2.3 Affine Transformations
   2.3.1 Types of Affine Transformations 35
   2.3.2 Transformation Around a Pivot 39
   2.3.3 Example: Hierarchical Modeling 39

2.4 Eye Coordinate System 42

2.5 Projections
   2.5.1 Near and Far Planes and the Depth Buffer 45
   2.5.2 A General View Frustum 47
   2.5.3 Parallel Projection 50

2.6 Viewport and 2D Coordinate Systems 51

CHAPTER 3. LOW-LEVEL RENDERING 55

3.1 Rendering Primitives 57
   3.1.1 Geometric Primitives 57
   3.1.2 Raster Primitives 60

3.2 Lighting 61
   3.2.1 Color 61
   3.2.2 Normal Vectors 63
   3.2.3 Reflection Models and Materials 64
   3.2.4 Lights 68
   3.2.5 Full Lighting Equation 70

3.3 Culling and Clipping 70
   3.3.1 Back-Face Culling 71
   3.3.2 Clipping and View-Frustum Culling 71

3.4 Rasterization 73
   3.4.1 Texture Mapping 74
   3.4.2 Interpolating Gradients 82
   3.4.3 Texture-Based Lighting 83
   3.4.4 Fog 88
   3.4.5 Antialiasing 90

3.5 Per-Fragment Operations 92
   3.5.1 Fragment Tests 92
   3.5.2 Blending 95
   3.5.3 Dithering, Logical Operations, and Masking 99

3.6 Life Cycle of a Frame 100
   3.6.1 Single versus Double Buffering 101
   3.6.2 Complete Graphics System 101
   3.6.3 Synchronization Points 102

CHAPTER 4. ANIMATION 105

4.1 Keyframe Animation 105
   4.1.1 Interpolation 106
   4.1.2 Quaternions 111
4.2 Deforming Meshes
  4.2.1 Morphing 113
  4.2.2 Skinning 114
  4.2.3 Other Dynamic Deformations 116

CHAPTER 5. SCENE MANAGEMENT 117
5.1 Triangle Meshes 118
5.2 Scene Graphs 120
  5.2.1 Application Area 120
  5.2.2 Spatial Data Structure 121
  5.2.3 Content Creation 123
  5.2.4 Extensibility 125
  5.2.5 Class Hierarchy 125
5.3 Retained Mode Rendering 128
  5.3.1 Setting Up the Camera and Lights 129
  5.3.2 Resolving Rendering State 130
  5.3.3 Finding Potentially Visible Objects 130
  5.3.4 Sorting and Rendering 132

CHAPTER 6. PERFORMANCE AND SCALABILITY 133
6.1 Scalability 134
  6.1.1 Special Effects 135
  6.1.2 Tuning Down the Details 136
6.2 Performance Optimization 136
  6.2.1 Pixel Pipeline 137
  6.2.2 Vertex Pipeline 139
  6.2.3 Application Code 140
  6.2.4 Profiling OpenGL ES Based Applications 141
  6.2.5 Checklists 142
6.3 Changing and Querying the State 145
  6.3.1 Optimizing State Changes 146
6.4 Model Data 146
  6.4.1 Vertex Data 147
  6.4.2 Triangle Data 148
6.5 Transformation Pipeline 148
  6.5.1 Object Hierarchies 148
  6.5.2 Rendering Order 149
  6.5.3 Culling 150
6.6 Lighting 151
  6.6.1 Precomputed Illumination 151
15.4 Layering and Multi-Pass Effects 360
15.5 Picking 362
15.6 Optimizing Performance 364
   15.6.1 Visibility Optimization 365
   15.6.2 Scope Masks 365

CHAPTER 16. ANIMATION IN M3G 367
16.1 Keyframe Animation: KeyframeSequence 367
16.2 Animation Targets: AnimationTrack 372
16.3 Timing and Speed: AnimationController 374
16.4 Animation Execution 377
16.5 Advanced Animation 378
   16.5.1 Deformable Meshes 378
   16.5.2 Animation Blending 385
   16.5.3 Creating Discontinuities 387
   16.5.4 Dynamic Animation 388

PART IV  APPENDIX
A FIXED-POINT MATHEMATICS 393
A.1 Fixed-Point Methods in C 395
   A.1.1 Basic Operations 395
   A.1.2 Shared Exponents 397
   A.1.3 Trigonometric Operations 399
A.2 Fixed-Point Methods in Assembly Language 400
A.3 Fixed-Point Methods in Java 405

B JAVA PERFORMANCE TUNING 407
B.1 Virtual Machines 408
B.2 Bytecode Optimization 409
B.3 Garbage Collection 410
B.4 Memory Accesses 411
B.5 Method Calls 413

C GLOSSARY 415
   Bibliography 419
   Index 425