

---

<b>CHAPTER 1</b>	<b>Introduction</b>	<b>15</b>
	The RM Scene Graph Libraries: rm, rmax, rmv, rmi	16
	What is a Scene Graph Model?	16
	Retained Mode and Immediate Mode Rendering	18
	Scope of Control	19
	Further Reading	23
<b>CHAPTER 2</b>	<b>RM Scene Graph Theory of Operation</b>	<b>25</b>
	The Scene Graph	25
	Data Model	29
	RM Primitive Types	30
	Explicit Surface and Shape Primitives	30
	Vector Primitives	32
	Semi-Procedural Primitives	32
	Image and Bitmap Primitives	36
	Text Primitives	37
	Indexed Primitives	38
	Multiresolution Control	38
	Scene Parameters	39
	Viewports	40
	Framebuffer Clear and Fill Modes	41
	Cameras and Viewpoints	43
	Lights and Lighting Models	44
	Material Properties and Rendering Styles	45
	Clipping Planes	47
	Textures, Texture Mapping and Environments, Multitexturing	48
	Geometric Transformations	50
	Text Properties	50
	Window Systems, Rendering Pipes and Initialization	51
	Event Management	52
	Frame-Based Rendering	53
	Multipass and Stereo Rendering	53
	Node Traversal Masks	53
	Frame Callbacks	55
	Picking	55
	Constant-Rate Rendering	56

Postscript Output .....	56
Multiprocessing and Thread Safety .....	56
Distributed Memory Parallel Rendering .....	57
Interfacing RM with Third-Party Tools .....	58
Third Party Modeling Applications .....	58
Third Party GUI and Event Processing Frameworks .....	58
Summary .....	59

## **CHAPTER 3**                      **Nodes, Primitives and Fundamental Data Objects**    **61**

Data Models and Management .....	62
Data Blobs and Meta Data: To Share or Not To Share? .....	62
Nodes and Primitives .....	64
Creating and Deleting Nodes, RMnodes and Multipass Rendering ..	66
Creating New RMnodes .....	66
The RM “Root Node” Default Values .....	69
Scene Graph Node Insertion and Removal .....	70
Deleting Nodes and Trees .....	72
Adding Renderable Primitives to RMnodes .....	74
Creating New Primitives .....	75
Populating the RMprimitive with Data .....	77
Assigning the RMprimitive to an RMnode .....	84
Accessing RMprimitives in an RMnode .....	85
Removing All RMprimitives from an RMnode .....	85

## **CHAPTER 4**                      **Surfaces and Shape Geometry**                      **87**

Vector-Based Primitives .....	87
Disjoint Lines .....	88
Line Strips .....	89
Surface Primitives .....	90
Disjoint Triangles .....	92
Indexed Disjoint Triangles .....	94
Triangle Strips .....	96
Indexed Triangle Strips .....	97
Triangle Fans .....	99
Indexed Triangle Fans .....	100
Disjoint Quads .....	102

Indexed Disjoint Quads .....	103
Quadrilateral Strip .....	104
Indexed Quadrilateral Strips .....	105
Quadmeshes .....	106
Octmeshes .....	107
Implicit Surfaces and Procedural Objects .....	107
Spheres .....	108
Cylinders .....	111
Cones .....	114
Box Primitives .....	116
Ellipses (2D) .....	119
Circles (2D) .....	121
Strategies for Using Indexed Primitives .....	122
Multiresolution Control with Indexed Shape Primitives .....	123
Third Party Display Lists as RMprimitive Data .....	125

## CHAPTER 5

## RMimages, RMbitmaps, Sprite and Bitmap Primitives 127

1-, 2- and 3-D Image Data .....	128
The RMimage Object .....	128
Creating Image Objects .....	130
Setting and Getting The Raw Pixel Data in an Image Object .....	131
Pixel Zoom .....	134
OpenGL Imaging Pipeline Operations: Pixel Transfer and Scale/Bias ..	135
Unary Image Manipulation .....	142
Sprite Primitives .....	144
Assigning Data to the Sprite Primitive .....	145
Sprite Primitive Example .....	146
Visualization Colormaps and Pixel Transfer in RMimages .....	147
Creating and Destroying Visualization Colormaps .....	148
Manipulating Color Entries in Visualization Colormaps .....	148
Visualization Colormap Utilities .....	152
Bitmaps .....	153
Creating and Destroying Bitmaps .....	155
Getting the Size of a Bitmap .....	155
Setting and Getting Bitmap “Pixel Data” .....	156
Manipulating Bitmaps .....	157

---

	The Bitmap Primitive .....	157
	Bitmap Primitive Coding Example .....	159
	Memory Alignment of Image and Bitmap Pixel Data .....	160
<b>CHAPTER 6</b>	<b>Text .....</b>	<b>163</b>
	Text and Indexed Text .....	164
	Example: Creating an RM_TEXT RMprimitive .....	166
	Example: Creating an RM_INDEXED_TEXT RMprimitive .....	167
	RM Text Properties .....	169
	Creating and Destroying RMtextProps Objects .....	170
	Specifying Text Attributes .....	171
	Assigning the RMtextProps as a Scene Parameter .....	174
<b>CHAPTER 7</b>	<b>Bounding Boxes and Center Points .....</b>	<b>177</b>
	Computing and Assigning Bounding Boxes .....	177
	RMprimitive-level Bounding Boxes .....	178
	RMnode-level Bounding Boxes .....	179
	Bounding Box Operations .....	181
	Computing and Assigning Center Points .....	182
	When to Compute and Assign Bounding Boxes and Center Points ..	183
	When to Compute and Assign Bounding Boxes .....	183
	When to Compute and Assign Center Points .....	184
	Suggested Practices for Bounding Boxes and Center Points .....	184
<b>CHAPTER 8</b>	<b>Geometric Transformations .....</b>	<b>187</b>
	Overview of Transformations .....	187
	The Composite Transformation .....	187
	Transformation Inheritance .....	190
	The RM API for Specifying and Querying Model Transformations ..	190
	Vector Transformation Attributes .....	191
	Matrix Transformation Attributes .....	193
	Querying the Composite Transformation Matrix .....	197
	The RMmatrix Object .....	198
	RMmatrix Constructor and Destructor Routines .....	198

RMmatrix Initialization Routines .....	199
Setting or Getting Individual RMatrix Values .....	199
RMatrix Math Routines: Inversion, Transposition, Multiplication and Point/Matrix Transformations .....	200
Copying and Printing RMatrices .....	202

## CHAPTER 9

## Scene Parameters ..... 203

Defining Views: Viewports and Cameras .....	204
Viewports .....	204
Two Dimensional Cameras .....	207
Three Dimensional Cameras .....	211
Inserting Cameras into the Scene Graph .....	224
Backgrounds: Colors, Image Tiles, Depth Buffers .....	227
Types of Framebuffer Clear Operations: Single Valued vs. Image .....	227
“Scheduling” Framebuffer Clear Operations .....	228
Scope of Framebuffer Clears .....	229
Solid Color Background Fills .....	229
Pasting an Image into the Background .....	231
Clearing the Depth Buffer with a Single Value .....	234
Loading an Image into the Depth Buffer .....	234
Summary of Framebuffer Clear Operations .....	236
Clipping Planes .....	237
Creating Clip Plane Objects .....	238
Specifying a Clip Plane .....	238
Activating or Disabling Clip Planes .....	239
Clip Planes and the Scene Graph .....	239
Clip Plane Coding Example .....	241
Textures and Texture Mapping .....	242
Surface/Material Properties .....	242
Object Color .....	242
RM Node-level Color and Material Property Parameters .....	243
Transparency .....	247
Render Modes .....	249
Polygon Render Modes .....	249
Polygon Cull Modes .....	250
Point Primitive Render Modes .....	252
Line Segment Render Modes .....	253
Shader Selection .....	254

Lights	256
Light Sources	257
Lighting Environment	268
Lights and Lighting Environment: Putting it all Together	273
Scene Parameters Processing Order	276

**CHAPTER 10**      **Texture Mapping and Volume Rendering . . . . 277**

Texture Mapping Overview	278
Creating RMtextures	278
Building a Texture Object	278
Adding Images to the Texture Object	280
Texture Filtering, Wrap Modes and Environment	283
Texel Storage Formats	286
Deleting RMtexture Objects	288
Assigning RMtextures as Scene Parameters	289
RMprimitives and Texture Coordinates	289
Assigning Texture Coordinates to RMprimitives	290
Updating Existing Textures	291
2D Texturing Examples	293
3D Texturing	294
Texture-Based Volume Rendering: Octmeshes	294
Multitexturing	297
Multitexturing Background	297
Runtime Checks for Multitexturing Support	298
Specifying Multitexture Images	299
Specifying Multitexture Texture Coordinates	300
Multitexturing Example	301
Texture Utilities	304
Hardware Image Resize Caveats	305
Texture Instancing	306

**CHAPTER 11**      **Rendering and Frame-Based Operations . . . . 307**

Scene Graph Traversal	308
Scene Graph Node Traversal Masks and Processing	309
The General Traverse Enable Mask	310

The Pick Traversal Mask .....	311
Multipass Rendering .....	312
Fundamental Frame Rendering .....	314
Frame Rendering with rmFrame .....	314
Using rmFrame in Applications .....	314
Picking .....	315
Picking in RM .....	315
Raster Output .....	324
Obtaining the Color Planes of the Framebuffer After Rendering .....	324
Obtaining the Depth Buffer After Rendering .....	326
PostScript Output .....	326
PostScript Rendering Theory of Operation .....	327
PostScript Rendering and Output Parameters .....	328
Creating PostScript Output with rmFramePS and rmFramePSHeartbeat ...	338
PostScript Creation Tips and Tricks .....	342

**CHAPTER 12**                      **Extending RM Scene Graph: Callbacks      . . . . . 345**

RMnode Callback Functions .....	346
Render State Interface .....	352
Render State Interface Overview .....	352
Querying the Render State Interface .....	353
RMnode and RMprimitive Client Data .....	359
RMprimitive Client Data .....	360
RMnode Client Data .....	361

**CHAPTER 13**                      **Application Initialization and Event Processing with  
RMaxx      363**

The Big Picture .....	364
Background: OpenGL and Window System Initialization .....	365
Generic OpenGL Initialization .....	365
Initializing OpenGL in X Windows .....	366
Initializing OpenGL in Win32 .....	366
Overview of RM Initialization .....	367
Initialization Step One: Initializing RM .....	368
Initialization Step Two: Create an RMpipe Object .....	368

What is an RMPipe? .....	368
Creating an RMPipe .....	369
Which RMPipe Enumerator to Use? .....	369
Initialization Steps Three and Four: Creating a Window and Assigning It to an RMPipe .....	370
Using RMAux to Create a Display Window .....	371
Assigning the Window and Window Dimensions to the RMPipe .....	374
Initialization Step Five: Making the RMPipe and OpenGL Context “Current”	376
Initialization Step Six: Assign the Initialization Function .....	378
Initialization Step Seven: The Event Loop .....	379
The RMAux Event Loop .....	380
Initialization Step Eight: Application Epilogue .....	382
RMAux Action Handlers .....	382
RMAux Routines to Assign Button to Action Mappings .....	382
Interactive Transformations with RMAux .....	385
Interactive Geometric Transformations: Virtual Trackball Interface .....	385
Interactive 3D Viewpoint Transformations .....	387
Application Customizations to the Default RMAux User Interface .....	390
Changing the Default RMAux Render Function .....	391

## CHAPTER 14

### RMPipe Attributes .....

Creating and Destroying RMPipes .....	394
Creating RMPipes with rmPipeNew .....	394
Closing and Deleting RMPipes .....	396
Multipass Rendering Control and Scene Graph Traversals .....	396
Display Characteristics: Monoscopic or Stereoscopic Rendering ...	398
The OpenGL Context and the RMPipe .....	399
RM Manages the OpenGL Context Exclusively .....	399
Your Application Manages the OpenGL Context .....	400
Specifying How an RMPipe Uses OpenGL Resources .....	400
Specifying How the OpenGL Matrix Stack is Initialized .....	401
Controlling Use of OpenGL Display Lists .....	402
Post-Rendering Application RMPipe Callbacks .....	403
Swapbuffers and RMPipes .....	408
Enumeration of RMPipes in a Parallel, Multipipe Application .....	409

---

Constant-Rate Rendering Controls .....	412
What is constant-rate rendering? .....	412
Caveats and Limitations .....	415
Examples .....	418

**CHAPTER 15**                      **Parallel Rendering and Thread Safety    .....** **419**

Thread Safety .....	420
What is Thread Safety? .....	420
The Component Manager and Context Cache .....	420
What Operations in RM are Thread Safe? .....	421
Multistage, Multithreaded Rendering .....	422
RMpipe Multithreaded Processing Modes .....	422
Scene Graph Data Management in Two-Stage Rendering .....	425
Which RMpipe Processing Mode to Use? .....	428

**CHAPTER 16**                      **Parallel Rendering with RM and Chromium    ..** **431**

Architecture Overview .....	433
One to Many Parallelism .....	433
Many to Many Parallelism .....	434
Creation of Windows in RM/Chromium Applications .....	436
Application-Created Windows .....	436
Chromium-Created Windows .....	437
Mandatory Initialization Sequence for Applications that Render only to Chromium-Created Windows .....	437
Known Limitations and Future Directions (September 2005) .....	438
Fundamental Parallel Scene Graph Concepts in RM/Chromium Applications	439
Fundamental Synchronization Required in Parallel Environments .....	439
Using Parallel Synchronization Constructs Provided by RM .....	439
Sample Application Skeleton .....	442
Advanced Parallel Scene Graph Rendering in RM/Chromium Applications	443
Modifying Chromium Configuration Files for Use with RM Applications	446
Known Bugs .....	447
Summary .....	448

---

<b>CHAPTER 17</b>	<b>Measuring Time in RM</b> .....	<b>449</b>
	The Rmtime Object .....	450
	What Time Is It Now? .....	451
	How Much Time Has Elapsed? .....	451
	Elapsed Time in Milliseconds .....	452
	Elapsed Rmtime .....	452
	Unary Rmtime Operations .....	453
	Taking a Nap – Precision Sleeping in RM .....	454
<b>CHAPTER 18</b>	<b>Using RM with the Fast Light Toolkit (FLTK)</b>	<b>457</b>
	FLTK and OpenGL .....	458
	FLTK Overview .....	458
	OpenGL in FLTK Applications .....	458
	RM Initialization in FLTK/RM Applications .....	459
	Detecting When to Initialize in FLTK/RM Applications .....	459
	Comparing Initialization in RM-only and FLTK/RM Applications .....	460
	The Required Initialization Sequence in FLTK/RM Applications .....	462
	Why This Approach Works .....	463
	The Event Loop in FLTK/RM Applications .....	463
	Summary .....	464
<b>CHAPTER 19</b>	<b>Reading and Writing Images with RMI</b> .....	<b>465</b>
	Reading and Writing JPEG Raster Image Files .....	465
	Reading JPEG Files .....	466
	Writing JPEG Files .....	467
	Prerequisites for Building RMI/JPEG .....	467
	Reading and Writing PPM Raster Image Files .....	468
	Reading PPM Files .....	468
	Writing PPM Files .....	470
	Raster File Format References and Resources .....	470
<b>CHAPTER 20</b>	<b>Visualization</b> .....	<b>471</b>
	Grid Types in RMV .....	472

---

---

	RMV Naming Conventions .....	473
	RMV Visualization Taxonomy and Overview .....	474
	Common Parameters .....	475
	Visualization of 1D Data .....	476
	Visualization of 2D Data .....	503
	Visualization of 3D Data .....	542
	Visualization of 3D Vector Data .....	545
	Visualization Utilities .....	554
<b>CHAPTER 21</b>	<b>Modifying RM Defaults .....</b>	<b>561</b>
	Routines for Getting and Setting RM Defaults .....	562
	Queryable and Modifiable RM Defaults .....	563

