

CONTENTS IN DETAIL

ACKNOWLEDGMENTS

xv

INTRODUCTION

xvii

Who This Book Is For	xviii
What This Book Covers	xviii
Why Read This Book?	xix
About This Book	xx
About the Author	xxi

1

INTRODUCTORY CONCEPTS

1

The Canvas	1
Coordinate Systems	2
Color Models	3
Subtractive Color Model	4
Additive Color Model	6
Forget the Details	7
Color Depth and Representation	7
Color Manipulation	8
The Scene	9
Summary	10

PART I RAYTRACING

2

BASIC RAYTRACING

13

Rendering a Swiss Landscape	13
Basic Assumptions	15
Canvas to Viewport	17
Tracing Rays	18
The Ray Equation	19

The Sphere Equation	19
Ray Meets Sphere	20
Rendering our First Spheres	22
Summary	27

3 LIGHT 29

Simplifying Assumptions	29
Light Sources	30
Point Lights	30
Directional Lights	31
Ambient Light	32
Illumination of a Single Point	32
Diffuse Reflection	33
Modeling Diffuse Reflection	34
The Diffuse Reflection Equation	36
Sphere Normals	36
Rendering with Diffuse Reflection	37
Specular Reflection	39
Modeling Specular Reflection	42
The Specular Reflection Term	44
The Full Illumination Equation	44
Rendering with Specular Reflections	45
Summary	48

4 SHADOWS AND REFLECTIONS 51

Shadows	51
Understanding Shadows	51
Rendering with Shadows	54
Reflections	57
Mirrors and Reflection	57
Rendering with Reflections	60
Summary	62

5 EXTENDING THE RAYTRACER 65

Arbitrary Camera Positioning	65
Performance Optimizations	67
Parallelization	67
Caching Immutable Values	68

Shadow Optimizations	68
Spatial Structures	69
Subsampling	70
Supporting Other Primitives	70
Constructive Solid Geometry	71
Transparency	73
Refraction	74
Supersampling	75
Summary	75

PART II RASTERIZATION

6 LINES 79

Describing Lines	80
Drawing Lines	81
Drawing Lines with Any Slope	86
The Linear Interpolation Function	87
Summary	90

7 FILLED TRIANGLES 91

Drawing Wireframe Triangles	91
Drawing Filled Triangles	92
Summary	96

8 SHADED TRIANGLES 97

Defining Our Problem	97
Computing Edge Shading	98
Computing Interior Shading	100
Summary	102

9 PERSPECTIVE PROJECTION 105

Basic Assumptions	105
Finding P'	106
The Projection Equation	107

Properties of the Projection Equation	108
Projecting Our First 3D Object	109
Summary	111

10

DESCRIBING AND RENDERING A SCENE 113

Representing a Cube	113
Models and Instances	117
Model Transform	119
Camera Transform	122
The Transform Matrix	124
Homogeneous Coordinates	126
Homogeneous Rotation Matrix	127
Homogeneous Scale Matrix	127
Homogeneous Translation Matrix	127
Homogeneous Projection Matrix	128
Homogeneous Viewport-to-Canvas Matrix	129
The Transform Matrix Revisited	129
Summary	131

11

CLIPPING 133

An Overview of the Clipping Process	134
The Clipping Volume	134
Clipping the Scene Against a Plane	135
Defining the Clipping Planes	138
Clipping Whole Objects	139
Clipping Triangles	142
Segment-Plane Intersection	144
Clipping Pseudocode	145
Clipping in the Rendering Pipeline	147
Summary	147

12

HIDDEN SURFACE REMOVAL 149

Rendering Solid Objects	149
Painter's Algorithm	150
Depth Buffering	151
Using $1/Z$ instead of Z	154

Back Face Culling	157
Classifying Triangles	159
Summary	161

13

SHADING 163

Shading vs. Illumination	163
Flat Shading	164
Gouraud Shading	165
Phong Shading	169
Summary	173

14

TEXTURES 175

Painting a Crate	175
Bilinear Filtering	181
Mipmapping	183
Trilinear Filtering	187
Summary	187

15

EXTENDING THE RASTERIZER 189

Normal Mapping	189
Environment Mapping	192
Shadows	193
Stencil Shadows	193
Shadow Mapping	199
Summary	200

AFTERWORD 201

APPENDIX: LINEAR ALGEBRA 203

Points	203
Vectors	204
Representing Vectors	204
Vector Magnitude	205
Point and Vector Operations	205
Subtracting Points	205
Adding a Point and a Vector	206

Adding Vectors	207
Multiplying a Vector by a Number	207
Multiplying Vectors	208
Matrices	210
Matrix Operations	210
Adding Matrices	211
Multiplying a Matrix by a Number	211
Multiplying Matrices	211
Multiplying a Matrix and a Vector	212

INDEX

213