The Game Development Process

Game Programming

Outline

- Teams and Processes
- Select Languages
- Debugging
- 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

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++)

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

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

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
- More than 10 programmers, several leads (graphics lead, AI lead, etc.)

Based on Chapter 3.1, *Introduction to Game Development*

Software Methodologies

- Code and Fix
- Waterfall
- Iterative
- Agile

- (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
  - 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
- Can scale, add new features, adjust
- 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

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 programmer aware others 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

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*

Outline

- Teams and Processes (done)
- Select Languages (next)
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- 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)
- List *pros* (+) and *cons* (-)
- (Take cs2102 OO Design Concepts or cs4233 OOAD)

+ C Heritage
  - Learning curve easier
  - 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

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")

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 iteration
  - Brittle, hard to try new things
  - Code change can take a looong time as can compile

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)

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

Based on Chapter 3.2, *Introduction to Game Development*

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

Based on Chapter 3.2, *Introduction to Game Development*

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

Scripting Languages (1 of 3)

- Not compiled, rather specify (script) 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, often debuggers worse
  - 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)

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.)

Based on Chapter 3.3, *Introduction to Game Development*

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

Based on Chapter 3.3, *Introduction to Game Development*

Outline

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

Debugging Introduction

- New Integrated Development Environments (IDEs) have debugging tools
  - Trace code, print values, profile
- But debugging frustrating
  - Beginners not know how to proceed
  - Even advanced can get "stuck"
- Don't know how long takes to find
  - Variance can be high
- Mini-outline
  - 5-step debugging process
  - Debugging tips
  - Touch scenarios and patterns
  - Prevention

Based on Chapter 3.5, *Introduction to Game Development*

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, skirmish map 44, find enemy camp, use projectile weapon …
  - Produces systematic way to reproduce

Step 2: Collect Clues

- Collect clues as to bug
  - But beware that some clues are false
    - Ex: if bug follows explosion may think they are related, but may be from something else
  - Ex: if crash using projectile, what about that code that makes it possible to crash?
- Don't spend too long, get in and observe
  - Ex: see reference pointer from arrow to unit that shot arrow should get experience points, but it is may be NULL
  - That's the bug, but why is it NULL?

Step 3: Pinpoint Error

- 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. *Wrong*.
  - Ex: suppose unit deleted before experience point. Print out values of all in camp before fire and all deleted. *Yep, that's it*.
- Or, divide-and-conquer method (note, can use in conjunction with hypo-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

Based on Chapter 3.5, *Introduction to Game Development*

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. At least, 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

Based on Chapter 3.5, *Introduction to Game Development*

Step 5: Test Solution

- Obvious, but can be overlooked if programmer is sure they have fix (but programmer can be wrong!)
- So, test that fix repairs bug
  - Best by independent tester
- Test if other bugs introduced (beware "ripple" effect)

Based on Chapter 3.5, *Introduction to Game Development*

Debugging Tips (1 of 3)

- *Question your assumptions* – don't even assume simple stuff works, or "mature" products
  - Ex: libraries can have bugs
- *Minimize interactions* – systems can interfere, make slower so isolate the bug to avoid complications
- *Minimize randomness* – ex, can be caused by random seed or player input. Fix input (script player) so reproducible

Based on Chapter 3.5, *Introduction to Game Development*

Debugging Tips (2 of 3)

- Break complex calculations into steps – may be equation that is fault or "cast" badly
- Check boundary conditions – classic "off by one" for loops, etc.
- Disrupt parallel computations – "race conditions" if happen at same time (cs3013)
- Use debugger – breakpoints, memory watches, stack …
- Check code recently changed – if bug appears, may be in latest code (not even yours!)

Based on Chapter 3.5, *Introduction to Game Development*

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
- *Get outside help* – tech support for consoles, libraries, …

Based on Chapter 3.5, *Introduction to Game Development*

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
  - Ex: values change without touching. Usually memory problem. Could be from supporting system. Retry, rebuild, reboot, re-install.
- 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.

Based on Chapter 3.5, *Introduction to Game Development*

Debugging Prevention (1 of 2)

- Understand underlying system
  - Knowing language not enough
  - Must understand underlying system
    - At least one level down
      - Engine for scripters
      - OS for engine
    - Maybe two layers down (hardware, assembly)
- Add infrastructure, tools to assist
  - Make general
  - Alter game variables on fly (speed up)
  - Visual diagnostics (maybe on avatars)
  - Log data (events, units, code, time stamps)
  - Record and playback capability

Based on Chapter 3.5, *Introduction to Game Development*

Debugging Prevention (2 of 2)

- Set compiler on highest level warnings
  - Don't ignore warnings
- Compile with multiple compilers
  - See if platform specific
- Write own memory manager (for console games, especially, since tools worse)
- Use asserts
- Always initialize when declared
- Indent code, use comments
- Use consistent style, variable names
- Avoid identical code – harder to fix if bug
- Avoid hard-coded (magic numbers) – makes brittle
- Verify coverage (test all code) when testing

Based on Chapter 3.5, *Introduction to Game Development*

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)

Based on Chapter 5.3, *Introduction to Game Development*

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*

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*

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)

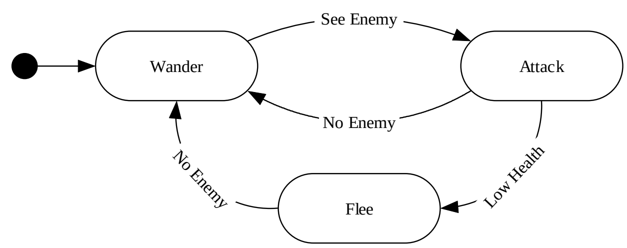
- Making agents stupid
  - Many cases, easy to make agents dominate
    - Ex: bot always gets head-shot
  - Dumb down by giving "human" conditions, longer reaction times, make unnecessarily vulnerable
- Agent cheating
  - Ideally, don't have unfair advantage (such as more attributes or more knowledge)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

Based on Chapter 5.3, *Introduction to Game Development*

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*

Finite-State Machine: Hardcoded FSM

```
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)

Based on Chapter 5.3, *Introduction to Game Development*