Game Engines: Why and What?

Dan White
Technical Director
Pipeworks
danw@pipeworks.com

Message

- As you learn techniques, consider how they can be integrated into a production pipeline.

Sense of scale…

- Video games word-wide: $110 billion business in 2015
  - Main driver of 3D graphics hardware
    - Not simulations or NORAD
  - Main driver of 3D rendering software
    - Not Hollywood

Budgets and Timeline

- Individual Game budgets are big.
  - Current AAA titles:
    - $30 million budget, 2+ year dev cycle.
    - GTAV = 1 $Billion, $265 million to develop.
  - Even mobile games: $500 thousand
  - Project completion date is very important.
    - Particularly for licensed properties, sports, holiday launches, or anything with advertising.
  - Schedules from 3 month to 5+ years

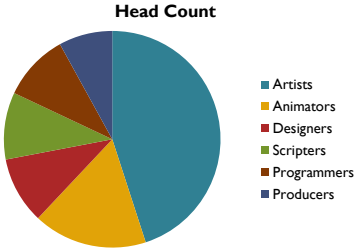
Managerial Ideal

Olde Tyme Game Making

35 years ago, a game might have 1 programmer, and maybe 1 artist

They were written…like a novel is written.

A current mid/large size project looks very different…



On large projects, programmers are a small part
On smaller projects, a larger part
This doesn't even include QA

A different approach

Jumpman
Atari 800
circa 1983:

This game had an EDITOR!
At the time, this seemed revolutionary to me.

Doom Engine cemented the idea

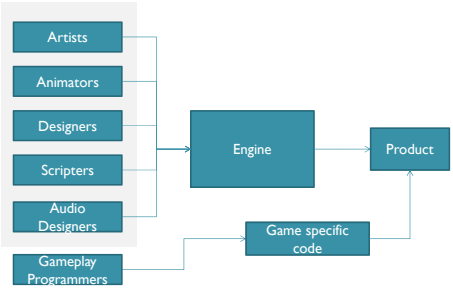
Doom released in 1993

- Spawned HeXen, Heretic and so on.
- Started the idea that an engine is potentially valuable on its own.

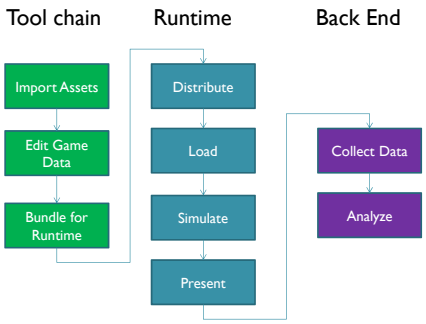
Game Engine Concept

- A collection of reusable tools and runtime for making games.
- An **integration** platform for all the different features of the game.
- Used by the different disciplines to do their work.
- Ideal is you don't need engineers to make a game.
  - After all, you don't need engineers to write a book or design a building
  - Still plenty of work for engineers!!

How the team works…



Production should be a pipeline



Who are the engine users?

- Artists
  - People with art talent and a wide range of technical skills.
  - They want to make assets in a DCC tool (e.g. Maya) and put them in the game.
  - Need to be able to see the final result.
- Designers
  - Also a wide range of technical skills.
  - They want to arrange content to produce fun.
    - Place objects, manipulate values, script actions.
- Game programmers
  - Engineers writing code specific to the game you are making.
  - Organizationally separate from the people making the engine.

Everybody wants…

- Easy of use:
  - Intuitive UI
  - Stability
- Fast iteration times:
  - Make a change
  - See the result
  - Make another change
- **Iteration is the KEY to making games good!**
  - Good: Play in editor…10 second loop
  - Bad: Bundle and launch full game…8 minute loop

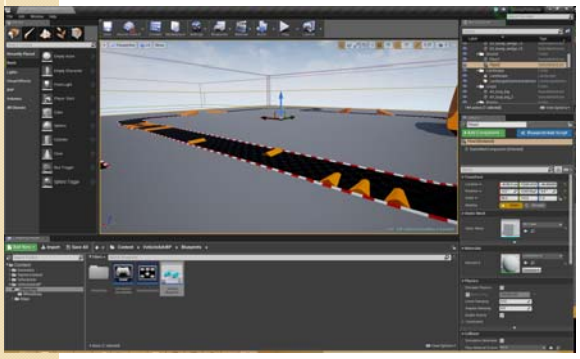
Key Engine Features

- Rendering
- Serialization
  - Asset loading
- Object simulation
- Camera & Controls
- UI system
  - Need for shell and HUD
    - Do not underestimate!

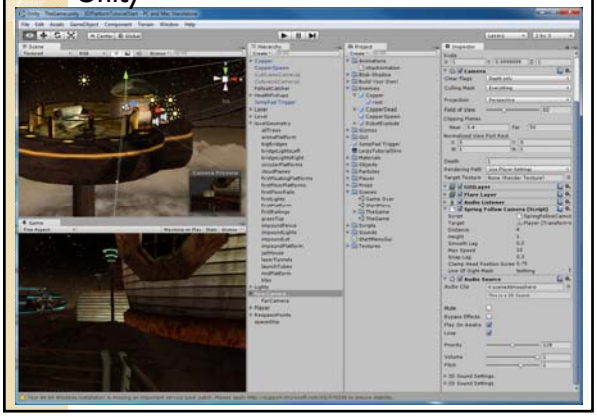
Other Features

- Asset Management
  - Versioning
- Build system
- Sound
- Animation
- Physics
  - Cloth
- (Simple) Networking
- And on and on...
  - Feature set grows over time
  - No feature is minor when your game requires it!

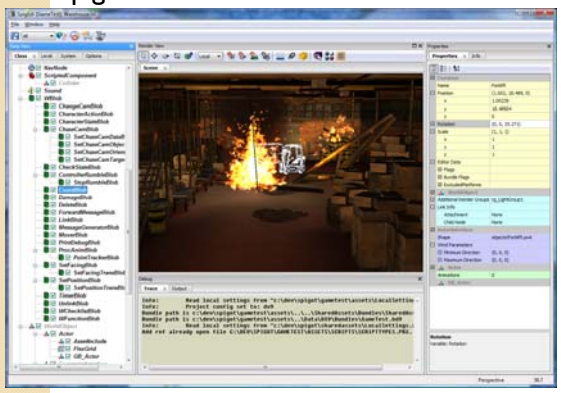
Unreal



Unity



Spigot



It's a hard problem

- Engines take many years to develop.
  - Many fail.
- **Not** because of the difficulty of basic research.
  - Most features begin in academia, or with graphics card manufactures.
- Hard part is integration into a usable system.

Key Integration Points For a Feature

- Tool Chain
  - How do you get external assets into the game?
  - Example Meshes:
    - Built in Maya
    - Exported as FBX
    - Imported into editor for display
- In-editor UI
  - How will artists and designers configure your feature?
    - Visual editing is better.
    - This is usually the most time consuming part.
  - How do people preview and iterate?

More Integration Points

- Storage & Loading
  - How are your configuration parameters stored by the editor?
    - Ideally, this will be text so you can diff results.
  - How will the data be preprocessed at build time?
    - Runtime data is highly optimized, and this can take a long time.
  - How will data be quickly loaded at runtime?
    - May need to stream it.

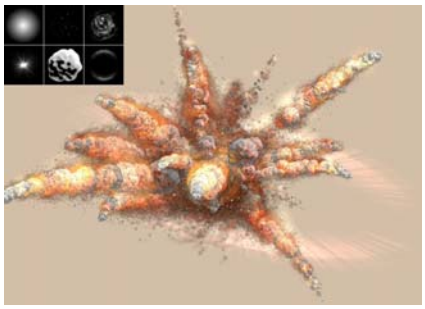
More Integration Points

- Runtime
  - What code runs in the actual game?
  - Games are real-time systems, hence predictable performance is key.
    - Do not amortize costs in algorithms.
  - What resources to you need:
    - Memory
    - Texture Memory
    - CPU
    - GPU
  - Can you make the code parallel?
- Interactions with other features.

Interactions

- How does a feature interact with other features?
  - Sometimes features work against each other.
  - You can't just change the rendering pipeline cause you want to.
- Usually this is the **hardest** (if not the most time consuming) part.

Example Feature: Particle Systems



Basic Idea

- Render a sprite many many times to produce smoke, explosions, etc.
- Can produce a wide variety of effects with small amounts of source art.
  - Great for engineers who want to make cool stuff.
- Generally not physically based.
  - Not widely studied in academia.

Tool Chain

- Particle system:
  - Input is textures.
    - Made in Photoshop
    - Imported as PSD, JPEG, etc.

Editor UI

- Particle systems:
  - Invent the concept of "emitters" which produce particles.
  - Using existing UI for materials.
    - In Unreal, this is a graph-based system.
  - Use a property sheet for parameters.
  - Use a visual editor for curves.
    - Supports splines.

Unreal Material Editor

Unreal Cascade Particle Editor

Storage, Preprocessing, Loading

- Particle system:
  - Editor description could be text.
  - Runtime data is small.
    - Store as binary POD.
    - Reference materials, which pull in textures.
      - Converted to DXT or similar.

Runtime

- Particles:
  - Straightforward to write.
  - Render large numbers of dynamically updated quads or primitives.
    - It's a bad idea to call DX/OpenGL many times.
      - Need to coalesce in vertex buffers or display lists.
  - Extremely fill intensive.
  - Updating many particles is CPU intensive.
    - Particle systems very suitable for parallel processing.

Interactions

- Particles are typically translucent.
  - Rendered with alpha.
  - Should they write to the Z-buffer? Probably not.
    - You will likely have to sort them relative to other objects.
- Depth complexity of particle systems is very high.
  - Will destroy your fill rate if they are close to the camera.
    - Have to LOD particles as you get close, or limit camera.
  - May implement lower-res render to texture.
- If you have depth based fog, do you apply fog to the particles?
- Deferred rendering
  - A screen space rendering technique that uses passes.
  - Doesn't handle alpha. What to do?
    - Dithering
    - Separate forward rendering pass.

Some observations…

- The editor and tool chain are much more complex than the runtime.
  - Lots of UI work!
- The whole team works with the tool chain, but only engineers work with the runtime.
  - Productivity payoffs for improved tools can be very large.

Downside of Engines

- Cost.
- Produces external dependencies.
- Poor support for particular genres.
  - e.g. RTS
- Generic performance may not be as good as special code.

These are issues as old as software.

Hardware Evolution: Where are we going?

	NES	PS1	PS2	PS3	Current PC	Xbox One
CPU	MOS Tech 6502 1.79MHz	MIPS R3000A-32-bit RISC chip at 33 MHz	294 MHz MIPS "Emotion Engine"	3.2 GHz POWER PPE, seven 3.2 GHz SPEs	8 Cores at 3 GHz	8 Core AMD custom CPU Frequency: 1.75 GHz
GPU	-	66 MIPS vector math unit on CPU	147 MHz "Graphics Synthesizer"	550 MHz based on Nvidia G70	Gerforce 650 1058 Mhz 384 Cores	853 MHz GPU Custom AMD
Storage	Cartridge	CD	DVD	Blu-Ray	HDD	HDD

Content is King

- We have already reached the sweet spot for most game features:
  - 4 enemies to 8 → big difference
  - 64 enemies to 128 → small difference
- PS2 was the tipping point between ability to display content and ability to make it.
- We are now firmly in the era where content creation cost is the driving factor.
- Runtime performance gets even less important.

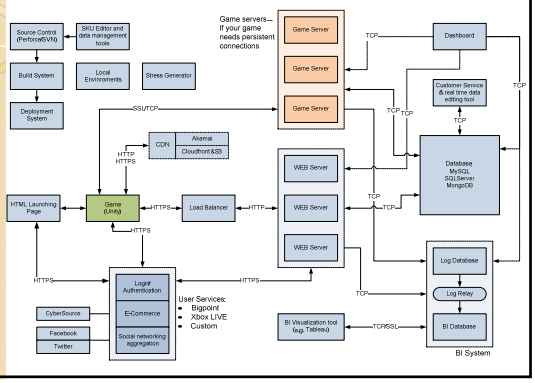
Beyond the Engine: The Back End

- Disruptive force since late 2000's:
  - Piracy, and the need to control it
  - Digital Distribution
  - Success of MMORPGS (e.g. WOW)
  - High broadband penetration
  - Microtransactions as business model
  - Resurgence of the PC, and emergence of mobile
  - Abundant web technology & infrastructure
- Result has been the rise of games with a "back end" component
  - Means: the game connects to a database

Implementation

- Backend is typically not part of the game engine.
- Uses technologies not traditionally part of game development.
- Primary reason: "mainstream" software development tools can be used.
  - Node.js
  - .NET
  - CodeIgniter

Live Game Components



Back End Implications

- Once you connect to a database, many things become easy:
  - Cloud based save load
  - Multiplayer lobbies & leaderboards
    - But not synchronous MP
  - Social integration
  - Freemium economy & transactions
  - Piracy protection
  - Telemetry, which has changed game design forever
- Typically implemented via a HTTP/HTTPS & REST
  - Most common back ends are PHP, but all kinds used
  - Most common database is MySQL, but nosql is gaining
    - Games are much more write heavy than other Web apps
  - Scalability is a problem
- 3rd party hosting services (AWS, Rackspace) used a lot
- One of the biggest areas of active "research."

What it takes…

- Games are a serious career for people who are serious about it.
- Game programming involves skills missing from a traditional CS program:
  - Mathematical modeling, vector math
  - Simulation & physics
  - Graphics, particularly special effects
    - This is why I'm so excited about this class!
- Programming tasks often end up with a complex integration step.
  - Strong programming skills are essential.

Message Recap

- As you learn techniques, consider how they can be integrated into a production pipeline.
- Iteration! Iteration! Iteration!