# WebGL Survey

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## Contents

# 1 Introduction

## 1.1 WebGL and OpenGL standard

### 1.1.1 Evolving of the standards

The publication and draft dates of WebGL specification:

- Version 1.0, 10 February 2011
- Version 1.0.1, 27 January 2012
- Version 1.0.2, 01 March 2013
- Version 1.0.3, 27 October 2014
- Version 2.0, 19 February 2016 (latest draft)

NOTE: Version 1.x are based on OpenGL ES 2.0; Version 2.x are based on OpenGL ES 3.0.

NOTE:The 2.0 draft spec provided here should be read as an extension to the WebGL 1.0 specification. It will only describe the differences from 1.0.

### 1.1.2 Information in the standards

**WebGL** In WebGL spec, it introduces *Context Creation* and *Drawing Buffer Presentation*, *WebGL Resources* and *Security* only briefly. The major parts are: *DOM Interfaces* and *Differences with OpenGL ES 2.0*.

In DOM interfaces, the types and various object interfaces are introduced, in which the `WebGLRenderingContext` is the biggest one. The IDLs are presented here, and its intended semantics are described. However, it refers OpenGL ES 2.0 frequently and don't give a lot of information which appears in the OpenGL spec.

Here is a sample spec:

**OpenGL ES** The OpenGL ES 2.0 spec is a rather detailed specification. Some implementation contrives are explained. So it is necessary for understanding the browser implementation.

Here is a sample spec:

**Example Implementation** As an example of implementation, we will see part of code in Firefox's Browser Engine – Gecko.

- `WebGLRenderingContext.webidl`
- `RendererGL.h`
- `WebGLContextBuffers.cpp`

#### 5.14.5 Buffer objects

Buffer objects (sometimes referred to as VBOs) hold vertex attribute data for the GLSL shaders.

**`void bindBuffer(GLenum target, WebGLBuffer? buffer)`** *(OpenGL ES 2.0 §2.9, man page)*
Binds the given WebGLBuffer object to the given binding point (target), either ARRAY_BUFFER or ELEMENT_ARRAY_BUFFER. If the buffer is null then any buffer currently bound to this target is unbound. A given WebGLBuffer object may only be bound to one of the ARRAY_BUFFER or ELEMENT_ARRAY_BUFFER target in its lifetime. An attempt to bind a buffer object to the other target will generate an `INVALID_OPERATION` error, and the current binding will remain untouched.

**`void bufferData(GLenum target, GLsizeiptr size, GLenum usage)`** *(OpenGL ES 2.0 §2.9, man page)*
Set the size of the currently bound WebGLBuffer object for the passed target. The buffer is initialized to 0.

**`void bufferData(GLenum target, BufferDataSource? data, GLenum usage)`** *(OpenGL ES 2.0 §2.9, man page)*
Set the size of the currently bound WebGLBuffer object for the passed target to the size of the passed data, then write the contents of data to the buffer object.

If the passed data is null then an `INVALID_VALUE` error is generated.

**`void bufferSubData(GLenum target, GLintptr offset, BufferDataSource? data)`** *(OpenGL ES 2.0 §2.9, man page)*
For the WebGLBuffer object bound to the passed target write the passed data starting at the passed offset. If the data would be written past the end of the buffer object an `INVALID_VALUE` error is generated. If `data` is null then an `INVALID_VALUE` error is generated.

**`WebGLBuffer? createBuffer()`** *(OpenGL ES 2.0 §2.9, similar to glGenBuffers)*
Create a WebGLBuffer object and initialize it with a buffer object name as if by calling glGenBuffers.

## 2.9 Buffer Objects

The vertex data arrays described in section 2.8 are stored in client memory. It is sometimes desirable to store frequently used client data, such as vertex array data, in high-performance server memory. GL buffer objects provide a mechanism that clients can use to allocate, initialize, and render from such memory.

The name space for buffer objects is the unsigned integers, with zero reserved for the GL. A buffer object is created by binding an unused name to `ARRAY_BUFFER`. The binding is effected by calling

`void` **BindBuffer**`(` `enum` *target*`,` `uint` *buffer*`);`

with *target* set to `ARRAY_BUFFER` and *buffer* set to the unused name. The resulting buffer object is a new state vector, initialized with a zero-sized memory buffer, and comprising the state values listed in Table 2.5.

**BindBuffer** may also be used to bind an existing buffer object. If the bind is successful no change is made to the state of the newly bound buffer object, and any previous binding to *target* is broken.

While a buffer object is bound, GL operations on the target to which it is bound affect the bound buffer object, and queries of the target to which a buffer object is bound return state from the bound object.

### 1.1.3 Conformity status of popular implementations

Older but more completed from [8].

#### Desktop browsers

- Google Chrome – WebGL has been enabled on all platforms that have a capable graphics card with updated drivers since version 9, released in February 2011.
- Mozilla Firefox – WebGL has been enabled on all platforms that have a capable graphics card with updated drivers since version 4.0.
- Safari – Safari 6.0 and newer versions installed on OS X Mountain Lion, Mac OS X Lion and Safari 5.1 on Mac OS X Snow Leopard implemented support for WebGL, which was disabled by default before Safari 8.0.
- Opera – WebGL has been implemented in Opera 11 and 12, although was disabled by default in 2014.
- Internet Explorer – WebGL is partially supported in Internet Explorer 11.
- Microsoft Edge – The initial stable release supports WebGL version 0.95 (context name: "experimental-webgl").

#### Mobile browsers

- BlackBerry 10 – WebGL is available for BlackBerry devices since OS version 10.00
- BlackBerry PlayBook – WebGL is available via WebWorks and browser in PlayBook OS 2.00
- Android Browser – Basically unsupported.
- Internet Explorer - WebGL is available on Windows Phone 8.1
- Firefox for mobile – WebGL is available for Android and MeeGo devices since Firefox 4.
- Firefox OS
- Google Chrome – WebGL is available for Android devices since Google Chrome 25 and enabled by default since version 30.
- Maemo – In Nokia N900, WebGL is available in the stock microB browser from the PR1.2 firmware update onwards.
- MeeGo - WebGL is unsupported in the stock browser "Web." However, it is available through Firefox.
- Opera Mobile - Opera Mobile 12 supports WebGL (on Android only).
- Sailfish OS - WebGL is supported in the default Sailfish browser.
- Tizen - WebGL is supported
- Ubuntu Touch
- WebOS
- iOS – WebGL is available for mobile Safari, in iOS 8.

**More updated information** You can check out the updated information in MDN [5]

> Support for WebGL is present in Firefox 4+, Google Chrome 9+, Opera 12+, Safari 5.1+ and Internet Explorer 11+; however, the user's device must also have hardware that supports these features.

## 1.2 Online API documentation

> The junior developer read books and tutorials; The senior developers read the API documentation; Only the platform developers and library writers read the standards and specs.

Why I should investigate into this part? The reason is simple: we want to know *how developer learns about the APIs and its intended usage.*

Thus, we should pay attention to the following several things:

1. How does the single interface documentation look like?
2. Can developer find the usage of some particular functionality quick?
3. Is there enough but concise examples along side?
4. How is the edge cases and correctness issues mentioned?
5. How is the compatibility, security and performance issues mentioned?

### 1.2.1 Sources

I found the MDN and MSDN have detailed API docs:

- Mozilla Developer Network
- Microsoft Developer Network

On the contrary, I don't find API doc about WebGL on Chromium's online documentation;

Dev.Opera has a lot of tutorials but not API docs.

I find nothing significant on Apple Developer site either.

### 1.2.2 Interface structure

**MDN** For example, copyTexImage2D

There are short induction, syntax, parameters and return value (semantics, types, ranges), examples, specification, browser compatibility, related interfaces.

**MSDN** Same example, copyTexImage2D

Short intro, syntax, parameters and return value (semantics, more explicit types, ranges), remarks, WebGL errors, related interfaces

#### 1.2.3 Usability

The navigation of MDN is better than MSDN. And most of time the Google will return MDN on searching a particular interface.

Also, the MDN provides per-interface examples and a lot of tutorials; MSDN is short at this.

#### 1.2.4 Edge cases and correctness

Both consider edge cases and special values. The MSDN has a WebGL errors documentation, so it is more explicit about correctness.

#### 1.2.5 Compatibility, security and performance

**MDN**

- Compatibility: Information about conformity in all major desktop and mobile browsers.
- Security: Not explicit
- Performance: Not explicit

**MSDN**

- Compatibility: Only one icon showing IE version supporting the interface.
- Security: Not explicit
- Performance: Not explicit

### 1.3 Ecosystem

#### 1.3.1 Books

There are about 200 results returned for searching "WebGL" on amazon.com. As a comparison, searching "JavaScript" gives you 9000+ results.

The most popular books are:

***WebGL Programming Guide: Interactive 3D Graphics Programming with WebGL (OpenGL)* by Kouichi Matsuda and Rodger Lea [3]:**

> You'll move from basic techniques such as rendering, animating, and texturing triangles, all the way to advanced techniques such as fogging, shadowing, shader switching, and displaying 3D models generated by Blender or other authoring tools. This book won't just teach you WebGL best practices, it will give you a library of code to jumpstart your own projects.

***Learning Three.js: The JavaScript 3D Library for WebGL* by Jos Dirksen [2]:**

> If you know JavaScript and want to start creating 3D graphics that run in any browser, this book is a great choice for you. You don't need to know anything about math or WebGL; all that you need is general knowledge of JavaScript and HTML.

***Programming 3D Applications with HTML5 and WebGL: 3D Animation and Visualization for Web Pages* by Tony Parisi [7]:**

> In two parts—Foundations and Application Development Techniques—author Tony Parisi provides a thorough grounding in theory and practice for designing everything from a simple 3D product viewer to immersive games and interactive training systems. Ideal for developers with Javascript and HTML experience.

***WebGL: Up and Running* by Tony Parisi [6]:**

> You don't have to be a game development wizard or have 3D graphics experience to get started. If you use HTML, CSS, and JavaScript—and have familiarity with JQuery and Ajax—this book will help you gain a working knowledge of WebGL through clear and simple examples.

***WebGL Insights* by Patrick Cozzi [1]:**

> WebGL Insights shares experience-backed lessons learned by the WebGL community. It presents proven techniques that will be helpful to both intermediate and advanced WebGL developers.

It seems apparent that advanced materials share a high proportion. Also, one books is not really teaching WebGL but Three.js.

These popular books' publication dated range from 2012 to 2015; In all books, the newest is published in Feb 12, 2016 while the oldest is in Oct 5, 2011 as I found.

### 1.3.2 Tutorials

Google gives me about 373,000 results for "WebGL tutorial" (28,900,000 for "JavaScript" at the same time).

The popular ones are:

1. MDN tutorial
2. LearningWebGL
3. WebGL Academy
4. WebGL Fundamentals

### 1.3.3 Misc

- High-level libraries: BabylonJS, three.js, O3D, OSG.JS, CopperLicht and GLGE
- Game engines: Unreal Engine 4 and Unity 5
- Languages:
  - JavaScript (native)
  - TypeScript
  - PureScript
  - CoffeeScript
  - Haxe

## 1.4 Applications

### 1.4.1 Examples

- NASA: Exploring Curiosity
- Chrome Experiments
- Three.js featured projects

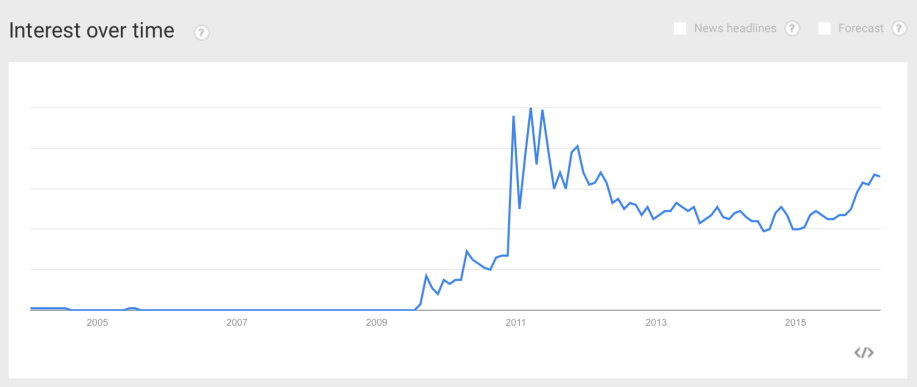



Figure 1: Google Trend for "WebGL"

### 1.4.2 Chrome Experiments

Currently, it has 567 experiments using WebGL. (About half of all experiments).

From the first page, we will list the used technologies for each application (only ones include WebGL), "Open" means it is open-sourced.

1. WebGL, Three.js, WebAudio; Open
2. Javascript,WebGL,Three.js,GLSL,WebRTC,WebAudio
3. Three.js, WebGL, Javascript
4. Three.js, Javascript; Open
5. Javascript es6, WebGL, Three.js, Glsl
6. Web Audio API, Tone.JS, pixi.JS, WebGL, WebRTC; Open
7. WebGL, WebAudio, Particulate.js, Three.js; Open
8. WebGL, Three.js, JavaScript (ES2015); Open
9. Javascript, WebGL, THREE.js, web audio API

So as we can see, Three.js is really popular; And half of them are open sourced.

### 1.4.3 Error and warnings sampling

I tested the nine applications listed above, to see if there are any errors or warnings in my browser (The experiment UA: Safari 9). Here is the result for erros/warnings, and the rest is fine:

- From 2nd app: `[Error] TypeError: undefined is not an object (evaluating 'camera.updateProjectionMatrix')`
- From 3rd app: `[Warning] THREE.Material: 'envMap' parameter is undefined. (three.min.js, line 428)`

- From 4th app: `[Warning] THREE.WebGLProgram: gl.getProgramInfoLog() - "WARNING: Output of vertex shader 'vNormal' not read by fragment shader " (three.js, line 29952)`
- From 6th app: `[Warning] THREE.WebGLProgram: gl.getProgramInfoLog() - "WARNING: Output of vertex shader 'vPosition' not read by fragment shader "`

# 2 Troubles and Trouble-Shooting

## 2.1 Overview

### 2.1.1 Categories

In typical WebGL applications, we might have following kinds of errors (only the ones which *will* happen every time, we don't count the resource loading failure etc. in).

- GLSL
- Typo
- unexpected parameter
- Buffer not bound
- GLSL
- Resource deallocation
- Lack of certain step
- Buffer deallocation
- Type error
- Memory leak
- Improper sharing
- missing properties
- Name not in scope
- Undeclared identifier
- Context management
- Resource loading order
- API usage error
- Shader error
- Threejs
- Type errors
- Matrix related
- Others

### 2.1.2 GLSL errors

Referencing the GLSL errors in IE [4], we can divide GLSL errors further into:

- Internal compiler error
- Compiler memory error - shader exceeds x bytes
- Syntax error - x
- Undeclared identifier x
- Invalid arguments passed to function x

- Postfix expression cannot be indexed
- Index out of range
- Incompatible index expression. For non-uniforms, the index must be an expression formed of the loop_index and integer constants. For uniforms, the index must be an integer constant.
- Index must be a constant
- Argument x is not a sampler
- Invalid macro name - cannot start with `GL_` or contain `__`
- Incompatible types in expression
- Expression in if statement does not evaluate to a boolean
- Divide or mod by zero in constant expression
- Invalid parameter count for macro
- Maximum uniform vector count exceeded
- Maximum attribute vector count exceeded
- Maximum varying vector count exceeded
- Maximum shader complexity exceeded
- Identifier already declared
- Invalid character used outside of comment
- Invalid initializer in for loop, needs to be a single variable of type float or int and initialized to a constant
- Invalid condition in for loop, needs to be in form `loop_index { > | >= | < | <= | == | != } constant`
- Invalid iteration in for loop, needs to be in form `{ --loop_index | ++loop_index | loop_index++ | loop_index-- | loop_index+=constant | loop_index-=constant }`
- Invalid modification to loop index inside loop body
- Invalid identifier name - cannot start with `gl_`, `webgl_`, `_webgl_` or contain `__`
- Token exceeds maximum length
- Invalid qualifier on array - cannot make arrays of attribute or const variables
- Incompatible type used for return expression
- Invalid qualifier on sampler variable declaration - must be uniform
- Invalid type passed to matrix constructor - arguments must be a matrix, or a scalar / vector of float / int / bool
- Invalid type passed to componentwise vector or matrix constructor - arguments must be a scalar / vector of float / int / bool
- Invalid argument count in componentwise vector or matrix constructor - total components passed must equal vector or matrix size
- Invalid expression on left of assignment expression
- Invalid swizzle in field selection - swizzle component count must be equal or less than max vector size (4)
- Invalid swizzle in field selection - swizzle components must be all from

same set (xyzw, rgba or stpq)
- Invalid swizzle component in field selection - must be from a valid GLSL set (xyzw, rgba or stpq)
- Swizzle component out of range - must select a component that exists in the vector
- This hardware is unable to support `gl_FrontFacing`
- Const variable requires initialization
- Variables declared with uniform, attribute, or varying qualifier cannot be initialized
- Varying variable cannot have bool, int, or struct type
- Invalid argument passed to constructor - argument must be a basic GLSL type
- Invalid type qualifier for function parameter - only const on in parameters is allowed
- Array declarator requires a constant expression
- Array was declared with size less than or equal to zero
- Type qualifiers `uniform` and `attribute` are invalid for structs
- Invalid field name for struct type
- Invalid type for left hand side of field selection
- Samplers are not allowed in structs
- Macros must be redefined the same as original definition
- Invalid loop index expression passed as out / inout parameter
- Type cannot be used as a constructor
- Undeclared type x
- Embedded struct declarations are not allowed
- Function x is declared and used but not defined
- Function redefinition not allowed
- Function redeclaration not allowed
- Invalid single argument to vector constructor - must be a scalar type, or another vector, or a 2x2 matrix
- Struct constructor arguments' types do not match the struct's field types
- Invalid location for continue statment - must be inside of a loop
- Cannot call main
- Invalid qualifier on non-global variable - non-global variables can be const but cannot be varying, attribute or invariant
- Cannot redefine main or define main with incorrect signature
- Cannot use reserved operators such as `~`, `%=`, `>>=`, `<<=`, `&=`, `|=`, or `^=`
- Ternary conditional operator must have boolean expression for test condition
- Ternary conditional operator must have two expressions of equal types after test condition
- Invalid location for break statement - break statements must be inside a

loop
- Invalid location for discard statement - discard statements must be inside a fragment shader
- Initializer for const variable must initialize to a constant value
- Functions cannot be overloaded on return type
- Known functions cannot be re-declared or re-defined
- Function header definition parameter qualifiers must match declaration parameter qualifiers
- Array size must be an integer constant expression
- Array size expression too complex
- `#version` directive must specify 100 for version
- `#version` directive can only be preceded by whitespace or comments
- Unary operator not defined for type
- Struct declarations are disallowed in function parameter declarators
- Struct type declaration exceeds maximum nesting level of
- Operator not defined for struct types
- Operator not defined for user-defined types that contain array types
- Unknown extension: x
- Invalid behavior specified for extension - behavior must be require, warn, enable or disable for regular extensions, or warn or disable for `all`
- Required extension x is not supported
- Preprocessor directives can only be preceded by whitespace on a line
- Function declarations cannot be local
- Variable declared as type void is not allowed
- 'void' is an invalid parameter type unless used as `(void)`

## 2.2 Compiled Information from MDN

Source: API, Best Practices

### 2.2.1 Source of bugs

**canvas element** To get the rendering context, i.e., the canvas element, we usually use `getElementById` or similar way to fetch the DOM object. The caveat is, the `id` is specified in HTML tag, such as

```
<canvas id="glcanvas" width="640" height="480">
```

And you must use the exact name in your JavaScript code. **It is possible that you will type it wrongly or refer to another unrelated canvas**.

### `gl` Object

```
function initWebGL(canvas) {
  gl = null;

  try {
    // Try to grab the standard context. If it fails, fallback to experimental.
    gl = canvas.getContext("webgl") || canvas.getContext("experimental-webgl");
  }
  catch(e) {}

  // If we don't have a GL context, give up now
  if (!gl) {
    alert("Unable to initialize WebGL. Your browser may not support it.");
    gl = null;
  }

  return gl;
}
```

First, we might not have a functional `gl` (not `null`) always, which depends on the browser support. And second, in the `getContext`, we are also forced to consider two standards.

**Shader's source** The shader code is essentially a string. So as a result, you might either define it in JavaScript, or store it as a HTML element, or even request it as a resource dynamically from other address.

```
if (!gl.getProgramParameter(shaderProgram, gl.LINK_STATUS)) {
  alert("Unable to initialize the shader program.");
}
```

The above snippet checks if the `gl.linkProgram` calling succeeds by checking if return value is `null`. It is apparently something easy to forget.

**Attribute names** The shader code will use some variable to communicate with JavaScript. For example

```
<script id="shader-vs" type="x-shader/x-vertex">
  attribute vec3 aVertexPosition;

  uniform mat4 uMVMatrix;
  uniform mat4 uPMatrix;
```

```
  void main(void) {
   gl_Position = uPMatrix * uMVMatrix * vec4(aVertexPosition, 1.0);
  }
</script>
```

On the JavaScript side, we have to

```
// During Shader initialization
vertexPositionAttribute = gl.getAttribLocation(shaderProgram, "aVertexPosition");
gl.enableVertexAttribArray(vertexPositionAttribute);

// During scene rendering
var pUniform = gl.getUniformLocation(shaderProgram, "uPMatrix");
gl.uniformMatrix4fv(pUniform, false, new Float32Array(perspectiveMatrix.flatten()));

var mvUniform = gl.getUniformLocation(shaderProgram, "uMVMatrix");
gl.uniformMatrix4fv(mvUniform, false, new Float32Array(mvMatrix.flatten()));

gl.bindBuffer(gl.ARRAY_BUFFER, squareVerticesBuffer);
gl.vertexAttribPointer(vertexPositionAttribute, 3, gl.FLOAT, false, 0, 0);
```

So, we have to match the names (i.e. `aVertexPosition`, `uPMatrix` and `uMVMatrix` in the above example) in two language domains, both in syntax and semantics.

**Array** This is how to fill data into GL buffer: `gl.bufferData(gl.ELEMENT_ARRAY_BUFFER, new Uint16Array(cubeVertexIndices), gl.STATIC_DRAW);`

The `Uint16Array` is a raw, platform-dependent way of storing an array of data. Similarly, we also have `Array`, `Int8Array`, `Float32Array` …

Interestingly, let compare it with OpenGL ES interface: `void BufferData( enum target, sizeiptr size, const void *data, enum usage );`.

You can see that, the `Uint16` array could be translated into a raw array and a element size indicator.

### 2.2.2 Things to avoid

- You should never use `#ifdef GL_ES` in your WebGL shaders; although some early examples used this, it's not necessary, since this condition is always true in WebGL shaders.

- Using `high` precision in fragment shaders will prevent your content from working on some older mobile hardware. You can use `medium` instead, but be aware that this often results in corrupted rendering due to lack of precision on most mobile devices, and the corruption is not going to be visible on a typical desktop computer. In general, only using `high` in both vertex and fragment shaders is safer unless shaders are thoroughly tested on a variety of platforms. Starting in Firefox 11, the WebGL `getShaderPrecisionFormat()` function is implemented, allowing you to check if `high` precision is supported, and more generally letting you query the actual precision of all supported precision qualifiers.
- Anything that requires syncing the CPU and GPU sides is potentially very slow, so if possible you should try to avoid doing that in your main rendering loops. This includes the following WebGL calls: `getError()`, `readPixels()`, and `finish()`. WebGL getter calls such as `getParameter()` and `getUniformLocation()` should be considered slow too, so try to cache their results in a JavaScript variable.
- Simpler shaders perform better than complex ones. In particular, if you can remove an `if` statement from a shader, that will make it run faster. Division and math functions like `log()` should be considered expensive too.
- Always have vertex attrib 0 array enabled. If you draw with vertex attrib 0 array disabled, you will force the browser to do complicated emulation when running on desktop OpenGL (e.g. on Mac OS X). This is because in desktop OpenGL, nothing gets drawn if vertex attrib 0 is not array-enabled. You can use `bindAttribLocation()` to force a vertex attribute to use location 0, and use `enableVertexAttribArray()` to make it array-enabled.

## 2.3 Compiled Information from Stackoverflow

Source

### 2.3.1 Examples

#### Undeclared identifier

- gl-color-is-undeclared-identifier-on-webgl

#### Context management

- another `canvas.getContext('2d')` occupied this canvas context.
- webgl-scene-doest-render-because-of-lost-context

### Resource loading order

- Try to render the scene before the shader program is downloaded and compiled

### API usage error

- WebGL Fragment Shader constructor error - Too many arguments
- Where is your setup code
- WebGL error when attempting to get color data from vec4
- API name typo
- what-is-wrong-with-this-webgl-code
- Because `createProgram` don't return anything
- should be calling `gl.drawArrays()` once for every object that is currently on the screen
- have to create an array buffer for each object you are drawing
- 3 reasons of failing to call `gl.drawElements`
- webgl-drawarrays-with-invalid-mode-is-not-generating-a-error
- webgl-drawelements-out-of-range
- webgl-failing-at-drawing-points-gldrawarrays-attempt-to-access-out-of-range
- webgl-invalid-value-attachshader-no-object-or-object-deleted-is-this-secretl
- why-doesnt-my-sphere-render-complete
- webgl-drawelements-out-of-range
- webgl-invalid-operation-useprogram
- type-canvasrenderingcontext2d-webglrenderingcontext-is-not-assignable-to-typ
- webgl-shader-errors
- what-will-happen-if-an-attribute-is-used-in-program-without-enabled-and-binding
- webgl-gl-error-gl-invalid-operation-gldrawelements-attempt-to-access-out-of

### Shader error

- `uniform1i(3, 0)` Is not valid WebGL
- GLSL interpreted as javascript
- WebGL - compileShader syntax error
- WebGL shader errors
- webgl-unable-to-initialize-shader-program
- google-chrome-webgl-shader-compile-linker-error-uniforms-with-the-same-name-but

- wrong-integer-math-in-webgl-shaders
- shader-compile-errors
- using-a-uniform-in-an-if-instruction-inside-a-fragment-shader-dont-work-since
- webgl-unable-to-initialize-shader-program
- gl-invalid-operation-caused-by-samplercube

### Threejs

- Three.js: WebGL (error) drawing texture on a plane
- Normalize takes a vec3 not a vec4
- three-js-webgl-invalid-operation-bindtexture-object-not-from-this-context
- canvas-renderer-not-working
- three-js-particlesystem-creation-gives-invalid-operation-not-bound-buffer-array

### Others

- WebGL: get error/warning message text as a string
- WebGL texture creation trouble
- Understanding WebGL State
- problems-with-texture-array-sending-to-shaders-in-webgl
- webgl-rendering-an-float32array-of-a-lot-of-elements-showing-out-of-range-vertic
- array-buffer-not-working-with-webgl
- webgl-texture-is-not-showing-correctly
- passing-color-to-fragment-shader-from-javascript
- is-there-a-lint-tool-for-opengl-shading-language
- three-js-shader-extention-errors

### Type errors

- webgl-invalid-operation-vertexattribpointer-stride-or-offset-not-valid-for-ty
- webgl-glsl-shader-accessing-texture2d-overrides-other-texture
- So finally it is a typing mistake

### Matrix related

- webgl-using-gl-matrix-library-mat4-translate-not-running
- square-doesnt-appear-using-perspective-matrix

## 2.4 Compiled Information from three.js

### 2.4.1 Overview

- threejs-issue-5421: Buffer deallocation
- threejs-issue-5569: Type mismatch
- threejs-issue-5680: Memory leak
- threejs-issue-5871: Improper sharing
- threejs-issues-83: Name not in scope
- threejs-pull-1602: GLSL
- threejs-issue-4834: Unexpected parameter
- threejs-issue-5098: Buffer not bound
- threejs-issue-5196: Buffer not bound
- threejs-issue-5222: GLSL & Unexpected parameter
- threejs-issue-5269: Resource deallocation
- threejs-issue-5293: Lack of certain step
- threejs-issue-6952: Missing properties
- threejs-issue-6956: GLSL

### 2.4.2 Details

### 2.4.3 threejs-pull-1602

**Categories**

- GLSL

**Link** https://github.com/mrdoob/three.js/pull/1602

**Remark** This PR mentioned a problem about adding precision qualifiers to resolve shader compilation errors on mobile device. This is also a nasty problem which is platform-dependent

**threejs-issue-1329**

**Categories**

- Typo

**Link** https://github.com/mrdoob/three.js/issues/1329

**Remark** `THREE.UnsignedIntType` is written wrongly as `THREE.UnsignedShortType`. However, its namespace is `THREE`, which is defined by library, not by WebGL.

**Possible fix** I think TAJS might be able to resolve this by analyzing information of object property?

### threejs-issue-4834

#### Categories

- unexpected parameter

**Link** https://github.com/mrdoob/three.js/issues/4834

**Remark** Discussed 2 problems here related to the compilation failure of the shader.

````
- [This commit](https://github.com/Nimanf/three.js/commit/7f7650c5e012890a34c26c1

- Then there is a discussion about the warning X3557 caused by `MAX_DIR_LIGHTS` is 1 a
    ```
    #define MAX_DIR_LIGHTS 1
    #if MAX_DIR_LIGHTS > 0
    for( int i = 0; i < MAX_DIR_LIGHTS; i++ ) { ...
    ```
````

**Possible fix** maybe same as threejs issue 5222

### threejs-issue-5098

#### Categories

- Buffer not bound

**Link** https://github.com/mrdoob/three.js/issues/5098

**Remark** An eye catched error.

> `THREE.Float32Attribute` has been removed.

Use THREE.BufferAttribute( array, itemSize ) instead.

this commit solves this:

```
- geometry.addAttribute( 'position', new THREE.Float32Attribute( numEdges * 2 * 3, 3 ) );
+ geometry.addAttribute( 'position', new THREE.BufferAttribute( new Float32Array( numEdges
```

**Possible fix** Search for available functions in the lib

#### threejs-issue-5196

#### Categories

- Buffer not bound

**Link** https://github.com/mrdoob/three.js/issues/5196#issue-40214568

**Remark** Found while playing with threejs.org/editor

After adding a Mesh with the Menubar's 'Add' panel, sidebar geometry parameter changes cause the object to stop displaying.

Console warnings from WebGL: `WebGL: INVALID_OPERATION: vertexAttribPointer: no bound ARRAY_BUFFER three.min.js:545 WebGL: INVALID_OPERATION: vertexAttribPointer: no bound ARRAY_BUFFER three.min.js:549 WebGL: INVALID_OPERATION: drawElements: no ELEMENT_ARRAY_BUFFER bound three.min.js:552 [17:54:37] Saved state to IndexedDB. 0.71ms Storage.js:64`

**Possible fix** Track the `gl` context and the `buffer` might avoid these.

#### threejs-issue-5222

#### Categories

- GLSL
- unexpected parameter

**Link** https://github.com/mrdoob/three.js/issues/5222

**Remark** As referred to to GLSL mannual P65, in `genType pow (genType x, genType y)`, results are undefined if x = 0 and y <= 0. So in the generated GLSL in the issue, `pow(pointDotNormalHalf, shininess)` could be undefined and not warned. In the commit #7252, this was fixed by: `- uniforms.shininess.value = material.shininess; + uniforms.shininess.value = Math.max( material.shininess, 1e-4 );`

**Possible fix** Interval analysis and warning

**Related**

- messed up OBJMTL loader #7252
- MeshPhongMaterial with shininess = 0 causes artifacts on Windows #6057

**threejs-issue-5269**

**Categories**

- Resource deallocation

**Link** https://github.com/mrdoob/three.js/issues/5269

**Remark** The child of object3D was not removed before removing the object3D itself. This arouse the memory leakage.

**Possible fix** Might be fixed by tracking the state of the object?

**threejs-issue-5293**

**Categories**

- Lack of certain step

**Link** https://github.com/mrdoob/three.js/issues/5293

**Remark** `WebGLRenderer` is not doing `updateObject( object )` because is not visible from the main camera. hen an error `glDrawElements: range out of bounds for buffer` would occur.

**Possible fix** Might be fixed by tracking the state of the object?

**Related**

- The author broke it again recently in #6996

**threejs-issue-5421**

**Categories**

- Buffer deallocation

**Link** https://github.com/mrdoob/three.js/issues/5421

**Remark** According to the commit, the problem is that we should not only call `_gl.deleteBuffer(buffer_obj)`, but also call `delete buffer_obj [Document aboutdeleteBuffer‘](https://developer.mozilla.org/en-US/docs/Web/API/WebGLRenderingContext/deleteBuffer).

**Possible fix** The problem might cause the old state to persist unexpectedly. So one way of elimination is to require a “fresh” state explicitly at some point, which can preclude such presence if possible.

**threejs-issue-5569**

**Categories**

- Type error

**Link** https://github.com/mrdoob/three.js/commit/1311c0e315326bdb9c02a5c7b8733bb0c27fb1ea

**Remark** Commit. Well, it is recognised by naked eyes. But first it is a silent bug, which is rather harmful. Second, although threejs doesn’t depend on `gl-matrix.js`, it has a similar internal system

**Possible fix** Add additional type information

**threejs-issue-5680**

**Categories**

- Memory leak

**Link** https://github.com/mrdoob/three.js/issues/5680

**Remark** Fixed in PR, with commit. This is very nasty … I can't give a reasonable fix now.

**threejs-issue-5871**

**Categories**

- Improper sharing

**Link** https://github.com/mrdoob/three.js/issues/5871

**Remark** This is caused by the geometry being shared across contexts outside of the closure in `ArrowHelper`'s definition. A length related discussion.

**Possible fix** Globally, we might be able to couple a context with a buffer.

**threejs-issue-6952**

**Categories**

- missing properties

**Link** https://github.com/mrdoob/three.js/pull/6952

**Remark** When exporting `BoxGeometry` parameters(width, height, depth) by `SceneExporter`, it should be `g.parameters.width` rather than `g.width`. Fixed by this commit.

**Possible fix** Track object's properties.

**Related**

- SceneExporter doesn't handle box/sphere/plane parameters #4739
- SceneExporter // BoxGeometry Inconsistent #5067
- #5067 make SceneExporter use correct BoxGeometry parameters #5068

**threejs-issue-6956**

**Categories**

- GLSL

**Link** https://github.com/mrdoob/three.js/issues/6956

**Remark** Pull: https://github.com/thothbot/parallax/pull/43 In GLSL, extension directive must occur before any non-preprocessor tokens, otherwise a warning is raised. Threejs fixed in 72dev.

**Related**

- parallax
- ancient-earth

**threejs-issues-83**

**Categories**

- Name not in scope

**Link** https://github.com/mrdoob/three.js/issues/83

**Remark** The `scene` referenced isn't passed in as an argument or declared above - so it's looking in the global scope. So it tends to be some programming style issue, which is related to the problem being solved.

**threejs-pull-1602**

**Categories**

- GLSL

**Link** https://github.com/mrdoob/three.js/pull/1602

**Remark** This PR mentioned a problem about adding precision qualifiers to resolve shader compilation errors on mobile device. This is also a nasty problem which is platform-dependent.

## 2.5 Compiled Information from applications

NOTE: needs more feedback from community

### 2.5.1 fireworks-webgl

Repo

Issues:

- drawing buffer alert

### 2.5.2 medusae

Repo

Issues:

- Fix alpha material shaders

## 2.6 Trouble-shooting WebGL code

### 2.6.1 *Professional WebGL Programming: Developing 3D Graphics for the Web*

A list of problems:

- JavaScript syntax error
- Runtime error

- Compilation error in the shader
- Linking error in the shader program
- If your fragment shader tries to use a caring variable that is not defined in your vertex shader
- WebGL specific errors

Trouble-shooting checklist (only debug the code part):

1. Check that you didn't misspell a name of an object property.
2. Check you have spelled all properties of `WebGLRenderingContext` correctly.

### 2.6.2 *An Introduction to WebGL Programming*

Link

> Just a with regular programs, a syntax error from the compilation stage, or a missing symbol from the linker stage could prevent the successful generation of an executable program. There are routines for verifying the results of the compilation and link stages of the compilation process, but are not shown here. Instead, we've provided a routine that makes this process much simpler, as demonstrated on the next slide.

### 2.6.3 *Beginning WebGL for HTML5*

Chapter 9: Debugging and Performance

The main error codes are:

- `INVALID_ENUM`
- `INVALID_VALUE`
- `INVALID_OPERATION`
- `OUT_OF_MEMORY`

Context errors:

1. Context creation — might fail to obtain a WebGL context

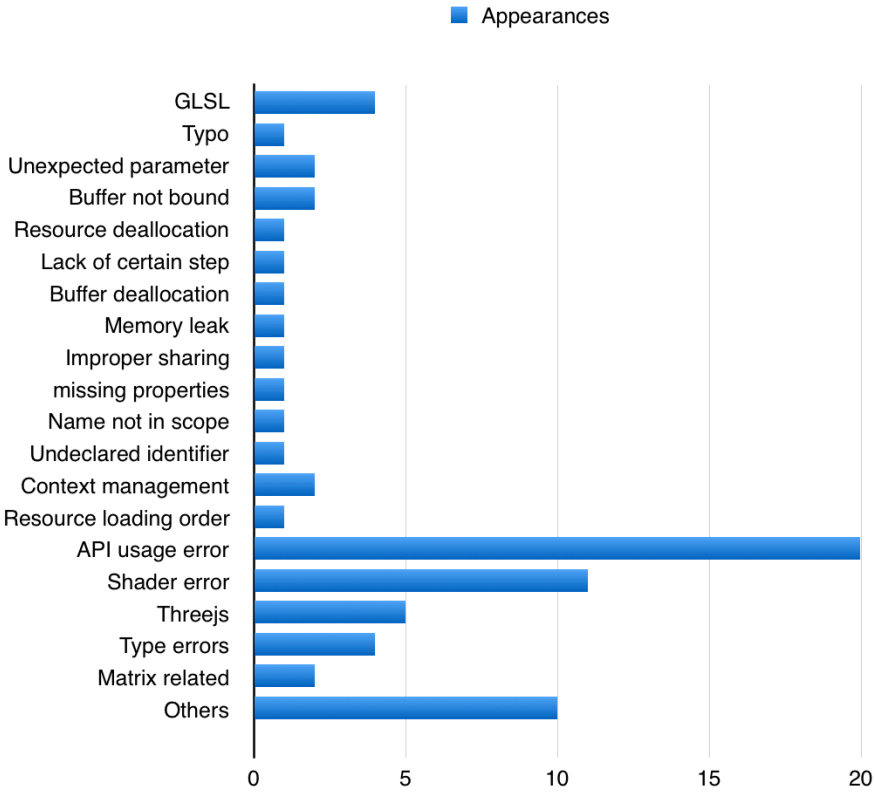
### 2.6.4 Misc

- http://www.gamedev.net/topic/673408-debugging-pure-webgl-and-js-is-hell/
- https://yulian.kuncheff.com/using-intellijwebstorm-to-debug-web-applications/

## 2.7 Statistics

Collected from the bugs in three.js sampling and stackoverflow sampling.

- GLSL: 4
- Typo: 1
- Unexpected parameter: 2
- Buffer not bound: 2
- Resource deallocation: 1
- Lack of certain step: 1
- Buffer deallocation: 1
- Memory leak: 1
- Improper sharing: 1
- missing properties: 1
- Name not in scope: 1
- Undeclared identifier: 1
- Context management: 2
- Resource loading order: 1
- API usage error: 20
- Shader error: 11
- Threejs: 5
- Type errors: 4
- Matrix related: 2
- Others: 10


Appearances
GLSL
Typo
Unexpected parameter
Buffer not bound
Resource deallocation
Lack of certain step
Buffer deallocation
Memory leak
Improper sharing
missing properties
Name not in scope
Undeclared identifier
Context management
Resource loading order
API usage error
Shader error
Threejs
Type errors
Matrix related
Others
0
5
10
15
20

# 3 Library Support

## 3.1 Overview

### 3.1.1 Popular libraries

- High-level libraries: BabylonJS, three.js, O3D, OSG.JS, CopperLicht and GLGE
- Matrix libraries: gl-matrix, sylvester

### 3.1.2 Abstractions

Take three.js as an example:

- Geometry
- Objects
- Materials
- Lights
- Resource loaders
- Linear algebra
- Scenes
- Camera
- Renderer (not just WebGL)
- Textures

### 3.1.3 Why libraries?

1. The developer can focus on the logic of their applications/business, rather than the implementation details;
2. The third-party library's APIs are better designed to fit the language construct of JavaScript
3. The high-level library is simpler and more restricted in effects – which means less error-prone.

As a result, the following errors can be eliminated by using a library:

- Typo
- Buffer binding
- Resource Management
- Lack of certain step
- Missing properties
- Name not in scope

- Undeclared identifier
- API usage error
- Matrix related

## 3.2 Case study: gl-matrix

Home

glMatrix is designed to perform vector and matrix operations stupidly fast! The latest version uses WebPack to manage the modules.

### 3.2.1 APIs

Exposed interfaces: `glMatrix`, `mat2`, `mat2d`, `mat3`, `mat4`, `quat`, `vec2`, `vec3`, `vec4`

# Class glMatrix

Common utilities
*Defined in:* common.js.

## Methods

`glMatrix.setMatrixArrayType(type)`
Sets the type of array used when creating new vectors and matricies

## Method Detail

### glMatrix.setMatrixArrayType(type)

Sets the type of array used when creating new vectors and matricies

**Parameters:**
**{Type} type**
Array type, such as Float32Array or Array

**Common utilities**

**3x3 Matrix**

# Class mat3

3x3 Matrix
*Defined in:* mat3.js.

## Methods

`mat3.adjoint(out, a)`
Calculates the adjugate of a mat3

`mat3.clone(a)`
Creates a new mat3 initialized with values from an existing matrix

`mat3.copy(out, a)`
Copy the values from one mat3 to another

## Method Detail

### {mat3} mat3.adjoint(out, a)

Calculates the adjugate of a mat3

**Parameters:**
**{mat3} out**
the receiving matrix
**{mat3} a**
the source matrix

**Returns:**
{mat3} out

### 3.2.2 Library structure

- `glMatrix`: Common utilities, including config constants, compatibility detection, and things like `setMatrixArrayType`.
- `mat3` etc: Represent one type of data and the related operations.
  - Constructors: `create`, `clone`, `copy`
  - Computations: `identity`, `transpose`
  - Conversions: `fromMat4`

### 3.2.3 Possible problems

1. **Hard to maintain**: Even such a simple library is over 6000 lines of JS; and the author suggested a "sorry" for breaking the APIs from 1.0 to 2.0.
2. **Type Unsafe**: Concretely, it is easy to pass a `vec3` to where a `vec4` is expected. And since here is no type checking, so you won't get any explicit warning.

## 3.3 Case Study: Threejs

### 3.3.1 API samples

Docs

A example app, its workflow:

- initialize `scene`, `camera` and `renderer`.
- Create mesh object from geometry and material add them to the scene
- Render based on scene and camera frame by frame

```
<html>
    <head>
        <title>My first Three.js app</title>
        <style>
            body { margin: 0; }
            canvas { width: 100%; height: 100% }
        </style>
    </head>
    <body>
        <script src="js/three.min.js"></script>
        <script>
            var scene = new THREE.Scene();
            var camera = new THREE.PerspectiveCamera( 75,
                                window.innerWidth/window.innerHeight, 0.1, 1000 );
```

```
            var renderer = new THREE.WebGLRenderer();
            renderer.setSize( window.innerWidth, window.innerHeight );
            document.body.appendChild( renderer.domElement );

            var geometry = new THREE.BoxGeometry( 1, 1, 1 );
            var material = new THREE.MeshBasicMaterial( { color: 0x00ff00 } );
            var cube = new THREE.Mesh( geometry, material );
            scene.add( cube );

            camera.position.z = 5;

            var render = function () {
                requestAnimationFrame( render );

                cube.rotation.x += 0.1;
                cube.rotation.y += 0.1;

                renderer.render(scene, camera);
            };

            render();
        </script>
    </body>
</html>
```

### 3.3.2 Library structure

> The current three.js implementation is too huge – I will take its early release `three.js-r16` as a preliminary analysis object.

The `src` contains

1. cameras: set up the perspective matrix etc. based on camera paramters
2. core
    1. Color: convert hexadecimal code into internal representation and better format
    2. Face3/Face4: Wrap end-points and normal vector into a high-level structure `Face`
    3. Geometry: A geometry is a set of vertices and faces connecting the vertices, this function computes the normals of each face (which might be useful in texture or fragment shader?)
    4. Vector(2, 3, 4)/Matrix4: Basically same as `gl-matrix`
    5. Vertex: Wrapper over position and normal (normal?)

6. UV: (u, v) coordinate (NOTE: UV mapping is a process of flattening the 3-dimensional object)
7. Rectangle: Again, a geometry wrapper

3. materials: Wrap the attribute values of different materials
4. objects: Simple wrappers of `Line`, `Mesh`, `Object3D` etc.
5. renderers
    1. `renderables`: `RendererableFace(3,4)`, `RenderableLine`, `RenderableParticle` etc., looks like another set of wrappers
    2. `CanvasRenderer`: In construction, context is get from created `canvas` element; A lot of other vectors and rectangle are created as well. The functions provided include `setSize`, `clear`, `render`, `drawTexturedTriangle` and `expand`. However, this is only a 2d canvas.
    3. `Renderer`: Its data includes pools of face3, face4, line and particles, as well as a vector4 and a matrix4. The exposed interfaces include a `renderList` and method `project`. I suppose that this will do some transformation (like projection), and push the things left to render into `renderList`
    4. `SVGRenderer`: Similar to `CanvasRenderer`
    5. `WebGLRenderer`: Similar to `CanvasRenderer`, we have some basic bootstrapping and after that, we call `initGL` and `initProgram`; The utilities provided include `setSize`, `clear render`, `getShader`; There are also internal functions `getShader` and `matrix2Array`.
        - `initGL`: It will try to get context, and will throw in case of incompatibility. If context is ready, it will do `clearColor`, `clearDepth` and other config and setups.
        - `initProgram`: Two shaders, fragment and vertex shaders are hard-coded here. With attached shaders, it link and use the program. Finally, it will set other attributes related.
        - `clear`: Clear the `COLOR_BUFFER_BIT` and `DEPTH_BUFFER_BIT` bits.
        - `render`: Given a `scene` and a `camera`, it will render the mesh object in `scene` one by one. Every mesh object will have its vertex buffer. The related data also contains faces and color. For every face, its three vertices will be push into the array, same for color. With buffers ready, it will create, bind and fill in one by one with `createBuffer`, `bindBuffer` and `bufferData`. After that, the view matrix and projection matrix is set. Next, the material of object is rendered as well. The color of face are pushed into the buffer, bind and filled in. Finally, we will call `drawElements`.
        - `getShader`: It is basically wrapping around `createShader`, `shaderSource`, `compileShader`.
6. scenes: Wrapper of an array of objects

# 4 Tool Support

## 4.1 Exclusive Debug tools

Some debugging tools for WebGL development are listed here.

Another post

### 4.1.1 WebGL Insights

Home

This tool looks very powerful and mature. Look at the features:

- Chrome Extension embedded in the Chrome DevTools panel
- Overdraw Inspector
- Mipmap Inspector
- Depth Inspector
- Call Stack Timeline and Statistics
- Program Usage Count
- Duplicate Program Usage Detector
- Program Viewer
- Frame Control
- State Variable Editor
- Resource Viewer

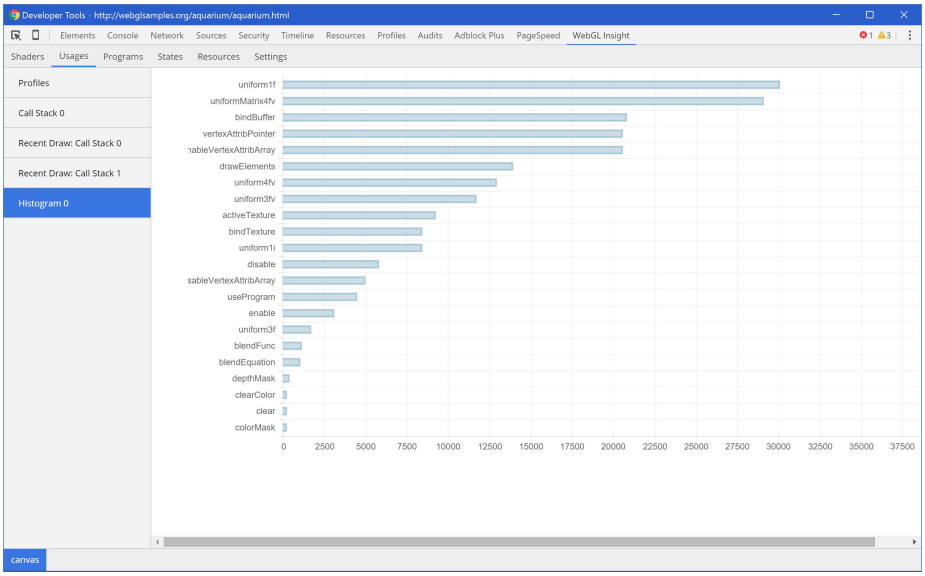
One screen-shot:

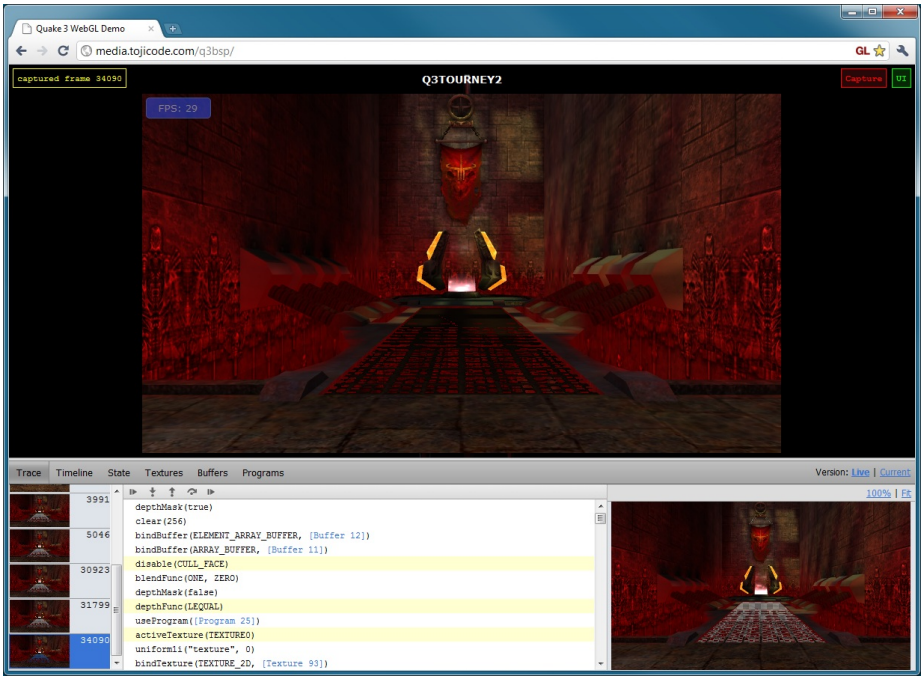
### 4.1.2 WebGL-Inspector

Home

Features

- Extension for injecting into pages
- Embed in an existing application with a single script include
- Capture entire GL frames
- Annotated call log with stepping/resource navigation and redundant call warnings
- Pixel history - see all draw calls that contributed to a pixel + blending information
- GL state display


Developer Tools - http://webglsamples.org/aquarium/aquarium.html
Elements Console Network Sources Security Timeline Resources Profiles Audits Adblock Plus PageSpeed WebGL Insight
Shaders Usages Programs States Resources Settings
Profiles
Call Stack 0
Recent Draw: Call Stack 0
Recent Draw: Call Stack 1
Histogram 0
uniform1f
uniformMatrix4fv
bindBuffer
vertexAttribPointer
nableVertexAttribArray
drawElements
uniform4fv
uniform3fv
activeTexture
bindTexture
uniform1i
disable
sableVertexAttribArray
useProgram
enable
uniform3f
blendFunc
blendEquation
depthMask
clearColor
clear
colorMask
0 2500 5000 7500 10000 12500 15000 17500 20000 22500 25000 27500 30000 32500 35000 37500
canvas


Quake 3 WebGL Demo
media.tojicode.com/q3bsp/
captured frame 34090
Q3TOURNEY2
Capture
UI
FPS: 29
Trace Timeline State Textures Buffers Programs
Version: Live | Current
100% | Fit
3991
5046
30923
31799
34090
depthMask(true)
clear(256)
bindBuffer(ELEMENT_ARRAY_BUFFER, [Buffer 12])
bindBuffer(ARRAY_BUFFER, [Buffer 11])
disable(CULL_FACE)
blendFunc(ONE, ZERO)
depthMask(false)
depthFunc(LEQUAL)
useProgram([Program 25])
activeTexture(TEXTURE0)
uniform1i("texture", 0)
bindTexture(TEXTURE_2D, [Texture 93])

- Resource browsers for textures, buffers, and programs

Demo

This is a very convenient debugger, it can be useful when you application's logic is wrong (compared to our analyzer's target – the syntax and API is wrong).

#### 4.1.3 webgl-debug.js

- Repo
- Home

It will wrap the `WebGLRenderingContext` with a debugging wrapper, which will make any GL errors show up in the JavaScript console of browser.

Also, we can log function calls with by passing a logger in the above mentioned wrapper.

It provides a sample.

#### 4.1.4 WebGL Linter

Repo

This is a discontinued and very primitive project – but the idea is there. ## Browser Support and IDE Support

#### 4.1.5 Browser

**Chrome Canvas Inspector** See the post

**Firefox Shader Editor** See this post

#### 4.1.6 IDE

Generally speaking, by using an IDE, you can avoid a lot of silly bugs all-together.

Also, there are some graphical editors for modeling.

**JetBrain - WebStorm** It has support for GLSL language by plugin.

**WebGL Studio** Home

**Three.js editor** Home

**3Dmol.js** Home

**Blend4Web** Home

# 5 Conclusion

## 5.1 Best practices in WebGL development

### 5.1.1 General ones

1. If you are writing code – Use a good IDE or modern editor, such as WebStorm, Eclipse, and Atom. This can help you prevent most silly errors when you are still a newbie.
2. Use the graphical editor to get your model (in fact, you can model in softwares like Blender and Maya, then import the model into the JS).
3. Make error explicit – Check return value always, catch possible errors.
4. Take advantages of debugging tools like WebGL inspector.

### 5.1.2 Technical ones

- Article from MDN
- glQuery/webgl-best-practices

## 5.2 Future of WebGL tooling

### 5.2.1 Static analysis technique

The interoperation between JavaScript and GLSL opens a door for static analysis; Besides, editors and current IDE is unaware of if you have check `null`; The dynamic type information is simply ignored.

Also, the correct use of API involves side-effects, which is easy to get wrong.

### 5.2.2 Verified libraries

Three.js is a huge code base, and highly dynamic. You never know if some feature does work or it is just coincidence.

By verifying:

1. The library does what it is intended to do
2. The library does its job the right way

We will have more confidence and rely on it in the long run.

### 5.2.3 Integration

The integration into mature product is important, such as debug tools and IDEs.

# References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