Computer Graphics

The Vertex and Fragment Shader

Raimond Tunnel

The Standard Graphics Pipeline

Construct geometry
Define transformations
Assign material properties
...

Vertex Transformations

Vertex Shader
Object's local space → viewport space

Culling & Clipping

Determine front-facing triangles
Determine which vertices are visible

Rasterization

Fill the triangle with fragments

Fragment Shading

Fragment Shader
Calculate correct color values

Visibility Tests
Blending

Is the fragment visible?
Blend together multiple fragments

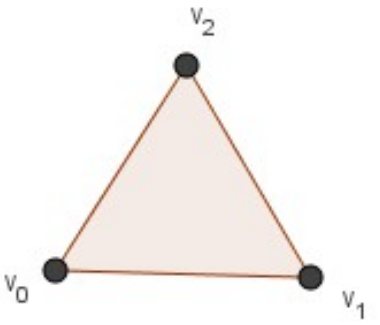
WebGL

- Based on **OpenGL ES 2.0**
- Used in the **browsers** for accessing the pipeline
- Has a shader programming language **GLSL**

- In newer OpenGL the syntax is different, but the ideas are the same...

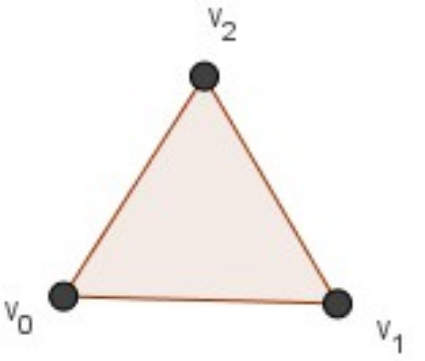
Shaders

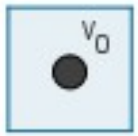
- First we will have a triangle
  - All meshes are made up of triangles
- Triangle will have 3 vertices

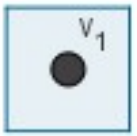


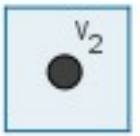
Shaders

- **The Vertex Shader** will be ran on the 3 vertices
- **Purpose:** transform positions from **local space** to clip space (and later **screen space**)



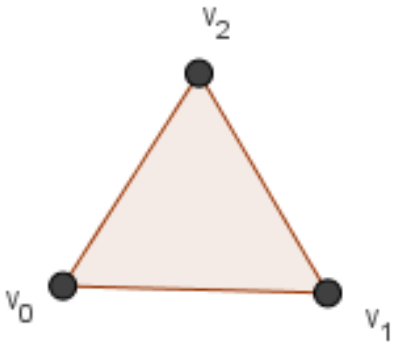




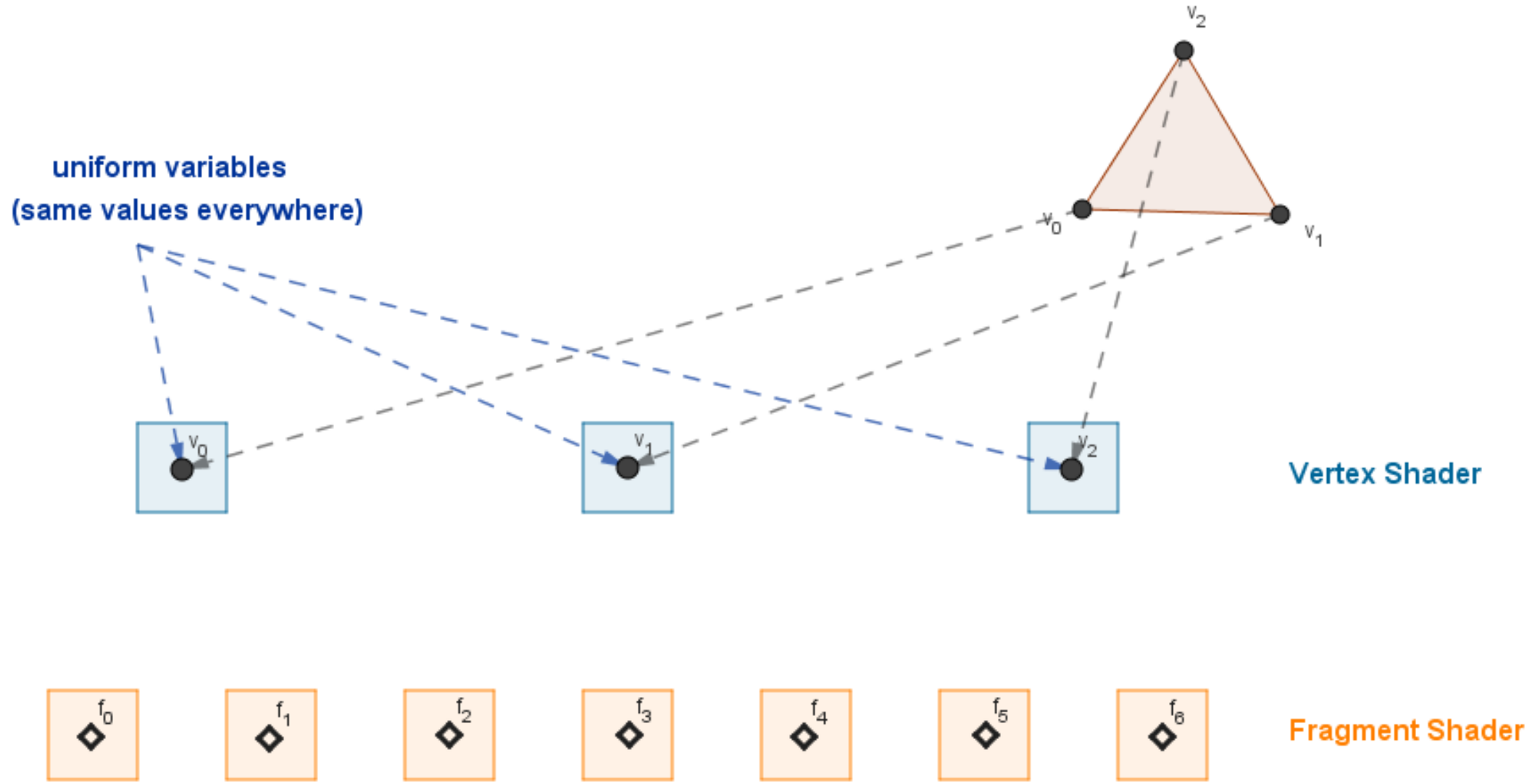


Vertex Shader

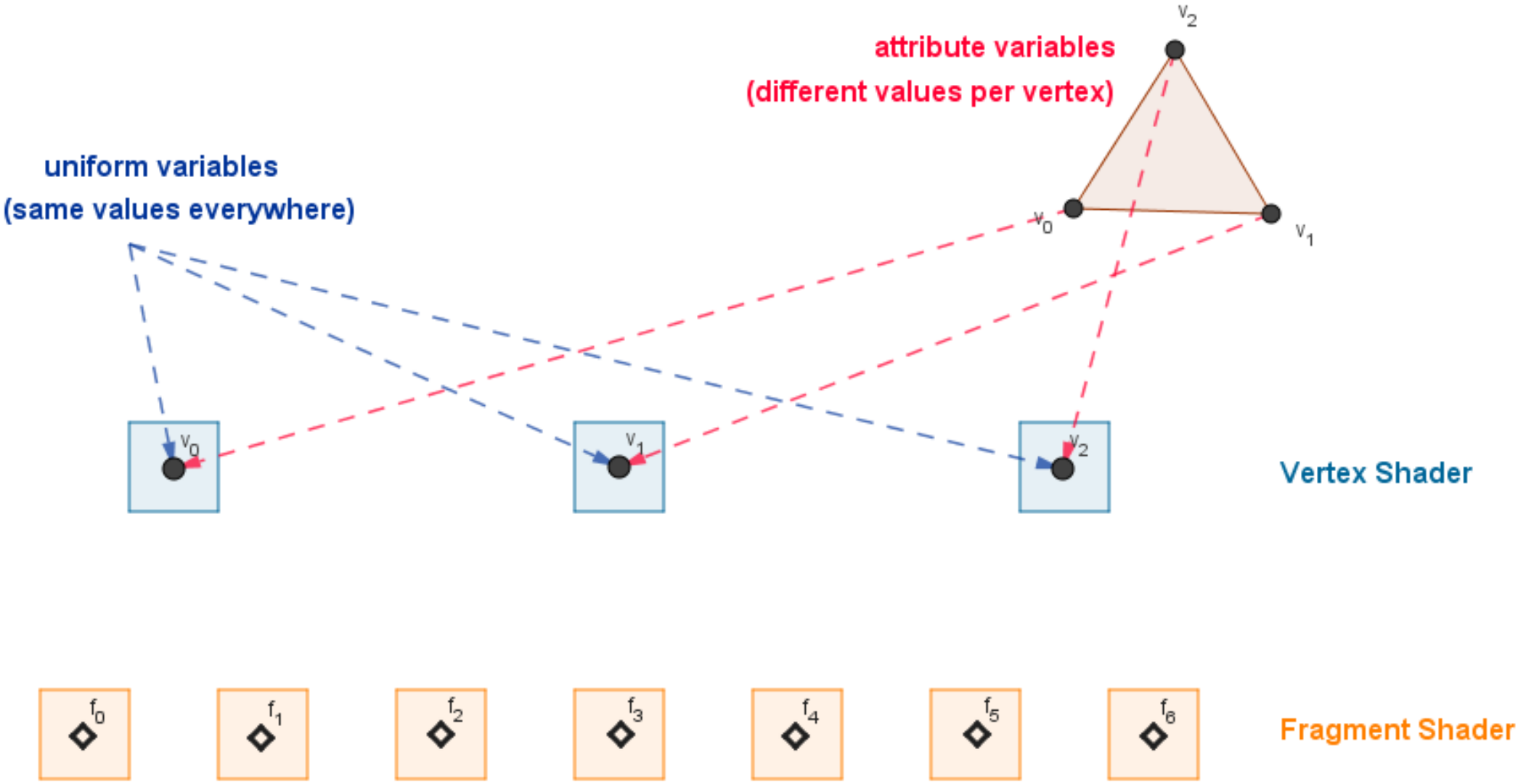
- Rasterization will create fragments (pixels)
- On those the **Fragment Shader** will be ran
- **Purpose:** color the pixels



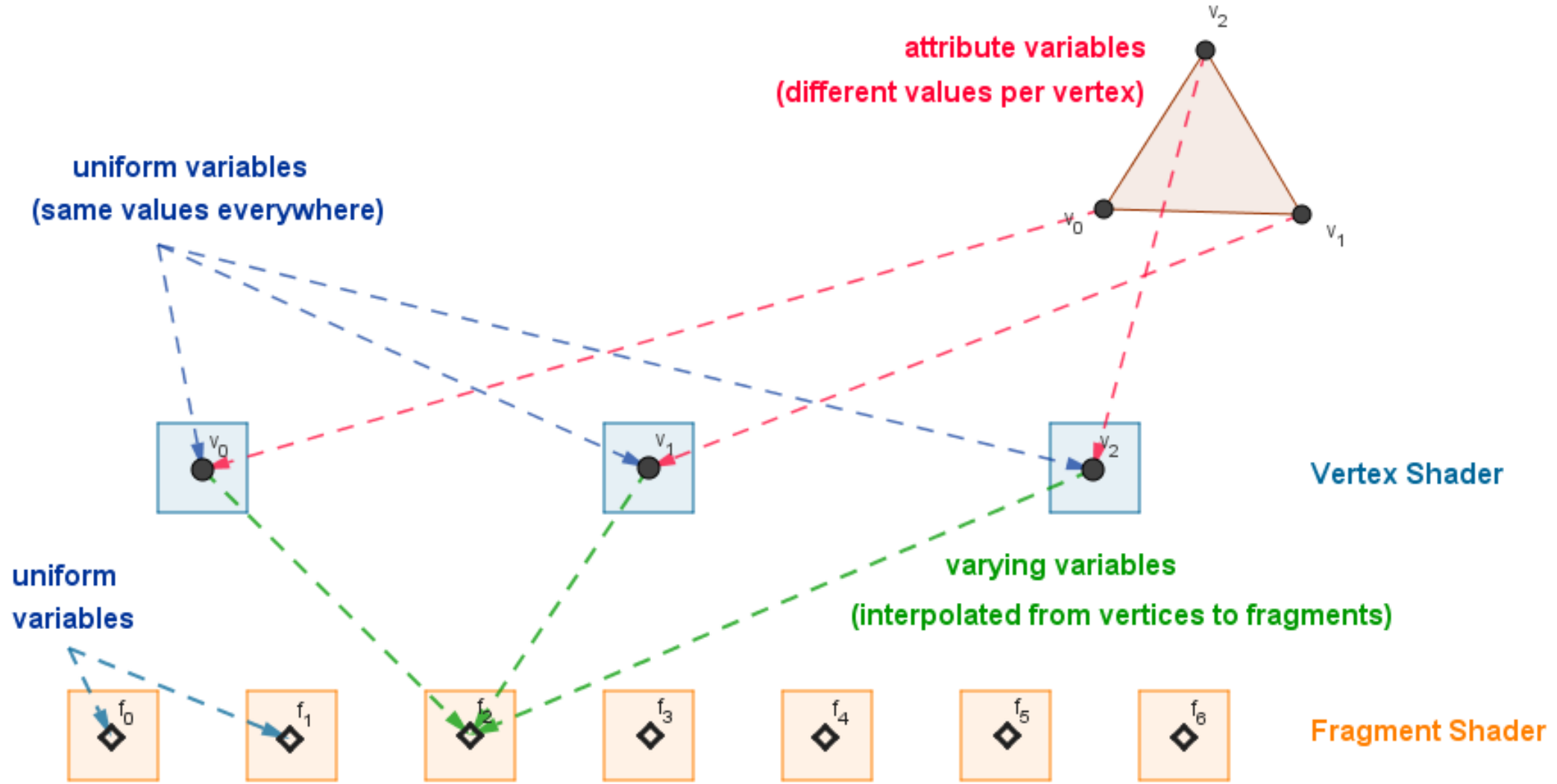
- **Uniform variables** – **global values** accessable from all shaders



- **Attribute variables** – values associated with **each vertex**

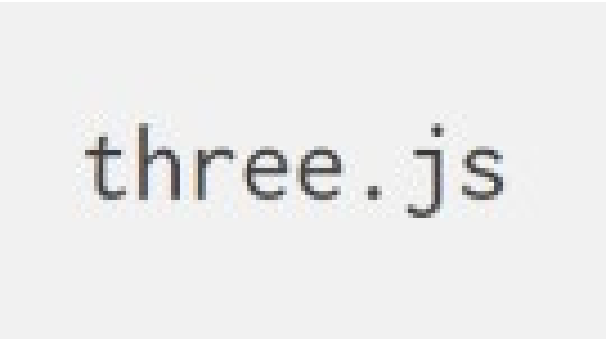


- **Varying variables** – values assigned in the vertex shader and **interpolated to fragments**



Three.js

- **JavaScript** library on top of **WebGL**
- Makes life **easier**
  - OOP
  - Encapsulates lower level WebGL stuff
  - Provides out of the box working graphics algorithms



https://threejs.org/

Task 1 – Coloring a Sphere

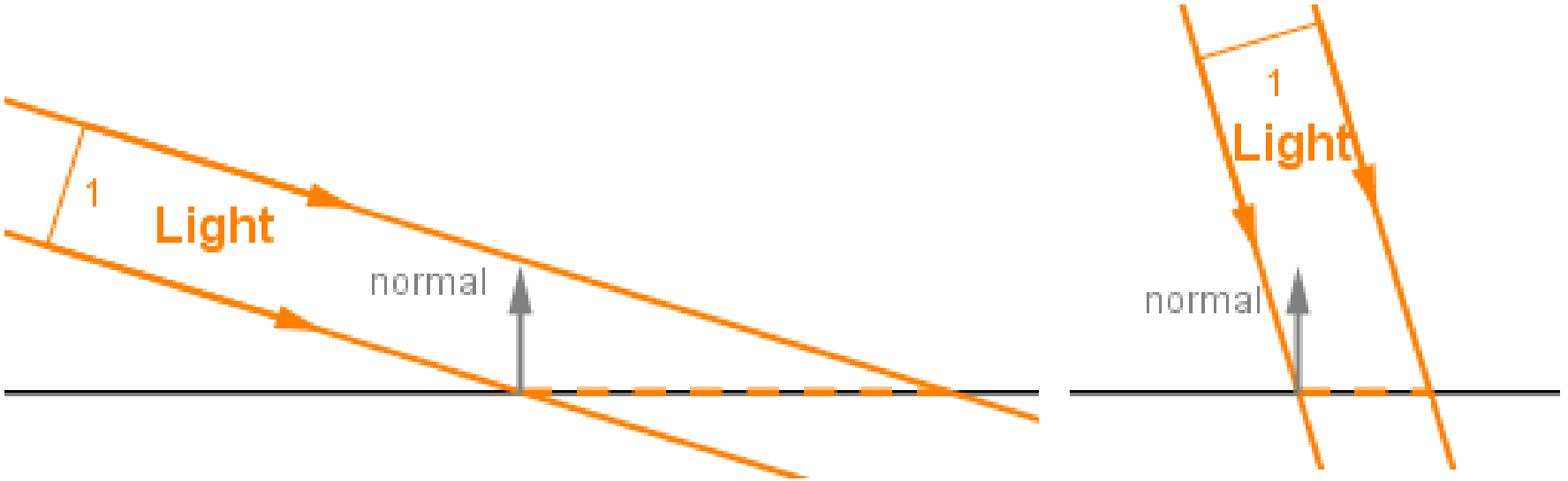
- Download the base files
- Open: ***1 – Coloring a Sphere.html***
  - In Notepad++
  - In SublimeText
  - In your favourite code editor
- Let's **look at the code**...

Lambertian Reflectance Model

- We assume that our material reflects light **equally in all directions**
  - The material is an *ideal matte*

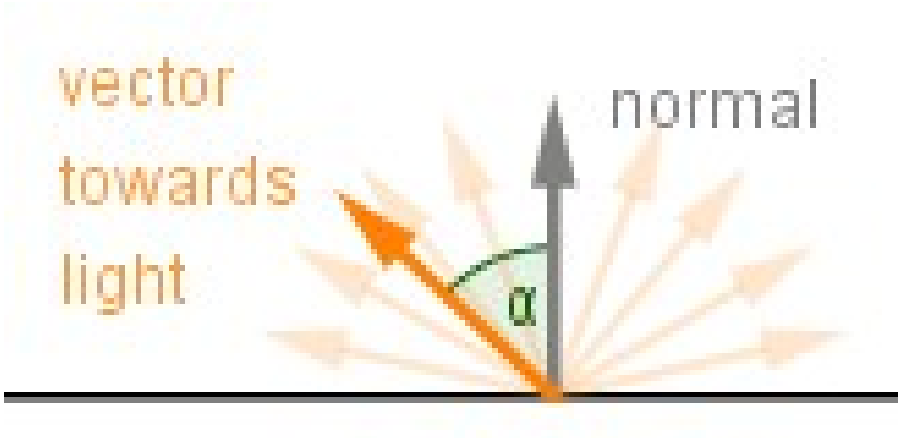
Lambertian Reflectance Model

- In which case the surface point emits more light?



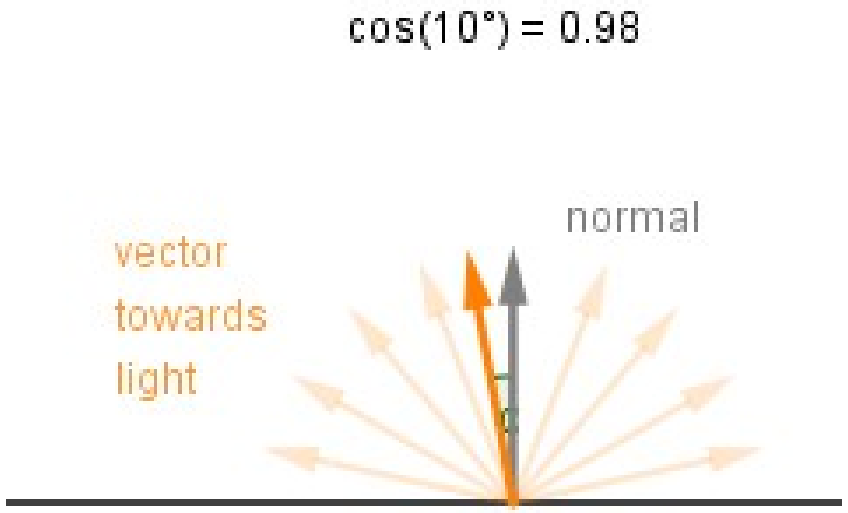
Lambertian Reflectance Model

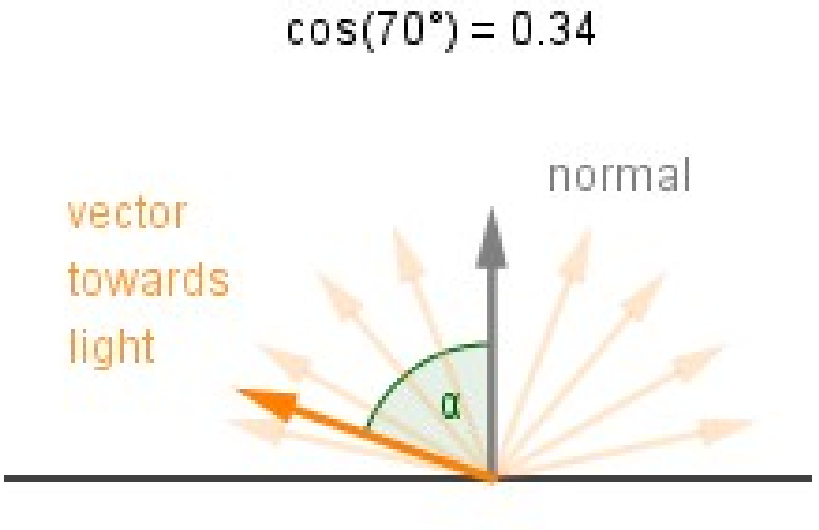
- With simple trigonometry it is easy to see that the **light reaching one surface unit** is proportional to the **cosine** between the surface **normal** and the **vector towards the light source**.



Lambertian Reflectance Model

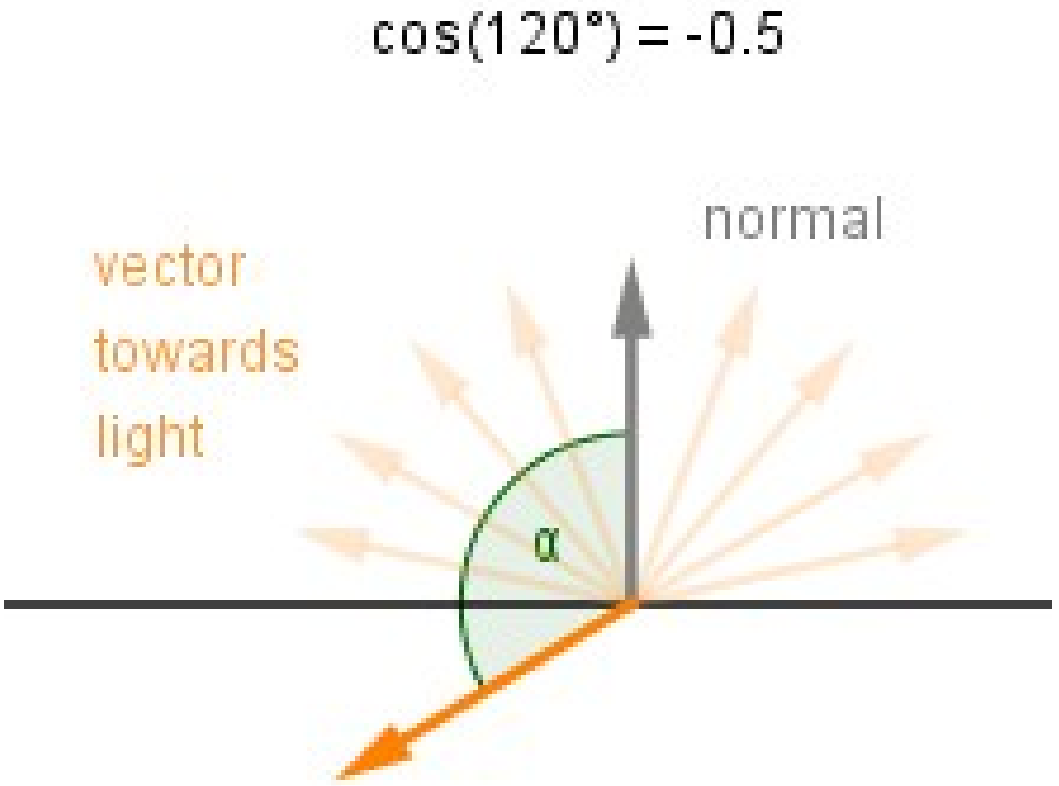
- Greater the angle, less light reaches one point





Lambertian Reflectance Model

- Oh my...



Lambertian Reflectance Model

- When the cosine is negative, we make it 0.
- The **dot product *(skalaarkorrutis)***:

$$v \cdot u = |v| \cdot |u| \cdot \cos\left(angle\left(u, v\right)\right)$$ ← Geometric definition

$$v \cdot u = v_1 \cdot u_1 + v_2 \cdot u_2 + v_3 \cdot u_3$$ ← Algebraic definition

- When the vectors are **normalized**, we get:

$$v \cdot u = v_1 \cdot u_1 + v_2 \cdot u_2 + v_3 \cdot u_3 = \cos\left(angle\left(u, v\right)\right)$$

Lambertian Reflectance Model

- Intensity of the reflected light also depends on:
  - The intensity of the **light source**
  - The reflectivity of the **material**
- In computer graphcis we store the intensities of the **red**, **green** and **blue** channel sperately.

$$I_{RGB} = L_{RGB} \cdot M_{RGB} \cdot \max(0, vectorTorwardsLight \cdot normal)$$

Pixel color!

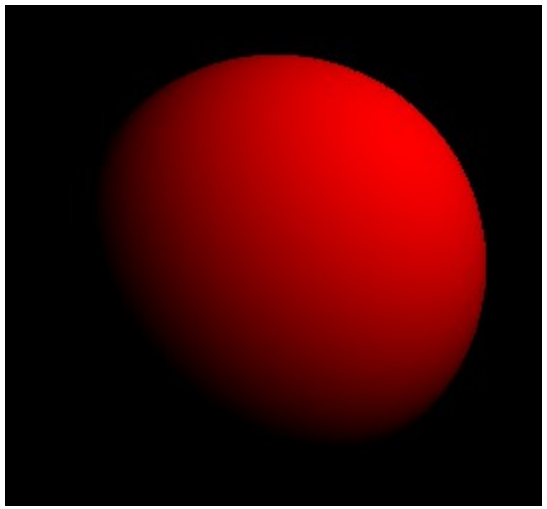
How much our light source emits?

How much our material reflects?

How much light reaches our surface?

Let's make it!

<script>



What happens when you have errors?

Ambient Light

- In reality the light does not only come from the light source
- Light bounces around and comes from **all directions** – that light is called **ambient light**
- Simplest way to take that into account is to just add a small value to the model

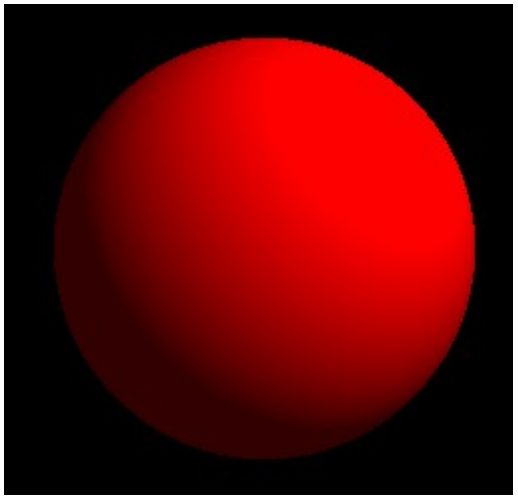
$$I = L_A \cdot M_A + L_L \cdot M_L \cdot \max\left(0, vectorTorwardsLight \cdot normal\right)$$

- Often the ambient material property is the same

$$I = M \cdot \left(L_A + L_L \cdot \max\left(0, vectorTorwardsLight \cdot normal\right)\right)$$

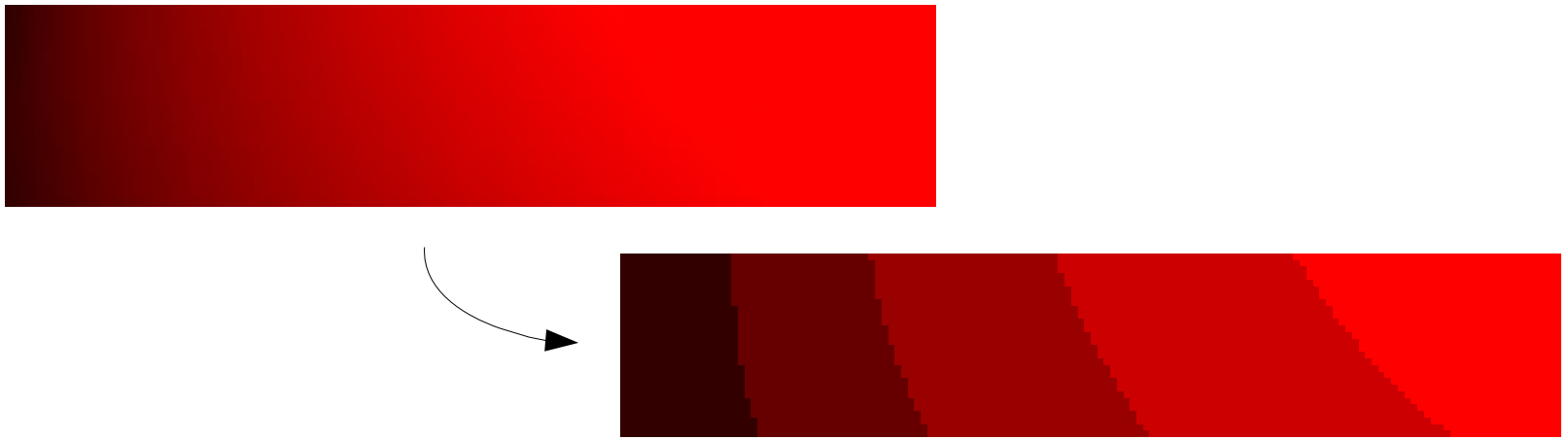
Add ambient light to the model

<script>



Toon Shading

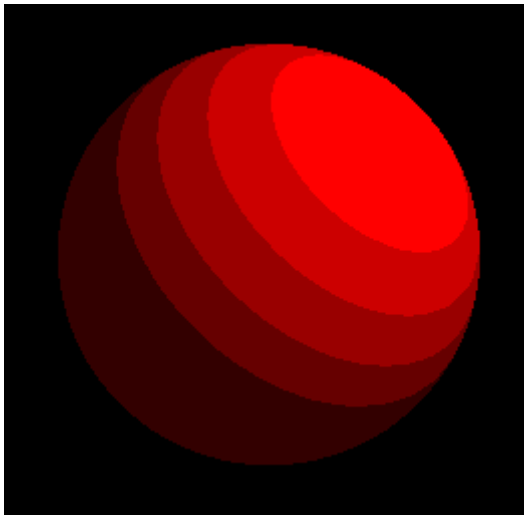
- Aka cel shading
- Toon shading **discretizes** the colors



- At times an outline of objects is also drawn, but that is a bit more complicated to do...

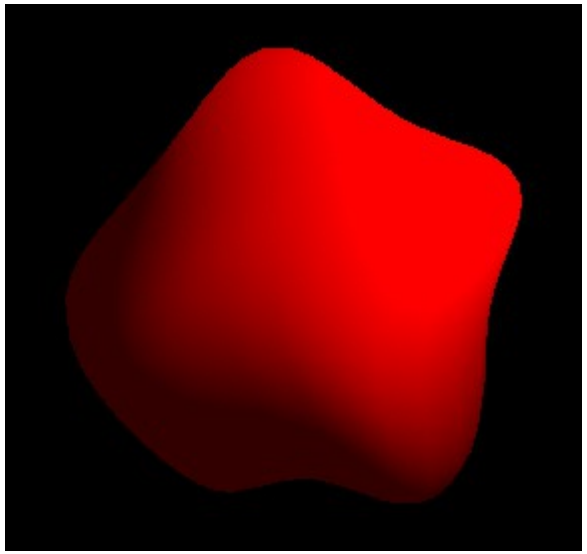
Toon Shading

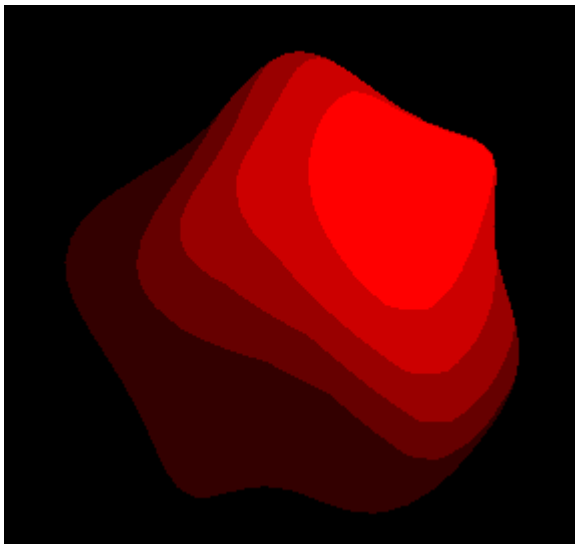
- Open: ***2 – Discrete Sphere.html***
- Follow the instructions in the fragment shader to discretize the colors
- Feel free to experiment yourself...



Wobbly Sphere

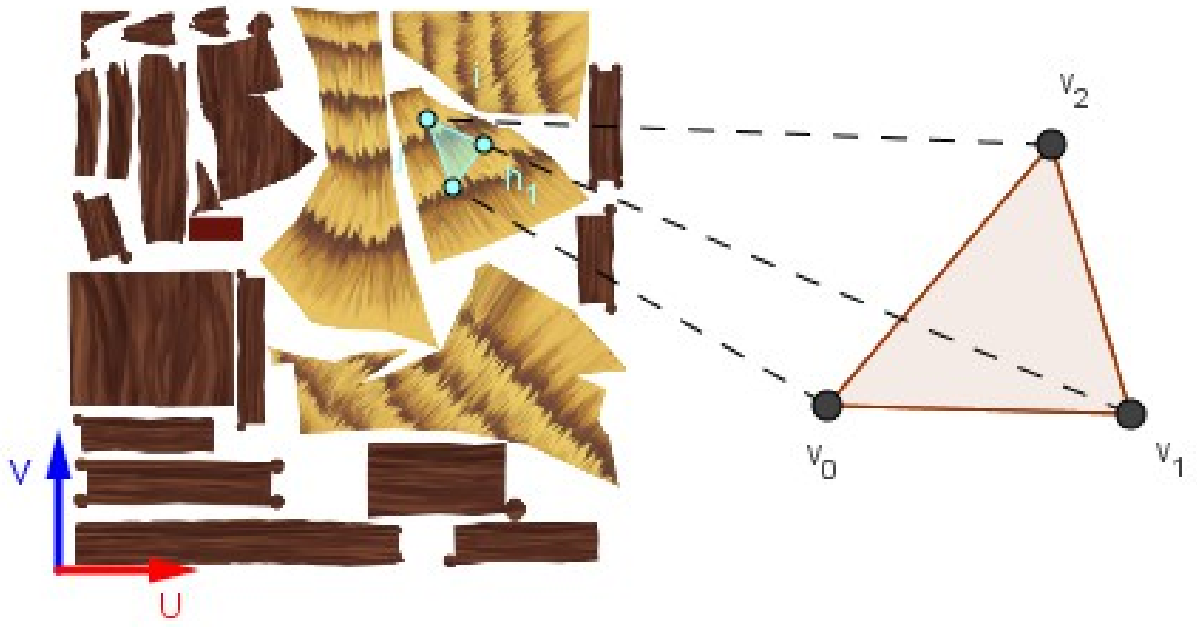
- Open: ***3 – Wobbly Sphere.html***
- Follow the instructions in the **vertex shader** and on the **CPU side**
- Make the vertices of the sphere move
- Feel free to go wild...





Texturing

- Texturing is mapping a 2D image to a 3D surface
- This is done by specifying 2D texture coordinates (called **UV coordinates**) for each vertex
- The mapping done in a 3D modelling software



Texturing

<script>

- Open: ***4 – Hut.html***
- As you can guess, if we **interpolate the UV** coordinates, the corresponding fragments will get the correct interpolated UV coordinate
- If we **sample the base color** from those coordinates, the object will be textured



Thanks!

- You now have good shader programming skills!