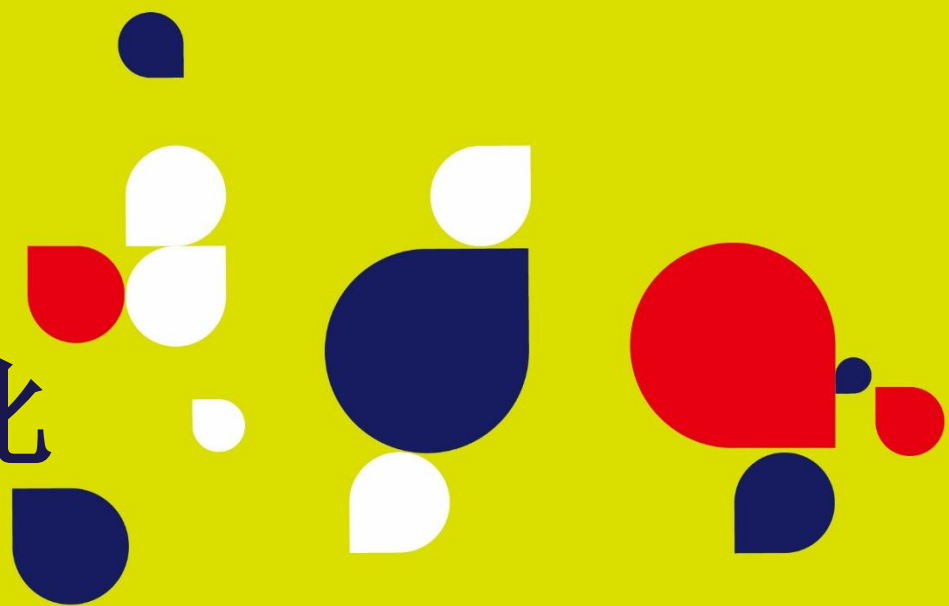


天涯明月刀渲染性能优化

解卫博

高级渲染工程师. 腾讯水银工作室



GDC 15 'Cn

游戏开发者大会·中国

GAME DEVELOPERS CONFERENCE CHINA

SHANGHAI INTERNATIONAL CONVENTION CENTER

SHANGHAI, CHINA · OCTOBER 25-27, 2015

Stat	CallCount	IncAvg	IncMax
Whole Draw Time	1.00	22.65 ms	28.51 ms
Wait FrameSync	1.00	2.12 ms	0.98 ms
Before Render Time	1.00	0.95 ms	1.33 ms
Impulse Render Time	1.00	0.13 ms	0.20 ms
Terrain List Parse Time	1.00	0.48 ms	0.70 ms
Mesh List Parse Time	1.00	1.43 ms	2.42 ms
Draw Depth Only	1.00	0.02 ms	0.02 ms
Draw Shadow Depth	1.00	0.82 ms	1.12 ms
Draw Shadow Combine	0.00	0.00 ms	0.00 ms
Draw GBuffer	1.00	4.10 ms	5.90 ms
GBuffer Opaque	1.00	1.98 ms	3.38 ms
GBuffer Terrain	1.00	0.78 ms	1.17 ms
GBuffer SpeedTree	1.00	0.49 ms	1.01 ms
Draw Lighting	1.00	5.82 ms	8.25 ms
Draw Translucent	1.00	4.01 ms	5.59 ms
Draw Particle	0.00	0.00 ms	0.00 ms
Draw Water	1.00	3.76 ms	5.22 ms
Water Refeect	1.00	3.62 ms	5.02 ms
WaterRef List Parse	1.00	2.09 ms	2.71 ms
WaterRef Opaque List Parse	1.00	0.52 ms	0.67 ms
WaterRef Terrain List Parse	1.00	0.16 ms	0.21 ms
Draw Opaque Refeect	1.00	1.27 ms	2.12 ms
Draw Terrain Refeect	1.00	0.20 ms	0.30 ms
SourceCurrentDraw Impostor Refeect	1.00	0.02 ms	0.04 ms
Speed Tree Cull	1.00	0.50 ms	0.65 ms
Draw PostProcess	1.00	0.14 ms	0.51 ms
Draw LightShaft Query	1.00	0.01 ms	0.04 ms
Draw LocalLigh	1.00	1.21 ms	1.87 ms
Build LocalLigt List	1.00	0.34 ms	0.44 ms
Present Scene	1.00	1.42 ms	1.19 ms
Draw UI	1.00	0.57 ms	1.12 ms
GetQueryDataTime	0.00	0.00 ms	0.00 ms
RenderQueryTime	1.00	0.26 ms	0.38 ms
Overlay	1.00	4.41 ms	6.53 ms
User 1	2.00	0.02 ms	0.02 ms
User 2	3.00	0.70 ms	0.94 ms
User 3	0.00	0.00 ms	0.00 ms
User 4	0.00	0.00 ms	0.00 ms
User 5	0.00	0.00 ms	0.00 ms

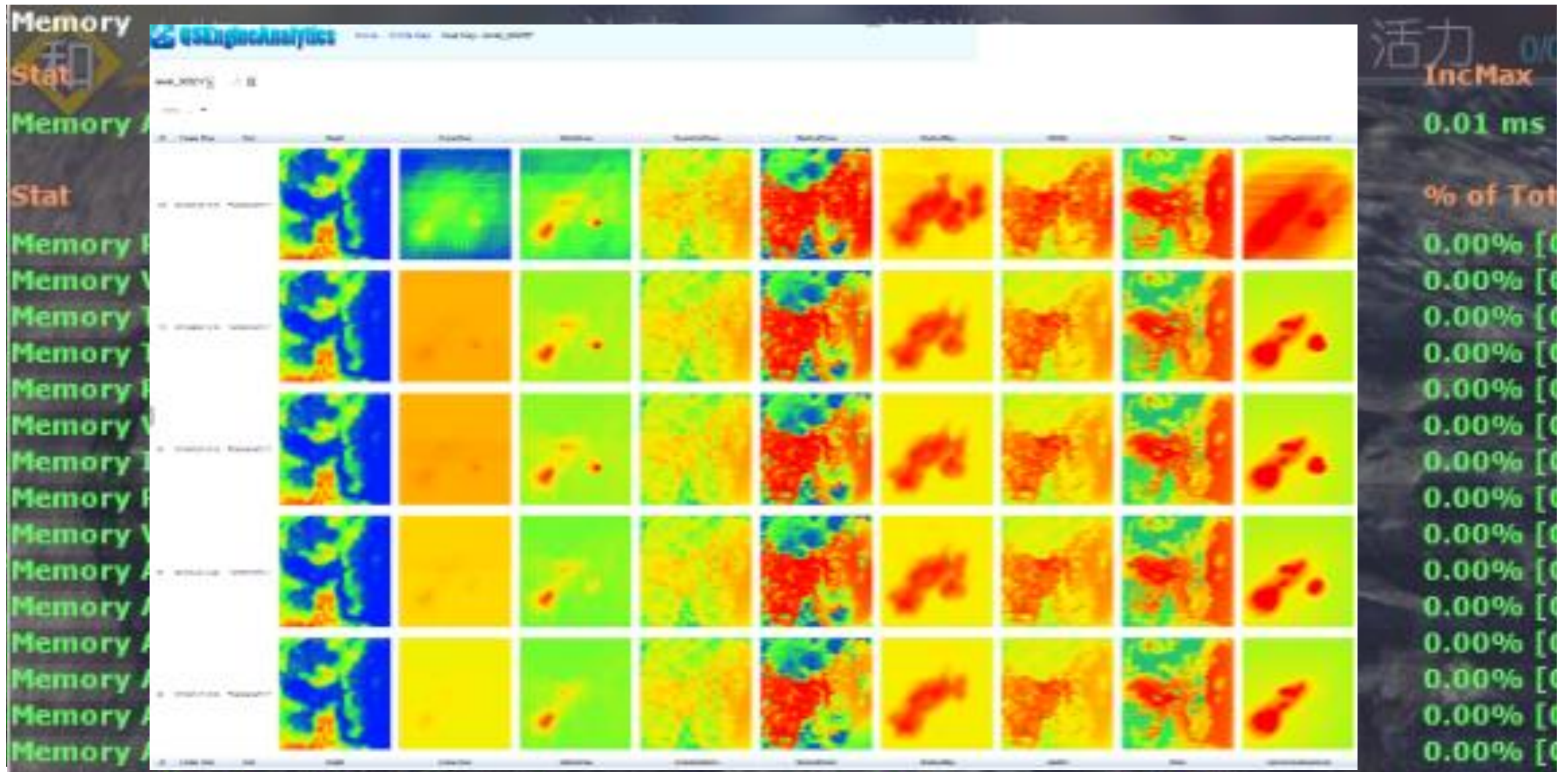
GPUProfileResult	AvgTime	MaxTime
PreRenderLogicWork	0.00 ms	0.00 ms
QSGameRenderGPU	19.23 ms	27.30 ms
ScaleForm	0.17 ms	1.18 ms
QSSceneRenderer_RenderScene	14.43 ms	22.05 ms
RenderImpulse_RenderWater	0.00 ms	0.00 ms
RenderImpulse_RenderGrass	0.01 ms	0.02 ms
LightViewDepthConstruct	0.80 ms	1.70 ms
OpaqueShadow	0.37 ms	0.83 ms
OpaqueShadow	0.11 ms	0.16 ms
OpaqueShadow	0.19 ms	0.70 ms
QSShadowVesturePolicy	0.00 ms	0.00 ms
QSSceneQueryRenderrer	1.76 ms	4.63 ms
depthList	0.01 ms	0.02 ms
OcclusionList	0.00 ms	0.01 ms
DepthOnlyPass	0.21 ms	0.29 ms
UIDepth	0.21 ms	0.28 ms
FillParticleTexture	0.01 ms	0.03 ms
GBufferConstruct	4.38 ms	6.49 ms
GBufferHair	0.01 ms	0.01 ms
GBufferOpaque	3.36 ms	5.13 ms
Makeup_Render	0.01 ms	0.01 ms
GBufferImpostor	0.14 ms	0.19 ms
GBufferSpeedTree	0.68 ms	0.92 ms
GBufferTerrain	0.17 ms	0.23 ms
GBufferRoad	0.00 ms	0.00 ms
RenderDecal	0.00 ms	0.00 ms
RenderShadowDecal	0.00 ms	0.00 ms
ScreenSpaceShadowMap	0.49 ms	0.66 ms
DeferredLighting	4.58 ms	8.15 ms
DirectLighting	0.36 ms	0.48 ms
RenderEmissive	0.03 ms	0.04 ms
LocalLight	1.76 ms	4.39 ms
SkyAndFog	0.53 ms	0.74 ms
TranslucencyRender	1.89 ms	2.96 ms
QSOuterGlowRenderrer	0.00 ms	0.00 ms
ResidueEffect	0.00 ms	0.00 ms
Distortion	0.00 ms	0.00 ms
MotionBlurRenderrer	0.00 ms	0.00 ms
QSWeatherParticle	0.00 ms	0.00 ms
LightShaft	0.00 ms	0.00 ms
PostFxDHDR_Render	0.71 ms	0.95 ms
LensFlare	0.00 ms	0.00 ms
OutlinePass	0.00 ms	0.00 ms
OverHeadTranlucentPass	0.00 ms	0.00 ms
PostFxCOLOR	0.00 ms	0.00 ms
QSUIMapCoverRenderrer	0.00 ms	0.00 ms
PostFxAA	0.59 ms	0.79 ms
InterlacedRendering	0.00 ms	0.00 ms
EndDrawUIOnRT	0.00 ms	0.00 ms
QSOverlay	0.15 ms	0.73 ms
Present	3.89 ms	6.33 ms

性能分析工具

● Stat系统

● GPU Profiler

Stat系统



ProfileResult	AvgTime	MaxTime
PreRenderLogicWork	0.00 ms	0.00 ms
QSGameRenderGPU	17.55 ms	24.30 ms
ScaleForm	0.02 ms	0.04 ms
QSSceneRenderer_RenderScene	13.96 ms	20.14 ms
RenderImpulse_RenderWater	0.00 ms	0.00 ms
RenderImpulse_RenderGrass	0.01 ms	0.02 ms
LightViewDepthConstruct	1.00 ms	2.39 ms
OpaqueShadow	0.34 ms	0.90 ms
SpeedTreeShadow	0.00 ms	0.00 ms
Render3dTrees	0.00 ms	0.00 ms
OpaqueShadow	0.16 ms	0.31 ms
SpeedTreeShadow	0.04 ms	0.05 ms
Render3dTrees	0.04 ms	0.05 ms
OpaqueShadow	0.14 ms	0.21 ms
SpeedTreeShadow	0.00 ms	0.00 ms
Render3dTrees	0.00 ms	0.00 ms
RenderBillboards	0.00 ms	0.00 ms
QSShadowVesturePolicy	0.22 ms	1.72 ms
SpeedTreeShadow	0.22 ms	1.72 ms
Render3dTrees	0.00 ms	0.00 ms
RenderBillboards	0.22 ms	1.72 ms
QSSceneQueryRenderer	1.68 ms	4.60 ms
depthList	0.01 ms	0.01 ms
OcclusionList	0.00 ms	0.00 ms
DepthOnlyPass	0.24 ms	0.32 ms
UIDepth	0.23 ms	0.31 ms
OverHeadDepthMask	0.00 ms	0.00 ms
FillParticleTexture	0.01 ms	0.02 ms
GBufferConstruct	4.54 ms	7.47 ms
GBufferHair	0.01 ms	0.01 ms
GBufferOpaque	3.38 ms	5.89 ms
GBufferOpaqueInstancing	0.29 ms	0.39 ms
Makeup_Render	0.01 ms	0.01 ms
GBufferImpostor	0.16 ms	0.21 ms
GBufferSpeedTree	0.75 ms	1.01 ms
Render3dTree	0.55 ms	0.74 ms
RenderBillboard	0.20 ms	0.26 ms
RenderGrass	0.00 ms	0.00 ms
GBufferTerrain	0.21 ms	0.39 ms
GBufferRoad	0.00 ms	0.00 ms
RenderDecal	0.00 ms	0.00 ms
RenderShadowDecal	0.02 ms	0.11 ms
ScreenSpaceShadowMap	0.54 ms	0.72 ms
DeferredLighting	4.25 ms	6.75 ms
DirectLighting	0.39 ms	0.53 ms
SkinLighting	0.09 ms	0.12 ms
RenderEmissive	0.10 ms	0.58 ms
LocalLight	1.16 ms	2.79 ms
SkyAndFog	0.57 ms	0.82 ms
TranslucencyRender	2.02 ms	2.83 ms
RenderWaterAndTranslucency	2.02 ms	2.83 ms
TransBeforeWater	0.00 ms	0.00 ms
RestoreRefraction	0.26 ms	0.34 ms
RenderWaterSelf	0.01 ms	0.04 ms
RenderWaterSelf	0.00 ms	0.01 ms
WaterRenderRef	1.65 ms	2.35 ms
RenderWaterSelf	0.02 ms	0.03 ms
RenderWaterSelf	0.00 ms	0.00 ms
TransAfterWater	0.07 ms	0.11 ms
QSOuterGlowRenderer	0.00 ms	0.00 ms
ResidueEffect	0.00 ms	0.00 ms
Distortion	0.00 ms	0.00 ms
MotionBlurRenderer	0.00 ms	0.00 ms
QSWeatherParticle	0.00 ms	0.00 ms
LightShaft	0.00 ms	0.00 ms
PostFxHDR_Render	0.74 ms	1.01 ms
LensFlare	0.00 ms	0.00 ms
OutlinePass	0.00 ms	0.00 ms
OverHeadTranlucentPass	0.00 ms	0.00 ms
PostFxColor	0.00 ms	0.00 ms
QSUIMapCoverRenderer	0.00 ms	0.00 ms
PostFxAA	0.63 ms	0.85 ms
InterlacedRendering	0.00 ms	0.00 ms
EndDrawUIOnRT	0.00 ms	0.00 ms
QSOverlay	0.04 ms	0.06 ms
Present	2.88 ms	4.75 ms

GPU Profiler

- 实时统计游戏每个模块的GPU开销
- 轻量级，对游戏本身性能影响很小
- 内置Profiler，不依赖于第三方
- 别的项目也可以方便使用
- UE3,FarCry没有这个功能

Shader指令优化案例

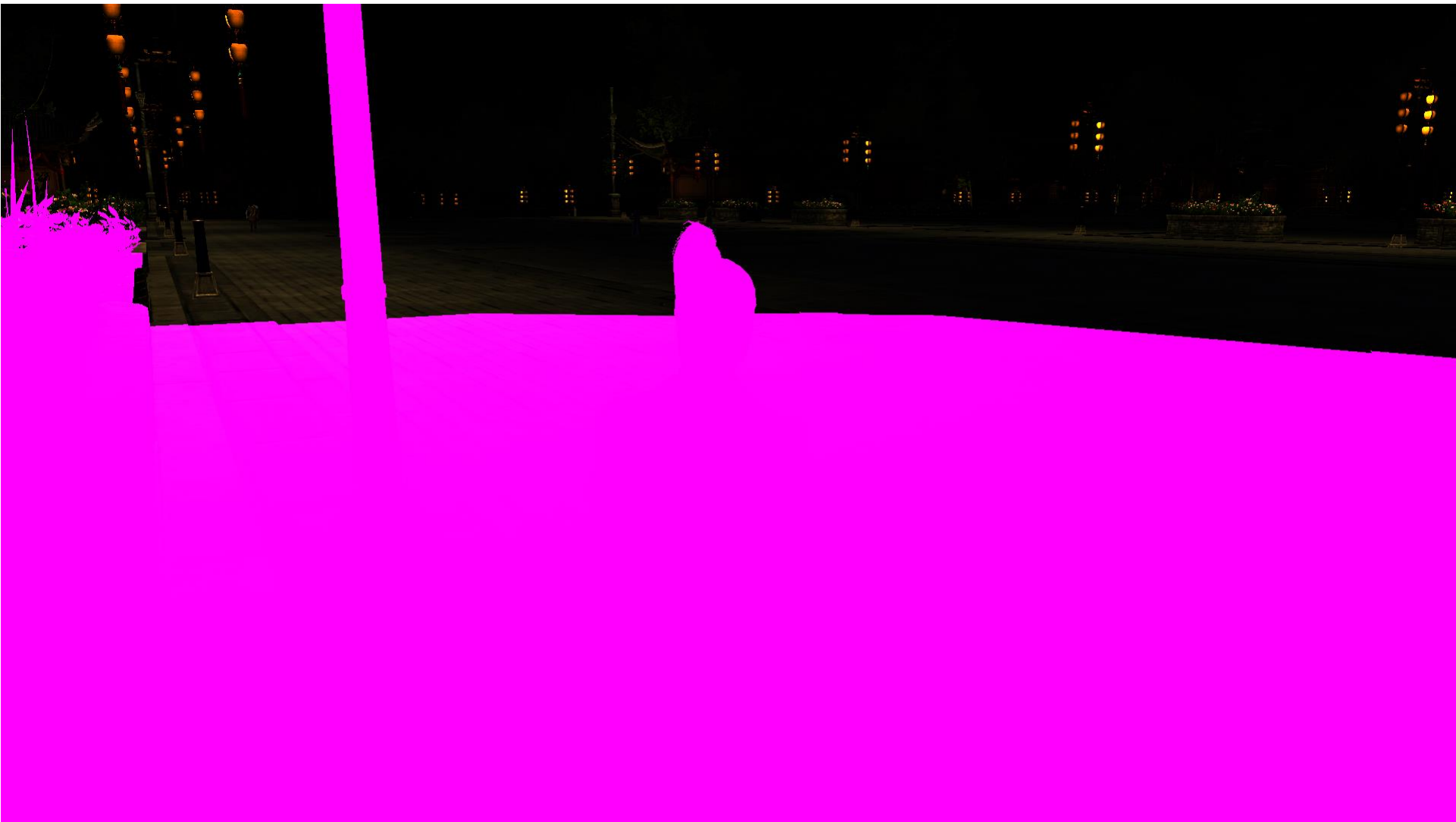


点光源渲染



点光源优化

- 避
- 超
-
-
-
-
-
- 超



水体反射优化

The screenshot displays a game engine's GPU profiler interface, showing a list of rendering tasks and their performance metrics. The main game view shows a character in a blue and white outfit standing in a grassy field with a large rock formation in the background. The right side of the screen shows a mini-map and a quest log.

GPU Profile Result

Task	AvgTime	MaxTime
PreRenderLogicWork	0.00 ms	0.00 ms
QSGPURenderGPU	8.47 ms	14.49 ms
QSSceneRender_RenderScene	5.76 ms	8.05 ms
RenderImpulse	0.12 ms	0.16 ms
RenderNodes	0.00 ms	0.00 ms
RenderImpulse	0.01 ms	0.01 ms
RenderNodes	0.00 ms	0.00 ms
LightViewDepthConstruct	1.11 ms	2.00 ms
OpaqueShadow	0.30 ms	0.40 ms
SpeedTreeShadow	0.23 ms	0.30 ms
OpaqueShadow	0.62 ms	1.35 ms
SpeedTreeShadow	0.51 ms	1.21 ms
OpaqueShadow	0.16 ms	0.22 ms
SpeedTreeShadow	0.09 ms	0.12 ms
QSShadowVestureMultiFramePolicy	0.00 ms	0.00 ms
SpeedTreeShadow	0.00 ms	0.00 ms
QSSceneQueryRenderer	0.01 ms	0.01 ms
depthList	0.00 ms	0.00 ms
OcclusionList	0.00 ms	0.00 ms
DepthOnlyPass	0.03 ms	0.03 ms
OverHeadDepthMask	0.00 ms	0.00 ms
CalcExposureScale	0.00 ms	0.00 ms
GBufferConstruct	2.12 ms	3.28 ms
GBufferHair	0.00 ms	0.00 ms
GBufferOpaque	0.11 ms	0.43 ms
GBufferSpeedTree	1.17 ms	1.56 ms
GBufferTerrain	0.79 ms	1.06 ms
GBufferRoad	0.00 ms	0.00 ms
RenderDecal	0.00 ms	0.00 ms
RenderShadowDecal	0.03 ms	0.23 ms
ScreenSpaceShadowMap	0.65 ms	0.87 ms
LocalLightShadow	0.00 ms	0.00 ms
DeferredLighting	0.53 ms	0.72 ms
DirectLighting	0.41 ms	0.55 ms
SkinLighting	0.07 ms	0.09 ms
RenderEmissive	0.00 ms	0.00 ms
LocalLight	0.00 ms	0.00 ms
SkyAndFog	0.09 ms	0.12 ms
QSSunRenderer	0.00 ms	0.00 ms
Atmo	0.09 ms	0.12 ms
TranslucencyRender	0.00 ms	0.00 ms
ResidueEffect	0.00 ms	0.00 ms
RenderWater	0.00 ms	0.00 ms
Silhouette	0.00 ms	0.00 ms
FlowingLight	0.00 ms	0.00 ms
FlowingColor	0.00 ms	0.00 ms
Distortion	0.00 ms	0.00 ms
MotionBlurRenderer	0.00 ms	0.00 ms
PostFxDHRRender	0.63 ms	1.15 ms
DownScale4	0.08 ms	0.42 ms
Luminance	0.02 ms	0.03 ms
BloomBrightFilter	0.04 ms	0.05 ms
PostFxDHRR_BloomBlur	0.07 ms	0.10 ms
BlendColorGradingRt	0.00 ms	0.00 ms
ToneMappingFinal	0.26 ms	0.35 ms
ReleaseLightShaftRt	0.00 ms	0.00 ms
LensFlare	0.02 ms	0.02 ms
OutlinePass	0.00 ms	0.00 ms
OverHeadTranlucentPass	0.01 ms	0.01 ms
PostFxCOLOR	0.00 ms	0.00 ms
QSUIMapCoverRenderer	0.00 ms	0.00 ms
PostFxA	0.65 ms	0.87 ms
EdgeDetect	0.17 ms	0.23 ms
BlendWeight	0.22 ms	0.29 ms
NeighborBlend	0.26 ms	0.35 ms
InterlacedRendering	0.00 ms	0.00 ms
ScaleForm	0.26 ms	0.63 ms
RenderUIBillBoardRT	0.25 ms	0.63 ms
QSOVERLAY	0.03 ms	0.04 ms
Present	1.77 ms	5.54 ms

Game Status: 活力 150/150 背包 15/40 11 35

Location: 杭州: 落云滩 非安全区 1433,2141

Quest Log:

- 第十四回: 飞流翻浪现连环
- 百里激荡 翻浪水寨
- 消灭翻浪坞外国水匪
- 翻浪坞水匪 16/20
- 翻浪坞弓手 8/10
- 翻浪坞狂徒 5/5

Task Rewards:

- 翻浪坞水匪 16/20
- 翻浪坞弓手 8/10
- 翻浪坞狂徒 5/5

Character Info: qs7777 6088/6088 58

Local Reflection



Quarter Buffer渲染透明物体

- 大规模粒子像素填充是个大的瓶颈
- 很多粒子以低频信息为主



Quarter Buffer造成明显的锯齿

Full Resolution



Quarter Resolution



Bilateral Filter

- 一个补

- AMD

- 1

- NV C

- Nea

- 对于e
性插值



采用双向

Quarter Buffer性能数据

Frame: 1233227 Time: 1523.9 sso File: 0.0 MB

VolumeCloud	QuarterDepth	Particles	UpSample	Total
¼Buffer 关闭	0.0ms	2.5ms	0.0ms	2.5ms
¼Buffer 打开	0.05ms	0.8ms	0.15ms	1.0ms

Save 1.5ms!!!

内存显存优化方面

A	B	C	D	E	F
TextureName	TexMem	Width	Height	MipLevels	Format
.\Data\Scene\Texture\MipMapChain.dds	2796344	2048	2048	12	DXT1
Bone	786432	384	128	1	A32B32G32R32F
Bone	786432	384	128	1	A32B32G32R32F
Bone	786432	384	128	1	A32B32G32R32F
.\Data\Scene\Texture\water_rui_007_a.dds	349680	512	512	10	DXT5
data\Effects\WetNormal.dds	131200	512	512	1	DXT1
data\Effects\LightningMask.dds	131200	512	512	1	DXT1
.\Data\Scene\Texture\Distortion02.dds	131200	512	512	1	DXT1
Data\Scene\skybox\moon.dds	65664	256	256	1	DXT5
data\engine\AreaMap33.dds	54578	165	165	1	PF_A8L8
.\Data\Scene\Texture\shadow01.dds	22000	128	128	8	DXT5
.\Data\Scene\Texture\random.bmp	17464	128	128	1	G8
.\Data\Scene\Texture\Caustics_0.dds	11064	128	128	8	DXT1
.\Data\Scene\Texture\Caustics_1.dds	11064	128	128	8	DXT1
.\Data\Scene\Texture\Caustics_2.dds	11064	128	128	8	DXT1
.\Data\Scene\Texture\Caustics_3.dds	11064	128	128	8	DXT1
.\Data\Scene\Texture\Caustics_4.dds	11064	128	128	8	DXT1
.\Data\Scene\Texture\Caustics_5.dds	11064	128	128	8	DXT1
.\Data\Scene\Texture\Caustics_6.dds	11064	128	128	8	DXT1
.\Data\Scene\Texture\Caustics_7.dds	11064	128	128	8	DXT1

RenderTarget分配

- 采用Pool来分配
 - 共享RenderTarget
 - 管理RenderTarget生命周期
 - 根据名字来跟踪RenderTarget分配
 - GC

7e3 Buffer

- A2
- 7e

With pre-exposed color

20MB VM Saved



Visibility优化

- 采用Tag Visibility Test大幅提升了Visibility Test的效率(接近4倍)
- 采用Tag的Software Occlusion Culling，根据地形Height Map来裁剪看不见的物体，性能大幅提升
- 整合物件内包围盒功能，主城性能大幅提升
- Speed Tree采用Tag Occlusion Culling提升性能

Occlusion Debug View



九华关闭Occlusion测试结果



九华开启Occlusion测试结果



九华Occlusion Culling Debug View



九华数据比较

测试条件	Culling Total	Terrain List Parse	Mesh List Parse	Draw GBuffer	Total CPU	CPU Saved	
关闭Occlusion Culling	0.29ms	0.68ms	0.26ms	2.35ms	16.10ms	0	
开启Occlusion Culling	0.76ms	0.24ms	0.05ms	0.99ms	14.53ms	1.57ms	
测试条件	Triangles Total	Triangles Terrain	Triangles Static Mesh	Triangles Speed Tree	Triangles Saved	GPU Total	GPU Saved
关闭Occlusion Culling	1132884	129040	438958	518486	0	10.71ms	0
开启Occlusion Culling	515151	71968	193032	203795	617733	9.2ms	1.51ms
测试条件	DP Total	DP Terrain	DP Static Mesh	DP Speed Tree	DP Saved		
关闭Occlusion Culling	1198	430	341	105	0		
开启Occlusion Culling	608	123	88	83	590		

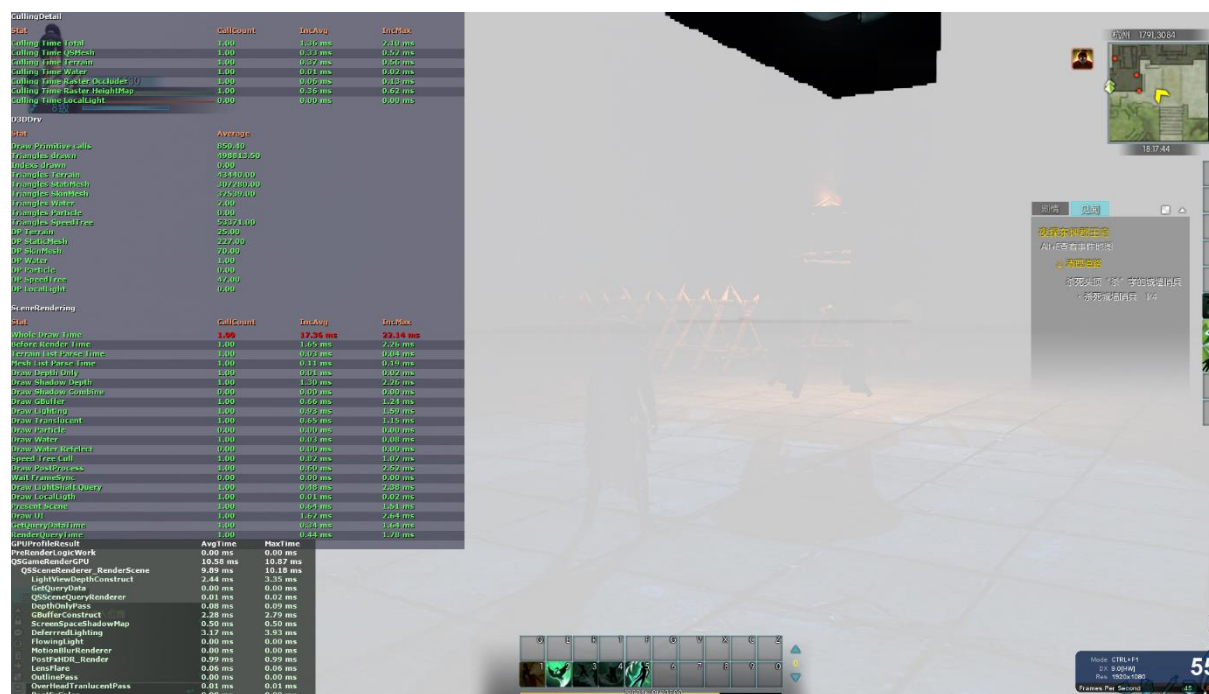
杭州主城关闭Occlusion Culling测试结果



杭州主城开启Occlusion Culling测试结果



杭州主城Occlusion Culling Debug View



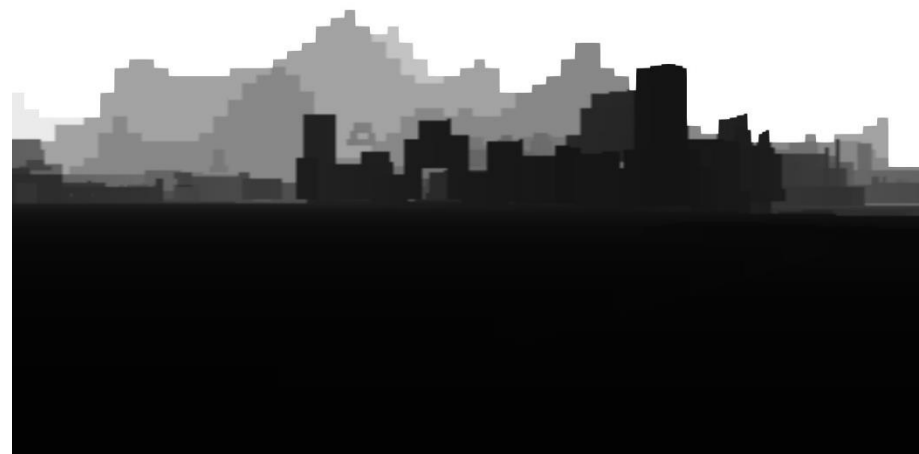
杭州主城数据比较

测试条件	Culling Total	Terrain List Parse		Mesh List Parse	Draw GBuffer	Total CPU	CPU Saved
关闭Occlusion Culling	0.51ms	0.61ms		0.78ms	3.53ms	21.91ms	0
开启Occlusion Culling	1.35ms	0.03ms		0.10ms	0.59ms	16.50ms	5.41ms
测试条件	Triangles Total	Triangles Terrain	Triangles Static Mesh	Triangles Speed Tree	Triangles Saved	GPU Total	GPU Saved
关闭Occlusion Culling	1546871	102128	952971	239556	0	13.92ms	0
开启Occlusion Culling	408263	33536	259931	41463	1138608	9.83ms	4.09ms
测试条件	DP Total	DP Terrain	DP Static Mesh	DP Speed Tree	DP Saved		
关闭Occlusion Culling	2225	417	832	77	0		
开启Occlusion Culling	764	23	192	43	1461		

Visibility优化

- 采用Tag Visibility Test大幅提升了Visibility Test的效率(接近4倍)
- 采用Tag的Software Occlusion Culling，根据地形Height Map来裁剪看不见的物体，性能大幅提升
- 整合物件内包围盒功能，主城性能大幅提升
- Speed Tree采用Tag Occlusion Culling提升性能

Occlusion Debug View



九华关闭Occlusion测试结果



九华开启Occlusion测试结果



九华Occlusion Culling Debug View



九华数据比较

测试条件	Culling Total	Terrain List Parse	Mesh List Parse	Draw GBuffer	Total CPU	CPU Saved	
关闭Occlusion Culling	0.29ms	0.68ms	0.26ms	2.35ms	16.10ms	0	
开启Occlusion Culling	0.76ms	0.24ms	0.05ms	0.99ms	14.53ms	1.57ms	
测试条件	Triangles Total	Triangles Terrain	Triangles Static Mesh	Triangles Speed Tree	Triangles Saved	GPU Total	GPU Saved
关闭Occlusion Culling	1132884	129040	438958	518486	0	10.71ms	0
开启Occlusion Culling	515151	71968	193032	203795	617733	9.2ms	1.51ms
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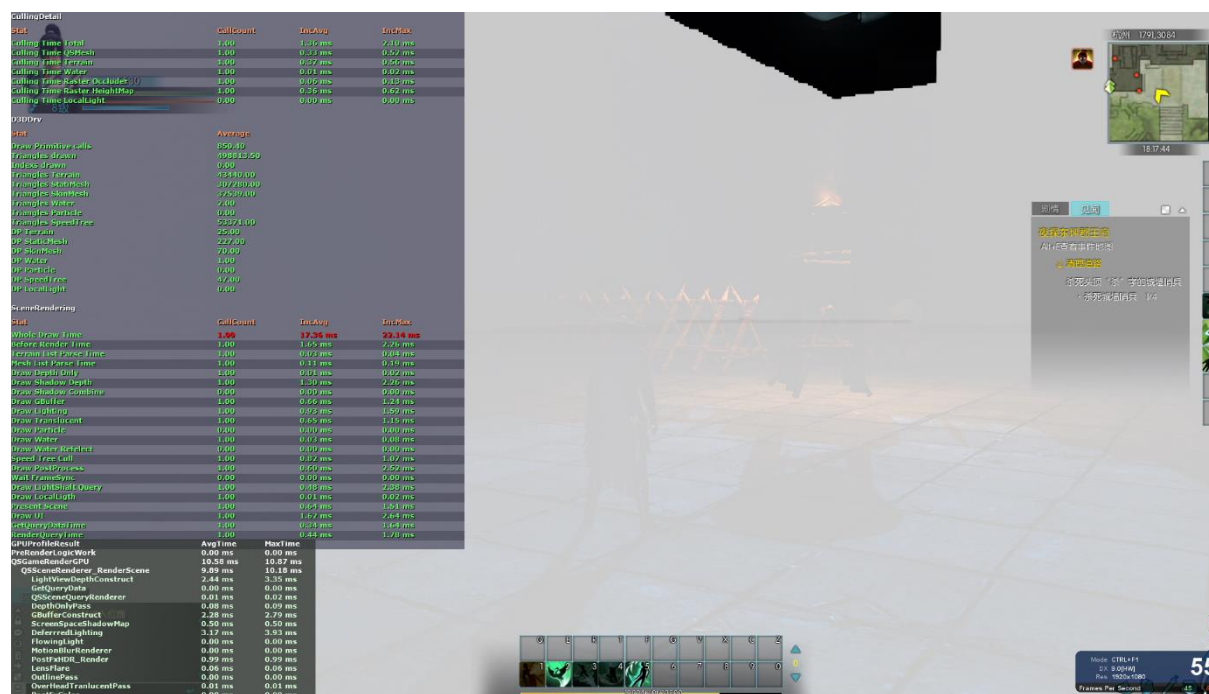
杭州主城关闭Occlusion Culling测试结果



杭州主城开启Occlusion Culling测试结果



杭州主城Occlusion Culling Debug View



杭州主城数据比较

测试条件	Culling Total	Terrain List Parse		Mesh List Parse	Draw GBuffer	Total CPU	CPU Saved
关闭Occlusion Culling	0.51ms	0.61ms		0.78ms	3.53ms	21.91ms	0
开启Occlusion Culling	1.35ms	0.03ms		0.10ms	0.59ms	16.50ms	5.41ms
测试条件	Triangles Total	Triangles Terrain	Triangles Static Mesh	Triangles Speed Tree	Triangles Saved	GPU Total	GPU Saved
关闭Occlusion Culling	1546871	102128	952971	239556	0	13.92ms	0
开启Occlusion Culling	408263	33536	259931	41463	1138608	9.83ms	4.09ms
测试条件	DP Total	DP Terrain	DP Static Mesh	DP Speed Tree	DP Saved		
关闭Occlusion Culling	2225	417	832	77	0		
开启Occlusion Culling	764	23	192	43	1461		

植被

- 提升Billboard细节
- Billboard和地表融合
- 远景树
- 植被镜像
- 优化手段



提升Billboard细节



植被Billboard和地表融合



远景树



植被镜像



优化植被性能

- 阴影优化
- CPU优化
- 数据优化
- Occlusion Culling
- 内存显存优化

阴影优化

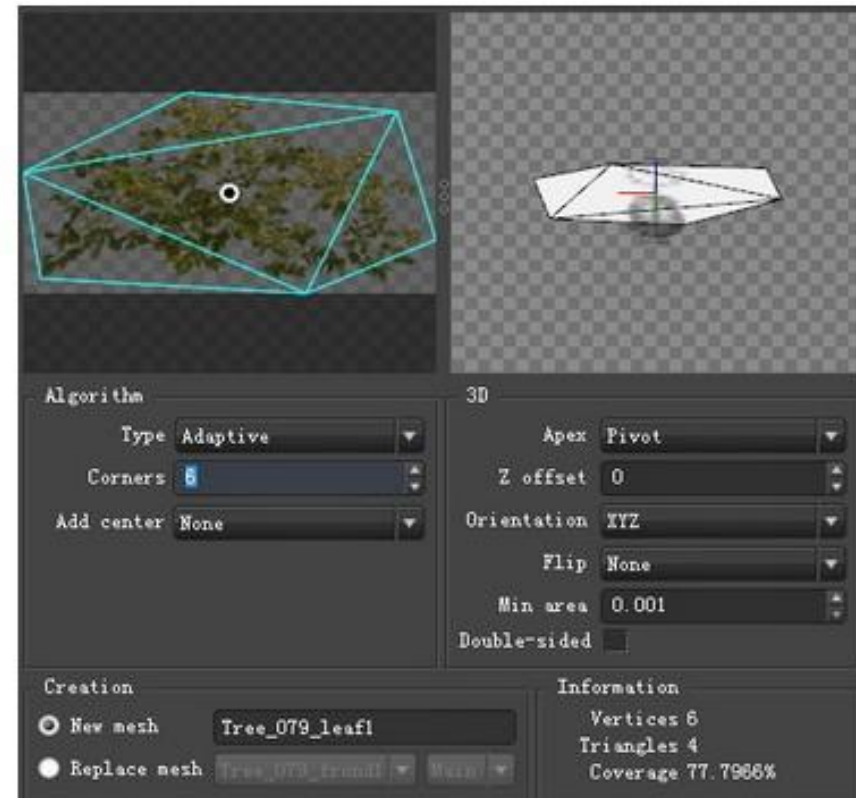
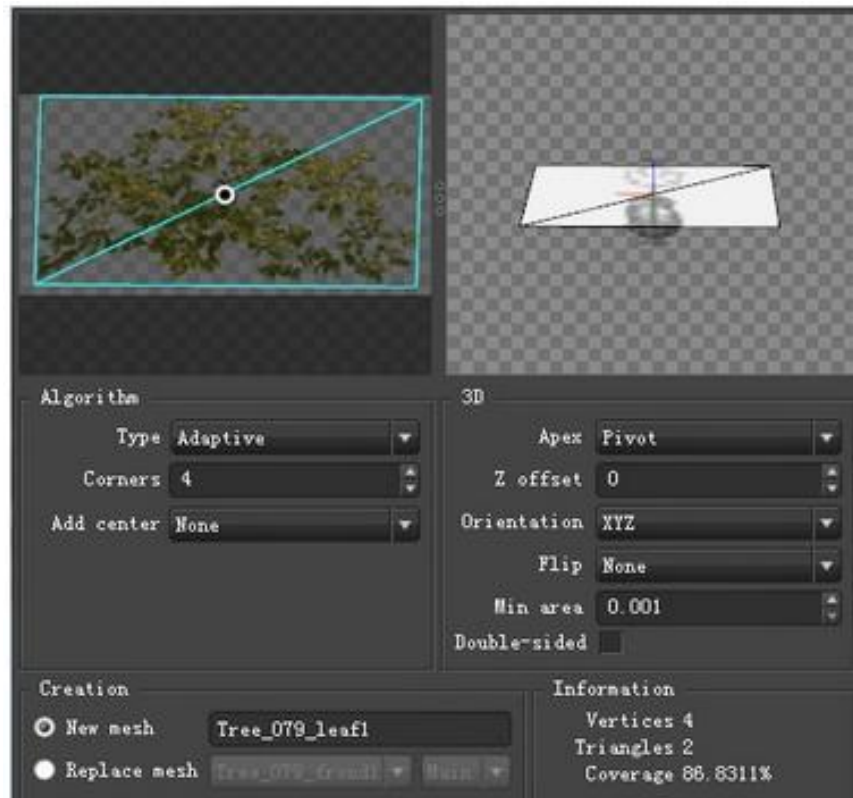
- 植
- 分
- 植



CPU优化

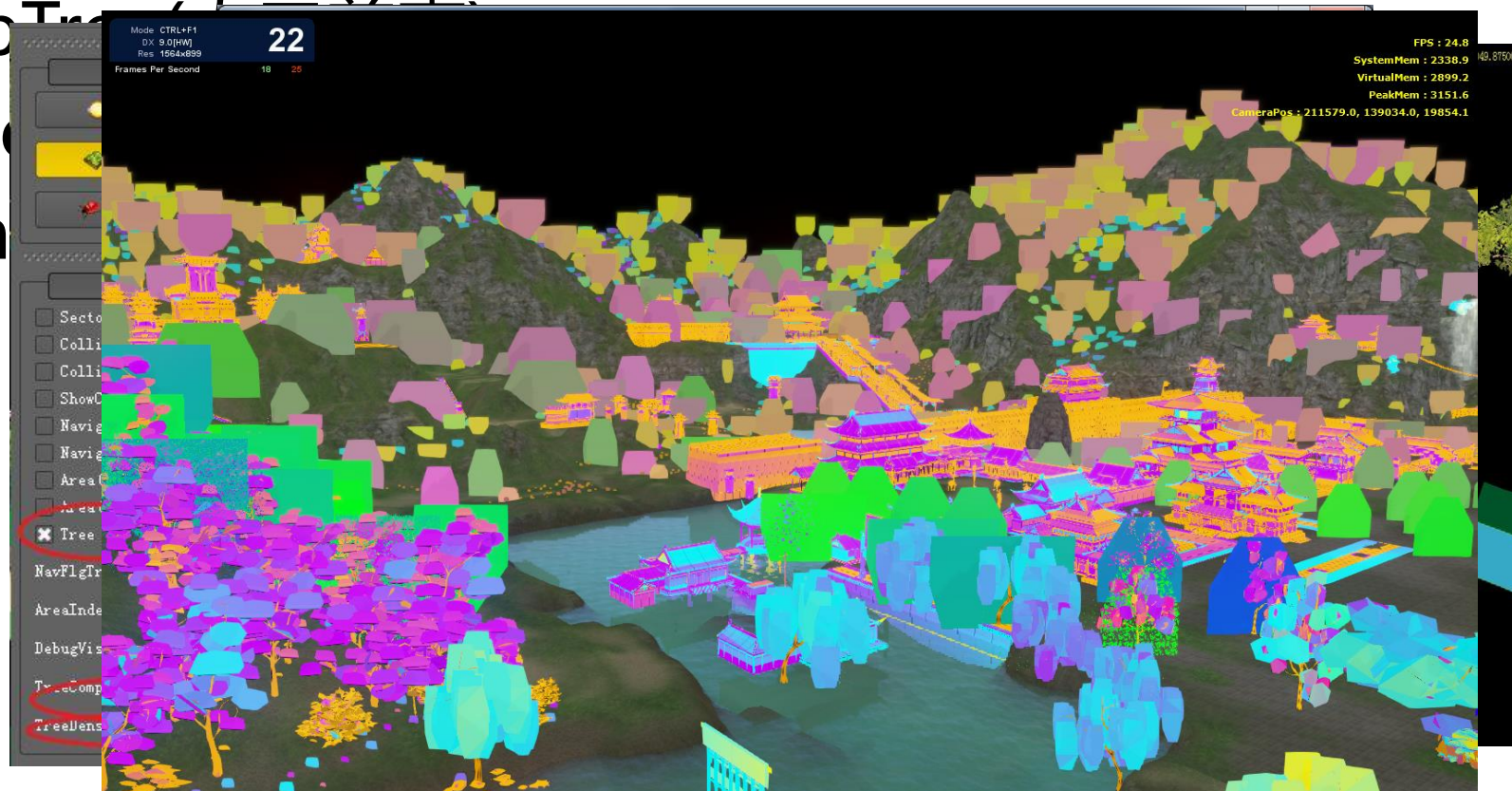
- FreeAlloc和快速分配释放树节点大幅降低顿卡
- Cache BuildInstanBuffer时间从7-8ms优化到0.5ms
- 启用编译器SSE优化

植被资源优化

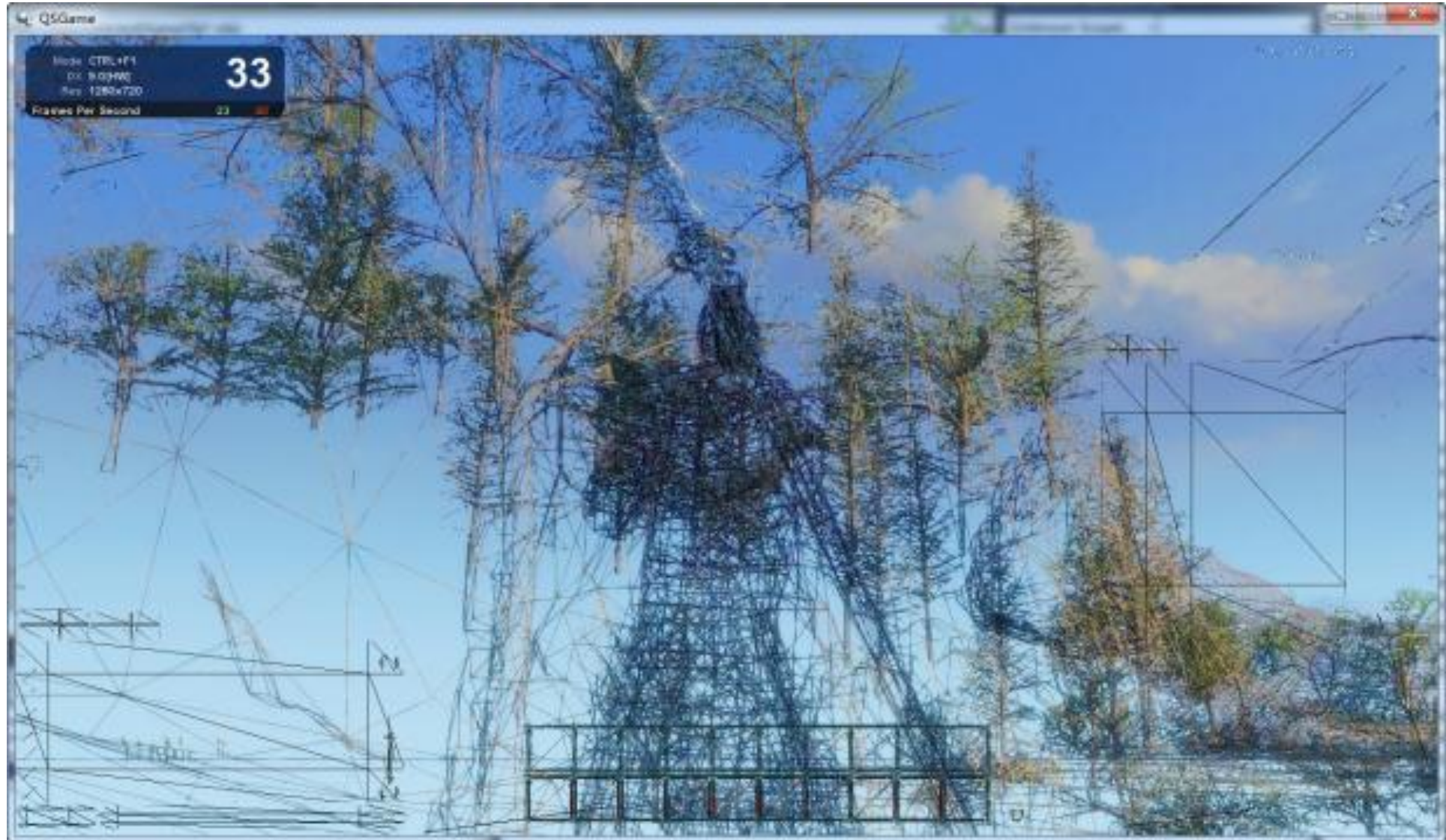


数据优化

- Dump Tree
- TreeCulling
- Mipmapping



Occlusion Culling



内存显存优化

- 使用DefaultPool分配贴图，减少内存使用
- Instance Buffer 压缩技术，浪费内存只有

Stat	MemUsedAvg	MemUsedMax	% of Total
Memory Texture	38.17 MB	38.17 MB	0.00% [0 Bytes]
Memory Allocator	30.88 MB	30.88 MB	0.00% [0 Bytes]
Memory Vertex	104.12 MB	104.12 MB	0.00% [0 Bytes]
Memory Index	1.52 MB	1.52 MB	0.00% [0 Bytes]

Stat	MemUsedAvg	MemUsedMax	% of Total
Memory Texture	37.82 MB	37.82 MB	0.00% [0 Bytes]
Memory Allocator	30.09 MB	30.09 MB	0.00% [0 Bytes]
Memory Vertex	11.45 MB	11.45 MB	0.00% [0 Bytes]
Memory Index	1.76 MB	1.76 MB	0.00% [0 Bytes]

远景树性能

无远景树GPU性能



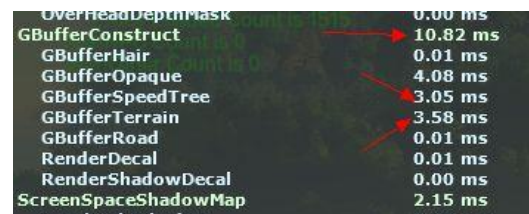
GBufferConstruct	10.37 ms
GBufferHair	0.01 ms
GBufferOpaque	4.17 ms
GBufferSpeedTree	1.44 ms
GBufferTerrain	4.65 ms
GBufferRoad	0.01 ms
RenderDecal	0.01 ms
RenderShadowDecal	0.00 ms

GPU 增加0.5ms

CPU增加0.5-1ms

树的数目从2-3000增加到5-9w，大幅提升场景丰富程度

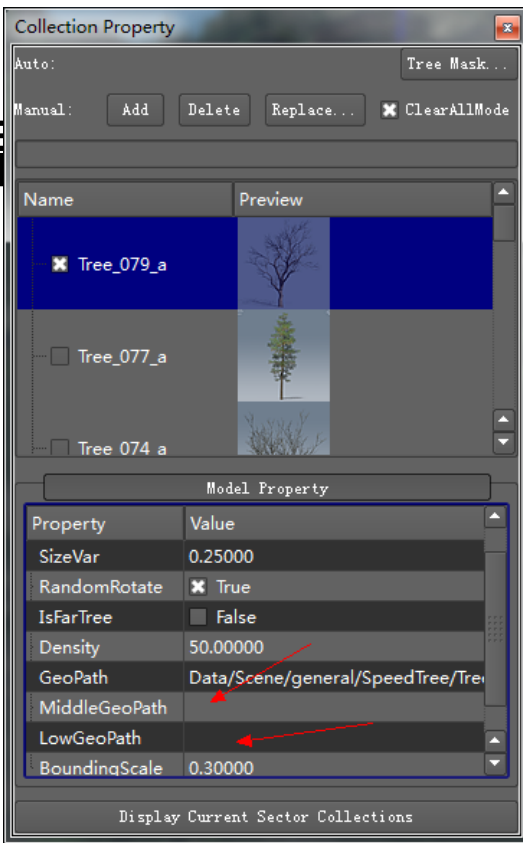
使用远景树GPU性能



OverHeadDepthMask	0.00 ms
GBufferConstruct	10.82 ms
GBufferHair	0.01 ms
GBufferOpaque	4.08 ms
GBufferSpeedTree	3.05 ms
GBufferTerrain	3.58 ms
GBufferRoad	0.01 ms
RenderDecal	0.01 ms
RenderShadowDecal	0.00 ms
ScreenSpaceShadowMap	2.15 ms

中低配优化

- 树的替代降低开销
- 贴图尺寸减半，贴图显
- 远景树数目减少
- 树显示距离减少



植被远景最后结果



花海

- 可
- 显
- 密
- 近
- 远



麦田

SpeedTreeDetail			
Stat	CallCount	IncAvg	IncMax
Tree Culling	1.00	0.77 ms	1.17 ms
UpdateInstanceBuffer	5.00	1.67 ms	2.81 ms
UpdateBillboardInstanceBuffer	0.00	0.00 ms	0.00 ms
AppendInstance	0.00	0.00 ms	0.00 ms
TreeSetExtent	1.00	0.07 ms	0.14 ms
TreeSetInstance	1.00	0.00 ms	0.00 ms
FineCull	1.00	0.11 ms	0.18 ms
BuildCellInstance	0.00	0.00 ms	0.00 ms
AllocTreeNode	0.00	0.00 ms	0.00 ms
FreeTreeNode	0.00	0.00 ms	0.00 ms
Grass Culling	GBufferConstruct	7.76 ms	10.47 ms
Grass Rough Cullin	GBufferHair	0.00 ms	0.00 ms
Grass Fine Culling	GBufferOpaque	0.66 ms	1.18 ms
Grass SetInstance	GBufferOpaqueInstancing	0.18 ms	0.54 ms
Grass SetExtent	Makeup_Render	0.00 ms	0.00 ms
Grass UpdateInsta	GBufferImpostor	0.03 ms	0.05 ms
GC Time	GBufferSpeedTree	6.52 ms	8.89 ms
CalcExtent	Render3dTree	6.28 ms	8.58 ms
SplitCell	RenderBillboard	0.22 ms	0.30 ms
	RenderGrass	0.02 ms	0.03 ms
Stat	GBufferTerrain	0.51 ms	0.83 ms
Grass Mem	GBufferRoad	0.02 ms	0.11 ms
Memory Texture	RenderDecal	0.00 ms	0.00 ms
Memory Allocator	RenderShadowDecal	0.00 ms	0.01 ms
Memory Vertex	ScreenSpaceShadowMan	0.65 ms	0.90 ms
Memory Instance		879.00 KB	879.00 KB
Memory Index		1.58 MB	1.58 MB
Memory PixelShader		0.00 Bytes	0.00 Bytes
Memory VertexShader		0.00 Bytes	0.00 Bytes
Stat	Average		
Grass Num	4.00		
Triangles Draw	829817.00		
Drwa Primitive Num	110.00		
Tree Total Num	22409.00		
Grass Total Num	460.00		
Tree/Grass Instance Num	59150.00		
Vest Cell Num	0.00		
Vest Triangles Num	0.00		

Impostor Rendering

- 产
- 基
- 天
- 实
- 性



基本思路

- Offline Texture Generate
- 相同物体共享同一个贴图
- Instance一次画完，每个物体是一个面片

天刀的需求

- 小物件的Entity不需要被Load
- 全自动Cook Impostor Texture
- Offline Impostor接管所有小物体的渲染
- 一个DP绘制所有的小物件

Impostor实战

• Co

• 扩
• 发

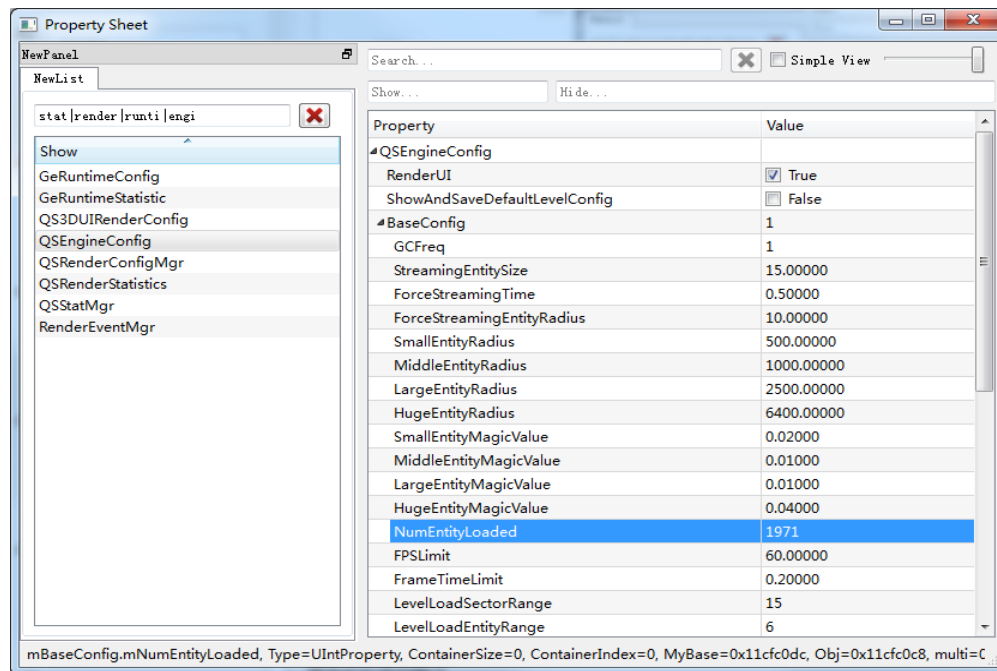


主城性能测试

- Entity数目
- 内存显存
- CPU时间
- GPU时间
- 显卡负载
- Culling
- 反射

Entity数目

- 2206下降到1971



CPU时间

- MeshListParse节省0.36ms
- Gbuffer节省0.65ms

Mesh List Parse Time	1.00	1.04 ms	1.56 ms
GBuffer Opaque	1.00	1.63 ms	2.70 ms
GBuffer Terrain	1.00	0.53 ms	0.88 ms
GBuffer SpeedTree	1.00	0.40 ms	0.59 ms

Mesh List Parse Time	1.00	1.40 ms	1.92 ms
GBuffer Opaque	1.00	2.28 ms	3.02 ms
GBuffer Terrain	1.00	0.51 ms	0.69 ms
GBuffer SpeedTree	1.00	0.38 ms	0.46 ms

GPU时间

- GBufferOpaque 共11个

GBufferConstruct	6.30 ms	9.01 ms
GBufferHair	0.00 ms	0.00 ms
GBufferOpaque	5.22 ms	7.57 ms
GBufferOpaqueInstancing	0.40 ms	0.54 ms
Makeup_Render	0.01 ms	0.01 ms
GBufferImpostor	0.00 ms	0.00 ms
GBufferSpeedTree	0.82 ms	1.10 ms
GBufferTerrain	0.25 ms	0.33 ms
GBufferRoad	0.00 ms	0.00 ms
RenderDecal	0.00 ms	0.00 ms
RenderShadowDecal	0.00 ms	0.00 ms

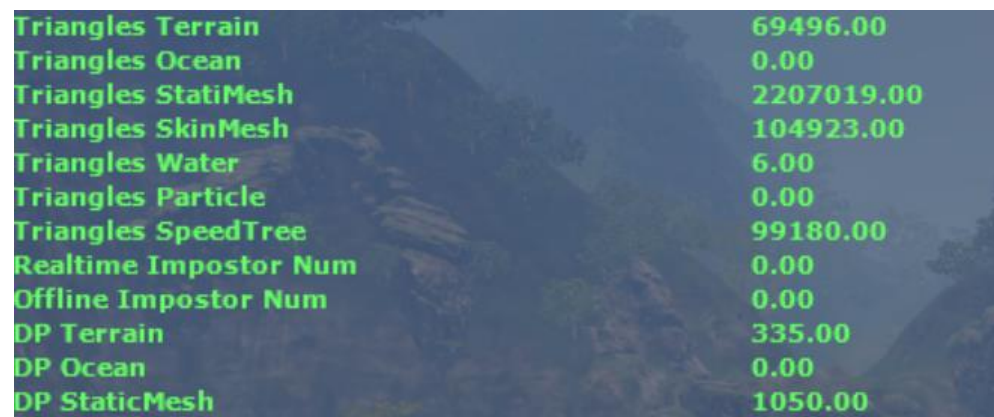
GBufferConstruct	4.96 ms	7.22 ms
GBufferHair	0.00 ms	0.00 ms
GBufferOpaque	3.77 ms	5.63 ms
GBufferOpaqueInstancing	0.41 ms	1.07 ms
Makeup_Render	0.01 ms	0.01 ms
GBufferImpostor	0.15 ms	0.22 ms
GBufferSpeedTree	0.81 ms	1.46 ms
GBufferTerrain	0.21 ms	0.29 ms
GBufferRoad	0.00 ms	0.00 ms
RenderDecal	0.00 ms	0.00 ms
RenderShadowDecal	0.00 ms	0.02 ms

显卡负载



A screenshot of a GPU load monitoring interface. It displays a list of assets and their corresponding triangle counts. Two red arrows point to the 'Triangles StatiMesh' and 'DP StaticMesh' rows, highlighting them as significant components of the load.

Triangles Terrain	76080.00
Triangles Ocean	0.00
Triangles StatiMesh	1723201.00
Triangles SkinMesh	112347.00
Triangles Water	6.00
Triangles Particle	0.00
Triangles SpeedTree	97660.00
Realtime Impostor Num	0.00
Offline Impostor Num	4180.00
DP Terrain	351.00
DP Ocean	0.00
DP StaticMesh	791.00



A second screenshot of the same GPU load monitoring interface, showing a different set of values. The 'Triangles StatiMesh' value has increased significantly, and 'DP StaticMesh' has also increased.

Triangles Terrain	69496.00
Triangles Ocean	0.00
Triangles StatiMesh	2207019.00
Triangles SkinMesh	104923.00
Triangles Water	6.00
Triangles Particle	0.00
Triangles SpeedTree	99180.00
Realtime Impostor Num	0.00
Offline Impostor Num	0.00
DP Terrain	335.00
DP Ocean	0.00
DP StaticMesh	1050.00

Culling

- Impostor做了额外的Visibility需要1ms
- 远处的Entity不Load
- Raster Obb的时间从2ms到0.5ms!!!
- 基本持平

反射

- CPU时间节省0.35s
- GPU时间节省0.35s

TranslucencyRender	2.98 ms	4.74 ms	
ResidueEffect	0.00 ms	0.00 ms	
RenderWaterAndTranslucency	2.98 ms	4.74 ms	
UpdateWave	0.00 ms	0.01 ms	4.25 ms
InvFFT	0.07 ms	0.09 ms	2.63 ms
RestoreRefraction	0.38 ms	0.51 ms	0.78 ms
RenderWaterSelf	0.00 ms	0.00 ms	0.32 ms
RenderWaterSelf	0.00 ms	0.00 ms	1.49 ms
WaterRenderRef	2.48 ms	4.07 ms	0.26 ms
RenderWaterSelf	0.02 ms	0.03 ms	0.00 ms
SourceCurrentDraw Impostor Refelect	1.00	0.00 ms	0.00 ms

Water Refelect		1.00	3.04 ms	4.41 ms
WaterRef Lis	TranslucencyRender	2.55 ms	3.90 ms	2.77 ms
WaterRef Op	ResidueEffect	0.00 ms	0.00 ms	0.64 ms
WaterRef Te	RenderWaterAndTranslucency	2.55 ms	3.90 ms	0.64 ms
Draw Opaqu	UpdateWave	0.00 ms	0.00 ms	1.36 ms
Draw Terrain	InvFFT	0.06 ms	0.08 ms	0.29 ms
SourceCurre	RestoreRefraction	0.34 ms	0.48 ms	0.04 ms
	RenderWaterSelf	0.00 ms	0.00 ms	
	RenderWaterSelf	0.00 ms	0.00 ms	
	WaterRenderRef	2.10 ms	3.26 ms	
	RenderWaterSelf	0.02 ms	0.03 ms	

反射的隐藏Buff

- 另类思维
 - 反射和主Camera一起做裁剪
- 结果
 - 反射和主Camera共享Culling结果
 - 反射和主Camera共享Instance Buffer的填充
 - 反射+主Camera变成2个并集，平视时性能double☺
 - 全场景反射Impostor
- 背后的哲学
 - 求同存异

Offline Impostor小结

- 增加了丰富的远景
- 绘制的东西多了，性能反而还更好
- 质量稍差，距离远配上雾完全可以接受
- 经受了三测的洗礼

数据优化

- 产品导向
- 合适资源的定义
- 玩法聚集区域深入分析
- 产出非常不错

数据优化

- 混合纹理岩石
- 模型LOD
- 内包围盒
- 植被数据优化

混合纹理岩石

• 实

•
•

• 效

•
•
•

岩石优化	三角形数目	GPU时间	FPS
优化前	220w	13ms	22
优化后	63w	5.1ms	32

模型优化

- LOD

- 大部分模型都有lod,由于lod切换pop未启用
- 从东越的案例得到很大的震惊，下定决启用lod
- 成功解决lod切换(screen door)

- 毛发占用了过多的三角形，并且双面

- 简化，远处强制CW

- 双面

- 模型只有一小部分需要双面

- AlphaTest

- 模型只有一小部分需要alphatest，拆分模型

内包围盒

- 对主
- 主坡
- 野外
- 有大



植被数据优化

- 简
- 降
- 减



数据优化结果

- 先解决性能问题
- 给项目组信心
- 成功经验推广

地图名	坐标	优化前 FPS	优化后 FPS	
巴蜀	巴蜀：洞悉林 1282,902	28	33	
杭州	杭州：钱塘门 2084,1325	57	59	
	杭州：杭州城 2162,1185	36	41	
	杭州：杭州城 2011,923	46	52	
	杭州：杭州城 2012,1259	28	35	
	杭州：红衣林 1801,2773	34	38	
开封	开封：开封 1997,1041	35	36	
	开封：皇城 2357,1173	33	39	
	开封：尧山 1515,849	22	36	
	开封：飞霞渡 1126,1250	28	36	天下镖
	开封：尧山 1292,1001	27	34	天下镖
	开封：西水关 1595,1258	34	44	
	云贵：桐梓湖 1473,2502	25	30	
徐海	徐海：平阳驿站 1460,2121	27	30	
	徐海：平阳驿站 1176,1839	30	33	
荆湖	荆湖：聚贤团 1420,1114	32	34	
	荆湖：聚贤团 993,1018	35	36	