WPI

IMGD 4000
Technical Game Development II
Game Engines

Robert W. Lindeman
Associate Professor
Interactive Media & Game Development
Human Interaction in Virtual Environments (HIVE) Lab
Department of Computer Science
Worcester Polytechnic Institute
gogo@wpi.edu

WPI

Pedagogical Goal

- Your technical skills should not be tied to any particular game engine
  - Just like your programming skills should not be tied to any particular programming language!
- Use the best tools for each job
- ... or the tools you were given ☺

Definition

Game Engine

A series of modules and interfaces that allows a development team to focus on product *game-play content*, rather than *technical content*.

[Julian Gold, OO Game Dev.]

- *But this class is about "the technical content" !* ☺

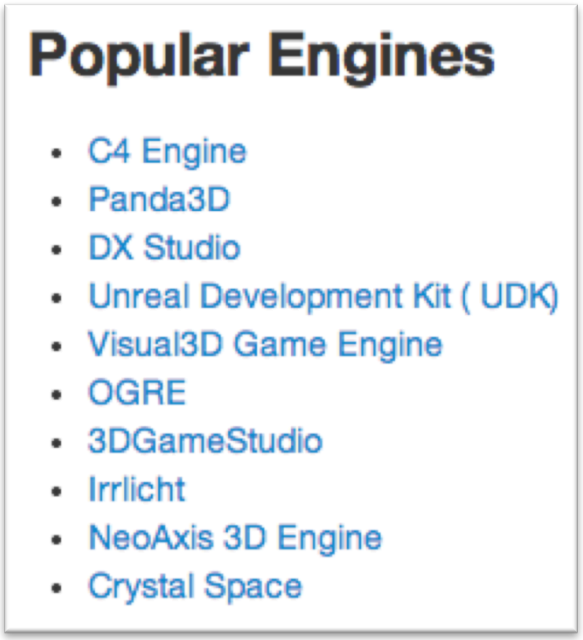
Buy Versus Build

- Depends on your needs, resources and constraints
  - Technical needs (e.g., "pushing the envelope" ?)
  - Financial resources (e.g., venture capital ?)
  - Time constraints (e.g., 1 mo. or 2 yr. ?)
  - Platform constraints (e.g., Flash ?)
  - Other factors (e.g., sequel ?)
- Most games commonly built today with some sort of "engine layer"

Choices:
It's a Jungle Out There!

WPI

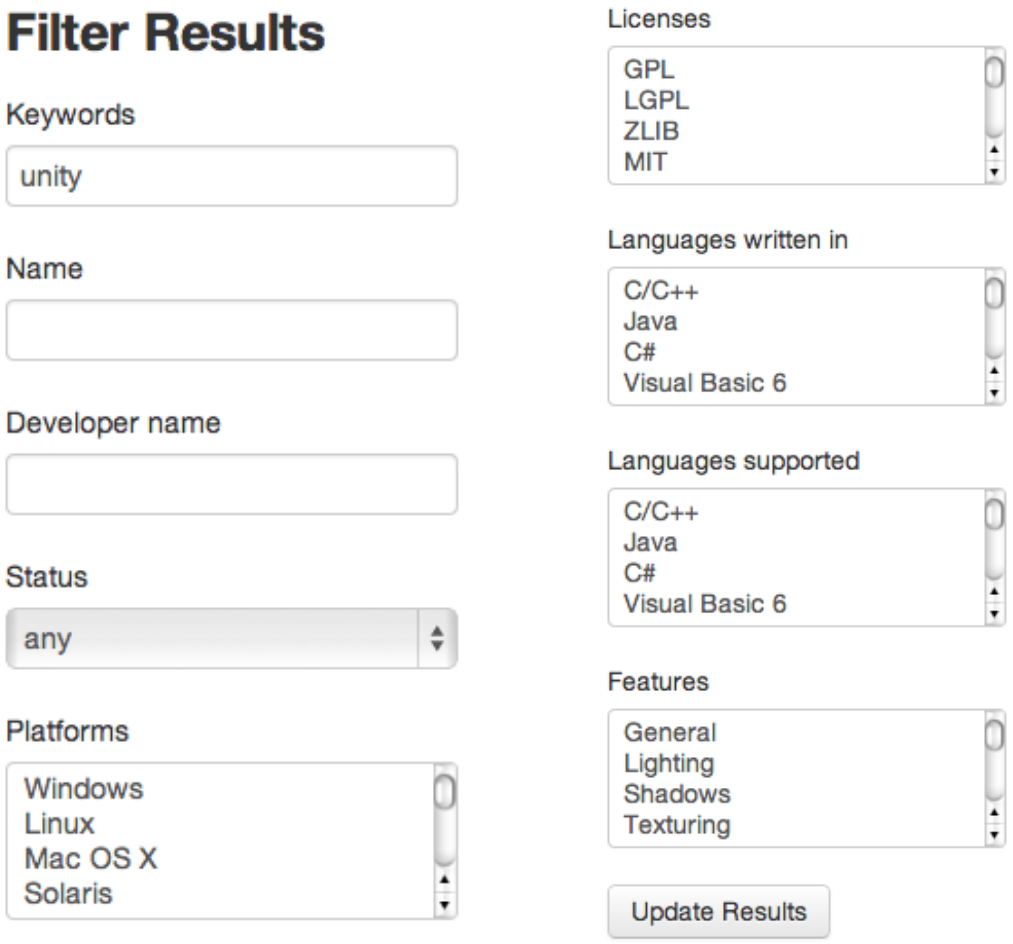
- 361 3D engines reviewed at devmaster.net/devdb/engines



- We are ***not*** going to try to review them all here!

Many Evaluation Dimensions/Features

[DevMaster.net]



If there's a feature term here you don't know, you should look it up!

Types of Engine Architectures (Roughly)

WPI

- **Monolithic** (e.g., Unreal Engine)
- **Modular**
  - **Extensible IDE** (e.g., Unity)
  - **Open Class Library** (e.g., C4 or Dragonfly?)

Monolithic Engines (e.g., Unreal)

WPI

- "Old style"
  - Typically grew out of specific game
- Tend to be genre-specific
- Difficult to go beyond extensions/ modifications not *anticipated* in (e.g., scripting) API
- Proven, comprehensive capabilities

Modular Engines (e.g., C4 and Unity)

- "Modern"
  - Often developed by *game engine company* (relatively new category)
- Use *object-oriented* techniques for greater modularity
- Much easier to extend/replace components than monolithic engines

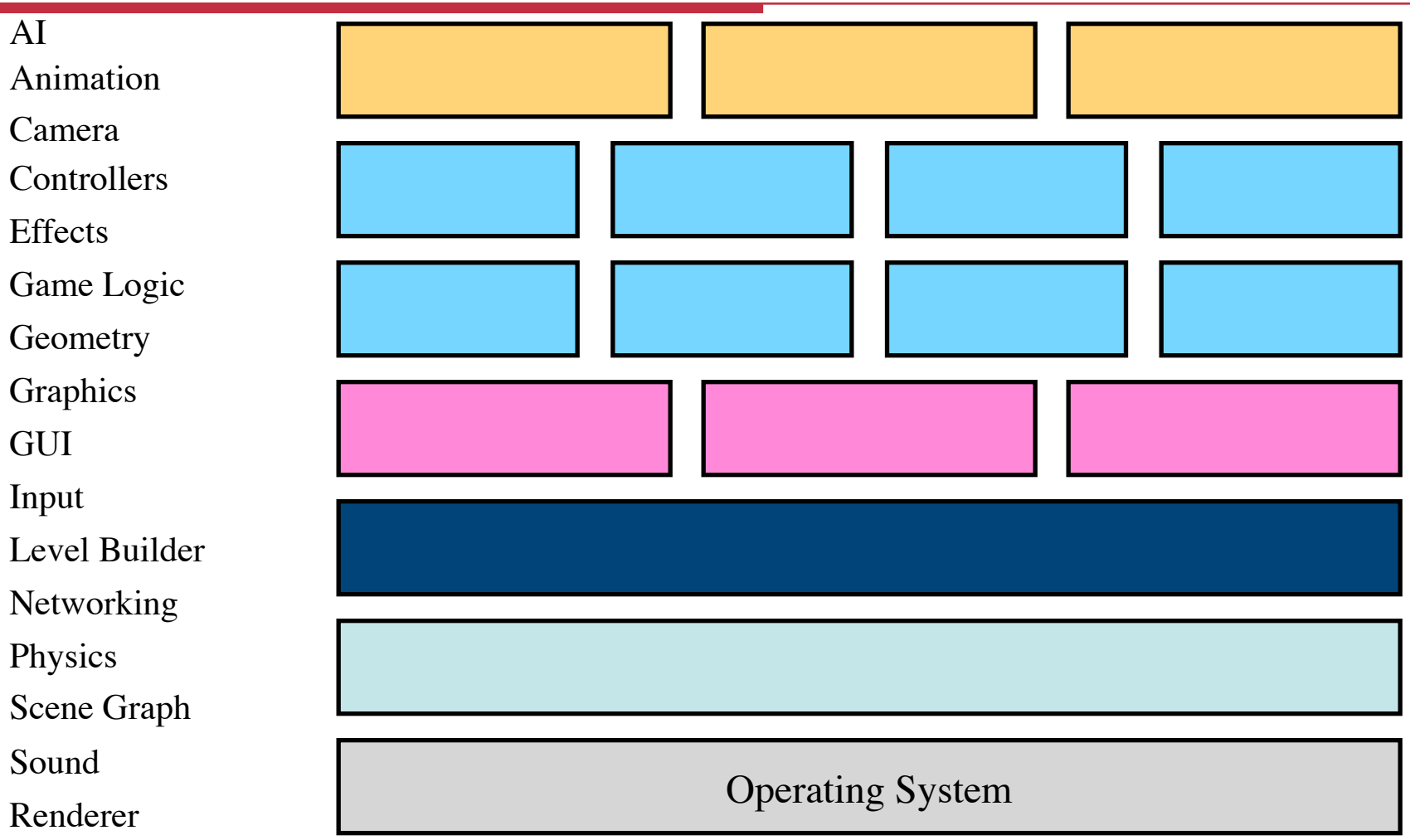
Modular: Extensible IDE's (e.g., Unity)

- GUI-oriented development process
  - More accessible for novice/casual programmers
  - More "art asset friendly"
- Comprehensive asset management
- Limited (controlled) exposure of internals
  - Prevents abuse
  - Prevents some extensions

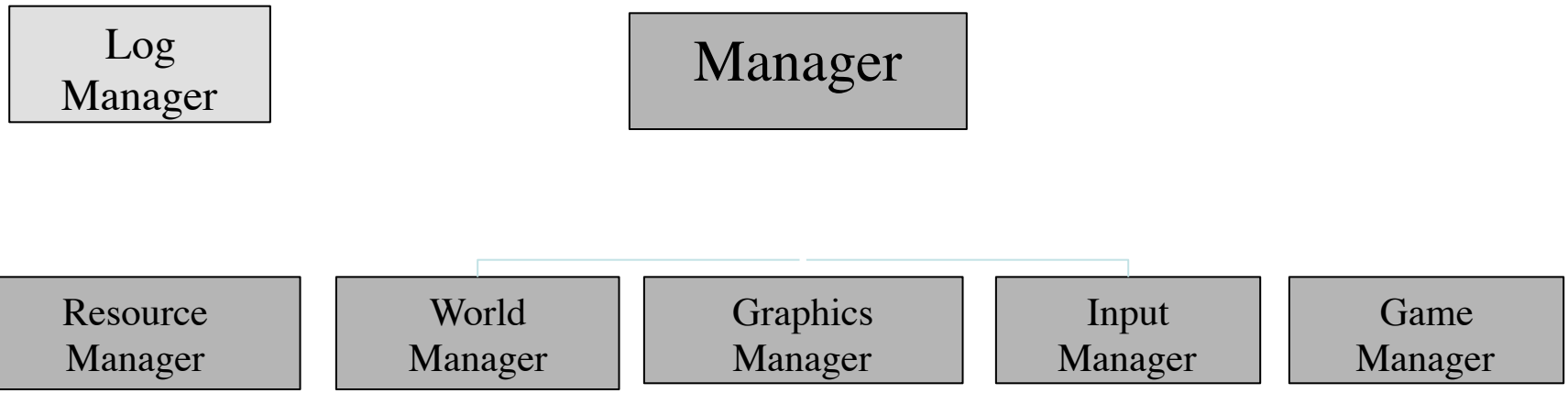
Modular: Open Class Library (e.g., C4)

- Code-oriented development
- Very carefully layered
- Allows maximum modifiability
- Often open source (e.g., jME)
- Not as accessible for novices and "casual" programmers

Basic Game Engine Architecture Blocks



Dragonfly


Log Manager
Manager
Resource Manager
World Manager
Graphics Manager
Input Manager
Game Manager

C4 Architecture

Base Services

Memory Manager
Low-level memory operations.

File Manager
Low-level file access.

Resource Manager
Loading resources, defining custom resource types.

Time Manager
Time access, deferred events, timers, date.

Math Library
Vectors, matrices, quaternions, random numbers.

Utility Library
Lists, maps, arrays, strings, graphs, trees, smart links.

System Managers

Graphics Manager
Renderables, textures, shaders, post-processing.

Sound Manager
Playing sounds, sound flow, audio streaming.

Network Manager
Low-level networking access.

Input Manager
Input devices, actions, control configuration.

System Utilities
Event handling, threads, mutexes, variables, logging.

http://www.terathon.com/docs/

C4 Architecture (cont.)

Large-Scale Architecture

World Manager
Scene graph, nodes, objects, model animation.

Controller System
Controllers, scripts, functions.

Physics Manager
Rigid bodies, joints, force fields.

Message Manager
High-level networking access.

Effect Manager
Particle systems, emitters, panels, markings.

Interface Manager
User interface widgets, windows, menus.

Movie Manager
Playing movies into interface widgets.

Plugin Modules

World Editor
The World Editor plugin API.

Browser Plugin
Displaying interactive web browsers in panels.

Logitech Plugin
Image output on the Logitech G15 keyboard.

http://www.terathon.com/docs/

"Best" Engine Choice is Relative to the Situation

WPI

- Similar issues of needs, resources, and constraints (as in buy vs. build)
  - Platform, programming language constraints
  - Cost constraints (commercial: $ to $$$)
  - Specific technical features required (e.g., MMO)
  - Previous experience of staff
  - Support from developers, user community (e.g., forums)
  - Pedagogical goals (e.g., this course)

Choice of Unity for IMGD 4000

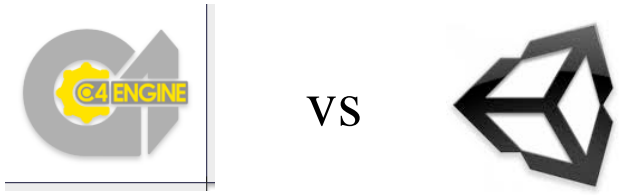
- Unity 3D  http://www.unity3d.com
  - Much better for artists (trivial importing) than, e.g., C4
  - Programming in C# (good for structure and robustness)
  - Debugger support with Monodevelop
  - Very popular
  - Could help you get an internship

But...
C4 would also be a solid option

WPI

- Written in C++
  - Builds on your Dragonfly experience
- We have a full source-code license
- Better control over lighting
  - Games look "better"
- Requires more work on your part
- Maybe next year...

Detailed Feature Comparisons



- C4/Unity from DevMaster.net
- Dragonfly from my/your knowledge
- Caveats:
  - Info is not audited
  - Let's not get bogged down in the details
    - The idea is to get overall sense of emphasis

General Features

- Object-Oriented Design, Plug-in Architecture, Save/Load System:
- Extremely clean class hierarchy for scene graph nodes, including geometries, cameras, lights, sounds, zones, portals, triggers, markers, and special effects
- General state serialization support for saving worlds
- Quick save and quick load capabilities
- Separation between per-instance and shared data
- Support for pack files and a virtual directory hierarchy
- Skinable GUI's

- Object-Oriented Design, Plug-in Architecture, Save/Load System:
- Professional FPS controller ready to drop in (and tune)
- Streamed loading for the Unity Web Player
- Unity asset server / asset source code version control
- Cross-platform web player content, the Unity Web Player is available for both Mac OS X and Windows users and works with all browsers
- Standalone executables for both Mac OS X and Windows
- Mac OS X Dashboard Widgets
- iPhone Publishing is available as add-on product
- Streaming Asset Bundles: the ability to stream in any asset (terrain, mesh, etc) into the game

Scripting

?

- Graphical script editor for easy artist/designer access
- Games can easily define custom script components, and these automatically appear in the editor
- Controllers can advertise custom function calls that can be accessed from scripts
- Scripts support variables, looping, and conditional execution, all shown in a concise graphical manner

- Uses the Mono and supports JavaScript, C# and Boo, interoperable (to a certain extent) and JIT'ted to native code
- Complete scripting documentation
- Source-level debugging

Built-in Editors

- Full-featured integrated cross-platform world editor
- Graphical shader editor
- Graphical script editor
- Interface panel editor
- Animation cue editor

- Editor provides zero-cost asset pipeline: save a file and it updates automatically
- Editor Extensibility: Create completely custom editor windows, and entirely new tools and workflows.
- Asset Server that provides version control capabilities for Unity projects
- Optimized for use with large projects
- New Server view integrated into the Unity user interface
- Updates, commits, and graphical version comparisons are all done inside the Unity editor.
- Procedural tree creator

Physics

- Rigid body simulation
- Real-time cloth simulation
- Real-time large-scale fluid surface simulation
- Continuous collision detection
- Contact forces and friction
- Precise buoyancy forces
- Customizable force fields
- Joints (spherical, universal, discal, revolute, cylindrical, and prismatic)
- Full networking support

- Basic Physics
- Collision Detection
- Rigid Body
- Vehicle Physics
- Powered by the PhysX Engine, which also supports particle physics
- Cloth simulation

Lighting

- Point lights, spot lights, directional lights
- Inter-zone lighting analysis
- Fully dynamic lighting
- Ambient lighting volumes
- True volumetric light shafts
- Screen Space Ambient Occlusion (SSAO)

- Per-vertex
- Per-pixel
- Lightmapping Beast-Lightmapping

Shadows

- Fully dynamic lighting
- Stencil shadows
- Cascaded shadow mapping with smooth transitions
- Projected light source shadows
- All types of shadows can be combined

- Projected planar
- Blob shadows
- Realtime dynamic soft shadows
- Shadows are dynamic, optimized, and allow self-shadowing (only available in Unity Pro)

Texturing

- Multitexturing
- Bump mapping
- Parallax mapping
- Horizon mapping
- Diffuse, specular, normal, gloss, emission, occlusion maps
- Emission glow and specular bloom effects
- Surface markings / decals on arbitrary geometry

- Basic
- Bump mapping
- Procedural

Shaders

- Large variety of standard shaders can be created with material attributes
- Complex custom shaders can be created with graphical shader editor
- Comprehensive bump/normal mapping capabilities
- Parallax bump texture mapping
- Horizon bump shadow mapping
- Bumpy reflection and refraction
- Cook-Torrance microfacet shading
- Cube environment reflections
- Realistic water shading

- Vertex
- Pixel
- High Level
- Unity comes with an extensive library of 40 shaders including Vertex Lit, Diffuse, Glossy, Bumped, Bumped Specular, Reflective, Self-illuminating, a Toon (Cell) shader, and 9 different particle shaders.
- Everything falls back gracefully on low-end GFX cards
- Parallax shaders
- GLSL support (in addition to Cg)

Scene Management

- Portals
- Visibility graph
- Occlusion culling
- Level of detail
- Fully lit impostors for massive forests
- Mirrors and remote portals
- Object instancing
- External scene referencing
- Game level save/load system

- Occlusion culling
- Umbra occlusion culling

Animation

- Skeletal animation
- Hierarchical animation blending system
- Forward kinematics
- Inverse kinematics

- Keyframe Animation
- Skinned character animation
- Procedural Characters and Animation: the ability to stitch multiple body parts into one character, and reassign bones to different characters. The entire skinned animation system is now scriptable.

Meshes

- Dynamic level-of-detail
- Skinning
- Constructive Solid Geometry (CSG) operations
- Import from Collada, OpenGEX

- Mesh Loading
- Skinning Native importing from Cinema 4D, Maya, Cheetah3D, Blender.
- Also support for Collada, FBX, 3DS, OBJ formats

Special Effects, etc.

- Full-scene cinematic motion blur
- Distortion effects such as heat haze and shockwaves
- High-quality and high-performance procedural fire effects
- Volumetric fog with multiple density functions
- Interactive in-game interface panels
- Fully extensible particle systems
- Voxel-based blob (metaball) particle systems
- Voxel terrain (Cliffs, overhangs, caves, arches)
- Transvoxel algorithm for dynamic seamless level-of-detail

- Rendering Terrain engine with full editor tools, dense foliage, lightmapping and more
- Rendering with Shader Replacement: This makes it simple to make incredible eye-candy like depth-of-field, soft particles, thermal goggles, etc.
- Lens Flares
- Particle System
- Motion Blur
- Sky, Water, Mirror
- Color correcting filter, grayscale, sepia, and twirl
- Skinnable in-game GUIs

Networking

- Client-Server
- Fast, reliable network implementation using UDP/IP
- Solid fault tolerance and hacker resistance
- Advanced security measures, including packet encryption
- Automatic message distribution to entity controllers
- Cross-platform internet voice chat

- Client-Server
- Build on Raknet
- Supports .NET library and asynchronous WWW API
- Multiplayer Networking (advanced NAT punch-through, delta compression, easy to set up)

Sound & Video

- 2D & 3D sound
- Streaming sounds
- Doppler shift and other frequency effects
- Reverberation
- Atmospheric effects
- Directional sounds with cone attenuation
- Obstruction attenuation applied to direct and reflected paths
- Audio capture for voice chat

- 2D & 3D Sound
- Streaming Sound
- Streaming video and audio based on FMOD, includes sound effects (Reverb Zones, Various Filters: Low Pass Filter, High Pass Filter, Echo Filter, Distortion Filter, Reverb Filter, Chorus)