System development

CSE 331
University of Washington

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What's missing from CSE 331

- Our focus: software design, specification, testing, and implementation
  - Absolutely necessary stuff for any nontrivial project
  - Not sufficient for the real world
- Techniques for larger systems and development teams
  - This lecture; focus of CSE 403
- Usability: interfaces engineered for humans
  - Focus of CSE 440

Outline

- Software architecture
- Tools:
  - Build automation
  - Version control
  - Bug tracking
- Scheduling
- Implementation and testing order

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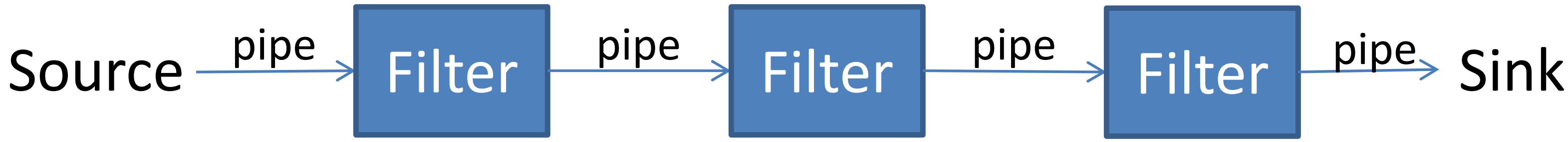
Architecture

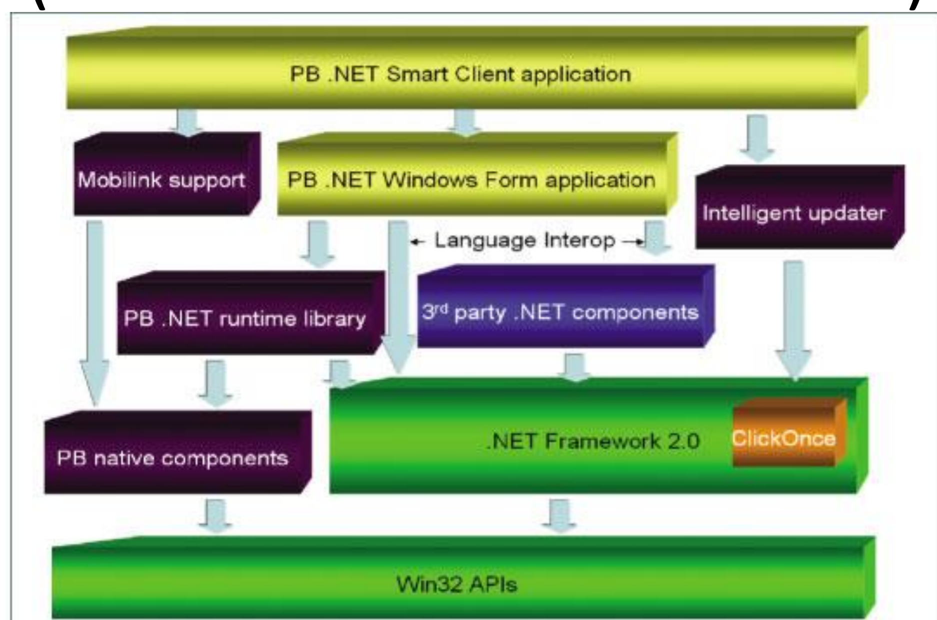
- Architecture = high-level structure of a system
  - Partitions the system into modules
  - Indicates dependences on, and data flow between, modules
  - Have names just like design patterns do
- A good architecture ensures that
  - Work can proceed in parallel
  - Progress can be closely monitored
  - The parts combine to provide the desired functionality

Example architectures

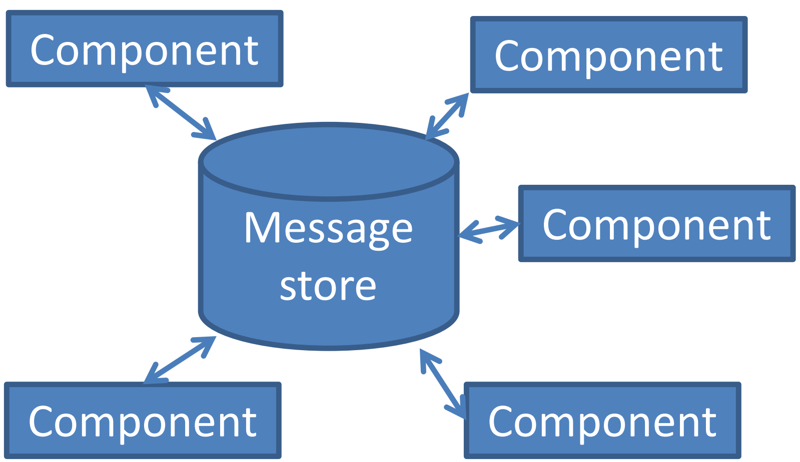
Pipe-and-filter (think: iterators)



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
  - Build your organization as well as the project
  - Organizational mission is not the same as the project
  - This will not happen by accident

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
  - Example: Java compiler, 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 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)

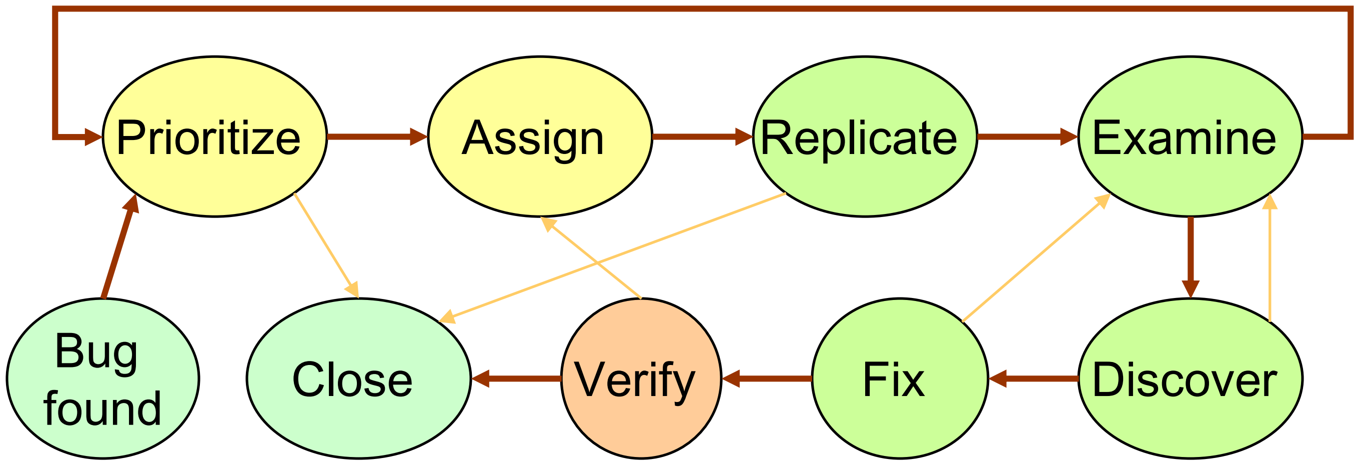
- A version control system supports:
  - Collect work (code, documents) from multiple team members
  - Synchronize all the team members to current source
  - Have multiple teams work in parallel
  - Manage multiple versions, releases of the software
  - Identify regressions
- Example tools:
  - Git, Mercurial (Hg), Blaze/Bazel, Buck, Subversion (SVN), …
- 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 between team members
  - Track regressions and repeated bugs
- Essential for any non-trivial project
- Example tools:
  - JIRA, Bugzilla, Flyspray, Trac, …
  - Hosted tools: GitHub, Gitlab, Sourceforge, …

Bug tracking

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



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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 scheduling paradox
  - Everything takes twice as long as you think
  - Hofstadter’s Law: It always takes longer than you expect, even when you take into account Hofstadter's Law

Effort is not the same as progress

- Cost is the product of workers and time
  - Easy to track
  - Reasonable approximation: non-labor costs are zero
- Progress is more complicated, and hard to track
- People don’t like to admit lack of progress
  - Mis-estimate progress
  - Think they can catch up before anyone notices (can’t!)
- 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
  - 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 far better than three small ones

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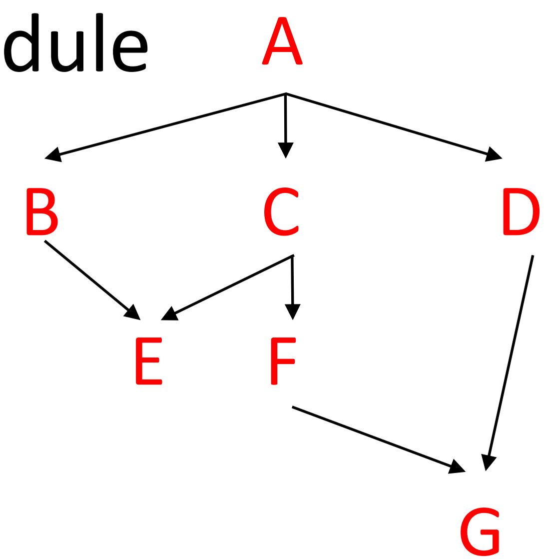
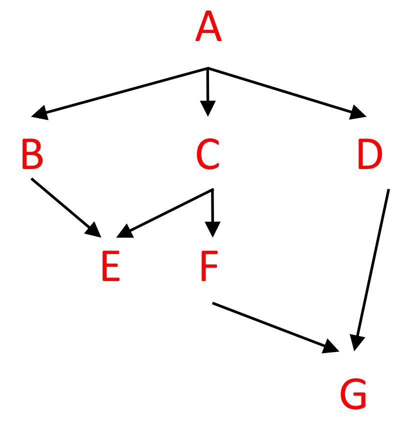
How to code and test your design

- You have a design and architecture
  - Need to code and test the system
- Key question, what to do when?
  - We'll assume an incremental development model
- Suppose the system has this module dependency diagram
  - In what order should you address the pieces?



Bottom-up implementation

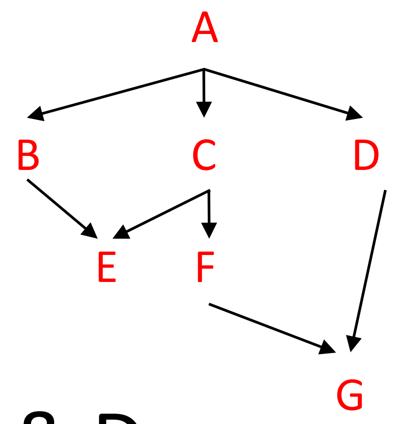


- Implement/test children first
  - For example: G, E, B, F, C, D, A
- First, test G stand-alone (also E)
  - Generate test data as discussed earlier
  - Construct drivers
- Next, implement/test B, F, C, D
- No longer unit testing: use lower-level modules
  - A test of module M tests:
    - whether M 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, & 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 or “mock”

- 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
    - This is 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
- Primitive (inefficient, incomplete) implementation
  - Best choice, if not too much work
  - Look-up table often works

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 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
  - A detected error means 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 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
    - In business environments this can be an issue

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  - 90% of code written and debugged
  - Yet little that can be demonstrated
- Top-down depth-first
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One good way to structure an implementation

- Largely top-down
  - But always unit test modules
- Bottom-up
  - When stubs are too much work
  - 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

Project management is challenging

- There are still major disasters
  - Over budget
  - Over schedule
  - Abandoned after large investments
- Disasters usually stem from a lack of discipline
- Always new challenges: we never build the same thing twice
- Is "software engineering" engineering?

- Project management is a mix of hard and soft skills

- We've only skimmed the surface
  - Next: other projects, CSE 403, internship, your startup