

Software Testing



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- The requested citation the overall tutorial is: David E. Bernholdt, Anshu Dubey, Mark C. Miller, Katherine M. Riley, and James M. Willenbring, Software Productivity Track, in Argonne Training Program for Extreme Scale Computing (ATPESC), online. DOI: 10.6084/m9.figshare.12719834
- Individual modules may be cited as Speaker, Module Title, in Software Productivity Track...

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Verification

- Code verification uses tests
 - It is much more than a collection of tests
- It is the holistic process through which you ensure that
 - Your implementation shows expected behavior,
 - Your implementation is consistent with your model,
 - Science you are trying to do with the code can be done.

How do verification and validation differ?

- Verification confirms that you have implemented what you meant to
 - Your method does what you wanted it to do
- Validation tells you were right in implementing what you meant to
 - What you wanted your method to do is valid
 - Your model correctly captures the phenomenon you are trying to understand





Stages and types of verification

- During initial code development
 - Accuracy and stability
 - Matching the algorithm to the model
 - Interoperability of algorithms
- In later stages
 - While adding new major capabilities or modifying existing capabilities
 - Ongoing maintenance
 - Preparing for production





Components of Verification

- Testing at various granularity
 - Individual components
 - Interoperability of components
 - Convergence, stability and accuracy
- Validation of individual components
 - Building diagnostics (e.g. ensure conservation of physical quantities)
- Testing practices
 - Error bars
 - Necessary for differentiating between drift and round-off
- Ensuring code and interoperability coverage





Why not always use the most stringent testing?

- Effort spent in devising running and maintaining test suite is a tax on team resources
- When the tax is too high...
 - Team cannot meet code-use objectives
- When is the tax is too low...
 - Necessary oversight not provided
 - Defects in code sneak through
- Evaluate project needs
 - Objectives: expected use of the code
 - Team: size and degree of heterogeneity
 - Lifecycle stage: new or production or refactoring
 - Lifetime: one off or ongoing production
 - Complexity: modules and their interactions

Balance is critical





Good Testing Practices

- Verify Code coverage
- Must have consistent policy on dealing with failed tests
 - Issue tracking
 - How quickly does it need to be fixed?
 - Who is responsible for fixing it?
- Someone should be watching the test suite
- When refactoring or adding new features, run a regression suite before check in
 - Add new regression tests or modify existing ones for the new features
- Code review before releasing test suite is useful
 - Another person may spot issues you didn't
 - Incredibly cost-effective





How do we determine what other tests are needed?

Code coverage tools

- Expose parts of the code that aren't being tested
 - gcov standard utility with the GNU compiler collection suite (we will use it in the next few slides)
 - Compile/link with –coverage & turn off optimization
 - counts the number of times each statement is executed
- gcov also works for C and Fortran
 - Other tools exist for other languages
 - JCov for Java
 - Coverage.py for python
 - Devel::Cover for perl
 - profile for MATLAB

- Lcov
 - a graphical front-end for gcov
 - available at http://ltp.sourceforge.net/coverage /lcov.php
 - Codecov.io in CI module
- Hosted servers (e.g. coveralls, codecov)
- graphical visualization of results
- push results to server through continuous integration server

Interoperability coverage Example Later





Checking coverage Example

- Example of heat equation
 - Add -coverage as shown below to Makefile
 - Run ./heat runame="ftcs_results"
 - Run gcov heat.C
 - Examine heat.C.gcov

- A dash indicates non-executable line
- A number indicated the times the line was called
- ##### indicates line wasn't exercised

```
143:static bool
       144:update solution()
       145:{
       146:
 500:
                if (!strcmp(alg, "ftcs"))
       147:
                    return update solution ftcs(Nx, curr, last, alpha, dx, dt, bc0, bc1);
       148:
#####:
                else if (!strcmp(alg, "upwind15"))
                    return update solution upwind15(Nx, curr, last, alpha, dx, dt, bc0, bc1);
#####:
       149:
                else if (!strcmp(alg, "crankn"))
       150:
#####:
                    return update_solution_crankn(Nx, curr, last, cn Amat, bc0, bc1);
       151:
#####:
       152:
                return false;
#####:
       153:}
        154:
        155:static Double
        156:update output files(int ti)
        157:
 500:
        158:
                Double change;
       159:
                if (ti>0 && save)
       160:
 500:
       161:
       162:
                    compute_exact_solution(Nx, exact, dx, ic, alpha, ti*dt, bc0, bc1);
#####:
#####:
        163:
                    if (savi && ti%savi==0)
        164:
                        write_array(ti, Nx, dx, exact);
       165:
####:
```





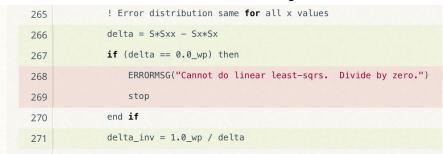


Graphical View of Gcov Output and Tutorials for Code Coverage

Overall Analysis



Detailed Analysis



Online tutorial - https://github.com/amklinv/morpheus
Other example - https://github.com/jrdoneal/infrastructure





How to build your test suite?

- Two purposes
 - Regression testing
 - May be long running
 - Provide comprehensive coverage
 - Continuous integration
 - · Quick diagnosis of error
- A mix of different granularities works well
 - Unit tests for isolating component or sub-component level faults
 - Integration tests with simple to complex configuration and system level
 - Restart tests
- Rules of thumb
 - Simple
 - Enable quick pin-pointing

Useful resources https://ideas-productivity.org/resources/howtos/





Test Development For a New Code

- Development of tests and diagnostics goes hand-in-hand with code development
 - Non-trivial to devise good tests, but extremely important
 - Compare against simpler analytical or semi-analytical solutions
 - Build granularity into testing
 - Use scaffolding ideas to build confidence
 - Always inject errors to verify that the test is working

Detailed example in the next presentation





Test Development For a Legacy Code

There may not be existing tests

- Isolate a small area of the code
- Dump a useful state snapshot
- Build a test driver
 - Start with only the files in the area
 - Link in dependencies
 - Copy if any customizations needed
- Read in the state snapshot
- Restart from the saved state
- Verify correctness
 - Always inject errors to verify that the test is working

