3D Game Programming
Game engine

Ming-Te Chi
Department of Computer Science,
National Chengchi University

Outline

- Game Development
  - Indie Game – Braid
  - AAA Game – Gear of War
- What is in a game?
- UDK (Unreal Develop kit)
  - Brush
  - lighting, material, volume, and physics

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開發成本?

	人數	月	成本
學期專案			
小型獨立遊戲開發			
大型AAA遊戲			

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群眾募資

- 國內數位遊戲募資平均約30萬NTD左右
- 但募資通常是已經開發到一定程度 再透過募資補足部份資金和增加曝光度

資料來源
[2019 TGDF] 群眾集資大亂鬥，遊戲集資顧問經驗分享 **(**鄭祤呈**)**
https://youtu.be/MMv7oYdunyM?t=936

多媒體圖形技術組

游戏开发团队(V2)

- 项目部
  - Head of Studio 工作室总监
  - Creative director 创意总监（制作人）
  - Director of product 项目总监（企划总监）
    - Manager of Product 项目经理（各部门都有）
- 编剧部
  - Written by 编剧
    - 叙事编剧
    - 对白编剧
    - 叙事分镜（脚本）
    - 叙事镜头导演
- 设计部（策划）
  - Design Director 设计总监（策划总监）
  - Systems design 系统设计
  - Level design 关卡设计
  - Combat design 战斗系统设计
  - Skill design 技能设计
  - Numerical design 数值设计
  - Gameplay animation design 游戏动画设计
- 程序部
  - Technical director 技术总监
  - Gameplay programming 游戏编程
  - Engine programming 引擎编程
    - 可能是一个单独团队
  - Tools programming 工具编程
  - Optimization 优化
  - Outsourcing 外包对接
- 团队运营
  - 总经办
  - 信息技术
  - 行政
  - 财务
- 美术部
  - Art Director 美术总监
  - Technical Art 技术美术
  - Concept art 概念美术（原画）
  - Character design 角色美术
    - 建模
    - 贴图
    - 骨骼绑定
  - Environment design 场景美术（重点）
    - 建模
    - 贴图
    - 地编
  - Visual effects 特效
  - Gameplay Animation 游戏动画
    - 动作捕捉
  - Lighting 灯光
  - Render 渲染
  - Camera 镜头
  - UI 交互界面
  - Outsourcing 外包对接
- 音乐音效部
  - Music producers 音乐制作人
    - 演奏团队
  - Music editing 音乐编辑
    - 混音
    - 录音师
  - Sound Design 音效制作
    - 音效编辑
  - Dialog coordinator 对白组织员
- CG动画部
  - Animation director 动画导演
  - Narrative animation 动画分镜
  - Outsourcing 外包对接
- Quality Assurance 质保部
  - QA Leader QA组长（重要）
  - QA grup QA人员
  - QA analysts QA分析
  - QA manager QA管理经理

发行团队

网游：运营团队

MEDIA

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HOW TO PROGRAM INDEPENDENT GAMES

Jonathan Blow

2011

摘自 https://igdshare.org/content/jonathan-blow-how-program-independent-games

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Braid (2008)

- 2005-2008 (42m)
- 221 個 C++ source，238 個 C++ header，3 個 C source，
- 20 個 HLSL source，
- 12k 行的註解與 90k 行的程式碼
- 200,000美元

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Review process

In Xbox Live Arcade

1. 512 MB RAM only 而且不能全用；它的 3 核 CPU 是 in-order 架構的；File System 因為安全性設計，速度也不快。
2. 遊戲審核 fps drop 容忍範圍很小；不能有 crash，讀取時間也設限。
3. "Soak Test"，遊戲要跑滿整整 3 天（以 60fps 換算成 frame 數的話要跑超過 15M 幅），簡單說你每個 frame 有 4 Bytes 的 memory leak 的話就絕對無法通過遊戲審核。

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程式效率最佳化

- 80/20 法則
  - Braid 中 90k 行的程式大約只有 6k 行是 performance-sensitive 。
- 真的該最佳化的是「你在每個程式實作上所耗用的生命」

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GAME DEVELOPMENT

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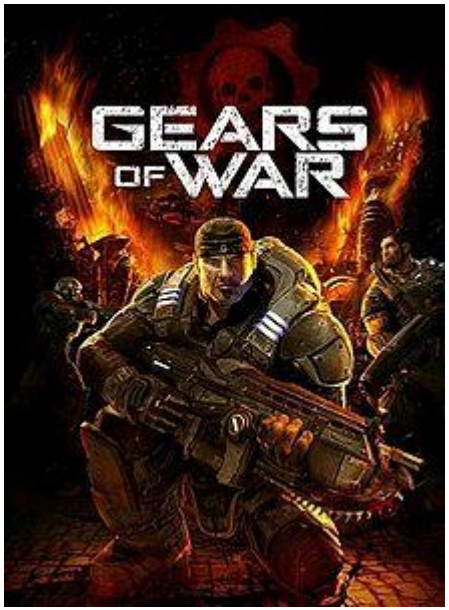
Game Development: Gears of War (2006)

- Resources
  - ~10 programmers
  - ~20 artists
  - ~24 month development cycle
  - ~$10M budget
- Software Dependencies
  - 1 middleware game engine
  - ~20 middleware libraries
  - OS graphics APIs, sound, input, etc



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Software Dependencies

Gears of War
Gameplay Code
~250,000 lines C++, script code

Unreal Engine 3
Middleware Game Engine
~250,000 lines C++ code

DirectX Graphics

OpenAL Audio

Ogg Vorbis Music Codec

Speex Speech Codec

wx Widgets Window Library

ZLib Data Compr-ession

…

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Game Development: Platforms

- The typical Unreal Engine 3 game will ship on:
  - Xbox 360
  - PlayStation 3
  - Windows
- Some will also ship on:
  - Linux
  - MacOS

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What is in a game?

The obvious:

- Rendering
- Pixel shading
- Physics simulation, collision detection
- Game world simulation
- Artificial intelligence, path finding

But it is not just fun and games:

- Data persistence with versioning, streaming
- Distributed Computing (multiplayer game simulation)
- Visual content authoring tools
- Scripting and compiler technology
- User interfaces

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Three Kinds of Code

- Gameplay Simulation
- Numeric Computation
- Shading

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Gameplay Simulation

- Models the state of the game world as interacting objects evolve over time
- High-level, object-oriented code
- Written in C++ or scripting language
- Imperative programming style
- Usually garbage-collected

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Gameplay Simulation – The Numbers

- 30-60 updates (frames) per second
- ~1000 distinct gameplay classes
  - Contain imperative state
  - Contain member functions
  - Highly dynamic
- ~10,000 active gameplay objects
- Each time a gameplay object is updated, it typically touches 5-10 other objects

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Numeric Computation

- Algorithms:
  - Scene graph traversal
  - Physics simulation
  - Collision Detection
  - Path Finding
  - Sound Propagation
- Low-level, high-performance code
- Written in C++ with SIMD intrinsics
- Essentially functional
  - Transforms a small input data set to a small output data set, making use of large constant data structures.

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Shading

- Generates pixel and vertex attributes
- Written in HLSL/CG shading language
- Runs on the GPU
- Inherently data-parallel
  - Control flow is statically known
  - "Embarassingly Parallel"
  - Current GPU's are 16-wide to 48-wide!

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Shading in HLSL

xacc-ide

File Edit View Project Tools Window Help

test.fx

```
//pixel shader
float backProjectionCut: register(c2);
float Ka: register(c3);
float Kd: register(c4);
float Ks: register(c5);
float4 modelColor: register(c0);
float shadowBias: register(c1);

sampler ShadowMap: register(s0);
sampler SpotLight: register(s1);

float4 main(float3 normal: TEXCOORD0,
            float3 lightVec: TEXCOORD1,
            float3 viewVec: TEXCOORD2,
            float4 shadowCrd: TEXCOORD3) : COLOR
{
   normal = normalize(normal);
   // Radial distance
   float depth = length(lightVec);
   // Normalizes light vector
   lightVec /= depth;

   // Standard lighting
   float diffuse = saturate(dot(lightVec, normal));
   float specular = pow(saturate(dot(reflect(-normalize(viewVec), normal), lightVec)), 16);

   // The depth of the fragment closest to the light
   float shadowMap = tex2Dproj(ShadowMap, shadowCrd);
   // A spot image of the spotlight
   float spotLight = tex2Dproj(SpotLight, shadowCrd);
   // If the depth is larger than the stored depth, this fragment
   // is not the closest to the light, that is we are in shadow.
   // Otherwise, we're lit. Add a bias to avoid precision issues.
   float shadow = (depth < shadowMap + shadowBias);
```

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Shading – The Numbers

- Game runs at 30 FPS @ 1280x720p
- ~5,000 visible objects
- ~10M pixels rendered per frame
  - Per-pixel lighting and shadowing requires multiple rendering passes per object and per-light
- Typical pixel shader is ~100 instructions long
- Shader FPU’s are 4-wide SIMD
- ~500 GFLOPS compute power

Three Kinds of Code

	Game Simulation	Numeric Computation	Shading
Languages	C++, Scripting	C++	CG, HLSL
CPU Budget	10%	90%	n/a
Lines of Code	250,000	250,000	10,000
FPU Usage	0.5 GFLOPS	5 GFLOPS	500 GFLOPS

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What are the hard problems?

- Performance
  - When updating 10,000 objects at 60 FPS, everything is performance-sensitive
- Modularity
  - Very important with ~10-20 middleware libraries per game
- Reliability
  - Error-prone language / type system leads to wasted effort finding trivial bugs
  - Significantly impacts productivity
- Concurrency
  - Hardware supports 6-8 threads
  - C++ is ill-equipped for concurrency

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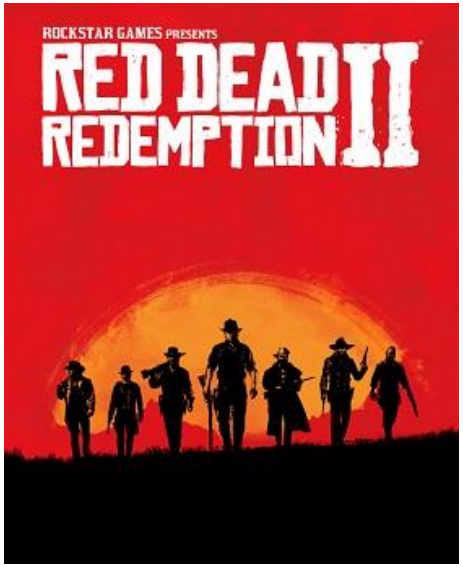
Red Dead Redemption 2 (2018)

- Seven years
- a team as high as 1,000 developers, artists, designers, writers, and more,
- the average Rockstar salary and associated healthcare costs for the company are about $100,000 a year.
- 644.2 million



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Cyberpunk 2077 (2020)

- 2014公佈demo
- PC/PS/XBOX 跨次世代
- 多語言配音
- 發售首日，CD Projeck宣布遊戲全平台預售已達800萬份，並且發售首日已經成功收回了遊戲的開發成本。
- 開發成本1億歐元

CD PROJEKT®

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GTA 6 (2025?)

- $1 billion and $2 billion

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GAME ENGINE

Unreal Development

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UDK

- UDK *is* Unreal Engine 3 – a complete professional development framework.

- Unreal Engine 3 has been used by game developers, researchers, television studios, machinima directors, artists and students.

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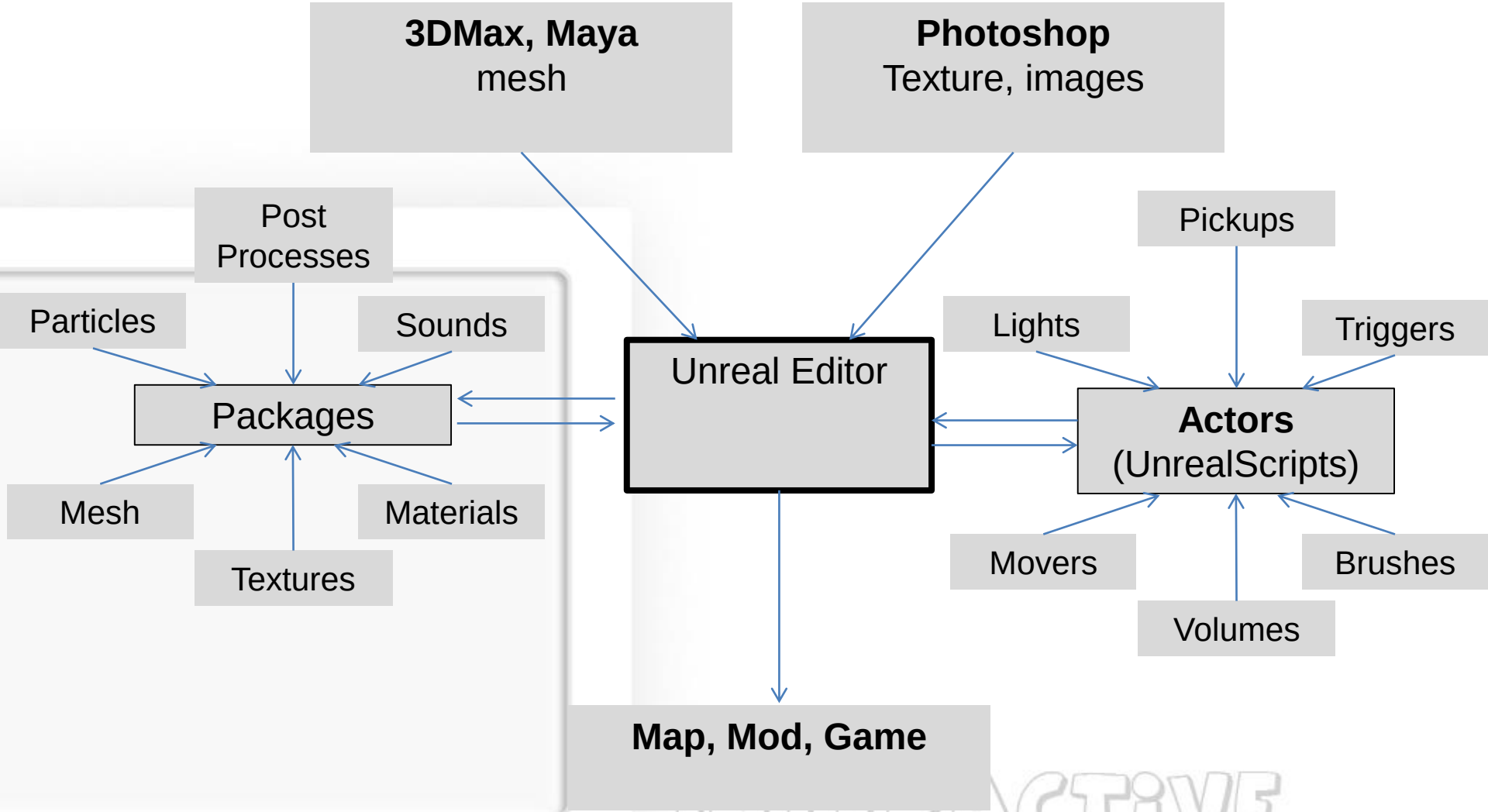
Workflow



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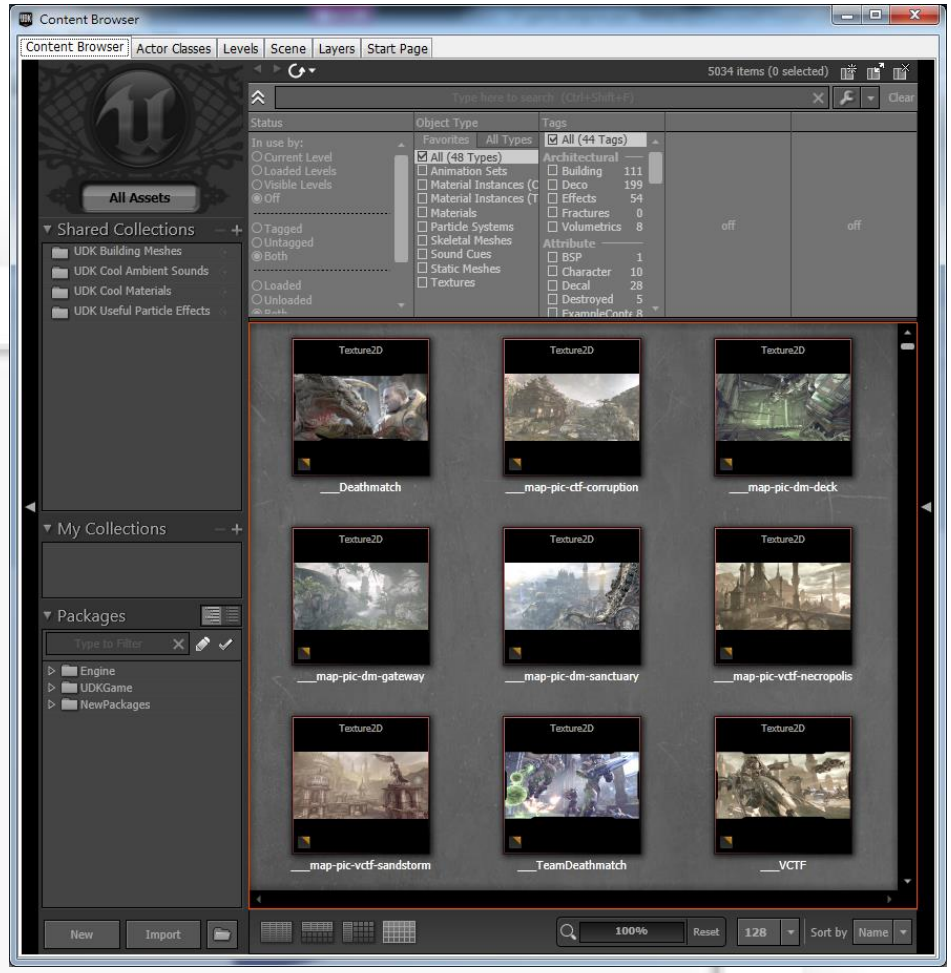
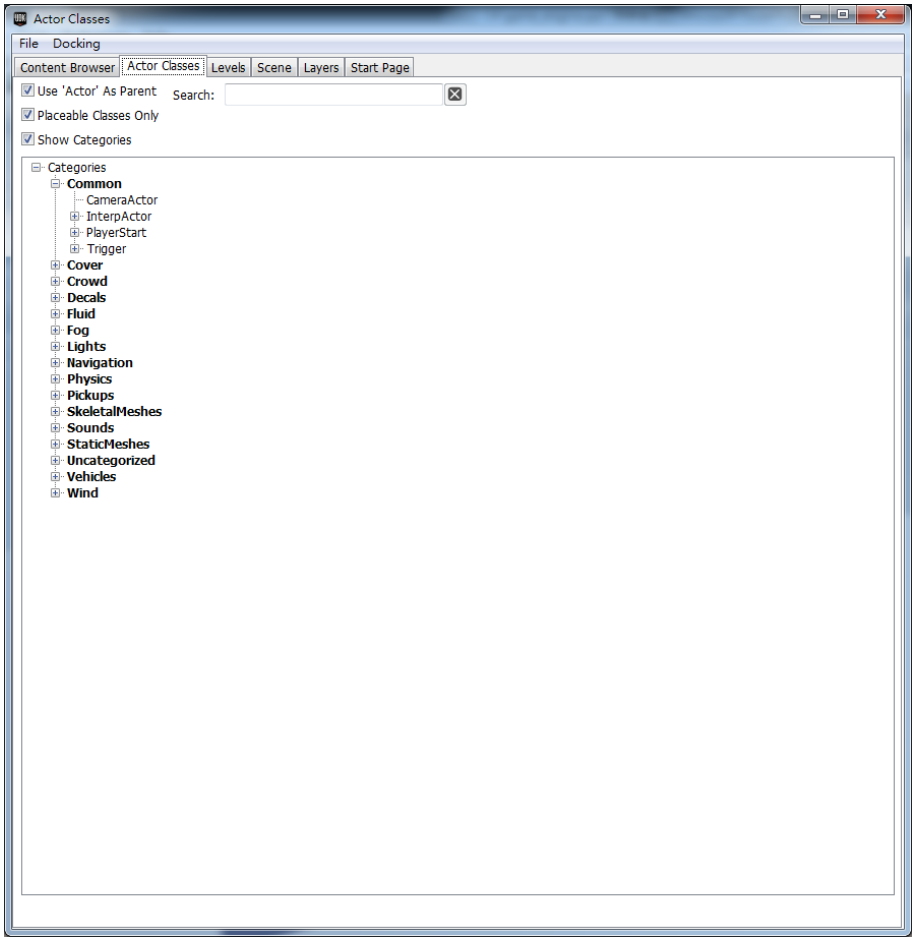


Packages



Actor Class

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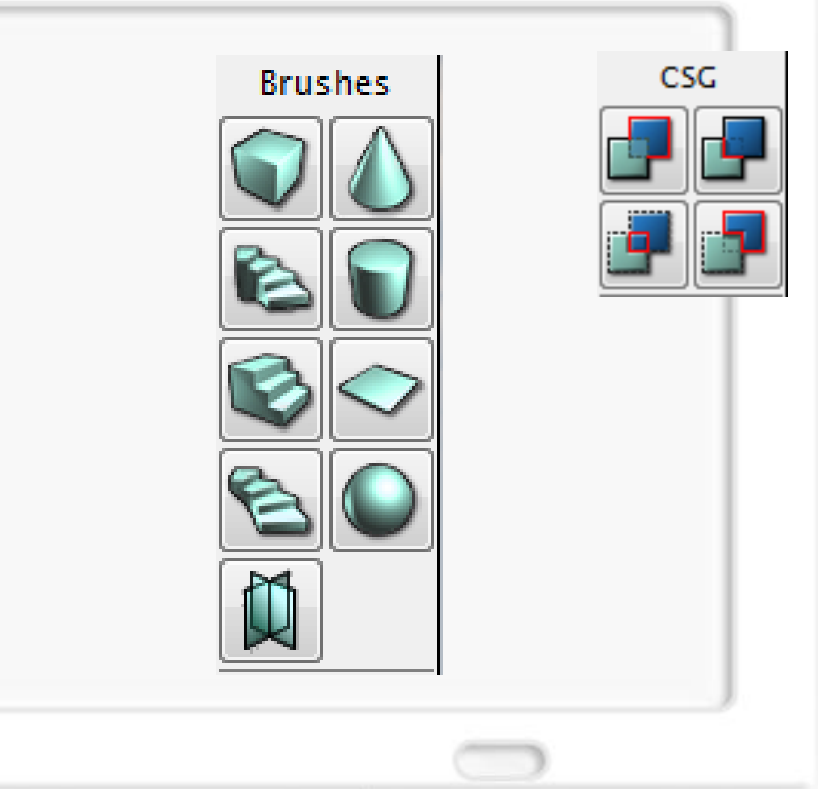
BSP - Brush

- BSP Brush define primary surface
- Binary Space Partition



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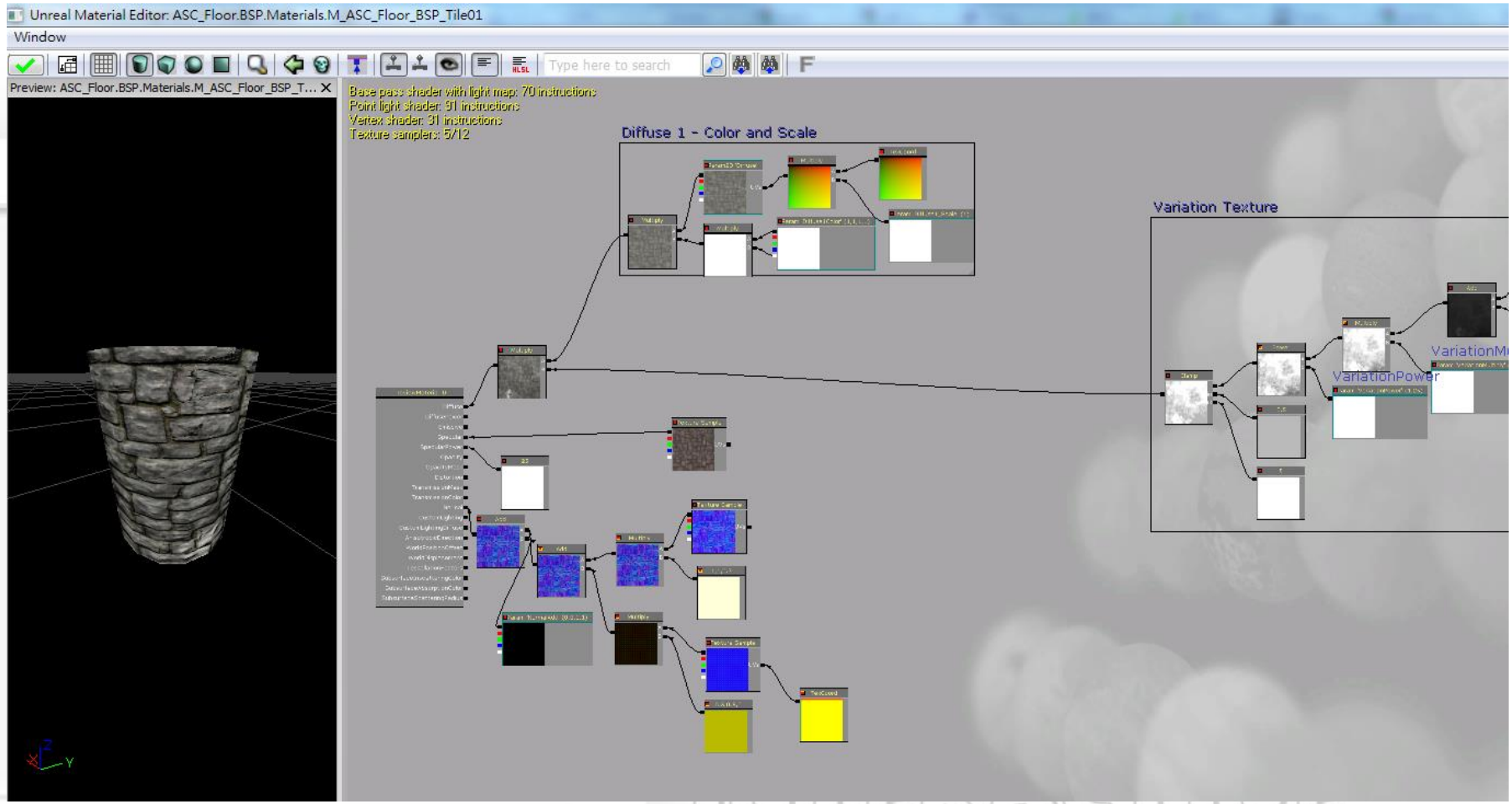
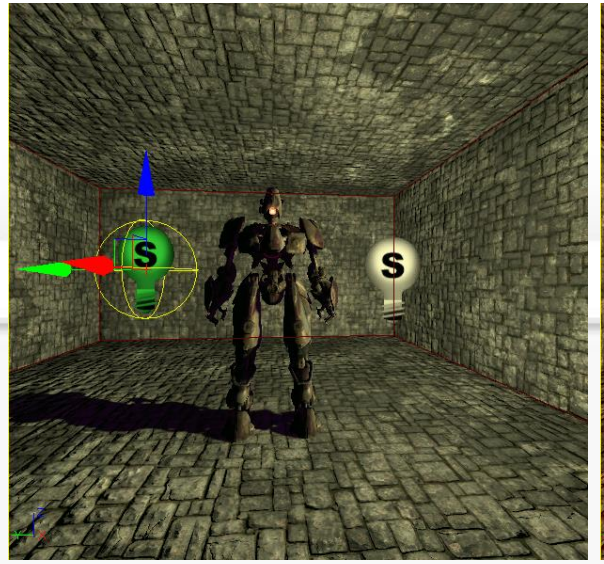
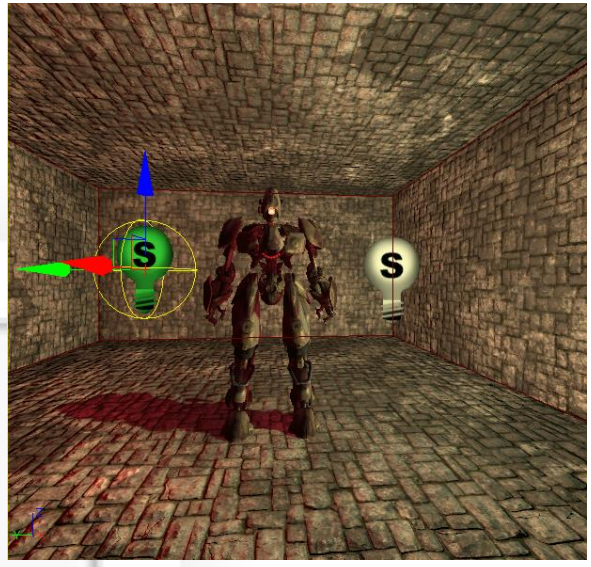
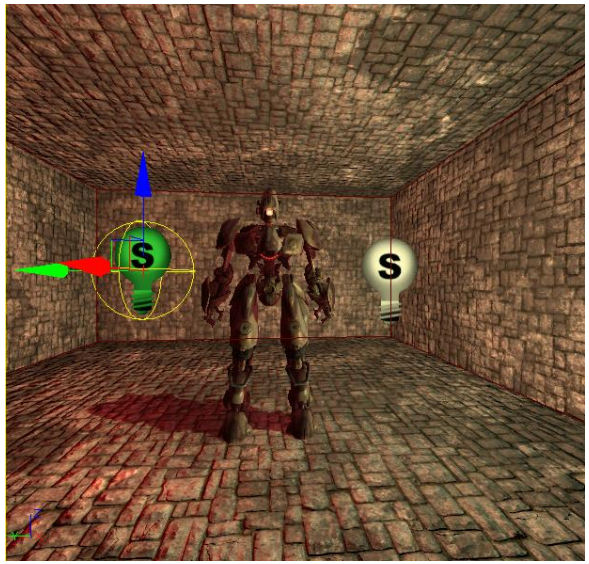
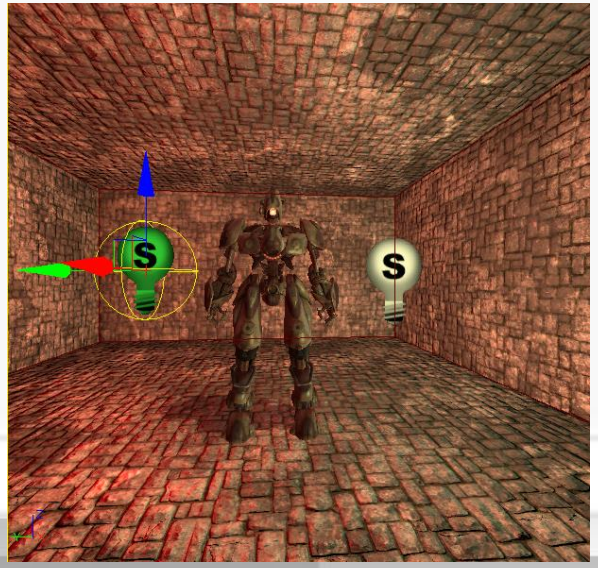
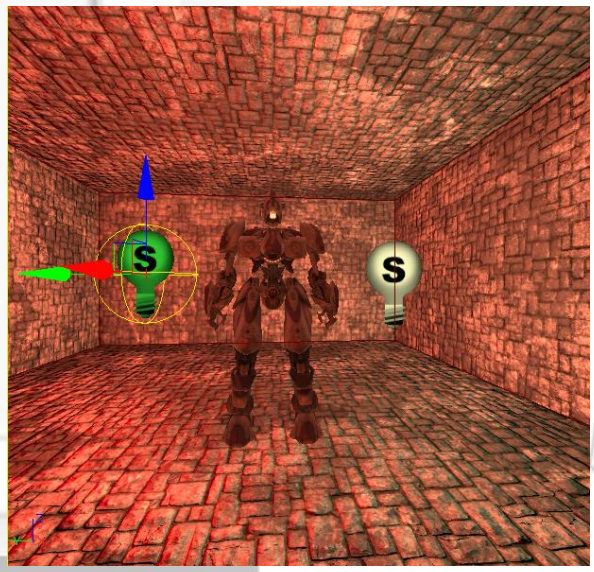
Material


Unreal Material Editor: ASC_Floor.BSP.Materials.M_ASC_Floor_BSP_Tile01
Window
Type here to search
Preview: ASC_Floor.BSP.Materials.M_ASC_Floor_BSP_T...
Base pass shader with light map: 70 instructions
Point light shader: 91 instructions
Vertex shader: 31 instructions
Texture samplers: 5/12
Diffuse 1 - Color and Scale
Variation Texture
VariationPower

Lighting

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Volume

Gravity Volume

1. Create a Sphere Brush
   RMC -> "Sphere" -> (radius: 64, Tesse: 2) -> Close
2. Add a Physics Volume
   Move Bursh to Corner
   RMC(Add Volume) -> Gravity Volume
   F4 -> (Zone-Velocity : 150)
3. Add a Brush
   Ctrl + A:
4. Build Light:

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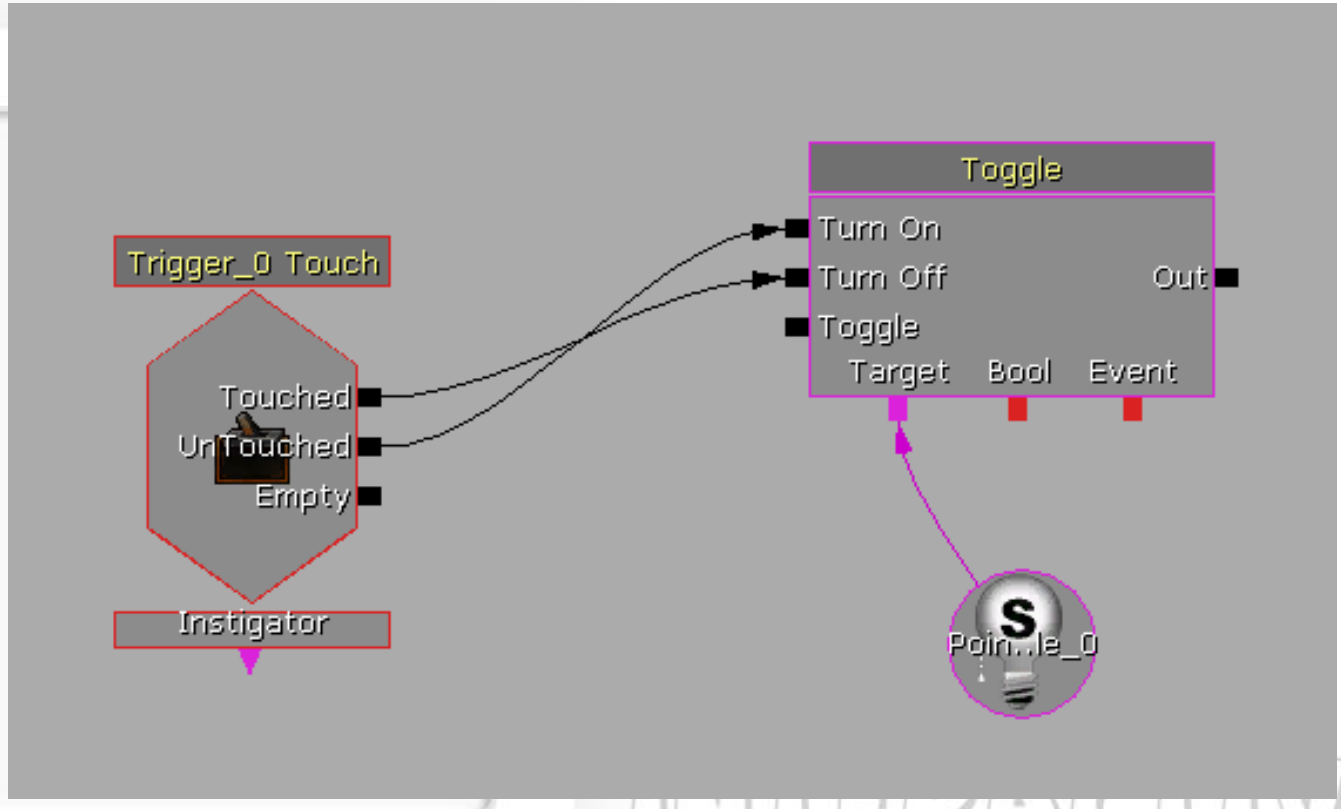
Kismet

- Visual Scripting System



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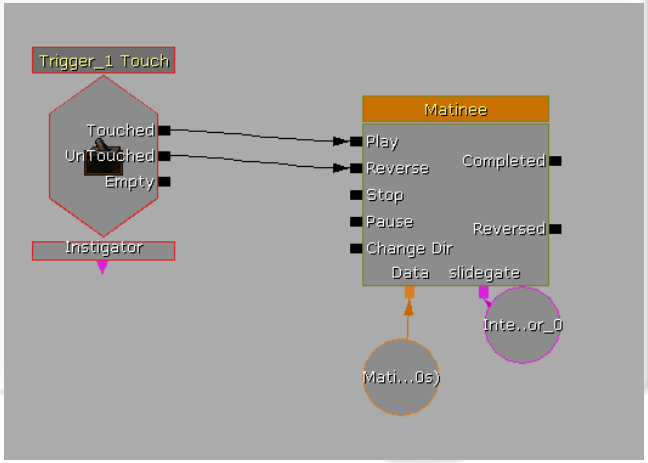
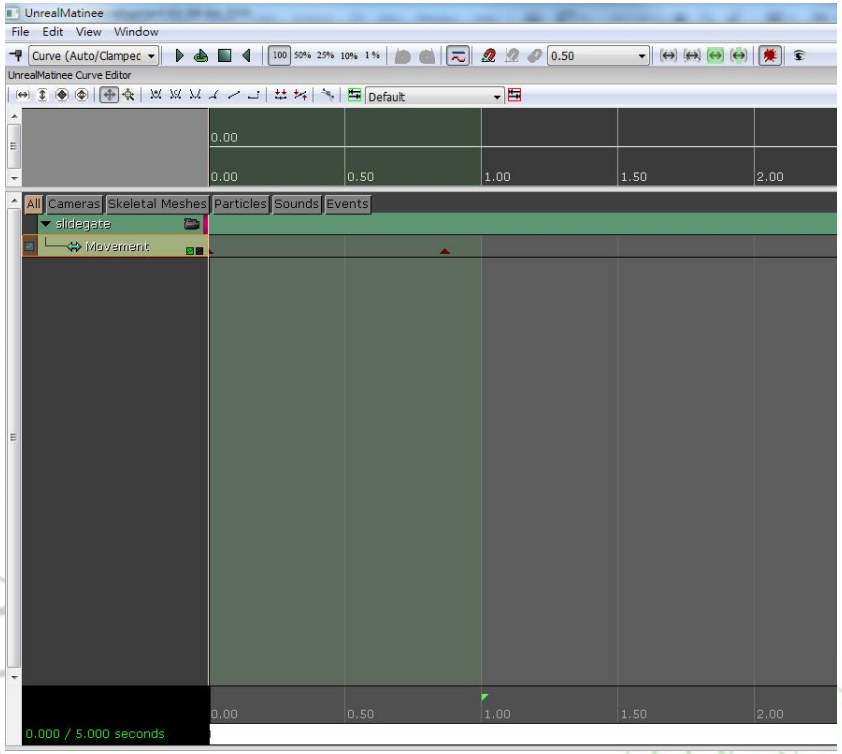
Matinee

- A scene animation tool that brings your game to life, and allows you to create in-game cinematic.





Physics

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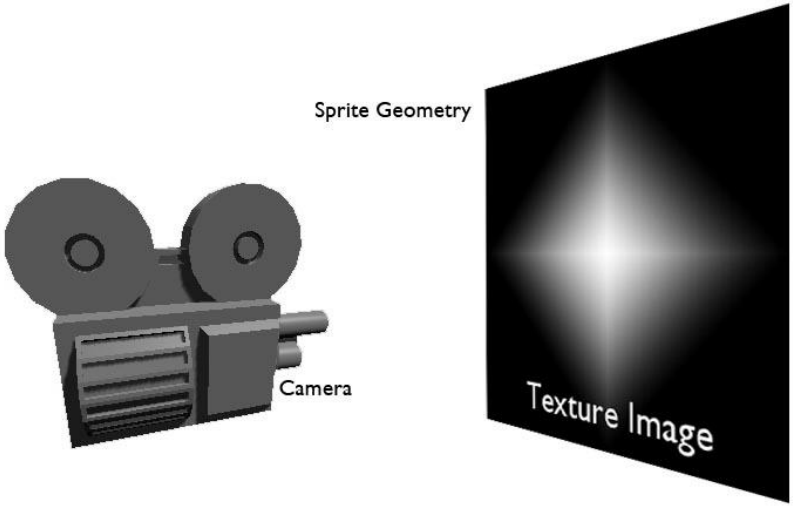
Particle



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Unreal engine 4

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24 Great Games That Use The Unreal 4 Game Engine

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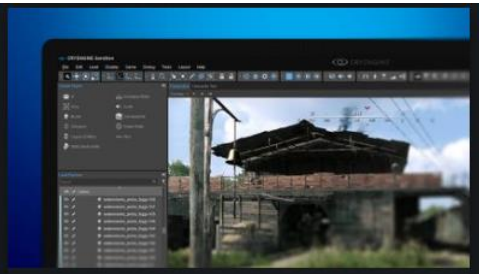
CryEngine 6

Visuals

Take advantage of CRYENGINE's legendary best-in-class visuals to blow players away.



Sandbox

A suite of tools that put the power to create stunning experiences at your fingertips.

AI & Animation

Fill your worlds with the most realistic characters ever seen in gaming.

Audio

Unleash the talent of audio artists and give them complete control over their creations.

Physics

Take advantage of CRYENGINE's built-in high-end physics solution.

Performance

Accomplish real-time visualization, interaction and immersion with CRYENGINE.

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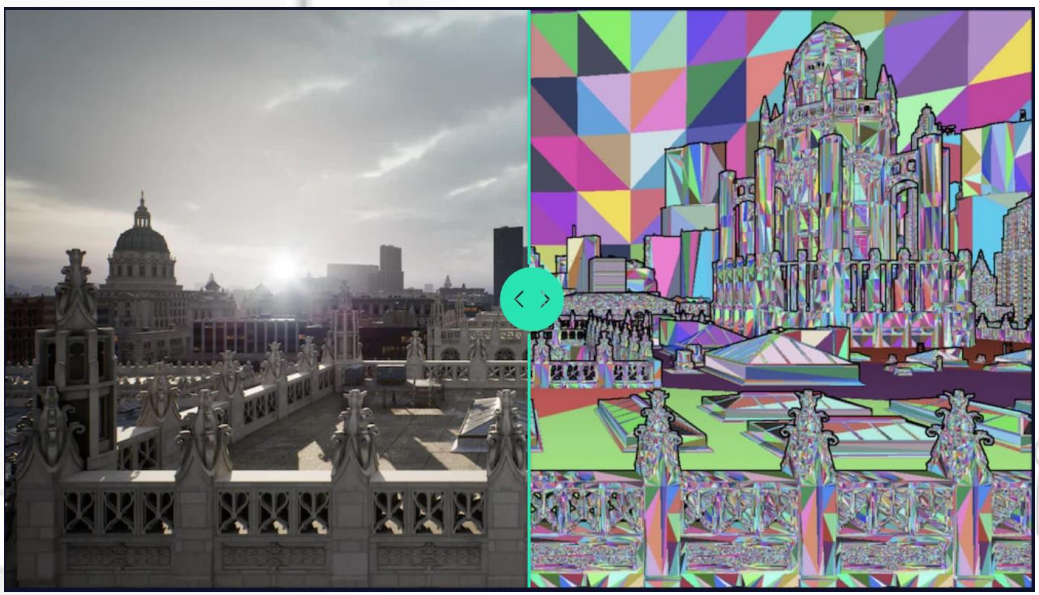
Unreal engine 5 (2022)

- NANITE & VIRTUAL SHADOW MAPS
  - MASSIVELY DETAILED WORLDS
- LUMEN
  - Dynamic global illumination and reflections



iVE MEDiA

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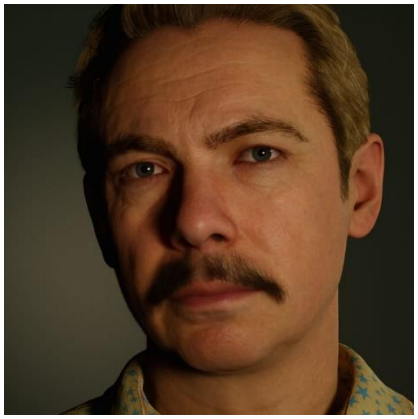
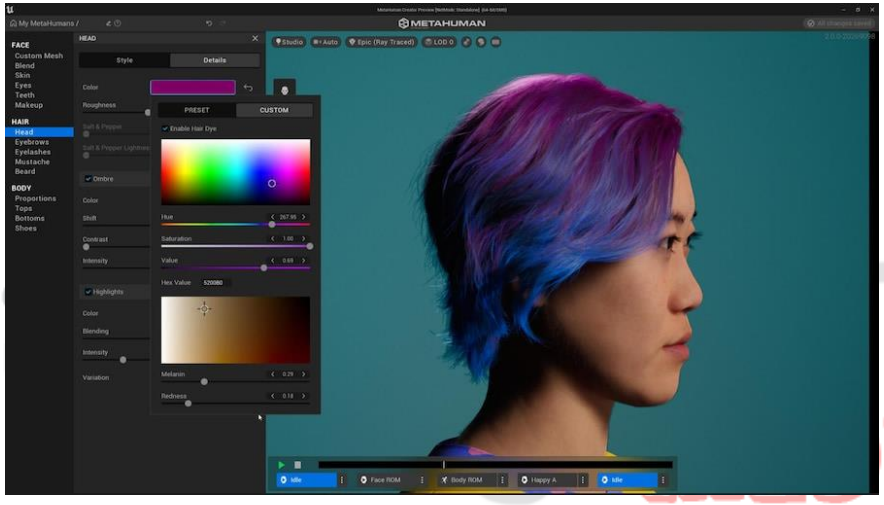
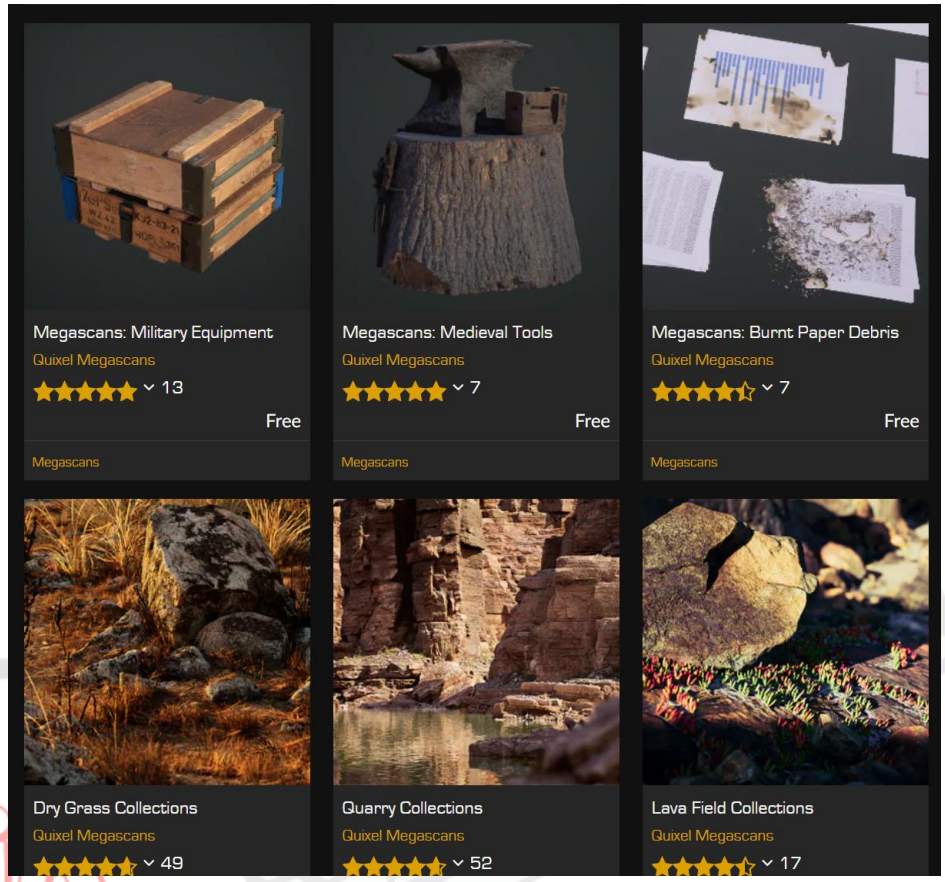
Unreal engine

- metahuman





- MEGASCANS



Unreal engine: virtual-production

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Unity3D

- Lightweight game engine
- Lower learning curve
- Integrated editor

- Powerful asset support
  - Blender, PS, 3DS Max, Maya, Sketchup…
- Web, Mobiles, PC, Consoles

Build mulitplatform games

Maintain performance and graphic fidelity on 20+ platforms, from mobile to consoles.

Iterate rapidly

Flexible architecture and C# foundation to accelerate your development process.

Build more ambitious games with DOTS

Boosts performance for complex gameplay in dynamic environments.

Customizability and an expansive ecosystem

Millions of pre-built assets and plug-ins and a suite of tools from growth to collaboration.

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2D visual programming

- Construct 2
  - Html5
- Love
- Raylib