

Game Engine Architecture

Jason Gregory



A K Peters, Ltd.
Wellesley, Massachusetts

Contents

Foreword	xiii
Preface	xvii
I Foundations	1
1 Introduction	3
1.1 Structure of a Typical Game Team	5
1.2 What Is a Game?	8
1.3 What Is a Game Engine?	11
1.4 Engine Differences Across Genres	13
1.5 Game Engine Survey	25
1.6 Runtime Engine Architecture	28
1.7 Tools and the Asset Pipeline	49
2 Tools of the Trade	57
2.1 Version Control	57
2.2 Microsoft Visual Studio	66
2.3 Profiling Tools	85

2.4	Memory Leak and Corruption Detection	87
2.5	Other Tools	88
3	Fundamentals of Software Engineering for Games	91
3.1	C++ Review and Best Practices	91
3.2	Data, Code, and Memory in C/C++	98
3.3	Catching and Handling Errors	128
4	3D Math for Games	137
4.1	Solving 3D Problems in 2D	137
4.2	Points and Vectors	138
4.3	Matrices	151
4.4	Quaternions	169
4.5	Comparison of Rotational Representations	177
4.6	Other Useful Mathematical Objects	181
4.7	Hardware-Accelerated SIMD Math	185
4.8	Random Number Generation	192
II	Low-Level Engine Systems	195
5	Engine Support Systems	197
5.1	Subsystem Start-Up and Shut-Down	197
5.2	Memory Management	205
5.3	Containers	223
5.4	Strings	242
5.5	Engine Configuration	252
6	Resources and the File System	261
6.1	File System	262
6.2	The Resource Manager	272
7	The Game Loop and Real-Time Simulation	303
7.1	The Rendering Loop	303
7.2	The Game Loop	304

7.3	Game Loop Architectural Styles	307
7.4	Abstract Timelines	310
7.5	Measuring and Dealing with Time	312
7.6	Multiprocessor Game Loops	324
7.7	Networked Multiplayer Game Loops	333
8	Human Interface Devices (HID)	339
8.1	Types of Human Interface Devices	339
8.2	Interfacing with a HID	341
8.3	Types of Inputs	343
8.4	Types of Outputs	348
8.5	Game Engine HID Systems	349
8.6	Human Interface Devices in Practice	366
9	Tools for Debugging and Development	367
9.1	Logging and Tracing	367
9.2	Debug Drawing Facilities	372
9.3	In-Game Menus	379
9.4	In-Game Console	382
9.5	Debug Cameras and Pausing the Game	383
9.6	Cheats	384
9.7	Screen Shots and Movie Capture	384
9.8	In-Game Profiling	385
III	Graphics and Motion	397
10	The Rendering Engine	399
10.1	Foundations of Depth-Buffered Triangle Rasterization	400
10.2	The Rendering Pipeline	444
10.3	Advanced Lighting and Global Illumination	469
10.4	Visual Effects and Overlays	481
II	Animation Systems	491
II.1	Types of Character Animation	491
II.2	Skeletons	496

11.3	Poses	499
11.4	Clips	504
11.5	Skinning and Matrix Palette Generation	518
11.6	Animation Blending	523
11.7	Post-Processing	542
11.8	Compression Techniques	545
11.9	Animation System Architecture	552
11.10	The Animation Pipeline	553
11.11	Action State Machines	568
11.12	Animation Controllers	593
12	Collision and Rigid Body Dynamics	595
12.1	Do You Want Physics in Your Game?	596
12.2	Collision/Physics Middleware	601
12.3	The Collision Detection System	603
12.4	Rigid Body Dynamics	630
12.5	Integrating a Physics Engine into Your Game	666
12.6	A Look Ahead: Advanced Physics Features	684
IV	Gameplay	687
13	Introduction to Gameplay Systems	689
13.1	Anatomy of a Game World	690
13.2	Implementing Dynamic Elements: Game Objects	695
13.3	Data-Driven Game Engines	698
13.4	The Game World Editor	699
14	Runtime Gameplay Foundation Systems	711
14.1	Components of the Gameplay Foundation System	711
14.2	Runtime Object Model Architectures	715
14.3	World Chunk Data Formats	734
14.4	Loading and Streaming Game Worlds	741
14.5	Object References and World Queries	750
14.6	Updating Game Objects in Real Time	757

14.7	Events and Message-Passing	773
14.8	Scripting	794
14.9	High-Level Game Flow	817
V	Conclusion	819
15	You Mean There's More?	821
15.1	Some Engine Systems We Didn't Cover	821
15.2	Gameplay Systems	823
	References	827
	Index	831