CSE 331
Software Design and Implementation

Lecture 22
System Development

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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

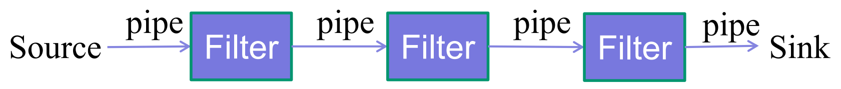
Software architecture refers to the high-level structure of a software system
- A principled approach to partitioning the modules and controlling dependencies and data flow among the modules

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

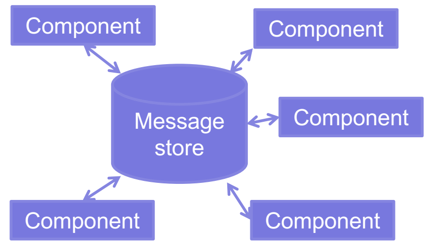
Example architectures

Pipe-and-filter (think: iterators)



Blackboard

(think: callbacks)



Layered

(think: levels of abstraction)

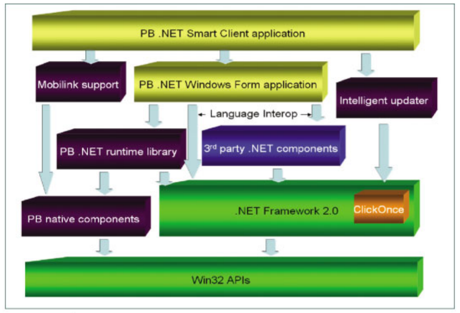


FIGURE 1 | ARCHITECTURAL DIAGRAM OF A POWERBUILDER SMART CLIENT APPLICATION

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

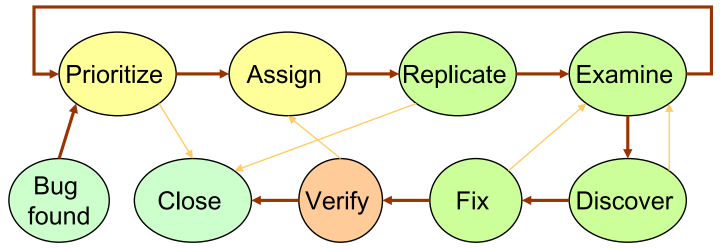
- An issue tracking system supports:
  - Tracking and fixing bugs
  - Identifying problem areas and managing them
  - Communicating among team members
  - Tracking regressions and repeated bugs
- Essential for any non-small or non-short project
- Example tools:

  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?

$$\begin{tikzcd}
 & & A \arrow[dll] \arrow[d] \arrow[drr] & & \\
B \arrow[dr] & & C \arrow[dl] \arrow[dr] & & D \arrow[dd] \\
 & E & & F \arrow[dr] & \\
 & & & & G
\end{tikzcd}$$

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

$$\begin{tikzcd}
 & & A \arrow[dll] \arrow[d] \arrow[drr] & & \\
B \arrow[dr] & & C \arrow[dl] \arrow[dr] & & D \arrow[dd] \\
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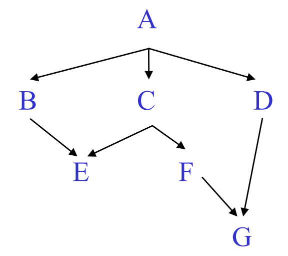
 & & & & G
\end{tikzcd}$$

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


$$\begin{tikzcd} & & A \arrow[dll] \arrow[d] \arrow[drr] & & \\ B \arrow[dr] & & C \arrow[dl] \arrow[dr] & & D \arrow[ddl] \\ & E & & F \arrow[dr] & \\ & & & & G \end{tikzcd}$$

- 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, ???