Software Testing: Introduction

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- Individual modules may be cited as Speaker, Module Title, in Better Scientific Software tutorial…

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Software Testing - Outline

Testing Introduction
  • Development context for testing
  • Challenges
  • Toy Example

Testing Walkthrough
  • Walk Through Testing Example

Advanced Testing
  • Guidelines for developing a testing & validation plan
  • Production Examples
    – Testing a legacy Fortran code
    – Designing tests alongside code development
  • Conclusions: Testing within a team context
Testing within the software development lifecycle
Testing within the software development lifecycle

• During initial code development
  – Accuracy and stability
  – Matching the algorithm to the model
  – Interoperability of algorithms

• In later stages
  – Adding new major capabilities
  – Modifying existing capabilities
  – Ongoing maintenance
  – Preparing for production
Testing as a development practice

Documentation

Build System

CI

SIAM CSE21, “Querying the ECP” - figshare
Audiences for this presentation

• New to testing / beginning development on a new project
  – Helpful starting points and ways to “start small.”

• Working with a legacy project that needs testing
  – Code isolation for incrementally adding testing

• Improving testing practices on an existing project
  – Ideas and guidelines for a holistic verification strategy
Definitions: Verification vs. Testing vs. Validation

• Software verification addresses design:
  – Does the operational standard make logical sense?
  – Is the implementation consistent with model?

• Model validation checks operation:
  – Is the code capable of handling your target science cases?
  – Is its answer consistent with use expectations?

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 says whether your science goals are met by your implementation
  • What you wanted your method to do is scientifically valid
  • Your model correctly captures the phenomenon you are trying to understand (outward-looking, not fully captured by tests)

https://www.energy.gov/nnsa/articles/face-uncertainties-nnsa-seeks-verification-and-validation
Components of Verification

• Testing at various granularity levels
  – Individual components
  – Interoperability of components
  – Convergence, stability and accuracy
  – Includes testing "upstream dependencies"

• 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
Challenges

• Exploratory Software
  – Implies one does not know the outcome
  – Still determining where model is valid
  – A: Validation from domain experts feeds back into design

• Legacy Codes
  – Original verification has been lost in the mists of time.
  – Assumptions, conditions, interactions unknown: “Bad code or necessary evil?”

• Releasing Codes
  – Code review to check scope of problem, solution, and documentation.
  – Verification before product release is a cost-effective way to prevent defects from getting through.
Toy Example

```bash
pip3 install pyscaffold
pip3 install tox
putup autoQCT
cd autoQCT # tests in tests/ subdir.
tox
```

default run-test: commands[0] | pytest

```
======================== test session starts ========================
platform darwin -- Python 3.9.0, pytest-6.2.2, py-1.10.0, pluggy-0.13.1 -- plugins: cov-2.11.1
collected 2 items

tests/test_skeleton.py::test_fib PASSED [ 50%]
tests/test_skeleton.py::test_main PASSED [100%]
```

```
---------- coverage: platform darwin, python 3.9.0-final-0 ----------
Name Stmts Miss Branch BrPart Cover Missing
---------------------------------------------------------------------
src/autoqct/__init__.py 6 0 0 0 100%
src/autoqct/skeleton.py 32 1 2 0 97% 135
---------------------------------------------------------------------
TOTAL 38 1 2 0 98%
```

```
======================== 2 passed in 0.07s ==========================
default: commands succeeded
congratulations :)
```
Toy Example

cat >CMakeLists.txt <<.
cmake_minimum_required(VERSION 3.8)
project( blank )
set(CMAKE_CXX_STANDARD 11)
set(CMAKE_CXX_STANDARD_REQUIRED ON)
include(blt/SetupBLT.cmake)
.
git clone https://github.com/LLNL/blt/
mkdir build && cd build
make –j && make test

...[100%]  Linking CXX executable ../../../tests/blt_gtest_smoke
[100%] Built target blt_gtest_smoke
mac0103234:build 99r$ make test
Running tests...
Test project /Users/99r/work/autoQCT/blank_project/build
  Start 1: blt_gtest_smoke
1/1 Test #1: blt_gtest_smoke ..................   Passed    0.46 sec

100% tests passed, 0 tests failed out of 1

Total Test time (real) =   0.46 sec
Going Further

• C, C++, Fortran
  – Running and Reporting Tests: ctest / cdash
  – Code Coverage: gcov / lcov (C, C++, Fortran)
  – Static Analysis: clang-tidy (only C, C++)

• Python
  – Running and Reporting Tests: pytest / unittest / nose
  – Code Coverage: pytest-cov
  – Static Source Code Analysis: pylint / flake8
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
  - Codecov.io in CI module

- Hosted servers (e.g. coveralls, codecov)
  - graphical visualization of results
  - push results to server through continuous integration server
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
Graphical View of Gcov Output and Tutorials for Code Coverage

Coverage Summary

<table>
<thead>
<tr>
<th>SOURCE FILES ON BUILD 45</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST 2</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>▲ COVERAGE</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>74.39</td>
</tr>
<tr>
<td>100.0</td>
</tr>
</tbody>
</table>

Line-by-line details

```
265 ! Error distribution same for all x values
266 delta = 5x5x - 5x5x
267 if (delta == 0.0_wp) then
268   ERRORMSG(" Cannot do linear least-sqrs. Divide by zero.")
269   stop
270 end if
271 delta_inv = 1.0_wp / delta
```

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

• A productive software team is always checking their work.
  – Take time to recognize these checks and harden them into “real,” repeatable tests.

• Test layout should mirror the logical structure of your code.
  – Test each module, being aware of module to module dependencies.

• Different challenges are associated with exploratory, legacy, and release codes.
  – Adapt your strategy to fit your situation.
  – Eventually you will want to be able to verify all components in a code release.

• Don’t get distracted by all the technologies out there – focus on exercising your code.
  – Scaffolding projects can help with mechanics.