Script - Week 3 - November 19, 2017

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Hey guys! My name is Lindsey, and these are my team members (introduce everyone). We've been tasked with explaining the three different shading models to you today, and they are flat, gouraud, and phong. These shading and illumination models are used in computer graphics to realistically simulate light and its behavior when interacting with a surface. In order to understand how these models behave, we will also be going over different light sources and different light reflection models such as ambient light, diffuse reflection, and specular reflection.

Light Behavior in Real Life

- Three characteristics of light
    - Intensity
    - Quality
    - Direction
    - https://www.ndsu.edu/pubweb/~rcollins/242photojournalism/lightingeffects.html

---------- Wrap up light behavior and introduce the first lighting model, ambient light ----------

Light Reflection Models

- Ambient Light
    - Ambient light is the base level of illumination in a general area.
    - Unlike the other reflection models, it does not have a defined source or direction.
    - With overhead lights, light rays are sent in all directions, and bounce off surfaces around the room until all the light energy is absorbed and the room is lit evenly.
    - In computer graphics, it is a simulation of light that has already been reflected so that it appears to come equally from all directions.
    - Ambient light will in most cases be lower in intensity, but is always uniformly spread across all surfaces of an object, no matter the object's position or orientation.
- Diffuse Reflection
    - We know how shiny objects like mirrors appear when reflecting light, but dull objects take on a different appearance.
    - When an incident light bounces off of a dull surface, it splits into multiple rays of equal intensity in multiple directions.
    - Unlike ambient light, diffuse reflection does depend on the angle of the light source and the direction that the surface is facing.
- Specular Reflection
    - Specular reflection is used to highlight more shiny surfaces, going hand-in-hand with diffuse reflection
    - It is unique because it is the only reflection model that depends on the position of the viewer.

    - If you look directly at an apple for example, one corner will have a tiny white highlight compared to the bright red of the rest of the surface. This is a specular highlight.

Light Sources in Graphics

- Directional Light
    - Produced by a light source an infinite distance from the scene.
    - All of the light rays emanating from the light strike the polygons in the scene from a single parallel direction, and with equal intensity everywhere.
    - Does not lose intensity with distance.
        - Sunlight is for all intents and purposes a directional light.
        - Characterized by color, intensity, and direction.
- Point Light
    - A light that gives off equal amounts of light in all directions.
    - Polygons, and parts of polygons which are closer to the light appear brighter than those that are further away.
    - The angle at which light from a point light source hits an object is a function of the positions of both the object and the light source.
    - The intensity of the light source hitting the object is a function of the distance between them.
    - Different graphics programs may (or may not) allow the programmer to adjust the falloff function in different ways.
        - A bare bulb hanging from a cord is essentially a point light.
        - Characterized by color, intensity, location, and falloff function.
- Spot Light
    - Most complex light source.
    - Light still emanates from a point.
    - Cut-off by cone determined by angle theta.
    - A spotlight describes light that radiates from a location in space out in a cone shape. For a real world example, consider headlights on a car which cast light in a roughly similar manner.
    - The simplest spotlight would just be a point light that is restricted to a certain angle around its primary axis of direction - Think of something like a flashlight or car headlight as opposed to a bare bulb hanging on a wire.
    - Some spotlights have a falloff function that makes the light more intense at the center of the cone and softer towards the outside edges of the cone.

Normal Vectors

- As you saw in the light sources diagrams, the light sources were represented by arrows- these are vectors, a representation of light th
- A normal vector is a vector that is perpendicular to a surface. Normal vectors are used in shading models to determine the brightness at a point on an object being rendered.

Because calculating the surface normal at every point on an object is very computationally expensive, the various shading models use different methods to calculate a smaller number of surface normals and extrapolate their information to the whole surface. This ranges from calculating a single surface normal at a vertex, as in flat shading, to calculating surface normals for each point to be painted on the surface in Phong shading.

Shading Models in Graphics

- Flat Shading
    - Flat shading is the least computationally expensive shading model. Uses a single point on a polygon as the color value for the polygon. This allows for basic differentiation between the different surfaces that make up a geometry, but is far from realistic.
    - It is especially bad for specular highlights; if a surface's first vertex contains a highlight, the brightness at the point will be distributed across the face. If the highlight does not fall on a vertex, it is missed entirely.
- Gouraud Shading
    - Much more realistic looking than flat shading because it smooths the colors between all of the polygons on the meshes, making the shading appear higher quality and the overall shape look far less polygonal than it would using flat shading
    - Specular highlights are much easier to see and define once the level of shading is upped to Gouraud

********** Next Slide **********

    - For Gouraud shading, instead of just calculating the normal of a face and from that, its intended color, we instead calculate the normals of all of the vertices of each of our faces.
    - This is done by averaging all of the face normals that are neighbors of that vertex
    - We then determine which color each of those points at the vertices represents given the direction and intensity of the light shining on our face.
    - Finally, we then interpolate the colors between these vertices and then by using the results from that we bilinearly interpolate across scan lines for the whole face for each face in our geometry, just like we did in homework 2 where we had to create a bilinear interpolation of colors.
    - Just like we did in our homework, each color channel must be bilinearly interpolated across the paths between the vertex points
- Phong Shading
    - Much like Gouraud shading, Phong shading uses bilinear interpolation, but instead of interpolating from just the normals at the vertices of each face, with Phong shading, you interpolate between the normals as you paint each point along the surface

    - This means you have to compute the color at each point of color across the entire surface by comparing the normal vector at that point to the vector of light bouncing into it, making the amount of calculations needed for this method exponentially more than that of Gouraud shading.
    - Especially since each of these points of color considers all of the light sources and their ambient, diffuse, and specular components
    - Because of this, objects can look particularly shiny when rendered with Phong Shading
- Gouraud Shading Vs. Phong Shading
    - Gouraud shading is more computationally complex than flat shading, but also less computationally complex than Phong shading, and in general, Gouraud shading's cost is considered to be relatively moderate. This is the main reason you might choose to use Gouraud shading techniques over Phong
    - Phong shading on the other hand, produces much more visually realistic results at the cost of this complexity. This is especially relevant in the way Gouraud modeling represents specularity at times, because the parts of specularity on a face can appear and change on parts not on the edges of all of the faces, and Gouraud shading won't pick this up because all of the coloring is based on normals calculated from the edges.
    - In addition to this, unless the gouraud shading is very high quality with a high polygon count, sometimes the edges of the polygons can really show themselves on the specular parts of the surface like they do in this gouraud shaded ball here but not on the phong ball to its right.

********** NEXT SLIDE **********

    - And here we have a side by side comparison of the three shading models on our personal skeleton head model from the same angle. The Gouraud highlight looks pretty good on this model because it has such a high poly count, so Gouraud may be a good choice for this model, but you can see that the gouraud shading highlights look a bit smeared in comparison to the phong's specular highlight portions