CS 326
Building Systems in the Wild

Stephen Freund

Almost to the Finish Line...

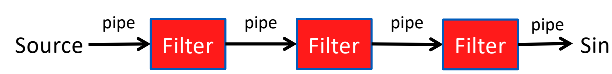
- CS 326 has been all about software design, specification, testing, and implementation
  - Absolutely necessary for any nontrivial project
- But not sufficient for the real world
  - Software Engineering: Techniques for larger systems and development teams
    - architecture, tools, scheduling, implementation order
  - Usability: interfaces engineered for humans (HCI)

Software Architecture

- High-level structure of a software system
  - Principled approach to partitioning modules and controlling dependencies / data flow among them
- 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

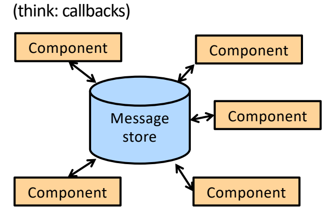
Example Software Architectures

Pipe-and-filter (think: iterators)



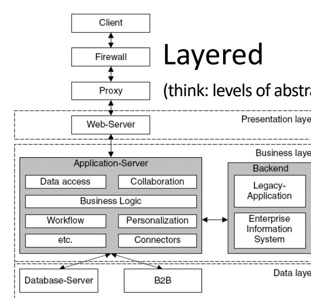
Blackboard

(think: callbacks)



Layered

(think: levels of abstraction)



Good Architectures Support

- Scaling to support large numbers of ______
- Flexibility
  - Adding and changing features
  - Easy customization (Ideally with no programming)
- Versatility
  - Integration of acquired components
  - Communication with other software
  - Software to be embedded within a larger system
- Recovery from wrong decisions
  - About technology… About markets…

Software Architecture

- Have one! Subject it to serious scrutiny!
  - At relatively high level of abstraction
  - Basically lays down communication protocols
- Strive for simplicity
  - 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**

Temptations to Avoid

- Avoid feature creep
  - Costs under-estimated
  - Benefits over-estimated
  - A Swiss Army knife is rarely the right tool
- Avoid digressions
  - eg: premature tuning
    - Often addresses the wrong problem

Tools: Build Management

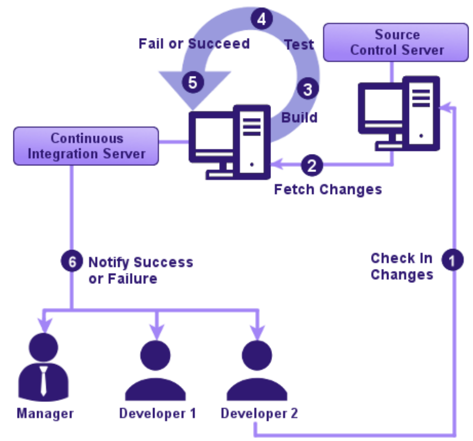
- Building software requires many tools:
  - Swift compiler, simulator, C/C++ compiler, GUI builder, Device driver build tool, Web server, Database, scripting language for build automation, parser generator, test generator, test harness
  - Reproducibility is essential
  - Wrong or missing tool can drastically 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.

Tools: Version Control

- You've all been using it
  - Collect work (code, documents) from team members
  - History of changes
  - Synchronize team members to current source
  - Have multiple teams make progress in parallel
  - Manage multiple versions, releases of the software
  - Identify regressions more easily
- Establish policies
  - When to check in, when to update, when to branch and merge, how builds are done, …

Tools: Continuous Integration

- Build and test every commit
  - Catch errors early
  - Localize bugs to specific change
  - Prevent bad code from spreading

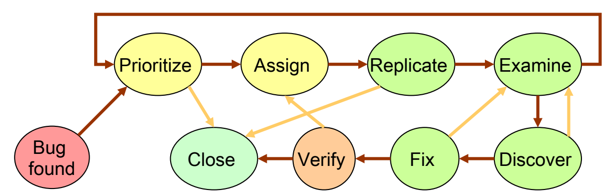


Tools: Bug Tracking

- Issue tracking system supports:
  - Tracking and fixing bugs
  - Identifying problem areas and managing them
  - Communicating among team members
  - Tracking regressions and repeated bugs
- Example tools:
  - GitHub, Bugzilla, Flyspray, Trac, Sourceforge, Google Developers, GitLab/GitHub, Bitbucket, …
  - https://github.com/stephenfreund/cs326

Tools: Bug Tracking

- Establish good process.
- Make it explicit in a policy.
- Keep it simple!



How Does a Project Become a Year Late?

- It's not the hurricanes that get you
- It's the termites
  - Someone missed a meeting
  - Someone's keyboard broke
  - The compiler wasn't updated
  - Bad flu season. Or maybe a pandemic…
  - Missing documentation
  - Manager quit

Scheduling

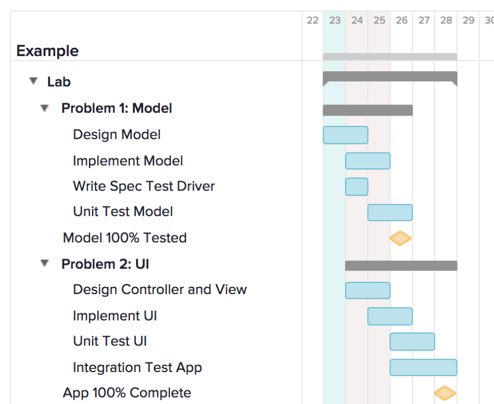
- Must predict time/cost to build software
- Schedule is needed to make slippage visible
  - Must be objectively checkable by outsiders
- Unrealistically optimistic schedules are a disaster
  - Decisions get made at the wrong time
  - Decisions get made by the wrong people
  - Decisions get made for the wrong reasons
- It will always take longer than you expect. **Always.**

Effort != Progress

- **Effort**
  - Product of workers and time. (eg: person-months)
  - Easy to track.
- **Progress**
  - Forward movement toward a destination.
  - Hard to track.
  - No one likes to admit lack of progress…
- Design the development process and architecture to facilitate tracking progress.

Controlling the Schedule

- Have one!
  - Know effects of slippage
  - Know what to work on when
- Gantt Chart



Milestones

- Verifiable
  - Module 100% coded
  - Unit testing 100% complete
- Non-verifiable
  - 90% of coding done
  - 90% of debugging done
  - Design complete
- Avoid non-verifiable milestones

Typical Milestones

- Design complete / design freeze
- Interfaces complete / feature freeze
- Code complete / code freeze
- Alpha release
- Beta release
- Release candidate (RC)
- FCS (First Commercial Shipment) release

When You Know You'll Miss Milestone

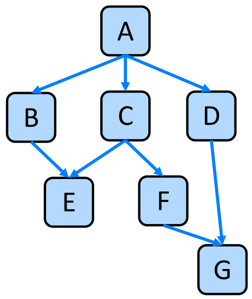
- Reflect on why. Hold people accountable.
- Four options
  - Same deadline, same amount of work ✗
  - Same deadline, reduced scope of work
  - Later deadline, same scope of work
  - Later deadline, increased scope of work ✗
- Wrong choice made often...
- Take no small slips
  - One big adjustment is better than three small ones

Possible Ways To Shorten Timeline

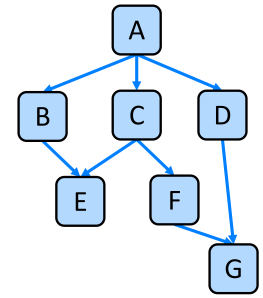
- Add people
  - Startup cost ("mythical man-month"), communication cost
- Buy components
  - Hard in mid-stream
- Change deliverables
  - Customer must approve
- Change schedule
  - Customer must approve

How to Code and Test Your Design

- You have a design and architecture
- Key question: what to do when?



Bottom-up

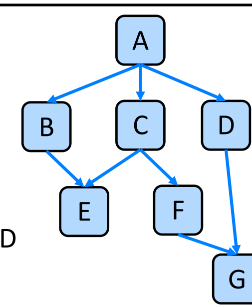


- Implement/test children first
  - For example: G, E, B, F, C, D, A
- First, G in isolation. Then E.
  - Generate test data
  - Construct drivers
- Then B, F, C, D.
  - A test of module M tests: whether M works, and whether modules M calls behave as expected
  - When a failure occurs, many possible 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
- Instead: Automated drivers in a test harness
  - GraphADT, SocialNetworks, CampusPaths,...

Top-down



- Implement/test parents first
- First: A
  - build stubs to simulate B, C, and D
- Then: B
  - Build a stub for E
  - Drive B using A
- Then: C
  - Possibly reuse E, if sufficient, or create new stub
- ...

Implementing a Stub

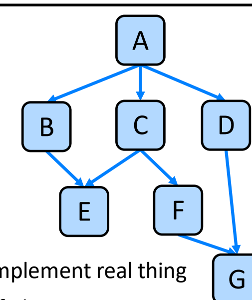
- Query a person at a console.
- Print a message describing the call.
  - Name of procedure and arguments
  - Fine if calling program does not need result
- Provide “canned” results.
  - UtterKit's canned responses
- Provide a primitive implementation.
  - Inefficient & incomplete
  - Best choice, if not too much work
  - Look-up table often works

Top-Down vs. Bottom-Up

- Which is Better?
- Neither dominates
  - Understand advantages/disadvantages of each
  - Helps you design an appropriate mixed strategy

Criteria	Top-Down	Bottom-Up
When Do You Catch Design Errors?		
When Do Visible Components Work?		
How Much Integration Work? (less is better)		
Amount of Work?		
Testing Time Distribution?		

Good Practice



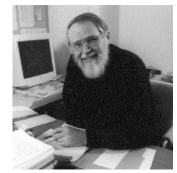
- Largely top-down
  - But always unit test modules
- Switch to bottom-up
  - When stubs are too much work, just implement real thing
  - Low level module that is used in lots of places
  - Low-level performance concerns
- Depth-first, visible-first
  - Allows interaction with customers, like prototyping
  - Lowers risk of having nothing useful
  - Improves morale of customers and programmers
    - Have something to show early on.

Perspective…

- Software project management is challenging
  - Different intellectual demands than programming
  - Mix of hard and soft skills
  - Communication, writing, problem solving, reflection
  - eg: a liberal arts education
- We've only skimmed the surface
  - Software Engineering is an entire field within CS

Wrap Up

"Controlling complexity is the essence of computer programming."



-- Brian Kernighan
(UNIX, AWK, C, …)

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Goals

- Primary focus: writing correct programs
  - What does it mean for a program to be correct?
    - Specification (vs Requirements)
  - How do we determine if a program is correct?
    - Reasoning, Verification, Testing
  - How do we build correct programs?
    - Principled design and development
    - abstraction, modularity
    - documentation
- Will cover both *principles* and tools.

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Outcomes

- Better at design
- Better at coding
- Better at debugging
- Better at using development tools
- Better at evaluating quality / behavior
- Better at *communication*
- Essential skills regardless of what you do next

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Life After 326...

- System building can be rewarding and fun
  - Never "easy" (but what worthwhile endeavors are?)
  - There are always new challenges
  - It's even more fun when you're successful
- Pay attention to what matters
  - Take advantage of the techniques and tools you've learned (and will learn!)
  - Make good decisions, not expedient decisions

Life After 326...

- Your next project can be much more ambitious.
  - Be confident but humble
  - Recognize your own strengths and weaknesses
    - We all have both
- Life-long process
  - Like being a good writer of prose
  - Practice is a good teacher
    - Requires thoughtful introspection
    - Don't learn only by trial and error!
  - Voraciously consume ideas and tools