### 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)
Source → pipe → Filter → pipe → Filter → pipe → 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 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?

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

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?)
### 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, ???