

Numbers

3D Computer Graphics, 370

A

accumulation buffer, 468, 470, 490–502

clearing, 32, 471

depth-of-field effect, use for, 497–501

examples of use, 490

full range for best results, use, 781

motion blur, use for, 497

sample program with depth-of-field effect, 499

sample program with full-scene antialiasing, 492

scene antialiasing, use for, 491

AGL, 14

`aglChoosePixelFormat()`, 744, 747

`aglConfigure()`, 748

`aglCopyContext()`, 745, 748

`aglCreateContext()`, 745, 747

`aglDescribePixelFormat()`, 747

`aglDescribeRenderer()`, 747

`aglDestroyContext()`, 745, 748

`aglDestroyPixelFormat()`, 747

`aglDestroyRendererInfo()`, 747

`aglDevicesOfPixelFormat()`, 747

`aglDisable()`, 748

`aglEnable()`, 748

`aglErrorString()`, 749

`aglGetCurrentContext()`, 745, 748

`aglGetDrawable()`, 745, 748

`aglGetError()`, 749

`aglGetInteger()`, 748

`aglGetVersion()`, 744, 747

`aglGetVirtualScreen()`, 748

`aglIsEnabled()`, 748

`aglNextPixelFormat()`, 747

`aglNextRendererInfo()`, 747

`aglQueryRendererInfo()`, 747

`aglResetLibrary()`, 749

`aglSetCurrentContext()`, 745, 748

`aglSetDrawable()`, 745, 748

`aglSetFullScreen()`, 746, 748

`aglSetInteger()`, 745, 748

`aglSetOffScreen()`, 746, 748

`aglSetVirtualScreen()`, 748

`aglSwapBuffers()`, 746, 748

`aglUpdateContext()`, 746, 748

`aglUseFont()`, 749

airbrushing, 629

Akeley, Kurt, 490

aliasing, *see* antialiasing

alpha, 231

destination alpha, 260

material properties, 213

multisampling coverage, 259

texture image data type, 422

alpha blending, *see* blending

alpha test, 476

querying current values, 477

rendering pipeline stage, 14, 683

ambient

contribution to lighting equation, 223

global light, 208, 222

light, 187, 188, 196

material properties, 189, 213

animation, 20–23, 780

antialiasing, 247–260

accumulation buffer used for, 491–496

characters (by masking), 613

characters (by texturing), 624

color-index mode, 252

coverage values, 247

enabling for points or lines, 249

enabling for polygons, 260

lines, 247, 249–255

lines (by texturing), 624

points, 249–255, 616

polygons, 260

RGBA mode, 249

sample program in color-index mode, 252

sample program in RGBA mode, 250

scene, with the accumulation buffer, 491

Apple Interface to OpenGL, *see* AGL

-
- ARB imaging subset, 346–368
 - architectural applications
 - orthographic parallel projection, use of, 136
 - Architecture Review Board
 - extensions, approved, 605
 - arcs, 524
 - array elements, *see* vertex arrays
 - aspect ratio
 - perspective projection, 135
 - viewport transformation, 139
 - atmospheric effects, *see* fog
 - attenuation of light, 197–198
 - attribute groups, 91–93
 - client, 91
 - list of, 688–733
 - multitexturing, with, 447
 - performance tips, 782
 - server, 91
 - stack depth, obtaining, 92
 - stacks, 91
 - auxiliary buffers, 469, 472
- B**
- back-facing polygons, 56
 - culling, 57
 - material property, specifying, 212
 - two-sided lighting, 209
 - background, 30–32
 - color, 30
 - drawing a fixed, 474, 625
 - background processing, 765
 - backward compatibility
 - tessellation, 522
 - basis functions, 535, 536
 - Bernstein
 - basis, 535
 - polynomial, 539
 - Bézier
 - basis, 535, 536
 - curve, 539
 - sample program using mesh for surface, 546
 - sample program which draws curve, 537
 - sample program which draws surface, 544
 - BGR and BGRA pixel formats, 315
 - billboarding, 239, 477
 - bitmaps, 302–308
 - display lists cache bitmap data, 283
 - distorting, 611
 - drawing, 306
 - feedback mode, 593
 - fonts, used for, 304, 310
 - imaging pipeline operations, 323
 - ordering of data in, 305
 - origin of, 307
 - sample program, 304
 - sample program that creates a font, 311
 - size of, 305
 - bitplanes, 170, 466
 - displayable colors, number of, 172
 - blending, 231–244, 487
 - antialiasing polygons, 260
 - coverage calculations for antialiasing, 247
 - destination alpha, 260
 - differences among releases, 230
 - enabling, 235
 - enabling for antialiasing, 249
 - equation, 235
 - factors (source and destination), 232
 - images, 616
 - ordering polygons before drawing, 243
 - rendering pipeline stage, 14, 683
 - sample program for three-dimensional, 244
 - sample program with blended polygons, 241
 - texture function, 425
 - three dimensions, in, 243
 - uses of, 238
 - buffer object, 817
 - buffer objects
 - binding, 84
 - creating, 83
 - deleting, 88
 - initializing with data, 84
 - mapping a buffer, 87
 - replacing data, 87
 - unmapping a buffer, 87
 - buffer, *see* framebuffer

C

- C programming language, 8
- CAD/CAM, *see* computer-aided design
- camera analogy, 106–107
 - environment mapping, 440
 - viewport transformations, 138
- capping, *see* computational solid geometry
- Chapter, 47
- characters
 - antialiasing, 624
- circles, 524
- clearing buffers, 31
- clearing the color buffer, 31
- clearing the framebuffer, 30–32, 470–471
 - affected by scissoring, dithering, and masking, 471, 684
 - performance tips, 783
- client-server, *see* networked operation
- clip coordinates, 108, 150
 - feedback mode, 593
- clip planes
 - user defined, 150
- clipping, 138
 - interference regions found using clipping planes, 620
 - overview, 105
 - primitives in rendering pipeline, 12
 - viewing volume, 134
- clipping planes
 - additional clipping planes, 108, 149–152
 - depth-buffer resolution, effect on, 780
 - far, 134–137, 142
 - near, 134–137, 142
 - querying number of additional, 150
 - sample program with additional clipping planes, 151
- color
 - alpha values, 231
 - background, 30
 - cube showing blended RGB values, 169
 - current raster color, 308
 - human perception, 167
 - RGBA values for, 33, 168
 - specifying, 33
 - specifying for tessellation, 512
 - specifying in color-index mode, 178
 - specifying in RGBA mode, 177
- color buffer, 168, 170, 467, 468, 469
 - clearing, 32
 - masking, 473
- color map, 168, 173
 - loading for antialiasing, 252
 - loading for smooth shading, 181
 - loading, using GLUT, 763
 - size of, 174
- color matrix, 361–362
 - example, 361
 - post transform scale and bias, 362
 - sample program, 362
- color sum mode, 455
- color tables, 348–350
 - proxies, 353
 - replacing part of, 352
 - sample program, 350
 - specifying, 348
- color-index mode, 173–175
 - changing between RGBA mode and, 176
 - choosing between RGBA mode and, 175
 - coverage calculations for antialiasing, 247
 - dithering, 488
 - layering with writemasks, 474
 - lighting, 226–228
 - lighting calculations in, 227
 - texturing limitations, 375, 383
 - vertex arrays, specifying values with, 69
- combiner functions, 449–454
- command syntax, 7–9
- compositing images, 239
- compositing transformations, 152–159
- computational solid geometry
 - capping, 483
 - difference of several contours, 517
 - interference regions, 619
 - intersection of two contours, 517
 - union of several contours, 517
- Computer Graphics: Principles and Practice*, xxxviii
- Computer Graphics: Principles and Practice*, 167, 171, 773

computer-aided design
 orthographic parallel projection, use of, 136

concave polygons
 GLU tessellation, 506
 stencil buffer, drawing with the, 618

cones, 524, 764
 improving rendering of, 627

constant attenuation, 198

contours, 435

control points, 534, 538, 542, 551

convex polygons, 39

convolutions, 353–361
 1d filters, 359
 2d filters, 353
 border modes, 360
 post convolution scale and bias, 361
 sample program, 355
 separable filters, 357

Conway, John, 627

coordinate systems
 grand, fixed, 119, 128, 153
 local, 119, 128, 153, 157
 simple 2D, 36

coordinates
 see clip coordinates, depth coordinates, eye coordinates, homogeneous coordinates, normalized device coordinates, object coordinates, q texture coordinates, texture coordinates, w coordinates, or window coordinates

coverage, pixel, 247

Coxeter, H. S. M., 773

cross product, 131, 769

CSG, *see* computational solid geometry

cube maps, 441

culling, 56–57
 enabling, 57
 rendering pipeline stage, 12, 682
 selection mode, 574

curves and curved surfaces, 41
 see also evaluators or NURBS

Curves and Surfaces for Computer-Aided Geometric Design, 535

cylinders, 524

D

data types
 RGBA color conversion, 177
 special OpenGL, 8
 texture data, 382
 warning about data type conversions, 782

decals, 477, 617
 polygon offset used for, 274
 texture function, 424

depth buffer, 186, 468, 469
 see also hidden-surface removal
 background, using masking for a common, 474
 blending, use for three-dimensional, 243
 clearing, 32, 186, 471
 decals, for, 617
 Dirichlet domains, for, 626
 drawing static backgrounds, 625
 masking, 473
 near frustum plane effect on resolution, 780
 pixel data, 321, 332

depth coordinates, 109, 141
 perspective division, 141
 picking use, 585
 polygon offset, 274–276
 rendering pipeline stage for depth-range operations, 12, 682
 sample program with picking, 585
 selection hit records, 574

depth test, 483
 see also depth buffer
 rendering pipeline stage, 14, 683

depth-cuing, *see* fog

depth-of-field effect, 497–501
 sample program, 499

destination factor, *see* blending

determining object coordinates from window coordinates, 160, 163

-
- diffuse
 - contribution to lighting equation, 223
 - light, 188, 196
 - material properties, 189, 213
 - directional light source, 197
 - Dirichlet domains, 626
 - disks, 524
 - display lists, 29, 279
 - changing mode settings, 299
 - compiling, 287
 - creating, 285
 - deleting, 292
 - disadvantages, 284, 290
 - error handling, 286, 780
 - executing, 285, 289
 - executing multiple, 292
 - font creation, 293, 309
 - hierarchical, 290
 - immediate mode, mixing with, 289
 - indices for, obtaining, 286
 - naming, 286
 - nesting, 290
 - nesting limit, querying, 290
 - networked operation, 289
 - performance tips, 782
 - querying use of an index, 291
 - rendering pipeline stage, 11
 - sample program creating a font, 294
 - sample program for creating, 279, 285
 - sharing among rendering contexts, 739, 754
 - state variables saved and restored, 298
 - tessellation, use with, 521
 - uses for, 283, 299
 - vertex-array data, 289
 - what can be stored in, 288
 - distorted images, 611
 - texture images, 428
 - dithering, 172–173, 488, 781
 - and clearing, 471
 - rendering pipeline stage, 14, 683
 - dot product
 - lighting calculations, use in, 223
 - texture combiner function, 451
 - double-buffering, 22–23
 - automatic glFlush(), 35
 - changing between single-buffering and, 176
 - object selection using the back buffer, 610
 - querying its presence, 469
 - drawing
 - clearing the window, 30
 - forcing completion of, 34
 - icosahedron, 96
 - points, 43
 - polygons, 43, 56
 - preparing for, 30
 - rectangles, 40
 - spheres, cylinders, and disks, 523–532
 - drawing pixel data, *see* pixel data
 - Duff, Tom, 239
- ## E
- edge flags, 62–63
 - tessellated polygons generate, 510
 - vertex arrays, specifying values with, 69
 - emission, 188, 214, 221
 - enabling
 - alpha test, 476
 - antialiasing of points or lines, 249
 - antialiasing polygons, 260
 - blending, 235
 - color material properties mode, 217
 - color sum mode, 455
 - culling, 57
 - depth test, 484
 - dithering, 173, 488
 - evaluators, 539, 543
 - fog, 261
 - lighting, 211
 - line stippling, 52
 - logical operations, 489
 - multisampling, 256
 - normal vectors for evaluated surfaces,
 - automatic generation of, 543, 551
 - polygon offset, 274
 - polygon stippling, 58
 - rescaling normals, 65, 192
 - stencil test, 478
 - texture coordinate generation, 438
 - texturing, 376, 379
 - unit length normal vectors ensured, 65, 192

-
- endianness, 327
 - environment mapping, 439, 441
 - errata, xl
 - error handling, 601–603
 - error string description, 603
 - recommended usage, 780
 - evaluators, 536–550
 - basis functions, 535, 539
 - evenly spaced values, 541, 545
 - one-dimensional, 536
 - rendering pipeline stage, 11
 - sample program using mesh for 2D Bézier surface, 546
 - sample program which draws 1D Bézier curve, 537
 - sample program which draws 2D Bézier surface, 544
 - sample program which generates texture coordinates, 548
 - tessellation usage, 783
 - texture coordinates, generating, 548
 - two-dimensional, 544
 - event management, using GLUT, 19
 - extensions
 - Architecture Review Board approved, 605
 - Microsoft Windows and
 - wglGetProcAddress(), 607
 - vendor-specific, 605
 - eye coordinates, 108, 150
 - texture coordinate generation, 434, 439
 - F**
 - fade effect, 608
 - Farin, Gerald E., 535
 - feedback, 591–598
 - array contents, 597
 - pass-through markers, 594
 - querying current rendering mode, 572
 - returned data, 593
 - sample program, 595
 - steps to perform, 592
 - tessellation, obtaining vertex data after, 521
 - Feiner, Steven K., xxxviii, 773
 - field of view, 112
 - calculate, using trigonometry to, 143
 - filtering, 411–413
 - mipmapped textures, 401–411, 413
 - texture border colors, 429
 - flat shading, 179
 - flight simulation
 - fog, use of, 261
 - flushing, 34, 780
 - fog, 261–271
 - blending factors, 264
 - color-index mode, 266
 - density, 265
 - enabling, 261
 - equations, 264
 - fog coordinates, 268
 - hints, 261
 - RGBA mode, 265
 - sample program in color-index mode, 266
 - sample program in RGBA mode, 262
 - sample program with fog coordinates, 269
 - Foley, James D., xxxviii, 167, 171, 773
 - fonts, 309–312
 - antialiased characters (by masking), 613
 - antialiased characters (by texturing), 624
 - bitmapped, 310
 - creating with display lists, 293
 - drawing, 308
 - drawing as bitmaps, 304
 - multi-byte, 310
 - same program, 311
 - sample program using multiple display lists, 294
 - X fonts, using, 740
 - Foran, Jim, 458
 - foreshortening, perspective, 133
 - fragments, 466
 - alpha test, 476
 - blending, 231
 - depth test, 483
 - rendering pipeline operations, 13, 683
 - scissor test, 476
 - tests, 475–489
 - texture functions, 423

framebuffer, 170, 467
 capacity per pixel, 468
 clearing, 470–471
 copying pixel data within, 313, 321, 322
 enabling for reading, 472
 enabling for writing, 472
 minimum configuration with the X Window System, 468
 querying color resolution, 170
 reading pixel data from, 313, 315
 writing pixel data to, 313, 319

front-facing polygons, 56
 specifying material property for, 212
 two-sided lighting, 209

frustum, 133

ftp (file-transfer protocol) site
 GLX specification, 738

Fundamentals of Computer Aided Geometric Design, 535

G

Game of Life, 627

gamma correction, 171

Gardner, Martin, 627

geometric primitives, 37–48, 680–682
 performance when specifying, 783
 rendering pipeline stage, 12

geosciences
 use of texturing in applications, 434

giraffe, 174

GL_VERTEX_PROGRAM_POINT_SIZE, 673

GL_VERTEX_PROGRAM_TWO_SIDE, 674

glActiveTexture(), 445

glAreTexturesResident(), 419

glArrayElement(), 72
 legal between glBegin() and glEnd(), 47

Glassner, Andrew S., xxxix

glAttachShader(), 640

glBegin(), 42, 43, 510
 restrictions, 46

glBeginQuery(), 486

glBindAttribLocation(), 671

glBindBuffer(), 84

glBindTexture(), 379, 416
 multitexturing, 445

glBitmap(), 303, 740
 feedback mode, 593
 fonts, used for, 310
 imaging pipeline operations, 323
 pixel-storage modes effect, 326

glBlendColor*(), 235

glBlendEquation(), 235

glBlendEquationSeparate(), 235

glBlendFunc(), 233

glBlendFuncSeparate(), 233

glBufferData(), 84

glBufferSubData(), 87

glCallList(), 282, 285, 290
 legal between glBegin() and glEnd(), 47

glCallLists(), 292
 fonts, use for, 309
 legal between glBegin() and glEnd(), 47
 sample program, 311

glClear(), 31, 471, 684
 depth buffer, clearing the, 186

glClearAccum(), 32, 471

glClearColor(), 31, 471

glClearDepth(), 31, 471

glClearIndex(), 32, 179, 471
 fog, use with, 266

glClearStencil(), 32, 471

glClientActiveTexture(), 448

glClipPlane(), 150

glColor*(), 33, 177
 legal between glBegin() and glEnd(), 46

glColorMask(), 471, 473

glColorMaterial(), 217
 performance tips, 782

glColorPointer(), 69

glColorSubTable(), 352

glColorTable(), 348

glColorTableParameter(), 350

glCompileShader(), 639

glCompressedTexImage1D(), 398

glCompressedTexImage2D(), 398
 glCompressedTexImage3D(), 398
 glCompressedTexSubImage1D(), 399
 glCompressedTexSubImage2D(), 399
 glCompressedTexSubImage3D(), 399
 glConvolutionFilter1D(), 359
 glConvolutionFilter2D(), 354
 glConvolutionParameter*(), 360
 glCopyColorSubTable(), 352
 glCopyColorTable(), 351
 glCopyConvolutionFilter1D(), 359
 glCopyConvolutionFilter2D(), 357
 glCopyPixels(), 313, 321
 alternative uses, 628
 dithering, turn off, 781
 feedback mode, 593
 glReadBuffer() effect, 473
 imaging pipeline operations, 322
 pixel-transfer modes effect, 330
 glCopyTexImage1D(), 391
 glReadBuffer() effect, 473
 pixel-transfer modes effect, 330
 glCopyTexImage2D(), 384
 glReadBuffer() effect, 473
 pixel-transfer modes effect, 330
 glCopyTexSubImage1D(), 392
 glReadBuffer() effect, 473
 pixel-transfer modes effect, 330
 glCopyTexSubImage2D(), 389
 glReadBuffer() effect, 473
 pixel-transfer modes effect, 330
 glCopyTexSubImage3D(), 395
 pixel-transfer modes effect, 330
 glCreateProgram(), 640
 glCreateShader(), 638
 glCullFace(), 57
 glDeleteBuffers(), 88
 glDeleteLists(), 292, 310
 glDeleteProgram(), 643
 glDeleteQueries(), 487
 glDeleteShader(), 643
 glDeleteTextures(), 418
 glDepthFunc(), 484
 glDepthMask(), 473
 blending opaque and translucent objects,
 244
 glDepthRange(), 141
 gluUnProject(), relationship to, 160
 glWindowPos*() effect, 306
 glDetachShader(), 640
 glDisable(), 10, 49
 glDisableClientState(), 68
 glDisableVertexAttribArray(), 673
 glDrawArrays(), 77
 glDrawBuffer(), 320, 321, 472
 glDrawBuffers(), 472
 glDrawElements(), 73
 glDrawPixels(), 313, 319, 480, 625
 alternative uses, 628
 feedback mode, 593
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glDrawRangeElements(), 76
 version, 29
 glEdgeFlag*(), 63
 legal between glBegin() and glEnd(), 47
 glEdgeFlagPointer(), 69
 glEnable(), 10, 49, 193
 see also enabling
 glEnableClientState(), 47, 67
 glEnableVertexAttribArray(), 673
 glEnd(), 42, 43, 510
 restrictions, 46
 glEndList(), 281, 285, 287
 glEndQuery(), 486
 glEvalCoord*(), 541
 legal between glBegin() and glEnd(), 47
 used instead of glVertex*(), 536, 539
 glEvalMesh1(), 542
 glEvalPoint*()
 legal between glBegin() and glEnd(), 47
 glFeedbackBuffer(), 592
 glRenderMode(), use with, 572
 glFinish(), 35

glFlush(), 35, 740, 780
 glFog*(), 265
 glFogCoord*(), 269
 glFogCoordPointer(), 69
 glFrontFace(), 57
 glFrustum(), 113, 134, 684
 glGenBuffers(), 83
 glGenLists(), 281, 286
 fonts, use for, 309
 glGenQueries(), 485
 glGenTextures(), 379, 415
 glGetAttachedShaders(), 686
 glGetAttribLocation(), 671
 glGetBooleanv(), 10, 49, 688
 double-buffering support, querying, 469
 stereo support, querying, 469
 glGetBufferParameteriv(), 686
 glGetBufferPointerv(), 686
 glGetBufferSubData(), 686
 glGetClipPlane(), 686
 glGetColorTable(), 686
 pixel-storage modes effect, 326
 glGetColorTableParameter*(), 686
 glGetCompressedTexImage(), 686
 glGetConvolutionFilter(), 686
 pixel-storage modes effect, 326
 glGetConvolutionParameter*(), 686
 glGetDoublev(), 10, 49, 688
 glGetError(), 10, 602, 686
 glGetFloatv(), 10, 49, 688
 line width attributes, obtaining, 51
 glGetHistogram(), 364, 686
 pixel-storage modes effect, 326
 glGetHistogramParameter*(), 686
 glGetIntegerv(), 10, 49, 688
 alpha test information, obtaining, 477
 attribute stack depth, obtaining, 92
 clipping planes, obtaining number of
 additional, 150
 color resolution, obtaining, 170
 display list nesting limit, obtaining, 290
 matrix stack depth, obtaining, 148
 maximum texture size, obtaining, 385
 name stack depth, obtaining, 573
 pixel map information, obtaining, 333
 rendering mode, obtaining current, 572
 stencil-related values, obtaining, 479
 vertex array range values, obtaining, 76
 glGetLight*(), 10, 687
 glGetMap*(), 687
 glGetMaterial*(), 687
 glGetMinmax(), 367, 687
 pixel-storage modes effect, 326
 glGetMinmaxParameter*(), 687
 glGetPixelMap(), 687
 glGetPointerv(), 10, 49, 688
 glGetPolygonStipple(), 10, 687
 glGetProgramInfoLog(), 641
 glGetProgramiv(), 687
 glGetProgramLogInfo(), 687
 glGetQueryiv(), 687
 glGetQueryObject*(), 486
 glGetQueryObjectiv(), 687
 glGetQueryObjectuiv(), 687
 glGetSeparableFilter(), 687
 pixel-storage modes effect, 326
 glGetShaderInfoLog(), 639, 687
 glGetShaderiv(), 687
 glGetShaderSource(), 687
 glGetString, 606
 glGetString(), 603, 687
 glGetTexEnv*(), 687
 glGetTexGen*(), 687
 glGetTexImage(), 687
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glGetTexLevelParameter*(), 386, 687
 glGetTexParameter*(), 687
 texture residency, obtaining, 419
 glGetUniformLocation(), 688
 glGetUniformLocation(), 653
 glGetVertexAttrib*(), 688
 glGetVertexAttribPointerv(), 688

`glHint()`
 fog use, 261
 texture use, 380

`glHistogram()`, 363

`glIndex*()`
 fog, use with, 266
 legal between `glBegin()` and `glEnd()`, 46

`glIndexMask()`, 471, 473

`glIndexPointer()`, 69

`glInitNames()`, 571, 572, 573

`glInterleavedArrays()`, 79

`glIsBuffer()`, 83, 688

`glIsEnabled()`, 10, 49, 688

`glIsList()`, 291, 688

`glIsProgram()`, 644, 688

`glIsQuery()`, 485, 688

`glIsShader()`, 644, 688

`glIsTexture()`, 415, 688

`glLight*()`, 193, 194, 195, 200

`glLightModel*()`, 208

`glLineStipple()`, 52

`glLineWidth()`, 51

`glLinkProgram()`, 641

`glListBase()`, 292
 fonts, use for, 309
 sample program, 311

`glLoadIdentity()`, 113, 115, 125, 684
 performance tips, 782
 viewing transformations, use before, 111

`glLoadMatrix*()`, 114, 115, 684

`glLoadName()`, 572, 574

`glLoadTransposeMatrix*()`, 114, 116

`glLogicOp()`, 236

`glMap*()`, 538

`glMap1*()`, 540

`glMapBuffer()`, 87

`glMapGrid1*()`, 541

`glMapGrid2*()`, 545

`glMaterial*()`, 194, 212
 legal between `glBegin()` and `glEnd()`, 46
 performance tips, 782

`glMatrixMode()`, 113, 115
 use with matrix stacks, 146

`glMinmax()`, 366

`glMultiDrawArrays()`, 78
 version, 29

`glMultiDrawElements()`, 75
 version, 29

`glMultiTexCoord*()`, 447

`glMultMatrix*()`, 114, 115, 684
 performance tips, 782

`glMultTransposeMatrix*()`, 114, 116

`glNewList()`, 281, 285, 287

`glNormal*()`
 legal between `glBegin()` and `glEnd()`, 46

`glNormal3*()`, 64

`glNormalPointer()`, 69

`glOrtho()`, 137, 684
 picking matrix use, 579

`glPassThrough()`, 592, 594

`glPixelMap*()`, 333

`glPixelStore*()`, 326, 395
 cannot be stored in display lists, 289
 polygon stippling, 58
 texture image data, effect on, 382, 384, 387, 389, 391, 394, 398, 399

`glPixelTransfer*()`, 330, 625
 texture image data, effect on, 382, 384, 387, 389, 391, 394, 398, 399

`glPixelZoom()`, 334, 611

`glPointParameter*()`, 272

`glPointSize()`, 50, 673

`glPolygonMode()`, 56
 antialiasing, effect on, 260
 polygon offset, use with, 274

`glPolygonOffset()`, 274

`glPolygonStipple()`, 58
 pixel-storage modes effect, 326

`glPopAttrib()`, 10, 92, 298, 447, 689

`glPopClientAttrib()`, 10, 93, 447, 689

`glPopMatrix()`, 146, 157, 203, 298
 restore orientation of coordinate systems, 159
 selection, use with, 571

glPopName(), 572, 573
 glPrioritizeTextures(), 420
 glPushAttrib(), 10, 92, 298, 447, 689
 glPushClientAttrib(), 10, 93, 447, 689
 glPushMatrix(), 146, 157, 203, 298
 save orientation of coordinate systems, 159
 selection, use with, 571
 glPushName(), 571, 572, 573
 glRasterPos*(), 303, 305
 images, for positioning, 313
 multitexturing, with, 447
 selection hit, 574
 glReadBuffer(), 320, 321, 473
 glReadPixels(), 313
 glReadBuffer() effect, 473
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glRect*(), 40
 glRenderMode(), 571, 572, 574, 592
 glResetHistogram(), 366
 glResetMinmax(), 368
 glRotate*(), 122, 153, 156, 684
 performance tips, 782
 glSampleCoverage(), 259
 glScale*(), 111, 122, 156, 684
 performance tips, 782
 glScissor(), 476
 glSecondaryColor*(), 455
 glSecondaryColorPointer(), 69
 glSelectBuffer(), 571, 572
 display lists, cannot be stored in, 289
 glSeparableFilter2D(), 358
 glShadeModel(), 179
 glShaderSource(), 639
 glStencilFunc(), 478
 glStencilFuncSeparate(), 478
 glStencilMask(), 473
 glStencilMaskSeparate(), 473
 glStencilOp(), 478
 glStencilOpSeparate(), 478
 glTexCoord*(), 379, 426
 legal between glBegin() and glEnd(), 47
 texture unit 0, for, 447
 glTexCoordPointer(), 69
 glTexEnv*(), 379, 421, 449
 level of detail bias, 405
 multitexturing, 445
 glTexGen*(), 434
 cube maps, 443
 environment mapping, 440
 multitexturing, 445, 448
 glTexImage1D(), 390
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glTexImage2D(), 379, 380
 cube map textures, 441
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 specifying mipmaps, 402
 glTexImage3D(), 393
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glTexParameter*(), 379, 432
 automatic mipmap regeneration, 411
 mipmap level of detail, controlling, 408
 mipmap levels, controlling base and maximum, 407
 multitexturing, 445
 specifying filtering methods, 412
 glTexSubImage1D(), 391
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glTexSubImage2D(), 387
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glTexSubImage3D(), 394
 pixel-storage modes effect, 326
 pixel-transfer modes effect, 330
 glTranslate*(), 121, 153, 156, 684
 performance tips, 782
 GLU, 3, 14, 506
 drawing spheres, cylinders, and disks, 523–532
 error string description, 603

GLU (*continued*)

- obsolete routines
 - gluBeginPolygon(), 522
 - gluEndPolygon(), 522
 - gluNextContour(), 522
- quadrics, 523–532
- tessellation, 39, 506–523
- version numbers, obtaining, 604
- gluBeginCurve(), 551, 561
- gluBeginSurface(), 551, 559
- gluBeginTrim(), 565
- gluBuild1DMipmapLevels(), 410
- gluBuild1DMipmaps(), 410
- gluBuild2DMipmapLevels(), 410
- gluBuild2DMipmaps(), 410
- gluBuild3DMipmapLevels(), 410
- gluBuild3DMipmaps(), 410
- gluCheckExtension(), 606
- gluCylinder(), 524, 527
- gluDeleteNurbsRenderer(), 555
- gluDeleteQuadric(), 524, 525
- gluDeleteTess(), 521, 522
- gluDisk(), 524, 528
- gluEndCurve(), 551, 561
- gluEndSurface(), 551, 559
- gluEndTrim(), 565
- gluErrorString(), 525, 559, 603
 - polygon tessellation, 510
- gluGetNurbsProperty(), 558, 688
- gluGetString, 606
- gluGetString(), 605, 688
- gluGetTessProperty(), 517, 688
- gluLoadSamplingMatrices(), 558
- gluLookAt(), 109, 111, 129, 153
- gluNewNurbsRenderer(), 551, 555
- gluNewQuadric(), 524, 525
- gluNewTess(), 508, 522
- glUniform*(), 654
- glUniformMatrix*(), 654
- glUnmapBuffer(), 87
- gluNurbsCallback(), 551, 559, 562
- gluNurbsCallbackData(), 563
- gluNurbsCurve(), 551, 561
- gluNurbsProperty(), 551
 - returning tessellated data, 561
- gluNurbsSurface(), 551, 560
- gluOrtho2D(), 138, 781
 - resized windows, use with, 36
- gluPartialDisk(), 524, 528
- gluPerspective(), 113, 136, 153
 - picking matrix use, 579
- gluPickMatrix(), 579
- gluProject(), 163
- gluPwlCurve(), 565
- gluQuadricCallback(), 524, 525
- gluQuadricDrawStyle(), 524, 525
- gluQuadricNormals(), 524, 526
- gluQuadricOrientation(), 524, 526
- gluQuadricTexture(), 524, 526
- gluScaleImage(), 383
- glUseProgram(), 641
- gluSphere(), 524, 527
- GLUT, 15, 759–765
 - basic functions, 16–20
 - event management, 19
 - glutCreateWindow(), 17, 761
 - glutDisplayFunc(), 17, 761
 - glutIdleFunc(), 20, 765
 - glutInit(), 17, 760
 - glutInitDisplayMode(), 17, 760
 - glutInitWindowPosition(), 17, 761
 - glutInitWindowSize(), 17, 761
 - glutKeyboardFunc(), 19, 762
 - glutMainLoop(), 18, 765
 - glutMotionFunc(), 19, 762
 - glutMouseFunc(), 19, 762
 - glutPostRedisplay(), 18, 282, 763
 - glutReshapeFunc(), 19, 762
 - simple example, 36
 - glutSetColor(), 17, 179, 227, 763
 - smooth shading, use for, 181
 - glutSolidCone(), 764

glutSolidCube(), 20, 764
 glutSolidDodecahedron(), 764
 glutSolidIcosahedron(), 764
 glutSolidOctahedron(), 764
 glutSolidSphere(), 20, 763
 glutSolidTeapot(), 764
 glutSolidTetrahedron(), 764
 glutSolidTorus(), 764
 glutSwapBuffers(), 23
 glutWireCone(), 764
 glutWireCube(), 20, 764
 glutWireDodecahedron(), 764
 glutWireIcosahedron(), 764
 glutWireOctahedron(), 764
 glutWireSphere(), 20, 153, 763
 glutWireTeapot(), 764
 glutWireTetrahedron(), 764
 glutWireTorus(), 764
 multisampling, 256
 window management, 17, 36
 gluTessBeginContour(), 519
 gluTessBeginPolygon(), 518
 gluTessCallback(), 519, 522
 gluTessEndContour(), 519
 gluTessEndPolygon(), 518
 gluTessNormal(), 517, 518, 521
 gluTessProperty(), 514, 519
 gluTessVertex(), 519, 522
 gluUnProject(), 160, 163
 gluUnProject4(), 163
 glValidateProgram(), 644
 glVertex*(), 41
 legal between glBegin() and glEnd(), 46
 using glEvalCoord*() instead, 536
 glVertexAttrib*(), 671
 glVertexAttrib4N*(), 671
 glVertexAttribPointer(), 672
 glVertexPointer(), 47, 69
 glViewport(), 114, 139
 using with resized windows, 36
 glWindowPos*(), 306
 multitexturing, with, 447
 selection hit, 574
 GLX, 14, 738
 ftp site for GLX specification, 738
 glXChooseFBConfig(), 738, 741
 glXChooseVisual(), 738, 743, 784
 glXCopyContext(), 739, 742
 glXCreateContext(), 740, 743
 glXCreateGLXPixmap(), 738, 743
 glXCreateNewContext(), 739, 742
 glXCreatePbuffer(), 738, 742
 glXCreatePixmap(), 738, 742
 glXCreateWindow(), 738, 742
 glXDestroyContext(), 739, 742
 glXDestroyGLXPixmap(), 741, 743
 glXDestroyPbuffer(), 741, 743
 glXDestroyPixmap(), 741, 743
 glXDestroyWindow(), 741, 743
 glXGetClientString(), 738, 741
 glXGetConfig(), 468, 738, 743
 glXGetCurrentContext(), 739, 742
 glXGetCurrentDisplay(), 739, 742
 glXGetCurrentDrawable(), 739, 742
 glXGetCurrentReadDrawable(), 739, 740, 742
 glXGetFBConfigAttrib(), 738, 741
 glXGetFBConfigs(), 741
 glXGetProcAddress(), 739, 742
 glXGetSelectedEvent(), 740, 742
 glXGetVisualFromFBConfig(), 738, 741
 glXIsDirect(), 739, 742
 glXMakeContextCurrent(), 739, 742
 glXMakeCurrent(), 740, 743
 glXQueryContext(), 739, 742
 glXQueryExtension(), 738, 741
 glXQueryExtensionsString(), 738, 741
 glXQueryServerString(), 738, 741
 glXQueryVersion(), 738, 741
 glXSelectEvent(), 740, 742
 glXSwapBuffers(), 23, 740, 743
 glXUseXFont(), 740, 743
 glXWaitGL(), 740, 743
 performance tips, 784
 glXWaitX(), 740, 743
 performance tips, 784
 glXQueryExtensionString(), 605
 Gouraud shading, *see* smooth shading

-
- H**
- Haeberli, Paul, 458, 490
 - haze, *see* fog
 - header file, 15
 - hidden-line removal, 622
 - polygon offset used for, 274
 - hidden-surface removal, 185–187, 483
 - hierarchical models, 145, 290
 - picking, 583–585
 - highlights, *see* specular
 - hints, 248
 - fog, 261
 - perspective correction, 248, 379, 380
 - histogram, 363–366
 - resetting, 364, 366
 - retrieving, 364
 - sample program, 364
 - hits (selection), *see* selection (hit records)
 - holes in polygons, 39, 619
 - homogeneous coordinates, 38, 774
 - Hoschek, Josef, 535
 - Hughes, John F., xxxviii, 773
- I**
- IBM OS/2 Presentation Manager to OpenGL Interface, *see* PGL
 - icosahedron, drawing, 96
 - identity matrix, 111, 115, 125, 782
 - illumination, *see* lighting
 - images, 302, 312–321
 - see also* pixel data
 - blending, 616
 - compositing, 232
 - distorted, 611
 - imaging pipeline, 321–337
 - interpolating between, 616
 - magnifying or reducing, 334
 - nonrectangular, 239
 - projecting, 624
 - sample code which draws an image, 320
 - sample program which draws, copies, and zooms an image, 335
 - scaling and rotating, 624
 - sources of, 312
 - superimposing, 617
 - transposing, 629
 - warping, 624
 - imaging pipeline, *see* images (imaging pipeline)
 - imaging subset, 346–368
 - extension string, 606
 - texture images, effect on, 383, 390
 - immediate mode, 29, 278
 - display lists, mixing with, 289
 - infinite light source, 197
 - input events
 - handling, using GLUT, 19
 - intensity
 - texture image data type, 422
 - Interactive Inspection of Solids: Cross-sections and Interferences*, 619
 - interference regions, 619
 - interleaved arrays, 78
 - interpolating
 - color values and texture coordinates, 248, 425
 - texture combiner function, 453
 - invariance
 - of an OpenGL implementation, 780, 785
- J**
- jaggies, 247
 - jittering, 491, 502
 - accFrustum() routine, 492
 - accPerspective() routine, 492
 - sample code to jitter projection transformations, 492
 - sample program with orthographic projection, 496
- K**
- Kilgard, Mark, xxxix, 15, 738, 759
 - Korobkin, Carl, 458

L

- Lasser, Dieter, 535
- layers, drawing, 612
- Life, Game of, 627
- light sources, 194–207
 - ambient light, 188, 196
 - contribution to lighting equation, 222
 - diffuse light, 188, 196
 - directional, 197
 - display lists cache values, 283
 - infinite light source, 197
 - local light source, 197
 - maximum number of sources, 193
 - moving along with the viewpoint, 205
 - moving light sources, 201–206
 - multiple light sources, 200
 - performance tips, 193
 - positional, 197
 - rendering pipeline stage, 12, 681
 - RGBA values, 189
 - sample program that moves the light source, 204
 - specifying a light source, 193
 - specular light, 188
 - spotlights, 199–200
 - stationary, 202
- lighting
 - see also* light sources, material properties
 - ambient light, 187
 - approximation of the real world, 187
 - attenuation, 197–198
 - calculations in color-index mode, 227
 - color-index mode, 226–228
 - default values, using, 194
 - display lists cache values, 283
 - enabling, 193, 194
 - enabling and disabling, 211
 - equation that calculates lighting, 221
 - global ambient light, 208, 222
 - lighting model, 207–210
 - lighting model, specifying a, 193
 - rendering pipeline stage, 12, 681
 - sample program introducing lighting, 190
 - specular color separated, 210, 225, 455
 - steps to perform, 190
 - two-sided materials, 209
 - viewer, local or infinite, 209
- line segment, 38
- linear attenuation, 198
- lines, 38
 - antialiasing, 249–255, 624
 - connected closed loop, specifying, 43, 45
 - connected strip, specifying, 43, 45
 - feedback mode, 593
 - querying line width, 51
 - sample program with wide, stippled lines, 54
 - specifying, 43, 45
 - stippling, 52
 - tessellated polygons decomposed into, 510
 - width, 51
- local light source, 197
- logical operations
 - rendering pipeline stage, 14, 683
 - transposing images, using for, 629
- lookup table, *see* color map
- luminance, 315, 341
 - pixel data formats for, 317, 325
 - texture image data type, 422

M

- magnifying images, 334
- masking, 473
 - antialiasing characters, 615
 - layers, drawing, 612
 - rendering pipeline stage, 14, 683
- material properties, 194, 211–220
 - ambient, 189, 213
 - changing a single parameter with `glColorMaterial()`, 217
 - changing material properties, 215
 - diffuse, 189, 213
 - display lists cache values, 283
 - emission, 188, 214, 221
 - enabling color material properties mode, 217
 - performance when changing, 782
 - rendering pipeline stage, 12, 681
 - RGBA values, 190

-
- material properties (*continued*)
 - sample program which changes material properties, 215
 - sample program which uses `glColorMaterial()`, 218
 - shininess, 214
 - specular, 189, 214
 - two-sided lighting, 209
 - matrix
 - see also* matrix stack
 - choosing which matrix is current, 115
 - column-major ordering, 116
 - current, 111
 - danger of extensive changes, 780
 - display lists cache matrix operations, 283
 - identity, 111, 115, 125, 782
 - loading, 115
 - loading transposed, 116
 - modelview, 108, 115
 - multiplying matrices, 115
 - multiplying transposed matrices, 116
 - NURBS, specifying for sampling, 557
 - orthographic parallel projection, 778
 - perspective projection, 777
 - projection, 113, 115
 - rotation, 776
 - row-major ordering, 116
 - scaling, 776
 - texture, 458
 - transformation pipeline, 106
 - transformations of homogeneous coordinates, 774
 - translation, 776
 - matrix stack, 145–149
 - choosing which matrix stack is current, 146
 - current matrix stack, 684
 - modelview, 148
 - popping, 146
 - projection, 148
 - pushing, 146
 - querying stack depth, 148
 - texture, 458
 - Megahed, Abe, 619
 - Microsoft
 - callback functions on Windows, 511
 - Microsoft Win32, *see* Win32
 - Microsoft Windows 95/98/NT, xl, 14, 753
 - Microsoft Windows to OpenGL interface, *see* WGL
 - minmax, 366–368
 - reseting, 367, 368
 - retrieving results, 367
 - sample program, 367
 - mipmapping, 401–411
 - automated generation, 409
 - base and maximum levels, 407
 - level of detail control, 406
 - minification filters, 413
 - texture objects for mipmaps, 418
 - mirroring objects, *see* scaling
 - modeling transformations, 111, 117, 120–125
 - camera analogy, 106
 - connection to viewing transformations, 111
 - example, 123
 - rotation, 122
 - rotation matrix, 776
 - sample program, 125
 - scaling, 122
 - scaling matrix, 776
 - translation, 121
 - translation matrix, 776
 - models
 - rendering wireframe and solid, 20, 763
 - modelview matrix, 108, 115
 - arbitrary clipping planes, effect on, 150
 - stack, 148
 - mosaicing, 406
 - motion blur, 497
 - stippling, with, 609
 - motion, *see* animation
 - movie clips, 628
 - multiple layers
 - displaying with overlap, 612
 - multisampling, 255–259
 - fading point primitives, 272
 - sample program, 256
 - multitexture
 - extension string, 606
 - multitexturing, 443–448

N

- name stack, 571–575
 - creating, 572
 - initializing, 572
 - loading, 572
 - multiple names, 583–585
 - popping, 572
 - pushing, 572
 - querying maximum depth, 573
 - networked operation, 34–35
 - attribute groups, saving and restoring, 91
 - display lists, 289
 - versions, 604
 - Non-Uniform Rational B-Splines, *see* NURBS
 - nonplanar polygons, 40
 - normal vectors, 63–65, 192
 - calculating, 768
 - calculating for analytic surfaces, 769
 - calculating for polygonal data, 771
 - calculating length, 65
 - cross product, calculating normalized, 98
 - enabling automatic unit length division, 65, 192
 - inverse matrix generated, 684
 - matrix transformations, 108
 - normalized, 65
 - NURBS, generating for, 560
 - quadrics, generated for, 526
 - rendering pipeline stage, 12, 681
 - specifying, 64
 - tessellation, specifying for, 512
 - transformations, 775
 - uniform rescaling, 65
 - unit length optimizes performance, 783
 - vertex arrays, specifying values with, 69
 - normal, *see* normal vectors
 - normalized device coordinates, 108
 - NURB Curves and Surfaces* (book title), 535
 - NURBS, 550–568
 - creating a NURBS curve or surface, 559–561
 - creating a NURBS object, 555
 - culling, 556
 - deleting a NURBS object, 555
 - display list use, 282
 - error handling, 558
 - method of display (lines or filled polygons), 556
 - normal vectors, generating, 560
 - properties, controlling NURBS, 555
 - querying property value, 558
 - references, 535
 - sample program which draws a lit NURBS surface, 552
 - sample program with a trimmed surface, 567
 - sampling precision, 556
 - source for matrices, 557
 - steps to use, 551
 - texture coordinate generation, 560
 - trimming, 565–568
 - NURBS Book, The*, 535
 - NURBS for Curve and Surface Design*, 535
 - NURBS tessellator
 - sample code, 563, 564
- ## O
- object coordinates, 108
 - texture coordinate generation, 434
 - objects, *see* models
 - occlusion query, 484
 - opacity, 232
 - OpenGL Extension to the X Window System,
 - see* GLX
 - OpenGL Programming for the X Window System*, xxxix
 - OpenGL Programming for the X Window System*, 15, 17, 738, 759
 - OpenGL Reference Manual*, xxxix
 - OpenGL Reference Manual*, 679, 686, 738
 - OpenGL Utility Library, *see* GLU
 - OpenGL Utility Toolkit, *see* GLUT
 - orthographic parallel projection, 113, 136–137
 - jittering, 495
 - matrix, 778
 - specifying with integer coordinates, 781
 - outer product, 357

outlined polygons, 56, 63
 polygon offset solution, 274
overlapping objects, 619

P

packed pixel data, 317–318
painting, 232, 238, 629
partial disks, 524
pass-through markers, 594
performance tips
 clearing the window, 32
 display lists, 282
 flat shading, 783
 flushing the pipeline, 34
 fog, 261
 GLX tips, 784
 hints, 248
 light source attenuation, effect of, 198
 light sources, effect of additional, 193
 list of general tips, 782
 material properties, changing, 782
 NURBS and display lists, 282
 pixel data alignment, 328
 pixel data, drawing, 345
 polygon restrictions, 39
 polygon subdivision, 95
 pushing and popping attribute groups, 782
 rasterization and fragment operations for
 pixel data, 784
 removing hidden surfaces, 187
 specifying geometric primitives, 783
 tessellation and display lists, 282
 tessellation, use of, 521
 texture images, internal format of, 382
 texture objects, 414, 782
 texture subimages, 782
 two-sided lighting, 210
 unit-length normal vectors, 783
 vector and scalar forms of commands, 783
 vertex arrays, 783
perspective projection, 133–136
 correction hint, 248, 379, 380
 depth coordinates, effect on, 141
 jittering, 492
 matrix, 777
 perspective division, 108
PGL, 14, 749
 pglChooseConfig(), 749, 751
 pglCopyContext(), 750, 752
 pglCreateContext(), 750, 752
 pglDestroyContext(), 750, 752
 pglGetCurrentContext(), 750, 752
 pglGetCurrentWindow(), 750, 752
 pglGrabFrontBitmap(), 750, 752
 pglIsIndirect(), 750, 752
 pglMakeCurrent(), 750, 752
 pglQueryCapability(), 749, 751
 pglQueryConfigs(), 750, 751
 pglQueryVersion(), 749, 751
 pglReleaseFrontBitmap(), 750, 752
 pglSelectColorIndexPalette(), 751, 752
 pglSwapBuffers(), 751, 752
 pglUseFont(), 751, 752
 pglWaitGL(), 750, 752
 pglWaitPM(), 750, 752
picking, 578–588
 back buffer for, using the, 610
 depth coordinates, 585
 hierarchical models, 583–585
 projection matrix, special, 579
 sample program, 580
 sample program with depth coordinates,
 585
 strategies, 589
 sweep selection, 590
Piegl, Les, 535
pipeline
 geometric processing, 681–682
 imaging, 321–337
 rendering, 10–14
 vertex transformation, 106
pixel
 coverage, 247
pixel data, 302, 312–321
 see also images
 BGR and BGRA formats, 315
 byte alignment, 328
 byte swapping, 327
 copying within the framebuffer, 13, 313,
 321, 322, 683

-
- depth buffer pixel data, 321, 332
 - drawing or reading a subrectangle of, 328
 - drawing process in detail, 338–339
 - endianness, 327
 - feedback mode, 593
 - formats for reading or drawing, 315
 - formats for storing in memory, 317, 325
 - mapping, 13, 333–334, 682
 - packed, 317–318
 - packing into processor memory, 13, 324–327, 682
 - performance tips, 345
 - pipeline operations, 12, 321–337, 682
 - pixel zoom, 334
 - querying pixel mapping information, 333
 - reading from the framebuffer, 313, 315
 - reading process in detail, 340–341
 - sample code which draws an image, 320
 - sample program that uses a pixel buffer object for storage, 342
 - sample program which draws, copies, and zooms pixel data, 335
 - stencil buffer pixel data, 317, 332
 - storage modes, 325, 395–397
 - transfer modes, 13, 330, 422, 682
 - unpacking from processor memory, 12, 324–327, 682
 - writing to the framebuffer, 313, 319
 - point light source, *see* positional light source
 - point parameters, 271
 - sample program, 273
 - points, 38
 - antialiasing, 249–255, 616
 - drawing, 43
 - feedback mode, 593
 - point parameters, 271
 - round, 249–255, 616
 - size, 50
 - specifying, 43, 45
 - polygon offset, 274–276
 - depth slope of a polygon, 275
 - enabling, 274
 - hidden-line removal, 622
 - sample program, 276
 - shadowing use, 460
 - polygonal approximations to surfaces, 94
 - polygons, 39
 - boundary edges, 62–63
 - concave, drawing filled, 506, 618
 - convex, 39
 - culling the faces, 56
 - drawing, 43
 - drawing as points, lines, or filled, 56
 - feedback mode, 593
 - front and back faces, 56
 - holes in, 39
 - non-convex, 39, 62
 - nonplanar, 40
 - polygon mode, 12, 56, 682, 784
 - reversing the faces, 56
 - self-intersecting, 513
 - simple, 39
 - specifying, 43, 46
 - stippling, 58
 - tessellation, specifying for, 518
 - Voronoi, 626
 - positional light source, 197
 - primitives
 - geometric, 37–48
 - raster, 302
 - priority of texture objects, 420
 - Procedural Elements for Computer Graphics*, 524
 - programs
 - aaindex.c, 252
 - aargb.c, 250
 - accanti.c, 496
 - accpersp.c, 492
 - alpha3D.c, 244
 - alpha.c, 241
 - bezcurve.c, 537
 - bezmesh.c, 546
 - bezsurf.c, 544
 - checker.c, 377
 - clip.c, 151
 - colormat.c, 218
 - colormatrix.c, 362
 - colortable.c, 350
 - combiner.c, 453
 - convolution.c, 355
 - cube.c, 110
 - cubemap.c, 443
 - dof.c, 499

-
- programs (*continued*)
 - drawf.c, 304
 - feedback.c, 595
 - fog.c, 262
 - fogcoord.c, 269
 - fogindex.c, 266
 - font.c, 311
 - histogram.c, 364
 - image.c, 335
 - light.c, 190
 - lines.c, 54
 - list.c, 285
 - material.c, 215
 - minmax.c, 367
 - mipmap.c, 403
 - model.c, 125
 - movelight.c, 204
 - multisamp.c, 256
 - multitex.c, 446
 - pboimage.c, 342
 - pickdepth.c, 585
 - picksquare.c, 580
 - planet.c, 154
 - pointp.c, 273
 - polyoff.c, 276
 - quadric.c, 529
 - robot.c, 157
 - select.c, 575
 - shadowmap.c, 460–462
 - smooth.c, 180
 - sprite.c, 457
 - stencil.c, 480
 - stroke.c, 294
 - surface.c, 552
 - surfpoints.c, 563, 564
 - tess.c, 512, 520
 - texbind.c, 416
 - texgen.c, 435
 - texsub.c, 388
 - texture3d.c, 393
 - texturesurf.c, 548
 - torus.c, using a display list, 279
 - trim.c, 567
 - unproject.c, 161
 - projecting images, 624
 - projection matrix, 113, 115
 - matrix stack, 148
 - orthographic parallel projection matrix, 778
 - perspective projection matrix, 777
 - shadows created with, 621
 - projection transformation
 - centered along view vector, 136
 - off-axis perspective, 134
 - parallel projection, 137
 - perspective, 134, 136
 - three-dimensional orthographic, 137
 - projection transformations, 112, 133–138
 - camera lens analogy, 106
 - collapsing geometry to a single plane, 780
 - jittering, 492, 495
 - orthographic parallel, 113, 136–137, 781
 - perspective, 133–136
 - picking, 579
 - texturing effects, 458
 - two-dimensional orthographic, 138
 - proxies
 - color table, *see* color table proxies, 353
 - proxy textures, 385
 - cube maps, 442
 - Q**
 - q texture coordinates, 458
 - avoiding negative values, 781
 - quadratic attenuation, 198
 - quadrics, 523–532
 - creating an object, 525
 - destroying an object, 525
 - drawing as points, lines, and filled
 - polygons, 525
 - error handling, 525
 - normal vectors, generating, 526
 - orientation, 526
 - quadratic equation, 524
 - sample program, 529
 - steps to use, 524
 - texture coordinates, generating, 526
 - quadrilateral
 - specifying, 43
 - strip, specifying, 43, 46

R

- raster position, 305
 - after drawing a bitmap, 307
 - current, 305, 684
 - current raster color, 308
 - current, obtaining the, 306
 - selection hit, 574
 - transformation of, 305
- rasterization, 170, 466
 - exact, two-dimensional, 781
 - rendering pipeline stage, 13
- readImage(), 351
- reading pixel data, *see* pixel data
- Real Projective Plane, The*, 773
- rectangles
 - specifying, 40
- reducing images, 334
- reflecting objects, *see* scaling
- reflection, *see* material properties
- reflective objects, *see* environment mapping
- refresh, screen, 21
- removing hidden surfaces, *see* hidden-surface removal
- repeatability, 786
- rescaling normals, 65, 192
- resident textures, 386, 419
 - management strategies, 420
 - querying residence status, 419
- RGBA mode, 171
 - changing between color-index mode and, 176
 - choosing between color-index mode and, 175
 - coverage calculations for antialiasing, 247
 - data type conversion, 177
 - light source colors, 189
 - lighting calculations in, 221
 - material property values, 190
 - vertex arrays, specifying values with, 69
- Robins, Nate, xl, 125, 131, 138, 160, 207, 216, 414, 425, 426, 433, 459
- robot arm example, 156–159
- Rogers, David, 524

- Rossignac, Jarek, 619
- rotating images, 624
- rotation, 122
 - matrix, 776

S

- scaling, 122
 - matrix, 776
- scaling images, 624
- Schneider, Bengt-Olaf, 619
- Scientific American*, 627
- scissor test, 476
 - and clearing, 471
 - rendering pipeline stage, 14, 683
- secondary color, 455–456
 - specular, 210, 225
- Segal, Mark, 458
- selection, 570–591
 - back buffer for, using the, 610
 - hit records, 574
 - programming tips, 589
 - querying current rendering mode, 572
 - rendering pipeline stage, 682
 - sample program, 575
 - steps to perform, 571
 - sweep selection, 590
- shading
 - flat, 179
 - performance tips, 783
 - sample program with smooth shading, 180
 - smooth, 179
 - specifying shading model, 179
 - shadows, 221, 502, 621
 - shininess, 214
 - see also* environment mapping
 - silhouette edges, 95
 - smoke, *see* fog
 - smooth shading, 179
 - solar system example, 153–156
 - source factor, *see* blending
 - specifying the background color, 31
 - specifying the depth buffer clear value, 31

-
- specular
 - contribution to lighting equation, 224
 - light, 188
 - material properties, 189, 214
 - secondary specular color, 210, 225, 455
 - sphere map, 439
 - spheres, 524, 763
 - split-screen
 - multiple viewports, 139
 - spotlights, *see* light sources
 - state attributes
 - perserving, 92
 - preserving vertex arrays, 93
 - reverting, 92
 - reverting vertex arrays, 93
 - state machine, 9–10
 - state variables, 48
 - attribute groups, 91–93
 - display list execution, effect of, 297
 - enable and disable states, 49
 - list of, 688–733
 - performance of storing and restoring, 782
 - querying, 49
 - stencil buffer, 468, 469
 - clearing, 32, 471
 - concave polygons, for drawing, 618
 - decals, for, 617
 - Dirichlet domains, for, 626
 - Game of Life, for the, 627
 - hidden-line removal, 623
 - masking, 473
 - pixel data, 317, 332
 - stencil test, 478–483
 - examples of using, 480
 - interference regions found using clipping planes, 620
 - querying stencil parameters, 479
 - rendering pipeline stage, 14, 683
 - sample program, 480
 - stereo, 469, 472
 - querying its presence, 469
 - stippling
 - display lists cache stipple patterns, 283
 - enabling line stippling, 52
 - enabling polygon stippling, 58
 - fade effect, use for, 608
 - line pattern reset, 53, 593, 597
 - lines, 52
 - polygons, 58
 - sample program with line stipple, 54
 - stencil test, use of, 483
 - translucency, use to simulate, 608
 - stitching, 274
 - stretching objects, *see* scaling
 - stride
 - vertex arrays, 71, 79
 - subdivision, 94–102
 - generalized, 101
 - icosahedron example, 99
 - recursive, 101
 - subimages, 387–390, 391, 394
 - superimposing images, 617
 - surface normals, *see* normal vectors
 - surfaces, *see* evaluators or NURBS
 - swapping buffers, *see* double-buffering
 - syntax, *see* command syntax
- ## T
- Terminator 2*, 439
 - tessellation, 40, 506–523
 - backward compatibility with obsolete routines, 522
 - begin and end callback routines, 510
 - callback routines, 508–513
 - combine callback routine, 510, 513
 - contours, specifying, 519
 - converting code to use the GLU 1.2 tessellator, 523
 - creating an object, 508
 - decomposition into geometric primitives, 510
 - deleting objects, 521
 - display list use, 282
 - edge flag generation, 510
 - error handling, 510
 - evaluators used to perform, 783
 - interior and exterior, determining, 514–517
 - intersecting contours combined, 510, 513

-
- performance tips, 521
 - polygons, specifying, 518
 - properties, 514–518
 - reuse of objects, 508, 522
 - reversing winding direction, 518
 - sample code, 512, 520
 - user-specified data, 513
 - vertices, specifying, 511, 519
 - winding rules, 514–517
 - texels, 14, 371
 - text, *see* characters
 - texture coordinates, 379, 425–441
 - assigning manually, 425
 - avoiding negative q values, 781
 - clamping, 428–432
 - computing manually, 427
 - cube maps, 443
 - enabling automatic generation of, 438
 - environment mapping, automatic generation for, 440
 - evaluators, generated by, 548
 - generating automatically, 434–441
 - multitexturing, special situations with, 448
 - NURBS, generating for, 560
 - q coordinate, 458
 - quadrics, generated for, 526
 - reference planes, specifying, 434
 - rendering pipeline stage, 12, 681
 - repeating, 428–432
 - sample program with texture coordinate generation, 435
 - tessellation, specifying for, 512
 - vertex arrays, specifying values with, 69
 - wrapping modes, 428–432
 - texture functions, 421–425
 - add, 425
 - blend, 425
 - blending color, 425
 - decal, 379, 424
 - fragment operations, 423
 - level of detail bias, 421
 - modulate, 424
 - pixel-transfer modes effect, 422
 - replace, 424
 - texture internal format, interaction with, 423
 - texture images
 - alpha data, 422
 - borders, 400, 429
 - components, 380
 - data types, 382
 - distorting, 428
 - framebuffer as a source of, 384, 389, 391, 395
 - imaging pipeline operations, 324
 - intensity data, 422
 - internal format, 380
 - luminance data, 422
 - mipmaps, 401–411
 - multitexturing, 445
 - one-dimensional, 390–392
 - performance affected by internal format, 382
 - performance of texture subimages, 782
 - power of 2 size restriction, 383
 - proxy textures, 385
 - querying maximum size, 385
 - residence status, 419
 - resident textures, 386, 419
 - resident textures, management strategies of, 420
 - sample program with mipmaps, 403
 - sample program with subimages, 388
 - specifying, 380–400
 - subimages, 387–390, 391, 394
 - three-dimensional, 392–397
 - working set of textures, 386, 414, 419
 - texture mapping
 - sample program using 3D textures, 393
 - texture mapping, *see* texturing
 - texture matrix, 458
 - rendering pipeline stage, 681
 - texture objects, 379, 414–419
 - binding, 415
 - creating, 415
 - data which can be stored in, 415
 - deleting, 418
 - fragmentation of texture memory, 421
 - least-recently used (LRU) strategy, 421
 - mipmaps, 418
 - naming, 415
 - performance tips, 414, 782

-
- texture objects (*continued*)
 - priority, 420
 - rendering pipeline, 13, 683
 - sample program, 377
 - sample program with multiple texture objects, 416
 - sharing among rendering contexts, 739, 754
 - steps to perform, 414
 - using, 415
 - texturing
 - see also* texture coordinates, texture functions, texture images, texture matrix, and texture objects
 - antialiasing characters, 624
 - antialiasing lines, 624
 - blending, 239
 - border colors, treatment of, 429
 - color-index mode limitations, 375, 383
 - combiner functions, 449–454
 - compressed textures, 397
 - creating contours, 435
 - cube maps, 441
 - decals with alpha testing, 477
 - differences among releases, 373
 - enabling, 376, 379
 - filtering, 411–413
 - image transformations, 624
 - mipmapping, 401–411, 413
 - mosaic texture, 406
 - multitexturing, 443–448
 - perspective correction hint, 379, 380
 - popping visual artifact, 406
 - rendering pipeline stage, 13, 683
 - sample code using point sprites, 457
 - sample code with a depth texture, 460–462
 - sample code with combiner functions, 453
 - sample code with multitexturing, 446
 - sample program, 377
 - sample program with cube maps, 443
 - sample program with evaluated, Bézier surface, 548
 - sample program with mipmapping, 403
 - sample program with texture coordinate generation, 435
 - sample uses for, 624
 - simulating shadows or spotlights, 458
 - specular color separated, 210, 225, 455
 - sphere map, 439
 - steps to perform, 375
 - 3D Computer Graphics: A User's Guide for Artists and Designers*, xxxix
 - 3D models, rendering, 20, 763
 - Tiller, Wayne, 535
 - tips, programming, 779
 - see also* performance tips
 - error handling, 780
 - selection and picking, 589
 - transformations, 142
 - transformations
 - see also* modeling transformations, projection transformations, viewing transformations, and viewport transformations
 - combining multiple, 152–159
 - display lists cache transformations, 283
 - general-purpose commands, 114
 - matrices, 775–778
 - modeling, 117, 120–125
 - ordering correctly, 117–120
 - overview, 104
 - performance tips, 782
 - projection, 112, 133–138
 - reversing the geometric processing pipeline, 160
 - sample program, 110
 - sample program combining modeling transformations, 154, 157
 - sample program for modeling transformations, 125
 - sample program showing reversal of transformation pipeline, 161
 - troubleshooting, 142–144
 - units, 136
 - viewing, 117, 126–131
 - viewport, 114, 138–140
 - translation, 121
 - matrix, 776
 - translucent objects, 232, 608
 - stencil test, creating with the, 483
 - transparent objects, 232
 - creating with the alpha test, 477
 - transposing images, 629

-
- triangle
 - fan, specifying, 43
 - specifying, 43, 45
 - strip, specifying, 43, 45
 - tessellated polygons decomposed into, 510
 - trimming
 - curves and curved surfaces, 565–568
 - sample program, 567
 - tutorials
 - on-line, xl
 - two-sided lighting, 209
- U**
- up-vector, 111
 - Utility Library, OpenGL, *see* GLU
 - Utility Toolkit, OpenGL, *see* GLUT
- V**
- van Dam, Andries, xxxviii, 167, 171, 773
 - van Widenfelt, Rolf, 458
 - vendor-specific extensions, 605
 - versions, 603–605
 - GLU, 604
 - vertex, 37
 - see also* vertex arrays
 - evaluators, generating with, 536
 - feedback mode, 593
 - per-vertex operations pipeline stage, 12, 681
 - specifying, 41
 - tessellation, specifying for, 511, 519
 - transformation pipeline, 106
 - vertex arrays, 65–81
 - dereference a list of array elements, 73, 75, 76
 - dereference a sequence of array elements, 77, 78
 - dereference a single element, 72
 - differences among releases, 29
 - disabling, 68
 - display list use, 289
 - enabling, 67
 - interleaved arrays, 78
 - interleaved arrays, specifying, 79
 - multitexturing texture coordinates, 448
 - performance tips, 783
 - querying, 688
 - querying range values, 76
 - reuse of vertices, 74
 - specifying data, 68
 - steps to use, 66
 - stride between data, 71, 79
 - vertex shader
 - rendering pipeline stage, 681
 - video
 - fake, 628
 - flipping an image with `glPixelZoom()`, 335
 - textured images, 387
 - viewing
 - camera analogy, 106–107
 - viewing transformations, 110, 117, 126–131
 - connection to modeling transformations, 111
 - default position, 111
 - different methods, 131
 - pilot view, 132
 - polar view, 132
 - tripod analogy, 106
 - up-vector, 111
 - viewing volume, 134
 - clipping, 138, 149
 - jittering, 492, 495
 - viewpoint
 - lighting, for, 209
 - viewport transformations, 109, 114, 138–140
 - photograph analogy, 106
 - rendering pipeline stage, 12, 682
 - visual simulation
 - fog, use of, 261
 - Voronoi polygons, 626
- W**
- w coordinates, 38, 109, 114
 - avoiding negative values, 781
 - lighting, use with, 197
 - perspective division, 141, 682
 - warping images, 624

Watt, Alan, 370

web sites, xxxix
errata list, xl
IBM OS/2 software and documentation, 749
Microsoft Developer Network, 753

WGL, 14, 753
wglCopyContext(), 754, 756
wglCreateContext(), 753, 754, 756
wglCreateLayerContext(), 754, 756
wglDeleteContext(), 756
wglDescribeLayerPlane(), 753, 756
wglDestroyContext(), 754
wglGetCurrentContext(), 754, 756
wglGetCurrentDC(), 754, 756
wglGetLayerPaletteEntries(), 755, 757
wglGetProcAddress(), 756
wglMakeCurrent(), 754, 756
wglRealizeLayerPalette(), 755, 757
wglSetLayerPaletteEntries(), 757
wglShareLists(), 754, 756
wglSwapLayerBuffers(), 755, 757
wglUseFontBitmaps(), 755, 757
wglUseFontOutlines(), 755, 757

wglGetProcAddress(), 607

Williams, Lance, 401

Win32
ChoosePixelFormat(), 753, 755
CreateDIBitmap(), 754, 756
CreateDIBSection(), 754, 756
DeleteObject(), 754, 756
DescribePixelFormat(), 753, 756
GetVersion(), 753, 755
GetVersionEx(), 753, 755
SetPixelFormat(), 753, 755
SwapBuffers(), 755, 757

winding, 57

winding rules, 514–517
computational solid geometry, used for, 515
reversing winding direction, 518

window coordinates, 109, 138
feedback mode, 593
polygon offset, 275
raster position, 305

window management
glViewport() called, when window resized, 139
using GLUT, 17, 36

Windows, *see* Microsoft

working set of textures, 386, 414, 419
fragmentation of texture memory, 421

writemask, *see* masking (buffers)

writing pixel data, *see* pixel data (drawing)

www.opengl.org, xxxix

X

X Window System, 14, 738
client-server rendering, 5
minimum framebuffer configuration, 468
X Visual, 176, 737

Z

z buffer, *see* depth buffer

z coordinates, *see* depth coordinates

zooming images, 334
filtered, 629