The Game Development Process

Game Programming

Outline

• Teams and Processes
• Debugging
• Select Languages
• Misc (as time allows)
  - AI
  - Multiplayer
Introduction

- Used to be programmers created games
  - But many great programmers not great game makers
- With budget shift, emphasis has shifted
  - Game content creators are artist and designers
- Programmers can be thought of as providing services for content
  - But fate of entire game rests in their hands
- Think about roles in your projects
  - Great design and art needed. But where is game without programming to make it work?

Based on Chapter 3.1, Introduction to Game Development

Programming Areas - Game Code

- Everything directly related to game itself
  - How camera behaves, score is kept, AI for bots, etc.
- Often in scripting language (rest is in C++, more on languages next)
  - Produce faster iterations
  - Allow technical designers/artists to change behaviors
  - More appropriate language for domain (ex: AI probably not easiest in C++)

Based on Chapter 3.1, Introduction to Game Development
Programming Areas – Game Engine

• Support code that is not game specific
  – More than just drawing pretty 3d graphics
    (that is actually the graphics engine, part of
    the game engine)
  – Isolate game code from hardware
    * ex: controller, graphics, sound
    * Allows designers to concentrate on game
  – Common functionality needed across game
    * Serialization, network communication,
      pathfinding, collision detection, discrete
      event simulator (timeline)

Based on Chapter 3.1, Introduction to Game Development

Programming Areas – Tools

• Most involve content creation
  – Level editors, particle effect editors, sound editors
• Some to automate repetitive tasks (ex: convert
  content to game format)
  – These usually have no GUI
• Sometimes written as plug-ins for off-the-shelf
  tools
  – Ex: extensions to Maya or 3dStudio or Photoshop
  – If no such extension available, build from scratch
• Some for level design and game balance

Based on Chapter 3.1, Introduction to Game Development
Programming Team Organization

- Programmers often specialize
  - Graphics, networking, AI
- May be generalists, know something about everything
  - Often critical for "glue" to hold specialists together
  - Make great lead programmers
- More than 3 or 4, need some organization
  - Often lead programmer, much time devoted to management
- If more than 10 programmers, will be several leads (graphics lead, AI lead, etc.)

Based on Chapter 3.1, Introduction to Game Development

Software Methodologies

- Code and Fix
- Waterfall
- Iterative
- Agile
- (Then, some common practices)

(Take cs3733, Software Engineering)
Methodologies – Code and Fix

• Really, lack of a methodology
  - And all too common
• Little or no planning, diving straight into implementation
• Reactive, no proactive
• End with bugs. If bugs faster than can fix, “death spiral” and may be cancelled
• Even those that make it, must have “crunch time”
  - Viewed after as badge of honor, but results in burnout

Based on Chapter 3.1, Introduction to Game Development

Methodologies – Waterfall

• Plan ahead
• Proceed through various planning steps before implementation
  - requirements analysis, design, implementation, testing (validation), integration, and maintenance
• The waterfall loops back as fixes required
• Can be brittle to changing functionality, unexpected problems in implementation
  - Requires going back to beginning

Based on Chapter 3.1, Introduction to Game Development
Methodologies - Iterative

• Develop for a period of time (1-2 months), get working game, add features
  - Periods can coincide with publisher milestones
• Allows for some planning
  - Time period can have design before implementation
• Allows for some flexibility
  - Can adjust (to new technical challenges or producer demands)

Based on Chapter 3.1, Introduction to Game Development

Methodologies - Agile

• Admit things will change, avoid looking too far in the future
• Value simplicity and the ability to change
• Develop for a period of time (1-4 weeks)
  - Each does not have enough features to release, but could be “done” and released
• Re-establish priorities
  - Can scale, add new features, adjust
• Feature “real-time” communication, often face-to-face over documents (writing!)
  - Locate people (programmers and designers) together in a “bullpen”
• Relatively new for game development
• Big challenge is hard to convince publishers

Based on Chapter 3.1, Introduction to Game Development
Common Practices – Version Control

- Database containing files and past history of them
- Central location for all code
- Allows team to work on related files without overwriting each other’s work
- History preserved to track down errors
- Branching and merging for platform specific parts

Based on Chapter 3.1, Introduction to Game Development

Common Practices – Quality (1 of 2)

- Code reviews - walk through code by other programmer(s)
  - Formal or informal
  - “Two eyes are better than one”
  - Value is that the programmer is aware that others will read
- Asserts
  - Force program to crash to help debugging
    - Ex: Check condition is true at top of code, say pointer not NULL before following
  - Removed during release

Based on Chapter 3.1, Introduction to Game Development
Common Practices – Quality (2 of 2)

- **Unit tests**
  - Low level test of part of game (Ex: see if physics computations correct)
  - Tough to wait until very end and see if bug
  - Often automated, computer runs through combinations
  - Verify before assembling
- **Acceptance tests**
  - Verify high-level functionality working correctly (Ex: see if levels load correctly)
- Note, above are programming tests (ie- code, technical). Still turned over to testers that track bugs, do gameplay testing.
- **Bug database**
  - Document and track bugs
  - Can be from programmers, publishers, customers
  - Classify by severity
  - Keeps bugs from falling through cracks
  - Helps see how game is progressing

Based on Chapter 3.1, Introduction to Game Development

Common Practices – Pair (or “Peer”) Programming

- Two programmers at one workstation
- One codes and tests, other thinks
  - Switch after fixed time
- Results:
  - Fewer breaks
  - More enjoyable, higher morale
  - Team-cohesion
  - Collective of ownership

http://en.wikipedia.org/wiki/Pair_programming
Debugging Introduction

• Debugging is methodical process for removing mistakes in program
• So important, whole set of tools to help. Called “debuggers”
  - Trace code, print values, profile
  - New Integrated Development Environments (IDEs) (such as Game Maker) have it built in
• But debugging still frustrating
  - Beginners not know how to proceed
  - Even advanced can get “stuck”
• Don’t know how long takes to find
  - Variance can be high
• What are some tips? What method can be applied?

Based on Chapter 3.5, Introduction to Game Development
Sub-Outline

• 5-step debugging process
• Prevention
• Game Maker specifics
• Debugging tips

Step 1: Reproduce the Problem Consistently

• Find case where always occurs
  - “Sometimes game crashes after kill boss” doesn’t help much
• Identify steps to get to bug
  - Ex: start single player, room 2, jump to top platform, attack left, ...
  - Produces systematic way to reproduce
Step 2: Collect Clues

- Collect clues as to bug
  - Clues suggest where problem might be
  - Ex: if crash using projectile, what about that code that handles projectile creation and shooting?
- And beware that some clues are false
  - Ex: if bug follows explosion may think they are related, but may be from something else
- Don’t spend too long - get in and observe
  - Ex: crash when shooting arrow. See reference pointer from arrow to unit that shot arrow should get experience points, but it is NULL
  - That’s the bug, but why is it NULL?

Step 3: Pinpoint Error

1) Propose a hypothesis and prove or disprove
   - Ex: suppose arrow pointer corrupted during flight. Add code to print out values of arrow in air. But equals same value that crashes. Hypothesis is wrong. But now have new clue.
   - Ex: suppose unit deleted before experience points added. Print out values of all in camp before fire and all deleted. Yep, that’s it.

Or 2), divide-and-conquer method (note, can use in conjunction with hypothesis test above, too)
   - Sherlock Holmes: “when you have eliminated the impossible, whatever remains, however improbably, must be the truth”
   - Setting breakpoints, look at all values, until discover bug
   - The ”divide” part means break it into smaller sections
     * Ex: if crash, put breakpoint ½ way. Is it before or after? Repeat.
   - Look for anomalies, NULL or NAN values
Step 4: Repair the Problem

• Propose solution. Exact solution depends upon stage of problem.
  - Ex: late in code cannot change data structures. Too many other parts use.
  - Worry about “ripple” effects.
• Ideally, want original coder to fix.
  - If not possible, at least try to talk with original coder for insights.
• Consider other similar cases, even if not yet reported
  - Ex: other projectiles may cause same problem as arrows did

Step 5: Test Solution

• Obvious, but can be overlooked if programmer is sure they have fix (but programmer can be wrong!)
• So, test that solution repairs bug
  - Best by independent tester
• Test if other bugs introduced (be aware “ripple” effect)
Debugging Prevention

- Use consistent style, variable names
- Indent code, use comments
- Always initialize variables when declared
- Avoid hard-coded (magic numbers) – makes brittle
- Add infrastructure, tools to assist
  - Alter game variables on fly (speed up)
  - Visual diagnostics (maybe on avatars)
  - Log data (events, units, code, time stamps)
- Avoid identical code – harder to fix if bug found
  - Use a script
- Verify coverage (test all code) when testing

Game Maker – Print Messages

- Display a Message
  - object → main2 → info
- Or, in code
  - show_message('Executed this code')
  - show_message('num:' + string(number_here))
- Beware if done every step!
  - Save code ahead of time
Game Maker – Debug Mode

- Ex: 1945
  - obj_plane.x
  - obj_plane.can_shoot
- Save/load
- Look at instances, global variables, local variables
- Execute code
- Set speed

Game Maker – Print Debug Messages

- Like show_message but in debug mode only
  - Note, doesn’t pause
- In code
  - show_debug_message ('Executed this code')
- Need to run in debug mode
- Debug Information → Tools → Show Messages
Game Maker – Log Messages

• Write messages to file
• Example:
  - At beginning (maybe create log object)
    * global.log_name = "logfile";
    global.fid = file_text_open_write(global.log_name);
  - Then, where needed:
    * file_text_write_string(global.fid,"Debug message here") ;
  - Close when done (object → event other → game end):
    * file_text_close(global.fid)
• More file operations at:
  - Note: files also useful for save/load game, etc.

Game Maker – Script/Code Syntax
Game Maker – Error Messages (1 of 2)

Pay attention!
Refers to:
- Object
- Event
- Line number
- Variable name

• Help pinpoint problem
  - Refer to object and method and offending code

Game Maker – Error Messages (2 of 2)

• Can write messages to log file
• Can ignore messages
  - Use "error_last" and "error_occurred" for custom handling
  - Typically, use only in release
Debugging Tips (1 of 3)

• **Fix one thing at a time** - don't try to fix multiple problems
• **Change one thing at a time** - tests hypothesis. Change back if doesn't fix problem.
• **Start with simpler case that works** - then add more complex code, one thing at a time
• **Question your assumptions** - don't even assume simple stuff works, or "mature" products
  - Ex: libraries and tutorials can have bugs
• **Minimize interactions** - systems can interfere, make slower so isolate the bug to avoid complications

Debugging Tips (2 of 3)

• **Minimize randomness** -
  - Ex: can be caused by random seed or player input. Fix input (script player) so reproducible
• **Break complex calculations into steps** - may be equation that is at fault or "cast" badly
• **Check boundary conditions** - classic "off by one" for loops, etc.
• **Use debugger** - breakpoints, memory watches, stack ...
• **Check code recently changed** - if bug appears, may be in latest code (not even yours!)
Debugging Tips (3 of 3)

• Take a break - too close, can't see it. Remove to provide fresh prospective
• Explain bug to someone else - helps retrace steps, and others provide alternate hypotheses
• Debug with partner - provides new techniques
  - Same advantage with code reviews, peer programming
• Get outside help - tech support for consoles, Web examples, libraries, ...

Tough Debugging Scenarios and Patterns (1 of 2)

• Bug in Release but not in Debug
  - Often in initialized code
  - Or in optimized code
    • Turn on optimizations one-by-one
• Bug in Hardware but not in Dev Kit
  - Usually dev kit has extra memory (for tracing, etc.). Suggest memory problem (pointers), stack overflow, not checking memory allocation
• Bug Disappears when Changing Something Innocuous
  - Likely timing problem (race condition) or memory problem
  - Even if looks like gone, probably just moved. So keep looking

Based on Chapter 3.5, Introduction to Game Development
Tough Debugging Scenarios and Patterns (2 of 2)

• Truly Intermittent Problems
  - Maybe best you can do is grab all data values (and stack, etc) and look at ("Send Error Report")

• Unexplainable Behavior

• Bug in Someone Else’s Code
  - "No it is not". Be persistent with own code first.
  - It’s not in hardware. (Ok, very, very rarely, but expect it not to be) Download latest firmware, drivers
  - If really is, best bet is to help isolate to speed them in fixing it.

Outline

• Teams and Processes (done)
• Debugging (done)
• Select Languages (next)
• Misc (as time allows)
  - AI
  - Multiplayer
C++ (1 of 3)

- Mid-late 1990’s, C was language of choice
- Since then, C++ language of choice for games
  - First commercial release in 1985 (AT&T)
- Here, list pros (+) and cons (-)
- (Take cs2102 OO Design Concepts or cs4233 OOAD)
  + C Heritage
    - Learning curve easier for those that know C
    - Compilers wicked fast
  + Performance
    - Used to be most important, but less so (but still for core parts)
    - Maps closely to hardware (can “guess” what assembly instructions will be)
    - Can not use features to avoid cost, if want (ie- virtual function have extra step but don’t have to use)
    - Memory management controlled by user

Based on Chapter 3.2, Introduction to Game Development

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C++ (2 of 3)

+ High-level
  - Classes (objects), polymorphism, templates, exceptions
  - Especially important as code-bases enlarge
  - Strongly-typed (helps reduce errors)
    * ex: declare before use, and const
+ Libraries
  - C++ middleware readily available
    * OpenGL, DirectX, Standard Template Library
      (containers, like “vectors”, and algorithms, like “sort”)

Based on Chapter 3.2, Introduction to Game Development
C++ (3 of 3)

- Too low-level
  - Still force programmer to deal with low-level issues
    * ex: memory management, pointers
- Too complicated
  - Years of expertise required to master (other languages seek to overcome, like Java and C#)
- Lacking features
  - No built-in way to look at object instances
  - No built-in way to serialize
  - Forces programmer to build such functionality (or learn custom or 3rd party library)
- Slow iterations
  - Code change can take a loong time as can compile
  - Brittle, hard to try new things

Based on Chapter 3.2, Introduction to Game Development

C++ (Summary)

- When to use?
  - Any code where performance is crucial
    * Used to be all, now game engine such as graphics and AI
    * Game-specific code often not C++
  - Legacy code base, expertise
  - When also use middle-ware libraries in C++
- When not to use?
  - Tool building (GUI's tough)
  - High-level game tasks (technical designers)

Based on Chapter 3.2, Introduction to Game Development
Java (1 of 3)

- Java popular, but only recently so for games
  - Invented in 1990 by Sun Microsystems
  - Concepts from C++ (objects, classes)
  - Powerful abstractions
    - Cleaner language
    - Memory management built-in
    - Templates not as messy
    - Object functions, such as virtualization
  - Code portability (JVM)
    (Hey, draw picture)
  - Libraries with full-functionality built-in

Java (2 of 3)

- Performance
  - Interpreted, garbage collection, security
  - So take 4x to 10x hit
  - Can overcome with JIT compiler, Java Native Interface (not interpreted)
- Platforms
  - JVM, yeah, but not all games (most PC games not, nor consoles)
  - Strong for browser-games, mobile
Java (3 of 3)

- Used in:
  - Downloadable/Casual games
    - PopCap games
      - *Mummy Maze, Seven Seas, Diamond Mine*
    - Yahoo online games (WorldWinner)
      - *Poker, Blackjack*
  - PC
    - *Star Wars Galaxies* uses Java (and simplified Java for scripting language)
    - *You Don't Know Jack* and *Who Wants to be a Millionaire* all Java

Based on Chapter 3.2, Introduction to Game Development

Scripting Languages (1 of 3)

- Not compiled, rather interpreted
  - Specify (script) a sequence of actions
- Most games rely upon some
  - Trigger a few events, control cinematic
- Others games may use it lots more
  - Control game logic and behavior (*Game Maker* has GML)
- Ease of development
  - Low-level things taken care of
  - Fewer errors by programmer
    - But script errors tougher, debuggers worse if custom
  - Less technical programming required
    - Still, most scripting done by *programmers*
  - Iteration time faster (don't need to re-compile all code)
  - Can be customized for game (ex: just AI tasks)

Based on Chapter 3.2, Introduction to Game Development
Scripting Languages (2 of 3)

+ Code as an asset
  - Ex: consider Peon in C++, with behavior in C++, maybe art as an asset. Script would allow for behavior to be an asset also
    * Can be easily modified, even by end-user in "mod"

- Performance
  - Parsed and executed "on the fly"
    * Hit could be 10x or more over C++
  - Less efficient use of instructions, memory management

- Tool support
  - Not as many debuggers, IDEs
    * Errors harder to catch

- Interface with rest of game
  - Core in C++, must "export" interface
    * Can be limiting way interact
  - (Hey, draw picture)

Based on Chapter 3.2, Introduction to Game Development

Scripting Languages (3 of 3)

- **Python**
  - Interpreted, OO, many libraries, many tools
  - Quite large (bad when memory constrained)
  - Ex: *Blade of Darkness, Earth and Beyond, Eve Online, Civilization 4* (Table 3.2.1 full list)

- **Lua** (pronounced: Loo-ah)
  - Not OO, but small (memory). Embed in other programs. Doesn’t scale well.
  - Ex: *Grim Fandango, Baldur’s Gate, Far Cry* (Table 3.2.2 full list)

- **Others:**
  - *Ruby, Perl, JavaScript*
  - Custom: *GML, QuakeC, UnrealScript*
    * Implementing own tough, often performs poorly so careful!

Based on Chapter 3.2, Introduction to Game Development
Macromedia Flash (1 of 2)

- More of a platform and IDE (ala Game Maker) than a language (still, has ActionScript)
  - "Flash" refers authoring environment, the player, or the application files
  - Released 1997, popular with Browser bundles by 2000
- Advantages
  - Wide audience (nearly all platforms have Flash player)
  - Easy deployment (embed in Web page)
  - Rapid development (small learning curve, for both artists and programmers)
- Disadvantages
  - 3D games
  - Performance (interpreted, etc.)

Macromedia Flash (2 of 2)

- Timeline Based
  - Frames and Frame rate (like animations)
  - Programmers indicate when (time) event occurs (can occur across many frames)
- Vector Engine
  - Lines, vertices, circles
  - Can be scaled to any size, still looks crisp
- Scripting
  - ActionScript similar to JavaScript
  - Classes (as of Flash v2.0)
  - Backend connectivity (load other Movies, URLs)
Outline

- Teams and Processes (done)
- Select Languages (done)
- Debugging (done)
- Misc (as time allows)
  - AI (next)
  - Multiplayer

Introduction to AI

- Opponents that are challenging, or allies that are helpful
  - Unit that is credited with acting on own
- Human-level intelligence too hard
  - But under narrow circumstances can do pretty well (ex: chess and Deep Blue)
- Artificial Intelligence (around in CS for some time)
AI for CS different than AI for Games

- Must be smart, but purposely flawed
  - Loose in a fun, challenging way
- No unintended weaknesses
  - No “golden path” to defeat
  - Must not look dumb
- Must perform in real time (CPU)
- Configurable by designers
  - Not hard coded by programmer
- “Amount” and type of AI for game can vary
  - RTS needs global strategy, FPS needs modeling of individual units at “footstep” level
  - RTS most demanding: 3 full-time AI programmers
  - Puzzle, street fighting: 1 part-time AI programmer

Based on Chapter 5.3, Introduction to Game Development

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AI for Games - Mini Outline

- Introduction   (done)
- Agents         (next)
- Finite State Machines
- Common AI Techniques
- Promising AI Techniques
Game Agents (1 of 2)

- Most AI focuses around game agent
  - think of agent as NPC, enemy, ally or neutral
- Loops through: sense-think-act cycle
  - Acting is event specific, so talk about sense+think
- Sensing
  - Gather current world state: barriers, opponents, objects
  - Needs limitations: avoid "cheating" by looking at game data
  - Typically, same constraints as player (vision, hearing range)
    - Often done simply by distance direction (not computed as per actual vision)
  - Model communication (data to other agents) and reaction times (can build in delay)

Based on Chapter 5.3, Introduction to Game Development

Game Agents (2 of 2)

- Thinking
  - Evaluate information and make decision
  - As simple or elaborate as required
  - Two ways:
    - Precoded expert knowledge, typically hand-crafted if-then rules + randomness to make unpredictable
    - Search algorithm for best (optimal) solution

Based on Chapter 5.3, Introduction to Game Development
Game Agents – Thinking (1 of 3)

• Expert Knowledge
  - finite state machines, decision trees, ... (FSM most popular, details next)
  - Appealing since simple, natural, embodies common sense
    * Ex: if you see enemy weaker than you, attack. If you see enemy stronger, then go get help
  - Often quite adequate for many AI tasks
  - Trouble is, often does not scale
    * Complex situations have many factors
    * Add more rules, becomes brittle

Based on Chapter 5.3, Introduction to Game Development

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Game Agents – Thinking (2 of 3)

• Search
  - Look ahead and see what move to do next
  - Ex: piece on game board, pathfinding (ch 5.4)

• Machine learning
  - Evaluate past actions, use for future
  - Techniques show promise, but typically too slow
  - Need to learn and remember

Based on Chapter 5.3, Introduction to Game Development
Game Agents – Thinking (3 of 3)

- Making agents stupid
  - Many cases, easy to make agents dominate
    * Ex: bot always gets head-shot
  - Dumb down by giving “human” conditions, longer reaction times, make unnecessarily vulnerable
- Agent cheating
  - Ideally, don’t have unfair advantage (such as more attributes or more knowledge)
  - But sometimes might to make a challenge
    * Remember, that’s the goal, AI lose in challenging way
  - Best to let player know

AI for Games – Mini Outline

- Introduction (done)
- Agents (done)
- Finite State Machines (next)
- Common AI Techniques
- Promising AI Techniques
Finite State Machines (1 of 2)

- Abstract model of computation
- Formally:
  - Set of states
  - A starting state
  - An input vocabulary
  - A transition function that maps inputs and the current state to a next state

Based on Chapter 5.3, Introduction to Game Development

Finite State Machines (2 of 2)

- Most common game AI software pattern
  - Natural correspondence between states and behaviors
  - Easy to diagram
  - Easy to program
  - Easy to debug
  - Completely general to any problem

- Problems
  - Explosion of states
  - Often created with ad hoc structure

Based on Chapter 5.3, Introduction to Game Development
Finite-State Machine: Approaches

- Three approaches
  - Hardcoded (switch statement)
  - Scripted
  - Hybrid Approach

Based on Chapter 5.3, Introduction to Game Development

```c
void RunLogic( int * state ) {
  switch( state ) {
    case 0:  //Wander
      Wander();
      if( SeeEnemy() )    { *state = 1; }
      break;

    case 1:  //Attack
      Attack();
      if( LowOnHealth() ) { *state = 2; }
      if( NoEnemy() )     { *state = 0; }
      break;

    case 2:  //Flee
      Flee();
      if( NoEnemy() )     { *state = 0; }
      break;
  }
}
```

Based on Chapter 5.3, Introduction to Game Development
Finite-State Machine:
Problems with switch FSM

1. Code is ad hoc
   - Language doesn't enforce structure
2. Transitions result from polling
   - Inefficient – event-driven sometimes better
3. Can't determine 1st time state is entered
4. Can't be edited or specified by game designers or players

Based on Chapter 5.3, Introduction to Game Development

Finite-State Machine:
Scripted with alternative language

```
AgentFSM
{
    State( STATE_Wander )
        OnUpdate
            Execute( Wander )
            if( SeeEnemy ) SetState( STATE_Attack )
        OnEvent( AttackedByEnemy )
            SetState( Attack )
    State( STATE_Attack )
        OnEnter
            Execute( PrepareWeapon )
        OnUpdate
            Execute( Attack )
            if( LowOnHealth ) SetState( STATE_Flee )
            if( NoEnemy ) SetState( STATE_Wander )
        OnExit
            Execute( StoreWeapon )
    State( STATE_Flee )
        OnUpdate
            Execute( Flee )
            if( NoEnemy ) SetState( STATE_Wander )
}
```

Based on Chapter 5.3, Introduction to Game Development
Finite-State Machine: Scripting Advantages

1. Structure enforced
2. Events can be handed as well as polling
3. OnEnter and OnExit concept exists
4. Can be authored by game designers
   - Easier learning curve than straight C/C++

Finite-State Machine: Scripting Disadvantages

• Not trivial to implement
• Several months of development
  - Custom compiler
    • With good compile-time error feedback
  - Bytecode interpreter
    • With good debugging hooks and support
• Scripting languages often disliked by users
  - Can never approach polish and robustness of commercial compilers/debuggers

Based on Chapter 5.3, Introduction to Game Development
Finite-State Machine: Hybrid Approach

- Use a class and C-style macros to approximate a scripting language
- Allows FSM to be written completely in C++ leveraging existing compiler/debugger
- Capture important features/extensions
  - OnEnter, OnExit
  - Timers
  - Handle events
  - Consistent regulated structure
  - Ability to log history
  - Modular, flexible, stack-based
  - Multiple FSMs, Concurrent FSMs
- Can’t be edited by designers or players

Based on Chapter 5.3, Introduction to Game Development

Finite-State Machine: Extensions

- Many possible extensions to basic FSM
  - OnEnter, OnExit
  - Timers
  - Global state, substates
  - Stack-Based (states or entire FSMs)
  - Multiple concurrent FSMs
  - Messaging

Based on Chapter 5.3, Introduction to Game Development
AI for Games - Mini Outline

• Introduction (done)
• Agents (done)
• Finite State Machines (done)
• Common AI Techniques (next)
• Promising AI Techniques

Common Game AI Techniques

• Whirlwind tour of common techniques
• (See book chapters)