Outline

• Architecture
• Tools: Build tools and version control
• Tools: Bug tracking
• Scheduling
• Implementation and testing order
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Architecture

• An **architecture** describes a **partitioning** of the system
  – It indicates dependences on, and data flow between, modules

• 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
  – Organizational mission is not the same as the project
  – Build your organization as well as the project
  – Software is capital
  – 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, missing tool can drastically reduce productivity
• Hard to switch tools in mid-project
Version control (source code control)

- A version control system supports:
  - Collecting work (code, documents) from multiple team members
  - Synchronizing all the team members to current source
  - Let multiple teams make progress in parallel
  - Manage multiple versions, releases of the software
  - Help identify regressions
- 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
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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

• Any medium to large size project requires bug tracking software

• Example tools:
  – Bugzilla, Flyspray, Trac, hosted tools
  (Sourceforge, Google Code)
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
  – Need an explicit policy that everyone knows, follows, and believes in

[Diagram of bug tracking process: Prioritize → Assign → Replicate → Examine → Fix → Discover → Verify → Close → Bug found]
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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
    ... even if you know that it will take twice as long as you think
Effort is not the same as progress

- **Cost** is the product of workers and time
  - Easy to track
- **Progress** is more complicated, and hard to track
- People don’t like to admit lack of progress
  - Think they can catch up before anyone notices
  - Not usually possible
- 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
  – 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
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
Top-down testing

- 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

• 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
  – Very 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
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
Amount of integration at each step

• Less is better
• Top-down adds one module at a time
  – When error 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
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
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
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
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