Software Testing Walkthrough

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- The requested citation the overall tutorial is: David E. Bernholdt, Anshu Dubey, Rinku K. Gupta, and David M. Rogers, Software Productivity and Sustainability track, in Argonne Training Program on Extreme-Scale Computing (ATPESC), online, 2021. DOI: 10.6084/m9.figshare.15130590
- Individual modules may be cited as Speaker, Module Title, in Better Scientific Software tutorial…

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Hello Numerical World Example (heat equation)

github.com/bssw-tutorials/hello-numerical-world

$ wc *.C
  125 494 4161 args.C  # parse arguments
  220 718 5667 heat.C  # main() – stores all vars
  151 498 3888 utils.C # l2_norm, write, copy, init
  26 119 820 ftcs.C    # standard, centered stencil
  27 123 833 upwind15.C # alternate integration schemes
  94 344 2134 crankn.C
  43 190 1299 exact.C  # comparison solution

• Lots of setup code – prepares problem for kernel calls
• Isolated, swappable kernel calls
  – Imagine adding kernels to larger, multi-physics application.
• How can we support testing all these kernel configurations?
What to Test?

• Types of Tests:
  – code coverage – ensure options parse, bad cases detected, utilities function, etc.
  – steady-state (should be straight line)
    • external script can test file write() as well
  – solution time-dependence vs. reference
    • \((d/dx)^2 \sin(ax) = -a^2 \sin(ax)\)
  – integration between codes?
  – test compile/run in multiple precisions?
    • combinatorial problems – listing tests in for() or matrix...
Running Tests via makefile

$ make check_all
  c++ -c -linclude -DHEAT_VERSION_MAJOR=0 -
  DHEAT_VERSION_MINOR=5  args.Č -o args.o
  c++ -o heat heat.o utils.o args.o exact.o ftcs.o upwind15.o
  crankn.o -Im
  ./heat runame=check outi=0 maxt=-5e-8 ic="rand(0,0.2,2)"
  runame="check"
  ...
  Stopped after 001490 iterations for threshold 2.46636e-15
  cat check/check_soln_final.curve
  # Temperature
  ...
  ./check.sh check/check_soln_final.curve 0

make completes: commands succeeded

steady-state test
(should be straight line)

error?
TODO – try out new build tools and add tests to them

• Replace makefile with *CMakeLists.txt*
  – replaces rules with *targets* (tied to a list of source files)
  – targets have *attributes*
    • target_link_libraries (e.g. MPI::MPI_CXX)
    • target_include_directories (many already inferred from link libraries)
    • target_compile_features (e.g. cxx_std11)
  – provides *find_package* command
  – targets can be installed

• Replace "make check_all" with *ctest*
  – reduces glue code
  – different interface for adding tests

• End Result: contrast two methods of testing.
existing makefile

makefile

...  

# Implicit rule for object files
%.o : %.C
   $(CXX) -c $(CXXFLAGS) $(CPPFLAGS) $< -o $@

# Linking the final heat app
heat: $(OBJ)
   $(CXX) -o heat $(OBJ) $(LDFLAGS) -lm

Standard makefile – user selects compile flags.
- but flags and features are compiler and system-specific
- enter automake and cmake -> generate makefiles
Conversion to cmake (entire file)

CMakeLists.txt

```cmake
# cmake_minimum_required(VERSION 3.8)
project(heat VERSION 0.5 LANGUAGES CXX)
# can change boolean variable with "-DCMAKE_BUILD_TESTS=OFF"
option(BUILD_TESTS "Build the tests accompanying this program." ON)
# pass cmake options (e.g. version) into a header
configure_file(include/version.H.in include/version.H)
add_executable(heat args.C crankn.C ...) # list sources
# feature – lets cmake adjust flags for compiler --std=c++11 vs -c11
target_compile_features(heat cxx_std_11)
# include directories for all files in this target:
target_include_directories(heat ${PROJECT_BINARY_DIR}/include)
if(BUILD_TESTS) add_subdirectory(tests) endif() # subdir for tests
install(TARGETS heat DESTINATION bin) # "make install" target
```

existing tests

makefile include (tests.mk)

...  
check_crankn/check_crankn_soln_final.curve:  
   ./heat alg=crankn runame=check_crankn outi=0 maxt=-5e-8 ic="rand(0,0.2,2)"
check_crankn: heat check_crankn/check_crankn_soln_final.curve
   cat check_crankn/check_crankn_soln_final.curve
   ./check.sh check_crankn/check_crankn_soln_final.curve

check_upwind15/check_upwind15_soln_final.curve:  
   ./heat alg=upwind15 ...

Create a test driver to:
   1. run executable
   2. check result
   3. clean up outputs
Addition to CMakeLists.txt

cmake.org/cmake/help/latest/command/add_test.html

tests/CMakeLists.txt

enable_testing()

add_test(NAME heat_help
  COMMAND $<TARGET_FILE:heat> help)

add_test(NAME crankn
  COMMAND testDriver.sh $<TARGET_FILE:heat> crankn)

# functions/for/if/adding tests

Lots of potential for programmatically creating tests!

Try and keep it simple – complex cmake code is bad form.
Bonus: swap out test driver (perl -> awk)

tests/testDriver.sh

#!/bin/bash
set –e            # exit immediately on error
errbnd=1e-7
alg="$2"
$1 alg=$alg runame=check_$alg outi=0 maxt=-5e-8 ic="rand(0,0.2,2)"

# absolute error check (deviation from straight line)
err=$(awk 'function abs(x){return ((x < 0.0) ? -x : x)}; BEGIN {err=1e10;} !/#/ {err1=abs($2-$1); if(err1 < err) err = err1;} END {print err;}' check_$alg/check_${alg}_soln_final.curve)

echo "Error = $err"
rm -fr check_$alg     # delete directory to test is re-runnable

awk "BEGIN {exit($err >= $errbnd);}"    # final return code
Running

cmake ..
make -j

cd tests && ctest

Test project hello-numerical-world/build/tests
  Start 1: ftcs
1/3 Test #1: ftcs ............................. Passed 0.02 sec
  Start 2: crankn
2/3 Test #2: crankn ........................... Passed 0.02 sec
  Start 3: upwind15
3/3 Test #3: upwind15 ......................... Passed 0.03 sec

100% tests passed, 0 tests failed out of 3

Total Test time (real) = 0.08 sec
Going Further

• Reproduce these testing strategies on another repository
  – github.com/frobnitzem/simple-heateq (same problem, different design)

• Brainstorm some simple tests you could add to your own project
  – checks you've run manually
  – difficult-to-setup and reproduce cases that could be automated

• Add some "blank tests" to your project
  – reduces the barrier to increased testing
  – What would make reporting on your build / run status better/simpler/more accessible?
Conclusion – C, kernels, makefiles, CMakeLists, coverage, etc.

• Start your projects small, stay organized
  – makefiles provide fast development path
  – add tests before complexity grows!
  – simple to do with a "make check" target

• cmake (like autoconf) helps make portable builds
  – find_package
  – programmatic build options
  – set target properties -> cmake looks up compiler flags for you

• good testing strategies exist for both
  – directly run the executable with all options
  – create shell-script "test driver"
  – build stand-alone executables loading a library