Tools for Tuning OpenGL ES Apps on iOS

Taking the printf() out of graphics debugging

Session 416

Benj Lipchak and Seth Sowerby
GPU Software Developer Technologies

Touch Fighter 2
TOUCH FIGHTER II
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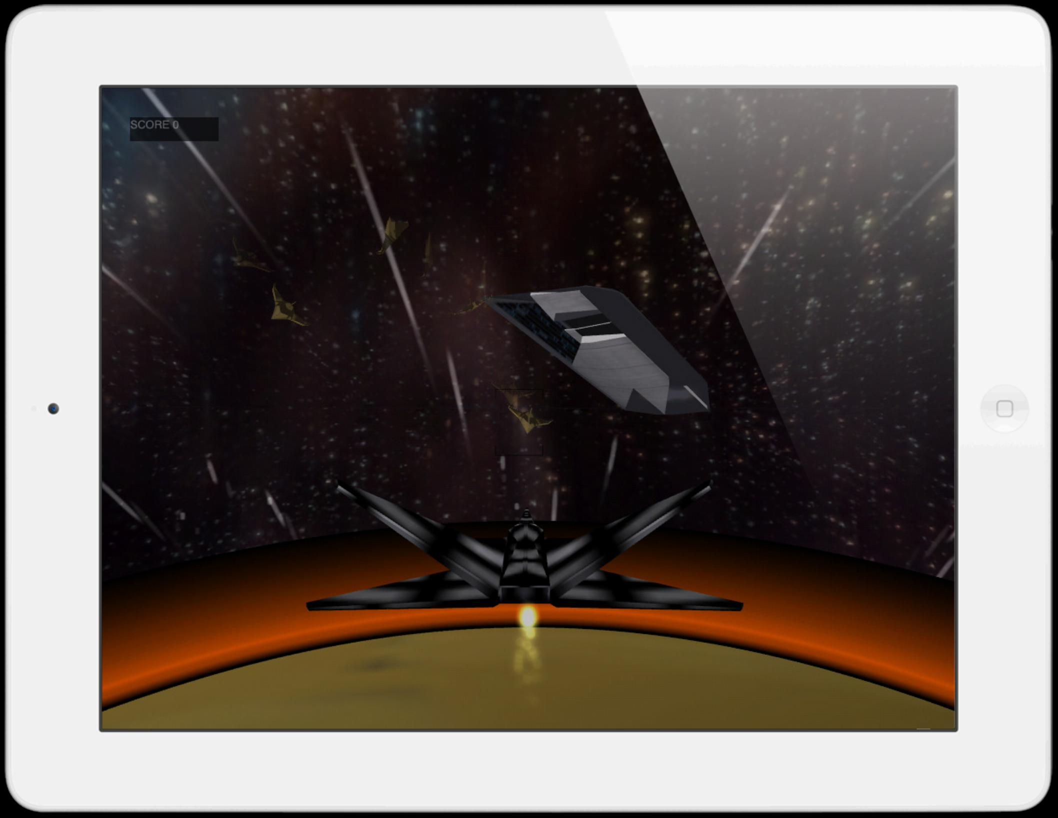

SCORE 0

Session Overview

- OpenGL ES Performance Detective
- Instruments—OpenGL ES Analyzer
- Xcode—OpenGL ES Debugger

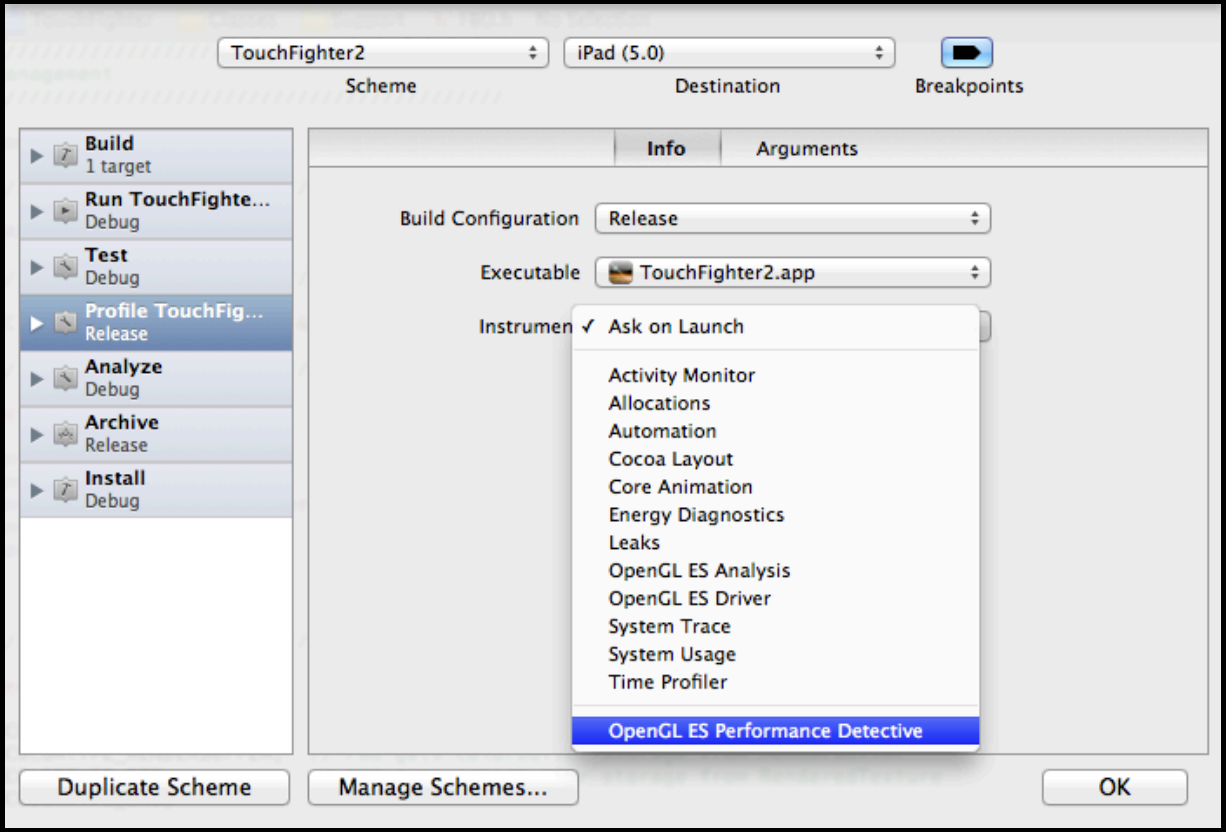
OpenGL ES Performance Detective

Benj Lipchak
GPU Software Developer Technologies

What Is It?

OpenGL ES Performance Detective

Where Can I Find It?



Scheme: TouchFighter2

Destination: iPad (5.0)

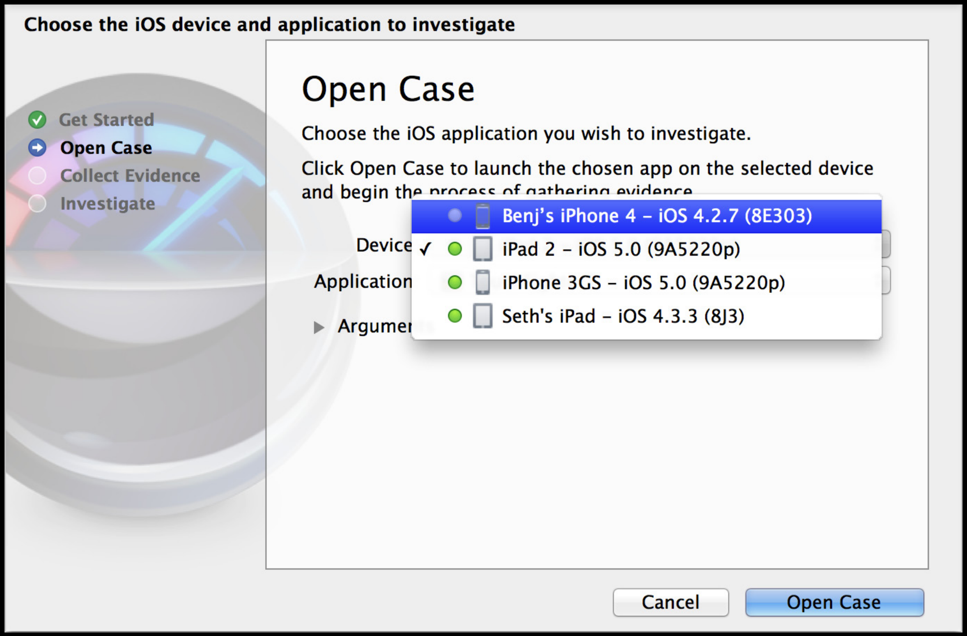
Build Configuration: Release

Executable: TouchFighter2.app

Instrumen ✓ Ask on Launch

How Do I Use It?

1. Select device
2. Select app
3. Trigger frame
4. Witness the magic
5. Look at the results



Choose the iOS device and application to investigate

✓ Get Started
Open Case
○ Collect Evidence
○ Investigate

Open Case

Choose the iOS application you wish to investigate.

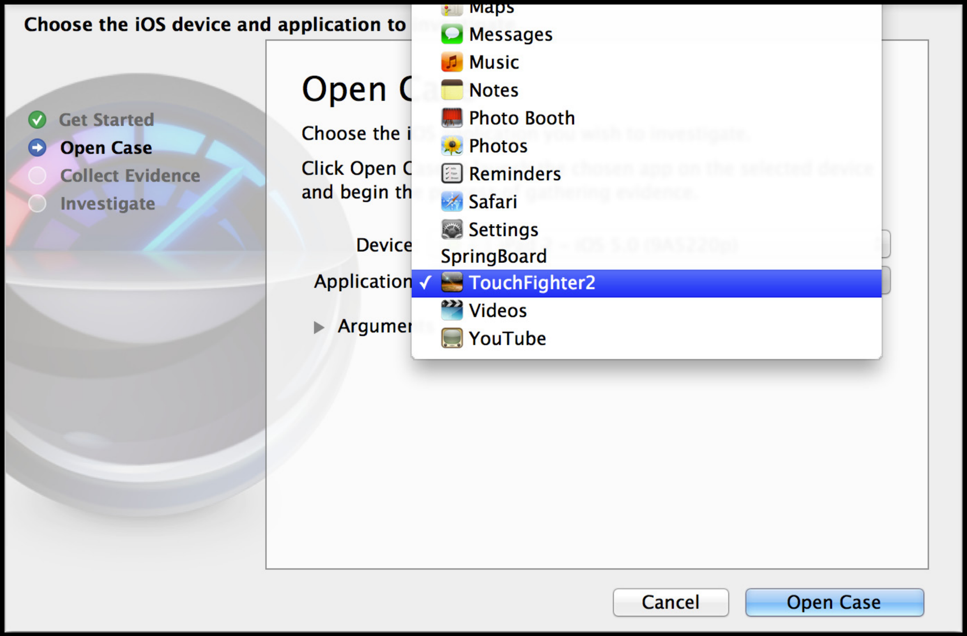
Click Open Case to launch the chosen app on the selected device and begin the process of gathering evidence.

Device ✓ iPad 2 – iOS 5.0 (9A5220p)

Benj's iPhone 4 – iOS 4.2.7 (8E303)
iPad 2 – iOS 5.0 (9A5220p)
iPhone 3GS – iOS 5.0 (9A5220p)
Seth's iPad – iOS 4.3.3 (8J3)
Application
Argumer
Cancel
Open Case

How Do I Use It?

1. Select device
2. Select app
3. Trigger frame
4. Witness the magic
5. Look at the results



Choose the iOS device and application to

Open C

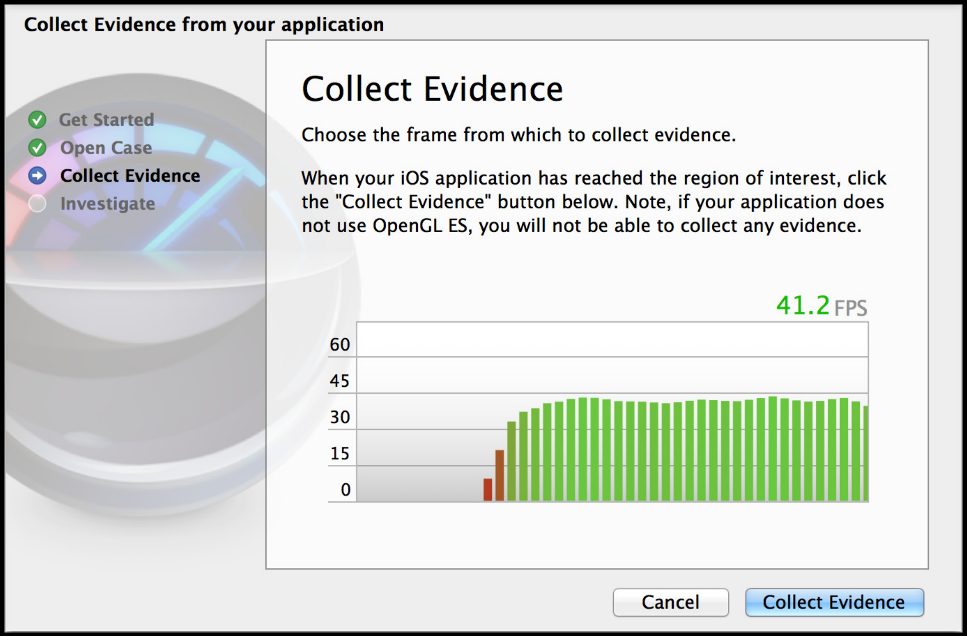
Choose the i

Click Open C
and begin th

Application ✓ TouchFighter2

How Do I Use It?

1. Select device
2. Select app
3. Trigger frame
4. Witness the magic
5. Look at the results



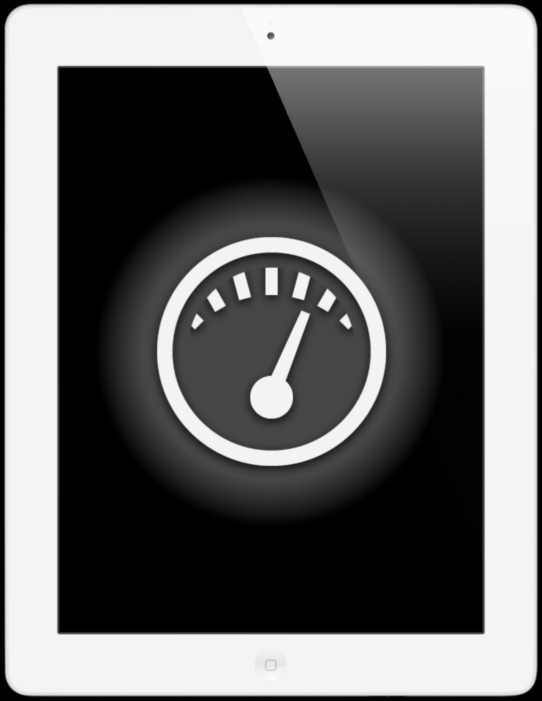
Collect Evidence

Choose the frame from which to collect evidence.

When your iOS application has reached the region of interest, click the "Collect Evidence" button below. Note, if your application does not use OpenGL ES, you will not be able to collect any evidence.

How Do I Use It?

1. Select device
2. Select app
3. Trigger frame
4. Witness the magic
5. Look at the results



How Do I Use It?

1. Select device
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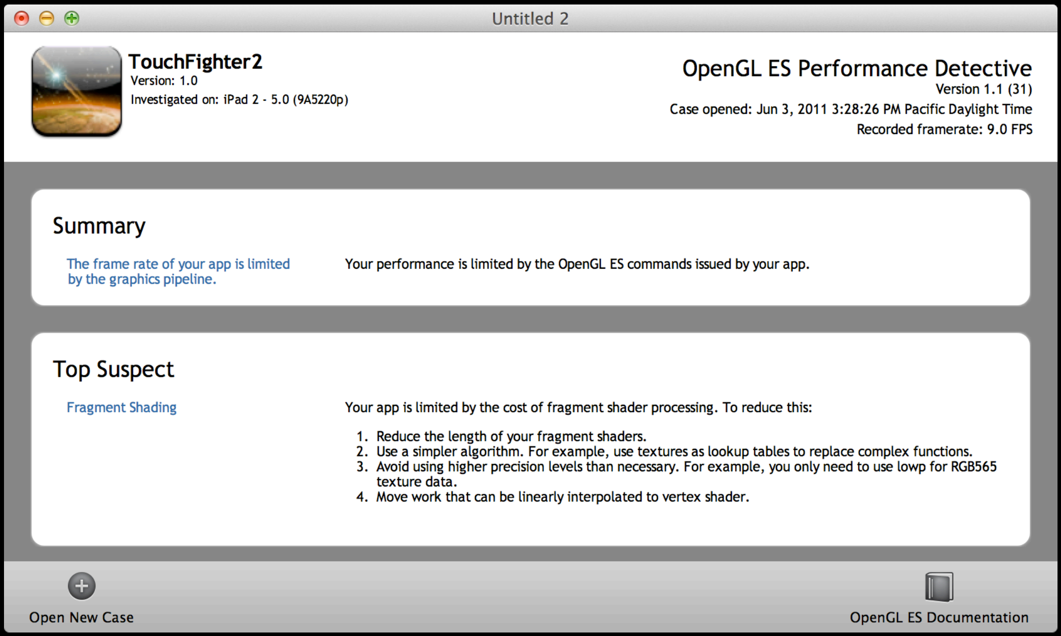


TouchFighter2
Version: 1.0
Investigated on: iPad 2 - 5.0 (9A5220p)

OpenGL ES Performance Detective
Version 1.1 (31)
Case opened: Jun 3, 2011 3:28:26 PM Pacific Daylight Time
Recorded framerate: 9.0 FPS

Summary

The frame rate of your app is limited by the graphics pipeline.

Your performance is limited by the OpenGL ES commands issued by your app.

Top Suspect

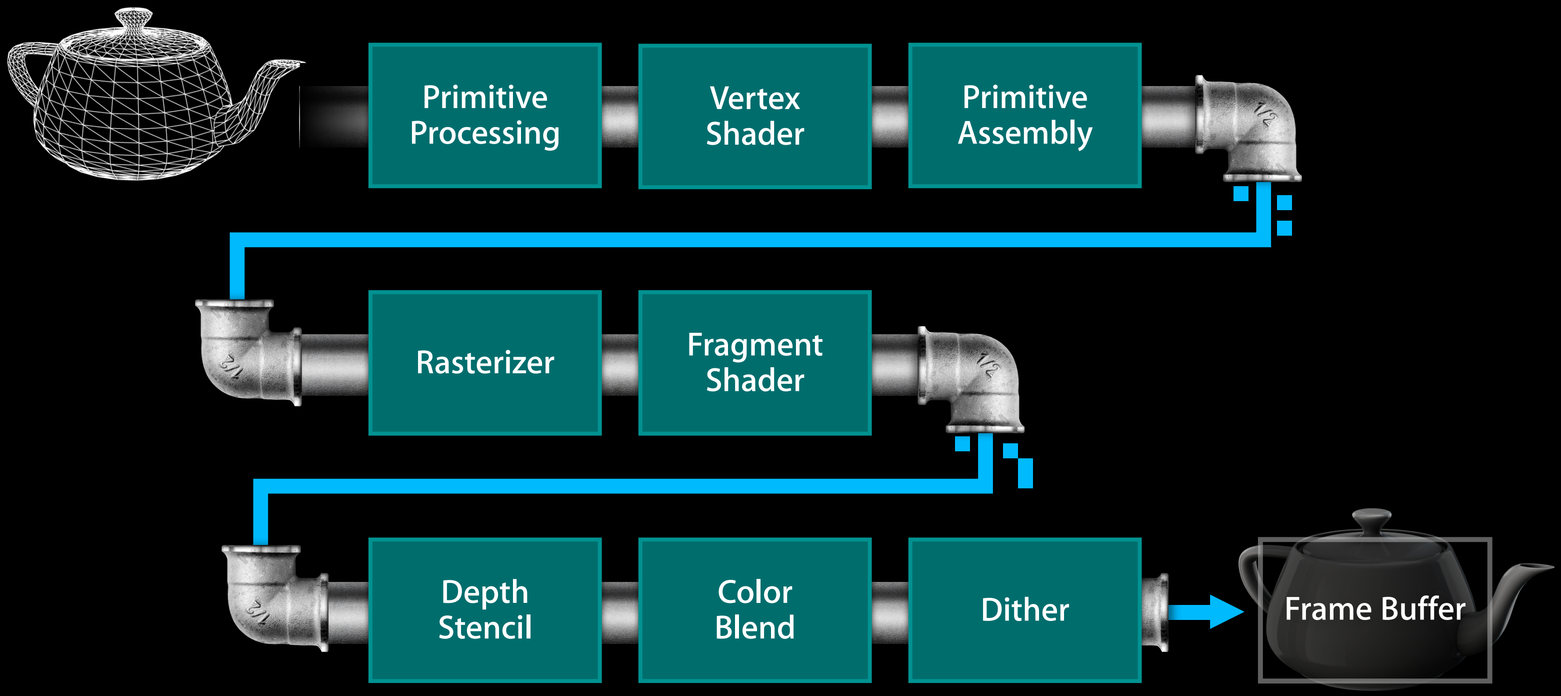
Fragment Shading

Your app is limited by the cost of fragment shader processing. To reduce this:

1. Reduce the length of your fragment shaders.
2. Use a simpler algorithm. For example, use textures as lookup tables to replace complex functions.
3. Avoid using higher precision levels than necessary. For example, you only need to use lowp for RGB565 texture data.
4. Move work that can be linearly interpolated to vertex shader.

What Is Happening Under the Hood?

Graphics pipeline



Primitive Processing

Vertex Shader

Primitive Assembly

Rasterizer

Fragment Shader

Depth Stencil

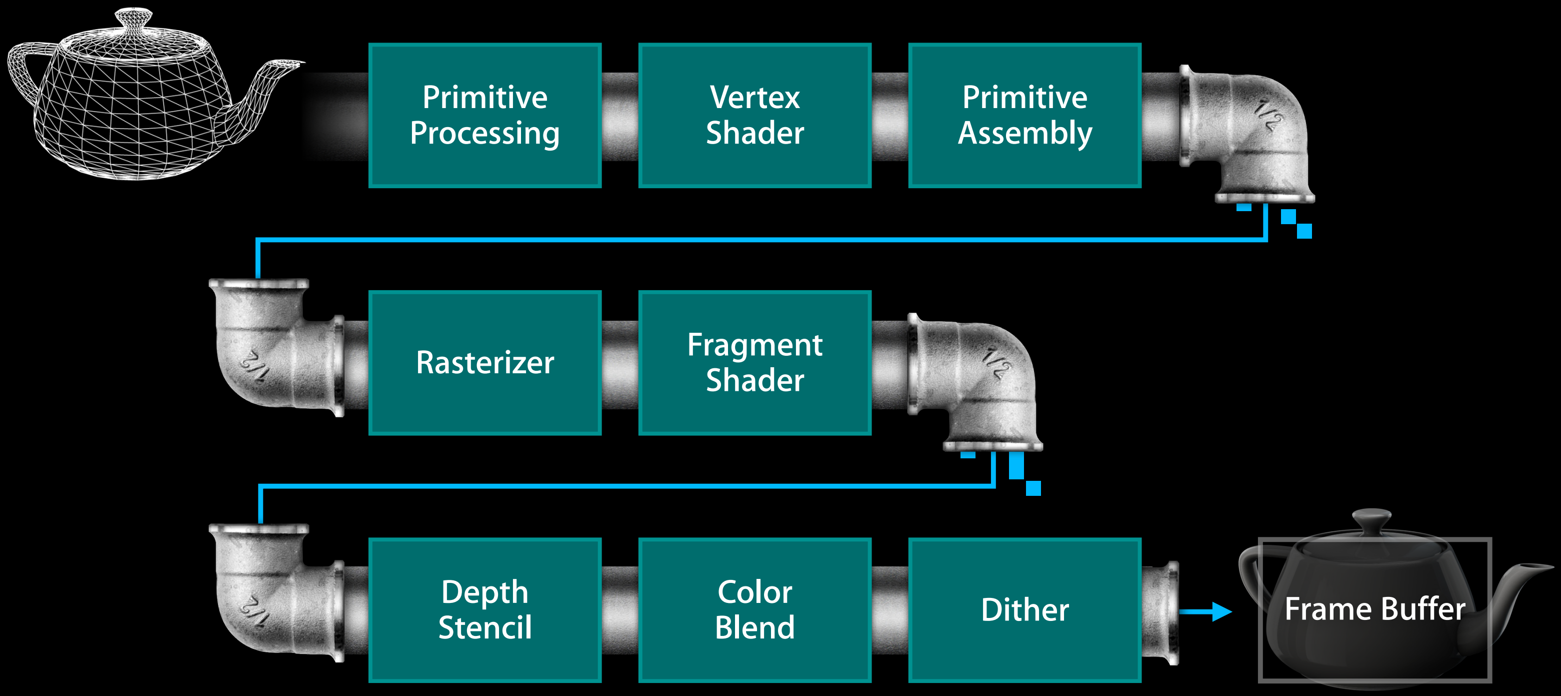
Color Blend

Dither

Frame Buffer

What Is Happening Under the Hood?

Infinitely fast OpenGL ES



Primitive Processing

Vertex Shader

Primitive Assembly

Rasterizer

Fragment Shader

Depth Stencil

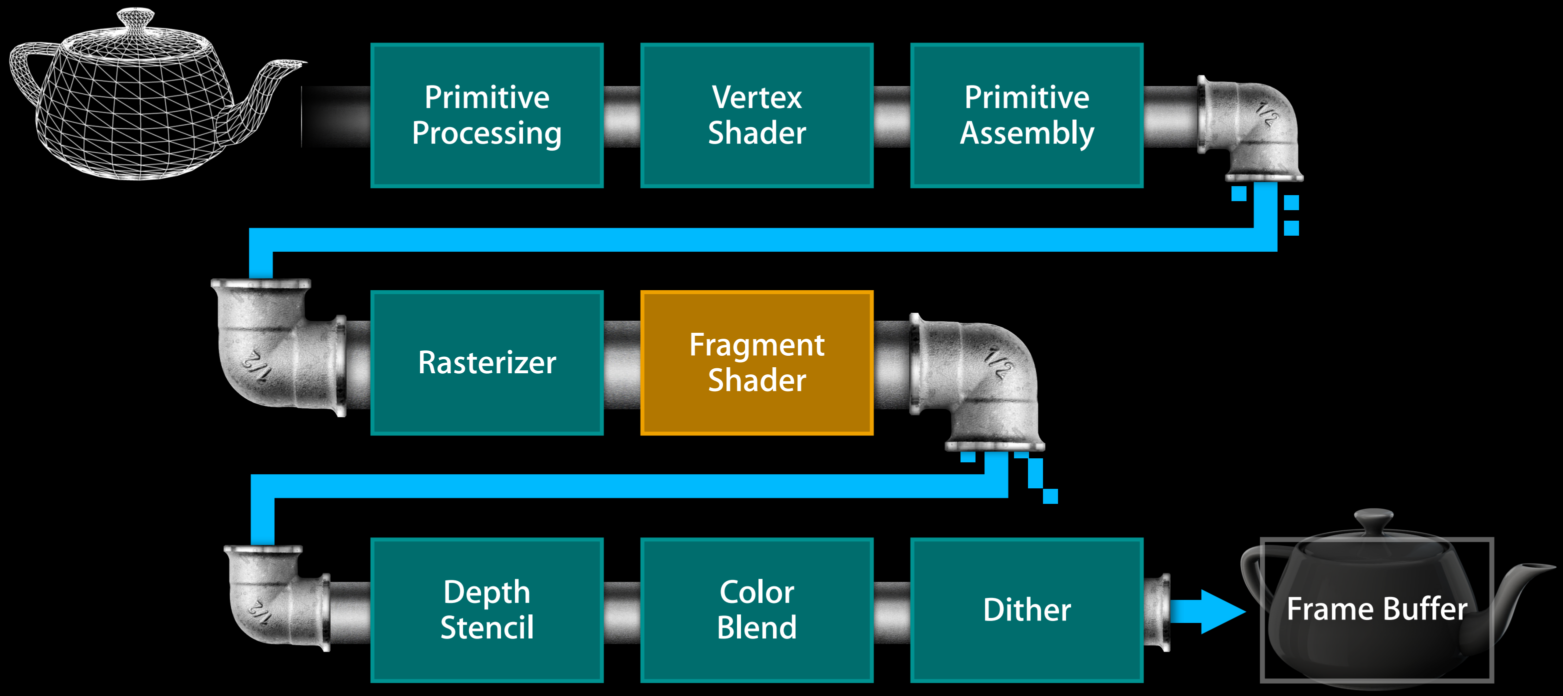
Color Blend

Dither

Frame Buffer

What Is Happening Under the Hood?

Infinitely fast fragment shader



Primitive Processing

Vertex Shader

Primitive Assembly

Rasterizer

Fragment Shader

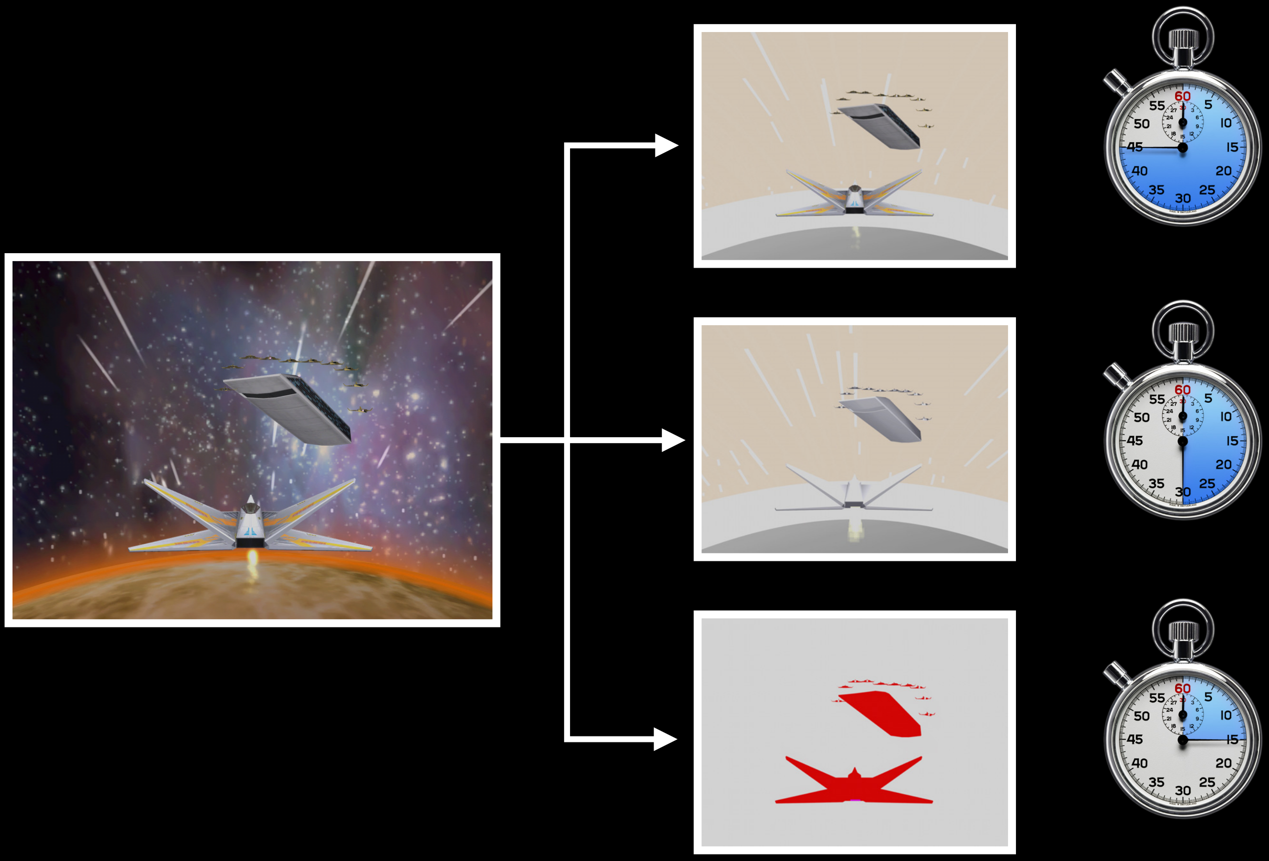
Depth Stencil

Color Blend

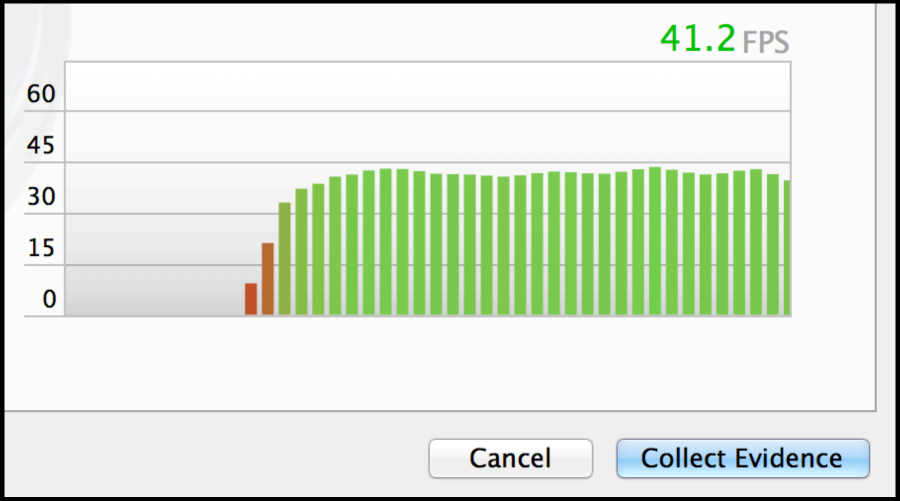
Dither

Frame Buffer

Experimental Runs

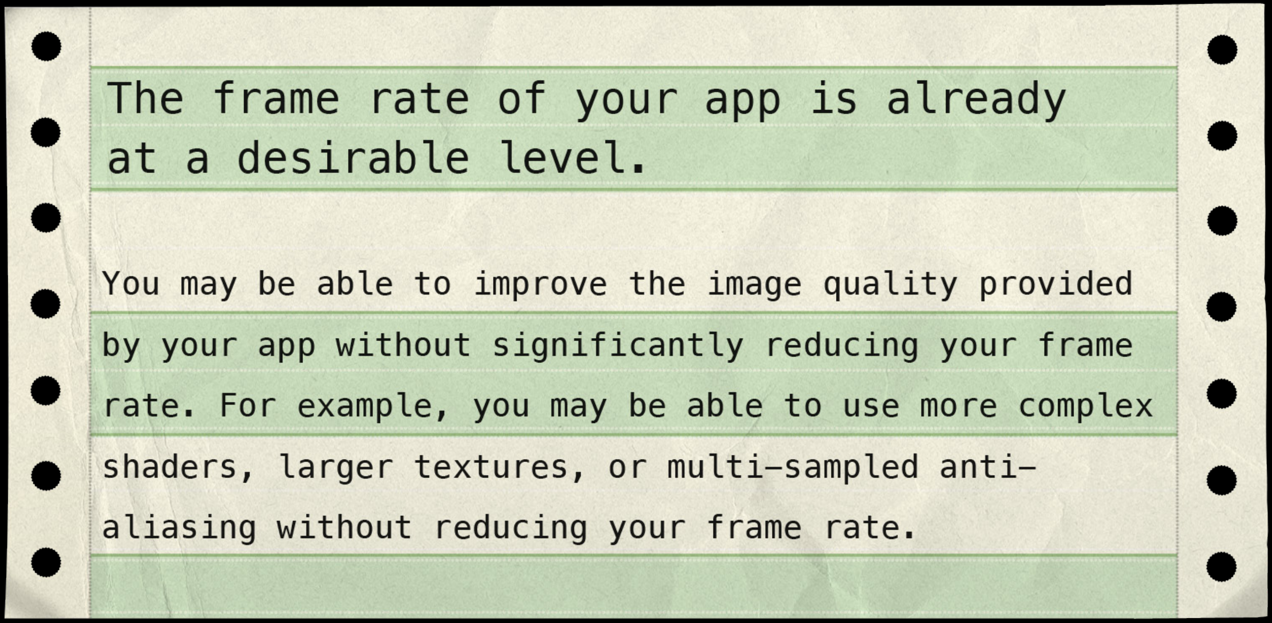


How Do I Trigger a Capture?



```
glInsertEventMarkerAPPLE(0, "com.apple.GPUTools.event.debug-frame");
```

What Sort of Results Will I Get?



The frame rate of your app is already at a desirable level.

You may be able to improve the image quality provided by your app without significantly reducing your frame rate. For example, you may be able to use more complex shaders, larger textures, or multi-sampled anti-aliasing without reducing your frame rate.

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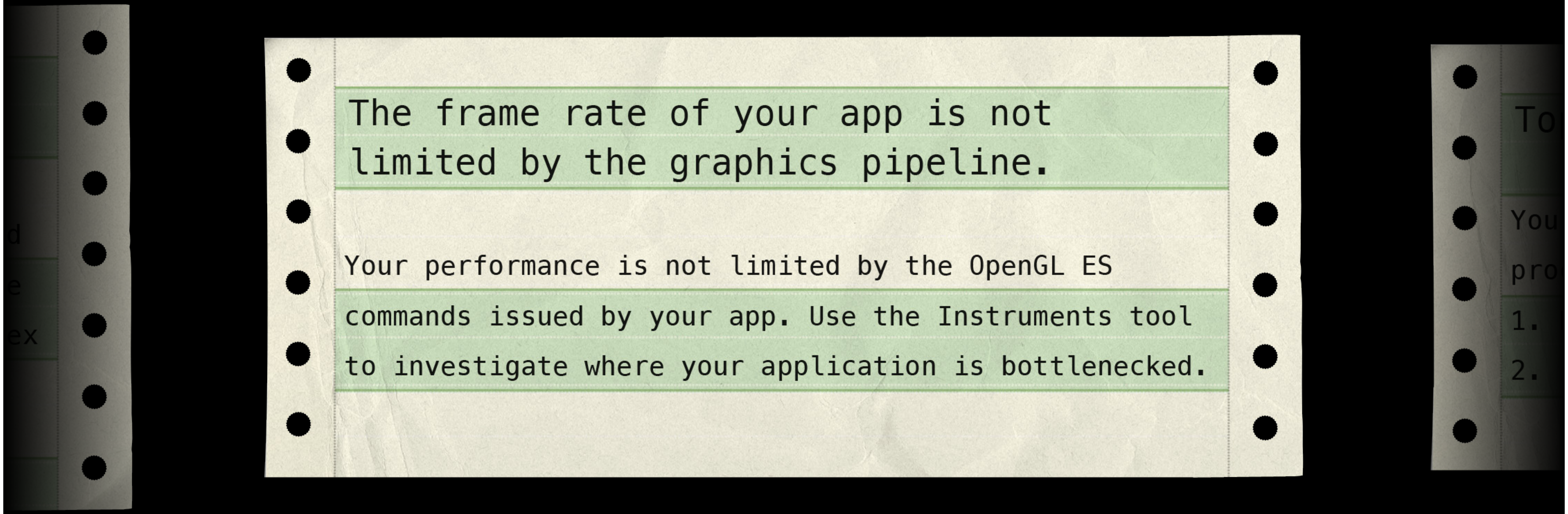
What Sort of Results Will I Get?



The frame rate of your app is not limited by the graphics pipeline.

Your performance is not limited by the OpenGL ES commands issued by your app. Use the Instruments tool to investigate where your application is bottlenecked.

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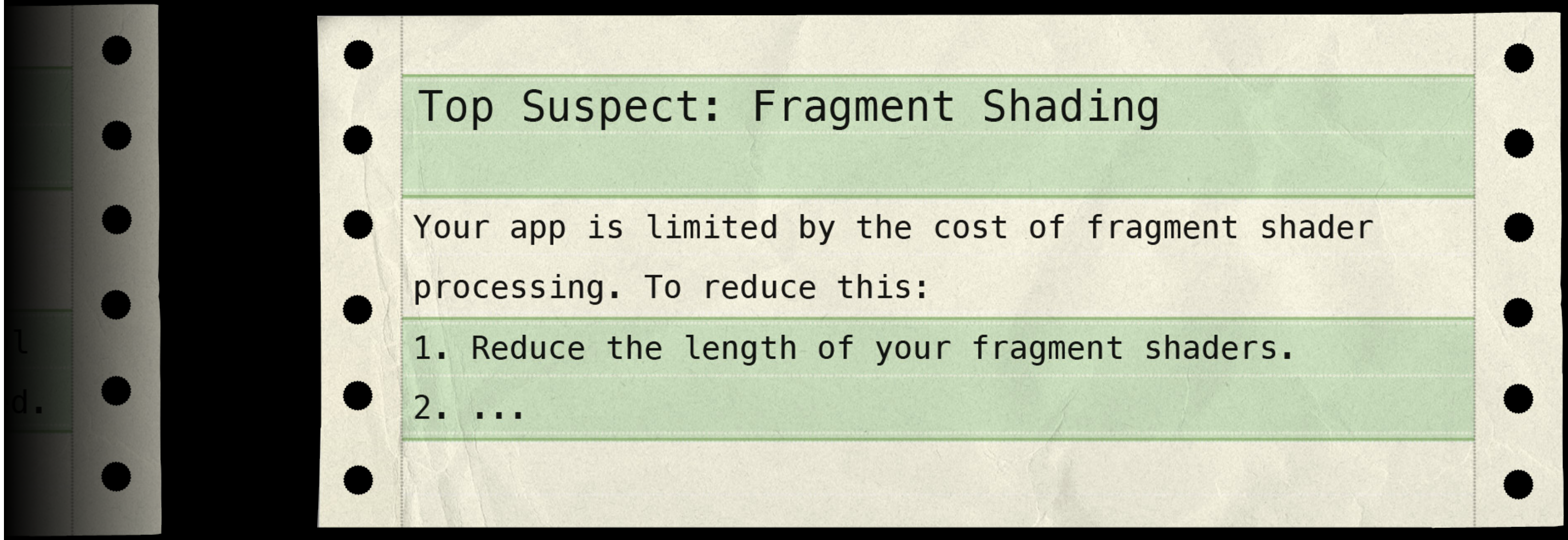
2.

What Sort of Results Will I Get?



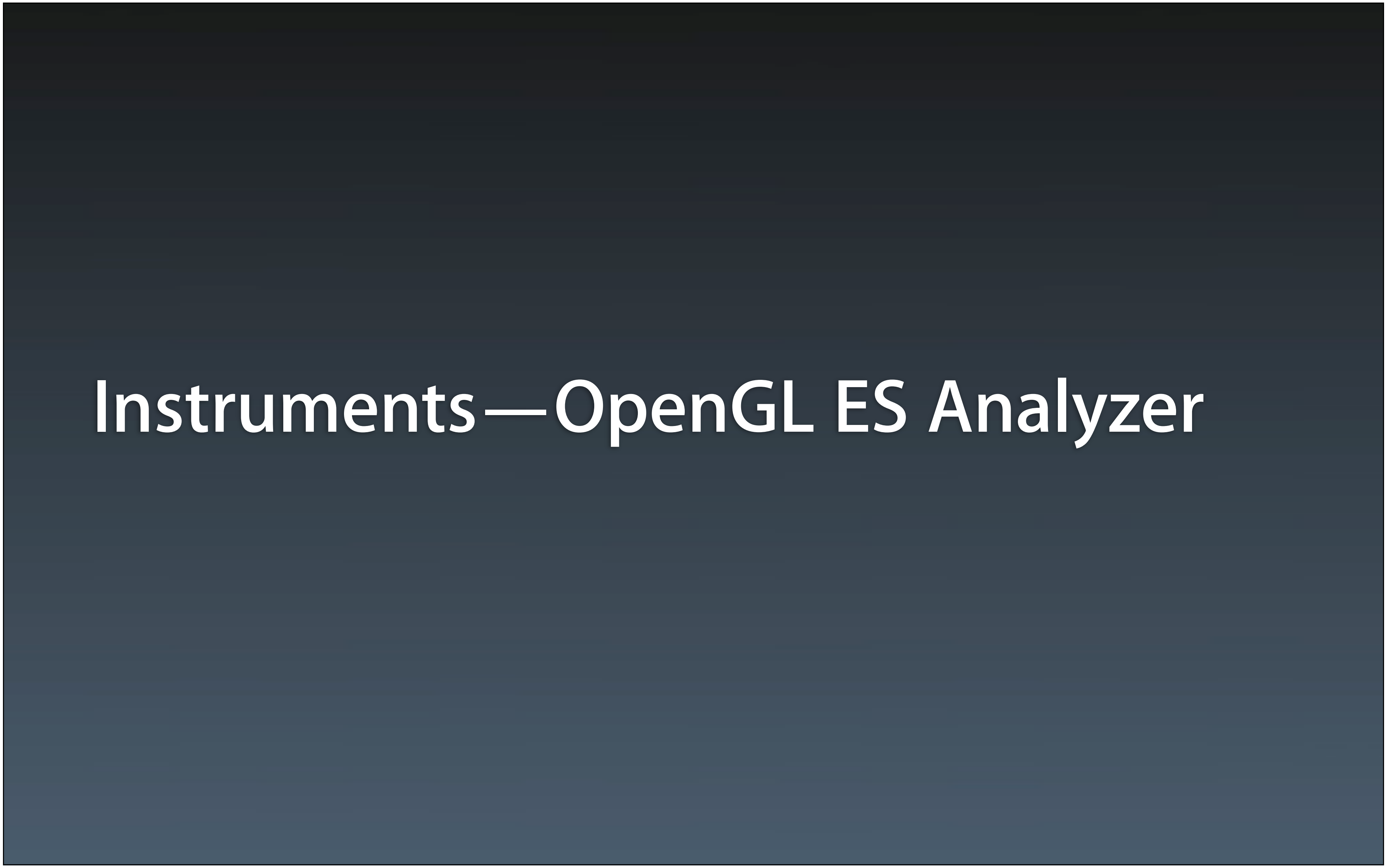
Top Suspect: Fragment Shading

Your app is limited by the cost of fragment shader processing. To reduce this:

1. Reduce the length of your fragment shaders.
2. ...

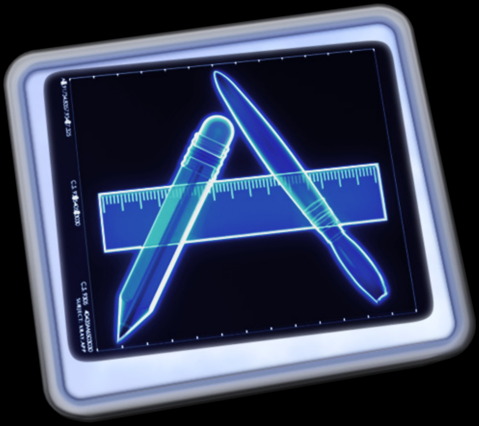
Demo

OpenGL ES Performance Detective

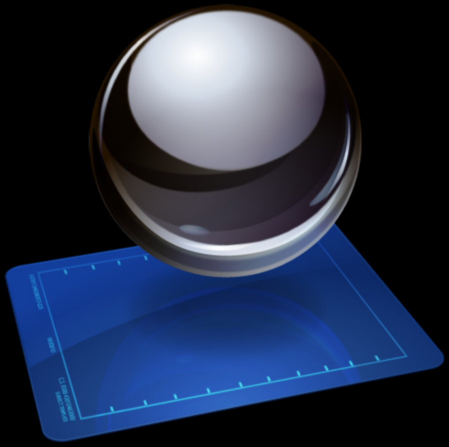


Instruments—OpenGL ES Analyzer

What Is It?

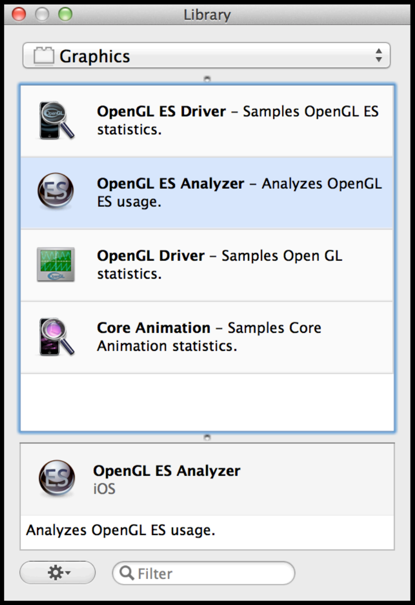


Instruments



OpenGL ES Analysis

Where Can I Find It?



OpenGL ES Driver – Samples OpenGL ES statistics.

OpenGL ES Analyzer – Analyzes OpenGL ES usage.

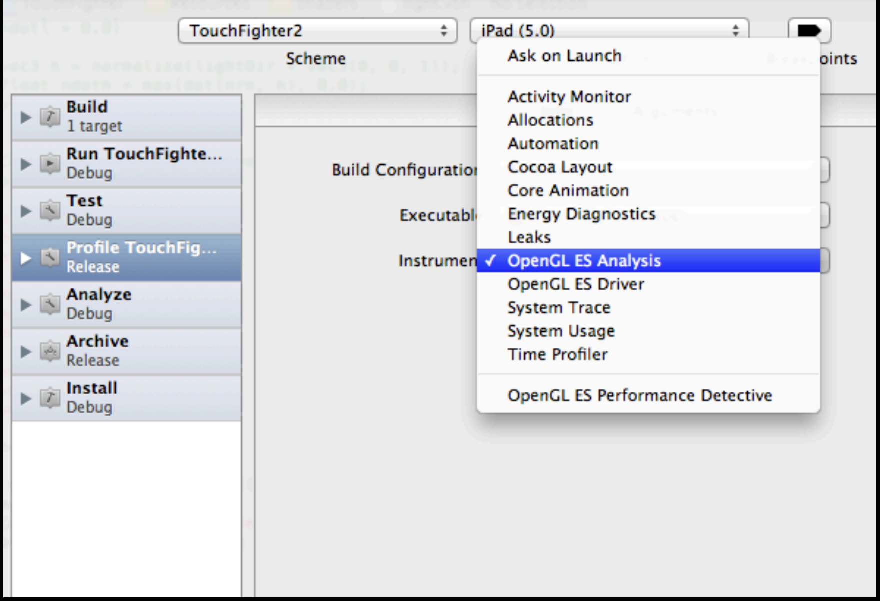
OpenGL Driver – Samples Open GL statistics.

Core Animation – Samples Core Animation statistics.

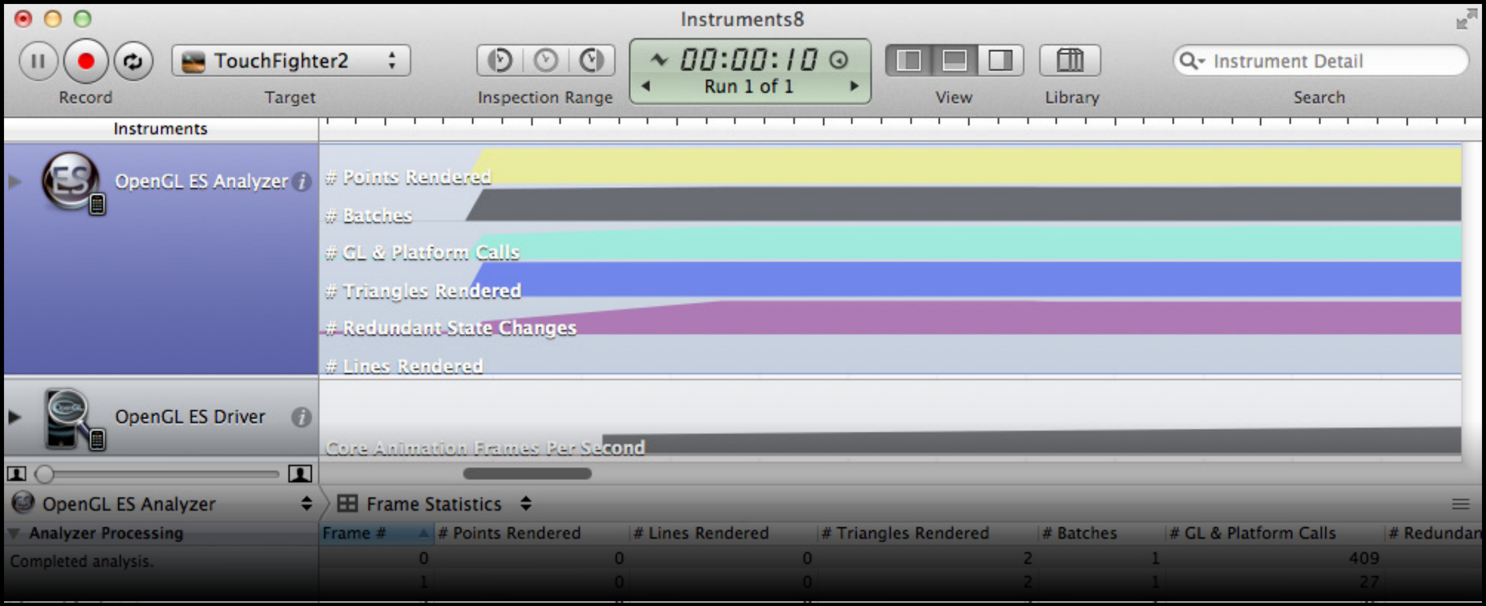
OpenGL ES Analyzer
iOS

Analyzes OpenGL ES usage.

Where Can I Find It?



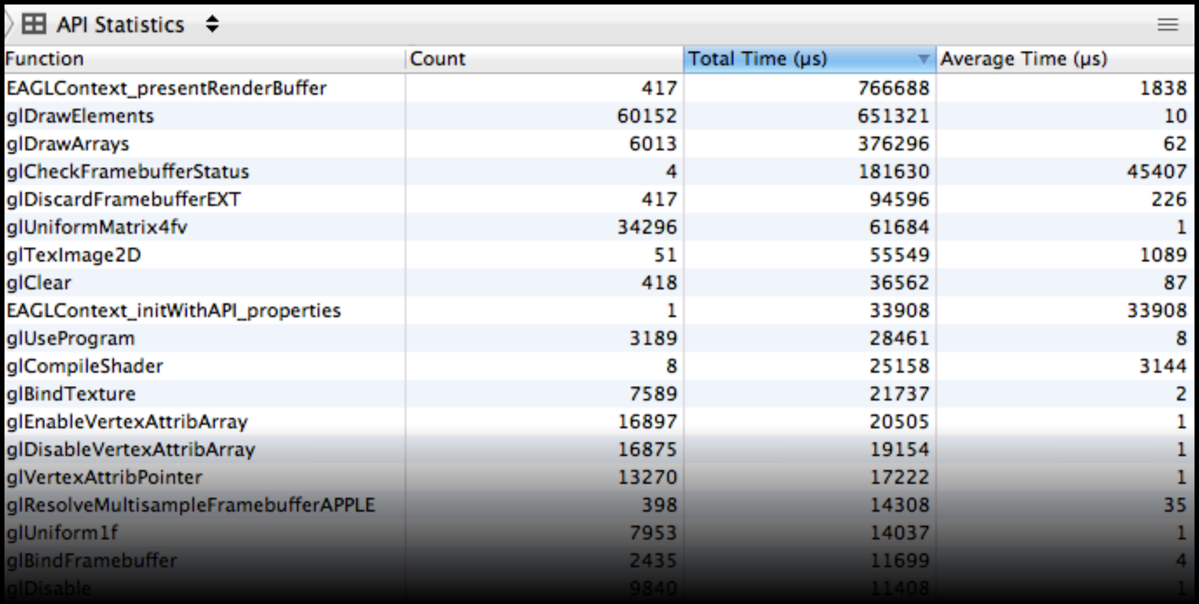
What Is Graphed on the Timeline?



Completed analysis.

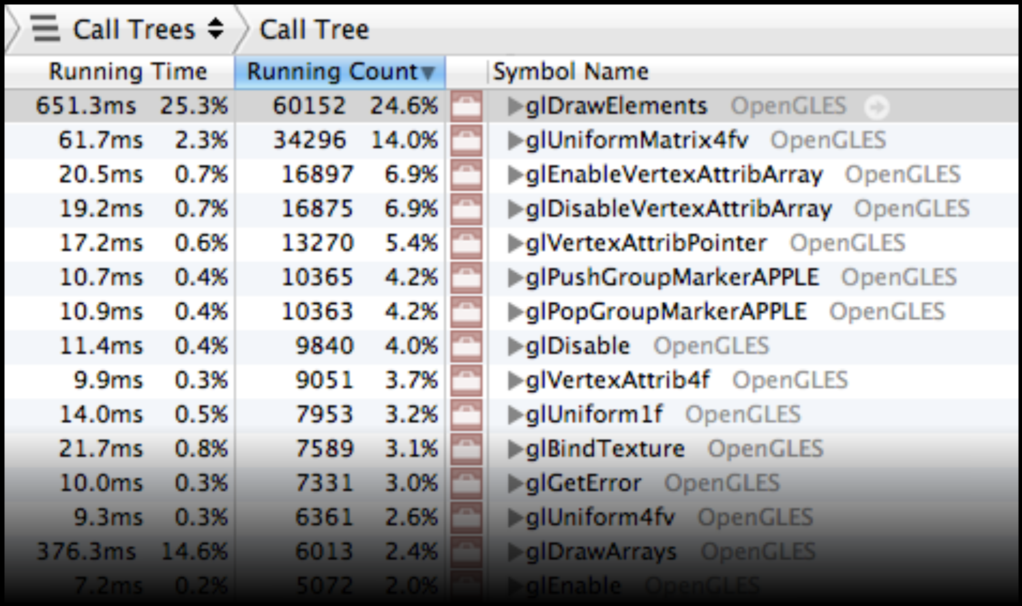
Frame #	# Points Rendered	# Lines Rendered	# Triangles Rendered	# Batches	# GL & Platform Calls	# Redundan
0	0	0	2	1	409	
1	0	0	2	1	27	

How Can I Find Out Where Time Was Spent?



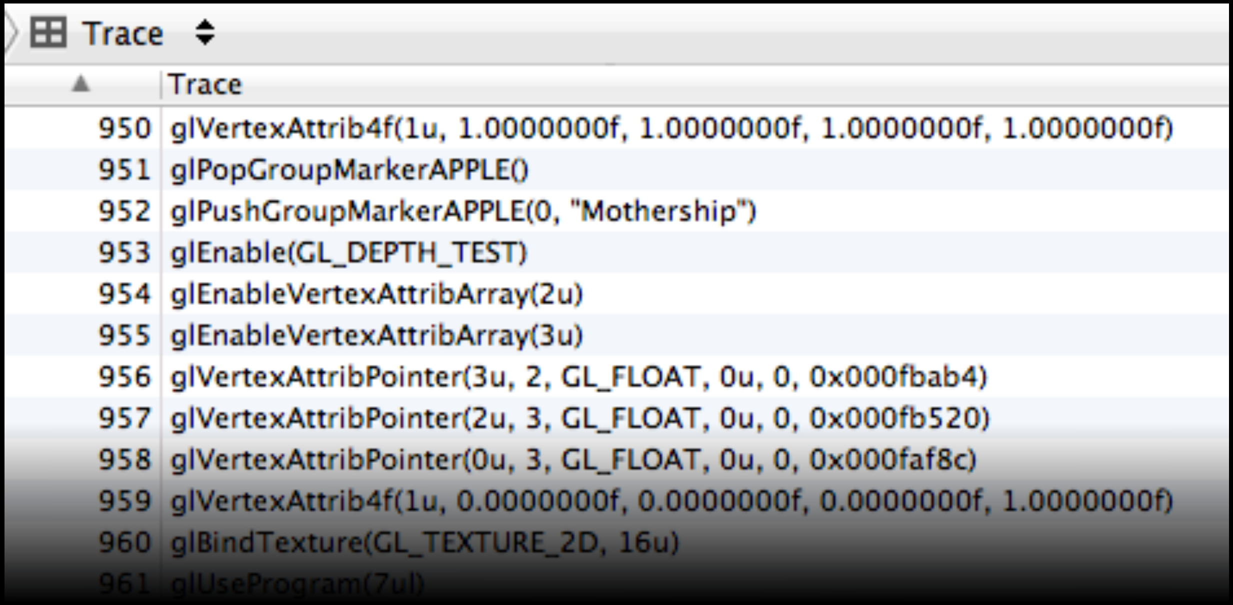
Function	Count	Total Time (µs)	Average Time (µs)
EAGLContext_presentRenderBuffer	417	766688	1838
glDrawElements	60152	651321	10
glDrawArrays	6013	376296	62
glCheckFramebufferStatus	4	181630	45407
glDiscardFramebufferEXT	417	94596	226
glUniformMatrix4fv	34296	61684	1
glTexImage2D	51	55549	1089
glClear	418	36562	87
EAGLContext_initWithAPI_properties	1	33908	33908
glUseProgram	3189	28461	8
glCompileShader	8	25158	3144
glBindTexture	7589	21737	2
glEnableVertexAttribArray	16897	20505	1
glDisableVertexAttribArray	16875	19154	1
glVertexAttribPointer	13270	17222	1
glResolveMultisampleFramebufferAPPLE	398	14308	35
glUniform1f	7953	14037	1
glBindFramebuffer	2435	11699	4
glDisable	9840	11408	1

How Can I Find Out Where Time Was Spent?



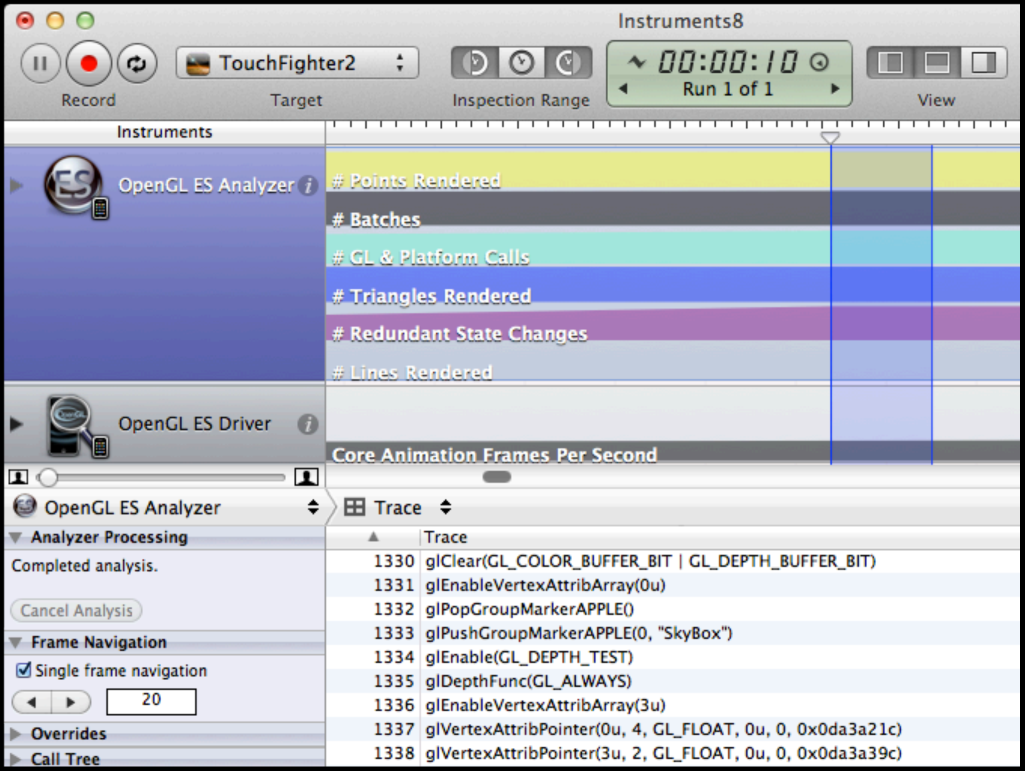
Running Time		Running Count▼		Symbol Name	
651.3ms	25.3%	60152	24.6%	▶glDrawElements	OpenGLES
61.7ms	2.3%	34296	14.0%	▶glUniformMatrix4fv	OpenGLES
20.5ms	0.7%	16897	6.9%	▶glEnableVertexAttribArray	OpenGLES
19.2ms	0.7%	16875	6.9%	▶glDisableVertexAttribArray	OpenGLES
17.2ms	0.6%	13270	5.4%	▶glVertexAttribPointer	OpenGLES
10.7ms	0.4%	10365	4.2%	▶glPushGroupMarkerAPPLE	OpenGLES
10.9ms	0.4%	10363	4.2%	▶glPopGroupMarkerAPPLE	OpenGLES
11.4ms	0.4%	9840	4.0%	▶glDisable	OpenGLES
9.9ms	0.3%	9051	3.7%	▶glVertexAttrib4f	OpenGLES
14.0ms	0.5%	7953	3.2%	▶glUniform1f	OpenGLES
21.7ms	0.8%	7589	3.1%	▶glBindTexture	OpenGLES
10.0ms	0.3%	7331	3.0%	▶glGetError	OpenGLES
9.3ms	0.3%	6361	2.6%	▶glUniform4fv	OpenGLES
376.3ms	14.6%	6013	2.4%	▶glDrawArrays	OpenGLES
7.2ms	0.2%	5072	2.0%	▶glEnable	OpenGLES

Which OpenGL ES Commands Am I Calling?



```
950  glVertexAttrib4f(1u, 1.0000000f, 1.0000000f, 1.0000000f, 1.0000000f)
951  glPopGroupMarkerAPPLE()
952  glPushGroupMarkerAPPLE(0, "Mothership")
953  glEnable(GL_DEPTH_TEST)
954  glEnableVertexAttribArray(2u)
955  glEnableVertexAttribArray(3u)
956  glVertexAttribPointer(3u, 2, GL_FLOAT, 0u, 0, 0x000fbab4)
957  glVertexAttribPointer(2u, 3, GL_FLOAT, 0u, 0, 0x000fb520)
958  glVertexAttribPointer(0u, 3, GL_FLOAT, 0u, 0, 0x000faf8c)
959  glVertexAttrib4f(1u, 0.0000000f, 0.0000000f, 0.0000000f, 1.0000000f)
960  glBindTexture(GL_TEXTURE_2D, 16u)
961  glUseProgram(7u)
```

What If I Want to Examine a Single Frame?



Completed analysis.

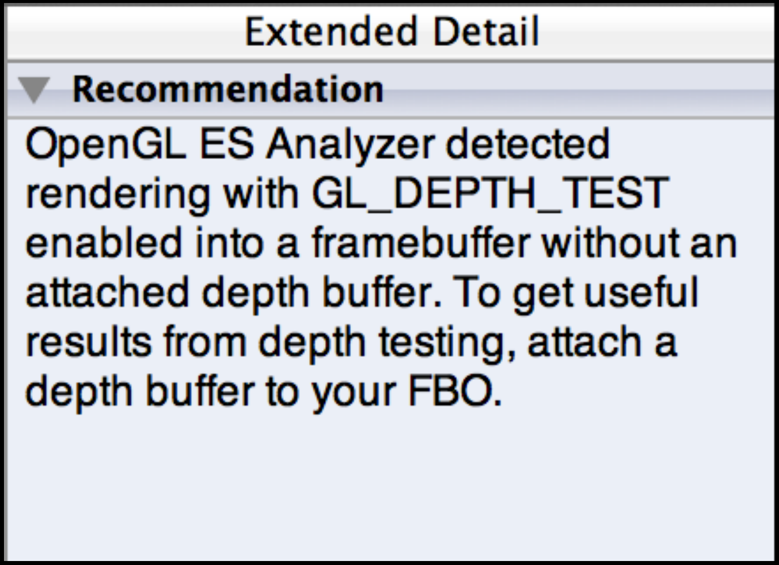
☑ Single frame navigation

20

▲	Trace
1330	glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT)
1331	glEnableVertexAttribArray(0u)
1332	glPopGroupMarkerAPPLE()
1333	glPushGroupMarkerAPPLE(0, "SkyBox")
1334	glEnable(GL_DEPTH_TEST)
1335	glDepthFunc(GL_ALWAYS)
1336	glEnableVertexAttribArray(3u)
1337	glVertexAttribPointer(0u, 4, GL_FLOAT, 0u, 0, 0x0da3a21c)
1338	glVertexAttribPointer(3u, 2, GL_FLOAT, 0u, 0, 0x0da3a39c)

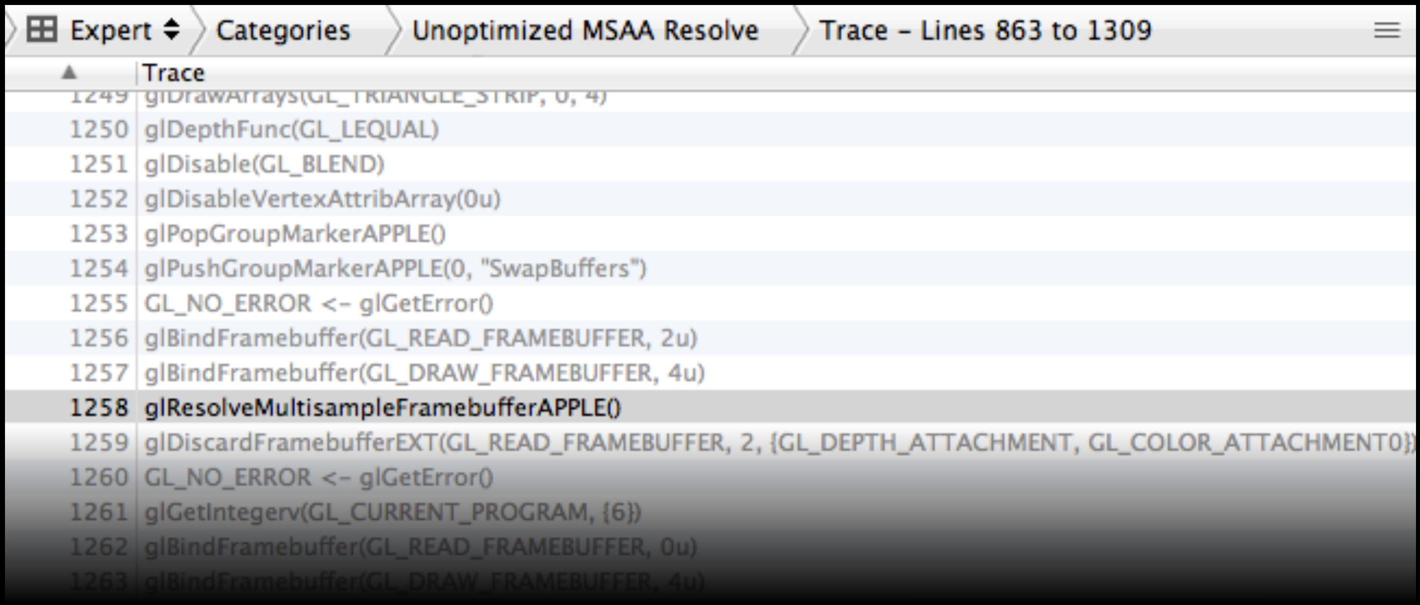
Is There Anything Else It Can Do?

How Do I Know What Action to Take?



OpenGL ES Analyzer detected rendering with GL_DEPTH_TEST enabled into a framebuffer without an attached depth buffer. To get useful results from depth testing, attach a depth buffer to your FBO.

Where in My Code Is the Problem?



```
1249 glDrawArrays(GL_TRIANGLE_STRIP, 0, 4)
1250 glDepthFunc(GL_LEQUAL)
1251 glDisable(GL_BLEND)
1252 glDisableVertexAttribArray(0u)
1253 glPopGroupMarkerAPPLE()
1254 glPushGroupMarkerAPPLE(0, "SwapBuffers")
1255 GL_NO_ERROR <- glGetError()
1256 glBindFramebuffer(GL_READ_FRAMEBUFFER, 2u)
1257 glBindFramebuffer(GL_DRAW_FRAMEBUFFER, 4u)
1258 glResolveMultisampleFramebufferAPPLE()
1259 glDiscardFramebufferEXT(GL_READ_FRAMEBUFFER, 2, {GL_DEPTH_ATTACHMENT, GL_COLOR_ATTACHMENT0})
1260 GL_NO_ERROR <- glGetError()
1261 glGetIntegerv(GL_CURRENT_PROGRAM, {6})
1262 glBindFramebuffer(GL_READ_FRAMEBUFFER, 0u)
1263 glBindFramebuffer(GL_DRAW_FRAMEBUFFER, 4u)
```

Demo

Instruments—OpenGL ES Analyzer

Scott Bassett
GPU Software Developer Technologies

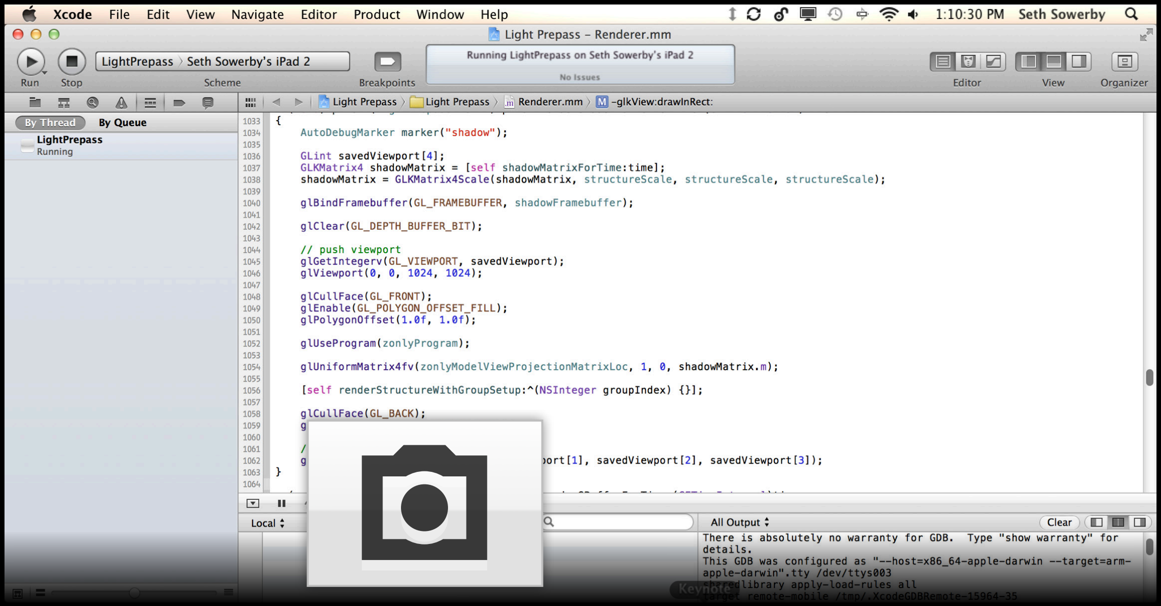
Xcode—Debugger for OpenGL ES

Seth Sowerby
GPU Software Developer Technologies

What Is It?

♥

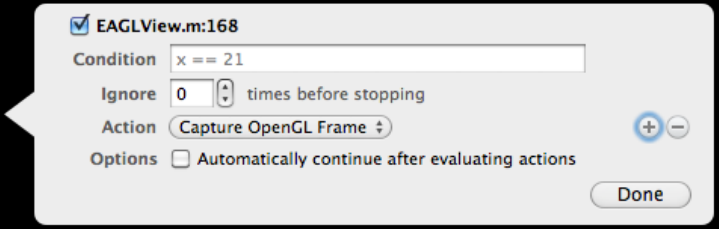
Where Can I Find It?


Xcode File Edit View Navigate Editor Product Window Help
1:10:30 PM Seth Sowerby
Light Prepass – Renderer.mm
Run
Stop
LightPrepass › Seth Sowerby's iPad 2
Scheme
Breakpoints
Running LightPrepass on Seth Sowerby's iPad 2
No Issues
Editor
View
Organizer
By Thread
By Queue
LightPrepass
Running
Light Prepass › Light Prepass › Renderer.mm › -glkView:drawInRect:
Local
All Output
Clear
Keynote

```
{
    AutoDebugMarker marker("shadow");

    GLint savedViewport[4];
    GLKMatrix4 shadowMatrix = [self shadowMatrixForTime:time];
    shadowMatrix = GLKMatrix4Scale(shadowMatrix, structureScale, structureScale, structureScale);

    glBindFramebuffer(GL_FRAMEBUFFER, shadowFramebuffer);

    glClear(GL_DEPTH_BUFFER_BIT);

    // push viewport
    glGetIntegerv(GL_VIEWPORT, savedViewport);
    glViewport(0, 0, 1024, 1024);

    glCullFace(GL_FRONT);
    glEnable(GL_POLYGON_OFFSET_FILL);
    glPolygonOffset(1.0f, 1.0f);

    glUseProgram(zonlyProgram);

    glUniformMatrix4fv(zonlyModelViewProjectionMatrixLoc, 1, 0, shadowMatrix.m);

    [self renderStructureWithGroupSetup:^(NSInteger groupIndex) {}];

    glCullFace(GL_BACK);
    g

    /
    g                                    ort[1], savedViewport[2], savedViewport[3]);
}
```

```
There is absolutely no warranty for GDB.  Type "show warranty" for
details.
This GDB was configured as "--host=x86_64-apple-darwin --target=arm-
apple-darwin".tty /dev/ttys003
sharedlibrary apply-load-rules all
target remote-mobile /tmp/.XcodeGDBRemote-15964-35
```

Where Can I Find It?



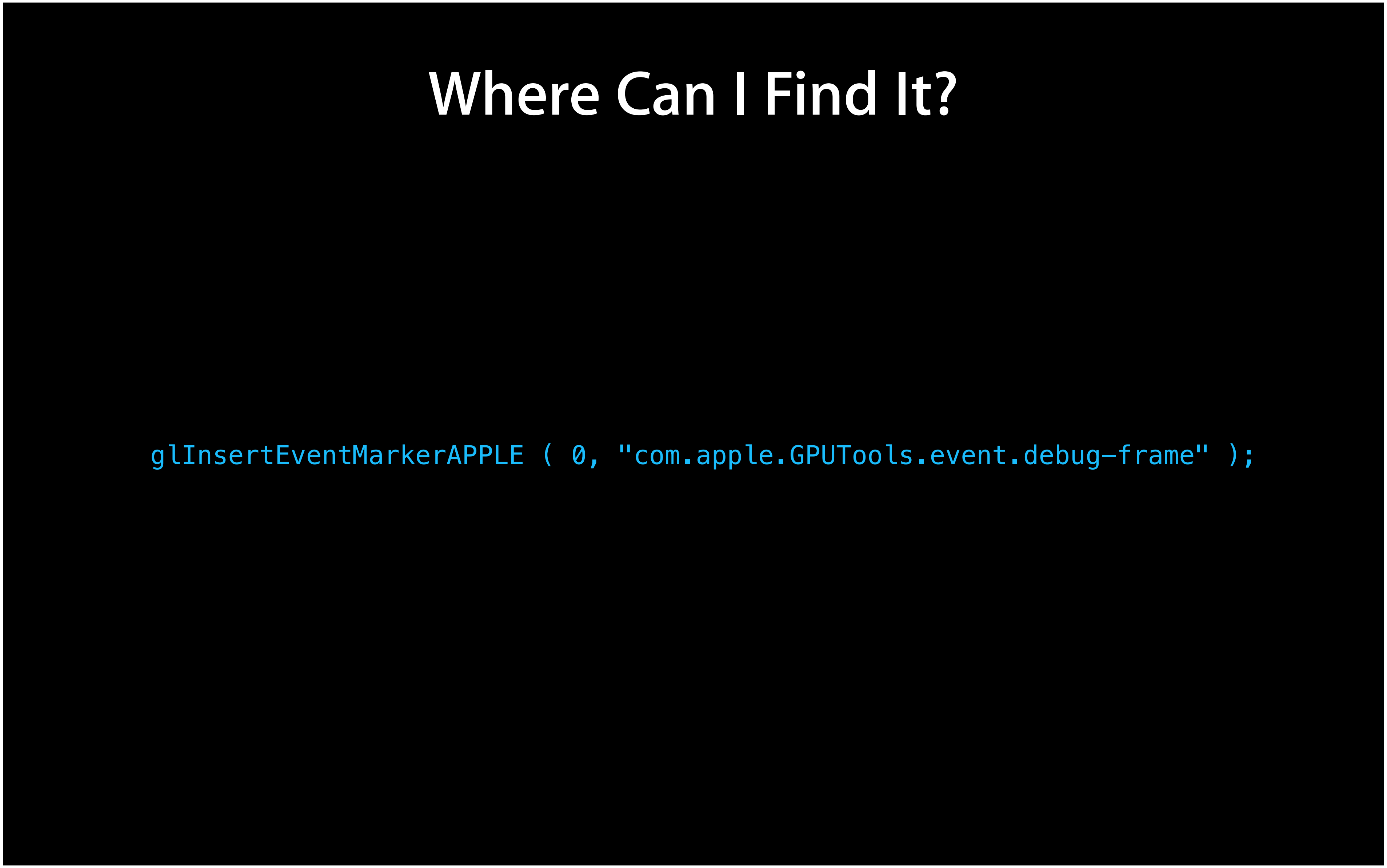
☑ EAGLView.m:168

Condition x == 21

Ignore 0 times before stopping

Action Capture OpenGL Frame

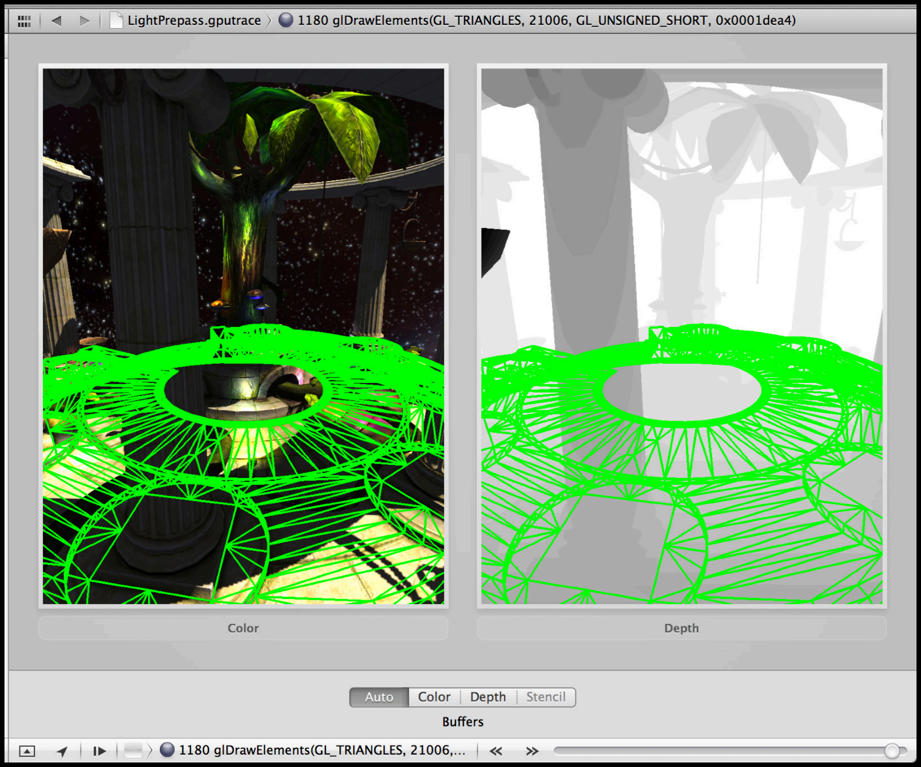
Options □ Automatically continue after evaluating actions



Where Can I Find It?

```
glInsertEventMarkerAPPLE ( 0, "com.apple.GPUTools.event.debug-frame" );
```

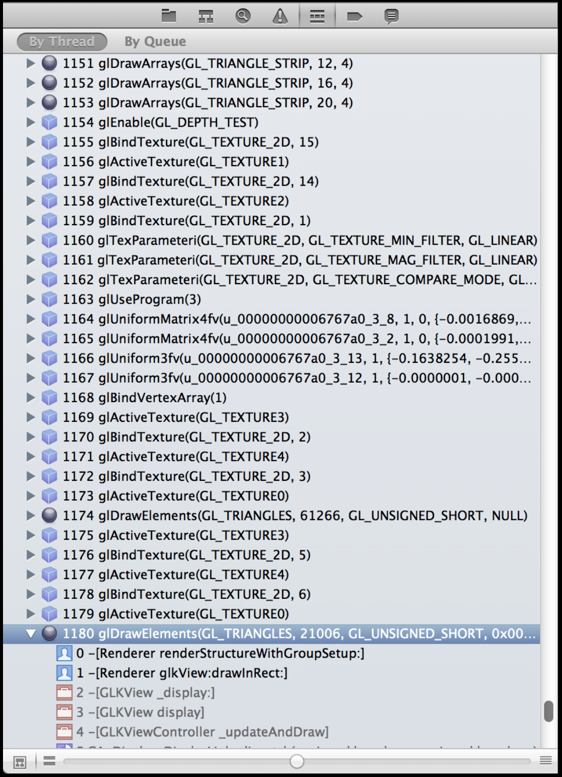
Inspect Your Framebuffer



LightPrepass.gputrace 〉 1180 glDrawElements(GL_TRIANGLES, 21006, GL_UNSIGNED_SHORT, 0x0001dea4)

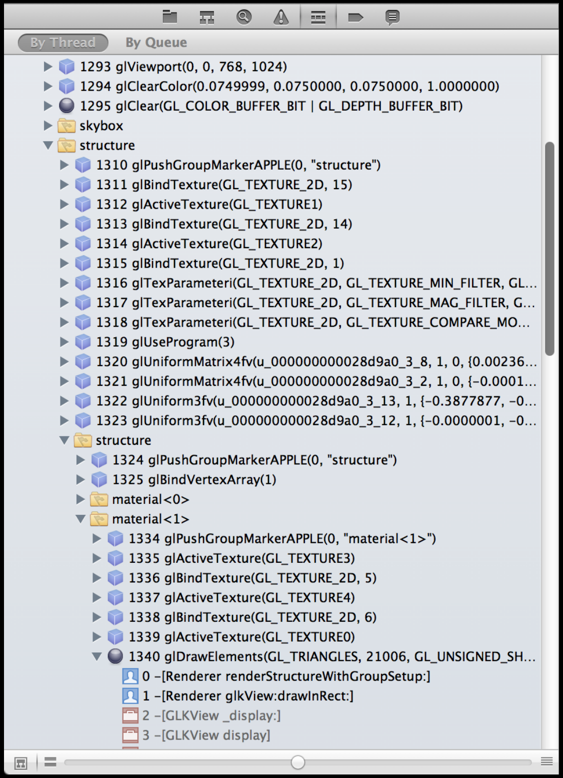
1180 glDrawElements(GL_TRIANGLES, 21006,...

Debug Navigator == Frame Navigator



```
1151 glDrawArrays(GL_TRIANGLE_STRIP, 12, 4)
1152 glDrawArrays(GL_TRIANGLE_STRIP, 16, 4)
1153 glDrawArrays(GL_TRIANGLE_STRIP, 20, 4)
1154 glEnable(GL_DEPTH_TEST)
1155 glBindTexture(GL_TEXTURE_2D, 15)
1156 glActiveTexture(GL_TEXTURE1)
1157 glBindTexture(GL_TEXTURE_2D, 14)
1158 glActiveTexture(GL_TEXTURE2)
1159 glBindTexture(GL_TEXTURE_2D, 1)
1160 glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR)
1161 glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR)
1162 glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_COMPARE_MODE, GL...
1163 glUseProgram(3)
1164 glUniformMatrix4fv(u_00000000006767a0_3_8, 1, 0, {-0.0016869,...
1165 glUniformMatrix4fv(u_00000000006767a0_3_2, 1, 0, {-0.0001991,...
1166 glUniform3fv(u_00000000006767a0_3_13, 1, {-0.1638254, -0.255...
1167 glUniform3fv(u_00000000006767a0_3_12, 1, {-0.0000001, -0.000...
1168 glBindVertexArray(1)
1169 glActiveTexture(GL_TEXTURE3)
1170 glBindTexture(GL_TEXTURE_2D, 2)
1171 glActiveTexture(GL_TEXTURE4)
1172 glBindTexture(GL_TEXTURE_2D, 3)
1173 glActiveTexture(GL_TEXTURE0)
1174 glDrawElements(GL_TRIANGLES, 61266, GL_UNSIGNED_SHORT, NULL)
1175 glActiveTexture(GL_TEXTURE3)
1176 glBindTexture(GL_TEXTURE_2D, 5)
1177 glActiveTexture(GL_TEXTURE4)
1178 glBindTexture(GL_TEXTURE_2D, 6)
1179 glActiveTexture(GL_TEXTURE0)
1180 glDrawElements(GL_TRIANGLES, 21006, GL_UNSIGNED_SHORT, 0x00...
    0 -[Renderer renderStructureWithGroupSetup:]
    1 -[Renderer glkView:drawInRect:]
    2 -[GLKView _display:]
    3 -[GLKView display]
    4 -[GLKViewController _updateAndDraw]
```

Debug Navigator == Frame Navigator

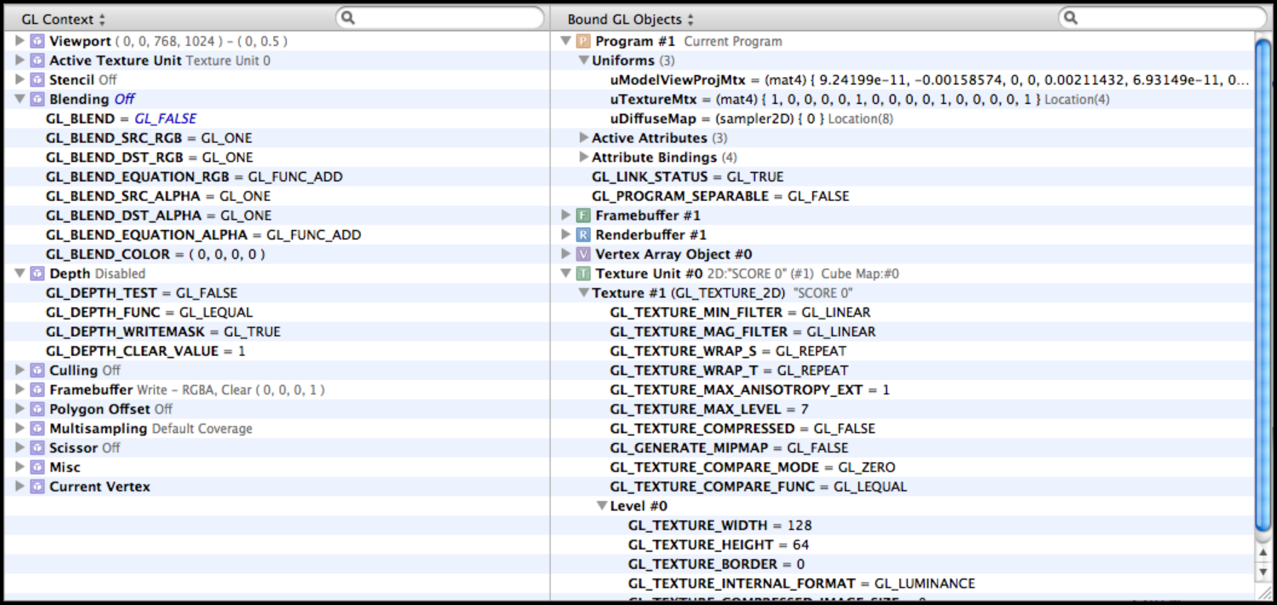


```
▶ 1293 glViewport(0, 0, 768, 1024)
▶ 1294 glClearColor(0.0749999, 0.0750000, 0.0750000, 1.0000000)
▶ 1295 glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT)
▶ skybox
▼ structure
  ▶ 1310 glPushGroupMarkerAPPLE(0, "structure")
  ▶ 1311 glBindTexture(GL_TEXTURE_2D, 15)
  ▶ 1312 glActiveTexture(GL_TEXTURE1)
  ▶ 1313 glBindTexture(GL_TEXTURE_2D, 14)
  ▶ 1314 glActiveTexture(GL_TEXTURE2)
  ▶ 1315 glBindTexture(GL_TEXTURE_2D, 1)
  ▶ 1316 glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL…
  ▶ 1317 glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, G…
  ▶ 1318 glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_COMPARE_MO…
  ▶ 1319 glUseProgram(3)
  ▶ 1320 glUniformMatrix4fv(u_000000000028d9a0_3_8, 1, 0, {0.00236…
  ▶ 1321 glUniformMatrix4fv(u_000000000028d9a0_3_2, 1, 0, {–0.0001…
  ▶ 1322 glUniform3fv(u_000000000028d9a0_3_13, 1, {–0.3877877, –0…
  ▶ 1323 glUniform3fv(u_000000000028d9a0_3_12, 1, {–0.0000001, –0…
  ▼ structure
    ▶ 1324 glPushGroupMarkerAPPLE(0, "structure")
    ▶ 1325 glBindVertexArray(1)
    ▶ material<0>
    ▼ material<1>
      ▶ 1334 glPushGroupMarkerAPPLE(0, "material<1>")
      ▶ 1335 glActiveTexture(GL_TEXTURE3)
      ▶ 1336 glBindTexture(GL_TEXTURE_2D, 5)
      ▶ 1337 glActiveTexture(GL_TEXTURE4)
      ▶ 1338 glBindTexture(GL_TEXTURE_2D, 6)
      ▶ 1339 glActiveTexture(GL_TEXTURE0)
      ▼ 1340 glDrawElements(GL_TRIANGLES, 21006, GL_UNSIGNED_SH…
          0 –[Renderer renderStructureWithGroupSetup:]
          1 –[Renderer glkView:drawInRect:]
          2 –[GLKView _display:]
          3 –[GLKView display]
```

APPLE_debug_marker

```
glPushDebugMarkerAPPLE(0, “Draw Planet”);

glBindTexture(GL_TEXTURE_2D, planetSurface);
glUseProgram(diffuse);
glBindVertexArrayOES(planetMesh);
glDrawElements(GL_TRIANGLE_STRIP, 256, GL_UNSIGNED_SHORT);

glPopDebugMarkerAPPLE();
```

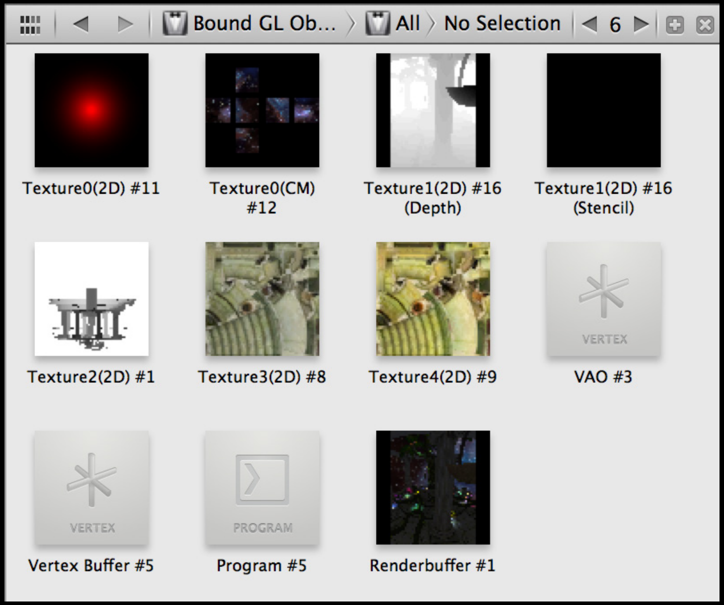
All the GL State You Can Eat



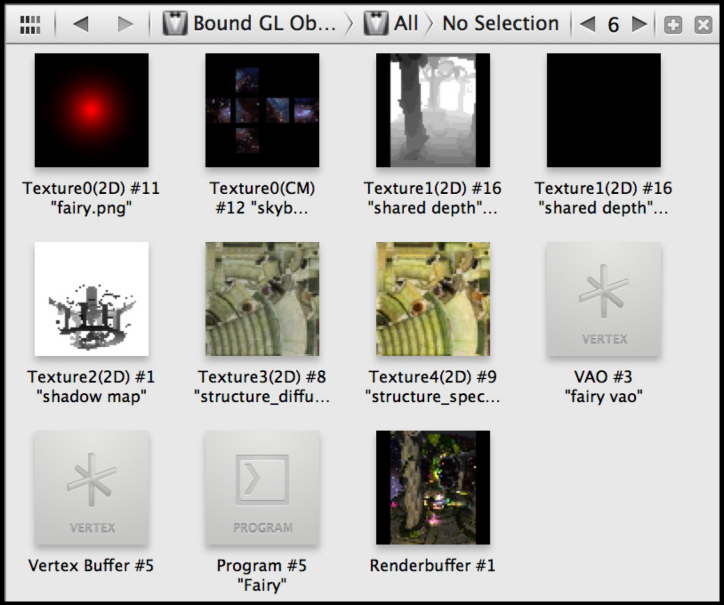
```
GL Context

▶ Viewport ( 0, 0, 768, 1024 ) – ( 0, 0.5 )
▶ Active Texture Unit Texture Unit 0
▶ Stencil Off
▼ Blending Off
    GL_BLEND = GL_FALSE
    GL_BLEND_SRC_RGB = GL_ONE
    GL_BLEND_DST_RGB = GL_ONE
    GL_BLEND_EQUATION_RGB = GL_FUNC_ADD
    GL_BLEND_SRC_ALPHA = GL_ONE
    GL_BLEND_DST_ALPHA = GL_ONE
    GL_BLEND_EQUATION_ALPHA = GL_FUNC_ADD
    GL_BLEND_COLOR = ( 0, 0, 0, 0 )
▼ Depth Disabled
    GL_DEPTH_TEST = GL_FALSE
    GL_DEPTH_FUNC = GL_LEQUAL
    GL_DEPTH_WRITEMASK = GL_TRUE
    GL_DEPTH_CLEAR_VALUE = 1
▶ Culling Off
▶ Framebuffer Write – RGBA, Clear ( 0, 0, 0, 1 )
▶ Polygon Offset Off
▶ Multisampling Default Coverage
▶ Scissor Off
▶ Misc
▶ Current Vertex
```

```
Bound GL Objects

▼ P Program #1  Current Program
  ▼ Uniforms (3)
      uModelViewProjMtx = (mat4) { 9.24199e-11, -0.00158574, 0, 0, 0.00211432, 6.93149e-11, 0...
      uTextureMtx = (mat4) { 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1 } Location(4)
      uDiffuseMap = (sampler2D) { 0 } Location(8)
  ▶ Active Attributes (3)
  ▶ Attribute Bindings (4)
    GL_LINK_STATUS = GL_TRUE
    GL_PROGRAM_SEPARABLE = GL_FALSE
▶ F Framebuffer #1
▶ R Renderbuffer #1
▶ V Vertex Array Object #0
▼ T Texture Unit #0 2D:"SCORE 0" (#1)  Cube Map:#0
  ▼ Texture #1 (GL_TEXTURE_2D)  "SCORE 0"
      GL_TEXTURE_MIN_FILTER = GL_LINEAR
      GL_TEXTURE_MAG_FILTER = GL_LINEAR
      GL_TEXTURE_WRAP_S = GL_REPEAT
      GL_TEXTURE_WRAP_T = GL_REPEAT
      GL_TEXTURE_MAX_ANISOTROPY_EXT = 1
      GL_TEXTURE_MAX_LEVEL = 7
      GL_TEXTURE_COMPRESSED = GL_FALSE
      GL_GENERATE_MIPMAP = GL_FALSE
      GL_TEXTURE_COMPARE_MODE = GL_ZERO
      GL_TEXTURE_COMPARE_FUNC = GL_LEQUAL
    ▼ Level #0
        GL_TEXTURE_WIDTH = 128
        GL_TEXTURE_HEIGHT = 64
        GL_TEXTURE_BORDER = 0
        GL_TEXTURE_INTERNAL_FORMAT = GL_LUMINANCE
        GL_TEXTURE_COMPRESSED_IMAGE_SIZE = 0
```

Show Me My GL Objects



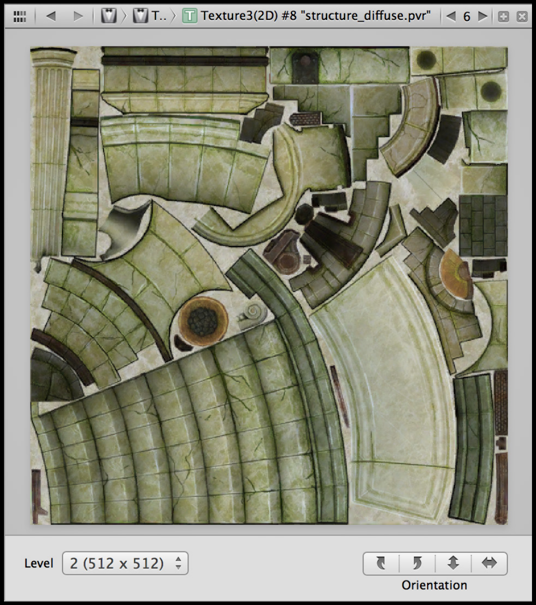
Show Me My GL Objects


Bound GL Ob...
All
No Selection
6
Texture0(2D) #11 "fairy.png"
Texture0(CM) #12 "skyb...
Texture1(2D) #16 "shared depth"...
Texture1(2D) #16 "shared depth"...
Texture2(2D) #1 "shadow map"
Texture3(2D) #8 "structure_diffu...
Texture4(2D) #9 "structure_spec...
VERTEX
VAO #3 "fairy vao"
VERTEX
Vertex Buffer #5
PROGRAM
Program #5 "Fairy"
Renderbuffer #1

APPLE_debug_label

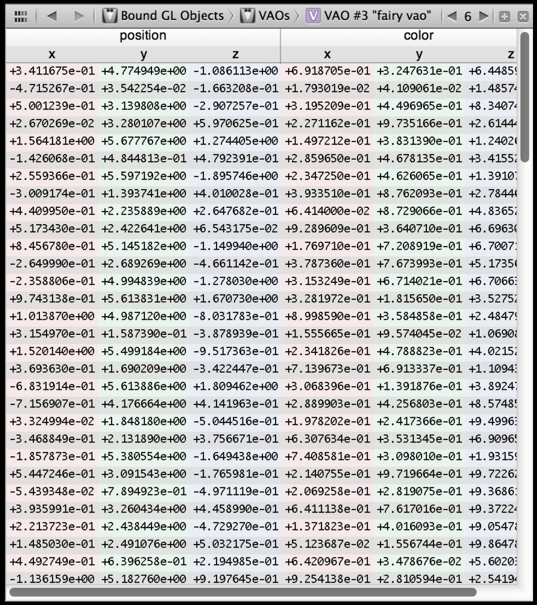
```
glGenTextures(1, &planetSurface);
glBindTexture(GL_TEXTURE_2D, planetSurface);
glLabelObjectAPPLE(GL_TEXTURE, planetSurface, 0, “Planet”);
```

Detailed Object Views—Texture



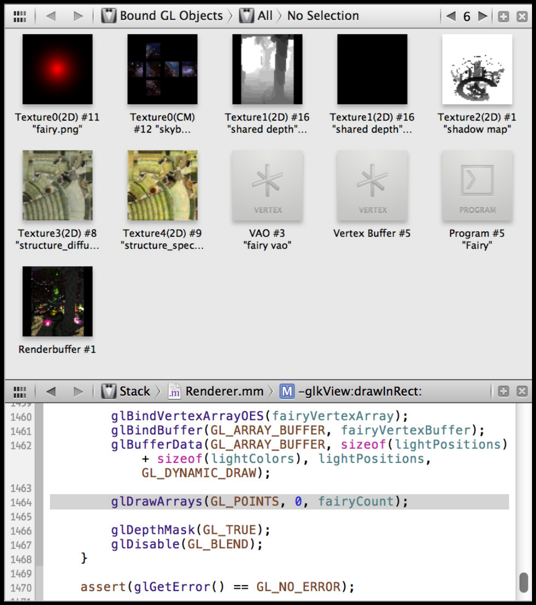
Level 2 (512 x 512)

Detailed Object Views—Vertices



position			color		
x	y	z	x	y	z
+3.411675e-01	+4.774949e+00	-1.086113e+00	+6.918705e-01	+3.247631e-01	+6.4485
-4.715267e-01	+3.542254e-02	-1.663208e-01	+1.793019e-02	+4.109061e-02	+1.4857
+5.001239e-01	+3.139808e+00	-2.907257e-01	+3.195209e-01	+4.496965e-01	+8.3407
+2.670269e-02	+3.280107e+00	+5.970625e-01	+2.271162e-01	+9.735166e-01	+2.6144
+1.564181e+00	+5.677767e+00	+1.274405e+00	+1.497212e-01	+3.831390e-01	+1.2402
-1.426068e-01	+4.844813e-01	+4.792391e-01	+2.859650e-01	+4.678135e-01	+3.4155
+2.559366e-01	+5.597192e+00	-1.895746e+00	+2.347250e-01	+4.626065e-01	+1.3910
-3.009174e-01	+1.393741e+00	+4.010028e-01	+3.933510e-01	+8.762093e-01	+2.7844
+4.409950e-01	+2.235889e+00	+2.647682e-01	+6.414000e-02	+8.729066e-01	+4.8365
+5.173430e-01	+2.422641e+00	+6.543175e-02	+9.289609e-01	+3.640710e-01	+6.6963
+8.456780e-01	+5.145182e+00	-1.149940e+00	+1.769710e-01	+7.208919e-01	+6.7007
-2.649990e-01	+2.689269e+00	-4.661142e-01	+3.787360e-01	+7.673993e-01	+5.1735
-2.358806e-01	+4.994839e+00	-1.278030e+00	+3.153249e-01	+6.714021e-01	+6.7066
+9.743138e-01	+5.613831e+00	+1.670730e+00	+3.281972e-01	+1.815650e-01	+3.5275
+1.013870e+00	+4.987120e+00	-8.031783e-01	+8.998590e-01	+3.584858e-01	+2.4847
+3.154970e-01	+1.587390e-01	-3.878939e-01	+1.555665e-01	+9.574045e-02	+1.0690
+1.520140e+00	+5.499184e+00	-9.517363e-01	+2.341826e-01	+4.788823e-01	+4.0215
+3.693630e-01	+1.690209e+00	-3.422447e-01	+7.139673e-01	+6.913337e-01	+1.1094
-6.831914e-01	+5.613886e+00	+1.809462e+00	+3.068396e-01	+1.391876e-01	+3.8924
-7.156907e-01	+4.176664e+00	+4.141963e-01	+2.889903e-01	+4.256803e-01	+8.5748
+3.324994e-02	+1.848180e+00	-5.044516e-01	+1.978202e-01	+2.417366e-01	+9.4996
-3.468849e-01	+2.131890e+00	+3.756671e-01	+6.307634e-01	+3.531345e-01	+6.9096
-1.857873e-01	+5.380554e+00	-1.649438e+00	+7.408581e-01	+3.098010e-01	+1.9315
+5.447246e-01	+3.091543e+00	-1.765981e-01	+2.140755e-01	+9.719664e-01	+9.7226
-5.439348e-02	+7.894923e-01	-4.971119e-01	+2.069258e-01	+2.819075e-01	+9.3686
+3.935991e-01	+3.260434e+00	+4.458990e-01	+6.411138e-01	+7.617016e-01	+9.3722
+2.213723e-01	+2.438449e+00	-4.729270e-01	+1.371823e-01	+4.016093e-01	+9.0547
+1.485030e-01	+2.491076e+00	+5.032175e-01	+5.123687e-02	+1.556744e-01	+9.8647
+4.492749e-01	+6.396258e-01	+2.194985e-01	+6.420967e-01	+3.478676e-02	+5.6020
-1.136159e+00	+5.182760e+00	+9.197645e-01	+9.254138e-01	+2.810594e-01	+2.5419

Configure Multiple Resource Views


Bound GL Objects
All
No Selection
6
Texture0(2D) #11 "fairy.png"
Texture0(CM) #12 "skyb...
Texture1(2D) #16 "shared depth"...
Texture1(2D) #16 "shared depth"...
Texture2(2D) #1 "shadow map"
Texture3(2D) #8 "structure_diffu...
Texture4(2D) #9 "structure_spec...
VERTEX
VAO #3 "fairy vao"
VERTEX
Vertex Buffer #5
PROGRAM
Program #5 "Fairy"
Renderbuffer #1
Stack
Renderer.mm
-glkView:drawInRect:

```
        glBindVertexArrayOES(fairyVertexArray);
        glBindBuffer(GL_ARRAY_BUFFER, fairyVertexBuffer);
        glBufferData(GL_ARRAY_BUFFER, sizeof(lightPositions)
            + sizeof(lightColors), lightPositions,
            GL_DYNAMIC_DRAW);

        glDrawArrays(GL_POINTS, 0, fairyCount);

        glDepthMask(GL_TRUE);
        glDisable(GL_BLEND);
    }

    assert(glGetError() == GL_NO_ERROR);
```

Demo

Xcode—Debugger for OpenGL ES

Filip Iliescu
GPU Software Developer Technologies

Summary

- When to use each tool
- Where to find them—Xcode integration
- Go try them out!

More Information

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Related Sessions

Best Practices for OpenGL ES Apps in iOS	Mission Wednesday 4:30PM
Advances in OpenGL for Mac OS X Lion	Marina Thursday 10:15AM

Labs

OpenGL ES Lab	Graphics, Media & Games Lab A Thursday 9:00AM
OpenGL ES Lab	Graphics, Media & Games Lab A Thursday 2:00PM
OpenGL for Mac OS X Lab	Graphics, Media & Games Lab B Thursday 2:00PM

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