

Subject Index

3D display, 18
4-adjacent, 579
4-connected, 579

A

abutting polygons, 570
ACM SIGGRAPH, 7, 480
active edge list, 575
additive color model, 420
adjacency primitive, *see* primitive
AEL, *see* active edge list
affine
 invariance
 Bézier curve, 594, 596
 Bézier surface, 603
 NURBS, 697
 spline curve, 632
transformation, 192–203, 855
 defining matrix, 193
 definition, 193
 geometric 2D, 203–208
 geometric 3D, 237–239
 translational component, 193
algebraic curve, 842
aliasing, 490, 524
alpha, 513
 alpha-morph, 520
ambient light, *see* light
angle of incidence, 430
angular attenuation, *see* light
animation
 articulated figure (character),
 168–172
 code, 131–140, 168
 control, 128
 key-frame, 168
 technicals, 128–130
 transformations, *see* model-
 ing transformation
annular disc, *see* GLU quadric
annulus
 circular, 48
 double, 45
 square, 42
antialiasing, 525
antipodal points, 278
API (Application Programming
 Interface), 9, 23
 API-independent, 66
 OpenGL, *see* OpenGL
 POV-Ray, *see* POV-Ray
application programming interface,
 see API
approximation
 mesh, 368
 of control points, 584
 polyline, 348
aspect ratio, 28
atmospheric effect, 520
attenuation, *see* light, angular at-
 tenuation *and* light, dis-
 tance attenuation
attractors, 401, 404, 584
attribute, 37

- attribute variable, 753
- automorphism, *see* inner automorphism
- axis
 - axis-aligned, 102
 - calibration, 28, 30
- B**
- B-spline, 605–649
 - blending function, *see* blending function
 - curve, 611–641
 - blending function, 611
 - cubic (fourth-order), 623
 - definition, 617
 - degree, 626
 - degree 0 (first-order), 612
 - drawing, 643–644
 - linear (second-order), 614
 - non-uniform arbitrary order, 625
 - order, 626
 - quadratic (third order), 618
 - vs. Bézier curve, 640
 - rational, *see* NURBS
 - surface, 641–643
 - bicubic, 645
 - blending function, 642
 - drawing, 645
 - lighting and texturing, 646
 - trimmed, 646
 - uniform, 613
- back face
 - back-face culling (polygon culling), 332
 - back-facing polygon, 320
- background
 - (clearing) color, 36
 - light, 425
- barrier (synchronization), 805
- barycentric
 - combination, *see* convex combination
 - coordinates, 291, 293, 299
- base
 - curve, 373
 - texture, 493
- basis
 - function, *see* blending function
- Bernstein polynomial, 586, 588, 590, 591
- Bézier, 583–604
 - curve, 584–600
 - affine invariance, 596
 - arbitrary order, 591
 - blending function, 586
 - cubic (fourth-order), 589
 - de Casteljau’s recursion, 592
 - drawing, 401–403
 - end tangent, 597
 - evaluator, 402
 - linear (second-order), 584
 - order, 401
 - quadratic (third-order), 586
 - rational, *see* rational Bézier curve
 - vs. B-spline curve, 640
 - vs. polynomial curve, 599
 - patch, 404
 - surface, 600–604
 - affine invariance, 603
 - blending function, 603
 - drawing, 404–408
 - evaluator, 404
 - parameter curve, 603
 - rational, *see* rational Bézier surface
- bias matrix, 677
- bicubic
 - B-spline surface, 645
 - Bézier patch, 406
 - surface patch, *see* Hermite surface patch
- bilinear patch, 381
- billboarding, 523–524
 - billboard, 523
- bitmap, 82
 - bitmapped text, *see* text
- bitplane, 537

blending, 510–520
 blend function, 513
 equation, 512
 factor, 512
 function
 B-spline curve, 611
 B-spline surface, 642
 Bézier curve, 586
 Bézier surface, 603
 Hermite polynomial, 655
 Lagrange polynomial, 662
 NURBS curve, 697
 NURBS surface, 697
 rational Bézier curve, 684
 rational Bézier surface, 695
 Wish List, 611
 OpenGL 4.3, 794
 Blinn-Newell method, 529
 break-and-make procedure, 625
 Bresenham's line rasterizer, *see*
 raster algorithm
 brightness
 HSB, 423
 patch, *see* patch brightness
 BSP tree, 259
 buffer, 535
 accumulation, 536
 auxiliary color, 536
 back, *see* drawable
 color, 16, 130, 422, 536
 depth (z -), 49, 536
 double, 130
 drawable (back, swap), 130
 frame, 537
 front, *see* viewable
 hit, 175
 main, *see* viewable
 object, 75
 ping-pong, 130
 precision, 537
 refresh, 130
 single, 130
 stencil, *see* stencil buffer
 swap, *see* drawable
 viewable (front, main), 130
 z -, *see* depth
 built-in variable, 762
 bump mapping, 543–546, 767
 bump map, 544
 button, *see* programming mouse
 button

C
 C^m -continuity, *see* continuity
 calibrating axis, *see* axis calibra-
 tion
 callback routine, 63
 camera
 as input device, *see* input
 device
 box, 27
 OpenGL, 143
 orientation, *see* orientation
 point, 55
 pose, 143
 default, 143
 canoe, 406, 472
 canonical
 rectangle, 706
 viewing box, 666
 cardinal spline, 659–660
 cathode-ray tube, *see* CRT
 Catmull-Rom spline, 659
 CdM formula, *see* Cox-de Boor-
 Mansfield
 center of projection (COP), 55
 centroid, 296
 CGAL, 316
 CGI (computer-generated imagery),
 3
 checkered floor, 453
 chirality, 243
 CIE, 420
 XYZ color model (1931 color
 model), 425
 circle, 46
 as conic, 352
 circumscribed, 388
 rational parametrization, 352
 circular paraboloid, 385

- clamping, 36
 - texture, *see* texture wrapping mode
- clearing color, *see* background color
- clipping, 33
 - algorithm (clipper)
 - Cohen-Sutherland line clipper, 552–556
 - Liang-Barsky line clipper, 556
 - Sutherland-Hodgeman polygon clipper, 556–560
 - in the synthetic-camera pipeline, 703
 - plane, 34
 - planes, 91–93
 - rectangle, 552
- CMY color model, *see* color model
- CMYK color model, *see* color model
- Cohen-Sutherland line clipper, *see* clipping algorithm
- coherence, *see* edge coherence
- collinearity test, 232
- collision detection, 165
- color
 - background (clearing), 36
 - buffer, *see* buffer, color
 - coding, 180
 - cube, 420
 - desaturated, 424
 - foreground (drawing), 36
 - gamut, 423
 - material mode, 443
 - model
 - additive, 420
 - CIE XYZ (CIE 1931), 425
 - CMY, 422
 - CMYK, 423
 - HSV (HSB), 423
 - RGB, 420
 - subtractive, 422
 - primary, 420
 - purity, 424
 - saturation, 424
 - secondary, 447
 - space, 420
 - tuple, 420
 - Venn diagram, 420
 - wheel, 423
- column matrix, *see* matrix
- compatibility profile, *see* OpenGL profile
- composited drawing, 536
- computational geometry, 283, 306, 316
- Computer History Museum, 407
- computer-generated imagery, *see* CGI
- conditional rendering, 262
- cone, 377
 - doubly-curved, 377, 471
 - elliptic, 383
 - generalized, 381
 - GLUT, 91, 137
 - light, *see* light cone
 - right circular, 381
- cone cell, 419
- conic section (conic), 351
 - as a rational Bézier curve, 686
 - degenerate, 352, 354
 - rational parametrization, 352
- conical helix, 347
- conjugate quaternion, *see* quaternion
- continuity
 - C^0 , 355
 - coordinate patch, 395
 - curve, 355
 - parametrization, 355
 - surface, 397
 - C^1 , 356
 - curve, 356
 - parametrization, 356
 - surface, 400
 - C^2
 - curve, 361
 - surface, 400
 - C^m , 360
 - coordinate patch, 399

curve, 360
 function of two variables, 398
 parametrization, 360
 C^∞ , 360
 regular
 C^m surface, 399
 C^∞ surface, 399
 1D object, 359
 2D object, 400
 coordinate patch, 399
 curve, 356, 360
 parametrization, 356
 surface, 399
 smooth
 curve, 360
 function, 360
 surface, 399
 control
 point
 curve, 401, 584, 606
 surface, 404, 600, 641
 weight, 682
 polygon, 402, 588
 polyhedron, 404, 601
 convex (convexity)
 combination, 291, 293, 299
 hull, 301
 polygon, 300
 set, 299
 under affine transformation, 195
 under geometric transformation, 204, 238
 Cook-Torrance lighting model, *see* light, lighting model
 coordinate patch, *see* continuity
 coordinatization of \mathbb{P}^2 , 826
 COP, *see* center of projection
 core profile, *see* OpenGL profile
 coverage, *see* fragment
 Cox-de Boor-Mansfield (CdM) formula, 627
 cross-product (vector product), 231
 CRT (cathode-ray tube), 15, 421

 cube
 GLUT, 91
 mapping, 535
 cubic
 arc, 652
 B-spline curve, 623
 Bézier curve, 589
 interpolation, 652
 NURBS curve, 697
 rational Bézier curve, 684
 spline, *see* Hermite
 spline curve, 624
 culling
 back-face (polygon), *see* back-face culling
 frustum, *see* frustum culling
 curve
 B-spline, *see* B-spline curve
 Bézier, *see* Bézier curve
 base, 373
 C^m , *see* continuity
 conic section (conic), *see* conic section
 degree, *see* B-spline curve *and* Bézier curve
 drawing, 347–349
 mathematical formalism, 354–361
 NURBS, *see* NURBS
 order, *see* B-spline curve *and* Bézier curve
 piecewise Bézier, *see* piecewise
 piecewise cubic, *see* piecewise
 piecewise regular, *see* piecewise
 plane, 340
 implicit specification, 341
 parametric (explicit) specification, 342
 polynomial parametrization, 350
 profile, 372
 rational parametrization, 350
 regular, *see* continuity

- sequel, *see* sequel curve
- smooth, *see* continuity
- source, *see* source curve
- space, 345
 - implicit specification, 345
 - parametric (explicit) specification, 346
- spline, *see* B-spline curve
- cut-away view, 93
- cut-off depth, 259
- cylinder, 57, 366
 - as swept surface, 372
 - drawing, 369
 - elliptic, 383
 - equations, 366
 - generalized, 382
 - hyperbolic, 383
 - lit, 469
 - lit and textured, 504
 - parabolic, 383
 - right circular, 382
 - tapered, 388
- D**
- data glove, *see* input device
- DDA line rasterizer, *see* raster algorithm
- de Casteljau's method, 586
 - recursive formula, 592
- de-homogenization, 844
- default pose (OpenGL camera), 143
- defining
 - matrix, *see* affine transformation
 - trajectory, 381
- degenerate
 - conic, *see* conic
 - scaling, *see* scaling
- degree
 - curve, *see* B-spline curve and Bézier curve
 - of freedom, 345
- delta form factor, *see* form factor
- depth
 - buffer, *see* buffer
 - cue, 522
 - testing (*see also* hidden surface removal), 50, 536
 - texture, *see* texture
- destination pixel, 510
- differential geometry, 414
- diffuse light, *see* light
- Digital differential analyzer (DDA)
 - line rasterizer, *see* raster algorithm
- digitizing device, 14
- Direct3D, 65
- directional light source, *see* light
- disc, 48
 - annular, *see* GLU quadric
 - partial annular, *see* GLU quadric
- discard (fragment), 796
- discriminant
 - Bresenham's algorithm, 564
 - conic, 352
 - determinant, 211
- displacement vector, 185, 220
- display
 - list, 80–82
 - base, 82
 - mode, 130
- distance attenuation, *see* light
- distance-preserving transformation, *see* transformation
- dodecahedron, 389
 - GLUT, 91
- dot product (scalar product), 148
- double buffering, 130
- doubly-curved cone, *see* cone
- doubly-ruled surface, 386
- draw-and-swap loop, 130
- drawing
 - color, *see* foreground color
 - mode, 42
 - filled, 42
 - outlined, 42
 - wireframe, 42
 - primitive, *see* primitive
- duality

Euler angle, 267
 point-line, 826, 840
 regular polyhedron, 391

E

edge
 coherence, 575
 ownership rule, 570
 table (ET), 576

Eiffel Tower, 380

electromagnetic, *see* EM

ellipse, 56
 as conic, 352
 rational parametrization, 352

ellipsoid, 383

elliptic
 cone, 383
 cylinder, 383
 paraboloid, 383

EM
 radiation, 418
 spectrum, 418

embedding (\mathbb{R}^2 in \mathbb{P}^2), 829

emission rate, 732

emissive
 light, 427
 vector, 428

environment mapping, 529–535

equivalence class (of parallel lines), 831

Euclidean
 geometry, 825
 transformation (isometry)
 2D, 209, 214
 3D, 243, 245

Euler angle, 163, 263

Euler's Theorem, 246

evaluator, *see* Bézier

explicit specification, *see* curve
 and surface

external texture, 482

extreme point, 303

extrusion (extruded surface), 373
 extruded helix, 378

eye direction vector, 325, 432

F

face, 364
 viewing, *see* viewing

feedback mode, 176

feeler ray, 723

field of view angle (fovy), 94

filled drawing mode, *see* drawing
 mode

film-capture, 850

filter (filtering), 490–498
 magnification (mag), 492
 minification (min), 492
 mipmap, 493

fixed-functionality pipeline, *see*
 graphics pipeline

flash, *see* shimmer

flat shading, *see* shading

Flatland, 183

flood-fill, *see* raster algorithm

flush, 536

fog, 520–523
 color, 521
 factor, 521
 mode, 521
 parameters (start, end, den-
 sity), 521

font, 82

foreground (drawing) color, 36

foreshortening, 54

form factor, 732
 delta, 737

four-color printing, 423

fovy, *see* field of view angle

fractal, 409–412
 curve, 409
 tree, 411

fragment, 174, 510
 coverage, 525
 discard, 796

fragment shader, *see* shader

frame
 buffer, *see* buffer, frame
 rate, 129

FreeGLUT, 62, 98
 object, 90

friction (in animation), 135
front-facing polygon, 319
frustum, 52
 culling, 167, 254–259

G

game
 physics, 136
 programming, 254, 283
game console, 12
gamepad, *see* input device
gamut, *see* color gamut
generalized
 cone, *see* cone
 cylinder, *see* cylinder
geodesic path, 280
geometric primitive, *see* primitive
geometry shader, *see* shader
ghosting, 130
gimbal lock, 266
GIMP image editor, 423
GLEW (OpenGL Extension Wrangler Library), 63
glide reflection, *see* reflection
GLM (OpenGL Mathematics) library, 764
global
 ambient light, *see* light
 lighting (illumination) model, *see* light, lighting model
GLSL, 745
 data type, 750
 opaque, 753
 transparent, 753
 sampler, 753
GLU (OpenGL Utility Library)
 quadric, 386–388
 annular disc, 388
 partial annular disc, 388
 sphere, 387
 tapered cylinder, 388
GLUI User Interface Library, 98
golden ratio, 393
Gouraud shading, *see* shading
gradient (grad), 462

graphical
 text, *see* text
 user interface, *see* GUI
graphics
 pipeline
 fixed-functionality, 701–741
 OpenGL, 715
 programmable, 745–820
 ray tracing, *see* ray tracing
 synthetic-camera, 23, 173, 702–720
 system, 10
 interactive, 10
gravity, 134
grid, *see* sample grid
GUI (graphical user interface), 6, 98

H

half-plane, 300
half-space, 324
halfway vector, 432
handedness, 243
handheld device, 11
haptic device, *see* input device
HDTV, *see* high-definition TV
helical pipe, 371
helix, 51
 toroidal, 374
hemi-ellipsoid, 61
hemicube method, 735
hemisphere, 58
Hermite
 blending polynomial, 655
 cubic, 655
 interpolation, 651–662
 matrix, 654
 spline, 652–657
 surface patch, 660
hexahedron, 389
hidden surface removal (*see also* depth testing), 50, 332
high-definition TV (monitor), 16
history, 6–10
hit, 174

buffer, 175
 record, 174
 homogeneous
 coordinates, 201, 826–828
 homogenization, 843
 polynomial, 841
 HSV (HSB) color model, 423
 hue, 423
 hull, *see* convex hull
 hyperbola, 342
 as conic, 352
 rational parametrization, 352
 hyperbolic
 cylinder, 383
 paraboloid, 383
 hyperboloid
 1 sheet, 383, 385
 2 sheets, 383

I

icosahedron, 389
 GLUT, 91
 idle function, 128
 illumination model, *see* light, lighting model
 image manipulation, 541
 immediate mode, *see* rendering
 implicit specification (equation), *see* curve and surface
 incident ray, *see* ray
 infinite viewpoint, *see* light, viewpoint
 ink, 422
 inner automorphism, 273
 input
 key
 non-ASCII, *see* programming non-ASCII (special) key
 special, *see* programming non-ASCII (special) key
 mouse, 84
 input device, 12–15
 camera, 15
 data glove, 15
 gamepad, 14
 haptic, 14
 joy stick, 14
 keyboard, 12
 mouse, 12
 pointing stick, 12
 spaceball, 13
 tablet, 14
 touchpad, 12
 touchscreen, 15
 trackball, 12
 wheel, 14
 inside-outside test, 567
 instance counter, 778, 780
 instanced rendering, 778–781
 instanced vertex attribute, 778
 intensity, 36, 419
 interaction
 interactive system, *see* graphics system
 key, *see* input, key
 mouse, *see* input, mouse
 user, *see* user interaction
 interface block, 788
 International Commission on Illumination, *see* CIE
 interpolation, 38, 295
 first-order, 656
 linear, 295
 linear with perspective correction, 712
 perspectively correct, 712
 zeroth-order, 656
 interpolation qualifier, 763
 intersection detection, *see* collision detection
 intertwined array, 73
 invariance
 affine, *see* affine invariance
 projective, *see* projective invariance
 snapshot, *see* snapshot invariance
 inverse
 quaternion, *see* quaternion

- IRIS GL, 65
 isometry, *see* Euclidean transformation
- J**
 Jacobi's iterative method, 739
 jaggies, 524
 joint, 610
 joy stick, *see* input device
- K**
 kd-tree, 259
 keyboard, *see* input device
 Klein bottle, 331
 knot, 611
 insertion, 633
 interval, 611
 multiple (coincident, repeated), 634
 multiplicity, 634
 vector, 611
 non-uniform, 626
 standard, 638
 uniform, 611, 626
- Koch
 curve, 409
 polyline, 410
 snowflake, 411
- L**
 Lagrange
 curve, 662
 interpolation, 661
 polynomial, 661
 Lambert's law, 431
 Lambertian surface, 734
 layout qualifier, 753
 LCD (liquid crystal display), 17, 421
 LCD shutter glasses, 18
 left-handed system, 243
 Lemniscate
 of Bernoulli, 342
 of Geronno, 344
 lerp, 281
 level-of-detail (LOD), 498
 Liang-Barsky line clipper, *see* clipping algorithm
 lifting, 841
 light
 ambient light (reflectance), 425
 calculating, 429
 angular attenuation, 432
 animation, 453
 cone, 449
 diffuse light (reflectance), 426
 calculating, 429
 in ray tracing, 728
 transport via radiosity, 731
 direction vector, 430
 distance attenuation, 448
 first lighting equation, 435
 global ambient, 426, 445
 vector, 428
 lighting
 per-pixel, 477, 771
 per-vertex, 477, 767
 lighting model, 425
 Cook-Torrance, 480
 global, 724
 local, 437
 OpenGL, 444–447
 Phong's, 425–437
 OpenGL lighting equation, 451
 OpenGL specification, 438
 properties matrix, 428
 reflectance, 425
 reflected, 425, 428
 secondary, 437
 shininess exponent, 432
 source
 directional, 448
 positional (local), 448
 regular, 449
 specifying properties (color), 428
 specular light (reflectance), 427
 calculating, 431

spotlight, 449–451
 attenuation, 450
 cone angle, 450
 direction, 450
 two-sided, 446
 viewpoint
 infinite, 445
 local, 445

lighting model, *see* light

line
 antialiasing, 525
 at infinity, 832
 clipper, *see* clipping algorithm
 loop, *see* polygonal line loop
 of projection, 32, 55
 of sight (los), 143, 144, 151
 vector, 151
 OpenGL (straight line) segment, 39
 stipple, *see* stipple
 thickness (width), 39
 polygonal, *see* polygonal line
 rasterizer, *see* raster algorithm
 semi-infinite segment, 555
 tangent, *see* tangent line

linear
 interpolation, *see* interpolation
 transformation, 192
 related, 847

liquid crystal display, *see* LCD

local
 (object's) coordinate system, 120
 control, 606
 light source, *see* light source, positional
 lighting (illumination) model, *see* light, lighting model
 viewpoint, *see* light, viewpoint

LOD, *see* level-of-detail

M
 magnification, *see* filter

mapped sample, 348, 368

material
 ambient scaling factor, 429
 color mode, 443
 diffuse scaling factor, 430
 OpenGL specification, 439
 properties matrix, 428
 specifying properties (color), 428
 specular scaling factor, 432

matrix
 column matrix, 112
 pick, *see* picking
 rotation, *see* rotation
 tridiagonal, 658

medium of light, 727

menu, *see* programming (pop-up) menu

Mesa 3D, 66

mesh, 363
 boundary, 364
 polygonal, *see* polygonal mesh
 triangular, *see* triangular mesh

Meshing Roundtable Conference, 316

minification, *see* filter

mipmap, *see* filter

mirror, *see* reflection

Möbius band, 331

modeling transformation, 102–128
 composing, 110–117

modelview
 matrix, 114
 current, 125, 160, 240
 stack, 125, 160, 240
 transformation, 153

monitor, 421

morph, 519, 520

mouse, *see* input device

mouse button, *see* programming mouse button

mouse motion, *see* programming mouse motion

mouse wheel, *see* programming mouse wheel

- movie, 169, 473
 - multiple windows, 97
 - multiresolution, 498
 - multisampling, 526
 - multitexturing, *see* texture, multi-texturing
- N**
- name, 174
 - stack, 174
 - native color, 427, 439
 - natural
 - cubic spline, 657
 - NeHe Productions, 66
 - non-ASCII key input, *see* programming non-ASCII (special) key
 - non-orientable surface, *see* orientation
 - non-uniform rational B-spline, *see* NURBS
 - normal, 430
 - calculation, 463
 - line, 460
 - matrix, 475
 - normalizing, 476
 - programmed calculation, 472
 - reversal on back faces, 446
 - transforming, 474
 - vector, 430, 460
 - normalizing, *see* vector
 - NURBS, 696
 - curve, 696
 - blending function, 697
 - drawing, 697
 - surface, 697
 - blending function, 697
- O**
- object space, 31
 - object-object light interaction, 437, 480, 724
 - occlusion, 49, 733
 - culling, 259
 - query, 260
 - octahedron, 389
 - GLUT, 91
 - octant, 259
 - octree, 255
 - opaque, 513, 516
 - OpenGL
 - Architecture Review Board (ARB), 65
 - context, 749
 - Embedded Systems (ES), 10, 775
 - history, 9, 65
 - introduction, 23–66
 - lighting equation, *see* light
 - lighting model, *see* light, lighting model
 - pipeline, *see* graphics pipeline
 - primitive, *see* primitive
 - profile, 750
 - compatibility, 750
 - core, 750
 - forward compatible, 750
 - shading language, *see* GLSL
 - shading model, *see* shading model
 - state machine, 37
 - order
 - curve, *see* B-spline curve *and* Bézier curve
 - vertex, *see* vertex order
 - orientation
 - animating using Euler angles, 264
 - animating using quaternions, 282
 - consistent, 326
 - inconsistent, 326
 - non-orientable surface, 331
 - of camera, 161
 - of geometric primitive, 42, 317–335
 - under transformation, 334
 - of rigid body, 264, 272
 - orientable surface, 331

orientation-preserving transformation, 210, 243
 orientation-reversing transformation, 210, 243
 orthogonal projection, *see* projection
 orthographic projection, *see* projection
 oscillatory motion, 139
 outcode, 553
 outlined drawing mode, *see* drawing mode
 output device, 15–19
 output to command window, 47

P

parabola, 47
 as conic, 352
 rational parametrization, 352
 parabolic cylinder, 383
 paraboloid
 circular, 385
 elliptic, 383
 hyperbolic, 383
 parallel projection, *see* projection
 parallelepiped, 249
 parallelism
 projective plane, 826
 under affine transformation, 195
 under geometric transformation, 204, 238
 parameter
 curve, 366
 domain, 342
 function, 342
 parametrization, 342
 C^0 , *see* continuity
 C^1 , *see* continuity
 C^m , *see* continuity
 polynomial, 350
 rational, 350
 trigonometric, 350
 rectangle, 405, 499
 space, 342
 variable, 342
 parametric specification, *see* curve
 and surface
 parity, 567
 test, 567
 partial
 annular disc, *see* GLU quadric
 derivatives, 455–463
 particle system, 474, 528
 partition of unity, 594
 partitioning, *see* space partitioning
 patch, 732
 Bézier, *see* Bézier patch
 bicubic, *see* bicubic
 bilinear, *see* bilinear patch
 brightness, 732, 737–739
 vector, 737
 coordinate, *see* continuity
 domain (OpenGL 4.3), 801, 807
 Hermite, *see* Hermite surface patch
 input (OpenGL 4.3), 799, 802, 803
 OpenGL 4.3, 802
 output (OpenGL 4.3), 800
 patchification, 732
 PBO, *see* pixel buffer object
 pen-plotter, 580
 per-fragment operation, 715
 peripheral distortion, 56
 perpendicular projection, *see* projection
 perpendicularity test, 149
 Persistence of Vision Ray Tracer, *see* POV-Ray
 perspective
 correction, 710
 division, 674
 projection, *see* projection transformation, 54
 perspective correct interpolation, 712
 PHIGS, 9

- Phong's
 - lighting model, *see* light
 - shading model, *see* shading
- model
- physically-based modeling, 136
- physics in graphics, 136
- picking, 178
 - OpenGL 4.3, 787
 - pick matrix, 179
- piecewise
 - Bézier curve, 598, 641
 - cubic curve, 652
 - polynomial function, 610
 - regular
 - curve, 358
 - surface, 400
- ping-pong buffering, 130
- pipeline
 - graphics, *see* graphics pipeline
 - pipelining (the Sutherland-Hodgeman polygon clipper), 559
 - rendering, *see* graphics pipeline
- pitch, 33, 264
- pixel, 15, 297, 421
- pixel buffer object, 542
- pixel data, 541
- plane
 - clipping, *see* clipping
 - curve, *see* curve, plane
 - planar surface, *see* surface
 - planarity
 - under affine transformation, 195
 - under geometric transformation, 238
 - projective, *see* projective plane
 - tangent, *see* tangent plane
 - viewing, *see* viewing
- platform-independence, 65
- Platonic solid, 390
- point
 - antialiasing, 525
 - at infinity, 832
 - camera, 55
 - extreme, 303
 - OpenGL, 39
 - size, 38
 - OpenGL 4.3, 795
 - point-line duality, *see* duality
 - regular, 832
 - rendering, 526
 - sprite, 528
 - OpenGL 4.3, 797
 - vanishing, 834
- pointer (vector) form, 71
- pointing device, 12
- pointing stick, *see* input device
- polarized glasses, 18
- polygon
 - clipper, *see* clipping algorithm
 - culling, *see* back-face culling
 - drawing mode, *see* drawing mode
 - rasterizer, *see* raster algorithm
 - regular, *see* regular polygon
- polygonal
 - line (polyline), 39
 - line loop, 39
 - mesh, 363
- polyhedron, 389
 - polyhedral surface, 363
 - regular, *see* regular polyhedron
- polyline, *see* polygonal line
- polynomial
 - B-spline primitive, 605
 - Bézier primitive, 401, 583
 - Bernstein, *see* Bernstein polynomial
 - curve, 350
 - vs. Bézier curve, 599
 - function, 350
 - parametrization, 350
- pop-up menu, *see* programming (pop-up) menu
- popping, 497
- portability, 65
- positional light source, *see* light
- POV-Ray, 728

installation, 728
primitive
 adjacency, 812, 814
 assembly, 704, 714, 799
 drawing, 38–46
printer, 423
procedural texture, 482
profile curve, 372
programmable pipeline, *see* graphics pipeline
programming
 (pop-up) menu, 87
 mouse button, 84
 mouse motion, 86
 mouse wheel, 86
 non-ASCII (special) key, 87
progressive refinement, 739
projection
 matrix, 668
 current, 160, 175, 675
 stack, 160, 175, 675
 orthogonal, 32
 orthographic, 32
 parallel, 32
 perpendicular, 27
 perspective, 52
 statement, 26, 160
 transformation, 666
projective
 algebraic curve, 842
 geometry, 825
 invariance
 NURBS, 697
 rational Bézier curve, 689, 693
 rational Bézier surface, 695
 line, 824
 plane, 824–833
 point, 824, 846
 space, 824, 846
 transformation, 847–866
 algebraic definition, 847
 geometric definition, 850
projectivization, 841
propeller, 407

provoking vertex, 453
pruning, 255
pseudo-
 surface, 646
 transformation, 855
punctured rectangle, 395
push-pop pair, 126–128
pyramid, 52

Q

quadrant, 256
quadratic
 B-spline curve, 618
 Bézier curve, 586
 rational Bézier curve, 683
 spline curve, 621
quadric surface (quadric), 383–386
 GLU, *see* GLU quadric
quadrilateral
 projective transformation, 862
 quadrilateralization, 387
quadtrees, 255
quaternion, 268–283
 conjugate, 271
 inverse, 271
 pure, 268
 unit, 271

R

radial
 axis, 116, 221
 line, 190
 plane, 190
 primitive, 823
radian, 140
radiosity, 731–740
 equation, 733
range tree, 259
raster, 15, 297, 421
 algorithm, 551–580
 Bresenham's line rasterizer, 560–566
 DDA (Digital Differential Analyzer) line rasterizer, 560–562

- flood-fill, 578
- scan-based polygon rasterizer, 566–580
- rasterization, 297
- text, *see* text
- rational
 - B-spline, *see* NURBS
 - Bézier curve, 681–695
 - blending function, 684
 - Bézier surface, 695–696
 - blending function, 695
 - function, 350
 - parametrization, 350
- ray
 - incident, 432
 - reflected, 432, 725
 - tracing, 720–731
 - ray tracer, 722, 724, 726, 728
 - transmitted, 725
 - tree, 725
- reciprocity equation, 733
- rectangle
 - canonical, 706
 - clipping, 552
 - OpenGL, 43
 - punctured, 395
- reflectance, *see* light
- reflected
 - light, *see* light
 - ray, *see* ray
- reflection
 - about line, 190
 - about plane, 105, 236
 - glide, 191
 - in ray tracing, 728
 - mirror, 190, 236
 - model, *see* light, lighting model
 - through point, 247
 - vector, 432
- reflective scaling factor, 732
- refraction, 725
- refresh rate, 16, 129, 422
- regular
 - coordinate patch, *see* continuity
 - curve, *see* continuity
 - light source, *see* light
 - object, *see* continuity
 - parametrization, *see* continuity
 - piecewise, *see* piecewise
 - point, *see* point
 - polygon, 388
 - polyhedron, 388–394
 - duality, *see* duality
 - surface, *see* continuity
- related linear transformation, *see* linear transformation
- rendering, 27, 54
 - immediate mode, 74, 748
 - mode, 174
 - pipeline, *see* graphics pipeline
 - render farm, 730
 - retained mode, 74, 748
- renormalization, 476
- reshape routine, 85
- resolution, 16, 421, 490
 - buffer, 537
- retained mode, *see* rendering
- retina, 419
- RGB color model, 420
- RGBA, 482, 513
- right-handed system, 243
- rigid
 - object (body), 208
 - transformation
 - 2D, 210, 214
 - 3D, 243, 245
- rod cell, 419
- Rodrigues' rotation formula, 236
- roll, 264
- rotation
 - 2D theory, 186–190
 - 3D theory, 221–236
 - matrix, 187
 - OpenGL, 107–110
- ruled surface, 380–382
 - ruling, 380

S

- saddle surface, 383
- saf (spotlight attenuation factor),
see light, spotlight attenuation
- sample, 46
 - grid, 348, 368
 - mapped, *see* mapped sample
- satellite, 133
- scalar product, *see* dot product
- scaling
 - 2D theory, 186
 - 3D theory, 221
 - degenerate, 106, 172
 - OpenGL, 104–107
 - uniform, 857
- scan-based polygon rasterizer, *see*
raster algorithm
- Schläfli symbol, 390
- scintillate, *see* shimmer
- scissor
 - box, 541
 - rectangle, 541
 - test, 541
- screen
 - in printing, 422
 - space, 32
- SDL (scene description language),
729
- segment, *see* line
- selection, 174
 - mode, 174
 - volume, 174
- self-similarity, 409
- sequel curve, 410
- shader, 746
 - compiling, linking, 756
 - fragment, 747
 - geometry, 747, 812–820
 - pass-through, 762
 - stage, 746
 - tessellation, 747, 798–812
 - tessellation control (TCS), 799,
802
 - tessellation evaluation (TES),
799, 805
 - vertex, 746
- shader subroutine, 784
- shaderize, 754
- shading
 - flat, 453
 - Gouraud, *see* smooth
 - model
 - OpenGL, 453
 - Phong's, 477
 - smooth (Gouraud), 453
- shadow, 172
 - mapping, 676–680
 - perspective, 676
 - projective, 676
 - ray traced, 723
 - volume, 680
- shape-preserving transformation,
see transformation
- shark fin, 619
- shear
 - 2D, 217–219
 - angle of, 217
 - line of, 217
 - 3D, 248–251
 - angle of, 249
 - line of, 249
 - plane of, 249
- shimmer (flash, scintillate), 490
- shininess exponent, *see* light
- ship movie, 473
- shoot-and-print, 27, 54, 702
- shoot-em-up game, 173, 180
- SIGGRAPH, *see* ACM SIGGRAPH
- Singular Value Decomposition, 248
- Sketchpad, 6, 580
- slerp, 280
- sliver, 311
- smoke, 474
- smooth
 - curve, *see* continuity
 - function, *see* continuity
 - shading, *see* shading
 - surface, *see* continuity

- snapshot
 - invariance, 693
 - transformation, 833–838, 845, 855
- Snell's law, 727
- snowflake, *see* Koch
- solar system, 142
- source
 - curve, 409
 - fragment, 510
- space
 - curve, *see* curve
 - partitioning, 255, 259
 - travel, 164
- spaceball, *see* input device
- special key input, *see* programming non-ASCII (special) key
- spectrum
 - EM, *see* EM spectrum
 - visible, *see* visible spectrum
- specular light, *see* light
- sphere
 - GLU, *see* GLU quadric
 - GLUT, 91
 - mapping, 530–535
- spherical linear interpolation, *see* slerp
- spherizing filter, 534
- spiral, 51
- Spirograph, 349
- spline, 617
 - B-, *see* B-spline
 - curve, *see* B-spline curve
 - Hermite, *see* Hermite
- split-screen view, 97
- spotlight, *see* light
- stack
 - modelview matrix, *see* modelview matrix
 - name, *see* name
 - projection matrix, *see* projection matrix
 - texture matrix, *see* texture matrix
- standard
 - knot vector, *see* knot
- Standard Template Library, *see* STL
- state
 - machine, *see* OpenGL
 - variable, 36
- std430 layout, 788, 789
- Steiner vertex, 45, 311
- stencil
 - bit, 537
 - buffer, 536–541
 - mask, 538
 - tag, 537
 - test, 537
- stereoscopic viewing, 18, 536
- stereoscopy, 18
- stipple, 88–90
- STL (Standard Template Library), 85
- storage qualifier, 753
- straightness
 - under affine transformation, 195
 - under geometric transformation, 204, 238
- stroke text, *see* text
- sub-menu, *see* menu
- subroutine
 - type, 785
 - uniform, 785
- subtractive
 - color model, 422
 - primary, 422
- supercircle, 349
- superellipse, 349
- superellipsoid, 378
- support (of a function), 607
- surface
 - B-spline, *see* surface
 - Bézier, *see* Bézier
 - C^m , *see* continuity
 - closed, 331
 - doubly-ruled, *see* doubly-ruled surface

drawing, 367–371
extruded, *see* extrusion
implicit specification, 366
mathematical formalism, 394–401
non-orientable, *see* orientation
normal, *see* normal
NURBS, *see* NURBS
of revolution, 372
orientable, *see* orientation
parametric (explicit) specification, 366
planar, 365
polyhedral, 363
quadric, *see* quadric
regular, *see* continuity
ruled, *see* ruled surface
saddle, *see* saddle surface
smooth, *see* continuity
swept, *see* sweeping
Sutherland, Ivan, 6
Sutherland-Hodgeman polygon clipper, *see* clipping algorithm
sweeping, 372
 swept surface, 372–380
swizzle, 752
 operator, 752
synthetic texture, 482
synthetic-camera
 model, 55
 pipeline, *see* graphics pipeline

T

table, 375
tablet, *see* input device
Taj Mahal, 380
tangent, 356
 line, 357, 460
 plane, 400, 460
 vector, 358, 460
tapered cylinder, *see* cylinder
teapot
 GLUT, 91

Utah, 406
tension parameter, 659
tessellation
 isolines, 809
 quads, 808
 triangles, 810
tessellation level, 801, 804
tessellation primitive generator (TPG), 799, 807
tessellation shader, *see* shader
tetrahedron, 389
 GLUT, 91
 tetrahedralization, 316
texel, 482
text, 82–84
 bitmapped (raster), 82
 stroke (vector), 82
texture
 active unit, 506
 animation, 502
 base, 493
 blending, 519–520
 combiner function, 506
 combining, 505
 coordinates, 485, 499–502
 array, 499
 depth, 676
 external, 482
 filter, *see* filter
 lighting, 503–505
 loading, 482
 lookup function, 773
 map, 485
 matrix, 502
 current, 502
 stack, 502
 mipmap, *see* filter
 multitexturing, 505–507
 object, 483, 496
 pre-filtered, 494
 procedural, 482
 repeated, 489
 resolution, 493
 sampler, 753, 772
 space, 484

- synthetic, 482
 - texel, 482
 - tiled, 488
 - unit, 505
 - wrapping mode, 489
 - clamped, 489
 - repeated, 488
 - texture buffer object (TBO), 780
 - Timaeus dialogues, 390
 - timer function, 129
 - topological manifold, 397
 - toroidal helix, *see* helix
 - torpedo, 407
 - torus, 373
 - GLUT, 91, 137
 - torus knot, 375
 - touchpad, *see* input device
 - touchscreen, *see* input device
 - trackball, *see* input device
 - trajectory, 372
 - defining, 381
 - transform feedback, 790
 - buffer, 792
 - object, 792
 - transform-draw loop, 128
 - transformation
 - affine, *see* affine transformation
 - composing, *see* modeling transformation, composing
 - distance-preserving, 208
 - Euclidean, *see* Euclidean transformation
 - isolating, 125
 - modeling, *see* modeling transformation
 - modelview, *see* modelview transformation
 - orientation-preserving, *see* orientation
 - orientation-reversing, *see* orientation
 - perspective, *see* perspective transformation
 - projection, *see* projection transformation
 - projective, *see* projective transformation
 - rigid, *see* rigid transformation
 - shape-preserving, 208
 - snapshot, *see* snapshot transformation
 - viewing, *see* viewing transformation
 - translation
 - 2D theory, 185
 - 3D theory, 220–221
 - OpenGL, 102–104
 - translational component, *see* affine transformation
 - translucent, 516
 - transmitted ray, *see* ray
 - transparent, 524
 - Tree Huggers' Union, 317
 - triangle
 - fan, 43
 - OpenGL, 41
 - strip, 42
 - triangular mesh, 364
 - triangulation, 43, 307–316, 362
 - definition, 308
 - fan, 313
 - invalid, 308
 - valid, 308
 - Trick, 116
 - trigonometric parametrization, 350
 - trimmed B-spline surface, *see* B-spline surface
 - trimming loop, 647
 - tristimulus theory, 419
 - truncated pyramid, 52
 - tweening, 172
 - twist vector, 661
 - twisted cubic, 349, 653
- U**
- uniform
 - B-spline, *see* B-spline
 - knot vector, *see* knot vector

scaling, *see* scaling
uniform variable, 753
UNISURF CAD system, 604
up
 direction, 143
 vector, 147
user interaction, 47
Utah teapot, 406

V

vanishing point, *see* point
VAO, *see* vertex array object
variant
 Koch curve, 411
 Koch snowflake, 411
varying, 791
VBO, *see* vertex buffer object
vector
 displacement, *see* displacement
 vector
 eye direction, *see* eye direc-
 tion vector
 form, *see* pointer form
 halfway, *see* halfway vector
 knot, *see* knot vector
 light direction, *see* light direc-
 tion vector
 line of sight (los), *see* line of
 sight vector
 normal, *see* normal vector
 normalizing, 434
 patch brightness, *see* patch
 brightness vector
 product, *see* cross-product
 tangent, *see* tangent vector
 text, *see* text
 twist, *see* twist vector
 up, *see* up vector
vector form, *see* pointer form
vertex, 25, 27
 array, 71
 array object, 78–80
 buffer object, 75–78
 order, 41, 319
 equivalent, 322

Steiner, *see* Steiner vertex
vertex attribute array, 759
vertex shader, *see* shader
viewing
 box, 26
 canonical, 666
 face, 27, 52
 frustum, 52
 plane, 27, 52
 transformation, 115, 143–164
 trapezoid, 706
 volume, 65, 666
viewpoint, *see* light, viewpoint
viewport, 96–97
virtual
 object, 31
 screen, 721
 space, 32
viscous medium, 135
visibility determination, *see* hid-
 den surface removal *and*
 depth testing
visible spectrum, 419
vision, 419

W

WebGL, 776
weight
 angle-weighted, 466
 area-weighted, 467
 control point, 682
 weighted sum, 291
wheel, *see* input device
window
 aspect ratio, *see* aspect ratio
windows
 multiple, 97
wireframe drawing mode, *see* draw-
 ing mode
Wish List, *see* blending function
Witch of Agnesi, 342
world
 coordinate system, 30, 33
 space, 30

SUBJECT INDEX

X

XYZ color model, *see* CIE

Y

yaw, 264

Z

z-buffer, *see* buffer, depth
zoom, 168, 492

Program Index

animateMan1.cpp, 168
animateMan2.cpp, 169
antiAliasing+multisampling.cpp, 525
astroid.cpp, 348
ballAndTorus.cpp, 131
ballAndTorusClipped.cpp, 783
ballAndTorusPicking.cpp, 179
ballAndTorusPickingShaderized.cpp,
787
ballAndTorusReflected.cpp, 520
ballAndTorusShaderSubroutines.cpp,
785
ballAndTorusShaderized.cpp, 764
ballAndTorusShadowMapped.cpp, 677
ballAndTorusShadowed.cpp, 172
ballAndTorusStenciled.cpp, 539
ballAndTorusWithFriction.cpp, 135
ballsAndTorusTransformFeedback.cpp,
791
bezierCanoe.cpp, 406
bezierCurveTangent.cpp, 403
bezierCurveWithEvalCoord.cpp, 402
bezierCurveWithEvalMesh.cpp, 403
bezierCurves.cpp, 402
bezierSurface.cpp, 404
bicubicSplineSurface.cpp, 645
bicubicSplineSurfaceLitTextured.cpp,
646
bilinearPatch.cpp, 381
billboard.cpp, 523
blendRectangles1.cpp, 514
blendRectangles2.cpp, 516
box.cpp, 102
boxWithLookAt.cpp, 146
bSplines.cpp, 612
bumpMappingPerPixelLight.cpp, 771
bumpMapping.cpp, 546
bumpMappingShaderized.cpp, 767
canvas.cpp, 89
checkeredFloor.cpp, 453
circle.cpp, 46
circularAnnuluses.cpp, 48
clippingPlanes.cpp, 92
clown2.cpp, 139
clown3.cpp, 136, 140
compareFilters.cpp, 497
convexHull.cpp, 301
cubicSplineCurve1.cpp, 624
cubicSplineCurve2.cpp, 644
cylinder.cpp, 369
DDA.cpp, 562
deCasteljau3.cpp, 587
doublyCurledCone.cpp, 378
eulerAngles.cpp, 264
extrudedHelix.cpp, 378
fakeT.cpp, 413
fieldAndSky.cpp, 490
fieldAndSkyFiltered.cpp, 496
fieldAndSkyFilteredShaderized.cpp, 772
fieldAndSkyFogged.cpp, 520
fieldAndSkyLit.cpp, 503
fieldAndSkyTexturesBlended.cpp, 519
fieldAndSkyTexturesBlendedShaderized.cpp,
794

floweringPlant.cpp, 140
fonts.cpp, 83
fractals.cpp, 411
gluQuadrics.cpp, 387
glutObjects.cpp, 91
helicalPipe.cpp, 371
helix.cpp, 52
helixList.cpp, 81
helixListShaderizedInstancedVertAttrib.cpp, 778
helixListShaderizedShaderCounter.cpp, 780
hemisphere.cpp, 59
hemisphereMultidraw.cpp, 74
hemisphereMultidrawVBO.cpp, 78
hermiteCubic.cpp, 656
hyperboloid1sheet.cpp, 385
imageManipulation.cpp, 541
imageManipulationPBO.cpp, 543
interpolateEulerAngles.cpp, 265
interpolation.cpp, 296
intersectionDetectionRoutines.cpp, 258
invalidTriangulation.cpp, 309
lightAndMaterial1.cpp, 441
lightAndMaterial2.cpp, 441
lineStipple.cpp, 88
litBezierCanoe.cpp, 472
litCylinder.cpp, 470
litCylinderProgrammedNormals.cpp, 472
litCylinderShaderized.cpp, 769
litDoublyCurledCone.cpp, 471
litTexturedCylinder.cpp, 504
litTexturedCylinderShaderized.cpp, 774
litTriangle.cpp, 446
loadTextures.cpp, 482
manipulateModelviewMatrix.cpp, 240
manipulateProjectionMatrix.cpp, 675
menus.cpp, 88
mipmapLevels.cpp, 497
mouse.cpp, 84
mouseMotion.cpp, 86
mouseWheel.cpp, 86
moveSphere.cpp, 56
multipleLists.cpp, 82
multitexture.cpp, 505
occlusion.cpp, 260
occlusionConditionalRendering.cpp, 262
parabola.cpp, 47
perspectiveCorrection.cpp, 708
pointSprite.cpp, 528
points.cpp, 796
quadraticSplineCurve.cpp, 622
quaternionAnimation.cpp, 282
rationalBezierCurve1.cpp, 684
rationalBezierCurve2.cpp, 686
rationalBezierCurve3.cpp, 689
rationalBezierSurface.cpp, 696
relativePlacement.cpp, 124
rotatingHelix1.cpp, 128
rotatingHelix2.cpp, 128
rotatingHelix3.cpp, 129
rotatingHelixFPS.cpp, 129
selection.cpp, 174
shear.cpp, 250
shipMovie.cpp, 473
sizeNormal.cpp, 476
spaceTravel.cpp, 164
spaceTravelFrustumCulled.cpp, 258
sphereInBox1.cpp, 332
sphereInBox2.cpp, 465
sphereInBoxPOV.pov, 728
sphereInGlassBox.cpp, 518
sphereMapping.cpp, 530
spotlight.cpp, 444
square.cpp, 24
squareAnnulus1.cpp, 70
squareAnnulus2.cpp, 71
squareAnnulus3.cpp, 71
squareAnnulus4.cpp, 72
squareAnnulusAndTriangle.cpp, 72
squareAnnulusAndTriangleVAO.cpp, 79
squareAnnulusVBO.cpp, 76
squareOfWalls.cpp, 329
squareOfWallsReflected.cpp, 334
squareShaderized.cpp, 754
sweepBezierSurface.cpp, 601
table.cpp, 377

tessellatedCurve.cpp, 802
tessellatedHemisphere.cpp, 811
tetrahedron.cpp, 390
texturedTorpedo.cpp, 500
texturedTorus.cpp, 499
texturedTorusAnimated.cpp, 502
texturedTorusShaderized.cpp, 773
threeQuarterSphere.cpp, 329
throwBall.cpp, 134
torpedo.cpp, 407
torus.cpp, 374
torusSilhouette.cpp, 817
torusSweep.cpp, 374
trimmedBicubicBsplineSurface.cpp, 647
turnFilm1.cpp, 834
turnFilm2.cpp, 690
viewports.cpp, 97
windows.cpp, 98

PROGRAM INDEX