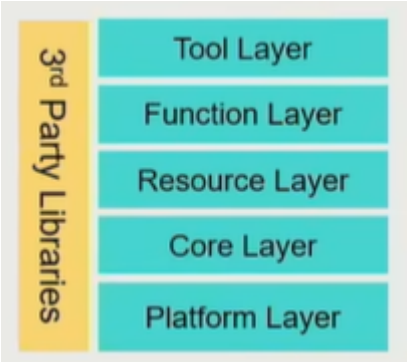
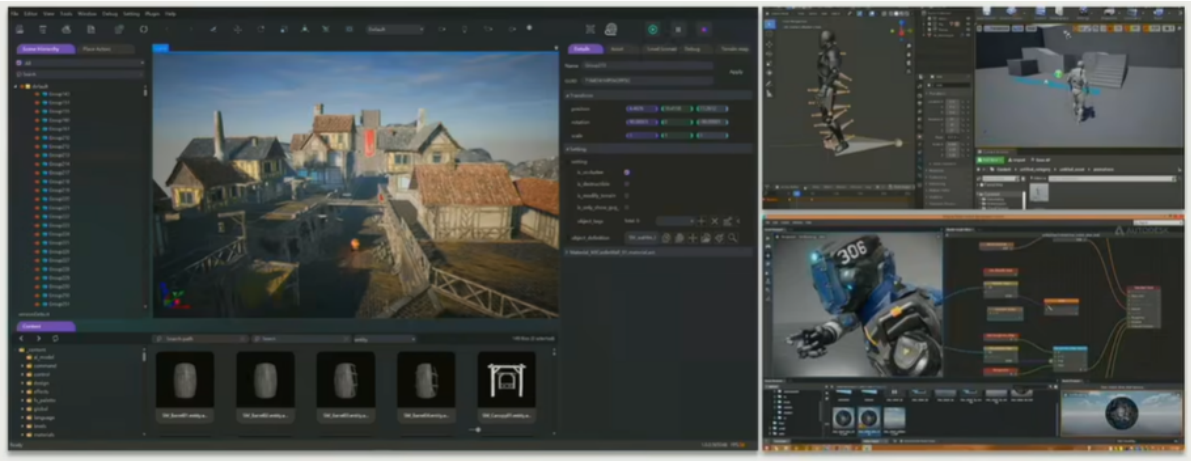
Lecture2 Layered Architecture of Game Engine

1. Sea of Codes - Where to begin

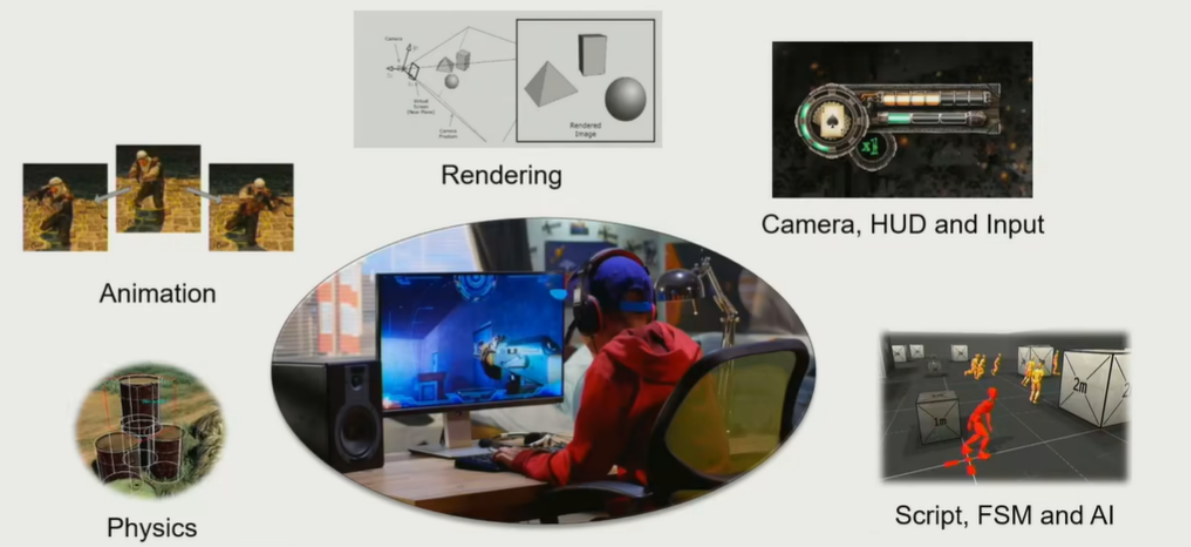
A Glance of Game Engine Layers



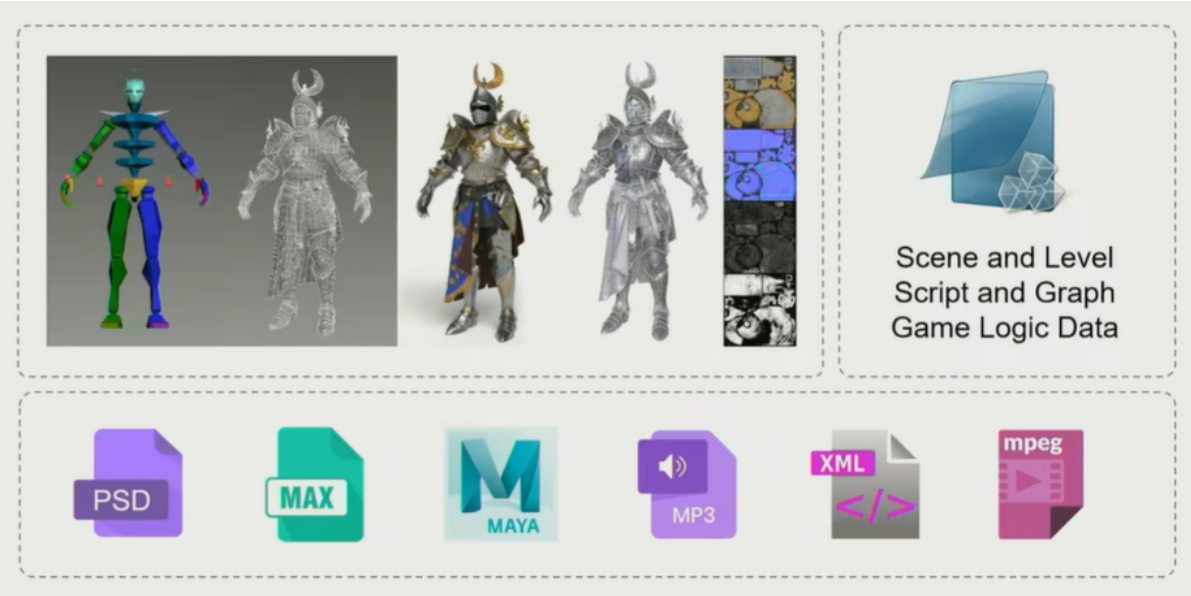
Tool Layer - Chain of Editors



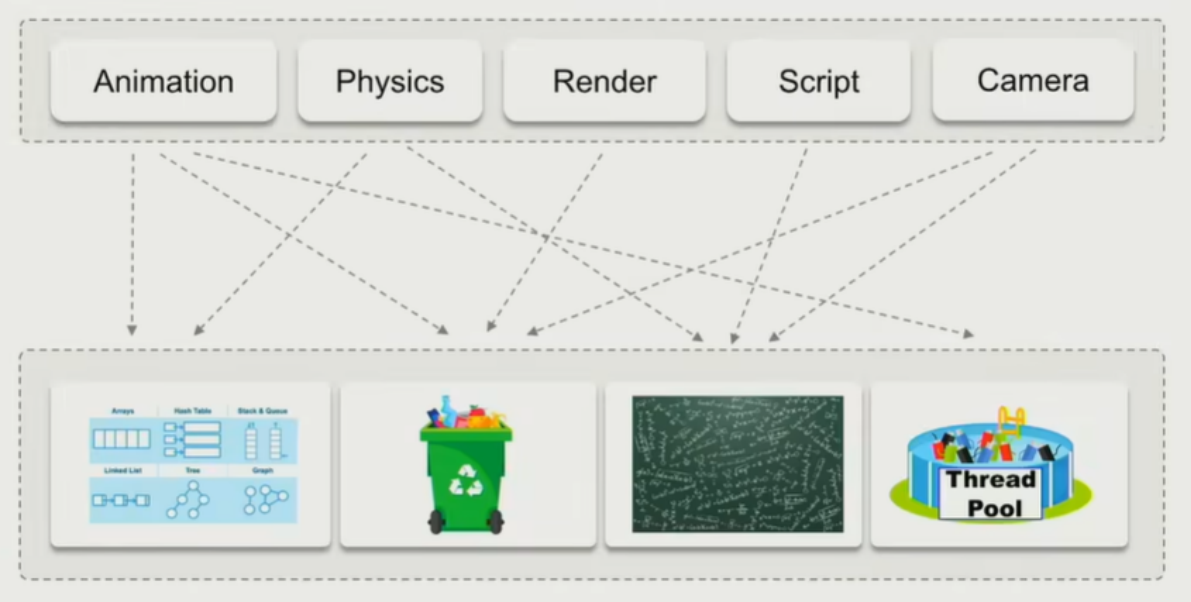
Function Layer - Make it visible, movable and playable



Resource Layer - Data and Files



Core Layer - Swiss Knife of Game Engine



Platform Layer - Launch on Different Platforms

Middleware and Third party Libraries

Why Layered Architecture

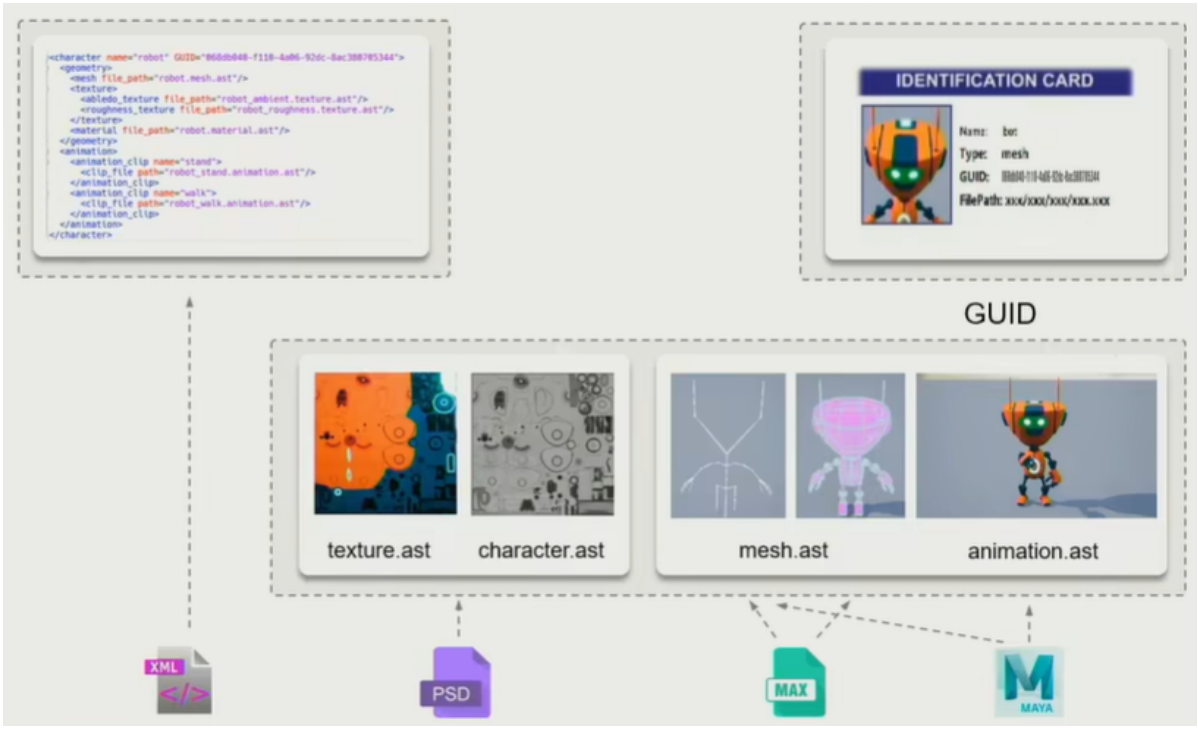
- Decoupling and Reducing Complexity
  - Lower layers are independent from upper layers
  - Upper layers don't know how lower layers are implemented
  - Upper layer can call lower layer, but lower layer can not call upper layer
- Response for Evolving Demands
  - Upper layers **evolve fast**, but lowers are **stable**

2. Practice is the Best Way to Learn

Task - Simple Animated Character Challenge

- Create, animate and render a character
- Playable on selected hardware platform

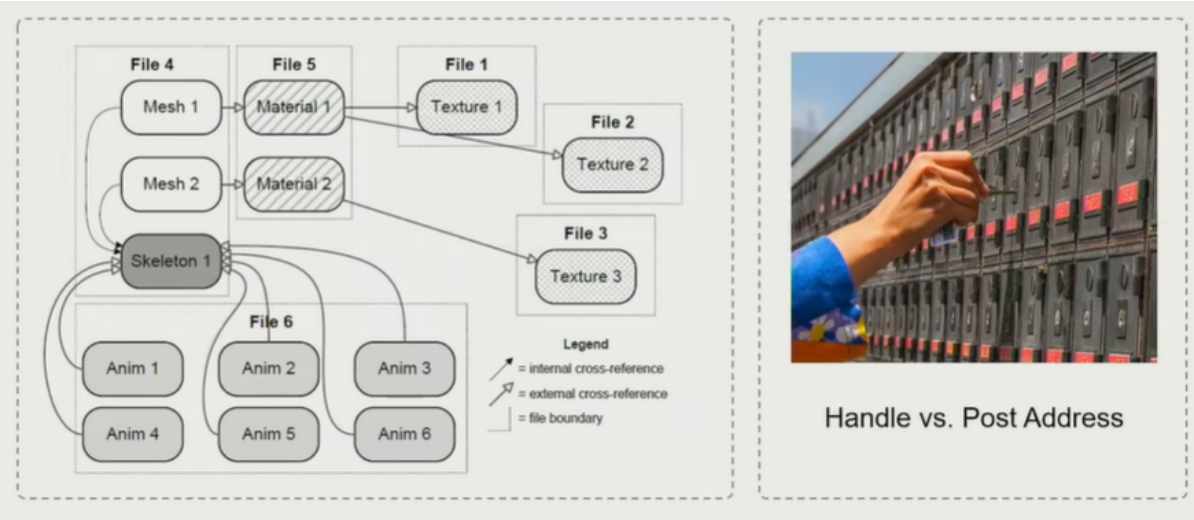
Resource - How to Access my Data



Offline Resource Importing

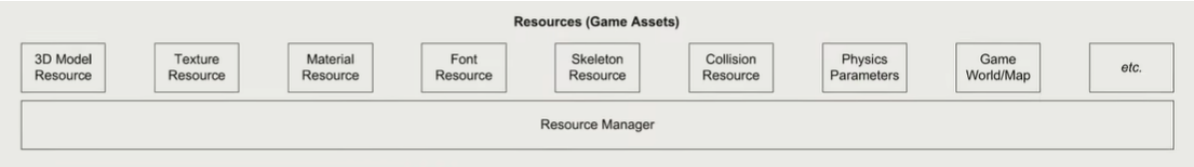
- Unify file access by defining a **meta asset** file format (eg, `.ast`)
  - easier for GPU to use
  - assets are faster to access by importing preprocess
- Build a **composite asset** file to refer to all resources
- **GUID** is an extra protection of reference
  - asset identity

Runtime Asset Manager



- A virtual file system to load/unload assets by path reference
- Manage asset lifespan and reference by handle system

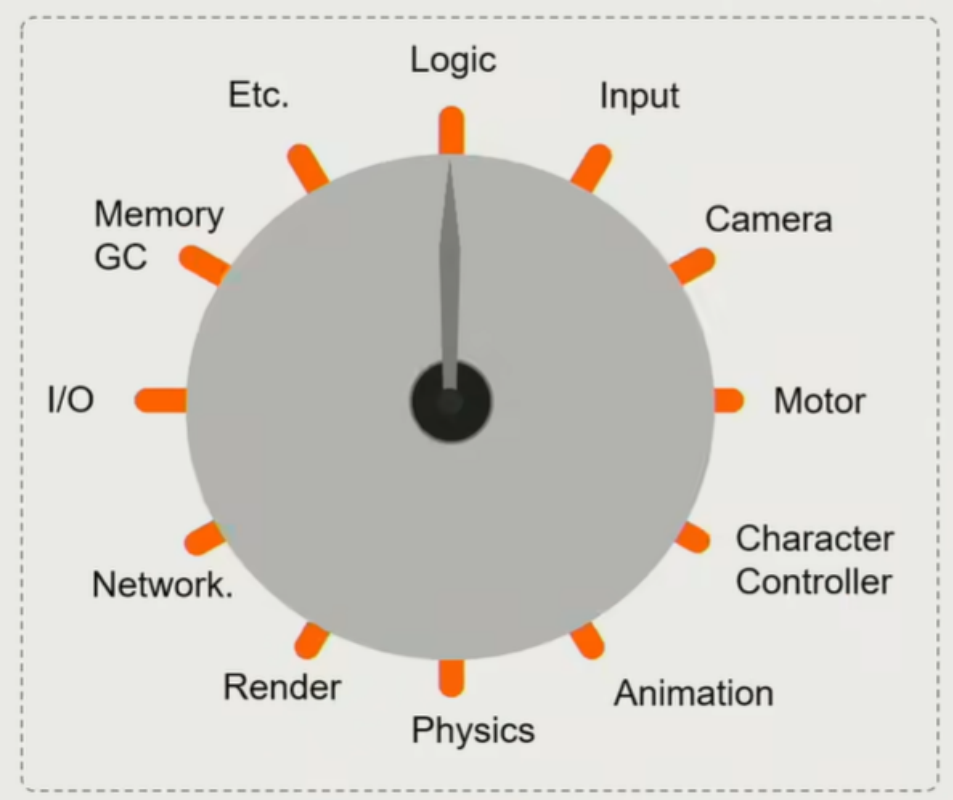
Manage Life Cycle



- Different resources have different life cycles
- Limited memory requires release of loaded resources when possible
- Garbage collection and deferred loading is critical features

Function - How to Make the World Alive

Dive into Ticks



- tick: experience all the functions with 1/30s to make the game looks natural

```
void tickMain(float delta_time)
{
    while (!exit_flag)
    {
        tickLogic(delta_time);
        tickRender(delta_time);
    }
}
```

```
void tickLogic(float delta_time)
{
    tickCamera(delta_time);
    tickMotor(delta_time);
    tickController(delta_time);
    tickAnimation(delta_time);
    tickPhysics(delta_time);
    /*...*/
}
```

```
void tickRender(float delta_time)
{
    tickRenderCamera();
    culling();
    rendering();
    postprocess();
    present();
}
```

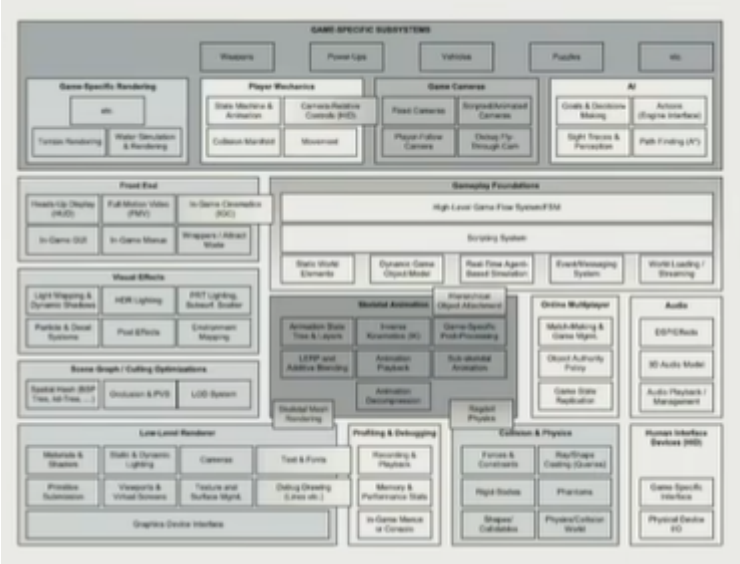
- `tickLogic` and `tickRender` are two different aspects

Tick the Animation and Renderer

- In each tick (over-simplified version)

- Fetch animation frame of character
- Drive the skeleton and skin of character
- Renderer process all rendering jobs in an iteration of render tick for each frame

Function is Heavy-duty Hotchpotch

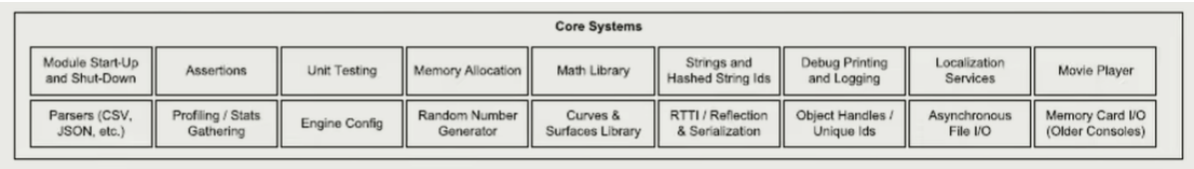


- Function Layer provides major function modules for the game engine
  - Object system (HUGE)
- Game Loop updates the systems periodically
  - Game Loop is the key of reading codes of game engines
- Blur the boundary between engine and game
  - Camera, character and behavior
  - Design extendable engine API for programmer

Multi-Threading

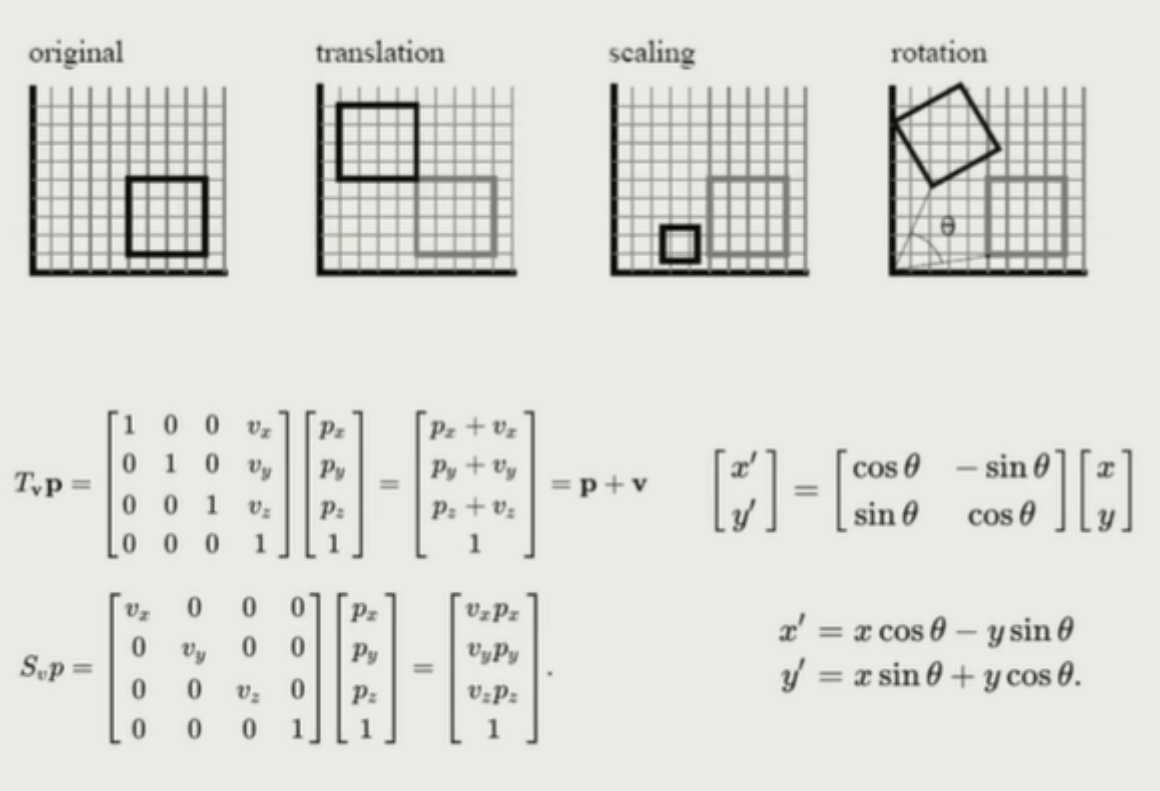
- **Multi-core processors** become the mainstream
  - Many systems in game engine are built for parallelism

Core - Foundation of Game Engine



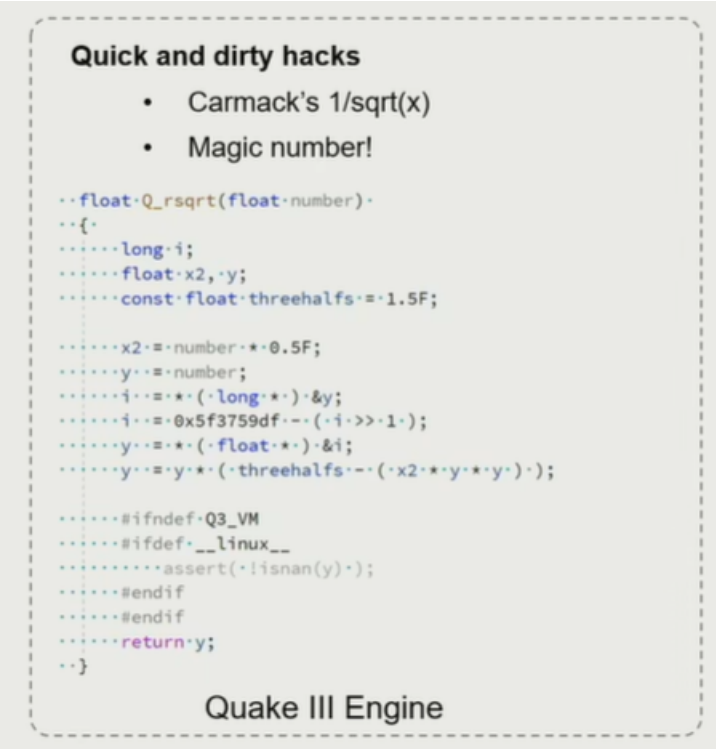
- Core layers provide utilities needed in various function modules
- Super high performance design and implementation
- High standard of coding

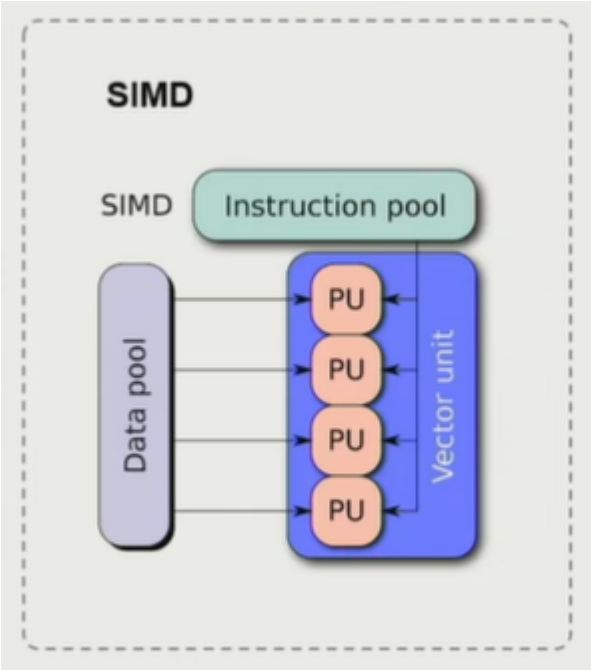
Math Library



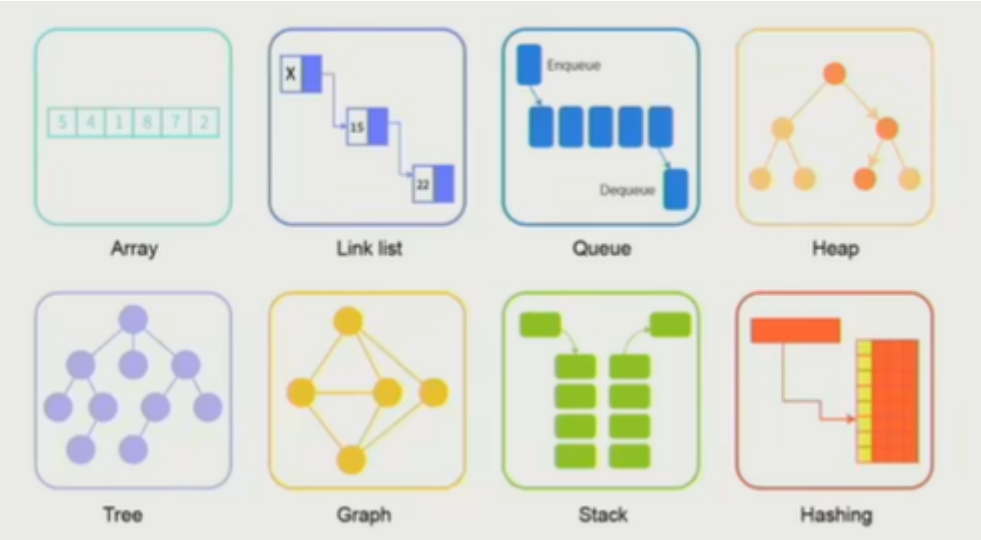
- Linear algebra
  - Rotation, translation, scaling
  - Matrix splines, quaternion

Math Efficiency





Data Structure and Containers



- Vectors, maps, trees, etc.
- Customized outperforms STL
- Avoid fragment memory

Memory Management

- Major bottlenecks of game engine performance
  - Memory Pool / Allocator
  - Reduce cache miss
  - Memory alignment
- Polymorphic Memory Resource (PMR)

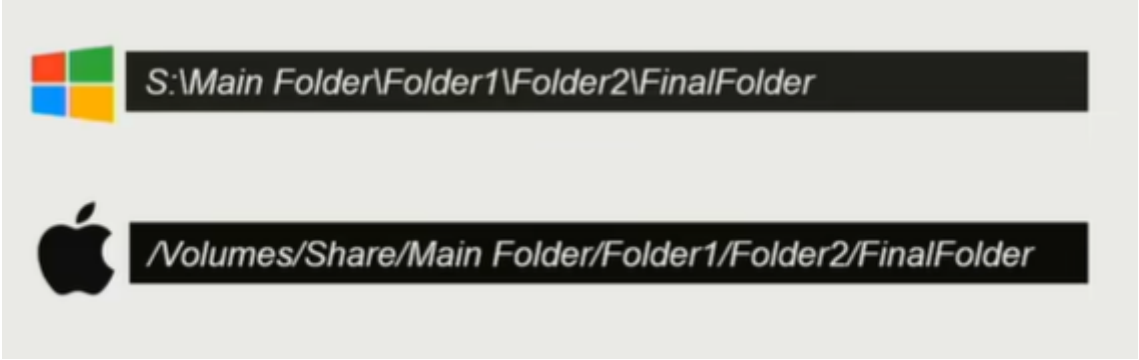
For game engine, it will request a large amount of memory at once, and then arrange on that basis

How to make memory management fast

- Put data together
- Access Data in Order
- Allocate and De-allocate as a block

Platform - Target on Different Platform

File system



Compatibility of different platforms, provides platform-independent services and information for upper layers

- Path: Slash/Backslash, Environment variables
- Directory Traversal

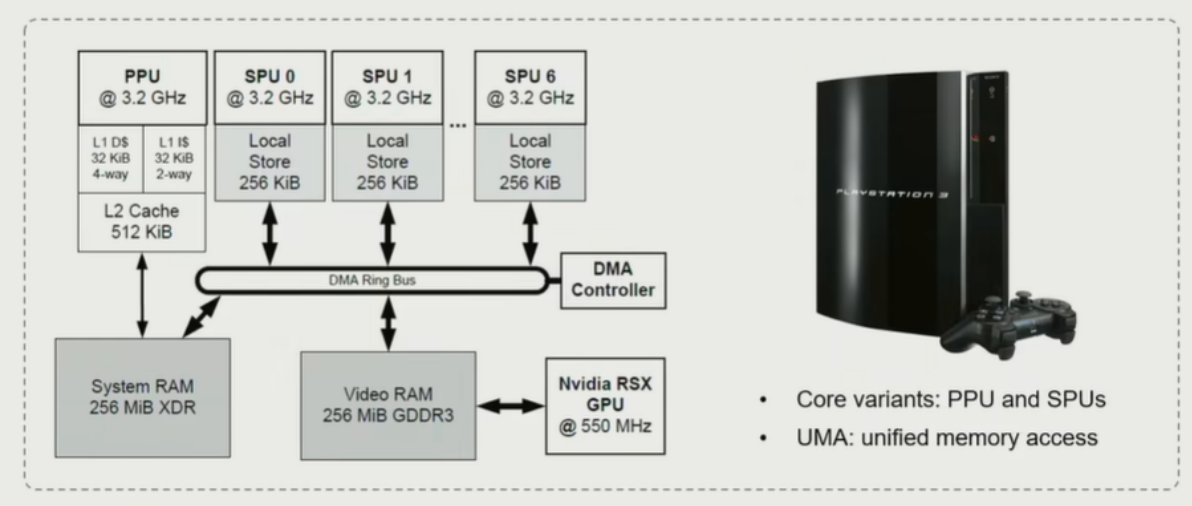
Graphics API

Render Hardware Interface (RHI)

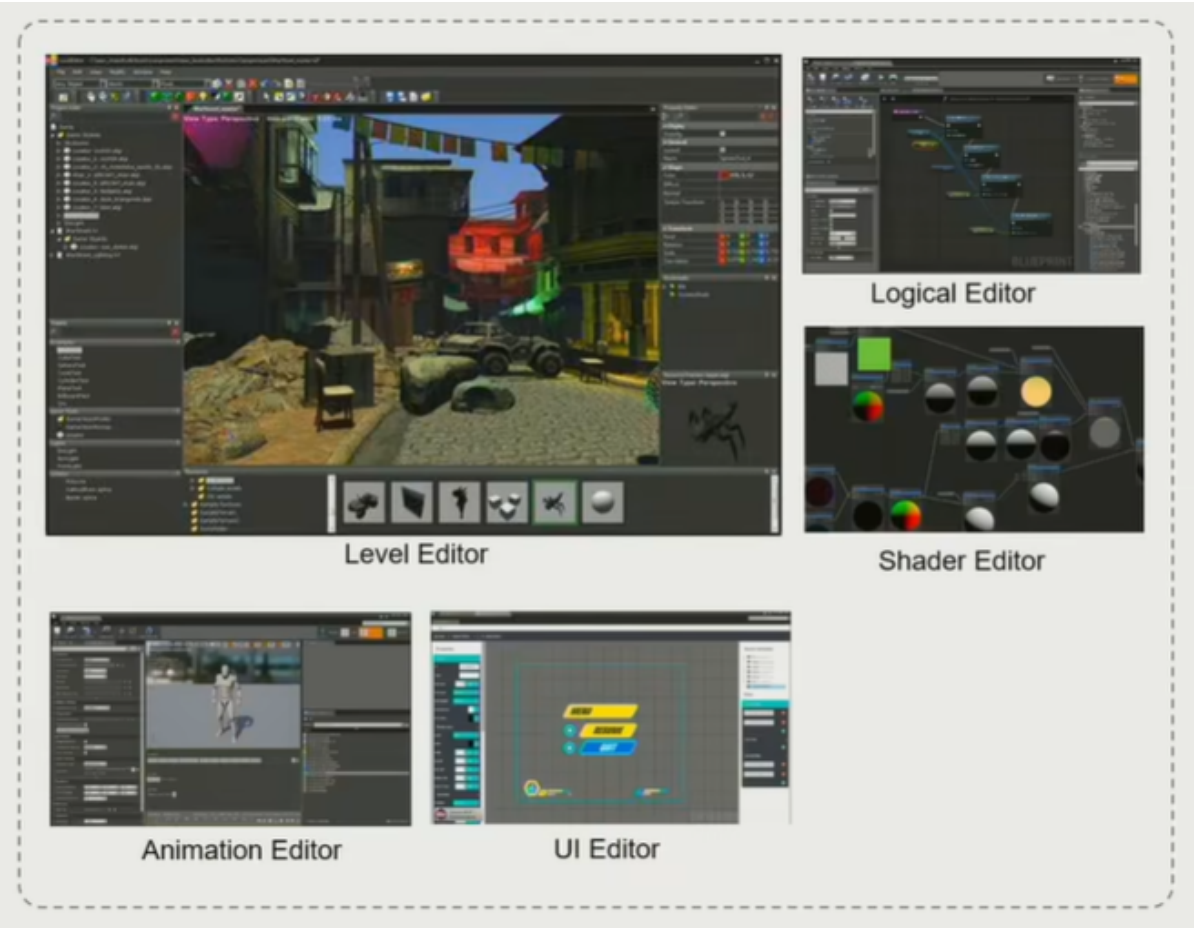
- Transparent different GPU architecture and SDK
- Automatic optimization of target platforms


```
// shader
virtual RHIVertexShader*        createVertexShader(const DynamicArray<UByte>& shader_bin_code) = 0;
virtual RHIHullShader*          createHullShader(const DynamicArray<UByte>& shader_bin_code) = 0;
virtual RHIDomainShader*        createDomainShader(const DynamicArray<UByte>& shader_bin_code) = 0;
virtual RHIGeometryShader*      createGeometryShader(const DynamicArray<UByte>& shader_bin_code) = 0;
virtual RHIPixelShader*         createPixelShader(const DynamicArray<UByte>& shader_bin_code) = 0;
virtual RHIComputeShader*       createComputeShader(const DynamicArray<UByte>& shader_bin_code) = 0;

// buffer
virtual RHIVertexBuffer*        createVertexBuffer(RHIResourceCreateInfo& create_info) = 0;
virtual void*                   lockVertexBuffer(RHIVertexBuffer* vertex_buffer, UInt offset, UInt size, EResourceLockMode lock_mode) = 0;
virtual void                    unlockVertexBuffer(RHIVertexBuffer* vertex_buffer) = 0;

virtual RHIIndexBuffer*         createIndexBuffer(RHIResourceCreateInfo& create_info) = 0;
virtual void*                   lockIndexBuffer(RHIIndexBuffer* index_buffer, UInt offset, UInt size, EResourceLockMode lock_mode) = 0;
virtual void                    unlockIndexBuffer(RHIIndexBuffer* index_buffer) = 0;
```

Hardware Architecture

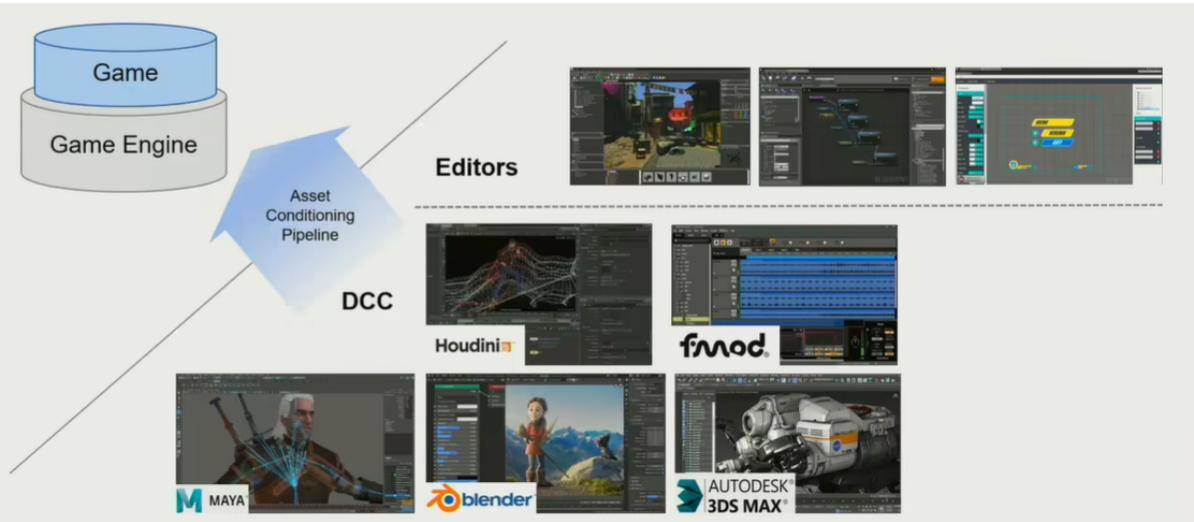


Tool - Allow Anyone to Create Game



- Unleash the creativity
  - Build upon game engine
  - Create, edit and exchange gameplay assets
- Flexible of coding languages
  - C++, C#, HTML

Digital Content Creation (DCC)



3. Mini Engine - Pilot

> https://github.com/BoomingTech/Piccolo

Introduction

- Build by C/C++
  - Runtime: ~13,000 lines
  - Editor: ~2,000 lines
- Follow Engine Layers
  - Source code still improving
- Support Platform
  - Windows
  - Linux
  - MacOS

Function

- Basic Editing
  - Add/Delete Objects
  - Move/Scale/Rotate objects
- Simple Functions
  - Character control
  - Camera