



---

# Contents

---

<b>Foreword</b>	<b>xix</b>
<b>Preface</b>	<b>xxiii</b>
<b>1. The Fixed-Function Graphics Pipeline</b>	<b>1</b>
The Traditional View	2
The Vertex Operation	2
The Fragment Processing Part of the Pipeline	6
State in the Graphics Pipeline	7

How the Traditional View Is Implemented	8
Vertex Processing	9
Rendering Processing	10
Homogeneous Coordinates in the Fixed-Function Pipeline	14
Vertex Arrays	17
Conclusions	20
Exercises	21
 <b>2. OpenGL Shader Evolution</b>	 25
History of Shaders	27
OpenGL Shader History	30
OpenGL 2.0/GLSL 1.10	30
OpenGL 3.x/GLSL 3.30	31
OpenGL 4.0/GLSL 4.00	32
OpenGL 4.x/GLSL 4.x0	33
What's Behind These Developments?	34
OpenGL ES	34
How Can You Respond to These Changes?	35
Our Approach in this Book	36
Variable Name Convention	36
Exercises	37
 <b>3. Fundamental Shader Concepts</b>	 39
Shaders in the Graphics Pipeline	39
Vertex Shaders	42
Fragment Shaders	47
Tessellation Shaders	50
Geometry Shaders	53

<b>The GLSL Shading Language</b>	<b>54</b>
<b>Passing Data from Your Application into Shaders</b>	<b>59</b>
Defining Attribute Variables in Your Application	59
Defining Uniform Variables in Your Application	62
A Convenient Way to Transition to the Newer Versions of GLSL	64
<b>Exercises</b>	<b>67</b>
<b>4. Using glman</b>	<b>69</b>
<b>Using glman</b>	<b>71</b>
Loading a GLIB File	72
Editing GLIB and Shader Source Files	72
<b>GLIB Scene Creation</b>	<b>72</b>
Window and Viewing	73
Transformations	73
Defining Geometry	73
Specifying Textures	76
Specifying Shaders	77
Miscellaneous	78
Specifying Uniform Variables	79
Examples of GLIB Files	81
<b>More on Textures and Noise</b>	<b>82</b>
Using Textures	82
Using Noise	84
<b>Functions in the glman Interface Window</b>	<b>86</b>
Generating and Displaying a Hardcopy of Your Scene	86
Global Scene Transformation	86
Eye Transformation	87
Object Picking and Transformation	87
Texture Transformation	88
Monitoring the Frame Rate	88
Miscellaneous	89
<b>Exercises</b>	<b>90</b>

<b>5. The GLSL Shader Language</b>	<b>91</b>
Factors that Shape Shader Languages	92
Graphics Card Capabilities	93
General GLSL Language Concepts	95
Shared Namespace	95
Extended Function and Operator Capabilities	96
New Functions	97
New Variable Types	97
New Function Parameter Types	98
Language Details	98
Omitted Language Features	98
New Matrix and Vector Types	99
Name Sets	100
Vector Constructors	101
Functions Extended to Matrices and Vectors	102
Operations Extended to Matrices and Vectors	105
New Functions	106
Swizzle	112
New Function Parameter Types	112
Const	113
Compatibility Mode	114
Defining Compatibility Mode	114
OpenGL 2.1 Built-in Data Types	114
Summary	120
Exercises	120
<b>6. Lighting</b>	<b>123</b>
The ADS Lighting Model	124
The ADS Lighting Model Function	125
Types of Lights	127
Positional Lights	128
Directional Lights	128
Spot Lights	129

---

<b>Setting Up Lighting for Shading</b>	<b>131</b>
Flat Shading	132
Smooth (Gouraud) Shading	133
Phong Shading	134
Anisotropic Shading	135
<b>Exercises</b>	<b>137</b>
<b>7. Vertex Shaders</b>	<b>139</b>
<b>Vertex Shaders in the Graphics Pipeline</b>	<b>140</b>
Input to Vertex Shaders	140
Output from Vertex Shaders	142
Fixed-Function Processing After the Vertex Shader	145
The Relation of Vertex Shaders to Tessellation Shaders	146
The Relation of Vertex Shaders to Geometry Shaders	146
<b>Replacing Fixed-Function Graphics with Vertex Shaders</b>	<b>146</b>
Standard Vertex Processing	147
<b>Going Beyond the Fixed-Function Pipeline with Vertex Shaders</b>	<b>148</b>
<b>Vertex Modification</b>	<b>148</b>
Issues in Vertex Shaders	151
<b>Creating Normals</b>	<b>152</b>
<b>Summary</b>	<b>153</b>
<b>Exercises</b>	<b>154</b>
<b>8. Fragment Shaders and Surface Appearance</b>	<b>157</b>
<b>Basic Function of a Fragment Shader</b>	<b>158</b>
Inputs to Fragment Shaders	158
Particularly Important “In” Variables for the Fragment Shader	161
Coordinate Systems	162

<b>Fragment Shader Processing</b>	<b>163</b>
Outputs from Fragment Shaders	163
<b>Replacing Fixed-Function Processing with Fragment Shaders</b>	<b>163</b>
Shading	164
Traditional Texture Mapping	165
False Coloring	166
<b>What Follows a Fragment Shader?</b>	<b>168</b>
<b>Additional Shader Effects</b>	<b>169</b>
Discarding Pixels	169
Phong Shading	169
Shading with Analytic Normals	170
Anisotropic Shading	172
Data-Driven Coloring	173
Images Using Other Data	175
<b>Exercises</b>	<b>177</b>
 <b>9. Surface Textures in the Fragment Shader</b>	<b>179</b>
<b>Texture Coordinates</b>	<b>180</b>
<b>Traditional Texture Mapping</b>	<b>180</b>
<b>GLSL Texture Mapping</b>	<b>182</b>
The Texture Context	184
Texture Environments in the Fixed-Function World	185
Texture Sampling Parameters	186
Samplers	186
Procedural Textures	187
Bump Mapping	193
Cube Maps	200
<b>Render to Texture</b>	<b>205</b>
<b>Render to Texture for Multipass Rendering in glman</b>	<b>209</b>
<b>Exercises</b>	<b>212</b>

<b>10. Noise</b>	<b>213</b>
<hr/>	
<b>Fundamental Noise Concepts</b>	<b>214</b>
Three Types of Noise: Value, Gradient, and Value+Gradient	214
Cubic and Quintic Interpolation	215
Noise Equations	216
<hr/>	
<b>Other Noise Concepts</b>	<b>220</b>
Fractional Brownian Motion (FBM, 1/f, Octaves)	220
Noise in Two and Three Dimensions	221
Using Noise with glman	223
Using Noise with the Built-In GLSL Functions	225
Turbulence	225
<hr/>	
<b>Some Examples of Noise in Different Environments</b>	<b>228</b>
Marble Shader	230
Cloud Shader	231
Wood Shader	233
<hr/>	
<b>Advanced Noise Topics</b>	<b>235</b>
<hr/>	
<b>Using Noisegraph</b>	<b>235</b>
<hr/>	
<b>Exercises</b>	<b>237</b>
<hr/>	
<b>11. Image Manipulation with Shaders</b>	<b>239</b>
<hr/>	
<b>Basic Concepts</b>	<b>240</b>
<hr/>	
<b>Single-Image Manipulation</b>	<b>241</b>
Luminance	241
CMYK Conversions	243
Hue Shifting	246
Image Filtering	248
Image Blurring	249
Chromakey Images	251
Stereo Anaglyphs	252
3D TV	256
Edge Detection	259
Embossing	260

Toon Shader	262
Artistic Effects	264
Image Flipping, Rotation, and Warping	265
<b>The Image Blending Process</b>	<b>270</b>
<b>Blending an Image with a Constant Base Image</b>	<b>271</b>
Color Negative	272
Brightness	273
Contrast	274
<b>Blending an Image with a Version of Itself</b>	<b>275</b>
Saturation	275
Sharpness	276
<b>Blending Two Different Images</b>	<b>277</b>
Other Combinations	278
Image Transitions	281
<b>Notes</b>	<b>286</b>
<b>Exercises</b>	<b>287</b>
<b>12. Geometry Shader Concepts and Examples</b>	<b>291</b>
<b>What Does the Geometry Shader Do?</b>	<b>292</b>
New Adjacency Primitives	294
Layouts for Input and Output Variables	295
New OpenGL API Functions	296
New GLSL Variables and Variable Types	299
Communication between a Vertex or Tessellation Shader and a Geometry Shader	299
<b>Normals in Geometry Shaders</b>	<b>301</b>
<b>Examples</b>	<b>301</b>
Bézier Curves	301
Shrinking Triangles	303
Sphere Subdivision	305
3D Object Silhouettes	309
<b>Exercises</b>	<b>312</b>

<b>13. Tessellation Shaders</b>	<b>315</b>
What Are Tessellation Shaders?	315
Tessellation Shaders or Geometry Shaders?	317
Tessellation Shader Concepts	318
Issues in Setting Tessellation Levels	323
Examples	323
Isolines	324
Bézier Surface	327
Sphere Subdivision	334
Whole Sphere Subdivision while Adapting to Screen Coverage	341
PN Triangles	344
Summary	350
Exercises	351
<b>14. The GLSL API</b>	<b>353</b>
Shaders in the OpenGL Programming Process	353
Handling OpenGL Extensions	355
How Is a GLSL Shader Program Created?	355
Creating and Compiling Shader Objects	357
The CheckGLErrors Function	359
Creating, Attaching, Linking, and Activating Shader Programs	360
Creating a Shader Program and Attaching Shader Objects	361
Linking Shader Programs	361
Activating a Shader Program	362
Passing Data into Shaders	364
Defining Uniform Variables in Your Application	364
Uniform Variables in Compatibility Mode	367
Defining Attribute Variables in Your Application	368
Attribute Variables in Compatibility Mode	370
A C++ Class to Handle Shader Program Creation	371
Exercises	372

<b>15. Using Shaders for Scientific Visualization</b>	<b>375</b>
Image-Based Visualization Techniques	376
Image Negative	376
Image Edge Detection	377
Toon Rendering	377
Hyperbolic Geometry	378
3D Scalar Data Visualization	381
Point Clouds	383
Cutting Planes	387
Volume Probe	390
Direct Volume Rendering	392
More on Transfer Functions	398
Passing in Data Values with Your Geometry	403
Terrain Bump-Mapping	405
Flow Visualization	408
2D Line Integral Convolution	408
3D Line Integral Convolution	411
Extruding Objects for Streamlines	413
Geometry Visualization	416
Silhouettes	416
Hedgehog Plots	417
Exercises	420
<b>16. Serious Fun</b>	<b>425</b>
Light Interference	426
Diffraction Gratings	427
Oil Slicks	431
Lens Effects	433

---

Bathroom Glass	438
Atmospheric Effects	440
Rainbows	441
The Glory	445
Fun with One	448
Using the glman Timer Function	449
Disco Ball	449
Fog, with and without Noise	452
Morphing 3D Geometry	453
Algorithmic Art	456
Connett Circles	456
Making Information Visible Through Motion	459
An Explosion Shader	461
Exercises	462

---

## Appendices

A. GLSLProgram C++ Class	465
B. Matrix4 C++ Class	469
C. Vec3 C++ Class	473
D. Vertex Array Class	477

---

References	483
------------	-----

---

Index	487
-------	-----