Lecture 22
System Development
CSE331 is almost over… 😞

- Focus on software design, specification, testing, and implementation
  - Absolutely *necessary* stuff for any nontrivial project

- But *not sufficient* for the real world: At least 2 key missing pieces
  - Techniques for larger *systems* and development *teams*
    - This lecture; yes fair game for final exam
    - Major focus of CSE403
  - *Usability*: interfaces engineered for *humans*
    - Another lecture: didn’t fit this quarter
    - Major focus of CSE440
Outline

• Software architecture

• Tools
  – For build management
  – For version control
  – For bug tracking

• Scheduling

• Implementation and testing order
Architecture

Software architecture refers to the high-level structure of a software system

- A principled approach to partitioning the modules and controlling dependencies and data flow among the modules

Common architectures have well-known names and well-known advantages/disadvantages

A good architecture ensures:

- Work can proceed in parallel
- Progress can be closely monitored
- The parts combine to provide the desired functionality
Example architectures

Pipe-and-filter (think: iterators)

Source $\rightarrow$ Filter $\rightarrow$ Filter $\rightarrow$ Filter $\rightarrow$ Sink

Blackboard
(think: callbacks)

Layered
(think: levels of abstraction)
A good architecture allows:

- Scaling to support large numbers of ______
- Adding and changing features
- Integration of acquired components
- Communication with other software
- Easy customization
  - Ideally with no programming
  - Turning users into programmers is good
- Software to be embedded within a larger system
- Recovery from wrong decisions
  - About technology
  - About markets
System architecture

• Have one!
• Subject it to serious scrutiny
  – At relatively high level of abstraction
  – Basically lays down communication protocols
• Strive for simplicity
  – Flat is good
  – Know when to say no
  – A good architecture rules things out
• Reusable components should be a design goal
  – Software is capital
  – This will not happen by accident
  – May compete with other goals the organization behind the project has (but less so in the global view and long-term)
Temptations to avoid

- Avoid featuritis
  - Costs under-estimated
    - Effects of scale discounted
  - Benefits over-estimated
    - A Swiss Army knife is rarely the right tool
- Avoid digressions
  - Infrastructure
  - Premature tuning
    - Often addresses the wrong problem
- Avoid quantum leaps
  - Occasionally, great leaps forward
  - More often, into the abyss
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Build tools

• Building software requires many tools:
  – Java compiler, C/C++ compiler, GUI builder, Device driver build tool, InstallShield, Web server, Database, scripting language for build automation, parser generator, test generator, test harness
• Reproducibility is essential
• System may run on multiple devices
  – Each has its own build tools
• Everyone needs to have the same toolset!
  – Wrong or missing tool can drastically reduce productivity
• Hard to switch tools in mid-project

If you’re doing work the computer could do for you, then you’re probably doing it wrong
Version control (source code control)

- A version control system lets you:
  - Collect work (code, documents) from all team members
  - Synchronize team members to current source
  - Have multiple teams make progress in parallel
  - Manage multiple versions, releases of the software
  - Identify regressions more easily

- Example tools:
  - Subversion (SVN), Mercurial (Hg), Git

- Policies are even more important
  - When to check in, when to update, when to branch and merge, how builds are done
  - Policies need to change to match the state of the project

- Always diff before you commit
Bug tracking

• An issue tracking system supports:
  – Tracking and fixing bugs
  – Identifying problem areas and managing them
  – Communicating among team members
  – Tracking regressions and repeated bugs

• Essential for any non-small or non-short project

• Example tools:
  Bugzilla, Flyspray, Trac, hosted tools (Sourceforge, Google Developers, GitLab/GitHub, Bitbucket, …)
Bug tracking

Need to configure the bug tracking system to match the project
- Many configurations can be too complex to be useful
A good process is key to managing bugs
- An explicit policy that everyone knows, follows, and believes in
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Scheduling

“More software projects have gone awry for lack of calendar time than for all other causes combined.”

-- Fred Brooks, *The Mythical Man-Month*

Three central questions of the software business

3. When will it be done?
2. How much will it cost?
1. When will it be done?

- Estimates are almost always too optimistic
- Estimates reflect what one wishes to be true
- We confuse effort with progress
- Progress is poorly monitored
- Slippage is not aggressively treated
Scheduling is crucial but underappreciated

- Scheduling is underappreciated
  - Made to fit other constraints
- A schedule is needed to make slippage visible
  - Must be objectively checkable by outsiders
- Unrealistically optimistic schedules are a disaster
  - Decisions get made at the wrong time
  - Decisions get made by the wrong people
  - Decisions get made for the wrong reasons
- The great paradox of scheduling:
  - Hofstadter’s Law: It always takes longer than you expect, even when you take into account Hofstadter's Law
  - But seriously: 2x longer, even if think it will take 2x longer
Effort is not the same as progress

Cost is the product of workers and time
  – Reasonable approximation: All non-people costs (mostly salary) are zero (?!)
  – Easy to track

Progress is more complicated
  – Hard to track

- People don’t like to admit lack of progress
  – Think they can catch up before anyone notices
  – Assume they (you) are wrong
- Design the process and architecture to facilitate tracking
How does a project get to be one year late?

One day at a time…

• It’s not the hurricanes that get you
• It’s the termites
  – Tom missed a meeting
  – Mary’s keyboard broke
  – The compiler wasn’t updated
  – …

If you find yourself ahead of schedule
  – Don’t relax
  – Don’t add features
Controlling the schedule

• First, you must have one
• Avoid non-verifiable milestones
  – 90% of coding done
  – 90% of debugging done
  – Design complete
• 100% events are *verifiable milestones*
  – Module 100% coded
  – Unit testing successfully complete
• Need *critical path* chart (Gantt chart, PERT chart)
  – Know effects of slippage
  – Know what to work on when
Milestones

- Milestones are critical to keep the project on track
  - Policies may change at major milestones
  - Check-in rules, build process, etc.

- Some typical milestones (names)
  - Design complete
  - Interfaces complete / feature complete
  - Code complete / code freeze
  - Alpha release
  - Beta release
  - Release candidate (RC)
  - FCS (First Commercial Shipment) release
Dealing with slippage

• People must be held accountable
  – Slippage is not inevitable
  – Software should be on time, on budget, and on function

• Four options
  – Add people – startup cost ("mythical man-month")
  – Buy components – hard in mid-stream
  – Change deliverables – customer must approve
  – Change schedule – customer must approve

• Take no small slips
  – One big adjustment is better than three small ones
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How to code and test your design

- You have a design and architecture
  - Need to code and test the system

- Key question, what to do when?

- Suppose the system has this module dependency diagram
  - In what order should you address the pieces?
Bottom-up

• Implement/test children first
  – For example: G, E, B, F, C, D, A
• First, test G stand-alone (also E)
  – Generate test data as discussed earlier
  – Construct drivers
• Next, implement/test B, F, C, D
• No longer unit testing: use lower-level modules
  – A test of module M tests:
    • whether M works, \textit{and}
    • whether modules M calls behave as expected
  – When a failure occurs, many possible sources of defect
  – Integration testing is hard, irrespective of order
Building drivers

• Use a person
  – *Simplest* choice, but also *worst* choice
  – Errors in entering data are inevitable
  – Errors in checking results are inevitable
  – Tests are not easily reproducible
    • Problem for debugging
    • Problem for regression testing
  – Test sets stay small, don’t grow over time
  – Testing cannot be done as a background task

• Better alternative: Automated drivers in a test harness
Top-down

- Implement/test parents (clients) first
  - Here, we start with A

- To run A, build *stubs* to simulate B, C, and D

- Next, choose a successor module, e.g., B
  - Build a stub for E
  - Drive B using A

- Suppose C is next
  - Can we reuse the stub for E?
Implementing a stub

- Query a person at a console
  - Same drawbacks as using a person as a driver

- Print a message describing the call
  - Name of procedure and arguments
  - Fine if calling program does not need result
    - More common than you might think

- Provide “canned” or generated sequence of results
  - Often sufficient
  - Generate using criteria used to generate data for unit test
  - May need different stubs for different callers

- Provide a primitive (inefficient & incomplete) implementation
  - Best choice, if not too much work
  - Look-up table often works
  - Sometimes called “mock objects” (ignoring technical definitions?)
Comparing top-down and bottom-up

• Criteria
  – What kinds of errors are caught when?
  – How much integration is done at a time?
  – Distribution of testing time?
  – Amount of work?
  – What is working when (during the process)?

• Neither dominates
  – Useful to understand advantages/disadvantages of each
  – Helps you to design an appropriate mixed strategy
Catching design errors

- Top-down tests global decisions first
  - E.g., what system does
  - Most devastating place to be wrong
  - Good to find early

- Bottom-up uncovers efficiency problems earlier
  - Constraints often propagate downward
  - You may discover they can’t be met at lower levels
What components work, when?

• Bottom-up involves lots of invisible activity
  – 90% of code written and debugged
  – Yet little that can be demonstrated

• Top-down depth-first
  – Earlier completion of useful partial versions
Amount of integration at each step

- Less is better

- Top-down adds one module at a time
  - When an error is detected, either:
    - Lower-level module doesn’t meet specification
    - Higher-level module tested with bad stub

- Bottom-up adds one module at a time
  - Connect it to multiple modules
  - Thus integrating more modules at each step
  - More places to look for error
**Amount of work**

- Always need test harness
- Top-down
  - Build stubs but not drivers
- Bottom-up
  - Build drivers but not stubs
- Stubs are usually more work than drivers
  - Particularly true for data abstractions
- On average, top-down requires more non-deliverable code
  - Not necessarily bad
Distribution of testing time

• Integration is what takes the time

• Bottom-up gets harder as you proceed
  – You may have tested 90% of code
    • But you still have far more than 10% of the work left
  – Makes prediction difficult

• Top-down more evenly distributed
  – Better predictions
  – Uses more machine time (could be an issue)
    • Because testing overall (even if stubbed) functionality
One good way to structure an implementation

- Largely top-down
  - But always unit test modules
- Bottom-up
  - When stubs are too much work [just implement real thing]
  - Low level module that is used in lots of places
  - Low-level performance concerns
- Depth-first, visible-first
  - Allows interaction with customers, like prototyping
  - Lowers risk of having nothing useful
  - Improves morale of customers and programmers
    - Needn’t explain how much invisible work done
    - Better understanding of where the project is
    - Don’t have integration hanging over your head
Test harnesses

- Goals:
  - Increase amount of testing over time
  - Facilitate regression testing
  - Reduce human time spent on testing
- Take input from a file
- Call module being tested
- Save results (if possible)
  - Including performance information
- Check results
  - At best, is correct
  - At worst, same as last time
- Generate reports
Regression testing

• Ensure that things that used to work still do
  – Including performance
  – Whenever a change is made

• Knowing exactly when a bug is introduced is important
  – Keep old test results
  – Keep versions of code that match those results
  – Storage is cheap
Perspective…

• Software project management is challenging
  – There are still major disasters – projects that go way over budget, take much longer than planned, or are abandoned after large investments
  – We’re better at it than we used to be, but not there yet (is “software engineering” real “engineering”?)

• Project management is a mix of hard and soft skills

• We’ve only skimmed the surface
  – Next: CSE 403, internship/real world, ???