System Integration and Software Process
(Based on slides by Mike Ernst, Dan Grossman, David Notkin, Hal Perkins)
Administrivia

• HW9 due tonight
  – Usual late days apply if any left
• We want to show off projects on Friday – please let us know if we can use yours!
  – Send mail to cse331-staff@cs
• Final exam Monday, 8:30 am (sigh), here
  – Review Q&A Sunday, 2 pm, EEB 037
• Course evals: please fill them out in the next couple of days
Context

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)

Layered (think: levels of abstraction)

Blackboard (think: callbacks)
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, 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
• 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, ???