Universidad de La Laguna

# WebGL

## Programación de Aplicaciones Interactivas

Cristo Daniel Navarro Rodríguez
Luciana Varela Díaz

# INDEX

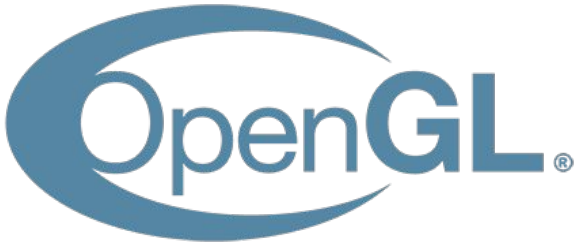


# INTRODUCTION

- Web Graphics Library
- Javascript API
- Runs on your GPU (Graphics Processing Unit)

# INTRODUCTION

- OpenGL
  - Multi Platform API
  - Used in multiple environments:
    - VR
    - Videogames
      - Direct3D
    - Flight Simulators



# INTRODUCTION

- Primitive figures:
  - Points
  - Lines
  - Triangles


# Canvas VS WebGL

- Platforms
- Learning rate
- Applications
- Performance

# Canvas VS WebGL

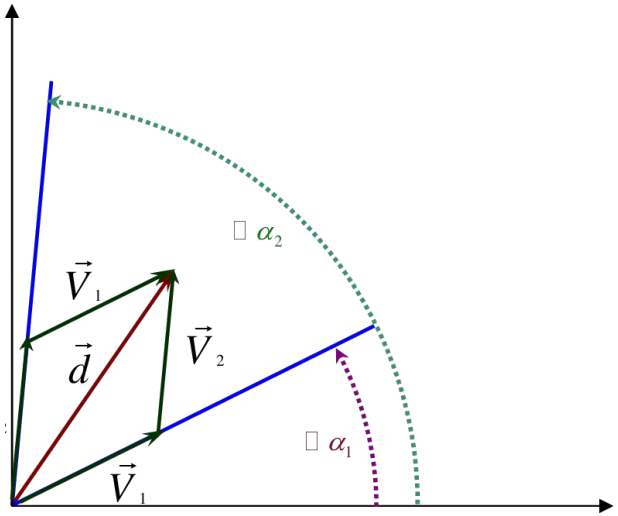
Platforms:

- Canvas: browsers
- WebGL: browsers + mobile

# Canvas VS WebGL

Learning rate:

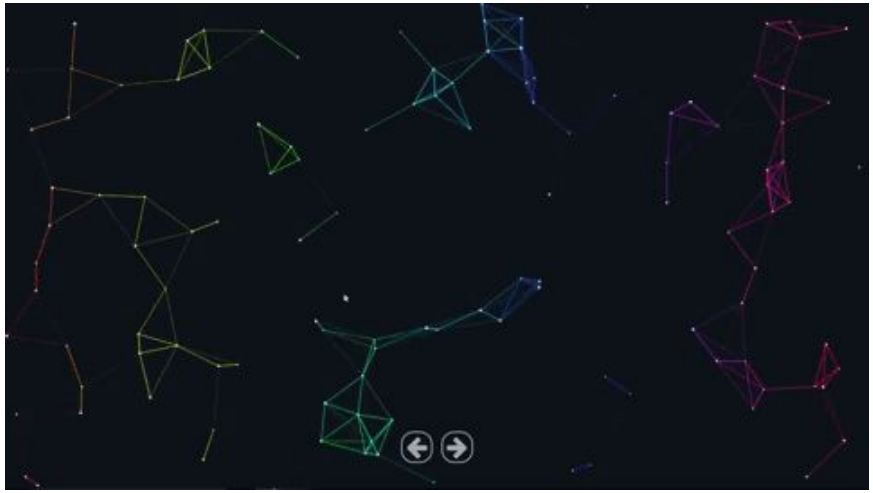
- Canvas: way easier
- WebGL: complicated

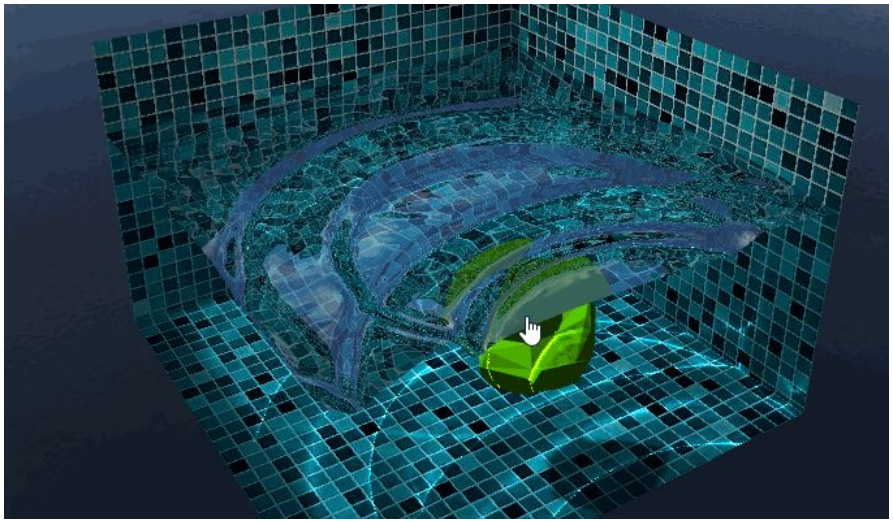



# Canvas VS WebGL

Applications:

- Canvas: 2D
- WebGL: 3D

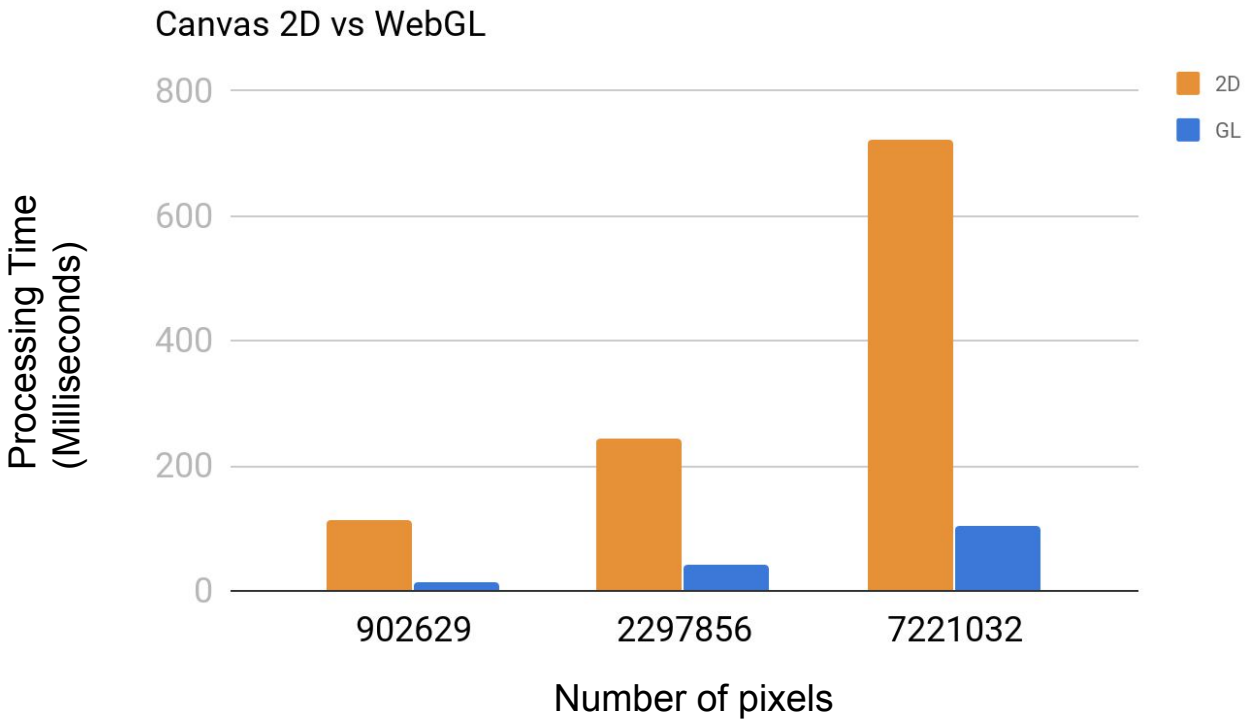




# Canvas VS WebGL

## Performance

- Rendering on GPU.

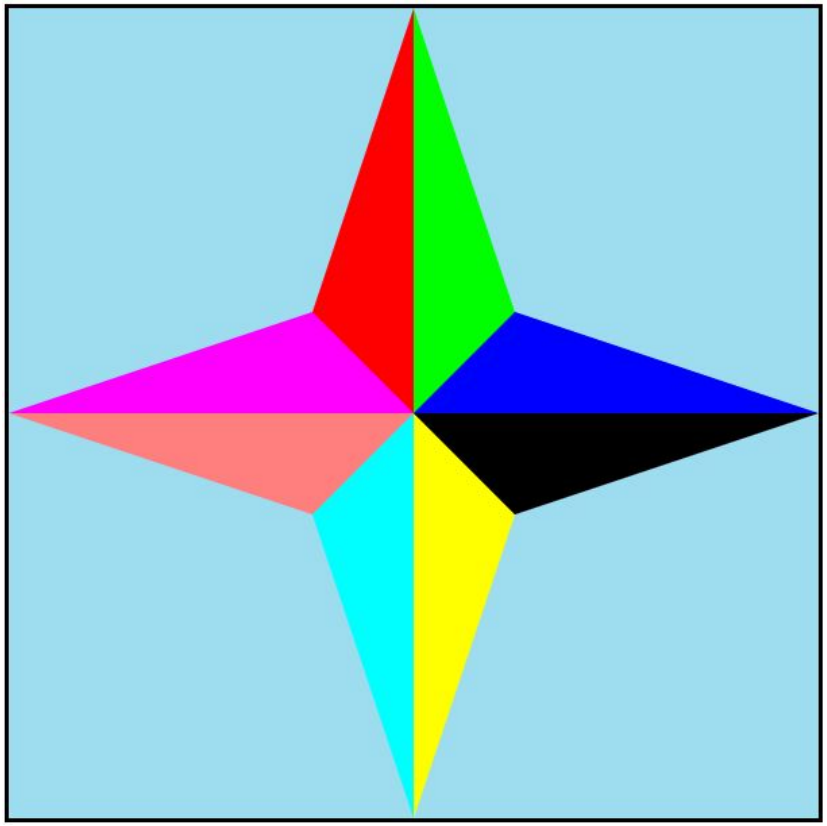


# How does it work?

- Prepare the canvas and the rendering context.
- Define geometry and store it.
- Create and compile shader programs.
- Associate the shaders with buffer objects.
- Draw the objects.

# How does it work?

What we want to achieve.



# How does it work?

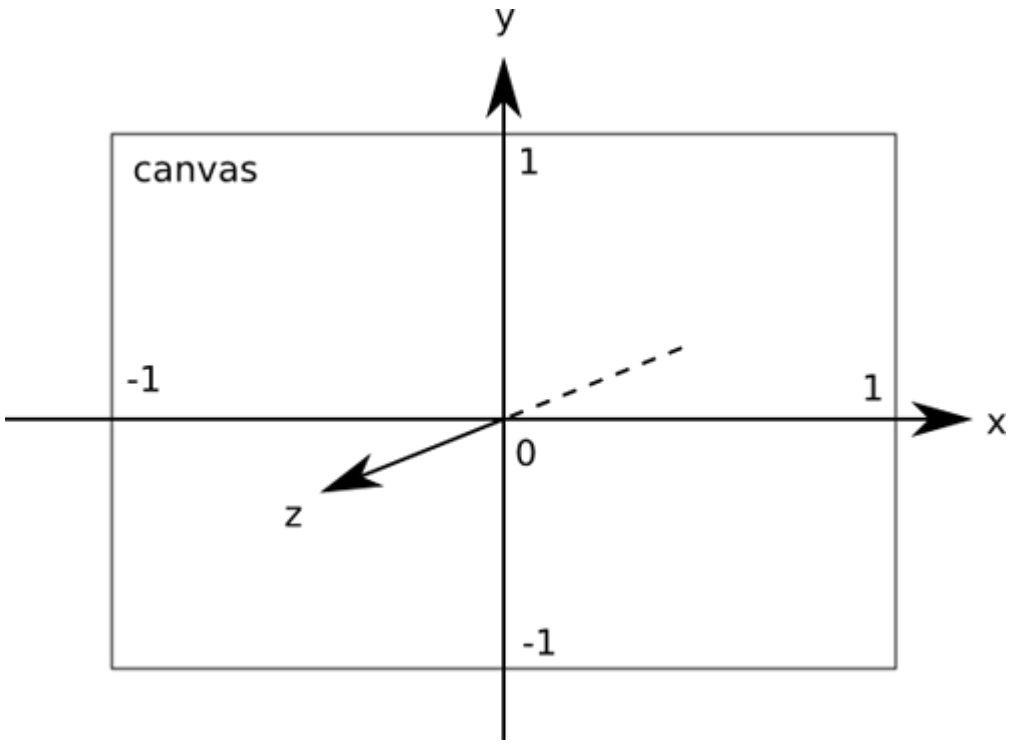
Prepare the canvas and the rendering context.

```
const CANVAS =
document.getElementById('canvas');
const CONTEXT = CANVAS.getContext('webgl');
```

# How does it work?

Define geometry and store it.

- Clipspace



# How does it work?

Define geometry and store it.

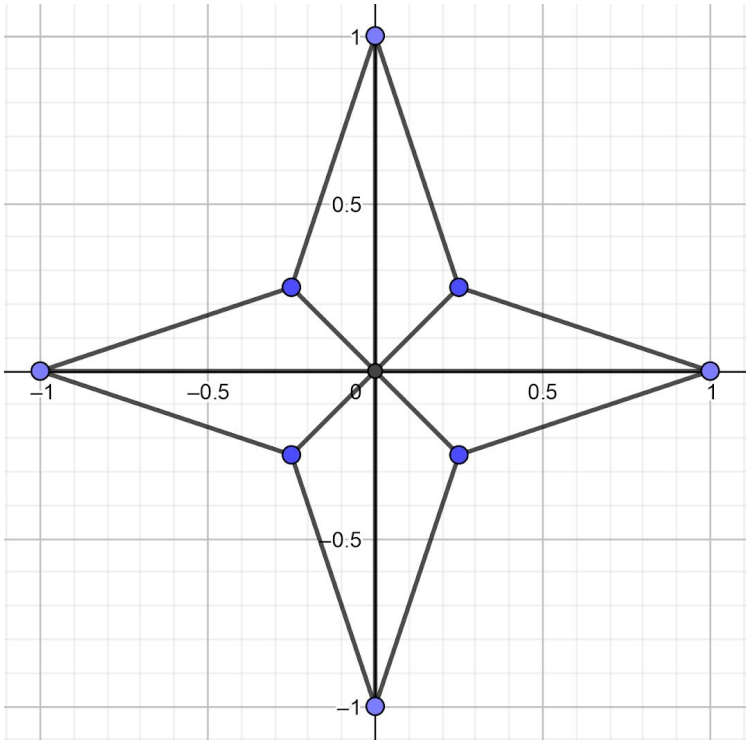
- Positions

```
let vertex = [-1.0, 0.0,   -0.25, 0.25,    0.0, 0.0
              … … … ];
```

# How does it work?

Define geometry and store it.

- Positions



# How does it work?

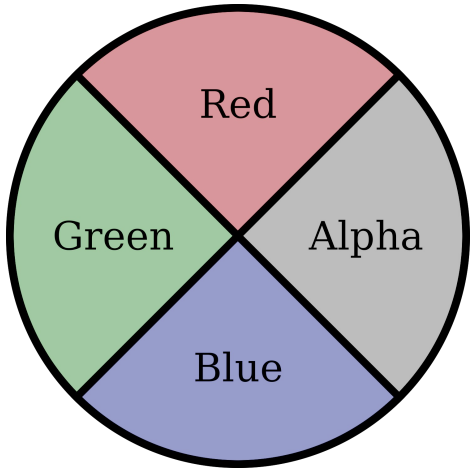
## Define geometry and store it.

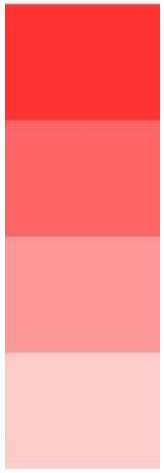
- Colors

```
let triangleColors = [[1.0, 0.0, 1.0, 1.0], … ];
```

[1.0, 0.0, 0.0, 1.0]

[0.0, 1.0, 0.0, 1.0]



[0.0, 0.0, 1.0, 1.0]

# How does it work?

Define geometry and store it.

- Colors

# How does it work?

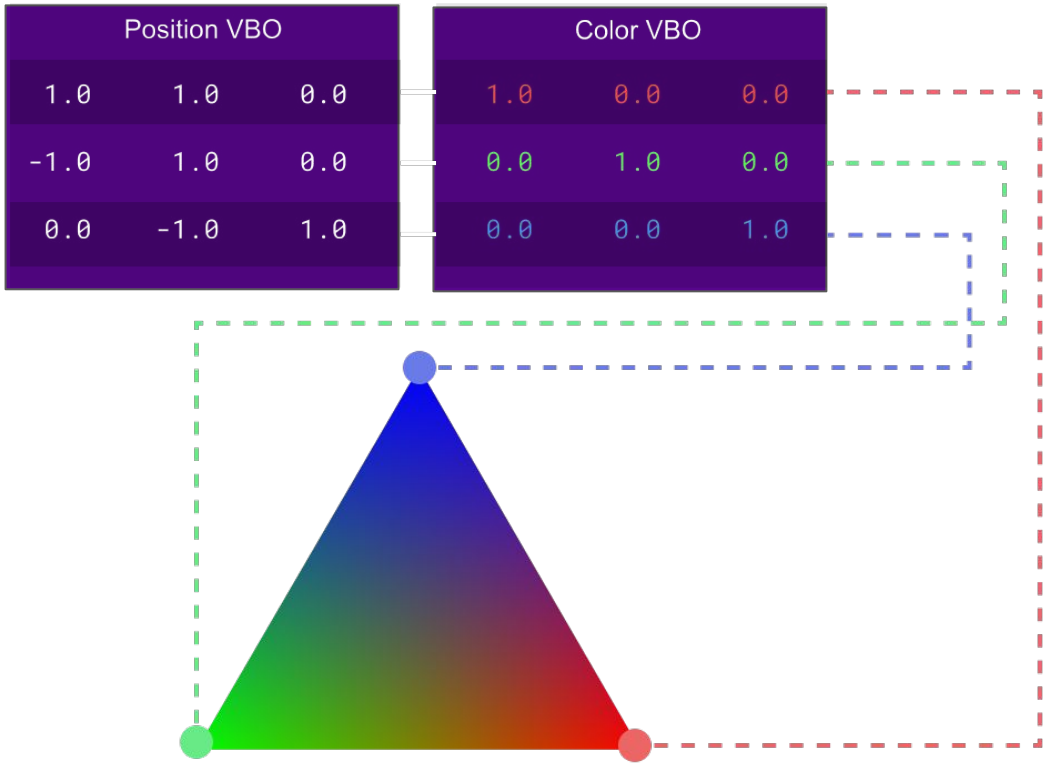
Define geometry and store it.

- Buffers
  - Contiguous block of memory
  - Data for attributes

# How does it work?

Define geometry and store it.

- Buffers



# How does it work?

Create and compile shader programs.

- Shader source code
  - Vertex shader
  - Fragment shader
- Uses the language GLSL

# How does it work?

Create and compile shader programs.

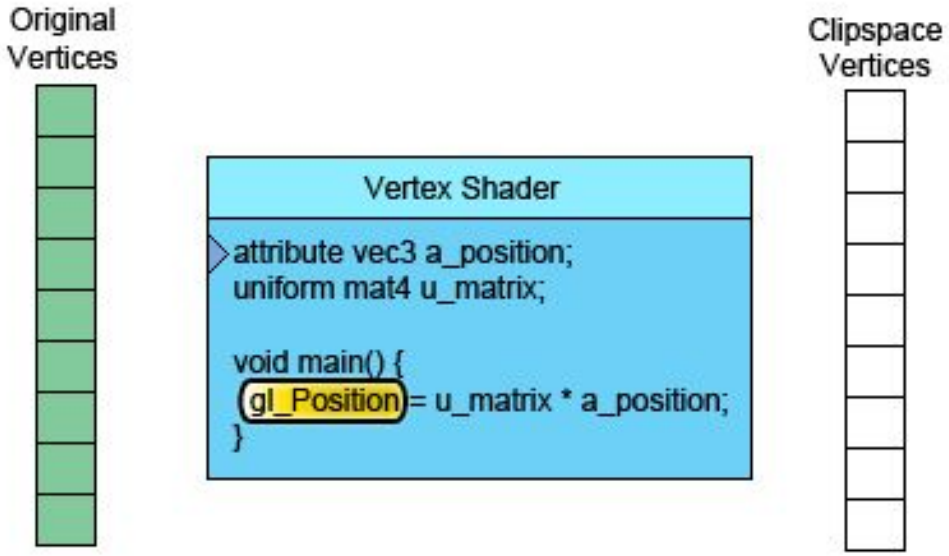
- Vertex shader
  - Generate the clipspace coordinates
  - Called once per vertex
  - Assigns the coordinates to “gl_Position”

**Always vec4!!!**

# How does it work?

Create and compile shader programs.

- Vertex shader



# How does it work?

## Create and compile shader programs.

- Vertex shader

```
const VERTEX_CODE = `
  attribute vec2 coordinates;
  attribute vec4 aVertexColor;
  varying lowp vec4 vColor;
  void main(void) {
    gl_Position = vec4(coordinates, 0.0, 1.0);
    vColor = aVertexColor;
  }`;
```

# How does it work?

Create and compile shader programs.

- Fragment shader
  - Assigns the color to the current pixel
  - Called once per pixel
  - Assigns the color to “gl_FragColor”

# How does it work?

Create and compile shader programs.

- Fragment shader
  - Precision
    - lowp
    - mediump
    - highp

# How does it work?

Create and compile shader programs.

- Fragment shader

```
const FRAG_CODE = `
    varying lowp vec4 vColor;
    void main(void) {
      gl_FragColor = vColor;
    }`;
```

# How does it work?

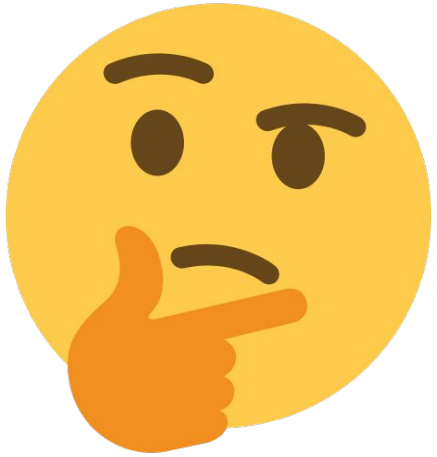
Create and compile shader programs.

- Shader Program
  - Vertex Shader
  - Fragment Shader

# How does it work?

Associate the shaders with buffer objects.

- How do we pull the data from the buffer?



# How does it work?

Associate the shaders with buffer objects.

- We tell WebGL where to put the data:
  - Location of the attribute
  - Link the buffer and the attribute

# How does it work?

## Associate the shaders with buffer objects.

- We tell WebGL where to put the data:

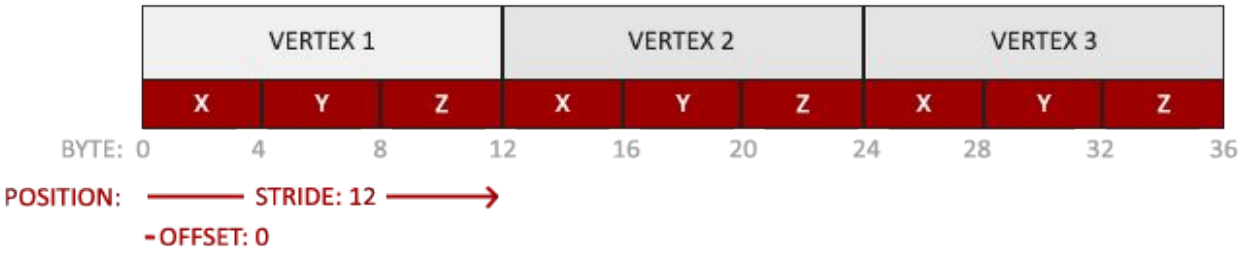
```
const VERTEX_CODE = `
    attribute vec2 coordinates;
    attribute vec4 aVertexColor;
    varying lowp vec4 vColor;
    void main(void) {
        gl_Position = vec4(coordinates, 0.0, 1.0);
        vColor = aVertexColor;
    }`;
```

# How does it work?

Associate the shaders with buffer objects.

- We tell WebGL how to do it:

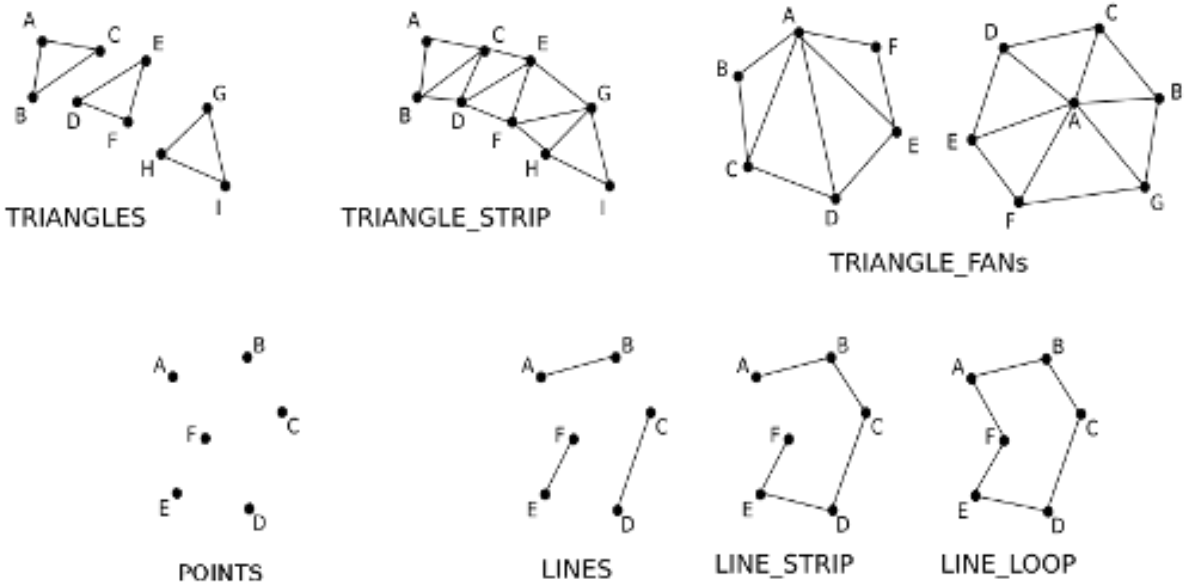
```
const NUM_COMPONENTS = 2;      // Pull out per iteration
const TYPE = gl.FLOAT;         // Data type
const NORMALIZE = false;       // Needed to normalize?
const STRIDE = 0;              // Bytes between elements
const OFFSET = 0;              // Bytes to start
```



# How does it work?

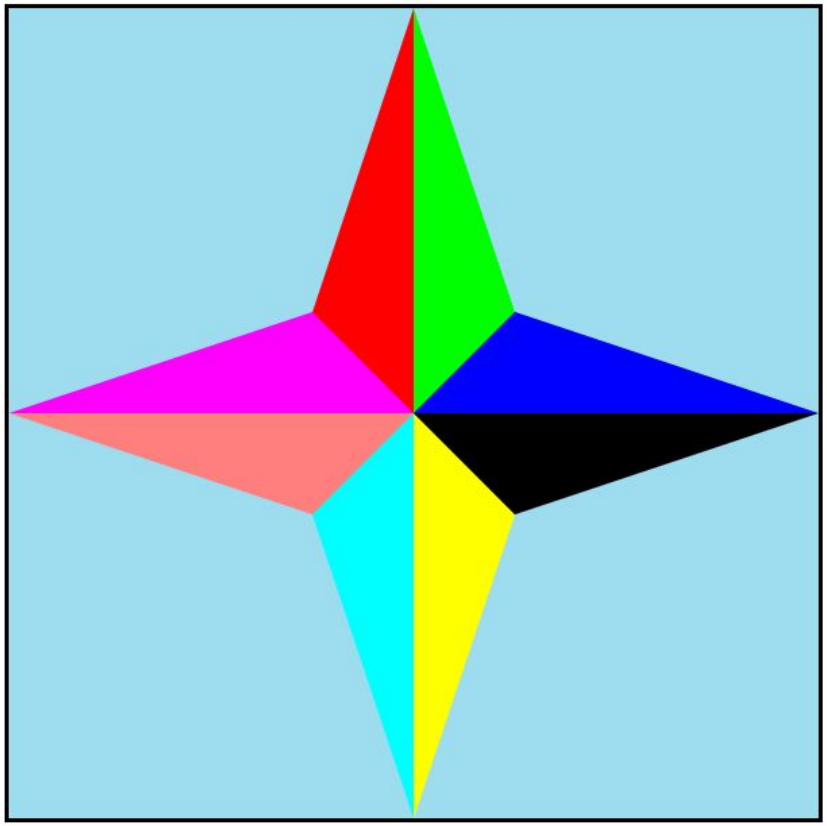
Draw the objects.

- Number of vertex → 24
- Primitive forms:



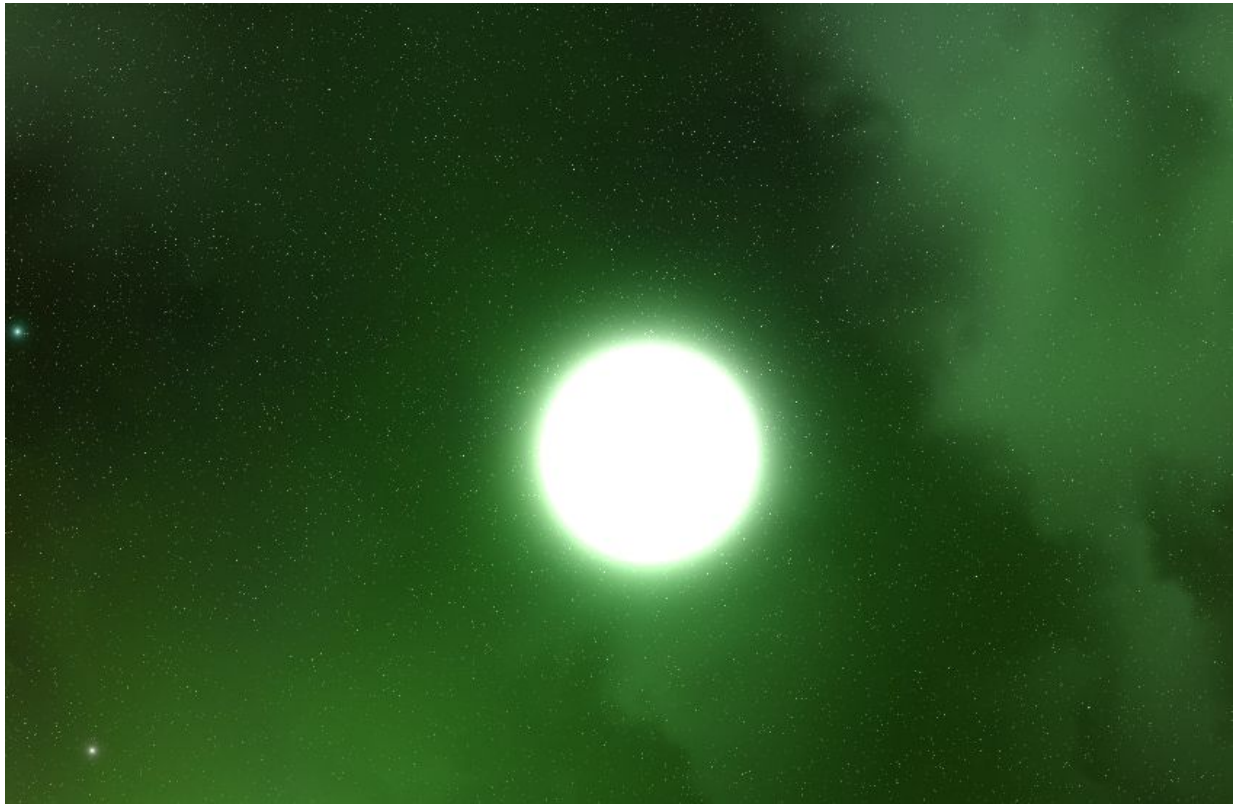
# How does it work?

Final result.



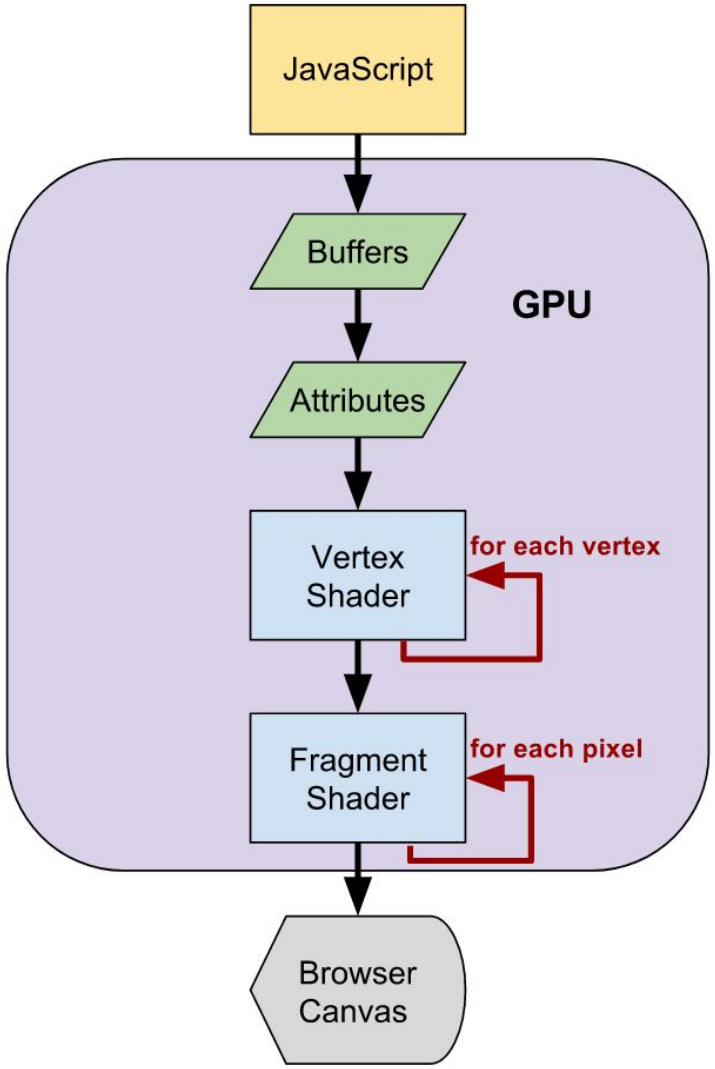
# Additional example

## Random 2D Space Scenes in WebGL



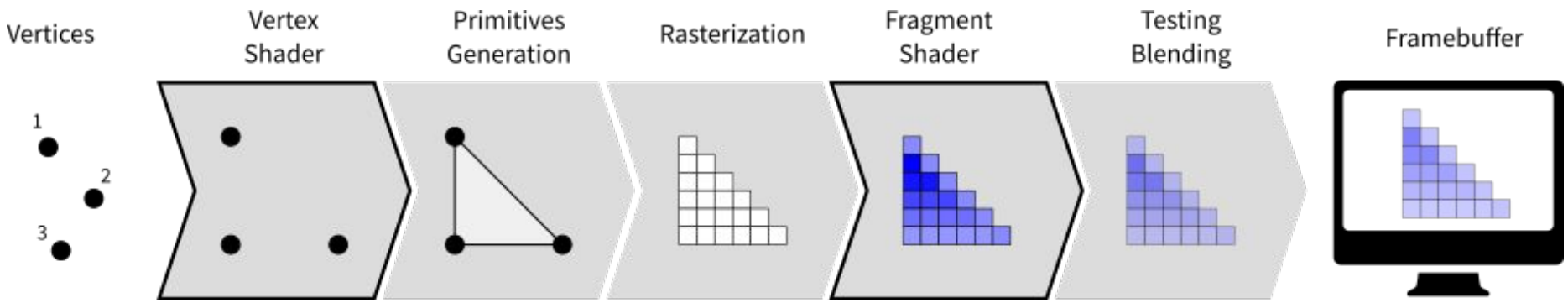
# How does it work?

## Summary



# How does it work?

## Summary



# Basic functions and Qualifiers

- Qualifiers:
  - **const**: constants during the execution
  - **attribute**: global variable that is constant in each vertex

# Basic functions and Qualifiers

- Qualifiers:
  - **uniform**: global variable that is constant in each primitive
  - **varying**: share information between the vertex shader and the fragment shader

# Basic functions and Qualifiers

- Buffer Objects
- Programs and shaders
- Uniforms and attributes
- Writing to the Draw Buffer
- Qualifiers

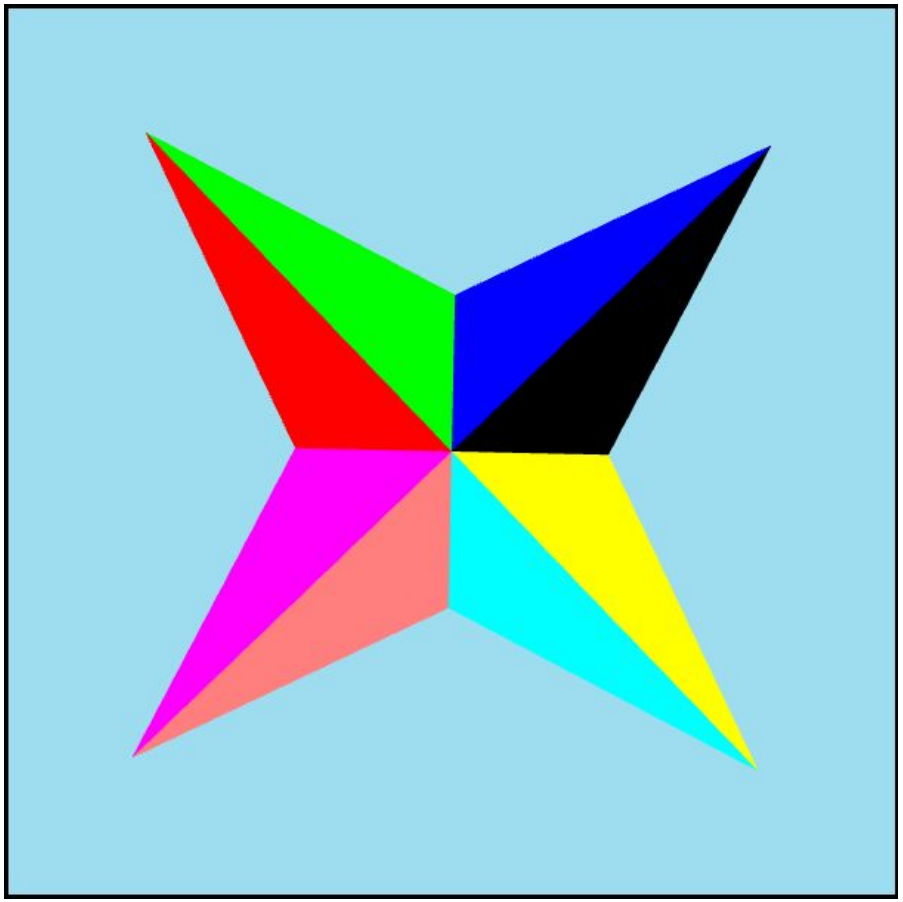
# Animations

In order to perform an animation:

- Track the movement.
- Update our shaders.
- Draw the current movement.
- Update our movement.

# Animations

What want to achieve.



# Animations

## Shaders

- We need to tell Webgl how to rotate the figure.
- Add a new variable to our shader to perform the rotation.

# Animations

## Shaders

```
const VERTEX_CODE = `
attribute vec2 coordinates;
attribute vec4 aVertexColor;
varying lowp vec4 vColor;
uniform mat4 uModelViewMatrix;   ← New
void main(void) {
  gl_Position = vec4(coordinates, 0.0, 1.0)
* uModelViewMatrix;
  vColor = aVertexColor;
}`;
```

# Animations

## Shaders

- Transformations

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(x) & \sin(x) & 0 \\ 0 & -\sin(x) & \cos(x) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Rotate X Matrix

$$\begin{bmatrix} \cos(y) & 0 & -\sin(y) & 0 \\ 0 & 1 & 0 & 0 \\ \sin(y) & 0 & \cos(y) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Rotate Y Matrix

$$\begin{bmatrix} \cos(z) & \sin(z) & 0 & 0 \\ -\sin(z) & \cos(z) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Rotate Z Matrix

# Animations

Updating rotation

- Variable that tracks rotation.

```
let rotation = 0.0;
```

- Each time we draw the figure, we update the rotation and the shaders.

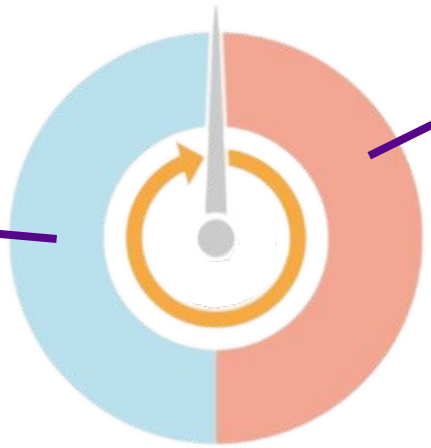
# Animations

## Rendering

- Using the current time to know how far to move the figure.
- **requestAnimationFrame** passes the number of milliseconds since the last frame was rendered to it's callback.

# Animations

Draw the figure



Update the rotation

Repeat in the next animation step

# Animations

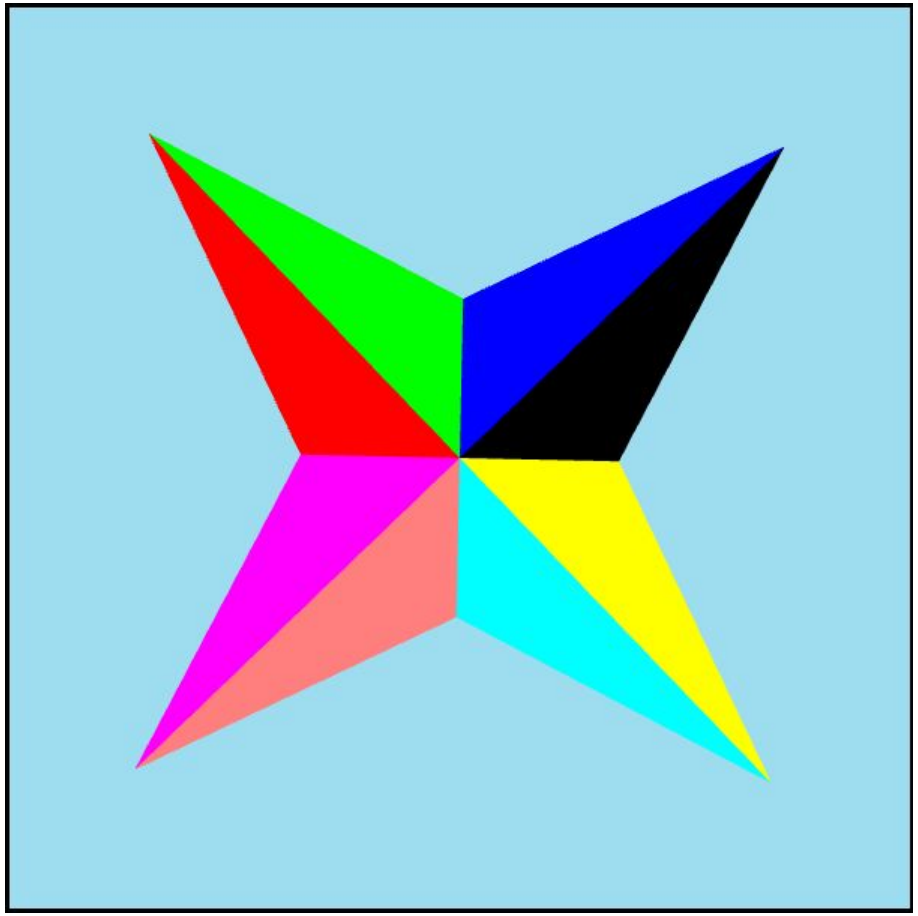
## Starting the animation

- We use the **requestAnimationFrame** function to call our rendering function.

```
function main() {
  ...
  requestAnimationFrame(render);
}
```

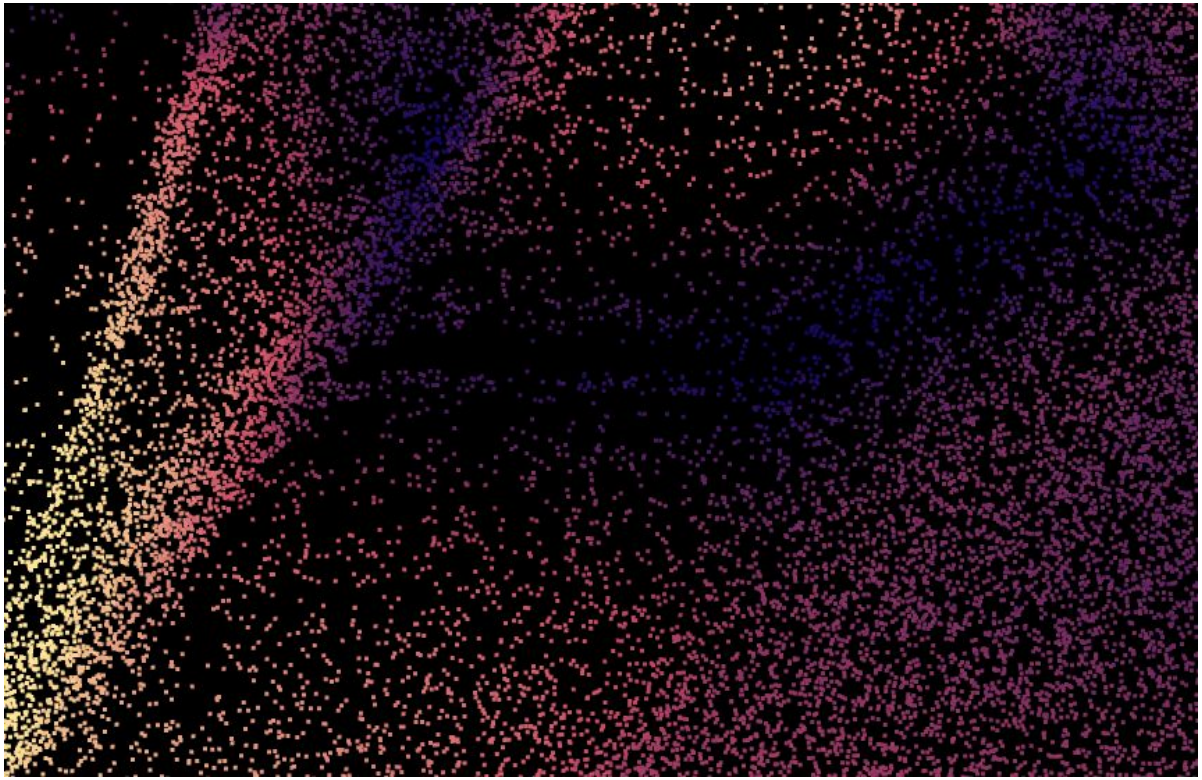
# Animations

## Final result



# Additional example

## Particles flowing

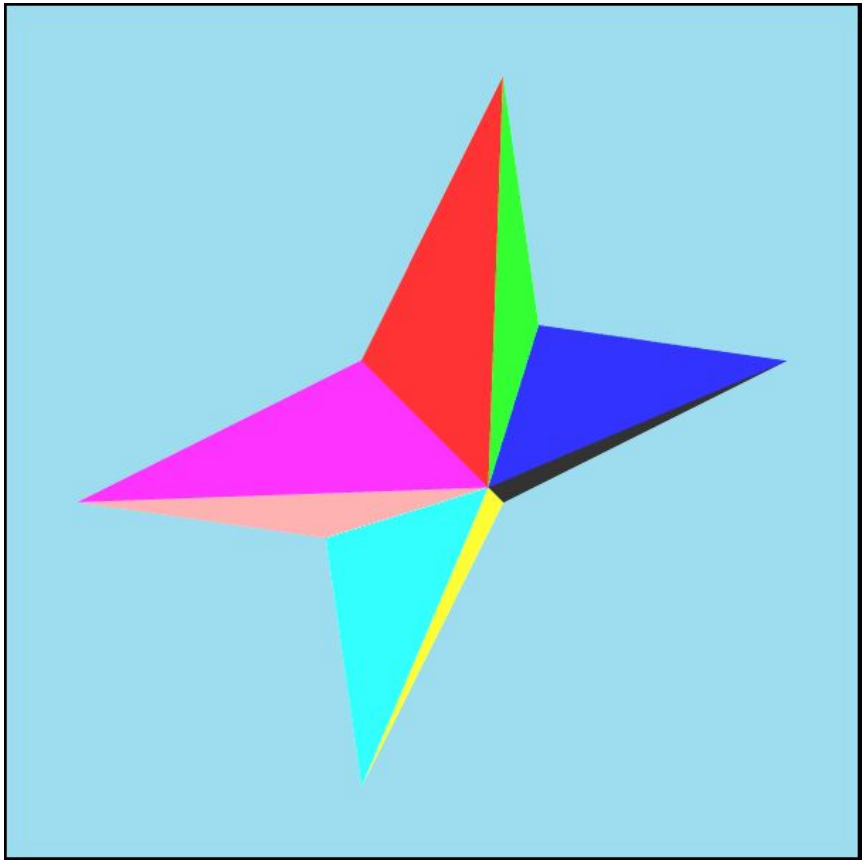


# Creating 3D figures

- Add new coordinates.
- Set the colors of the new elements.
- Update drawing parameters:
  - Vertex shader
  - Buffer access
  - Number of vertex to draw

# Creating 3D figures

## What we want to achieve.



# Creating 3D figures

- Adding new coordinates

```
let vertex = [-1.0, 0.0, 0.0,
              -0.25, 0.25, 0.0,
               0.0, 0.0, 0.25,
                    .
                    .
                    .
               -1.0, 0.0, 0.0,
               -0.25, 0.25, 0.0,
                0.0, 0.0, -0.25,
                    .
                    .
                    .
               ];
```



Opposite vertex

# Creating 3D figures

- Set the colors of the new elements.

```
let triangleColors = [[1.0, 0.0, 1.0, 1.0],
                      ...
                      [1.0, 0.0, 1.0, 0.8]];
```

# Creating 3D figures

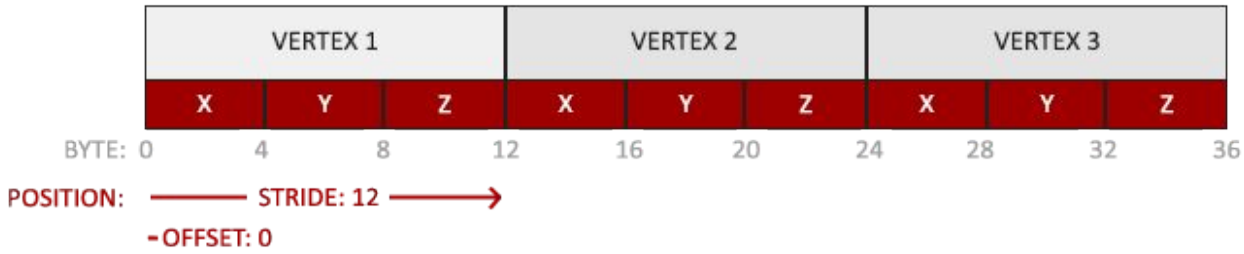
- Update vertex shader.

```
let VERTEX_CODE = `
  attribute vec3 coordinates;
  attribute vec4 aVertexColor;
  uniform mat4 uModelViewMatrix;
  varying lowp vec4 vColor;
  void main(void) {
    gl_Position = vec4(coordinates, 1.0) * uModelViewMatrix;
    vColor = aVertexColor;
  }`;
```

# Creating 3D figures

- Update buffer access.

```
const NUM_COMPONENTS = 3;     // Pull out per iteration
const TYPE = gl.FLOAT;        // Data type
const NORMALIZE = false;      // Needed to normalize?
const STRIDE = 0;             // Bytes between elements
const OFFSET = 0;             // Bytes to start
```



# Creating 3D figures

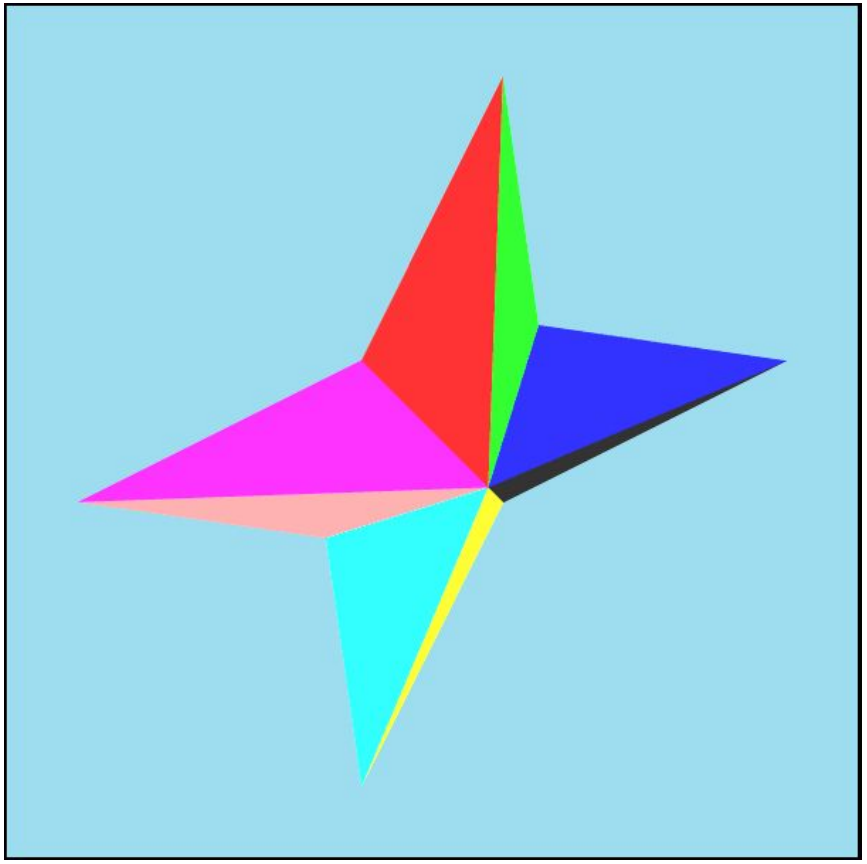
- Update the number of vertex to draw.

```
const MODE = CONTEXT.TRIANGLE_STRIP // Figure we are going to draw
const FIRST = 0; // Starting index of the array of vertex
const COUNT = 48; // Number of vertex to be rendered

// Draw the figure
context.drawArrays(MODE, FIRST, COUNT);
```

# Creating 3D figures

## Final result



# Additional example

## Interview

# Summary

- Canvas VS WebGL
- Geometry and colors in WebGL
- Shader programs
- Create a simple animation
- Create a simple 3D figure

# If this is not enough...

- Apply textures to the figures
- Apply lighting
- User interface
- three.js

# Impressive WebGL works

- Jellyfish
- Videogames
  - Quake
  - WebGL Games
- Reflektor - Arcade Fire

# Bibliografía

- Tutoriales
  - https://www.toptal.com/javascript/3d-graphics-a-webgl-tutorial
  - https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API/Tutorial
  - https://webglfundamentals.org/
  - https://www.tutorialspoint.com/webgl/webgl_shaders.htm
- Tarjeta referencia WebGL
  - https://www.khronos.org/files/webgl/webgl-reference-card-1_0.pdf
- Ejemplo aplicación
  - https://www.tutorialspoint.com/webgl/webgl_sample_application.htm
- Extras
  - http://glmatrix.net/docs/mat4.js.html
  - https://en.wikipedia.org/wiki/Triangle_strip

# Any questions?


Cristo Daniel Navarro Rodríguez
(alu0101024608@ull.edu.es)
Luciana Varela Díaz
(alu0101106175@ull.edu.es)


Universidad
de La Laguna