L - P).$$

- The intensity of the diffuse light at point P is

$$(\mathbf{N} \cdot \mathbf{L}) * \text{diffuse}$$

Outline

Shader `in` Variables

- Any variable that passed from the vertex shader to the fragment shader will be smoothly interpolated across the primitive to which it belongs.
- If the primitive is a line, then the interpolation is linear.
- If the primitive is a triangle, then the interpolation is bilinear, which means linear in each of two directions.

Linear Interpolation

- Let a and b be the values at opposite ends of a line segment.
- We want to find a *linear* function $f(t)$ such that $f(0) = a$ and $f(1) = b$.
- That is, a linear function from the point $(0, a)$ to the point $(1, b)$.
- The slope is
$$m = \frac{b - a}{1 - 0} = b - a.$$
- By the point-slope form, using $(0, a)$,
$$\begin{aligned} y &= a + (b - a)t \\ &= a(1 - t) + bt. \end{aligned}$$

Linear Interpolation

Example

- Write a function that interpolates linearly between the points $A = (1, 5, 4)$ and $B = (8, 6, 2)$.

Linear Interpolation

Example

- Write a function that interpolates linearly between the points $A = (1, 5, 4)$ and $B = (8, 6, 2)$.

$$f(t) = (1, 5, 4) + ((8, 6, 2) - (1, 5, 4))t$$

.

Linear Interpolation

Example

- Write a function that interpolates linearly between the points $A = (1, 5, 4)$ and $B = (8, 6, 2)$.

$$
\begin{aligned}
f(t) &= (1, 5, 4) + ((8, 6, 2) - (1, 5, 4))t \\
&= (1, 5, 4) + (7, 1, -2)t
\end{aligned}
$$

.

Linear Interpolation

Example

- Write a function that interpolates linearly between the points $A = (1, 5, 4)$ and $B = (8, 6, 2)$.

$$\begin{aligned} f(t) &= (1, 5, 4) + ((8, 6, 2) - (1, 5, 4))t \\ &= (1, 5, 4) + (7, 1, -2)t \\ &= (1 + 7t, 5 + t, 4 - 2t). \end{aligned}$$

Linear Interpolation

Example

- Write a function that interpolates linearly between the points $A = (1, 5, 4)$ and $B = (8, 6, 2)$.

$$\begin{aligned} f(t) &= (1, 5, 4) + ((8, 6, 2) - (1, 5, 4))t \\ &= (1, 5, 4) + (7, 1, -2)t \\ &= (1 + 7t, 5 + t, 4 - 2t). \end{aligned}$$

- What point is $1/3$ the way from A to B?

Linear Interpolation of Normal Vectors

Example

- Given two normal vectors $\mathbf{u} = \left(\frac{1}{3}, \frac{2}{3}, \frac{2}{3}\right)$ and $\mathbf{v} = \left(\frac{4}{5}, \frac{3}{5}, 0\right)$, write a function that interpolates linearly between them.

Linear Interpolation of Normal Vectors

Example

- Given two normal vectors $\mathbf{u} = \left(\frac{1}{3}, \frac{2}{3}, \frac{2}{3}\right)$ and $\mathbf{v} = \left(\frac{4}{5}, \frac{3}{5}, 0\right)$, write a function that interpolates linearly between them.

$$f(t) = \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right) + \left(\left(\tfrac{4}{5}, \tfrac{3}{5}, 0\right) - \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right)\right) t$$

Linear Interpolation of Normal Vectors

Example

- Given two normal vectors $\mathbf{u} = \left(\frac{1}{3}, \frac{2}{3}, \frac{2}{3}\right)$ and $\mathbf{v} = \left(\frac{4}{5}, \frac{3}{5}, 0\right)$, write a function that interpolates linearly between them.

$$\begin{aligned} f(t) &= \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right) + \left(\left(\tfrac{4}{5}, \tfrac{3}{5}, 0\right) - \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right)\right) t \\ &= \left(\tfrac{5}{15}, \tfrac{10}{15}, \tfrac{10}{15}\right) + \left(-\tfrac{7}{15}, \tfrac{1}{15}, \tfrac{10}{15}\right) t \end{aligned}$$

Linear Interpolation of Normal Vectors

Example

- Given two normal vectors $\mathbf{u} = \left(\frac{1}{3}, \frac{2}{3}, \frac{2}{3}\right)$ and $\mathbf{v} = \left(\frac{4}{5}, \frac{3}{5}, 0\right)$, write a function that interpolates linearly between them.

$$\begin{aligned} f(t) &= \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right) + \left(\left(\tfrac{4}{5}, \tfrac{3}{5}, 0\right) - \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right)\right) t \\ &= \left(\tfrac{5}{15}, \tfrac{10}{15}, \tfrac{10}{15}\right) + \left(-\tfrac{7}{15}, \tfrac{1}{15}, \tfrac{10}{15}\right) t \\ &= \left(\tfrac{1}{15}\right)(5 + 7t, 10 - t, 10 - 10t). \end{aligned}$$

Linear Interpolation of Normal Vectors

Example

- Given two normal vectors $\mathbf{u} = \left(\frac{1}{3}, \frac{2}{3}, \frac{2}{3}\right)$ and $\mathbf{v} = \left(\frac{4}{5}, \frac{3}{5}, 0\right)$, write a function that interpolates linearly between them.

$$\begin{aligned} f(t) &= \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right) + \left(\left(\tfrac{4}{5}, \tfrac{3}{5}, 0\right) - \left(\tfrac{1}{3}, \tfrac{2}{3}, \tfrac{2}{3}\right)\right) t \\ &= \left(\tfrac{5}{15}, \tfrac{10}{15}, \tfrac{10}{15}\right) + \left(-\tfrac{7}{15}, \tfrac{1}{15}, \tfrac{10}{15}\right) t \\ &= \left(\tfrac{1}{15}\right)(5 + 7t, 10 - t, 10 - 10t). \end{aligned}$$

- What vector is $1/3$ the way from $\mathbf{u}$ to $\mathbf{v}$?

Linear Interpolation of Normal Vectors

Example

- Note that for most values of t, the vector $f(t)$ is not a unit vector.
- Its magnitude is

$$\left(\tfrac{1}{15}\right)\sqrt{(5+7t)^2+(10-t)^2+(10-10t)^2}$$
$$=\left(\tfrac{1}{15}\right)\sqrt{225-150t+150t^2}$$
$$=\sqrt{1-\tfrac{2}{3}t+\tfrac{2}{3}t^2},$$

  which is probably not 1.
- Thus, any vector that is passed from the vertex shader to the fragment shader must be renormalized before it is used.

Outline

Assignment

Assignment

- Read pp. 373 - 385, Lighting Introduction, Classic Lighting Model.