CS 3110

Module dependencies
Testing

Lecture 10
Andrew Myers
30 Sept 08

Hierarchical decomposition

- In well-designed code:
  - Bottom level code units are methods/functions (~1–100 LOC)
  - Modules have up to a couple of dozen ops
  - At most a couple of dozen modules to implement related functionality
- Top-level modules scale to ~10k LOC progs
- Modularity alone isn't enough for large systems—need hierarchy of modules

2

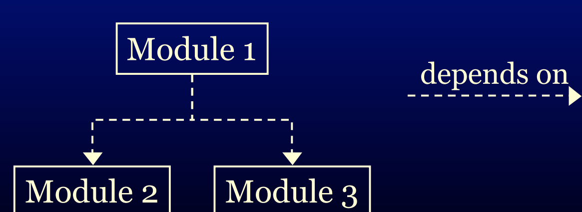
Hierarchical decomposition

- Divide and conquer: must break large modules into smaller modules
- Multiple levels of hierarchy
- Good design if: only need to think about one module, one level at a time
- How to manage large-scale design?

3

Modular structure

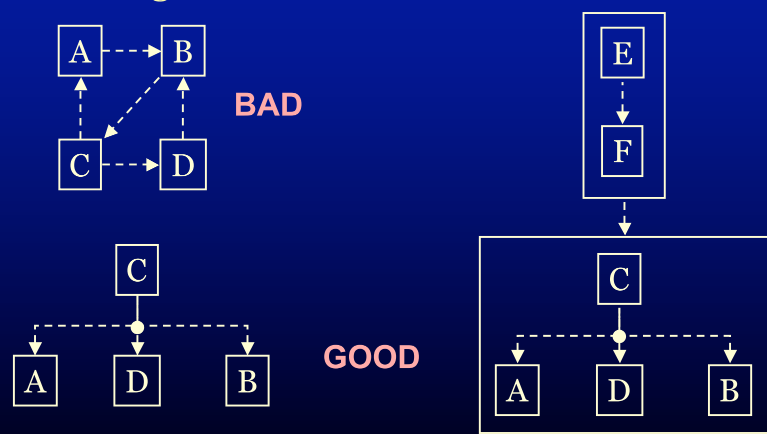
- Program is composed of modules
- One module *depends* on another if it uses a value, function, or type from it
- Module Dependency Diagram (MDD) helps understand large-scale program structure



4

Keeping dependencies simple

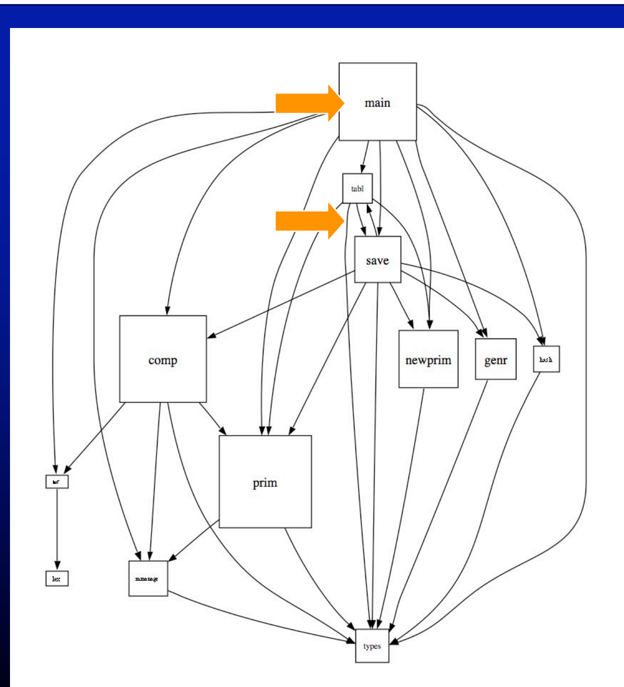
- Too many dependencies or cycles: harder to debug, maintain, extend software



5

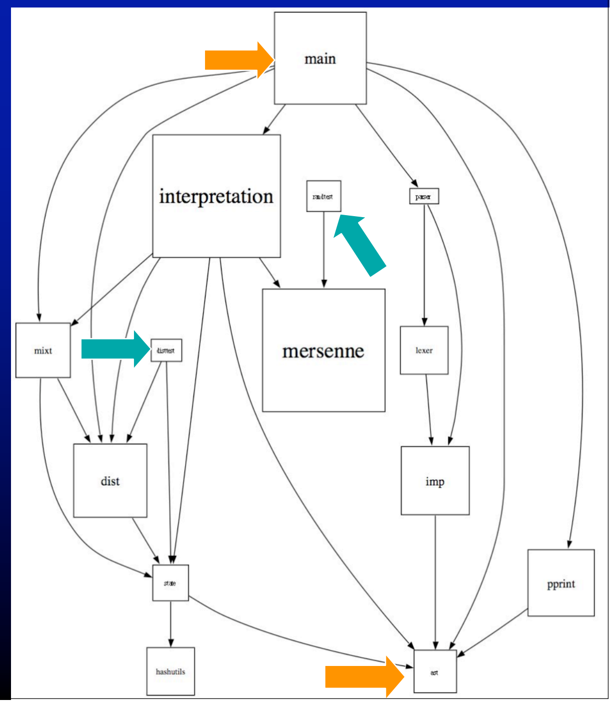
Example

Box size determined by source size



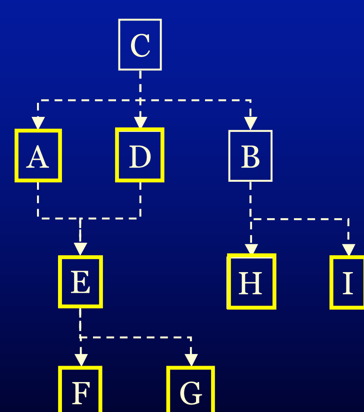
Example 2

(generated from OCaml source by *dep2dot*)



Bottom-up development

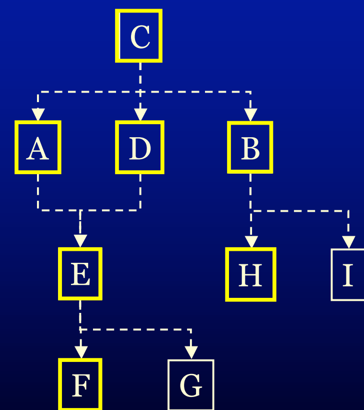
- Bottom-up: develop modules before the modules that depend on them
- Advantage: catch key technology/performance issues early
- Advantage: always working code, unit testing
- Disadvantage: catch large-scale design flaws late



8

Top-down development

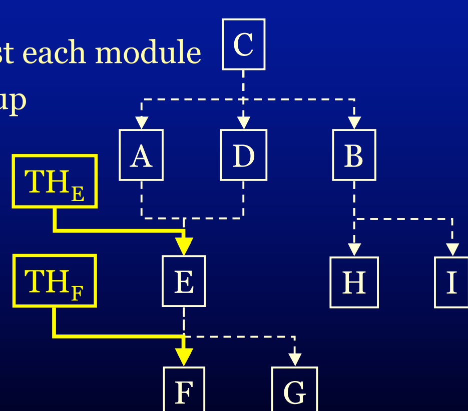
- Top-down: develop using modules before modules they depend on
- Advantage: get high-level design right from start, do integration testing
- Advantage: easier to design interfaces well, quickly spec out system
- Disadvantage: harder to test until program complete



9

Unit/component testing

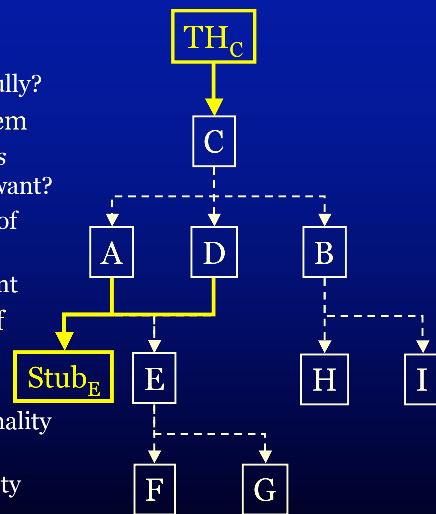
- Test modules through their interfaces
- Test each implementation against interface separately
- Write *test harness* to test each module
- Good match to bottom-up development



10

System and integration testing

- *Integration testing*: test many modules together
  - Do modules compose successfully?
- *System testing*: test entire system
  - May also validate *requirements specification* : is this what we want?
  - Check high-level structure, UI of program
  - Good for top-down development
- Stubs: low-cost replacements of missing module implementations
  - May partially simulate functionality
  - May be slow/simple/cheap implementations of functionality



11

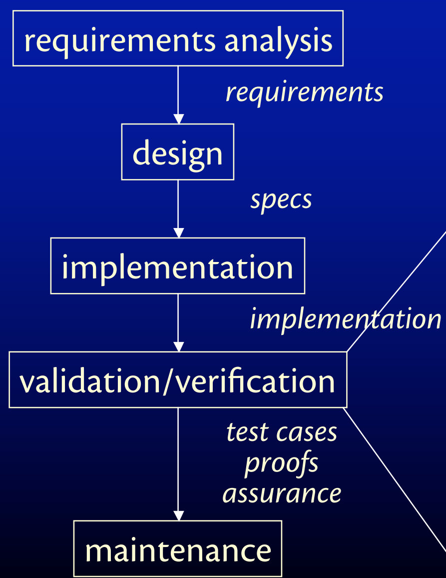
Top-down or bottom-up?

- Depends on the project!
- Goal: avoid huge redesign cost
  - Minimize risk: resolve uncertainties early
  - UI/high-level design: top-down
  - Core technology/performance: bottom-up
- Usually some mix of both strategies

  & both unit and integration testing

12

Waterfall model



- An abstraction of different activities in software projects
- Not always this neat!

- *Validation*:
  are requirements right?
- *Verification*:
  does impl meet spec?
  - Formal verification
  - Testing
- Assurance: reasonable confidence that right system has been built, correctly

Testing

- Goal is assurance that system works
- (Completely) working system is free of *faults:*
  - Errors in requirements
  - Errors in specifications
  - Errors in implementation
- Strategy: build a set of *test cases* that if passed give assurance
  - Test: compare actual to expected outputs
  - Test case: inputs to program/component, and expected outputs
  - Collection of test cases: *test suite*

14

Coverage

- How can finite test cases give strong assurance?
- Key: test cases that have good *coverage* of possible faults
- Exhaustive testing:
  - Test all possible inputs (against spec; against other, simpler, obviously correct implementation)
  - Usually infeasible (input space too large)

    `val plus: int->int->int` has 2^{64} inputs (584 years at 1/ns)
  - Sometimes can exhaustively test up to some input "size" -- faults usually have small counterexamples.
- Random testing:
  - Generate inputs randomly. Idea: if all tests pass, unlikely to see faults in production
  - Problem: only works if inputs have same random distribution as "in nature". Hard!
- Usually must design test cases -- an art

15

Black-box testing

- Idea: test cases achieve coverage based on *specification only*
  - Aka "closed-box"
- Idea: specification divides space of possible inputs into different regions.
  - Test boundary values and corner cases
- Examples:

  plus: int->int->int

  lmax : int list -> int
- Advantages:
  - Can write test cases before implementation
  - Can write test cases independently
  - Helps find problems in specifications
- Disadvantages:
  - May not test all code or test code thoroughly
- A good place to start designing tests

16

Glass-box testing

- Using the implementation to design test cases. Some approaches:

1. Use the AF and RI to identify interesting parts of input space
2. Statement coverage: ensure every statement or expression is evaluated in *some* test case
3. Branch (or condition) coverage: … every branch is tested both ways
4. Entry/exit coverage: … every function entry/exit is tried
5. Path coverage: …every path is followed

17

Regression testing

- Test suites are valuable!
- 1/3 of bug fixes introduce a new bug
- Regression testing:
  1. record outputs to entire test suite
  2. on changes to system, check that outputs haven't changed (meaningfully)
- Push-button automation is key. Lots of tools to help: expect, JUnit, …
  - Test early and often!

18