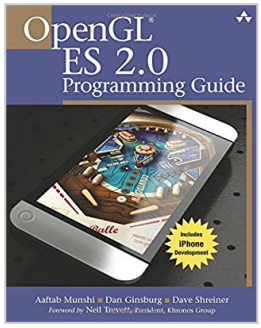

OpenGL ES 2.0 Programming Guide

By Aaftab Munshi, Dan Ginsburg, Dave Shreiner

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OpenGL ES 2.0 is the industry's leading software interface and graphics library for rendering sophisticated 3D graphics on handheld and embedded devices. With OpenGL ES 2.0, the full programmability of shaders is now available on small and portable devices—including cell phones, PDAs, consoles, appliances, and vehicles. However, OpenGL ES differs significantly from OpenGL. Graphics programmers and mobile developers have had very little information about it—until now.

In the ***OpenGL® ES 2.0 Programming Guide*** , three leading authorities on the Open GL ES 2.0 interface—including the specification's editor—provide start-to-finish guidance for maximizing the interface's value in a wide range of high-performance applications. The authors cover the entire API, including Khronos-ratified extensions. Using detailed C-based code examples, they demonstrate how to set up and program every aspect of the graphics pipeline. You'll move from introductory techniques all the way to advanced per-pixel lighting, particle systems, and performance optimization.

Coverage includes:

- Shaders in depth: creating shader objects, compiling shaders, checking for compile errors, attaching shader objects to program objects, and linking final program objects
- The OpenGL ES Shading Language: variables, types, constructors, structures, arrays, attributes, uniforms, varyings, precision qualifiers, and invariance
- Inputting geometry into the graphics pipeline, and assembling geometry into primitives
- Vertex shaders, their special variables, and their use in per-vertex lighting, skinning, and other applications
- Using fragment shaders—including examples of multitexturing, fog, alpha test, and user clip planes
- Fragment operations: scissor test, stencil test, depth test, multisampling, blending, and dithering
- Advanced rendering: per-pixel lighting with normal maps, environment mapping, particle systems, image post-processing, and projective texturing
- Real-world programming challenges: platform diversity, C++ portability,

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Editorial Review

From the Back Cover
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About the Author
Aaftab Munshi is the spec editor for the OpenGL ES 1.1 and 2.0 specifications. Now at Apple, he was formerly senior architect in ATI’s handheld group.

Dan Ginsburg is senior member of technical staff at AMD. At AMD and ATI, he has worked in a variety of roles, including the development of OpenGL drivers, the creation of desktop and handheld 3D demos, and the development of handheld GPU developer tools.

Dave Shreiner is one of the world’s foremost authorities on OpenGL. He is a systems architect at ARM, Inc., and the lead author of the official *OpenGL® Programming Guide, Sixth Edition* (Addison-Wesley, 2007) and series editor for the Addison-Wesley OpenGL Series.

OpenGL ES 2.0 is a software interface for rendering sophisticated 3D graphics on handheld and embedded devices. OpenGL ES 2.0 is the primary graphics library for handheld and embedded devices with programmable 3D hardware including cell phones, PDAs, consoles, appliances, vehicles, and avionics. With OpenGL ES 2.0, the full programmability of shaders has made its way onto small and portable devices. This book details the entire OpenGL ES 2.0 API and pipeline with detailed examples in order to provide a guide

for developing a wide range of high-performance 3D applications for handheld devices.

Intended Audience

This book is intended for programmers interested in learning OpenGL ES 2.0. We expect the reader to have a solid grounding in computer graphics. We will explain many of the relevant graphics concepts as they relate to various parts of OpenGL ES 2.0, but we do expect the reader to understand basic 3D concepts. The code examples in the book are all written in C. We assume that the reader is familiar with C or C++ and will only be covering language topics where they are relevant to OpenGL ES 2.0.

This book covers the entire OpenGL ES 2.0 API along with all Khronosratified extensions. The reader will learn about setting up and programming every aspect of the graphics pipeline. The book details how to write vertex and fragment shaders and how to implement advanced rendering techniquessuch as per-pixel lighting and particle systems. In addition, the book provides performance tips and tricks for efficient use of the API and hardware. After finishing the book, the reader will be ready to write OpenGL ES 2.0 applications that fully harness the programmable power of embedded graphics hardware.

Organization of the Book

This book is organized to cover the API in a sequential fashion, building up your knowledge of OpenGL ES 2.0 as we go.

Chapter 1--Introduction to OpenGL ES 2.0

This chapter gives an introduction to OpenGL ES, followed by an overview of the OpenGL ES 2.0 graphics pipeline. We discuss the philosophies and constraints that went into the design of OpenGL ES 2.0. Finally, the chapter covers some general conventions and types used in OpenGL ES 2.0.

Chapter 2--Hello Triangle: An OpenGL ES 2.0 Example

This chapter walks through a simple OpenGL ES 2.0 example program that draws a triangle. Our purpose here is to show what an OpenGL ES 2.0 program looks like, introduce the reader to some API concepts, and describe how to build and run an example OpenGL ES 2.0 program.

Chapter 3--An Introduction to EGL

This chapter presents EGL, the API for creating surfaces and rendering contexts for OpenGL ES 2.0. We describe how to communicate with the native windowing system, choose a configuration, and create EGL rendering contexts and surfaces. We teach you enough EGL so that you can do everything you will need to do to get up and rendering with OpenGL ES 2.0.

Chapter 4--Shaders and Programs

Shader objects and program objects form the most fundamental objects in OpenGL ES 2.0. In this chapter, we describe how to create a shader object, compile a shader, and check for compile errors. The chapter also covers how to create a program object, attach shader objects to it, and link a final program object. We discuss how to query the program object for information and how to load uniforms. In addition, you will learn about the difference between source and binary shaders and how to use each.

Chapter 5--OpenGL ES Shading Language

This chapter covers the shading language basics needed for writing shaders. The shading language basics described are variables and types, constructors, structures, arrays, attributes, uniforms, and varyings. This chapter also describes some more nuanced parts of the language such as precision qualifiers and invariance.

Chapter 6--Vertex Attributes, Vertex Arrays,and Buffer Objects

Starting with Chapter 6 (and ending with Chapter 11), we begin our walk through the pipeline to teach you how to set up and program each part of the graphics pipeline. This journey begins by covering how geometry is input into the graphics pipeline by discussing vertex attributes, vertex arrays, and buffer objects.

Chapter 7--Primitive Assembly and Rasterization

After discussing how geometry is input into the pipeline in the previous chapter, we then cover how that geometry is assembled into primitives. All of the primitive types available in OpenGL ES 2.0, including point sprites, lines, triangles, triangle strips, and triangle fans, are covered. In addition, we describe how coordinate transformations are performed on vertices and introduce the rasterization stage of the OpenGL ES 2.0 pipeline.

Chapter 8--Vertex Shaders

The next portion of the pipeline that is covered is the vertex shader. This chapter gives an overview of how vertex shaders fit into the pipeline and the special variables available to vertex shaders in the OpenGL ES Shading Language. Several examples of vertex shaders, including computation of per-vertex lighting and skinning, are covered. We also give examples of how the OpenGL ES 1.0 (and 1.1) fixed-function pipeline can be implemented using vertex shaders.

Chapter 9--Texturing

This chapter begins the introduction to the fragment shader by describing all of the texturing functionality available in OpenGL ES 2.0. This chapter covers all the details of how to create textures, how to load them with data, and how to render with them. The chapter details texture wrap modes, texture filtering, and mipmapping. In addition, you will learn about the various functions for compressed texture images as well as how to copy texture data from the color buffer. This chapter also covers the optional texture extensions that add support for 3D textures and depth textures.

Chapter 10--Fragment Shaders

Chapter 9 focused on how to use textures in a fragment shader. This chapter covers the rest of what you need to know to write fragment shaders. We give an overview of fragment shaders and all of the special built-in variables available to them. We show how to implement all of the fixed-functiontechniques that were available in OpenGL ES 1.1 using fragment shaders. Examples of multitexturing,

fog, alpha test, and user clip planes are all implemented in fragment shaders.

Chapter 11--Fragment Operations

This chapter discusses the operations that can be applied either to the entire framebuffer, or to individual fragments after the execution of the fragment shader in the OpenGL ES 2.0 fragment pipeline. These

operations include scissor test, stencil test, depth test, multi-sampling, blending, and dithering. This is the final phase in the OpenGL ES 2.0 graphics pipeline.

Chapter 12--Framebuffer Objects

This chapter discusses the use of framebuffer objects for rendering to offscreen surfaces. There are several uses of framebuffer objects, the most common of which is for rendering to a texture. This chapter provides a complete overview of the framebuffer object portion of the API. Understanding framebuffer objects is critical for implementing many advanced effects such as reflections, shadow maps, and post-processing.

Chapter 13--Advanced Programming with OpenGL ES 2.0

This is the capstone chapter, tying together many of the topics presented throughout the book. We have selected a sampling of advanced rendering techniques and show examples that demonstrate how to implement these features. This chapter includes rendering techniques such as per-pixel lighting using normal maps, environment mapping, particle systems, image post-processing, and projective texturing. This chapter attempts to show the reader how to tackle a variety of advanced rendering techniques.

Chapter 14--State Queries

There are a large number of state queries available in OpenGL ES 2.0. For just about everything you set, there is a corresponding way to get what the current value is. This chapter is provided as a reference for the various state queries available in OpenGL ES 2.0.

Chapter 15--OpenGL ES and EGL on Handheld Platforms

In the final chapter, we divert ourselves a bit from the details of the API to talk about programming with OpenGL ES 2.0 and EGL in the real world. There are a diverse set of handheld platforms in the market that pose some interesting issues and challenges when developing applications for OpenGL ES 2.0. We cover topics including an overview of handheld platforms, C++ portability issues, OpenKODE, and platform-specific shader binaries.

Appendix A--GL_HALF_FLOAT_OES

This appendix details the half-float format and provides a reference for how to convert from IEEE floating-point values into half-float (and back).

Appendix B--Built-In Functions

This appendix provides a reference for all of the built-in functions available in the OpenGL ES Shading Language.

Appendix C--Shading Language Grammar

This appendix provides a reference for OpenGL ES Shading Language grammar.

Appendix D--ES Framework API

This appendix provides a reference for the utility framework we developed for the book and describes what each function does.

Examples Code and Shaders

This book is filled with example programs and shaders. You can download the examples from the book Web site at www.opengles-book.com. The examples are all targeted to run on Microsoft Windows XP or Vista with a desktop GPU supporting OpenGL 2.0. The example programs are provided in source code form with Microsoft Visual Studio 2005 project solutions. The examples build and run on the AMD OpenGL ES 2.0 Emulator. Several of the advanced shader examples in the book are implemented in RenderMonkey, a shader development tool from AMD. The book Web site provides links on where to download any of the required tools. The OpenGL ES 2.0 Emulator and RenderMonkey are both freely available tools. For readers who do not own Visual Studio, you can use the free Microsoft Visual Studio 2008 Express Edition available for download at www.microsoft.com/express/.

Errata

If you find something in the book which you believe is in error, please send us a note at errors@opengles-book.com. The list of errata for the book can be found on the book Web site at www.opengles-book.com.

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Joe Bell:

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