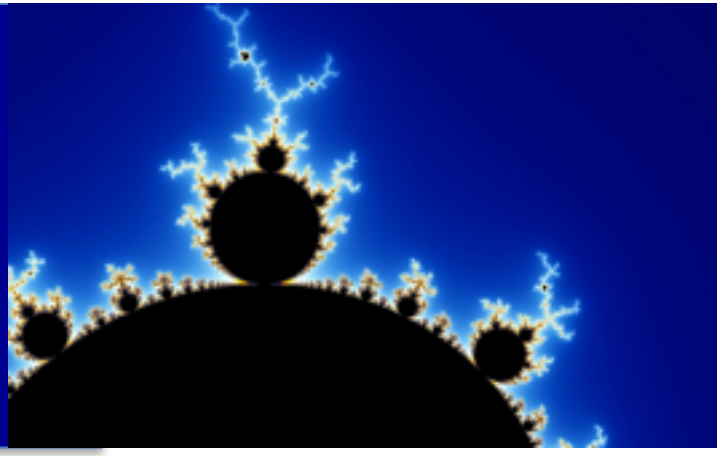
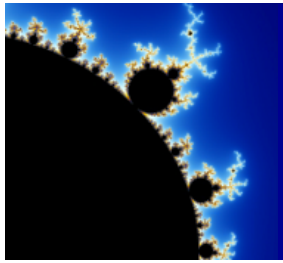
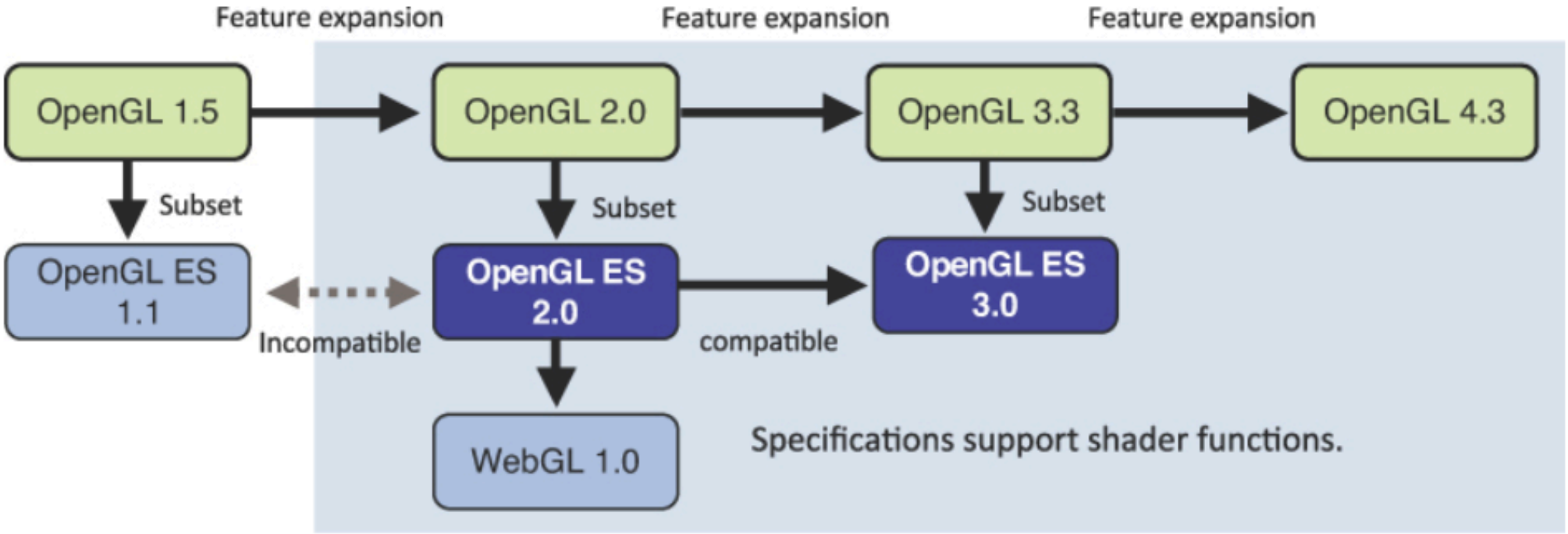
Computer Graphics



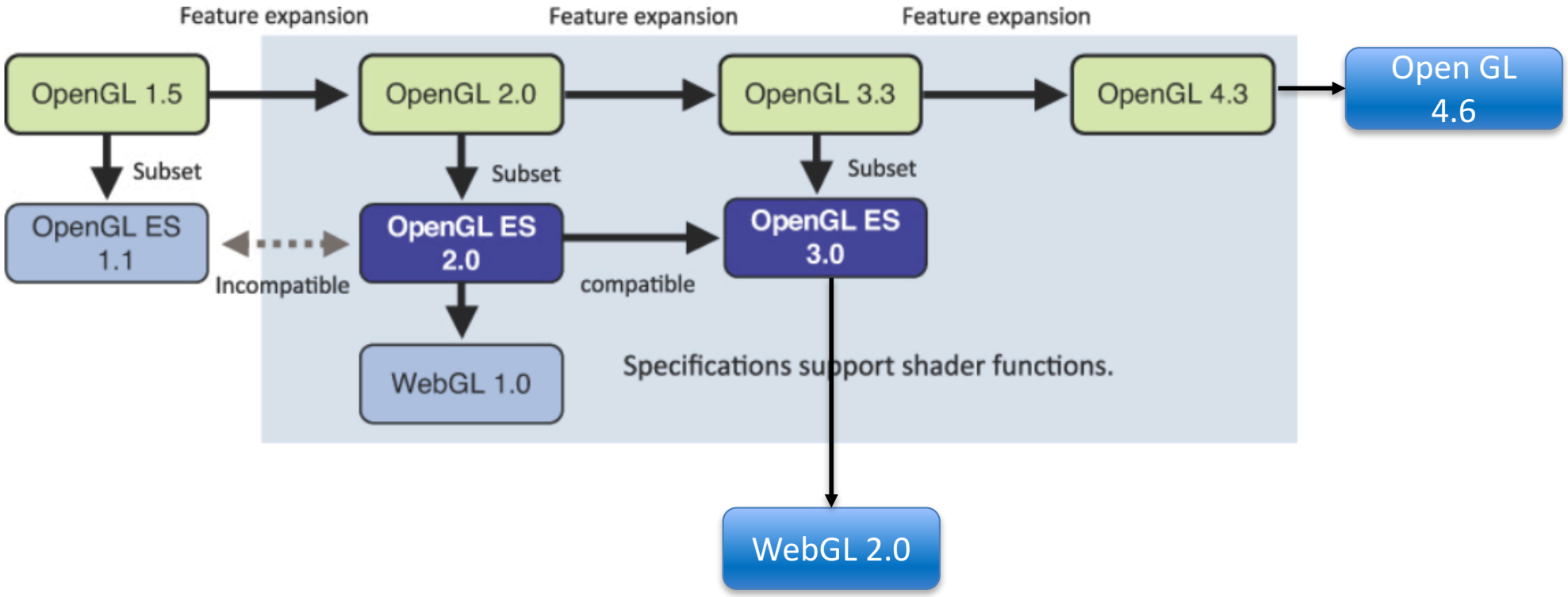
Programming with WebGL
Getting Started

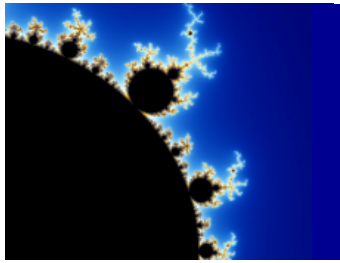


WebGL

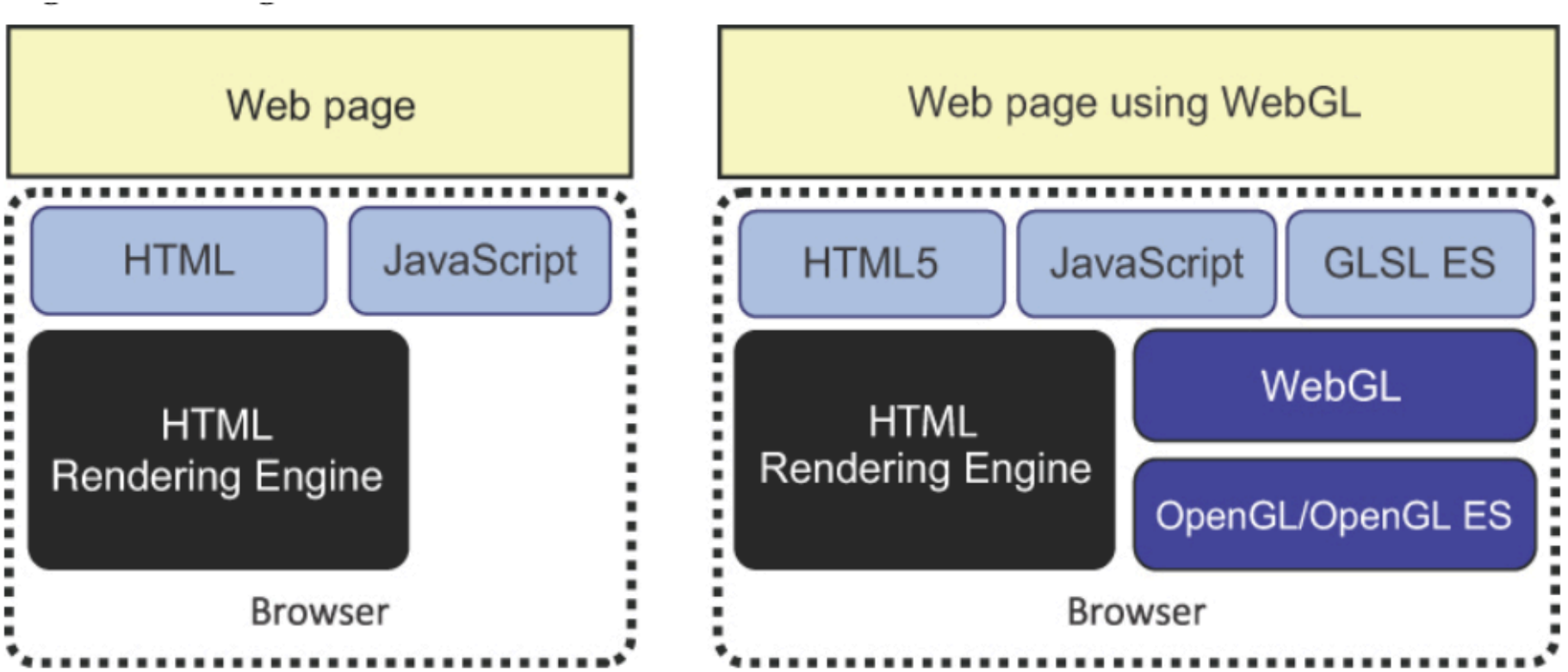

Feature expansion
Feature expansion
Feature expansion
OpenGL 1.5
OpenGL 2.0
OpenGL 3.3
OpenGL 4.3
Subset
Subset
Subset
OpenGL ES 1.1
OpenGL ES 2.0
OpenGL ES 3.0
Incompatible
compatible
WebGL 1.0
Specifications support shader functions.

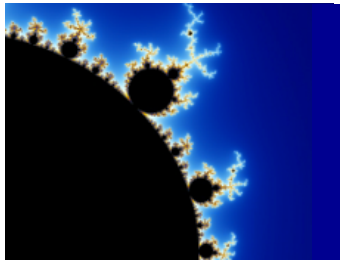
Current versions



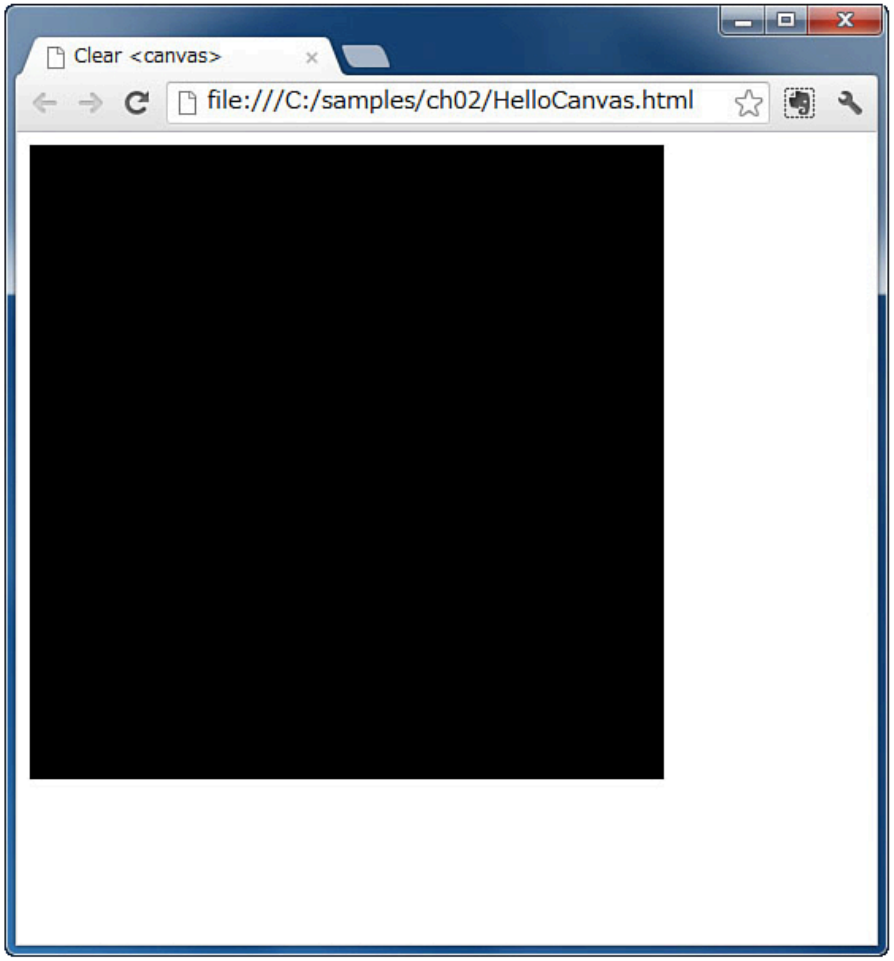


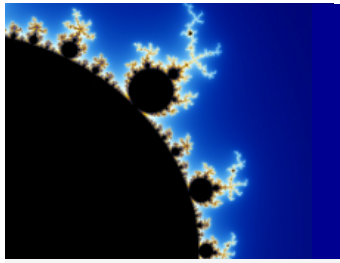
Execution in Browser





Example: Hello Canvas





Example: Hello Canvas

```html
<!DOCTYPE html>
<html>
<head>
    <meta charset="utf-8" />
    <title>Clear "canvas"</title>
</head>

<script type="text/javascript" src="../Common/webgl-utils.js"></script>
<script type="text/javascript" src="../Common/initShaders.js"></script>
<script type="text/javascript" src="../Common/MV.js"></script>
<script type="text/javascript" src="1-HelloCanvas.js"></script>

<body onload="main()">
<canvas id="webgl" width="400" height="400">
Oops ... your browser doesn't support the HTML5 canvas eleme
</canvas>
</body>
</html>
```

HelloCanvas.html

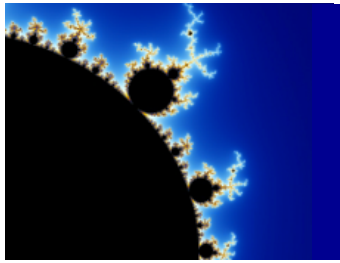
1-HelloCanvas.js

```
function main() {
  // Retrieve <canvas> element
  var canvas = document.getElementById("webgl");

  // Get the rendering context for WebGL
  var gl = WebGLUtils.setupWebGL(canvas);
  if (!gl) {
    console.log("Failed to get the
                 rendering context for WebGL");
    return;
  }

  // Set clear color
  gl.clearColor(1.0, 0.0, 0.0, 1.0);

  // Clear <canvas>
  gl.clear(gl.COLOR_BUFFER_BIT);
}
```



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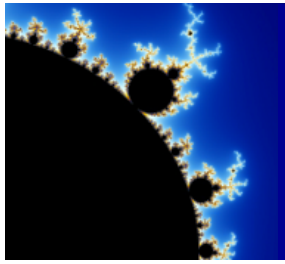
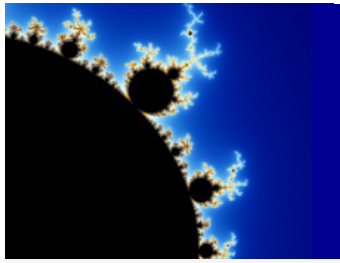
```

- onload function
- Supporting libraries/files
- javascript source file
- Console in Chrome



Files

- **`../Common/webgl-utils.js`**: Standard utilities for setting up WebGL context in Common directory on website
- **`../Common/initShaders.js`**: contains JS and WebGL code for reading, compiling and linking the shaders
- **`../Common/MV.js`**: our matrix-vector package
- **`1-HelloCanvas.js`**: the application file



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HelloCanvas.html

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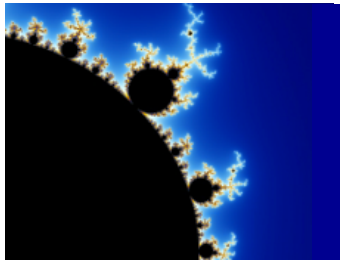
                 rendering context for WebGL");
    return;
  }

  // Set clear color
  gl.clearColor(1.0, 0.0, 0.0, 1.0);

  // Clear <canvas>
  gl.clear(gl.COLOR_BUFFER_BIT);
}
```



Example: Hello Canvas

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  var canvas = document.getElementById('webgl');

  // Get the rendering context for WebGL
  var gl = WebGLUtils.setupWebGL(canvas);
  if (!gl) {
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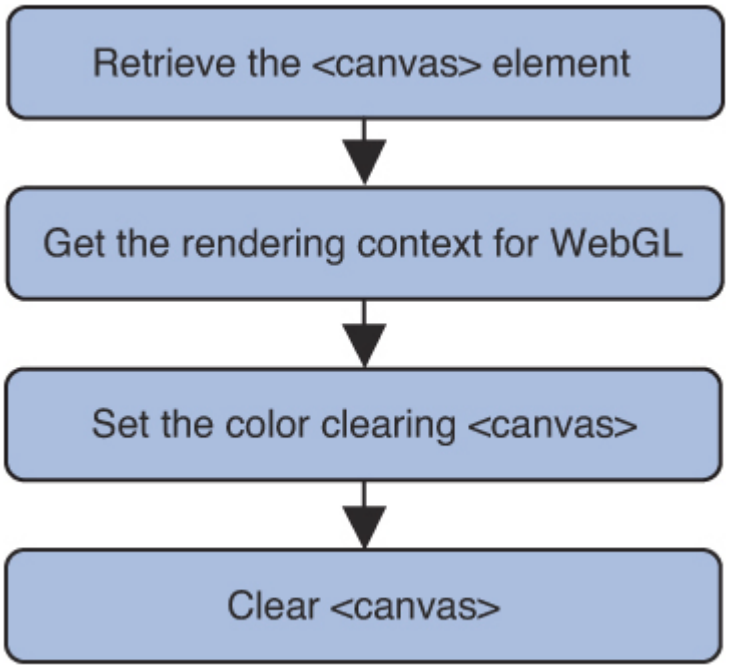
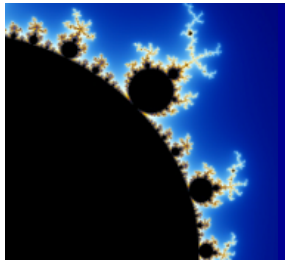
    return;
  }

  // Set clear color
  gl.clearColor(1.0, 0.0, 0.0, 1.0);

  // Clear <canvas>
  gl.clear(gl.COLOR_BUFFER_BIT);
}
```

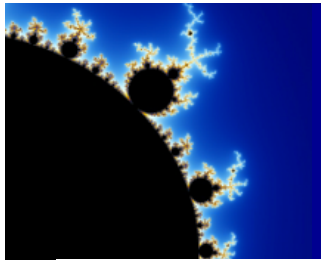




Example: Hello Canvas

- A WebGL context contains all the WebGL enumerations (such as COLOR_BUFFER_BIT) and APIs (such as drawArrays()). Therefore, you must create a WebGL context before making any WebGL API calls.

- https://www.khronos.org/registry/webgl/specs/latest/1.0/webgl.idl gives details of the WebGL context



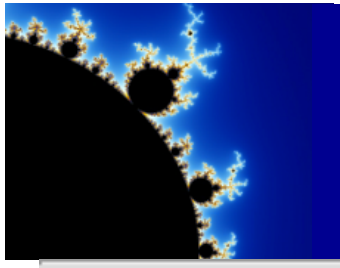
gl.clearColor

`gl.clearColor` `(red, green, blue, alpha)`

Specify the clear color for a drawing area:

Parameters	red	Specifies the red value (from 0.0 to 1.0).
	green	Specifies the green value (from 0.0 to 1.0).
	blue	Specifies the blue value (from 0.0 to 1.0).
	alpha	Specifies an alpha (transparency) value (from 0.0 to 1.0).
		0.0 means transparent and 1.0 means opaque.
	If any of the values of these parameters is less than 0.0 or more than 1.0 is truncated into 0.0 or 1.0, respectively.	
Return value	None	
Errors[2]	None	

```
(1.0, 0.0, 0.0, 1.0)    red
(0.0, 1.0, 0.0, 1.0)    green
(0.0, 0.0, 1.0, 1.0)    blue
(1.0, 1.0, 0.0, 1.0)    yellow
(1.0, 0.0, 1.0, 1.0)    purple
(0.0, 1.0, 1.0, 1.0)    light blue
(1.0, 1.0, 1.0, 1.0)    white
```



gl.clear(buffer)

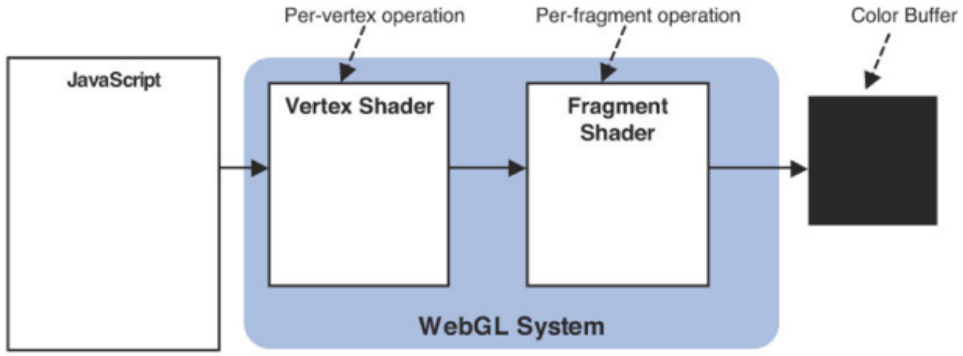
`gl.clear(buffer)`

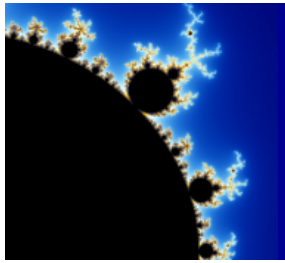
Clear the specified buffer to preset values. In the case of a color buffer, the value (color) specified by `gl.clearColor()` is used.

Parameters	buffer	Specifies the buffer to be cleared. Bitwise `OR` (`|`) operators are use to specify multiple buffers.	
		`gl.COLOR_BUFFER_BIT`	Specifies the color buffer.
		`gl.DEPTH_BUFFER_BIT`	Specifies the depth buffer.
		`gl.STENCIL_BUFFER_BIT`	Specifies the stencil buffer.
Return value	None		
Errors	INVALID_VALUE	*buffer* is none of the preceding three values.	

Example: Hello Point

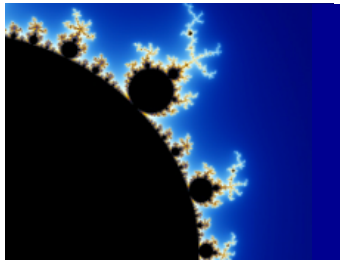
- Adding Vertex Shader and Fragment Shader
- Vertex Shader: Program that describes the traits (position, colors, and others) of a vertex
  - Examples of a vertex
- Fragment Shader: Program that deals with per fragment processing, such as lighting





Fragment shader

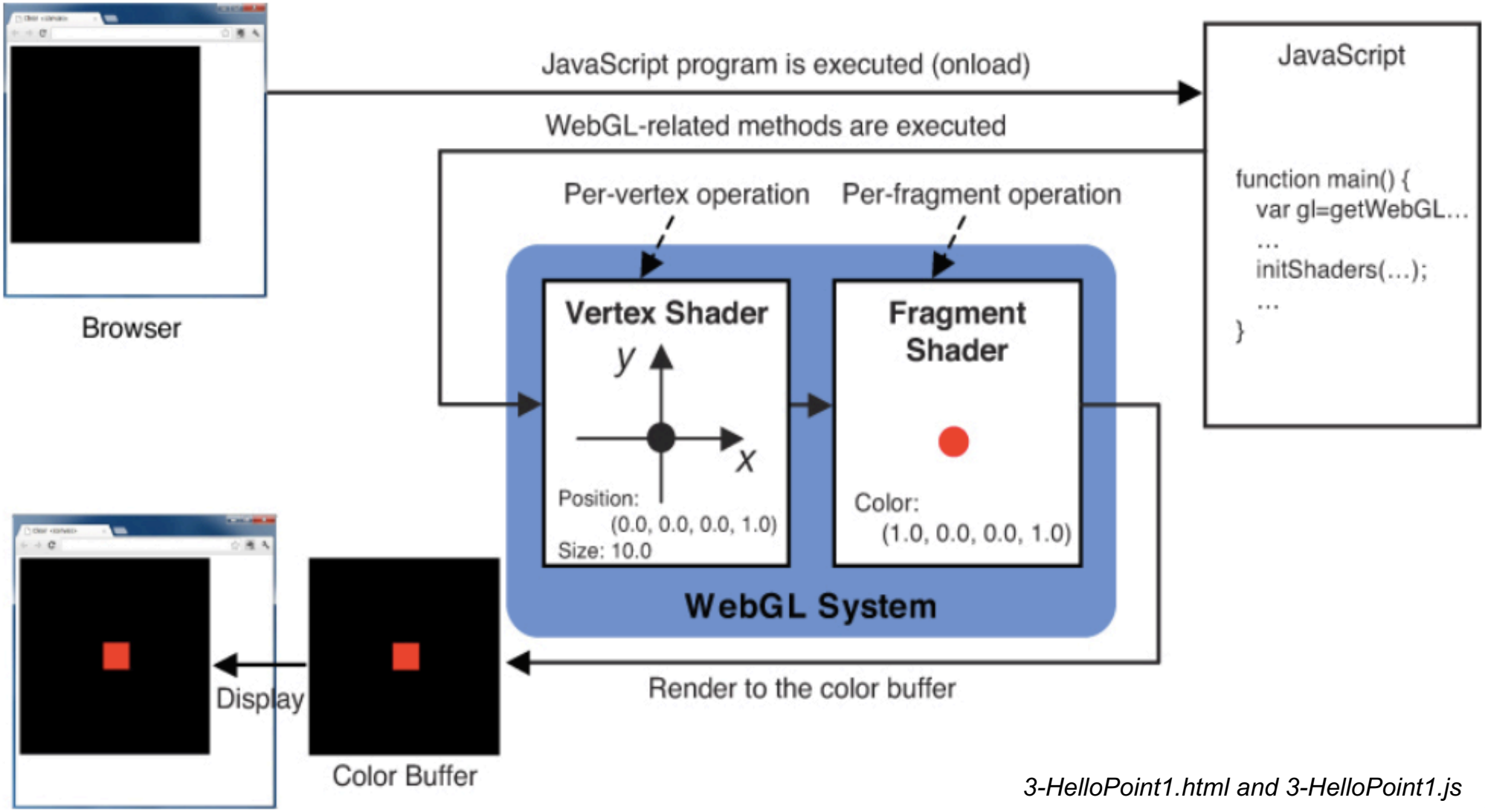
- Fragment Shader: Program that deals with per fragment processing, such as lighting
  - What is a fragment?
  - A **Fragment** is a collection of values produced by the Rasterizer. Each fragment represents a sample-sized segment of a rasterized Primitive. The size covered by a fragment is related to the pixel area, but rasterization can produce multiple fragments from the same triangle per-pixel, depending on various multisampling parameters and OpenGL state. There will be at least one fragment produced for every pixel area covered by the primitive being rasterized.
  - Must set precision in fragment shader, unless there is a default precision set
    - determines how much precision the GPU uses when calculating floats.
    - Highp, mediump, lowp



GLSL

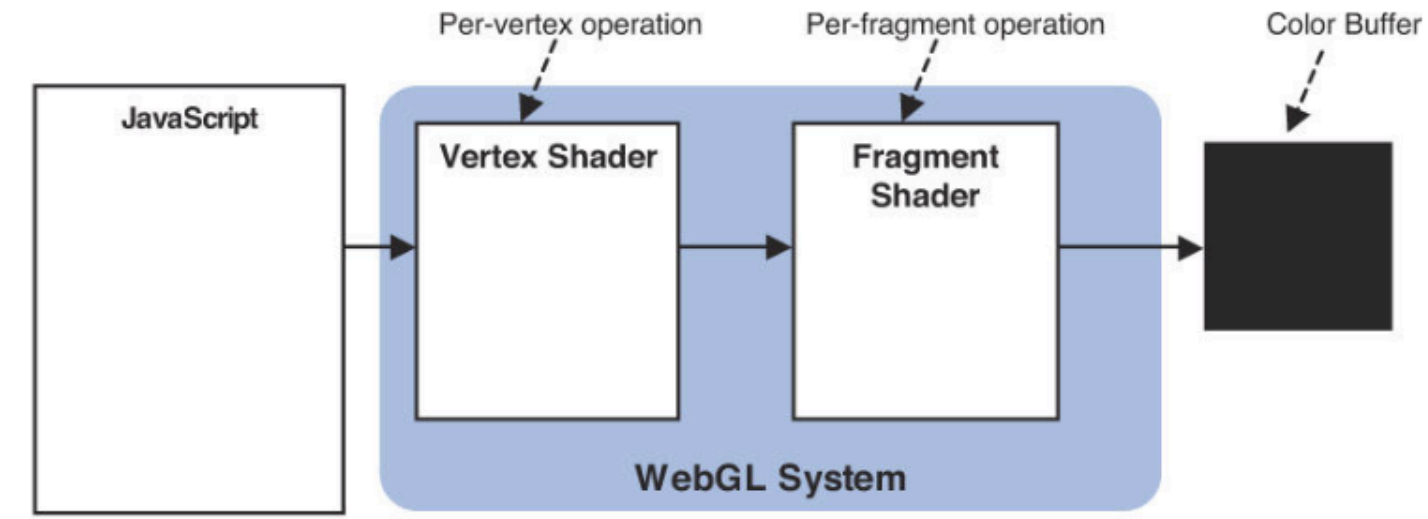
- OpenGL Shading Language
- C-like with
  - Matrix and vector types (2, 3, 4 dimensional)
  - Overloaded operators
  - C++ like constructors
- Code sent to shaders as source code
- WebGL functions compile, link and get information to shaders
  - Variables used back and forth in between the shaders

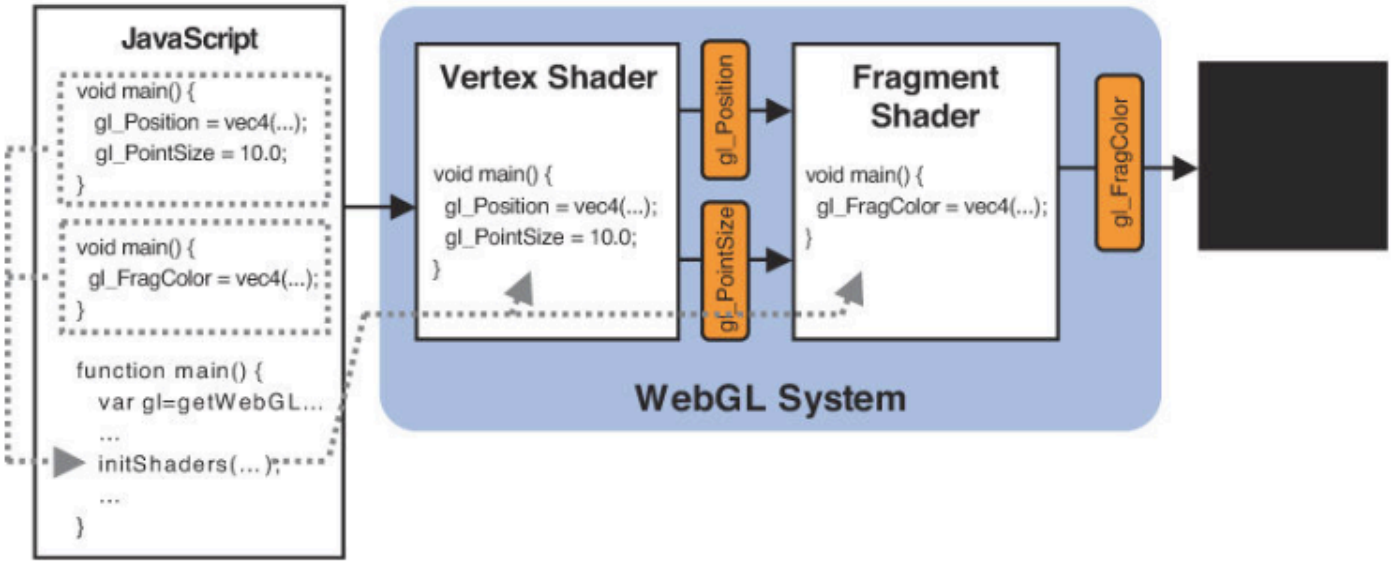
Example: Hello Point



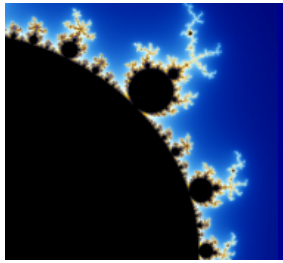
3-HelloPoint1.html and 3-HelloPoint1.js

Behavior of initShader





WebGL applications consist of a javascript program that is executed by the browser and the shader program executed within the WebGL system

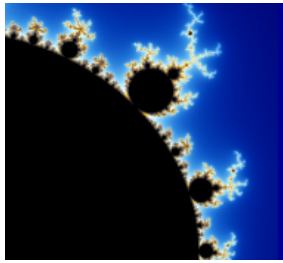


Hello Point (shader programs)

```
<script id="vertex-shader" type="x-shader/x-vertex">
// Vertex shader program
void main() {
  gl_Position = vec4(0.0, 0.0, 0.0, 1.0); // Set the vertex coordin
  gl_PointSize = 10.0;                    // Set the point size
}
</script>

<script id="fragment-shader" type="x-shader/x-fragment">
// Fragment shader program
void main() {
  gl_FragColor = vec4(1.0, 0.0, 0.0, 1.0); // Set the point color
}
</script>
```

3-HelloPoint1.html



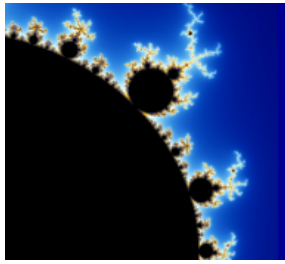
Hello Point (shader programs)

Type and Variable Name	Description
vec4 `gl_Position`	Specifies the position of a vertex
float `gl_PointSize`	Specifies the size of a point (in pixels)

Built in values in the vertex shader

Type and Variable Name	Description
vec4 `gl_FragColor`	Specify the color of a fragment (in RGBA)

Built in values in the fragment shader



Hello Point (shader programs)

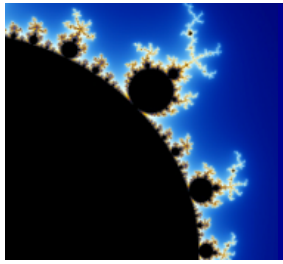
Type	Description
float	Indicates a floating point number
vec4	Indicates a vector of four floating point numbers

`float`	`float`	`Float`	`float`

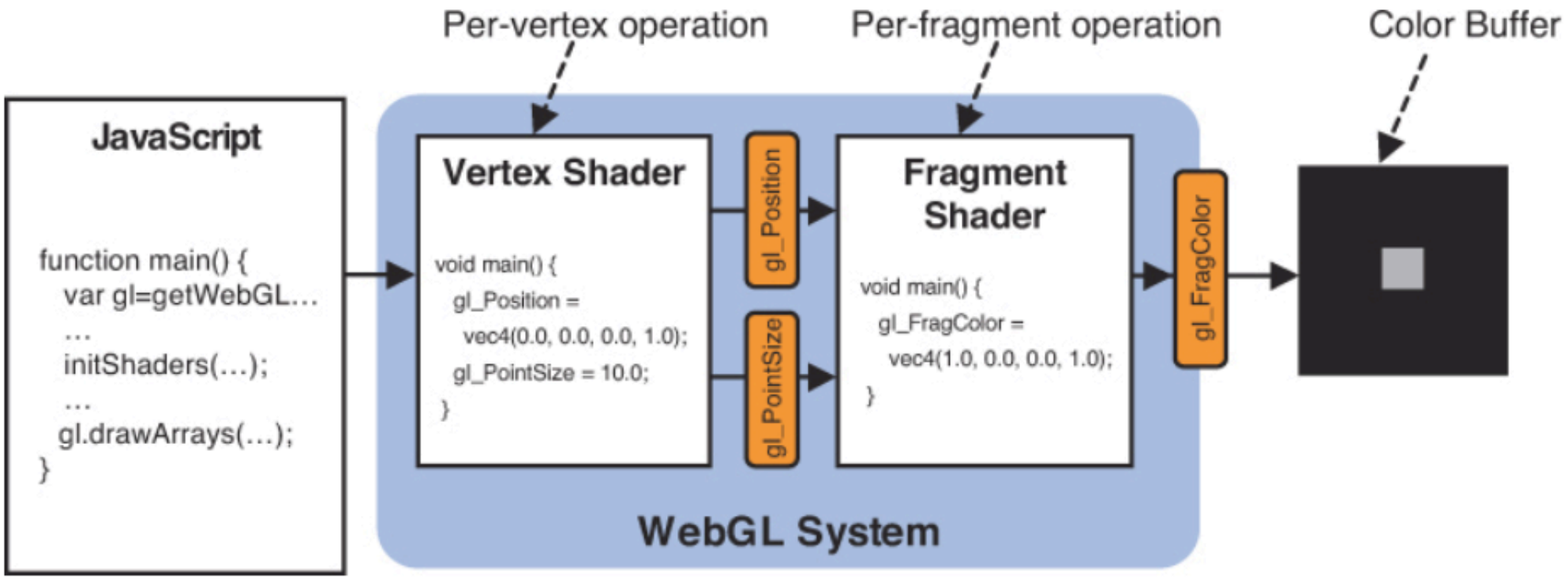
`vec4 vec4(v0, v1, v2, v3)`

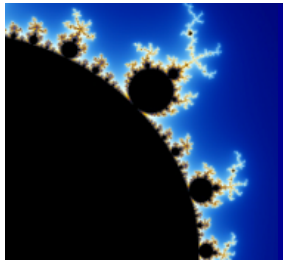
Construct a `vec4` object from *v0*, *v1*, *v2*, and *v3*.

Parameters	v0, v1, v2, v3	Specifies floating point numbers.
Return value	A `vec4` object made from *v0*, *v1*, *v2*, and *v3*.	

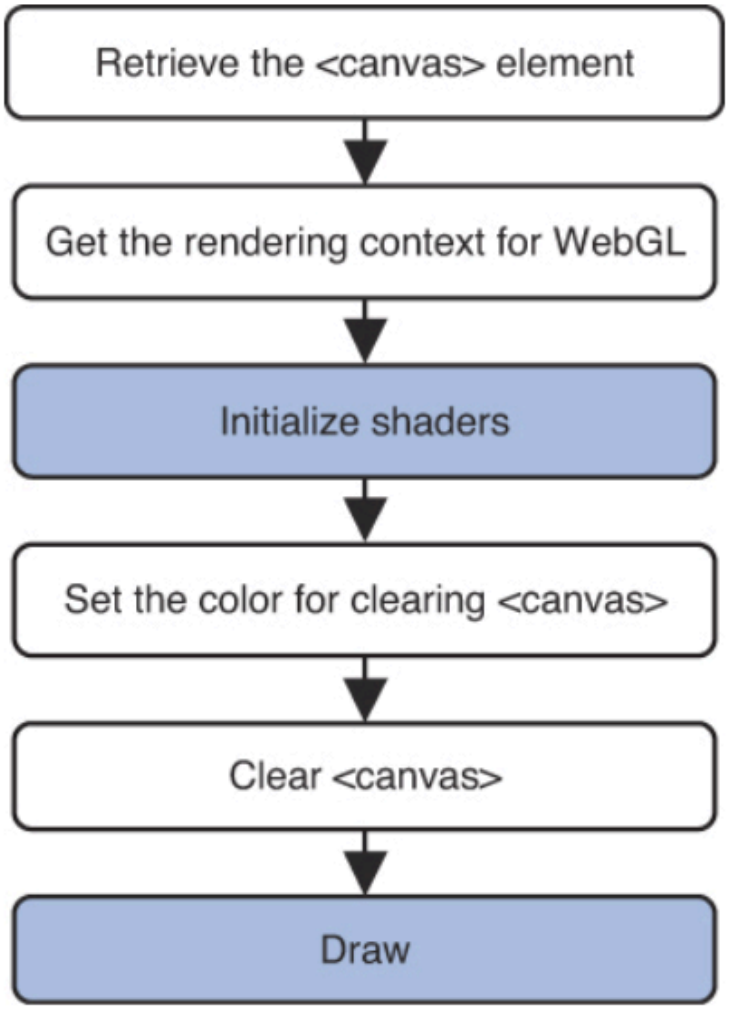


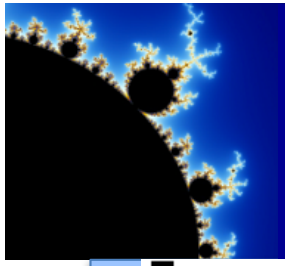
Variables in shader programs





Hello Point (Javascript)





Hello Point (Javascript)

```
function main() {
  // Retrieve <canvas> element
  var canvas = document.getElementById("webgl");

  // Get the rendering context for WebGL
  var gl = WebGLUtils.setupWebGL( canvas );
  if (!gl) {
    console.log('Failed to get the rendering context for WebGL');
    return;
  }

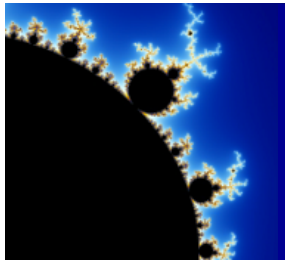
  // Initialize shaders
  var  program = initShaders( gl, "vertex-shader", "fragment-shader" );
  if (!program) {
    console.log('Failed to intialize shaders.');
    return;
  }
  gl.useProgram( program );

  // Specify the color for clearing <canvas>
  gl.clearColor(0.0, 1.0, 1.0, 1.0);

  // Clear <canvas>
  gl.clear(gl.COLOR_BUFFER_BIT);

  // Draw a point
  gl.drawArrays(gl.POINTS, 0, 1);
}
```

3-HelloPoint1.js

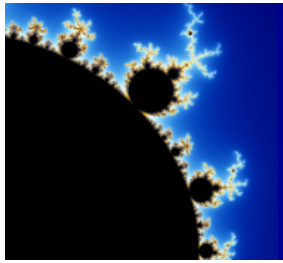


Hello Point : gl.drawArrays

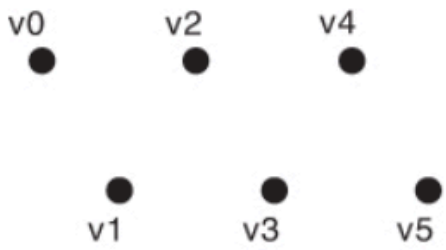
`gl.drawArrays(mode, first, count)`

Execute a vertex shader to draw shapes specified by the *mode* parameter.

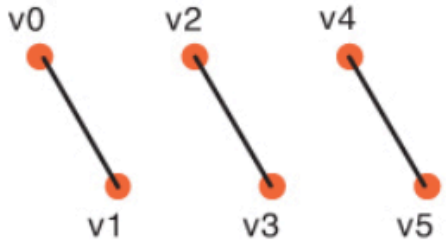
Parameters	mode	Specifies the type of shape to be drawn. The following symbolic constants are accepted: `gl.POINTS`, `gl.LINES`, `gl.LINE_STRIP`, `gl.LINE_LOOP`, `gl.TRIANGLES`, `gl.TRIANGLE_STRIP`, and `gl.TRIANGLE_FAN`.
	first	Specifies which vertex to start drawing from (integer).
	count	Specifies the number of vertices to be used (integer).
Return value	None	
Errors	INVALID_ENUM *mode* is none of the preceding values.	
	INVALID_VALUE *first* is negative or *count* is negative.	



drawArrays mode

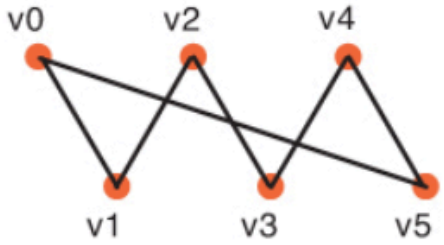


gl.POINTS

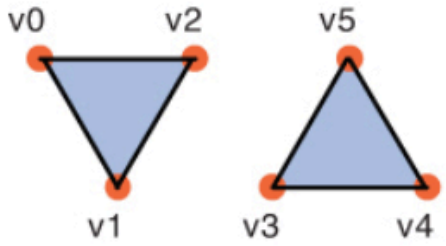


gl.LINES

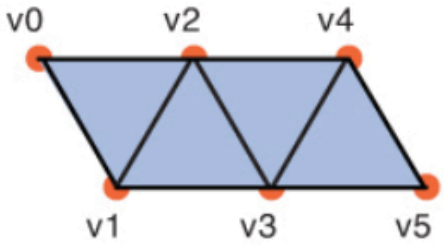
gl.LINE_STRIP



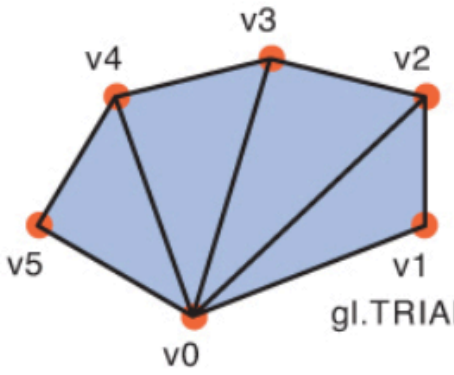
gl.LINE_LOOP



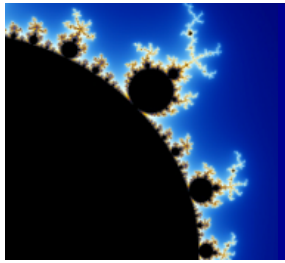
gl.TRIANGLES



gl.TRIANGLE_STRIP



gl.TRIANGLE_FAN

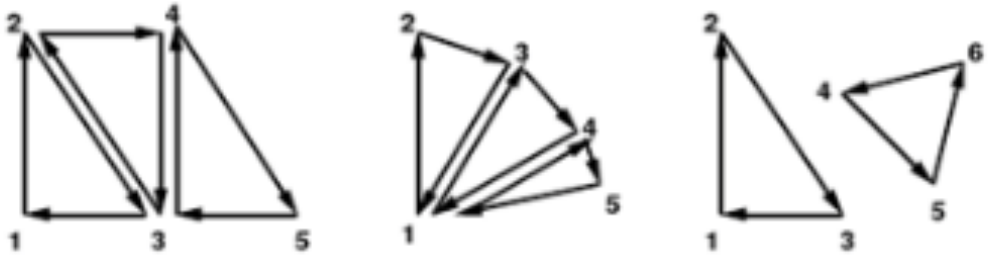


drawArrays mode

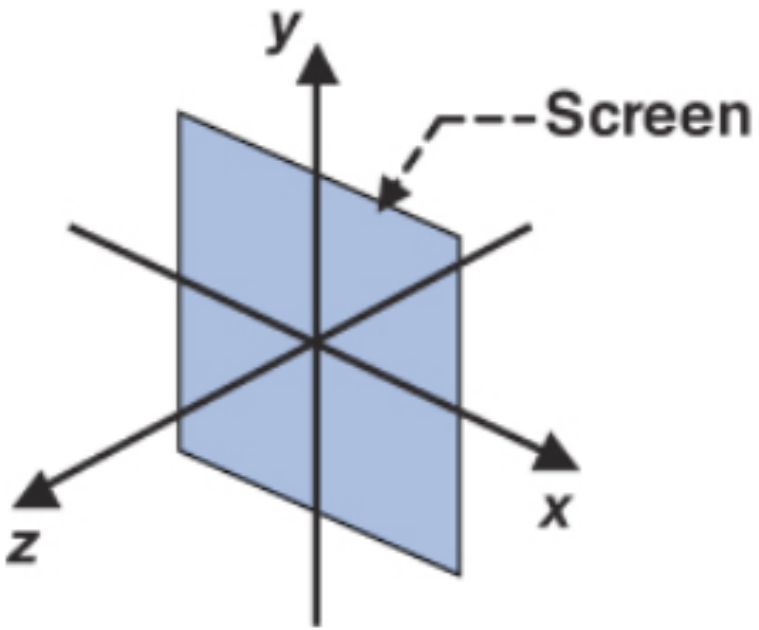
Points

Lines: Strips (connected), Loops (closed), Lines (separate)

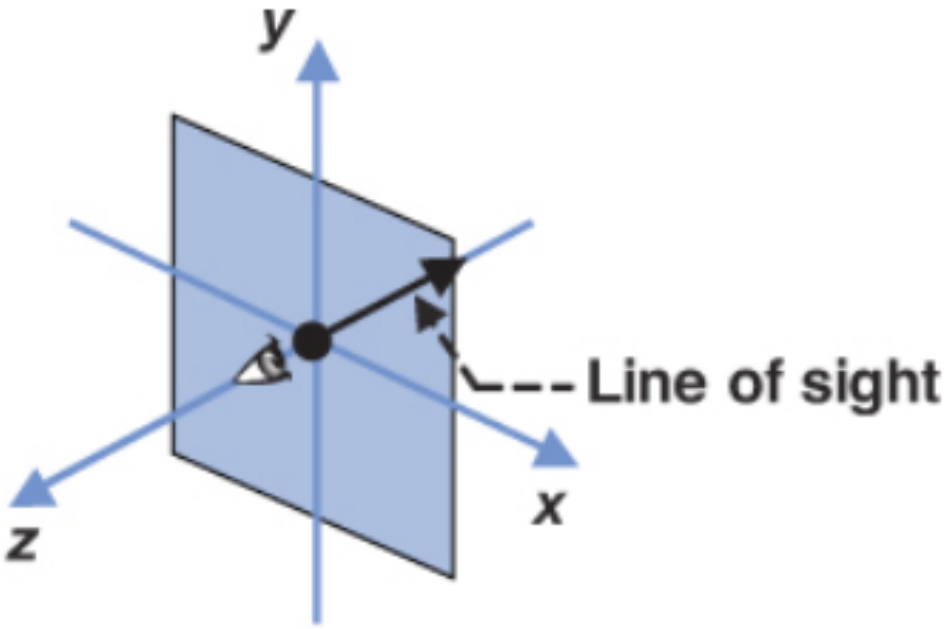
Triangle: Strips (shared common edge), Fans (shared first vertex), Triangles (separate)



WebGL Coordinate System



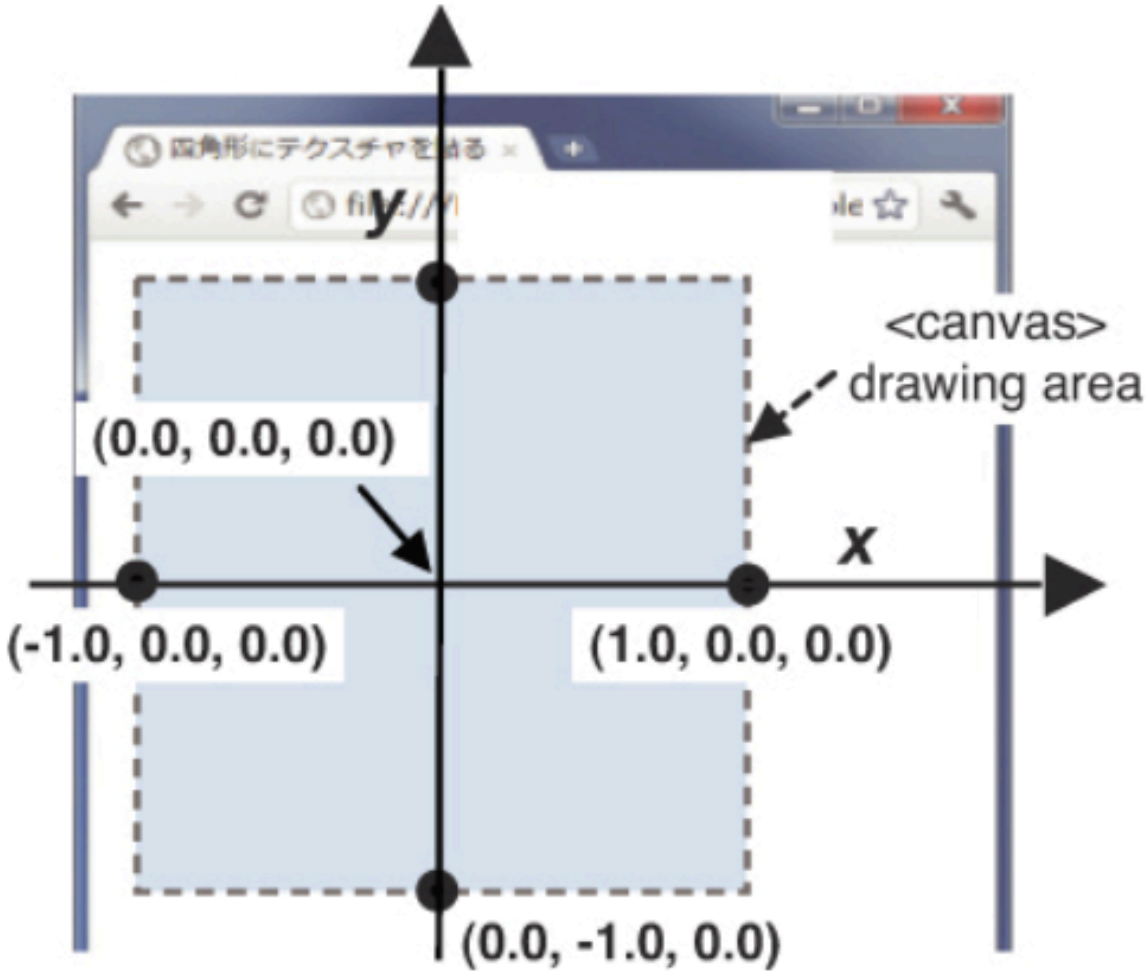
Use Right-Hand-Rule



Use Left-Hand-Rule

WebGL Coordinate System

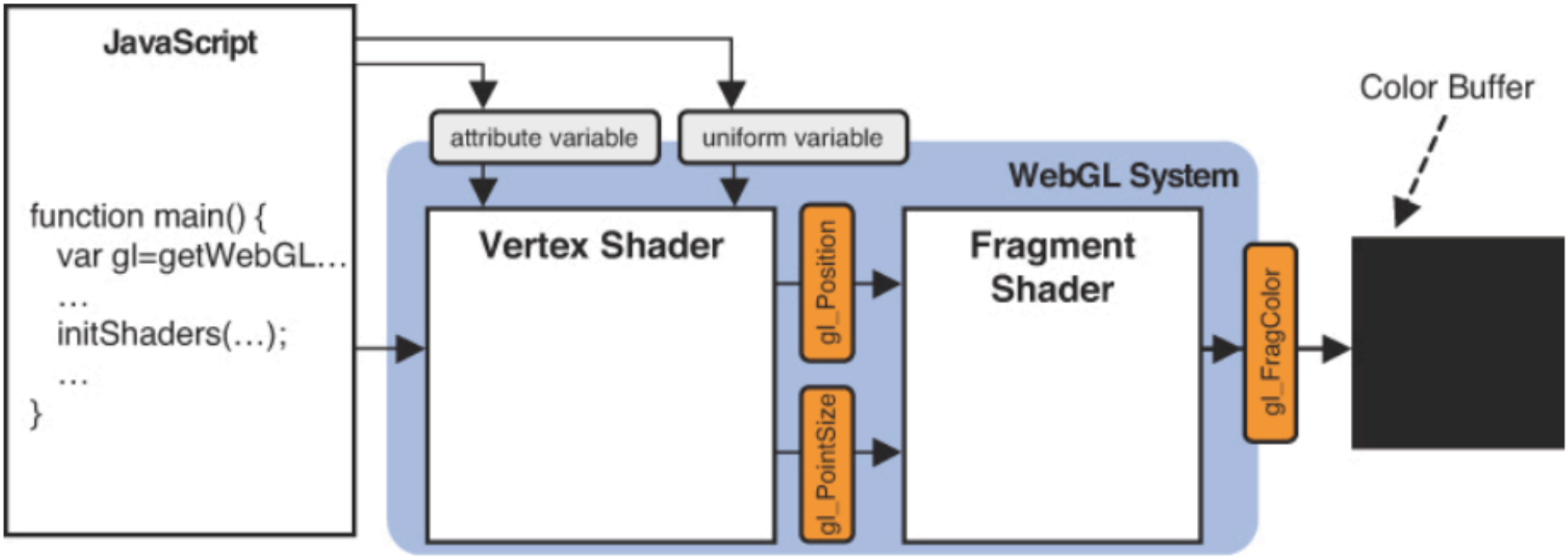
The Clipping Coordinates

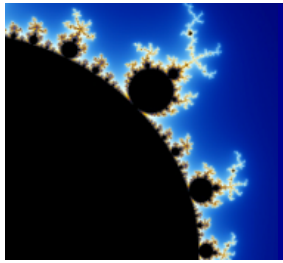


In this default clipping system,
specify point locations between
-1 and 1 along x, y, and z dimensions

Example: Hello Point 2 program

- How to pass data to the shader programs (glsl)?
  - attribute variable
  - uniform variable
  - varying variable



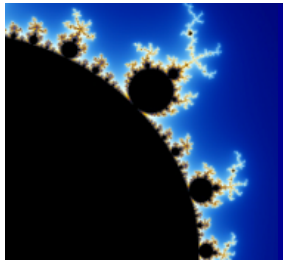


Variable Qualifier -- Attribute

- How to pass data to the Vertex Shader?
  - attribute variable: used for data pass from WebGL to Vertex Shader, that is different for each vertex
    - Examples:

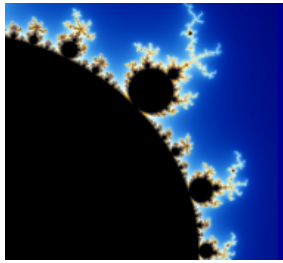
```
attribute float temperature;
attribute vec3 velocity;
```

    - Can only be used in Vertex Shader
    - Read only variable



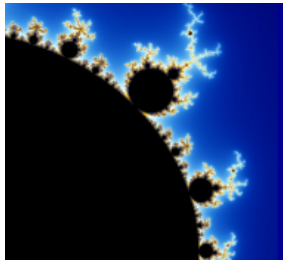
Variable Qualifier -- Uniform

- How to pass data to the shader programs?
  - uniform variable: used to pass data that is the same (or the uniform) for each vertex for a primitive
    - Variables do not change across the primitive being processed
    - Used to pass information to shader such as the time or a bounding box of a primitive or transformation matrices
    - Examples: `uniform float angle;`
    - Can be passed to Vertex Shader or Fragment Shader
    - Read-only variable



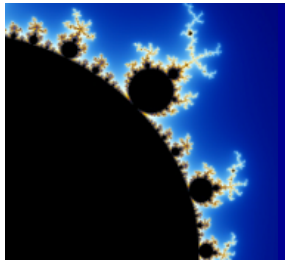
Variable Qualifier -- Varying

- How to pass data to the Shaders?
  - varying variable: used to pass interpolated data between a Vertex Shader and a Fragment Shader
    - Available for writing in the Vertex Shader, and
    - Read-only in Fragment Shader
    - For example, the interpolated color between two vertices



Example: Hello Point 2 program

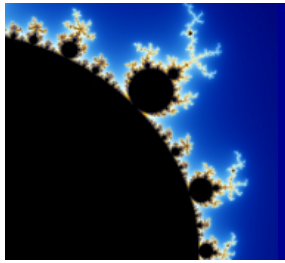
- Steps to pass data to the Vertex Shader
  1. In vertex shader:
     a. Declare the attribute variable
     b. Assign the attribute variable to the gl_Position variable (or compute gl_Position based on the attribute variable)
  2. In javascript:
     a. Establish corresponding reference (variable) for the attribute variable (in vertex shader) from javascript
     b. Pass the data to the attribute variable through the established reference



4-HelloPoint2 : Vertex Shader

- Step 1a and 1b:

```
<script id="vertex-shader" type="x-shader/x-vertex">
// Vertex shader program
attribute vec4 a_Position;
void main() {
  gl_Position = a_Position; // Set the vertex coordina
  gl_PointSize = 15.0;      // Set the point size
}
</script>
```



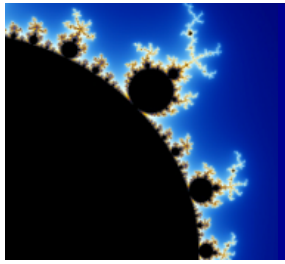
Hello Point 2 : Javascript program

- Step 2a:

```
// Get the storage location of a_Position
var a_Position = gl.getAttribLocation(program, "a_Position");
if (a_Position < 0) {
  console.log("Failed to get the storage location of a_Position");
  return;
}
```

- Step 2b:

```
// Pass vertex position to attribute variable
gl.vertexAttrib3f(a_Position, 0.0, 0.0, 0.0);
```

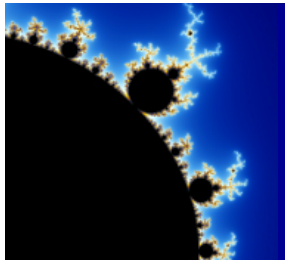


gl.getAttribLocation

```
gl.getAttribLocation(program, name)
```

Retrieve the storage location of the attribute variable specified by the *name* parameter.

Parameters	program	Specifies the program object that holds a verte shader and a fragment shader.
	name	Specifies the name of the attribute variable whose location is to be retrieved.
Return value	greater than or equal to 0	The location of the specified attribute variable.
	-1	The specified attribute variable does not exist its name starts with the reserved prefix `gl_` or `webgl_`.
Errors	INVALID_OPERATION	*program* has not been successfully linked (See Chapter 9.)
	INVALID_VALUE	The length of *name* is more than the maximum length (256 by default) of an attribute variable name.



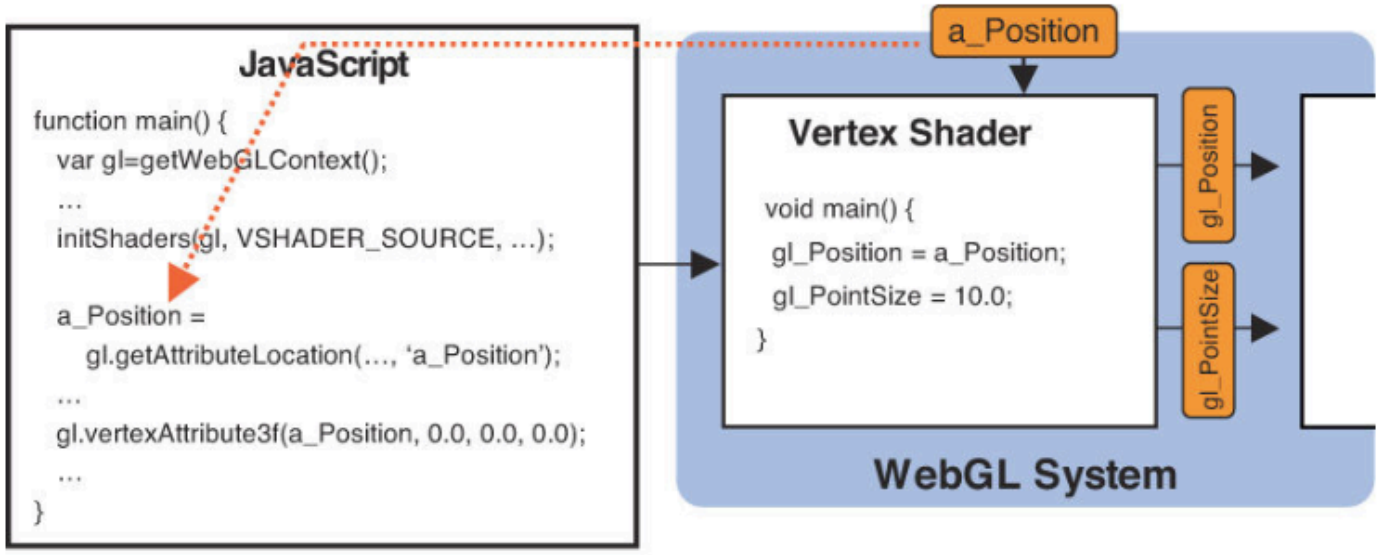
gl.vertexAttrib3f

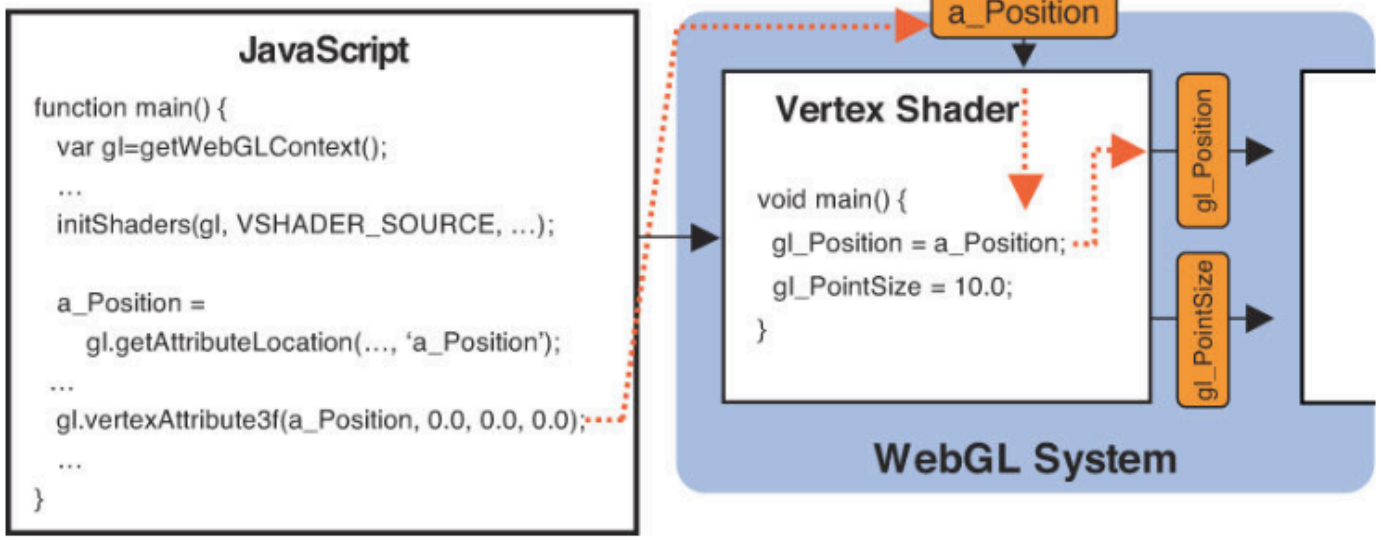
`gl.vertexAttrib3f(location, v0, v1, v2)`

Assign the data (*v0*, *v1*, and *v2*) to the attribute variable specified by *location*.

Parameters	location	Specifies the storage location of an attribute variable to be modifi
	v0	Specifies the value to be used as the first element for the attribut variable.
	v1	Specifies the value to be used as the second element for the attri bute variable.
	v2	Specifies the value to be used as the third element for the attribu variable.
Return value	None	
Errors	INVALID_OPERATION	There is no current program object.
	INVALID_VALUE	*location* is greater than or equal to the maximum number of attribute variables (8, by default).

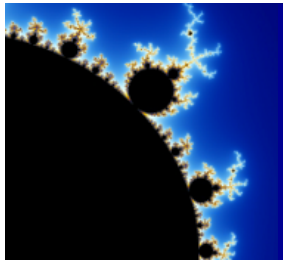
Getting the storage location and writing a value to the variable



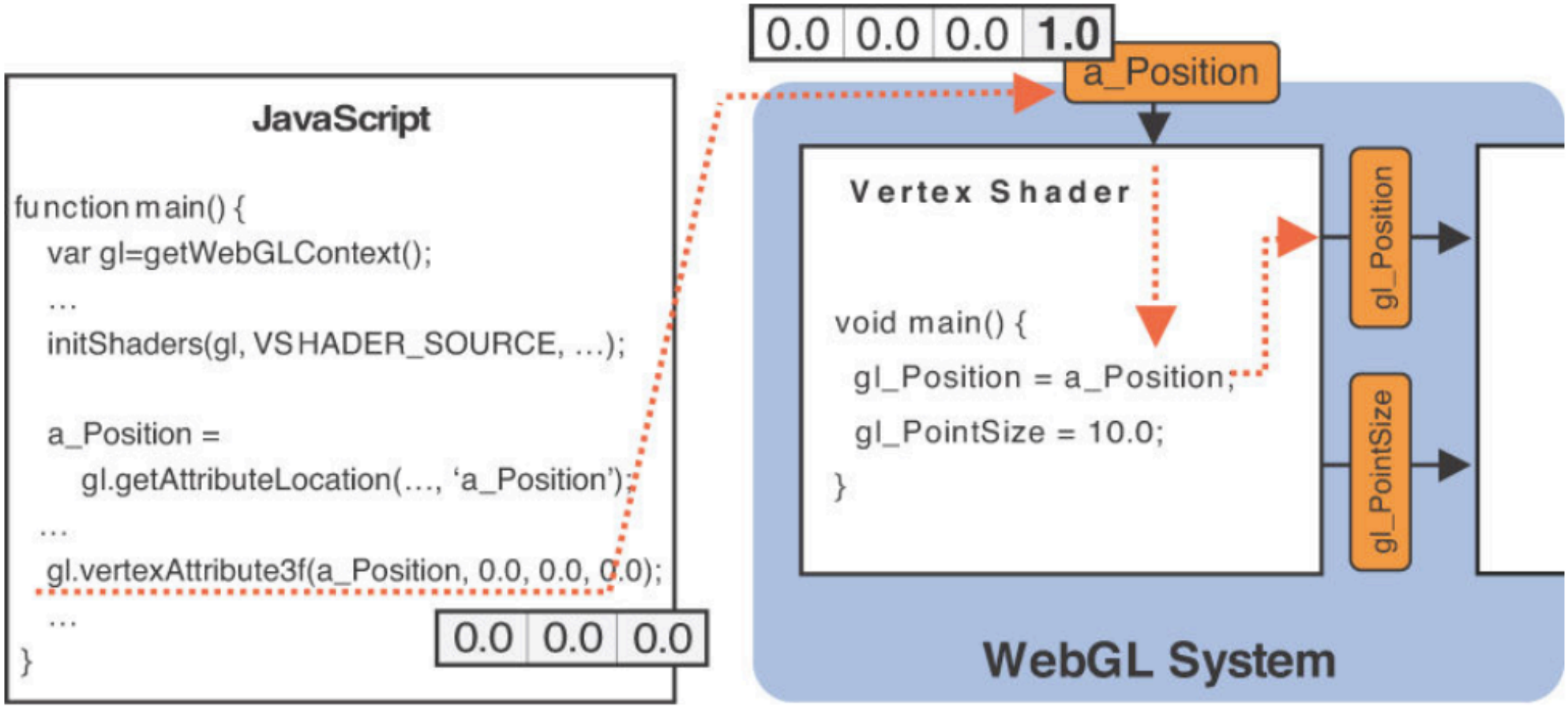


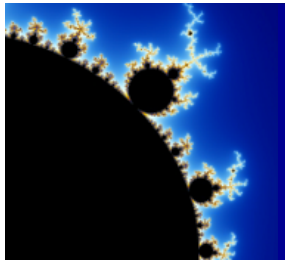
The variable "a_Position" has been allocated (on the webGL system) once the Vertex Shader is compiled through the "initShaders" process.

Therefore, its memory location may be retrieved using the gl.getAttributeLocation method

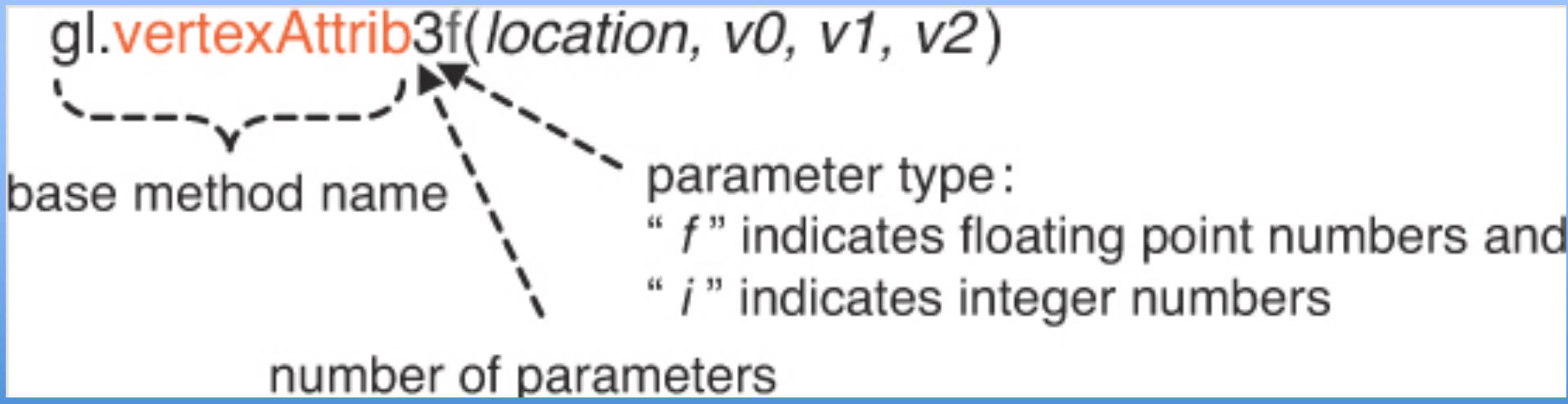


The missing data is auto-supplied

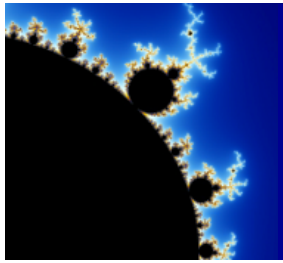




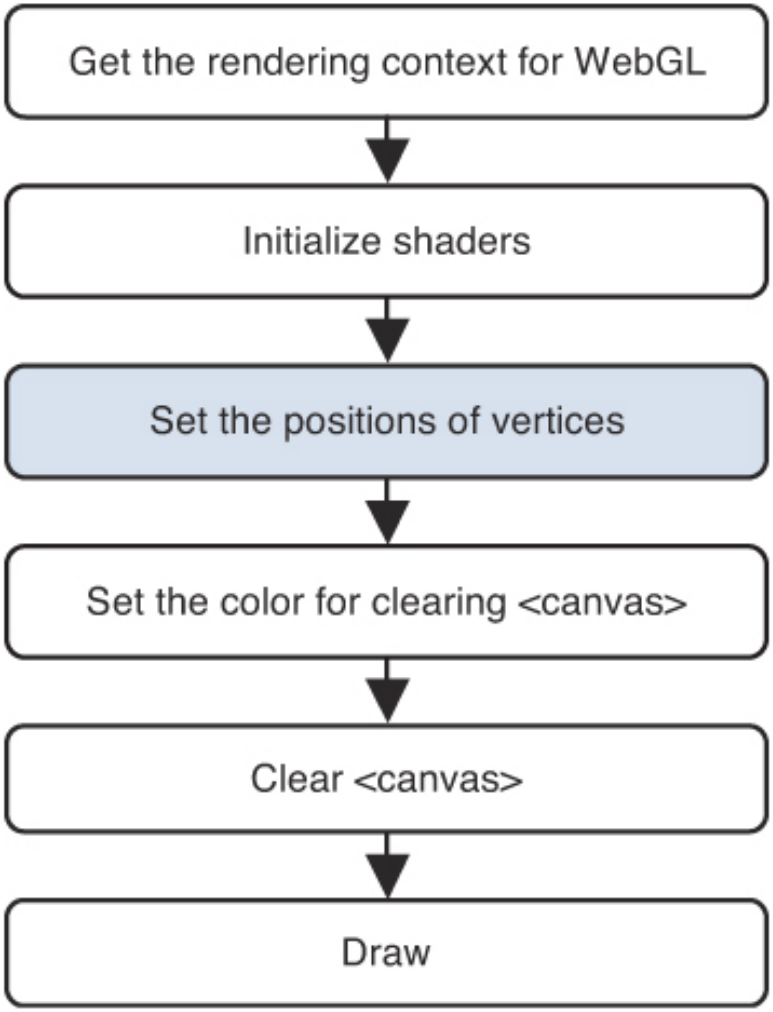
gl.vertexAttrib3f

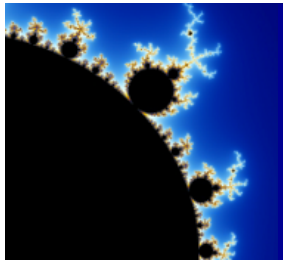



```
gl.vertexAttrib1f(a_Position, 0.5);
gl.vertexAttrib2f(a_Position, 0.5, 0.0);
gl.vertexAttrib4f(a_Position, 0.5, 0.0, 0.0, 1.0);
```

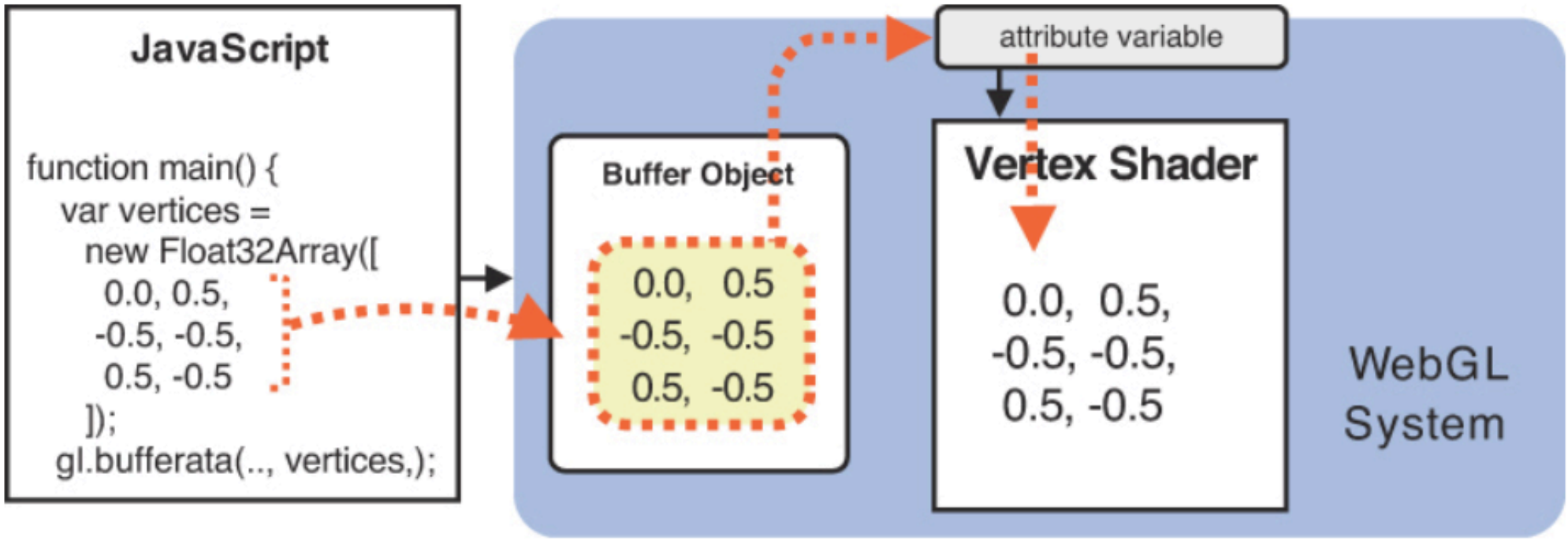


Example: Draw multiple points

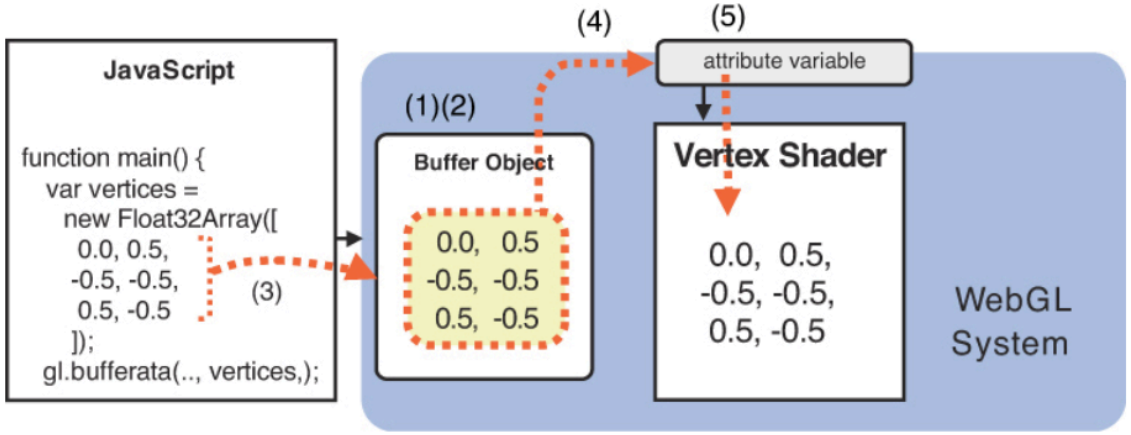




Example: Draw multiple points



Steps to pass multiple data to vertex shader through a buffer object



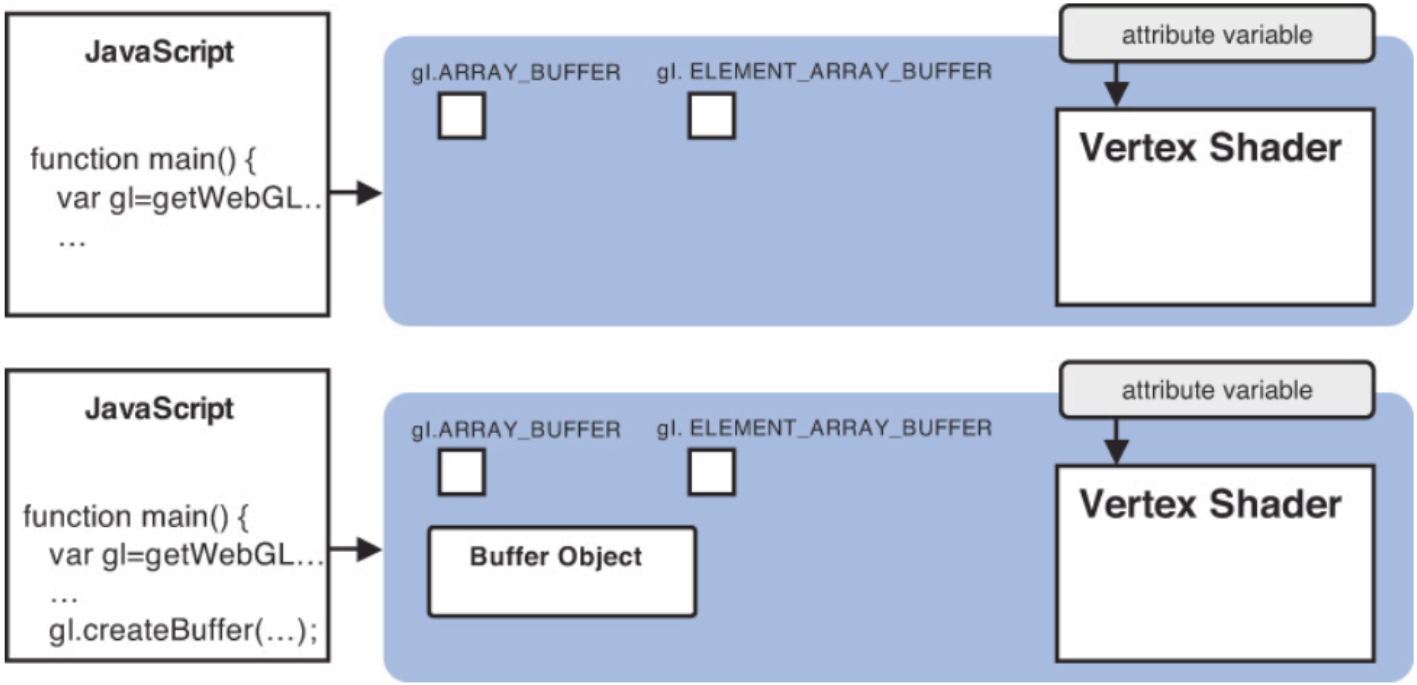
1. Create a buffer object (`gl.createBuffer()`).
2. Bind the buffer object to a target (`gl.bindBuffer()`).
3. Write data into the buffer object (`gl.bufferData()`).
4. Assign the buffer object to an attribute variable (`gl.vertexAttribPointer()`).
5. Enable assignment (`gl.enableVertexAttribArray()`).

Create buffer

`gl.createBuffer ()`

Create a buffer object.

Return value	non-null	The newly created buffer object.
	null	Failed to create a buffer object.
Errors	None	



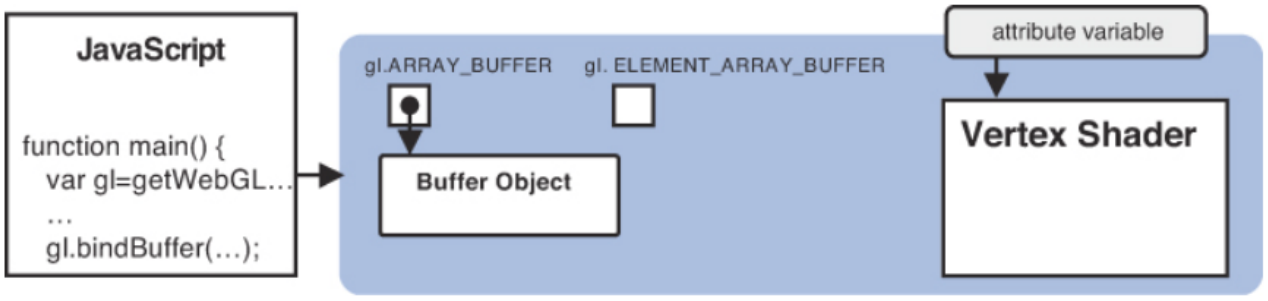
Bind Buffer

gl.bindBuffer(gl.ARRAY_BUFFER, vertexBuffer);

`gl.bindBuffer(target, buffer)`

Enable the buffer object specified by *buffer* and bind it to the *target*.

Parameters	Target can be one of the following:	
	`gl.ARRAY_BUFFER`	Specifies that the buffer object contains vertex data.
	`gl.ELEMENT_ARRAY_BUFFER`	Specifies that the buffer object contains index values pointing to vertex data. (See Chapter 6, "The OpenGL ES Shading Language [GLSL ES].)
	buffer	Specifies the buffer object created by a previous call to `gl.createBuffer()`. When `null` is specified, binding to the *target* is disabled.
Return Value	None	
Errors	INVALID_ENUM	*target* is none of the above values. In this case, the current binding is maintained.



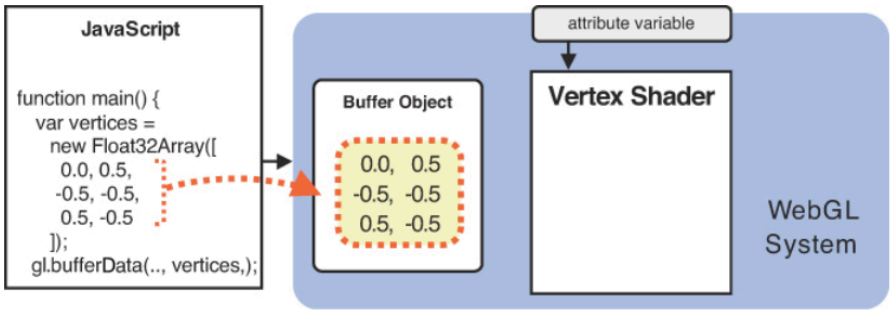
Write data into buffer

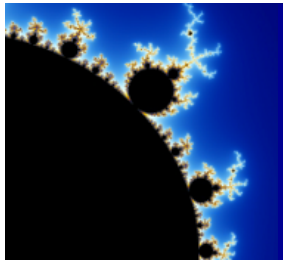
gl.bufferData(gl.ARRAY_BUFFER, vertices, gl.STATIC_DRAW);

`gl.bufferData(target, data, usage)`

Allocate storage and write the *data* specified by data to the buffer object bound to *target*.

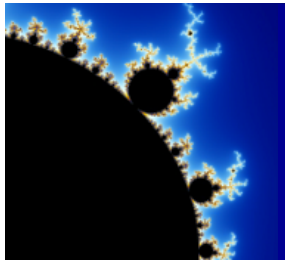
Parameters	target	Specifies `gl.ARRAY_BUFFER` or `gl.ELEMENT_ARRAY_BUFFER`.
	data	Specifies the data to be written to the buffer object (typed array; see the next section).
	usage	Specifies a hint about how the program is going to use the data stored in the buffer object. This hint helps WebGL optimize performance but will not stop your program from working if you get it wrong.
	`gl.STATIC_DRAW`	The buffer object data will be specified once and used many times to draw shapes.
	`gl.STREAM_DRAW`	The buffer object data will be specified once and used a few times to draw shapes.
	`gl.DYNAMIC_DRAW`	The buffer object data will be specified repeatedly and used many times to draw shapes.
Return value	None	
Errors	INVALID_ENUM	*target* is none of the preceding constants





Typed Arrays used in WebGL

Typed Array	Number of Bytes per Element	Description (C Types)
`Int8Array`	1	8-bit signed integer (signed char)
`Uint8Array`	1	8-bit unsigned integer (unsigned char)
`Int16Array`	2	16-bit signed integer (signed short)
`Uint16Array`	2	16-bit unsigned integer (unsigned short)
`Int32Array`	4	32-bit signed integer (signed int)
`Uint32Array`	4	32-bit unsigned integer (unsigned int)
`Float32Array`	4	32-bit floating point number (float)
`Float64Array`	8	64-bit floating point number (double)



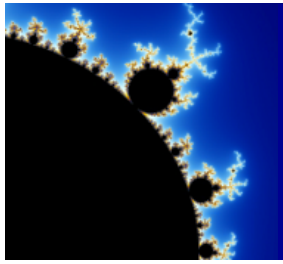
Assign the buffer object to an attribute variable
gl.vertexAttribPointer(a_Position, 2, gl.FLOAT, false, 0, 0);

`gl.vertexAttribPointer(location, size, type, normalized, stride, offset)`

Assign the buffer object bound to `gl.ARRAY_BUFFER` to the attribute variable specified by *location*.

Parameters	location	Specifies the storage location of an attribute variable.
	size	Specifies the number of components per vertex in the buffer object (valid values are 1 to 4). If *size* is less than the number of components required by the attribute variable, the missing components are automatically supplied just like `gl.vertexAttrib[1234]f()`. For example, if *size* is 1, the second and third components will be set to 0, and the fourth component will be set to 1.
	type	Specifies the data format using one of the following:

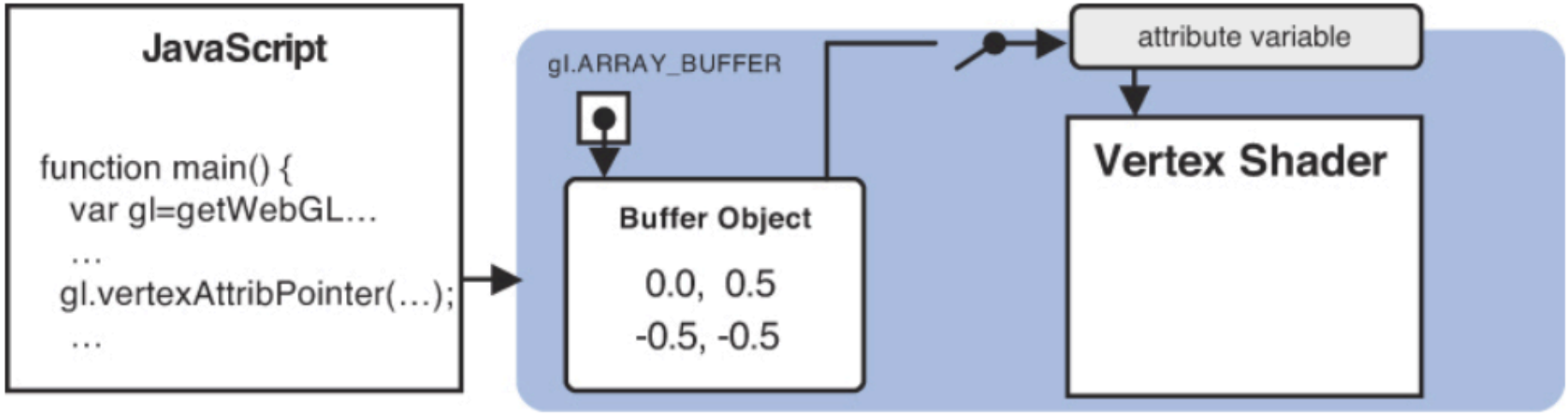
`gl.UNSIGNED_BYTE`	unsigned byte	for `Uint8Array`
`gl.SHORT`	signed short integer	for `Int16Array`
`gl.UNSIGNED_SHORT`	unsigned short integer	for `Uint16Array`
`gl.INT`	signed integer	for `Int32Array`
`gl.UNSIGNED_INT`	unsigned integer	for `Uint32Array`
`gl.FLOAT`	floating point number	for `Float32Array`



Assign the buffer object to an attribute variable
gl.vertexAttribPointer(a_Position, 2, gl.FLOAT, false, 0, 0);

	normalized	Either `true` or `false` to indicate whether nonfloating data should be normalized to [0, 1] or [–1, 1].
	stride	Specifies the number of bytes between different vertex data elements, or zero for default stride (see Chapter 4).
	offset	Specifies the offset (in bytes) in a buffer object to indicate what number-th byte the vertex data is stored from. If the data is stored from the beginning, *offset* is 0.
Return value	None	
Errors	INVALID_OPERATION	There is no current program object.
	INVALID_VALUE	*location* is greater than or equal to the maximum number of attribute variables (8, by default). *stride* or *offset* is a negative value.

Enable the assignment to an attribute variable
gl.enableVertexAttribArray(a_Position);

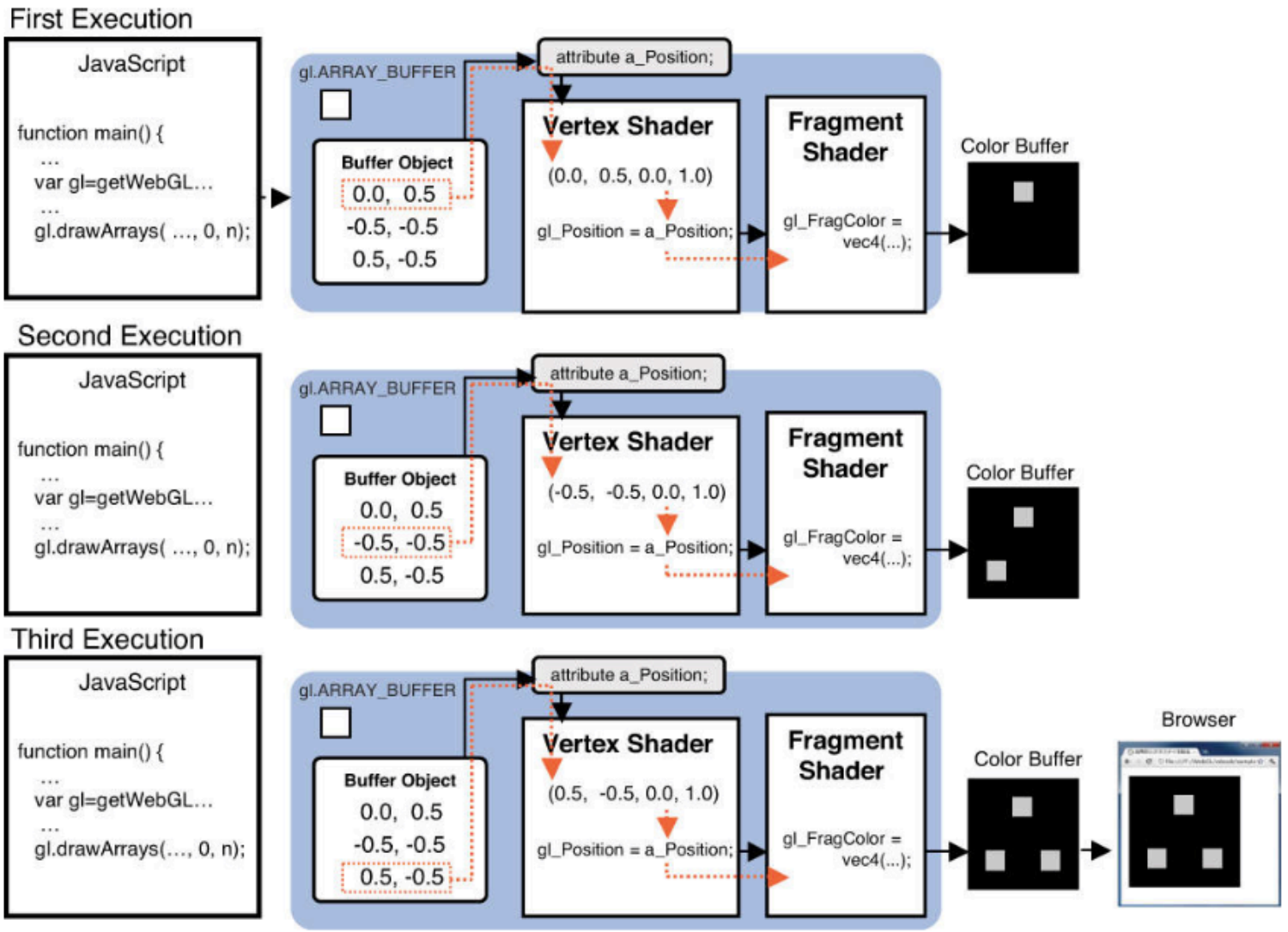


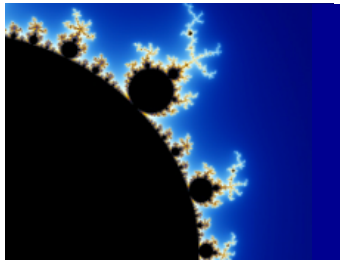
`gl.enableVertexAttribArray(location)`

Enable the assignment of a buffer object to the attribute variable specified by *location*.

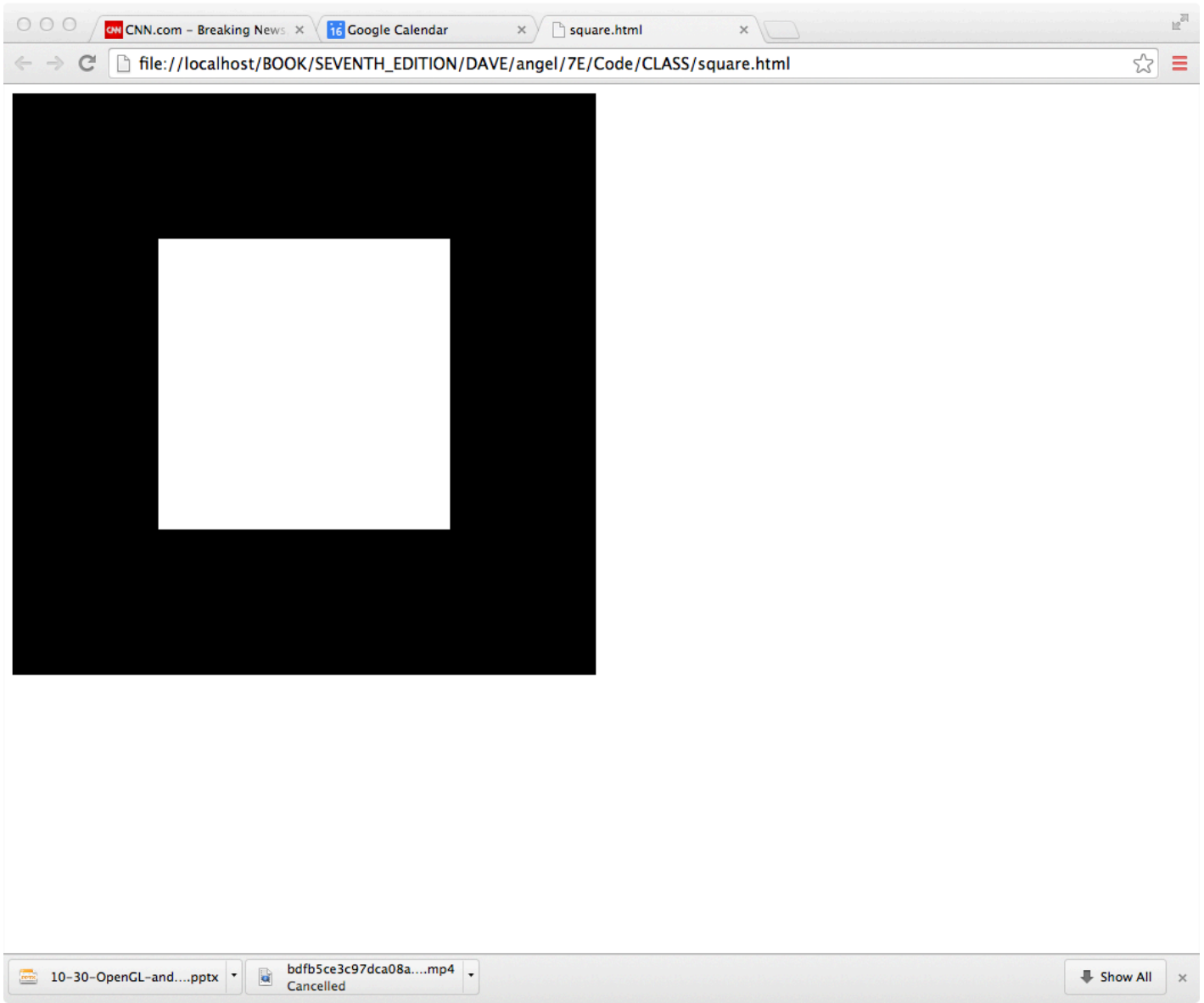
Parameters	location	Specifies the storage location of an attribute variable.
Return value	None	
Errors	INVALID_VALUE	*location* is greater than or equal to the maximum number of attribute variables (8 by default).

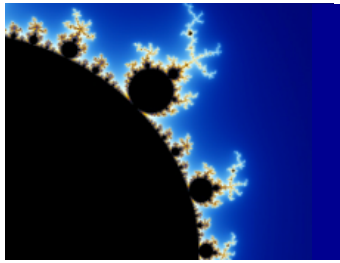
Execution Flow





Example : Square Program





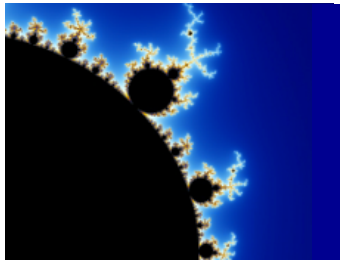
square.js

```
var gl;         // global
var points;  // global

function  main()   {
    var canvas = document.getElementById( "gl-canvas" );

    gl = WebGLUtils.setupWebGL( canvas );
    if ( !gl ) { console.log( "WebGL isn't available" ); return; }

    // Define the four vertices   (values in clip coordinates)
    // where are these 4 vertices located?
    var vertices = [
        vec2( -0.5, -0.5 ),
        vec2(  -0.5,  0.5 ),
        vec2(  0.5, 0.5 ),
        vec2( 0.5, -0.5)
    ];
```



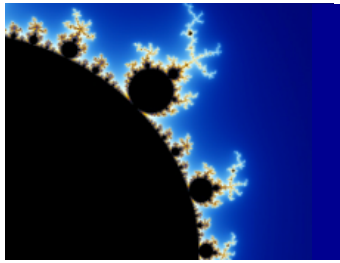
square.js (cont)

```
//  Configure WebGL
// gl.viewport( 0, 0, canvas.width, canvas.height );
gl.clearColor( 0.0, 0.0, 0.0, 1.0 );

 //  Load shaders and initialize attribute buffers
var program = initShaders( gl, "vertex-shader", "fragment-shader" );
gl.useProgram( program );

 // Load the data into the GPU
var bufferId = gl.createBuffer();
gl.bindBuffer( gl.ARRAY_BUFFER, bufferId );
gl.bufferData( gl.ARRAY_BUFFER, flatten(vertices), gl.STATIC_DRAW );
// flatten() to convert JS array to an array of float32's

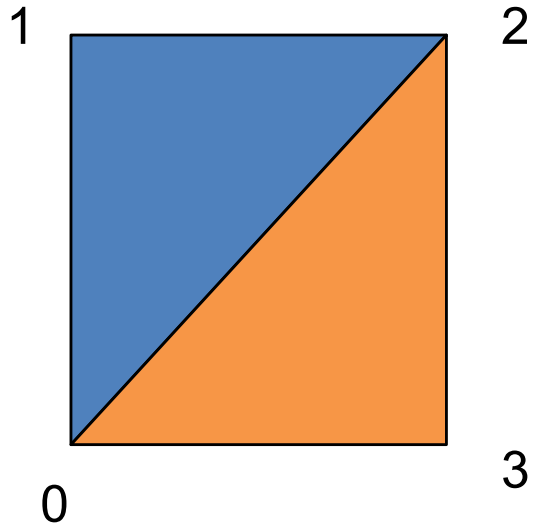
 // Associate out shader variables with our data buffer
var vPosition = gl.getAttribLocation( program, "vPosition" );
gl.vertexAttribPointer( vPosition, 2, gl.FLOAT, false, 0, 0 );
gl.enableVertexAttribArray( vPosition );
```

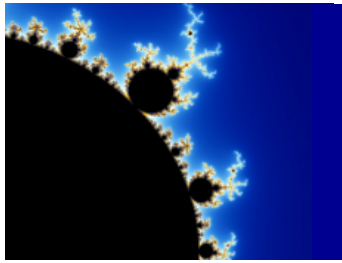


square.js (cont)

```
    render();
};

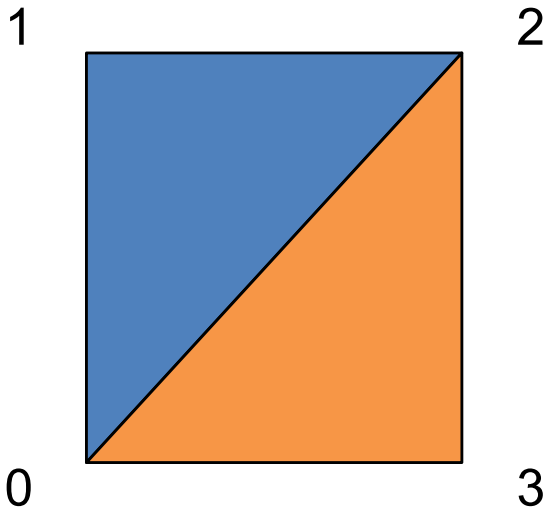
function render() {
    gl.clear( gl.COLOR_BUFFER_BIT );
    gl.drawArrays( gl.TRIANGLE_FAN, 0, 4 );
}
```

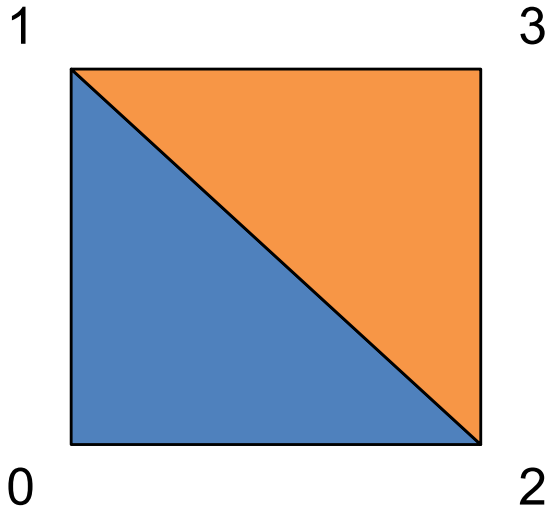




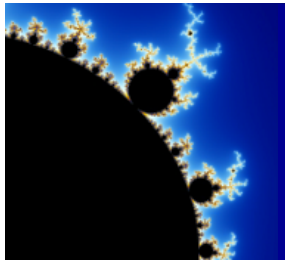
Triangles, Fans or Strips

gl.drawArrays(gl.TRIANGLES, 0, 6); // 0, 1, 2, 0, 2, 3 need 6 points
gl.drawArrays(gl.TRIANGLE_FAN, 0, 4); // 0, 1 , 2, 3





gl.drawArrays(gl.TRIANGLE_STRIP, 0, 4);
// 0, 1, 2, 3



Example: ClickPoints

```
// Register function (event handler) to be called on a mouse press
canvas.onmousedown = function(ev){ click(ev, gl, canvas, a_Position); };
```

Register event handler

```
function click(ev, gl, canvas, a_Position) {
  var x = ev.clientX; // x coordinate of a mouse pointer
  var y = ev.clientY; // y coordinate of a mouse pointer
  var rect = ev.target.getBoundingClientRect() ;

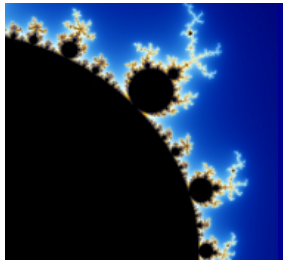
  x = ((x - rect.left) - canvas.width/2)/(canvas.width/2);
  y = (canvas.height/2 - (y - rect.top))/(canvas.height/2);

  // Store the coordinates to the "points" array
  points.push(x); points.push(y);

  // Clear <canvas>
  gl.clear(gl.COLOR_BUFFER_BIT);

  var len = points.length;
  for(var i = 0; i < len; i += 2) {
    // Pass the position of a point to a_Position variable
    gl.vertexAttrib3f(a_Position, points[i], points[i+1], 0.0);

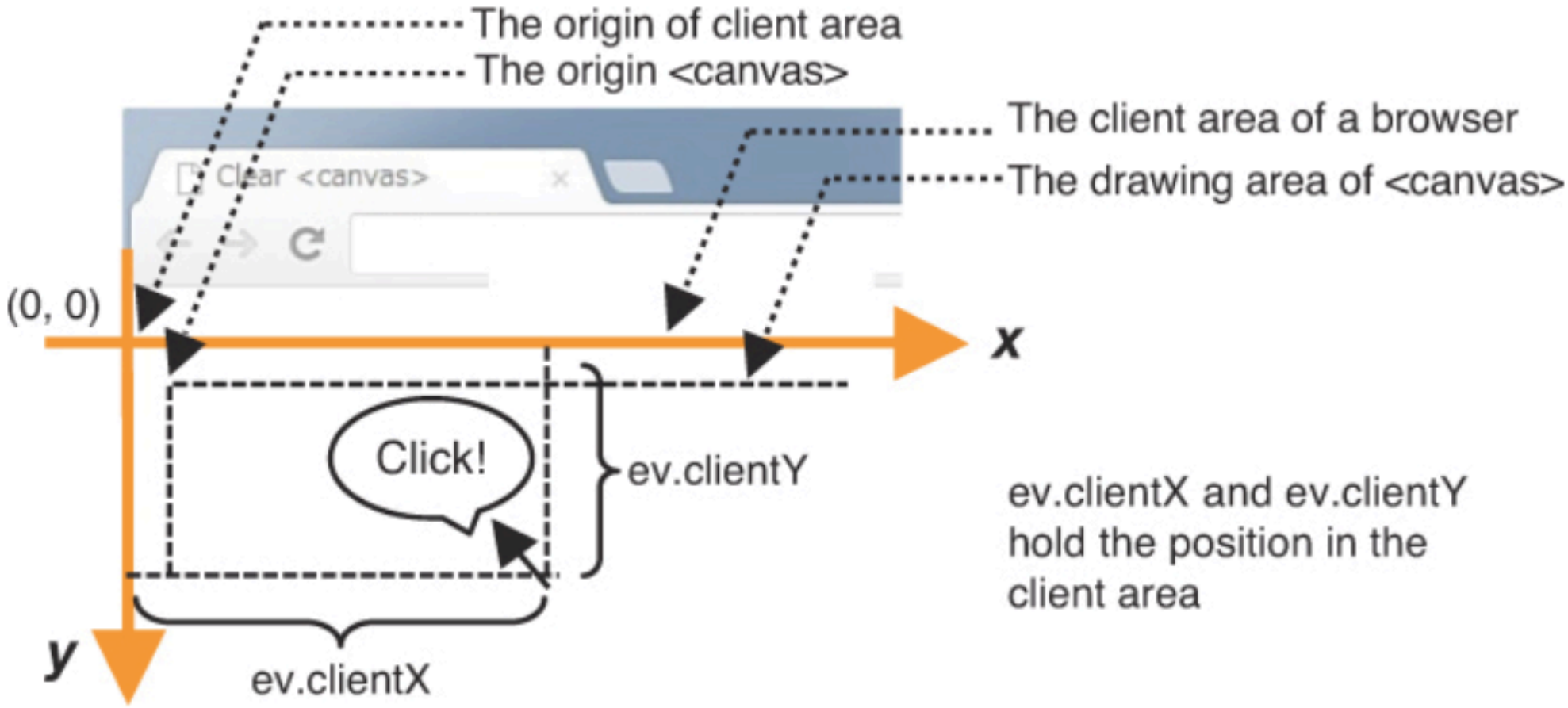
    // Draw
    gl.drawArrays(gl.POINTS, 0, 1);
  }
}
```

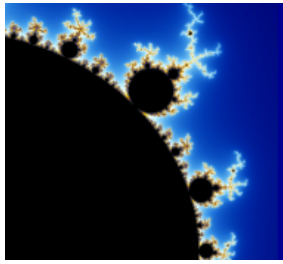


Example: ClickPoints

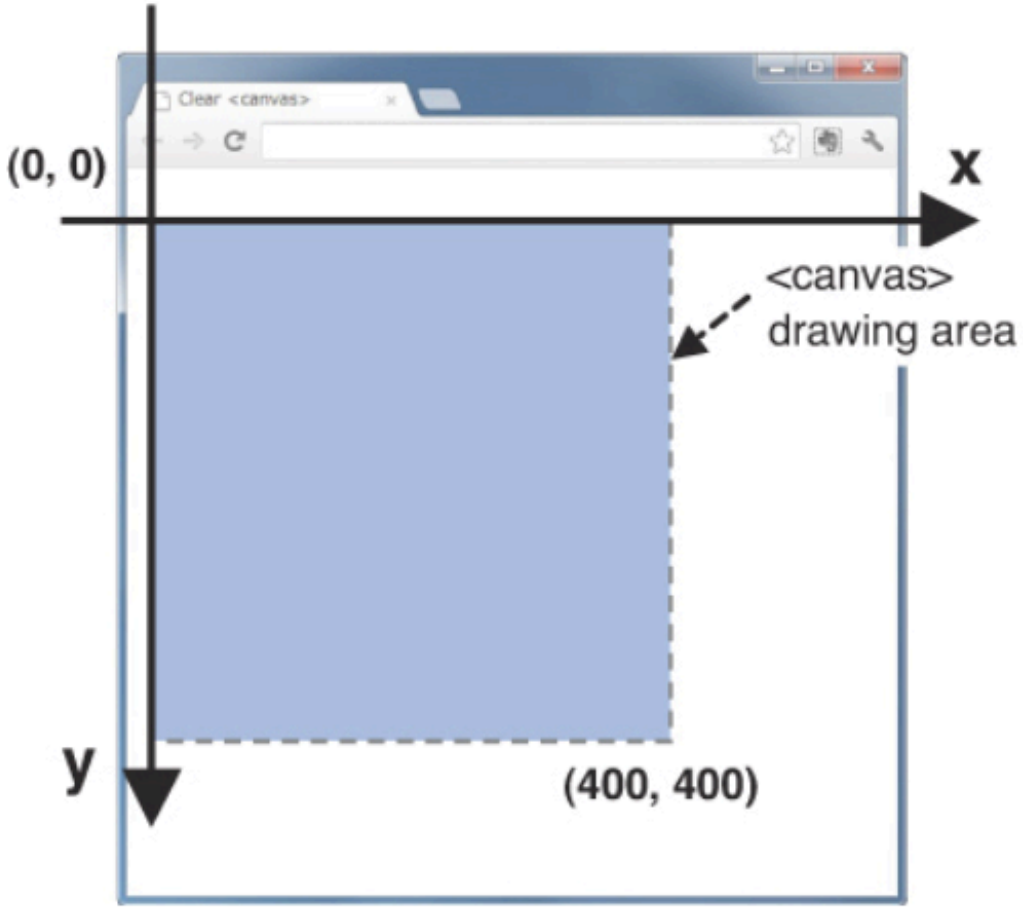
- How to transform the mouse click coordinates into the webGL coordinates and display the corresponding points?
- Can not use the mouse click coordinates directly
  - The coordinate is the position in the “client area” in the browser, not in the “canvas”
  - The coordinate system of the “canvas” is different from that of WebGL in terms of its origin and the direction of the y-axis

Coordinate system of the browser's client area and the position of the canvas

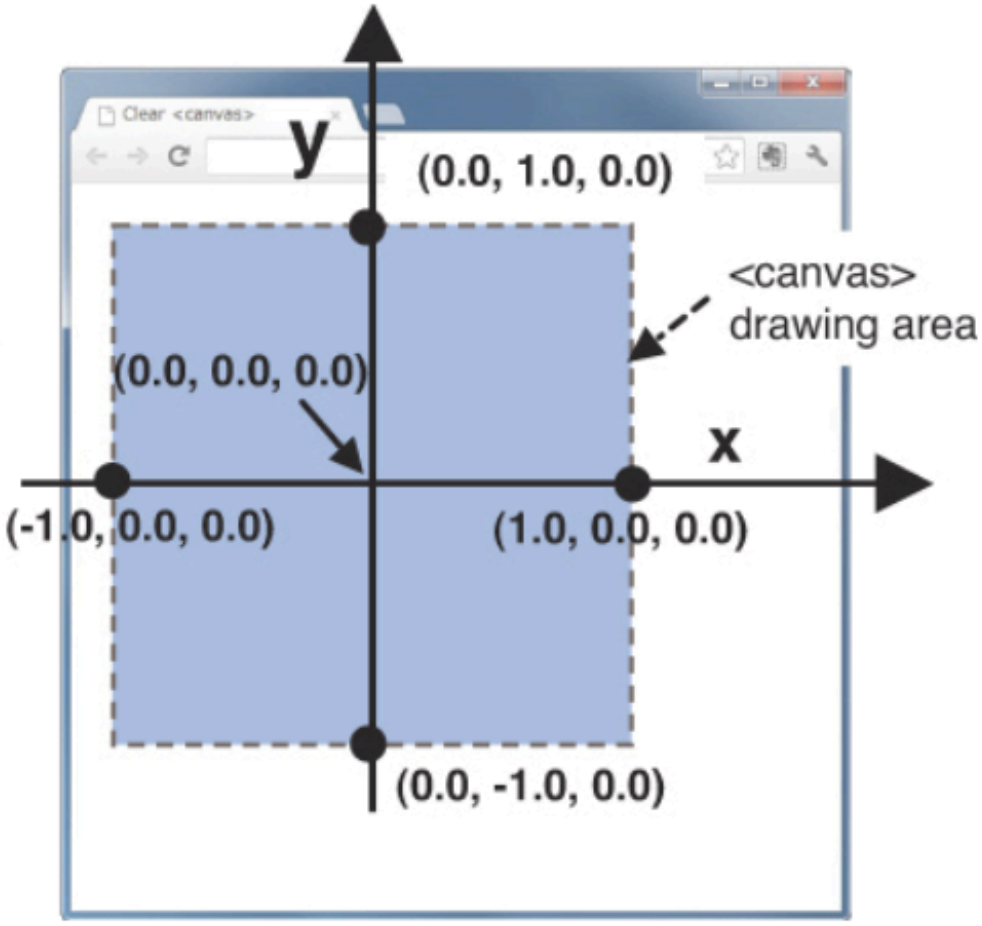




The coordinate system of the canvas and that of WebGL on canvas

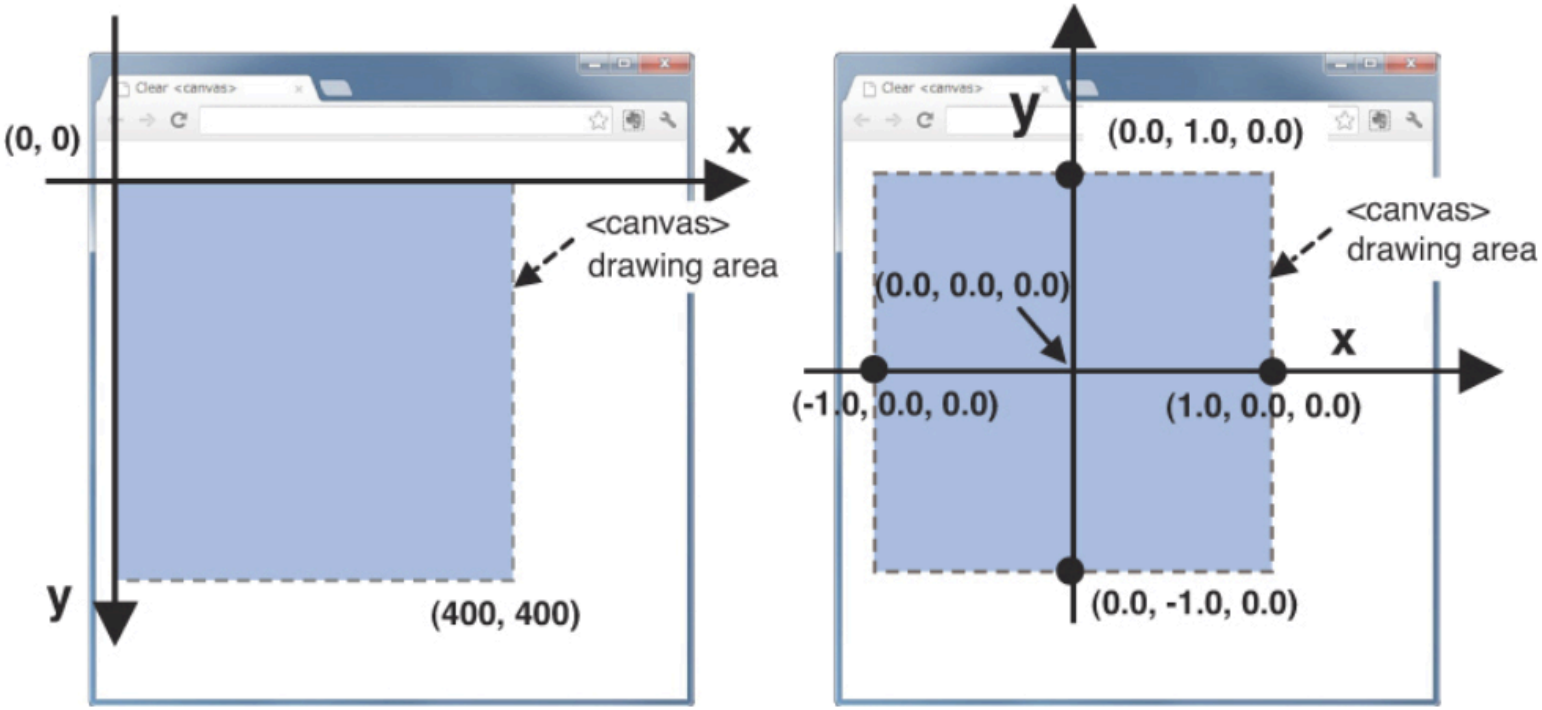


Canvas



WebGL

The coordinate system of the canvas and that of WebGL on canvas

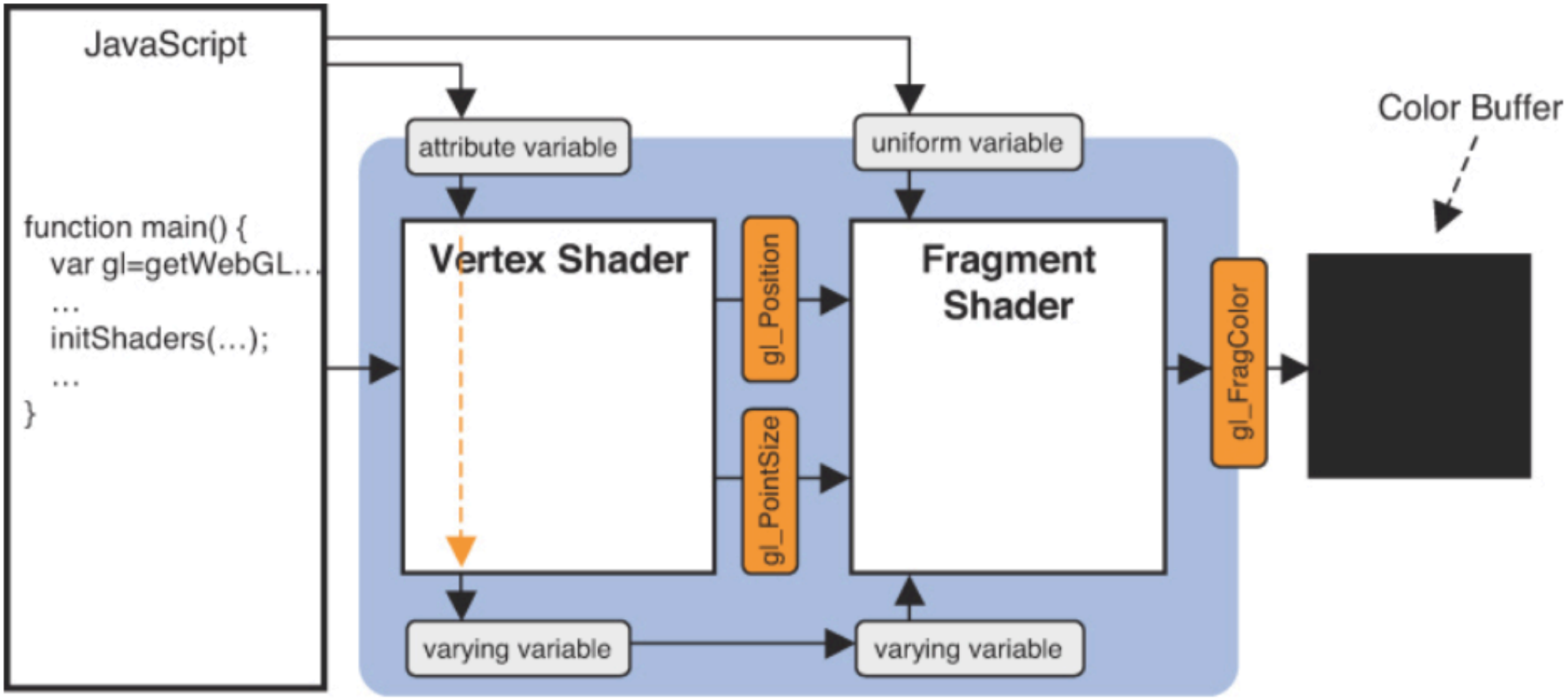


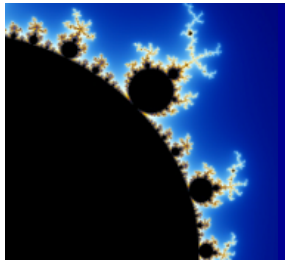

```
var x = ev.clientX; // x coordinate of a mouse pointer
var y = ev.clientY; // y coordinate of a mouse pointer
var rect = ev.target.getBoundingClientRect() ;

x = ((x - rect.left) - canvas.width/2)/(canvas.width/2);
y = (canvas.height/2 - (y - rect.top))/(canvas.height/2);
```

Example: Color Points

- Adding uniform variable to Fragment Shader → two methods

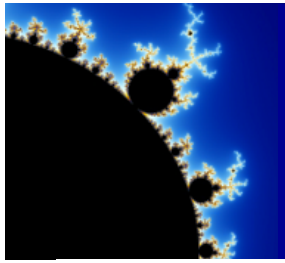




Example: Color Points

Fragment Shader:

```
<script id="fragment-shader" type="x-shader/x-fragment">
// Fragment shader program
precision mediump float;
uniform vec4 u_FragColor;
void main() {
    gl_FragColor = u_FragColor;
}
</script>
```



Example: Color Points – js

```
// Get the storage location of u_FragColor
var u_FragColor = gl.getUniformLocation(program, "u_FragColor");
if (!u_FragColor) {
  console.log('Failed to get the storage location of u_FragColor');
  return;
}

    // Store the colors to the "colors" array
    if (x >= 0.0 && y >= 0.0) {      // First quadrant
      colors.push([1.0, 0.0, 0.0, 1.0]);  // Red
    } else if (x < 0.0 && y >= 0.0) { // Second quadrant
      colors.push([0.0, 0.0, 1.0, 1.0]);  // Blue
    } else if (x < 0.0 && y < 0.0) { // Third quadrant
      colors.push([0.0, 1.0, 0.0, 1.0]);  // Green
    } else if (x >=0.0 && y< 0.0) { // Fourth quadrant
      colors.push([1.0, 1.0, 1.0, 1.0]);  // White
    }
```

Assume: rgba = colors[i];

```
// Pass the color of a point to u_FragColor variable
gl.uniform4f(u_FragColor, rgba[0], rgba[1], rgba[2], rgba[3]);
```