Game Engine Architecture

Chapter 2

Tools of the Trade

Hooman Salamat

Version Control

- A *version control* system is a tool that permits multiple users to work on a group of files collectively.
- It is sometimes called *source control*
  - provides a central repository from which engineers can share source code;
  - keeps a history of the changes made to each source file;
  - provides mechanisms allowing specific versions of the code base to be tagged and later retrieved; and
  - permits versions of the code to be branched off from the main development line, a feature often used to produce demos or make patches to older versions of the software.

Common Version Control Systems

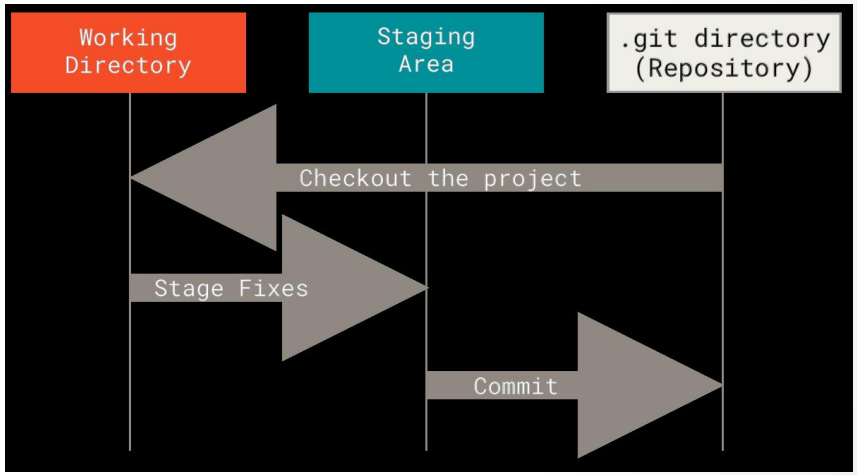
- *SCCS and RCS*. The Source Code Control System (SCCS) and the Revision Control System (RCS
- The Concurrent Version System (CVS)
- *Subversion*. an open source version control system aimed at replacing and improving upon CVS.
- *Git*. an open source revision control system
- *Perforce*. Perforce is a professional-grade source control system, with both text-based and GUI interfaces (used by many game companies, including *Naughty Dog* and *Electronic Arts*..)
- *NxN Alienbrain*. Alienbrain is a powerful and feature-rich source control system designed explicitly for the game industry.
- *ClearCase*. Rational ClearCase is a professional-grade source control system
- *Microsoft* Team Foundation **Version Control** for centralized version control.

GameEngineDevelopment repository

- Install GitHub Desktop
  - GitHub Desktop | Simple collaboration from your desktop
- Install Git command line
  - Git (git-scm.com)
- Create a repository
  - https://github.com/hsalamat/GameEngineDevelopment.git
  - Open the command line (cmd)
  - Cd c:\
  - Git clone https://github.com/hsalamat/GameEngineDevelopment.git
  - Cd GameEngineDevelopment
  - Git status
  - Git Pull

three main states

- Git has three main states that your files can reside in:
  - *modified*,*staged*, and *committed*:
  - Modified means that you have changed the file but have not committed it to your database yet.
  - Staged means that you have marked a modified file in its current version to go into your next commit snapshot.
  - Committed means that the data is safely stored in your local database.



config

- config file in the Git directory (that is, .git/config) of whatever repository you're currently using: Specific to that single repository. You can force Git to read from and write to this file with the --local option, but that is in fact the default.
- Unsurprisingly, you need to be located somewhere in a Git repository for this option to work properly.
- Set your user name
- git config --global user.name "Hooman Salamat"

```
cd .git

PS C:\Hooman\GBC\GAME3121\Course
Materials\GameEngineDevelopment\.git>
cat config
[core]
repositoryformatversion = 0
filemode = false
bare = false
logallrefupdates = true
symlinks = false
ignorecase = true
[submodule]
active = .
[remote "origin"]
url =
https://github.com/hsalamat/GameEngine
Development.git
fetch =
+refs/heads/*:refs/remotes/origin/*
[branch "master"]
remote = origin
merge = refs/heads/master
```

Master branch

- By default Git will create a branch called *master* when you create a new repository with git init.
- From Git version 2.28 onwards, you can set a different name for the initial branch.
- To set *main* as the default branch name do:
- git config --global init.defaultBranch main

Ignoring files

- Often, you'll have a class of files that you don't want Git to automatically add or even show you as being untracked.
- These are generally automatically generated files such as log files or files produced by your build system.
- In such cases, you can create a file listing patterns to match them named .gitignore.

- $ cat .gitignore
- *.[oa]
- *~
- The first line tells Git to ignore any files ending in ".o" or ".a" — object and archive files that may be the product of building your code.
- The second line tells Git to ignore all files whose names end with a tilde (~), which is used by many text editors such as Emacs to mark temporary files.
- You may also include a log, tmp, or pid directory; automatically generated documentation; and so on.
- Setting up a .gitignore file for your new repository before you get going is generally a good idea so you don't accidentally commit files that you really don't want in your Git repository.

.gitignore

```
# ignore all .a files
*.a
# but do track lib.a, even though you're ignoring .a files above
!lib.a
# only ignore the TODO file in the current directory, not subdir/TODO
/TODO
# ignore all files in any directory named build
build/
# ignore doc/notes.txt, but not doc/server/arch.txt
doc/*.txt
# ignore all .pdf files in the doc/ directory and any of its subdirectories
doc/**/*.pdf
```

Git status vs. git diff

- Let’s say you edit and stage the README file again and then edit the CONTRIBUTING.md file without
- staging it. If you run your git status command, you once again see something like this:

```
$ git status
On branch master
Your branch is up-to-date with 'origin/master'.
Changes to be committed:
(use "git reset HEAD <file>..." to unstage)
modified: README
Changes not staged for commit:
(use "git add <file>..." to update what will be committed)
(use "git checkout -- <file>..." to discard changes in working directory)
modified: CONTRIBUTING.md
```

- To see what you’ve changed but not yet staged, type git diff with no other arguments:

```
diff --git a/CONTRIBUTING.md b/CONTRIBUTING.md
index 8ebb991..643e24f 100644
--- a/CONTRIBUTING.md
+++ b/CONTRIBUTING.md
@@ -65,7 +65,8 @@ branch directly, things can get messy.
Please include a nice description of your changes when you submit your PR;
if we have to read the whole diff to figure out why you're contributing
in the first place, you're less likely to get feedback and have your change
-merged in.
+merged in. Also, split your changes into comprehensive chunks if your patch is
+longer than a dozen lines.
```

Inviting collaborators to a personal repository

1. Ask for the username of the person you're inviting as a collaborator. ...
2. On GitHub, navigate to the main page of the repository.
3. Under your repository name, click Settings.
4. In the left sidebar, click Manage access.
5. Click Invite a collaborator.

Conflict

- Let's change the test1.txt in the "Github" Website (mock the collaborator)
- Let's Change the test1.txt locally
- git add –A
- git commit -m "my stuff"
- Git pull
  - CONFLICT (content): Merge conflict in test1.txt

Add new files from yourself to the repo

- Create a file test1.txt under local git directory
- Git status
- git add test1.txt ➔ or whatever “untouched” file
- git commit -m "added test1.html“
- Git push
  - If some body else has already change the repository, you have to do “git pull” first before doing a git push

collaborator to your local machine

- Git pull
- Type git to see all the commands

Check out the conflict

- Go to your file and you see that your file has been modified.
  - <<<<<<< HEAD
  - just a test file
  - My changes
  - =======
  - just a test file -
  - collaborator changes
  - >>>>>>> a6cfb4be59754196af358eaff38b12be5dfddf0f
- You can modify the file and do a
  - Git add –A
  - Git commit
  - Then click on “Esc” then “:wq” to get out
  - Git push

Compilers, Linkers and IDEs

- Source Files, Headers and Translation Units
- Libraries, Executables and Dynamic Link Libraries
- Projects and Solutions
- Build Configurations
- Common Build Options
  - *Preprocessor Settings*
  - *Compiler Settings*
  - *Linker Settings*
- Local and Global Optimizations

Typical Build Configurations

- *Debug*
- *Development*
- *Ship*
- *Hybrid Builds*
  - A hybrid build is a build configuration in which the majority of the translation units are built in development mode, but a small subset of them is built in debug mode.

Project Configuration

- Right-clicking on any project in the Solution Explorer and selecting “Properties…” from the menu brings up the project’s “Property Pages” dialog.
  - Configuration Properties/General,
  - Configuration Properties/Debugging,
  - Configuration Properties/C++, and
  - Configuration Properties/Linker.

Macros

- $(TargetFileName). The name of the final executable, library or DLL file being built by this project.
- $(TargetPath). The full path of the folder containing the final executable, library or DLL.
- $(ConfigurationName). The name of the build config, which will be “Debug” or “Release” by default in Visual Studio, although as we’ve said, a real game project will probably have multiple configurations such

as “Debug,” “Hybrid,” “Development” and “Ship.”

- $(OutDir). The value of the “Output Directory” field specified in this dialog.
- $(IntDir). The value of the “Intermediate Directory” field in this dialog.
- $(VCInstallDir). The directory in which Visual Studio’s C++ standard library is currently installed.

Debugging Property Page

- *C/C++ Property Page*
  - *General Property Page/Additional Include Directories.*
  - *General Property Page/Debug Information Format.*
  - *Preprocessor Property Page/Preprocessor Definitions.*
- *Linker Property Page*
  - *General Property Page/Output File.*
  - *General Property Page/Additional Library Directories.*
  - *Input Property Page/Additional Dependencies.*

Debugging Your Code

- The Call Stack
- The Watch Window
  - The ",d" suffix forces values to be displayed in decimal notation.
  - The ",x" suffix forces values to be displayed in hexadecimal notation.
  - The ",*n*" suffix (where *n* is any positive integer) forces Visual Studio to treat the value as an array with *n* elements.
- Data Breakpoints
  - set a breakpoint that trips whenever a specific memory address is *written to*. Bring up the "Breakpoints" window found on the "Debug" menu under "Windows" and then "Breakpoints"
    - Select the "New" drop-down button in the upper-left corner of the window.
    - Select "New Data Breakpoint."
    - Type in the raw address or an address-valued expression, such as "&myVariable"

Conditional Breakpoints

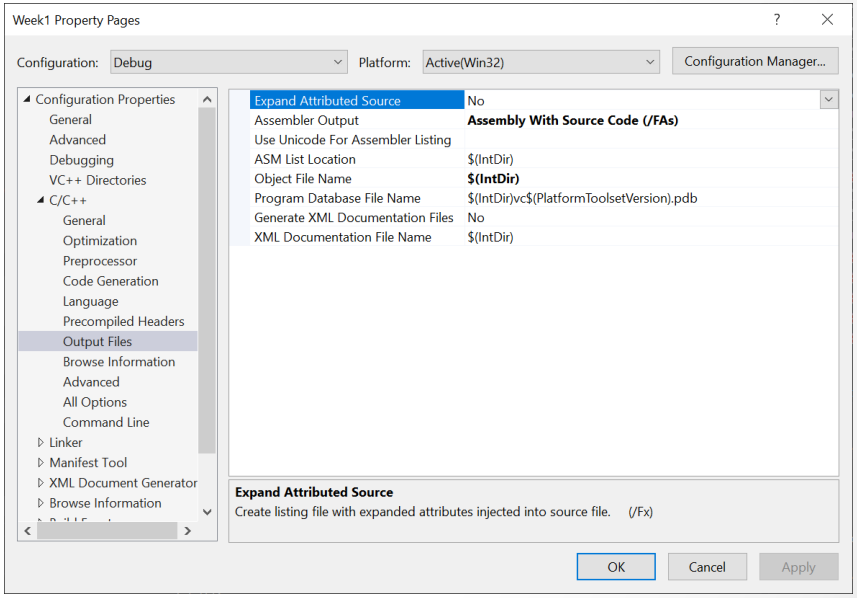
- set conditions on any type breakpoint—data breakpoints or regular line-of-code breakpoints.
- Example: game level with 20 tanks on-screen, and you want to stop your program when the third tank, whose memory address == 0x12345678, is running.
- By setting the breakpoint's condition expression to
- something like "(uintptr_t)this == 0x12345678", you can restrict the breakpoint only to the class instance whose memory address (this pointer) is 0x12345678.
- Conditional breakpoints cause the debugger to evaluate the conditional expression every time the breakpoint is hit, so they can bog down the performance of the debugger and your game.

Hit count

- Specifying a *hit count* for a breakpoint causes the debugger to decrement a counter every time the breakpoint is hit
- and only actually stop the program when that counter reaches zero!
- inspect what's happening during the 100th iteration of the loop (e.g., the 100th element in an array).
- Don't hit the F5 key 100 times!

Debugging Optimized Builds

- *Learn to read and step through disassembly in the debugger.*
  - You can normally see assembly code while debugging C++ in visual studio For this in Visual Studio put a breakpoint on code in question and when debugger hits it rigth click and find "Go To Disassembly" (or press CTRL+ALT+D)
  - Second approach is to generate assembly listings while compiling. For this go to project settings -> C/C++ -> Output Files -> ASM List Location and fill in file name. Also select "Assembly Output" to "Assembly With Source Code". The file *.asm will be saved in the same location as $(IntDir)



Debugging Optimized Builds

- *Use registers to deduce variables' values or addresses.*
  - The debugger will sometimes be unable to display the value of a variable
  - trace back through the disassembly to where the variable is first loaded into a register

```
ShaderInfo shaders[] = {
{ GL_VERTEX_SHADER,
"triangles.vert" },
{ GL_FRAGMENT_SHADER,
"triangles.frag" },
{ GL_NONE, NULL }
};
```

```
ShaderInfo shaders[] = {
{ GL_VERTEX_SHADER, "triangles.vert" },
00945CC2  mov         dword ptr [shaders],8B31h
00945CC9  mov         dword ptr [ebp-28h],offset
string "triangles.vert" (094FDA4h)
00945CD0  xor         eax,eax
00945CD2  mov         dword ptr [ebp-24h],eax
{ GL_FRAGMENT_SHADER, "triangles.frag" },
00945CD5  mov         dword ptr [ebp-20h],8B30h
00945CDC  mov         dword ptr [ebp-
1Ch],offset string "triangles.frag" (094FDB8h)
00945CE3  xor         eax,eax
00945CE5  mov         dword ptr [ebp-18h],eax
{ GL_NONE, NULL }
00945CE8  mov         dword ptr [ebp-14h],0
00945CEF  mov         dword ptr [ebp-10h],0
00945CF6  xor         eax,eax
00945CF8  mov         dword ptr [ebp-0Ch],eax
};
```

Debugging Optimized Builds

- *Inspect variables and object contents by address*
  - if an instance of the Foo class resides at address 0x1378A0C0,
  - We can type "(Foo*)0x1378A0C0" in a watch window,
  - and the debugger will interpret that memory address as if it were a pointer to a Foo object.
- *Leverage static and global variables*
  - Even in an optimized build, the debugger can usually inspect global and static variables.
  - Example: find the address of an internal object within the physics system,
  - discover that it is in fact stored in a member variable of the global PhysicsWorld object.

Profiling Tools

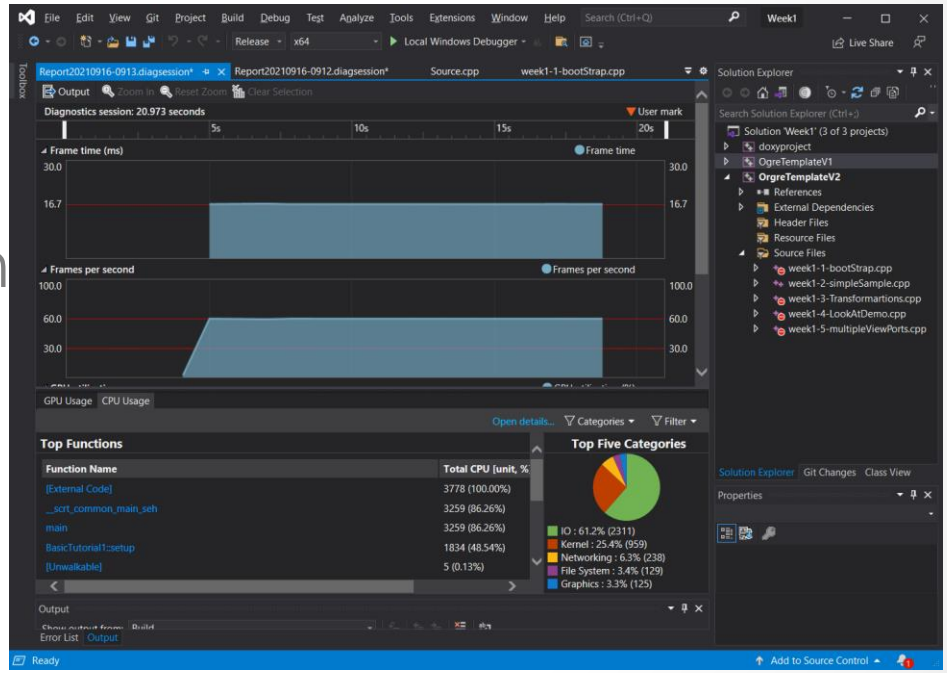
- *Pareto principle: 80/20 rule*, because it states that in many situations, 80% of the effects of some event come from only 20% of the possible causes
- 80% of the perceived bugs in a piece of software can be eliminated by fixing bugs in only 20% of the code
- how do you know *which* 20% of your code to optimize?
- A profiler is a tool that measures the execution time of your code.
  - how many *times* each function is called

Profilers Categories

- *Statistical profilers.*
  - the target code runs at almost the same speed, whether or not profiling is enabled.
  - sampling the CPU's program counter register periodically and noting which function is currently running.
  - Example: Intel's *VTune*
- *Instrumenting profilers*
  - The most accurate and comprehensive timing data possible, but at the expense of real-time execution of the target program
  - These profilers work by preprocessing your executable and inserting special prologue and epilogue code into every function.
  - Example: IBM's Rational Quantify

Visual Studio Profiler

- Debug --> Performance Profiler
- Make sure that you have your project in “release” configuration to be able to see the functions



LOP

- low-overhead profiler by Microsoft
- is a hybrid between the two approaches.
  - uses a statistical approach
    - sampling the state of the processor periodically, which means it has a low impact on the speed of the program's execution
  - it analyzes the call stack, thereby determining the chain of parent functions that resulted in each sample.
- On the PlayStation 4, SN Systems' *Razor CPU* is the profiler of choice for measuring game software running on the PS4's CPU
  - Support both statistical and instrumenting profilers
- https://en.wikipedia.org/wiki/List_of_performance_analysis_tools

Memory Leak and Corruption Detection

- Blame for both of these problems falls squarely on the language feature known as the *pointer*.
- A memory leak occurs when memory is allocated but never freed.
  - leads to a potentially fatal out-of-memory condition.
- Memory corruption occurs when the program inadvertently writes data to the wrong memory location
  - overwriting the important data that was there
- IBM's Rational Purify:
  - instruments your code prior to running it, in order to hook into all pointer dereferences and all memory allocations and deallocations made by your code.

Other Tools

- *Difference tools:*
  - A difference tool, or *diff tool*, is a program that compares two versions of a text file and determines what has changed between them. http://en.wikipedia.org/wiki/Diff
- *Three-way merge tools:*
  - When two people edit the same file, two independent sets of diffs are generated. A tool that can merge two sets of diffs into a final version of the file that contains both person's changes is called a three-way merge tool. https://en.wikipedia.org/wiki/Merge_(version_control)#Three-way_merge
- *Hex editors:*
  - A hex editor is a program used for inspecting and modifying the contents of binary files.
  - The data are usually displayed as integers in hexadecimal format
  - tracking down problems with binary file formats or when reverse-engineering an unknown binary format
  - https://hexed.it/

Doxygen

- Doxygen is a great tool for generating documentation from annotated C++ sources (Doxygen: Doxygen)
- Doxygen can help you in three ways:
  - It can generate an on-line documentation browser (in HTML) and/or an off-line reference manual (in $\mbox{\LaTeX}$) from a set of documented source files. There is also support for generating output in RTF (MS-Word), PostScript, hyperlinked PDF, compressed HTML, and Unix man pages. The documentation is extracted directly from the sources, which makes it much easier to keep the documentation consistent with the source code.
  - You can configure doxygen to extract the code structure from undocumented source files. This is very useful to quickly find your way in large source distributions. Doxygen can also visualize the relations between the various elements by means of include dependency graphs, inheritance diagrams, and collaboration diagrams, which are all generated automatically.
  - You can also use doxygen for creating normal documentation