Testing

Why Testing

- Researchers investigate many approaches to improving software quality
- But the world tests
- > 50% of the cost of software development is testing
- Testing is consistently a hot research topic

Testing Practice

Outline

- Manual testing
- Automated testing
- Regression testing
- Code coverage
- Bug trends

Manual Testing

- Test cases are lists of instructions
  - “test scripts”
- Someone manually executes the script
  - Do each action, step-by-step
    - Click on “login”
    - Enter username and password
    - Click “OK”
    - …
  - And manually records results
- Low-tech, simple to implement

Manual Testing

- Manual testing is very widespread
  - Probably not dominant, but very, very common
- Why? Because
  - Some tests can’t be automated
    - Usability testing
  - Some tests shouldn’t be automated
    - Not worth the cost

Manual Testing

- Those are the best reasons
- There are also not-so-good reasons
  - Not-so-good because innovation could remove them
  - Testers aren't skilled enough to handle automation
  - Automation tools are too hard to use
  - The cost of automating a test is 10X doing a manual test

Topics

- Manual testing
- Automated testing
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Automated Testing

- Idea:
  - Record manual test
  - Play back on demand
- This doesn’t work as well as expected
  - E.g., Some tests can’t/shouldn’t be automated

Fragility

- Test recording is usually very fragile
  - Breaks if environment changes
    - E.g., location of a textbox
    - Code changes – the name of dialog changes.
- More generally, automation tools cannot generalize a test
  - They literally record exactly what happened
  - If anything changes, the test breaks
- Maintaining tests is a lot of work
  - Broken tests must be fixed; this is expensive
  - Cost is proportional to the number of tests
- A hidden strength of manual testing
  - Because people are doing the tests, ability to adapt tests to slightly modified situations is built-in

Improved Automated Testing

- Recorded tests are too low level
  - E.g., every test contains the name of the dialog box
- Need to abstract tests
  - Replace dialog box string by variable name X
  - Variable name X is maintained in one place
    - So that when the dialog box name changes, only X needs to be updated and all the tests work again

Data Driven Testing (for Web Applications)

- Build a database of event tuples

  < Document, Component, Action, Input, Result >

- E.g.,

  < LoginPage, Password, InputText, $password, “OK”>

- A test is a series of such events chained together

- Complete system will have many relations
  - As complicated as any large database

Discussion

- Testers have two jobs
  - Clarify the specification
  - Find (important) bugs
- Only the latter is subject to automation
  - The oracle problem.
- Helps explain why there is so much manual testing

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Regression Testing

- Idea
  - When you find a bug,
  - Write a test that exhibits the bug,
  - And always run that test when the code changes,
  - So that the bug doesn't reappear

- Without regression testing, it is surprising how often old bugs reoccur

Regression Testing (Cont.)

- Regression testing ensures forward progress
  - We never go back to old bugs
- Regression testing can be manual or automatic
  - Ideally, run regressions after every change
  - To detect problems as quickly as possible
- But, regression testing is expensive
  - Limits how often it can be run in practice
  - Reducing cost is a long-standing research problem

Research in Regression Testing

- Test selection
  - A change is made at line x, should I rerun the whole regression set?

Efficient Regression Testing

- **Problem: Regression testing is expensive**
- **Observation: Changes don’t affect every test**
  - **And tests that couldn’t change need not be run**
- **Idea: Use a conservative static analysis to prune test suite**

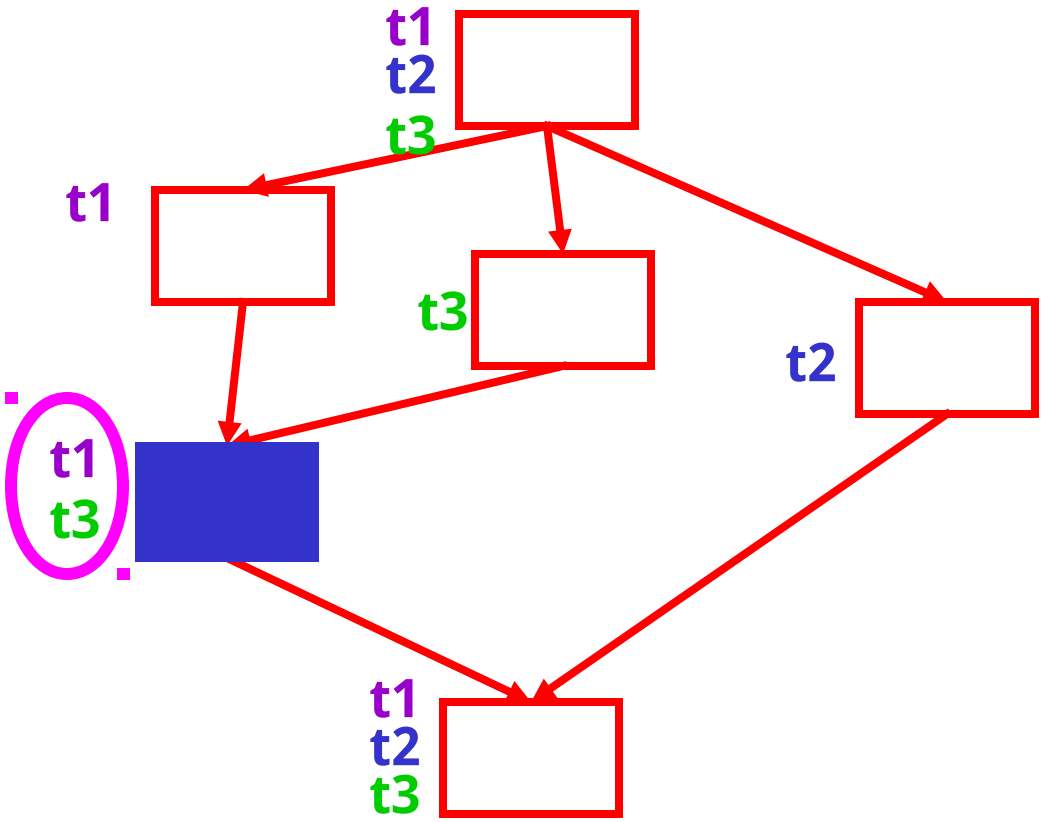
The Algorithm

Two pieces:

1. **Run the tests and record for each basic block which tests reach that block**

2. **After modifications, compare the old and new CFGs. Wherever the new CFG differs from the original CFG, run all tests that reach that point**

Example



Label each node of the control flow graph with the set of tests that reach it.

More

- Test minimization
  - A test suite is often redundant, select a minimal set that satisfies a certain criterion
- Test prioritization
  - Assign test cases different priorities given certain constraints.
    - Greedy algorithms

A Problem

- How do we know when we are done?
  - Could keep going forever
- But, testing can only find bugs, not prove their absence
  - We need a proxy for the absence of bugs

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Code Coverage

- Idea
  - Code that has never been executed likely has bugs
- This leads to the notion of *code coverage*
  - Divide a program into units (e.g., statements)
  - Define the coverage of a test suite to be

$$\frac{\text{\# of statements executed by suite}}{\text{\# of statements}}$$

Code Coverage (Cont.)

- Code coverage has proven value
  - It's a real metric, though far from perfect
- But 100% coverage does not mean no bugs
  - E.g., a bug visible after loop executes 1,025 times
- And 100% coverage is almost never achieved
  - Infeasible paths
  - Ships happen with < 60% coverage
  - High coverage may not even be desirable
    - May be better to devote more time to tricky parts with good coverage

Using Code Coverage

- Code coverage helps identify weak test suites
- Code coverage can’t complain about missing code
  - But coverage can hint at missing cases
    - Areas of poor coverage indicate areas where not enough thought has been given to specification

More on Coverage

- Statement coverage
- Edge coverage
- Path coverage
- Def-use coverage

Mutation Coverage

- Create mutations of the subject program by performing simple transformations
  - x<y transforms to x<=y, x<y+c, …
- Kill set= all mutations P’ s.t. there exists a test case t P(t)!=P’(t)
  - Adequacy= |kill set| / # of mutations

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Bug Trends

- **Idea: Measure rate at which new bugs are found**

- **Rational: When this flattens out it means**
  1. **The cost/bug found is increasing dramatically**
  2. **There aren't many bugs left to find**

Test Generation

- **Combinatorial testing**
- **Concolic testing.**