Tutorial 1

CS3241 Computer Graphics (AY22/23)

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Question 1

To be able to display **realistic** images, our display devices need to be able to produce every frequency in the visible light spectrum.

True or false? Why? What are the advantages and disadvantages?

Three-Color Theory

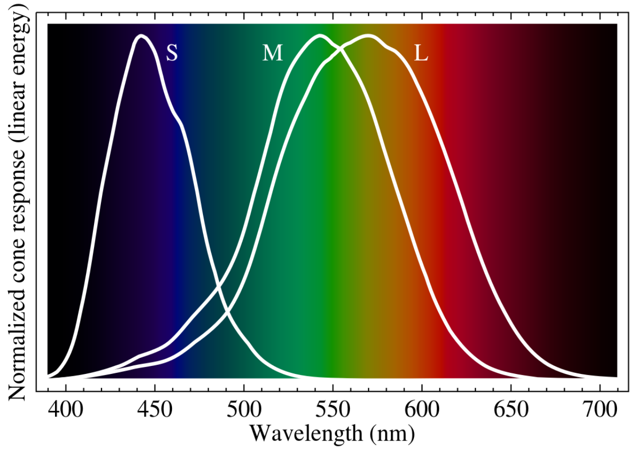
To be **realistic to human**
⇒ To be compatible with human visual system (L01, slide 35)

- Rods: Monochromatic
- **Cones**: Color sensitive to wavelengths
    - Long ≈ red
    - Medium ≈ green
    - Short ≈ blue

Proportion of the three gives us the sensation of different colors.

Cone sensitivity and Additive color theory

Single frequency = proportion of responses of each cone.



Additive Color Display

Pros

1. We don’t have to produce light of every wavelength in vis. light spectrum for realism
2. We can see colors that are **NOT** on vis. light spectrum (e.g. **PURPLE**).

Additive Color Display

Cons

Two different RGB values can produce the same color.

Q: What’s an example of this?

A: There is no definitive inverse mapping of RGB to a wavelength, as it is display dependent.

https://physics.stackexchange.com/questions/248139/can-two-different-rgb-color-triplets-give-the-same-color

Question 2

Each pixel in a frame-buffer has 8 bits for each of the R, G and B channels. How many different colors can each pixel represent? Is this enough?

32-bit color

Each of the following four channels is described in **8 bits**.

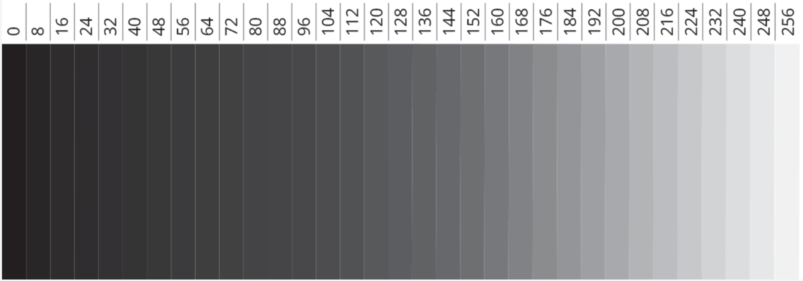
- R
- G
- B
- (not in this question) A for Alpha (transparency)

Hence color has 32 bits: 2^32 values (can be represented with an `int`)!
Based on RGB only: 2^{24} = **16,777,216**. See: Color Depth

32-bit color

Is this enough?

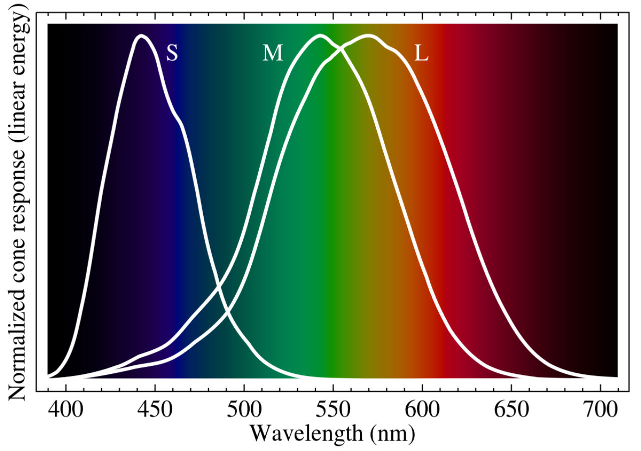
256 shades of gray: **banding artifacts**.



Use case decides if this is undesirable or not.

8-bit representation of color

On some systems, each pixel has only 8 bits (for all R, G, and B combined). How would you allocate the bits to the R, G and B primaries?



8-bit representation of color

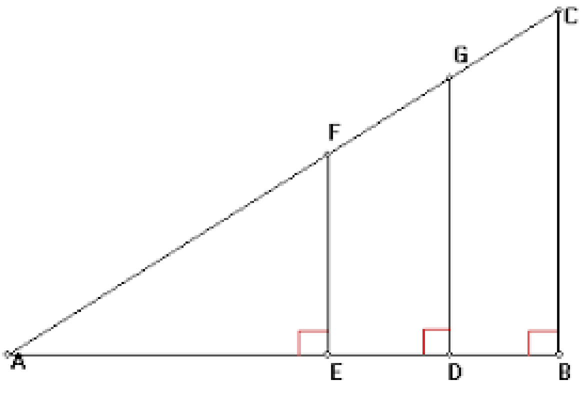
On some systems, each pixel has only 8 bits (for all R, G, and B combined). How would you allocate the bits to the R, G and B primaries?

3:3:2 for R:G:B. Our eyes are less sensitive to changes in blue.

Question 3

Referring to Lecture 1 Slide 26. If an imaginary image plane is d unit distance in front of the pinhole camera, what are the coordinates of the projection (on the imaginary image plane) of the 3D point (x, y, z)?

Similar triangles



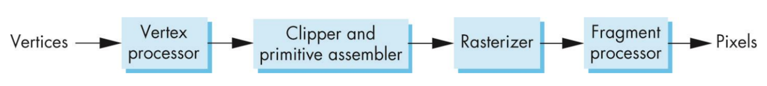
$$\frac{AE}{AD} = \frac{AF}{AG} = \frac{EF}{DG}$$

Answer

- $z_p = d$ (Why?)
- $x_p = dx/z$
- $y_p = dy/z$

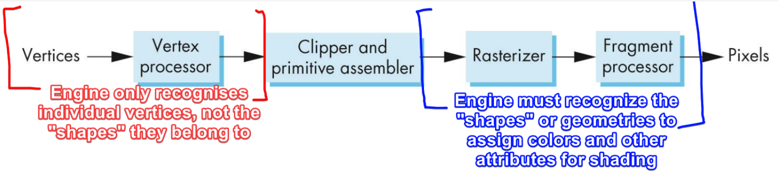
Question 4

Why do we need a **primitive assembly** stage in the rendering pipeline architecture?



Primitive Assembly

Rendering pipeline


Vertices
Vertex processor
Clipper and primitive assembler
Rasterizer
Fragment processor
Pixels
Engine only recognises individual vertices, not the "shapes" they belong to
Engine must recognize the "shapes" or geometries to assign colors and other attributes for shading

Primitive: One polygonal unit

Question 5

What does the rasterization stage (rasterizer) do in the rendering pipeline architecture?

Question 5

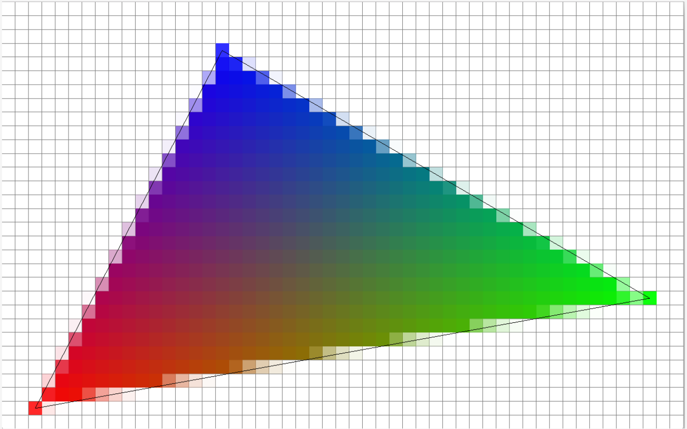
Describe what it does to a triangle that is supposed to be filled, and the three vertices have different color. Assume smooth shading is turned on.

Rasterization

(Lecture 1 Slide 40)

Assigning colors to pixels occupied by a primitive/polygon.

1. Each vertex has an attribute.
2. Each attribute is **interpolated** across the vertices.

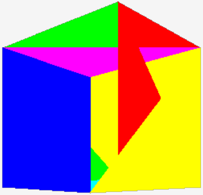


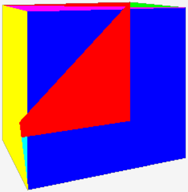
Question 6

What is hidden-surface removal? When is it not necessary?

Hidden Surface Removal

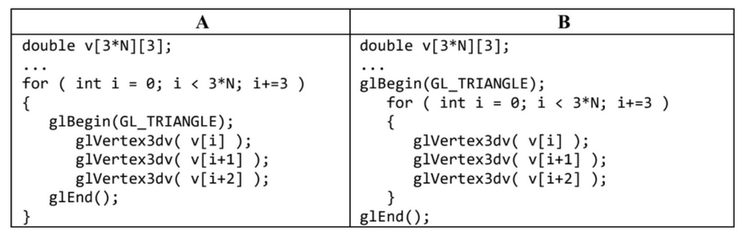
https://gabrielgambetta.com/computer-graphics-from-scratch/12-hidden-surface-removal.html





Question 7

Which of the two following program fragments is more efficient? Why?

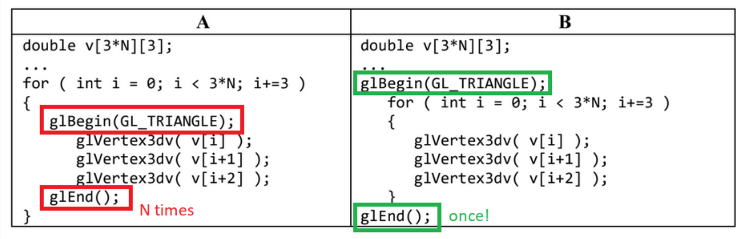


A	B

double v[3*N][3];
...
for (int i = 0; i < 3*N; i+=3)
{
    glBegin(GL_TRIANGLE);
        glVertex3dv(v[i]);
        glVertex3dv(v[i+1]);
        glVertex3dv(v[i+2]);
    glEnd();
}
	double v[3*N][3];
	...
	glBegin(GL_TRIANGLE);
	    for (int i = 0; i < 3*N; i+=3)
	    {
	        glVertex3dv(v[i]);
	        glVertex3dv(v[i+1]);
	        glVertex3dv(v[i+2]);
	    }
	glEnd();

Can the same optimization be done for the case of `GL_POLYGON`?

Calls to glBegin and glEnd



A

```
double v[3*N][3];
...
for ( int i = 0; i < 3*N; i+=3 )
{
  glBegin(GL_TRIANGLE);
      glVertex3dv( v[i] );
      glVertex3dv( v[i+1] );
      glVertex3dv( v[i+2] );
  glEnd();
}
```

N times

B

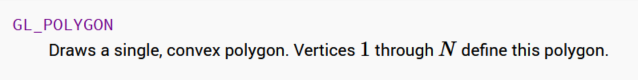
```
double v[3*N][3];
...
glBegin(GL_TRIANGLE);
   for ( int i = 0; i < 3*N; i+=3 )
   {
      glVertex3dv( v[i] );
      glVertex3dv( v[i+1] );
      glVertex3dv( v[i+2] );
   }
glEnd();
```

once!

Note that OpenGL (together with mosts other graphics engines) is a **state machine**. Method B greatly reduces the number of state changes.

What about GL_POLYGON?

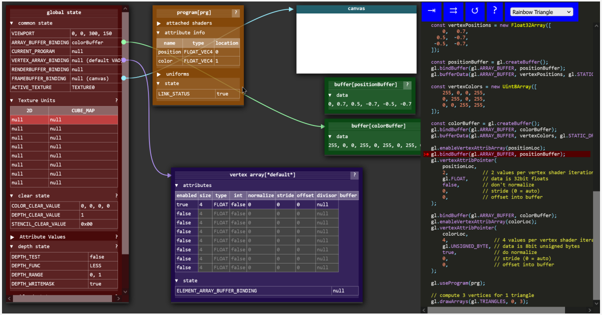
We can't do this with GL_POLYGON or we'll be defining one massive 3*N*-vertex polygon.



GL_POLYGON

Draws a single, convex polygon. Vertices 1 through N define this polygon.

WebGL State Machine visualizer/debugger tool



global state

▼ common state

VIEWPORT	0, 0, 300, 150
ARRAY_BUFFER_BINDING	colorBuffer
CURRENT_PROGRAM	null
VERTEX_ARRAY_BINDING	null (default VAO)
RENDERBUFFER_BINDING	null
FRAMEBUFFER_BINDING	null (canvas)
ACTIVE_TEXTURE	TEXTURE0

▼ Texture Units ?

2D	CUBE_MAP
null	null
null	null
null	null
null	null
null	null
null	null
null	null
null	null

▼ clear state ?

COLOR_CLEAR_VALUE	0, 0, 0, 0
DEPTH_CLEAR_VALUE	1
STENCIL_CLEAR_VALUE	0x00

▶ Attribute Values ?

▼ depth state ?

DEPTH_TEST	false
DEPTH_FUNC	LESS
DEPTH_RANGE	0, 1
DEPTH_WRITEMASK	true

program[prg] ?

▶ attached shaders

▼ attribute info

name	type	location
position	FLOAT_VEC4	0
color	FLOAT_VEC4	1

▶ uniforms

▼ state

LINK_STATUS	true

buffer[positionBuffer] ?

▼ data

0, 0.7, 0.5, -0.7, -0.5, -0.7

buffer[colorBuffer]

▼ data

255, 0, 0, 255, 0, 255, 0, 255,

vertex array[*default*] ?

▼ attributes

enabled	size	type	int	normalize	stride	offset	divisor	buffer
true	4	FLOAT	false	0	0	0	null	
false	4	FLOAT	false	0	0	0	null	
false	4	FLOAT	false	0	0	0	null	
false	4	FLOAT	false	0	0	0	null	
false	4	FLOAT	false	0	0	0	null	
false	4	FLOAT	false	0	0	0	null	
false	4	FLOAT	false	0	0	0	null	
false	4	FLOAT	false	0	0	0	null	

▼ state

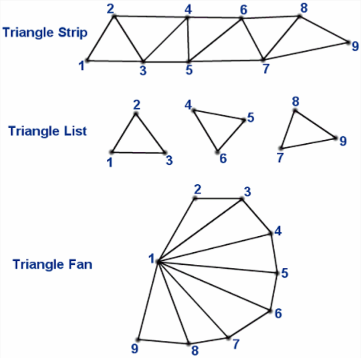
ELEMENT_ARRAY_BUFFER_BINDING	null

```
  const vertexPositions = new Float32Array([
      0,   0.7,
    0.5,  -0.7,
   -0.5,  -0.7,
  ]);

  const positionBuffer = gl.createBuffer();
  gl.bindBuffer(gl.ARRAY_BUFFER, positionBuffer);
  gl.bufferData(gl.ARRAY_BUFFER, vertexPositions, gl.STATIC

  const vertexColors = new Uint8Array([
      255, 0, 0, 255,
      0, 255, 0, 255,
      0, 0, 255, 255,
  ]);

  const colorBuffer = gl.createBuffer();
  gl.bindBuffer(gl.ARRAY_BUFFER, colorBuffer);
  gl.bufferData(gl.ARRAY_BUFFER, vertexColors, gl.STATIC_DR

  gl.enableVertexAttribArray(positionLoc);
>●gl.bindBuffer(gl.ARRAY_BUFFER, positionBuffer);
  gl.vertexAttribPointer(
      positionLoc,
      2,            // 2 values per vertex shader iteration
      gl.FLOAT,     // data is 32bit floats
      false,        // don't normalize
      0,            // stride (0 = auto)
      0,            // offset into buffer
  );

  gl.bindBuffer(gl.ARRAY_BUFFER, colorBuffer);
  gl.enableVertexAttribArray(colorLoc);
  gl.vertexAttribPointer(
      colorLoc,
      4,                // 4 values per vertex shader itera
      gl.UNSIGNED_BYTE, // data is 8bit unsigned bytes
      true,             // do normalize
      0,                // stride (0 = auto)
      0,                // offset into buffer
  );

  gl.useProgram(prg);

  // compute 3 vertices for 1 triangle
  gl.drawArrays(gl.TRIANGLES, 0, 3);
```

https://webglfundamentals.org/webgl/lessons/resources/webgl-state-diagram.html

Question 8

OpenGL supports the GL_TRIANGLES primitive type. Why do you think that OpenGL also supports GL_TRIANGLE_FAN and GL_TRIANGLE_STRIP?



Comparison

Type	Vertices	Triangles
GL_TRIANGLES	3n	n
GL_TRIANGLE_FAN	n + 2	n
GL_TRIANGLE_STRIP	n + 2	n

Question 9

Devise a test to check whether a polygon in 3D space is planar.

Question 10

Devise a test to check whether a polygon on the x-y plane is convex.

Thanks!

https://github.com/