

C O N T E N T S



UNIVERSIDAD NACIONAL DE ENTRE RÍOS
FACULTAD DE INGENIERIA
CENTRO DE MEDIOS
BIBLIOTECA

1790

■	1 Overview	1
	Introduction	1
	1.1 Applications of Computer Graphics	2
	1.1.1 Display of Information	3
	1.1.2 Design	3
	1.1.3 Simulation	4
	1.1.4 User Interfaces	4
	1.2 The Development of Computer Graphics	5
	1.2.1 1950–1960	5
	1.2.2 1960–1970	6
	1.2.3 1970–1980	7
	1.2.4 1980 to the Present	8
	1.3 A Basic Graphics System	9
	1.3.1 The Processor	10
	1.3.2 Memory	10
	1.3.3 Output Devices	10
	1.3.4 Input Devices	11
	1.4 Graphics Software	11
	1.4.1 Terminal-Based Software	12
	1.4.2 Turnkey Software	13
	1.5 The Rest of the Book	13
	1.6 Suggested Readings	14
	Exercises	15
■	2 Fundamental Ideas	17
	Introduction	17
	2.1 A Simple Plotting Procedure	17
	2.2 Image Formation	19

2.3	The Synthetic Camera	23
2.3.1	Separating the Viewer from the Objects	23
2.3.2	Two-Dimensional Viewing	25
2.3.3	Device Independence	26
2.4	Device-Independent Software	26
2.5	Windows and Viewports	28
2.6	Positioning	32
2.7	Points, Lines, and Curves	36
2.7.1	Points	36
2.7.2	Vectors	37
2.7.3	Curves	39
2.7.4	Explicit Curves	39
2.7.5	Implicit Form	40
2.7.6	Parametric Form	43
2.8	Portability Considerations	45
2.8.1	Functionality versus Format	45
2.8.2	Defaults and Choices	47
2.8.3	Error Handling	48
2.9	Suggested Readings	49
	Exercises	50

■ 3 Two-Dimensional Graphics 53

Introduction	53	
3.1	Device-Independent Graphics Standards	54
3.2	The Programmer's Model	55
3.2.1	Logical and Physical Workstations	56
3.2.2	Communicating with the Hardware	58
3.2.3	Implementation Issues	59
3.3	Graphics Functions	60
3.3.1	Output Functions	60
3.3.2	Control Functions	61
3.3.3	Attributes	61
3.3.4	Viewing and Transformation Functions	62
3.3.5	Input Functions	62
3.3.6	Segmentation Functions	63
3.3.7	Metafiles	63
3.3.8	Inquiry Functions	64
3.4	A Simple Program	64
3.4.1	The Pen-Plotter Model	64
3.4.2	Polyline and Text	66
3.5	Viewing	69
3.5.1	The Normalization Transformation	69
3.5.2	Clipping	71

3.5.3	The Workstation Transformation	73
3.6	Control	76
3.6.1	Initialization	76
3.6.2	The Error File	77
3.6.3	Opening the System	77
3.6.4	Opening and Activating Workstations	78
3.6.5	Termination	79
3.7	Polyline and Text Attributes	79
3.7.1	Geometric and Nongeometric Attributes	80
3.7.2	Polyline Attributes	80
3.7.3	Text Attributes	83
3.7.4	Bundled Attributes	85
3.8	Other Primitives	87
3.8.1	The Polymarker	87
3.8.2	The Fill Area	88
3.8.3	Cell Arrays	90
3.8.4	Generalized Drawing Primitives	91
3.9	A Self-Scaling Plotter	91
3.9.1	Setting up the Normalization Transformations	93
3.10	Metafiles	96
3.10.1	The GKS Metafile	97
3.10.2	Interpreting A GKS Metafile	98
3.10.3	The Computer-Graphics Metafile	100
3.11	Suggested Readings	100
Exercises		101

4 Interactive Graphics 105

Introduction	105	
4.1	Programming with Interaction	105
4.2	A Shape-Layout Program	106
4.2.1	Choosing Windows and Viewports	107
4.2.2	The Shape Menu	108
4.3	Defining Objects	110
4.3.1	Segments	110
4.3.2	Segments and Program Flow	112
4.3.3	Buffering	113
4.4	Segment Attributes	114
4.4.1	Visibility	114
4.4.2	Priority	115
4.4.3	Other Attributes	116
4.5	Input	117
4.5.1	Logical versus Physical Input	117
4.5.2	Logical Input Classes	118
4.5.3	Measure and Trigger	119



4.5.4	Input Modes	119
4.5.5	Prompt, Echo, and Status Feedback	121
4.5.6	Programming Input	122
4.6	Physical Input Devices	123
4.6.1	The Keyboard	123
4.6.2	The Lightpen	124
4.6.3	The Joy Stick	126
4.6.4	The Trackball and the Mouse	127
4.6.5	Data Tablets	127
4.6.6	Graphical Devices	128
4.6.7	Dragging	129
4.7	The Pick	129
4.7.1	Using the Returned Status	130
4.7.2	Pick Identifiers	131
4.7.3	Setting Up the Menus	132
4.7.4	The Control Loop	134
4.7.5	Mode Selection and Initialization	135
4.7.6	General Program Flow	136
4.8	The Locator	137
4.8.1	Request Locator	137
4.8.2	Inverting the Coordinate Transformations	137
4.8.3	Entering the Data	138
4.8.4	Device Initialization	140
4.9	String Input	141
4.9.1	Using an Inquiry	142
4.9.2	Pausing During Execution	142
4.9.3	Completing the Layout Program	143
4.10	Event-Driven Input	144
4.11	The User Interface	145
4.11.1	Menus	146
4.11.2	Icons	148
4.11.3	User Feedback	150
4.11.4	User Aids	151
4.11.5	Layout	152
4.11.6	color	154
4.12	The Burden of Interaction	154
4.13	Suggested Readings	155
	Exercises	155

■ 5 Transformations and Modeling 159

Introduction	159
5.1 Affine Transformations	160
5.1.1 General Transformations	160
5.1.2 Transforming Lines to Lines	161
5.1.3 Translation	161

5.1.4	Rotation	162
5.1.5	Scaling	163
5.1.6	Shear	164
5.2	Concatenating Transformations	165
5.2.1	Rotating About a Fixed Point	165
5.2.2	Homogeneous Coordinates	167
5.2.3	Matrix Representations	169
5.2.4	Inverse Transformations	170
5.2.5	Concatenation Examples	171
5.3	Transformations in GKS	174
5.4	A Transformation Package	176
5.4.1	Evaluation Procedures	177
5.4.2	Accumulation Procedures	178
5.4.3	Applying the Transformations	179
5.5	Symbols and Instances	181
5.5.1	Symbols	182
5.5.2	Modeling with Symbols	182
5.6	Modeling With Relationships	184
5.6.1	A Simple Robot Arm	185
5.6.2	Modeling With Transformation Matrices	186
5.6.3	Animating the Model	187
5.7	Using Hierarchy and Recursion	188
5.7.1	The Robot Arm as a Tree	189
5.7.2	Representing a Tree	190
5.7.3	Traversing the Model	192
5.7.4	Discussion	193
5.8	Implementation of Abstract Data Types	194
5.8.1	Operations on a Tree	194
5.8.2	Another Implementation	195
5.9	From Segments to Structures	199
5.9.1	Segment Contents	199
5.9.2	Directed Acyclic Graphs	200
5.9.3	Structures	200
5.10	PHIGS	202
5.10.1	Viewing a Database	203
5.10.2	Programming in PHIGS	204
5.10.3	Modeling with PHIGS	205
5.11	Suggested Readings	207
	Exercises	207

■ 6 Implementation 211

Introduction	211
6.1 Implementation Issues	211
6.2 Following the Pipeline	213

6.3	Clipping	215
6.3.1	The Difficulty of Clipping	215
6.3.2	Text Clipping	216
6.4	Clipping Line Segments	218
6.5	The Cohen-Sutherland Algorithm	222
6.5.1	Outcodes	222
6.5.2	The Accept and Reject Checks	223
6.5.3	Computing Intersections	223
6.6	Other Clipping Methods	226
6.6.1	Reentrant Clipping	227
6.6.2	Using Bounding Boxes	227
6.7	Device Drivers	229
6.7.1	ASCII Devices	230
6.7.2	REGIS Drivers	231
6.7.3	Tektronix Drivers	233
6.8	Scan Converting Line Segments	235
6.8.1	Setting Pixels	236
6.8.2	A Simple Algorithm	237
6.9	Bresenham's Algorithm	240
6.10	Real-Time Processors	245
6.10.1	The Display Processor	246
6.10.2	Graphics Workstations	249
6.11	Suggested Readings	250
	Exercises	250

■ 7 Raster Graphics 253

	Introduction	253
7.1	The Frame Buffer	254
7.1.1	Conceptualizing the Frame Buffer	255
7.1.2	Manipulating the Frame Buffer	255
7.2	Writing in the Frame Buffer	257
7.2.1	Swapping	258
7.2.2	Writing Modes	260
7.3	Using XOR	261
7.3.1	Swapping Revisited	262
7.3.2	Erasing, Cursors, and Rubberbanding	263
7.3.3	Simple Fill	265
7.4	BitBlt Operations	265
7.4.1	Formulating the Operations	266
7.4.2	Clipping	266
7.4.3	CharBlt	267
7.5	Polygons and Raster	268
7.5.1	Representation	269

7.5.2	Clipping	272
7.6	Fill	274
7.6.1	GKS Fill Areas	275
7.6.2	Where Are the Intersections?	276
7.6.3	Edge-Flag Methods	277
7.6.4	Priority Methods	277
7.6.5	Recursive Methods	279
7.6.6	Sorting Methods	281
7.7	Color	282
7.7.1	Brightness and Intensity	283
7.7.2	Three-Color Theory	284
7.7.3	The Color Solid	285
7.7.4	Producing Color	286
7.7.5	Color Matching and Color Systems	288
7.7.6	Perceptual Color	289
7.8	Using Multiple-Bit Pixels	291
7.8.1	Lookup Tables	291
7.8.2	Antialiasing	293
7.9	Suggested Readings	295
	Exercises	295

■ 8 Three-Dimensional Graphics 299

Introduction	299
8.1	Three-Dimensional Representations 300
8.1.1	Three-Dimensional Curves and Surfaces 301
8.1.2	Planes 302
8.2	Three-Dimensional Primitives 304
8.2.1	The Polyline 304
8.2.2	Extending the GKS Primitives 305
8.3	Transformations 306
8.3.1	Homogeneous Coordinates 306
8.3.2	Translation 307
8.3.3	Scaling and Shear 307
8.3.4	Rotation 309
8.3.5	A Three-Dimensional Transformation Package 311
8.4	An Example 312
8.4.1	Instantiating a Cube 312
8.4.2	Direction Cosines 315
8.5	Projections and Normalization 318
8.5.1	The Normalization Transformation 319
8.5.2	Specifying a Projection Plane 321
8.5.3	Viewing Coordinates 321
8.5.4	Projection 323

8.5.5 Clipping	324
8.6 Classical and Computer Graphics	326
8.6.1 Classical Viewing	326
8.6.2 Orthographic Projections	327
8.6.3 Axonometric Projections	327
8.6.4 Oblique Projections	330
8.6.5 Perspective Viewing	330
8.7 Implementation	332
8.7.1 Orthogonal Viewing	333
8.7.2 Computing the View-Orientation Transformation	335
8.7.3 An Example	339
8.7.4 Projection	340
8.7.5 Oblique Viewing	341
8.7.6 Implementing Perspective Viewing	343
8.8 Suggested Readings	346
Exercises	346

■ 9 Working with Polygons 351

Introduction	351
9.1 Polygons and Realism	351
9.2 Representing Polygons in Three Dimensions	353
9.2.1 Polygons and Normals	353
9.2.2 Computing the Normal	354
9.3 Polygon Meshes	356
9.3.1 Edges, Surfaces, and Volumes	357
9.3.2 Quadrilateral and Triangular Meshes	358
9.3.3 Approximating Spheres	360
9.4 Hidden-Surface Removal	361
9.4.1 Hidden-Surface Removal and Sorting	362
9.4.2 Object-Space versus Image-Space Approaches	363
9.5 Object-Space Algorithms	364
9.5.1 Removing Back-Facing Polygons	365
9.5.2 Depth Sort	366
9.5.3 The General Case	367
9.6 Image-Space Algorithms	369
9.6.1 The z -buffer Algorithm	369
9.6.2 The Scan-Line Algorithm	371
9.7 Rendering	372
9.7.1 Ray Tracing	373
9.7.2 Ray Casting	375
9.7.3 Aliasing and Rendering	376
9.7.4 Shadow Rays	376

9.7.5	Rendering Without Ray Tracing	377
9.8	Shading Models	378
9.8.1	Diffuse Reflections	380
9.8.2	Ambient Light	380
9.8.3	Specular Reflections	381
9.9	Polygonal Shading	382
9.9.1	Gouraud and Phong Shading	382
9.10	Suggested Readings	384
	Exercises	384

■ 10 Curves and Surfaces 387

Introduction	387
10.1	Explicit, Implicit, and Parametric Curves 388
10.1.1	Explicit Form 388
10.1.2	Implicit Form 389
10.1.3	Parametric Form 390
10.1.4	Example 390
10.2	Polynomial Curves 392
10.2.1	Cubic Polynomials 393
10.3	Interpolating Form 395
10.3.1	The Cubic Interpolating Polynomial 396
10.3.2	Joining Curve Segments 397
10.3.3	Blending Polynomials 399
10.3.4	Approximating a Circle 400
10.4	Smoothing Polynomials 404
10.4.1	Hermite Polynomials 405
10.4.2	Bezier Polynomials 406
10.4.3	Splines 408
10.4.4	Example 411
10.5	Scan Converting Polynomials 412
10.5.1	Forward Differences 413
10.5.2	Example 415
10.5.3	Scan Conversion by Subdivision 415
10.6	Parametric Surfaces 417
10.6.1	The Plane and the Sphere 418
10.6.2	Bicubic Polynomials 419
10.6.3	Interpolation 421
10.6.4	Bezier Patches 423
10.7	Realism 425
10.7.1	Hidden Surface Removal 425
10.7.2	Rendering 427
10.7.3	Scan Conversion 429

1790



UNIVERSIDAD NACIONAL DE INGENIERIA
FACULTAD DE INGENIERIA
CENTRO DE MEDIOS
BIBLIOTECA

10.8 Solid Modeling	429
10.8.1 Object Classes	430
10.8.2 Constructive Solid Geometry	432
10.8.3 Boundary Representations	433
10.9 Suggested Readings	434
Exercises	434

■ A GKS Functions Used in Text	473
---------------------------------------	-----

■ B GKS Data Types Used in Text	449
--	-----

■ C Self-Scaling Plotter	455
---------------------------------	-----

■ Bibliography	461
-----------------------	-----

■ Function Index	467
-------------------------	-----

■ Subject Index	469
------------------------	-----