

# **Best Practices for HPC Software Developers Webinar Series**

## **Session 4: Testing and Documenting Your Code**

We will also give a half day tutorial on testing at SC16:  
**“Testing of HPC Scientific Software”**

**Welcome! We will begin soon**

- Make sure you get counted. Please visit <http://bit.ly/hpcbp-s04>
- We want this webinar to be interactive, and we encourage questions
  - But we need to keep everyone's mic muted (too many participants)
  - Please use the Zoom Q&A tool to submit questions
  - Or use type them into this Google Doc: <http://bit.ly/hpcbp-qa>
  - Use the Zoom Chat tool for other issues
- Slides and a recording will be available from the OLCF training web site:  
<https://www.olcf.ornl.gov/training-event/webinar-series-best-practices-for-hpc-software-developers>
- We want to improve this series. Please send feedback to  
***HPCBestPractices+session04@gmail.com***



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# Testing and Documenting your Code

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# Outline

- Testing
  - Why testing is important
  - Types of tests
  - Testing tips
  - How Trilinos is tested
  - Code coverage
- Documentation
  - Why documentation is important
  - Types of documentation
  - How Trilinos is documented
  - Documentation generators

# TESTING

# Why testing is important: the protein structures of Geoffrey Chang

- Some inherited code flipped two columns of data, inverting an electron-density map
- Resulted in an incorrect protein structure
- Resulted in 5 retracted publications
  - One was cited 364 times
- Many papers and grant applications conflicting with his results were rejected

# Why testing is important: the 40 second flight of the Ariane 5

- Ariane 5: a European orbital launch vehicle meant to lift 20 tons into low Earth orbit
- Initial rocket went off course, started to disintegrate, then self-destructed less than a minute after launch
- Seven variables were at risk of leading to an Operand Error (due to conversion of floating point to integer)
  - Four were protected
- Investigation concluded insufficient test coverage as one of the causes for this accident
- Resulted in a loss of \$370,000,000.

# Why testing is important: the Therac-25 accidents

- Therac-25: a computer-controlled radiation therapy machine
- Minimal software testing
- Race condition in the code went undetected
- Unlucky patients were struck with approximately 100 times the intended dose of radiation,  $\sim 15,000$  rads
- Error code indicated that no dose of radiation was given, so operator instructed machine to proceed
  - Documentation gave no indication that the frequent malfunctions of the machine could place a patient at risk
  - See also: why documentation is important
- Recalled after six accidents resulting in death and serious injuries

# Granularity of tests

- Unit tests
  - Test individual functions or classes
  - Build and run fast
  - Localize errors
- Integration tests
  - Test interaction of larger pieces of software
- System-level tests
  - Test the full software system at the user interaction level

# Types of tests

- Verification tests
  - Does the code implement the intended algorithm correctly?
  - Check for specific mathematical properties
- Acceptance tests
  - Assert acceptable functioning for a specific customer
  - Generally at the system-level
- Regression (no-change) tests
  - Compare current observable output to a gold standard
  - Must independently verify that the gold standard is correct
- Performance tests
  - Focus on the runtime and resource utilization
  - Nothing to do with correctness
- Installation tests
  - Verify that the configure-make-install is working as expected

# CSE testing challenges

- Floating point issues
  - Different results
    - On different platforms
    - On different runs (due to multi-processor computation)
  - Ill-conditioning can magnify these small differences
    - Final solution may be different
    - Number of iterations may be different
  - Performing a diff is bad
- Non-unique solutions

# CSE testing challenges

- Scalability testing
  - Difficult to get accurate data on a shared machine
  - Getting access to many processors on a parallel machine is expensive
    - Many supercomputing facilities discourage routine scalability testing
    - Large jobs may sit in the queue for quite some time
  - How do you scale a problem for weak scaling studies?
    - A more refined problem may not have the same condition number

# Testing tips

- Ideal time to build a test suite is during development
  - Ensures that new code does not break existing functionality
- Failing tests should help you identify what part of the code needs to be fixed
- Software should be tested regularly
- Develop a consistent policy on dealing with failed tests
  - Use an issue tracking system
  - Add a regression test after the issue is fixed
- Run a regression test suite when checking in new code
- Avoid zero-diffing tests against gold standard output
  - spiff (<https://github.com/dontcallmedom/spiff>)

# What is Trilinos?

- A collection of libraries intended to be used as building blocks for the development of scientific applications
- Organized into 66 packages
  - Linear solvers
  - Nonlinear solvers
  - Eigensolvers
  - And more!
- 10,000+ commits
- 135 contributors (according to github)
- Millions of lines of code

# How is Trilinos tested?

- Trilinos has 1500 tests between its 66 packages
- Developers are strongly advised to run a checkin test script when committing
  - Detects which packages were modified by your commits
  - Determines which packages you potentially broke
  - Configures, builds, and tests those packages
    - On success, pushes to repo
    - On failure, reports why it failed
  - Useful for ensuring your changes don't break another package
  - May take a while, but many people run it overnight
- Automated testing on a variety of different platforms

# Why do we do automated testing if everyone uses the checkin script?

- May test a different set of packages
- May test different environments
  - Do your changes work with Intel compilers as well as GNU?
  - Do your changes work on a mac?
  - Do your changes work with CUDA?
- Identifies a small set of commits that could have broken a build or test
  - Average 12 commits per day
  - Identifies the person who knows how to un-break it
- Bugs are easier to fix if caught early

# Checkin test script examples

- Example 1: a harmless change to a comment
- Example 2: breaking the build
- Example 3: breaking some tests

# Example 1: a harmless change

Applications Places System

anasazi/s : vim

File Edit View Scrollback Bookmarks Settings Help

```
// @HEADER
// ****
// Anasazi: Block Eigensolvers Package
// Copyright (2004) Sandia Corporation
//
// Under terms of Contract DE-AC04-94AL85000, there is a non-exclusive
// license for use of this work by or on behalf of the U.S. Government.
//
// This library is free software; you can redistribute it and/or modify
// it under the terms of the GNU Lesser General Public License as
// published by the Free Software Foundation; either version 2.1 of the
// License, or (at your option) any later version.
//
// This library is distributed in the hope that it will be useful, but
// WITHOUT ANY WARRANTY; without even the implied warranty of
// MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU
// Lesser General Public License for more details.
//
// You should have received a copy of the GNU Lesser General Public
// License along with this library; if not, write to the Free Software
// Foundation, Inc., 51 Franklin St, Fifth Floor, Boston, MA 02110-1301
// USA
// Questions? Contact Michael A. Heroux (maherou@sandia.gov)
//
// ****
// @HEADER

/*! \file AnasaziTraceMinDavidson.hpp
 * \brief Implementation of the TraceMin-Davidson eigensolver
 */

#ifndef ANASAZI_TRACEMIN_DAVIDSON_HPP
#define ANASAZI_TRACEMIN_DAVIDSON_HPP

#include "AnasaziConfigDefs.hpp"
#include "AnasaziEigensolver.hpp"
#include "AnasaziMultiVecTraits.hpp"
-- INSERT --

```

30,61 Top

anasazi/s : vim

[System Monitor] Fix build of xSDKTrilino... CHECKIN : checkin-tes... anasazi/s : vim USInformationSheet\_I... \*Unsaved Document 1 ...

# Example 1: a harmless change

Applications Places System

CHECKIN : checkin-test-am

Thu Apr 21, 4:42 PM Alicia Klinvex

```
[amklinv@s995692 CHECKIN]$ ./checkin-test-amklinv --do-all
*****
Script: checkin-test.py \
--src-dir='/home/amklinv/TrilinosDir/github/Trilinos' \
--default-builds='MPI_DEBUG,SERIAL_RELEASE' \
--extra-repos-file='' \
--extra-repos-type='' \
--extra-repos='' \
--require-extra-repos-exist \
--enable-packages='' \
--disable-packages='FEI,Moertel,STK,Phalanx,PyTrilinos' \
--enable-all-packages='auto' \
--enable-fwd-packages \
--continue-if-no-updates \
--continue-if-no-changes-to-push \
--continue-if-no-enables \
--extra-cmake-options='' \
--test-categories='BASIC' \
--make-options='-j48' \
--ctest-options='-E '(Anasazi_Epetra_BlockDavidson_test|Anasazi_Epetra_BlockDavidson_auxtest_MPI_4|Anasazi_Epetra_GeneralizedDavidson_solverstest_MPI_4|Anasazi_BlockDavidsonThyra_test_MPI_4|NOX_Thyra_Heq_MPI_1|Rythmos_BackwardEuler_ConvergenceTest_MPI_1|Rythmos_IntegratorBuilder_ConvergenceTest_MPI_1|NOX_Thyra_Heq)' \
--ctest-timeout=60.0 \
--no-show-all-tests \
--st-extra-builds='' \
--extra-builds='' \
--send-email-to='amklinv@sandia.gov' \
--skip-case-send-email \
--send-build-case-email=always \
--send-email-for-all \
--send-email-to-on-push='trilinos-checkin-tests@software.sandia.gov' \
--no-force-push \
--do-push-readiness-check \
--rebase \
--append-test-results \
--do-all \

```

Starting time: Thu Apr 21 16:11:38 MDT 2016

...IN : checkin-test-am

[System Monitor] Klinvex, Alicia Marie - ... CHECKIN : checkin-test-am MPI\_DEBUG : bash USInformationSheet\_I... \*Unsaved Document 1 ...

# Example 1: a harmless change

Applications Places System

**CHECKIN : checkin-test-am**

Thu Apr 21, 4:44 PM Alicia Klinvex

```

File Edit View Scrollback Bookmarks Settings Help
Determining the set of packages to enable by examining /home/amklinv/TrilinosDir/github/Trilinos/CHECKIN/modifiedFiles.out ...

Modified file: 'packages/anasazi/src/AnasaziTraceMinDavidson.hpp'
=> Enabling 'Anasazi'!
Full package enable list: [Anasazi]

Removing package enables: [FEI,Moertel,STK,Phalanx,PyTrilinos]

Filtering the set of enabled packages according to allowed package types ...

Final package enable list: [Anasazi]

Enabling forward packages on request!

Adding hard disables for specified packages 'FEI,Moertel,STK,Phalanx,PyTrilinos' ...

cmakePkgOptions: [u'-DTrilinos_ENABLE_Anasazi:BOOL=ON', '-DTrilinos_ENABLE_ALL_OPTIONAL_PACKAGES:BOOL=ON', '-DTrilinos_ENABLE_ALL_FORWARD_DEP_PACKAGES:BOOL=ON',
', '-DTrilinos_ENABLE_FEI:BOOL=OFF', '-DTrilinos_ENABLE_Moertel:BOOL=OFF', '-DTrilinos_ENABLE_STK:BOOL=OFF', '-DTrilinos_ENABLE_Phalanx:BOOL=OFF', '-DTrilinos_ENABLE_PyTrilinos:BOOL=OFF']

cmakeOptions = ['-DTrilinos_TRIBITS_DIR:PATH=/home/amklinv/TrilinosDir/github/Trilinos/cmake/tribits', '-DTrilinos_ENABLE_TESTS:BOOL=ON', '-DTrilinos_TEST_CATEGORIES:STRING=BASIC',
'-DTrilinos_ALLOW_NO_PACKAGES:BOOL=OFF', '-DDART_TESTING_TIMEOUT:STRING=60.0', '-DTPL_ENABLE_Pthread:BOOL=OFF', '-DTPL_ENABLE_BinUtils:BOOL=OFF',
'-DTrilinos_ENABLE_SECONDARY_TESTED_CODE:BOOL=OFF', '-DTPL_ENABLE_MPI:BOOL=ON', '-DCMAKE_BUILD_TYPE:STRING=RELEASE', '-DTrilinos_ENABLE_DEBUG:BOOL=ON',
', '-DTrilinos_ENABLE_CHECKED_STL:BOOL=ON', '-DTrilinos_ENABLE_DEBUG_SYMBOLS:BOOL=ON', '-DTrilinos_ENABLE_EXPLICIT_INSTANTIATION:BOOL=ON', '-DTeuchos_ENABLE_DEFAULT_STACKTRACE:BOOL=OFF',
', -D Trilinos_ENABLE_EXPLICIT_INSTANTIATION:BOOL=ON', '-D CMAKE_INSTALL_PREFIX:PATH="/home/amklinv/TrilinosDir/trilinos-install"',
', -D CMAKE_CXX_FLAGS:STRING="-Wall -ansi -pedantic -Wshadow"', '-D MPI_EXEC_MAX_NUMPROCS:STRING=8', '-D HAVE_GCC_ABI_DEMANGLE:BOOL=ON', '-D Trilinos_ENABLE_OpenMP:BOOL=OFF',
', -D TPL_ENABLE_QT:BOOL=OFF', '-D BLAS_LIBRARY_NAMES:STRING="libf77blas.so.3"', '-D BLAS_LIBRARY_DIRS:PATH="/usr/lib64/atlas", -D LAPACK_LIBRARY_NAMES:STRING="liblapack.so.3"',
', -D LAPACK_LIBRARY_DIRS:PATH="/usr/lib64/atlas", -D TPL_ENABLE_Netcdf:OFF', '-D CMAKE_BUILD_TYPE:STRING=DEBUG', '-D Teuchos_ENABLE_DEBUG:BOOL=ON',
', -D Kokkos_ENABLE_BOUNDS_CHECK:BOOL=ON', '-D Kokkos_ENABLE_DEBUG:BOOL=ON', '-D TPL_ENABLE_MPI:BOOL=ON', u'-DTrilinos_ENABLE_Anasazi:BOOL=ON',
', '-DTrilinos_ENABLE_ALL_OPTIONAL_PACKAGES:BOOL=ON', '-DTrilinos_ENABLE_ALL_FORWARD_DEP_PACKAGES:BOOL=ON', '-DTrilinos_ENABLE_FEI:BOOL=OFF', '-DTrilinos_ENABLE_Moertel:BOOL=OFF',
', '-DTrilinos_ENABLE_STK:BOOL=OFF', '-DTrilinos_ENABLE_Phalanx:BOOL=OFF', '-DTrilinos_ENABLE_PyTrilinos:BOOL=OFF']

Creating base configure file do-configure.base ...

Running: chmod a+x do-configure.base
```

...IN : checkin-test-am

[System Monitor] Klinvex, Alicia Marie - ... CHECKIN : checkin-test-am MPI\_DEBUG : bash USInformationSheet\_I... \*Unsaved Document 1 ...

Note that the checkin script correctly identified what was modified.

# Example 1: a harmless change

Applications Places System

CHECKIN : checkin-test-am

Thu Apr 21, 4:46 PM Alicia Klinvex

```

File Edit View Scrollback Bookmarks Settings Help
E) Analyze the overall results and send email notification (MPI_DEBUG) ...

E.1) Determine what passed and failed ...

The pull passed!

The configure passed!

The build passed!

testResultsLine = '100% tests passed, 0 tests failed out of 237'
All of the tests ran passed!

E.2) Construct the email message ...

subjectLine = 'passed: Trilinos/MPI_DEBUG: passed=237,notpassed=0'

Running: touch email.success

E.3) Send the email message ...

Running: mailx -s "passed: Trilinos/MPI_DEBUG: passed=237,notpassed=0" amklinv@sandia.gov < email.out

*** Doing build and test of SERIAL_RELEASE ...
***
```

...IN : checkin-test-am

[System Monitor] Klinvex, Alicia Marie ... CHECKIN : checkin-t... MPI\_DEBUG : bash USInformationSheet\_... \*Unsaved Document... snapshot4.png snapshot5.png

Configure, build, and test  
passed for MPI\_DEBUG

# Example 1: a harmless change

Applications Places System

CHECKIN : checkin-test-am

Thu Apr 21, 4:47 PM Alicia Klinvex

```

READY TO PUSH: Trilinos: s995692.srn.sandia.gov
Thu Apr 21 16:22:57 MDT 2016

Enabled Packages: Anasazi
Disabled Packages: FEI,Moertel,STK,Phalanx,PyTrilinos
Enabled all Forward Packages

Build test results:
-----
0) MPI DEBUG => passed: passed=237,notpassed=0 (8.42 min)
1) SERIAL_RELEASE => passed: passed=243,notpassed=0 (2.71 min)

*** Commits for repo :
 982db3b Anasazi: Modified a comment in TraceMin-Davidson

0) MPI_DEBUG Results:
-----

  passed: Trilinos/MPI_DEBUG: passed=237,notpassed=0

Thu Apr 21 16:20:14 MDT 2016

Enabled Packages: Anasazi
Disabled Packages: FEI,Moertel,STK,Phalanx,PyTrilinos
Enabled all Forward Packages
Hostname: s995692.srn.sandia.gov
Source Dir: /home/amklinv/TrilinosDir/github/Trilinos
Build Dir: /home/amklinv/TrilinosDir/github/Trilinos/CHECKIN/MPI_DEBUG

CMake Cache Variables: -DTrilinos_TRIBITS_DIR:PATH=/home/amklinv/TrilinosDir/github/Trilinos/cmake/tribits -DTrilinos_ENABLE_TESTS:BOOL=ON -DTrilinos_TEST_CATEGORIES:STRING=BASIC -DTrilinos_ALLOW_NO_PACKAGES:BOOL=OFF -DDART_TESTING_TIMEOUT:STRING=60.0 -DTPL_ENABLE_Pthread:BOOL=OFF -DTPL_ENABLE_BinUtils:BOOL=OFF -DTrilinos_ENABLE_SECONDARY_TESTED_CODE:BOOL=OFF -DTPL_ENABLE_MPI:BOOL=ON -DCMAKE_BUILD_TYPE:STRING=RELEASE -DTrilinos_ENABLE_DEBUG:BOOL=ON -DTrilinos_ENABLE_CHECKED_STL:BOOL=ON -DTrilinos_ENABLE_DEBUG_SYMBOLS:BOOL=ON -DTrilinos_ENABLE_EXPLICIT_INSTANTIATION:BOOL=ON -DTeuchos_ENABLE_DEFAULT_STACKTRACE:BOOL=OFF -DTrilinos_ENABLE_EXPLICIT_INSTANTIATION:BOOL=ON -D CMAKE_INSTALL_PREFIX:PATH="/home/amklinv/TrilinosDir/trilinos-install" -D CMAKE_CXX_FLAGS:STRING="-Wall -ansi -pedantic -Wshadow" -D MPI_EXEC_MAX_NUMPROCS:STRING=8 -D HAVE_GCC_ABI_DEMANGLE:BOOL=ON -D Trilinos_ENABLE_OpenMP:BOOL=OFF -D TPL_ENABLE_QT:BOOL=OFF -D BLAS_LIBRARY_NAMES:STRING="libf77blas.so.3" -D BLAS_LIBRARY_DIRS:PATH="/usr/lib64/atlas" -D LAPACK_LIBRARY_NAMES:STRING="liblapack.so.3" -D LAPACK_LIBRARY_DIRS:PATH="/usr/lib64/atlas" -D TPL_ENABLE_Netcdf=OFF -D CMAKE_BUILD_TYPE:STRING=DEBUG -D Teuchos_ENABLE_DEBUG:BOOL=ON -D Kokkos_ENABLE_BOUNDS_CHECK:BOOL=ON -D Kokkos_ENABLE_DEBUG:BOOL=ON -D TPL_ENABLE_MPI:BOOL=ON -DTrilinos_ENABLE_Anasazi:BOOL=ON -DTrilinos_ENABLE_ALL_OPTIONAL_PACKAGES:BOOL=ON -DTrilinos_ENABLE_ALL_FORWARD_D
```

...IN : checkin-test-am

[System Monitor] Klinvex, Alicia Marie ... CHECKIN : checkin-t... MPI\_DEBUG : bash USInformationSheet... \*Unsaved Document... snapshot4.png snapshot5.png

We are ready to push because all tests passed

# Example 2: broken build

Applications Places System   Thu Apr 21, 4:50 PM   Alicia Klinvex

File Edit View Scrollback Bookmarks Settings Help

```

const Teuchos::RCP<StatusTest<ScalarType,MV,OP> >      &tester,
const Teuchos::RCP<MatOrthoManager<ScalarType,MV,OP> > &ortho,
Teuchos::ParameterList &params
);

private:
// Convenience typedefs
//
typedef MultiVecTraits<ScalarType,MV> MVT;
typedef OperatorTraits<ScalarType,MV,OP> OPT;
typedef Teuchos::ScalarTraits<ScalarType> SCT;
typedef typename SCT::magnitudeType MagnitudeType;

// TraceMin specific methods
void addToBasis(const Teuchos::RCP<const MV> Delta);

void harmonicAddToBasis(const Teuchos::RCP<const MV> Delta);
} ←
// Implementations
//
// Constructor
template <class ScalarType, class MV, class OP>
TraceMinDavidson<ScalarType,MV,OP>::TraceMinDavidson(
    const Teuchos::RCP<Eigenproblem<ScalarType,MV,OP> >      &problem,
    const Teuchos::RCP<SortManager<typename Teuchos::ScalarTraits<ScalarType>::magnitudeType> > &sorter,
    const Teuchos::RCP<OutputManager<ScalarType> >            &printer,
    const Teuchos::RCP<StatusTest<ScalarType,MV,OP> >          &tester,
-- INSERT --

```

Missing semicolon at the end of the class. This will break the build

anasazi/s : vim   99, 4   28%

[System Monitor] Fix build of xSDKTrilino... CHECKIN : checkin-tes... anasazi/s : vim USInformationSheet\_I... \*Unsaved Document 1 ...

# Example 2: broken build

```
Applications Places System 
File Edit View Scrollback Bookmarks Settings Help
C) Do the build (MPI_DEBUG) ...

Running: make -j48
Writing console output to file make.out ...
Runtime for command = 0.235778 minutes
Build failed returning 2!

Traceback (most recent call last):
  File "/home/amklinv/TrilinosDir/github/Trilinos/cmake/tribits/ci_support/CheckinTest.py", line 1586, in runBuildTestCase
    raise Exception("Build failed!")
Exception: Build failed!
E) Analyze the overall results and send email notification (MPI_DEBUG) ...

E.1) Determine what passed and failed ...

The pull passed!

The configure passed!

The build FAILED! ←
The tests were never even run!

E.2) Construct the email message ...

subjectLine = 'FAILED: Trilinos/MPI_DEBUG: build failed'

...IN : checkin-test-am
[System Monitor]  CHECKIN : checkin-test-am  USInformationSheet_I... *Unsaved Document 1 ...
```

The checkin script detected  
that I broke the build

# Example 2: broken build

MPI\_DEBUG : bash

Thu Apr 21, 4:56 PM Alicia Klinvex

```
Built target Rythmos_StepperHelpers_UnitTest
[100%] [100%] Built target Rythmos_Thyra_UnitTest
Built target Rythmos_TimeRange_UnitTest
[100%] [100%] [100%] Built target Rythmos_ForwardEuler_ConvergenceTest
[100%] Built target Rythmos_VanderPolModel_UnitTest
Built target Rythmos_BackwardEuler_ConvergenceTest
[100%] Built target Rythmos_ExplicitRK_ConvergenceTest
[100%] Built target Rythmos_ImplicitBDF_ConvergenceTest
Built target Rythmos_IntegratorBuilder_ConvergenceTest
[100%] Built target Rythmos_simpleAdjoint
In file included from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidsonSolMgr.hpp:40:0,
                 from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/tpetra/test/TraceMinDavidson/cxx_main_standard_noprec.cpp:8:
/home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidson.hpp:99:3: error: expected ';' after class definition
In file included from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidsonSolMgr.hpp:40:0,
                 from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/tpetra/example/TraceMinDavidson/TraceMinDavidsonUserOpEx.cpp:8:
/home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidson.hpp:99:3: error: expected ';' after class definition
In file included from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidsonSolMgr.hpp:40:0,
                 from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/tpetra/example/TraceMinDavidson/TraceMinDavidsonLaplacianEx.cpp:8:
/home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidson.hpp:99:3: error: expected ';' after class definition
In file included from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidsonSolMgr.hpp:40:0,
                 from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/tpetra/example/TraceMinDavidson/TraceMinDavidsonGeneralizedEx.cpp:8:
/home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidson.hpp:99:3: error: expected ';' after class definition
In file included from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidsonSolMgr.hpp:40:0,
                 from /home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/tpetra/example/TraceMinDavidson/TraceMinDavidsonSpecTransEx.cpp:8:
/home/amklinv/TrilinosDir/github/Trilinos/packages/anasazi/src/AnasaziTraceMinDavidson.hpp:99:3: error: expected ';' after class definition
make[2]: *** [packages/anasazi/tpetra/test/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TraceMinDavidson_largest_standard_test.dir/cxx_main_standard_noprec.cpp.o] Error 1
make[1]: *** [packages/anasazi/tpetra/test/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TraceMinDavidson_largest_standard_test.dir/all] Error 2
make[1]: *** Waiting for unfinished jobs....
make[2]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_UserOp_example.dir/TraceMinDavidsonUserOpEx.cpp.o] Error 1
make[1]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_UserOp_example.dir/all] Error 2
make[2]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_Gen_example.dir/TraceMinDavidsonGeneralizedEx.cpp.o] Error 1
make[1]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_Gen_example.dir/all] Error 2
make[2]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_Fiedler_example.dir/TraceMinDavidsonLaplacianEx.cpp.o] Error 1
make[1]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_Fiedler_example.dir/all] Error 2
make[2]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_Trans_example.dir/TraceMinDavidsonSpecTransEx.cpp.o] Error 1
make[1]: *** [packages/anasazi/tpetra/example/TraceMinDavidson/CMakeFiles/Anasazi_Tpetra_TD_Trans_example.dir/all] Error 2
make: *** [all] Error 2
[amklinv@s995692 MPI_DEBUG]$
```

Checkin script also creates a log file with the error

[MPI\_DEBUG : bash] [System Monitor] [Klinvex, Alicia Marie - ...] [MPI\_DEBUG : bash] [anasazi/s : bash] [USInformationSheet\_I... unsaved Document 1 ...]

# Example 3: broken tests

Applications Places System   Thu Apr 21, 5:02 PM   Alicia Klinvex

File Edit View Scrollback Bookmarks Settings Help

```

useMultipleShifts_ = params.get("Use Multiple Shifts", true);

shiftThresh_ = params.get("Shift Threshold", 1e-2);
useRelShiftThresh_ = params.get("Relative Shift Threshold", true);
shiftNorm_ = params.get("Shift Norm", "2");
TEUCHOS_TEST_FOR_EXCEPTION(shiftNorm_ != "2" && shiftNorm_ != "M", std::invalid_argument,
    "Anasazi::TraceMin::constructor: Invalid value for \"Shift Norm\"; valid options are \"2\", \"M\".");
considerClusters_ = params.get("Consider Clusters", true);

projectAllVecs_ = params.get("Project All Vectors", true);
projectLockedVecs_ = params.get("Project Locked Vectors", true);
useRHSR_ = params.get("Use Residual as RHS", true);
useHarmonic_ = params.get("Use Harmonic Ritz Values", false);
computeAllRes_ = params.get("Compute All Residuals", true);

// set the block size and allocate data
int bs = params.get("Block Size", problem_->getNEV());
int nb = params.get("Num Blocks", 1);
// setSize(bs,nb); ←
NEV_ = problem_->getNEV();

// Create the Ritz shift operator
ritzOp_ = rcp (new tracemin_ritz_op_type (Op_, MOp_, Prec_));

// Set the maximum number of inner iterations
const int innerMaxIts = params.get ("Maximum Krylov Iterations", 200);
ritzOp_->setMaxIts (innerMaxIts);

alpha_ = params.get ("HSS: alpha", ONE);
}

///////////////////////////////
// Destructor
template <class ScalarType, class MV, class OP>
TraceMinBase<ScalarType,MV,OP>::~TraceMinBase() {}

-- INSERT --

```

Added a logic error to the code.

anasazi/s : vim   746,3   19%

[System Monitor]   Klinvex, Alicia Marie - ...   anasazi/s : vim   modifyAnasazi : bash   USInformationSheet\_I...   \*Unsaved Document 1 ...

# Example 3: broken tests

Applications Places System

**CHECKIN : checkin-test-am**

Thu Apr 21, 5:16 PM Alicia Klinvex

File Edit View Scrollback Bookmarks Settings Help

FAILED CONFIGURE/BUILD/TEST: Trilinos: s995692.srn.sandia.gov

Thu Apr 21 17:14:53 MDT 2016

Enabled Packages: Anasazi  
 Disabled Packages: FEI,Moertel,STK,Phalanx,PyTrilinos  
 Enabled all Forward Packages

Build test results:

```
0) MPI_DEBUG => FAILED: passed=233,notpassed=4 => Not ready to push! (8.43 min)
1) SERIAL_RELEASE => FAILED: passed=239,notpassed=4 => Not ready to push! (2.74 min)
```

Failed because one of the build/test cases failed!

\*\*\* Commits for repo :  
 6bb949b Anasazi: Broke some TraceMin tests. Oops!

0) MPI\_DEBUG Results:

```
FAILED: Trilinos/MPI_DEBUG: passed=233,notpassed=4
```

Thu Apr 21 17:12:09 MDT 2016

Enabled Packages: Anasazi  
 Disabled Packages: FEI,Moertel,STK,Phalanx,PyTrilinos  
 Enabled all Forward Packages  
 Hostname: s995692.srn.sandia.gov  
 Source Dir: /home/amklinv/TrilinosDir/github/Trilinos  
 Build Dir: /home/amklinv/TrilinosDir/github/Trilinos/CHECKIN/MPI\_DEBUG

CMake Cache Variables: -DTrilinos\_TRIBITS\_DIR=PATH=/home/amklinv/TrilinosDir/github/Trilinos/cmake/tribits -DTrilinos\_ENABLE\_TESTS:BOOL=ON -DTrilinos\_TEST\_CATEGORIES:STRING=BASIC -DTrilinos\_ALLOW\_NO\_PACKAGES:BOOL=OFF -DDART\_TESTING\_TIMEOUT:STRING=60.0 -DTPL\_ENABLE\_Pthread:BOOL=OFF -DTPL\_ENABLE\_BinUtils:BOOL=OFF -D Trilinos\_ENABLE\_SECONDARY\_TESTED\_CODE:BOOL=OFF -DTPL\_ENABLE\_MPI:BOOL=ON -DCMAKE\_BUILD\_TYPE:STRING=RELEASE -DTrilinos\_ENABLE\_DEBUG:BOOL=ON -DTrilinos\_ENABLE\_CHECKED\_STL:BOOL=ON -DTrilinos\_ENABLE\_DEBUG\_SYMBOLS:BOOL=ON -DTrilinos\_ENABLE\_EXPLICIT\_INSTANTIATION:BOOL=ON -DTeuchos\_ENABLE\_DEFAULT\_STACKTRACE:BOOL=OFF -D Trilinos\_ENABLE\_EXPLICIT\_INSTANTIATION:BOOL=ON -D CMAKE\_INSTALL\_PREFIX:PATH="/home/amklinv/TrilinosDir/trilinos-install" -D CMAKE\_CXX\_FLAGS:STRING="-Wall -ansi -pedantic -Wshadow" -D MPI\_EXEC\_MAX\_NUMPROCS:STRING=8 -D HAVE\_GCC\_ABI\_DEMANGLE:BOOL=ON -D Trilinos\_ENABLE\_OpenMP:BOOL=OFF -D TPL\_ENABLE\_QT:BOOL=OFF -D BLAS\_LIB

...IN : checkin-test-am

[System Monitor] Klinvex, Alicia Marie - ... USInformationSheet\_I...

The checkin script detected  
that I broke several tests

# Example 3: broken tests

```

Applications Places System 🌐 🌐 🌐
File Edit View Scrollback Bookmarks Settings Help
MPI_DEBUG : bash
Thu Apr 21, 5:16 PM Alicia Klinvex
Start 227: Rythmos_complicatedExample_amesos_nox_bdf_MPI_1 ..... Passed 3.52 sec
227/237 Test #227: Rythmos_complicatedExample_amesos_nox_bdf_MPI_1 ..... Passed 0.39 sec
Start 228: Rythmos_complicatedExample_amesos_nox_bd_MPI_1 ..... Passed 0.45 sec
228/237 Test #228: Rythmos_complicatedExample_amesos_nox_bd_MPI_1 ..... Passed 0.47 sec
Start 229: Rythmos_complicatedExample_aztecoo_0_MPI_1 ..... Passed 3.59 sec
229/237 Test #229: Rythmos_complicatedExample_aztecoo_0_MPI_1 ..... Passed 0.45 sec
Start 230: Rythmos_complicatedExample_aztecoo_1_MPI_1 ..... Passed 0.47 sec
230/237 Test #230: Rythmos_complicatedExample_aztecoo_1_MPI_1 ..... Passed 0.47 sec
Start 231: Rythmos_complicatedExample_aztecoo_2_MPI_1 ..... Passed 3.93 sec
231/237 Test #231: Rythmos_complicatedExample_aztecoo_2_MPI_1 ..... Passed 0.65 sec
Start 232: Rythmos_complicatedExample_aztecoo_nox_MPI_1 ..... Passed 6.31 sec
232/237 Test #232: Rythmos_complicatedExample_aztecoo_nox_MPI_1 ..... Passed 0.52 sec
Start 233: Rythmos_complicatedExample_belos_0_MPI_1 ..... Passed 5.41 sec
233/237 Test #233: Rythmos_complicatedExample_belos_0_MPI_1 ..... Passed 0.52 sec
Start 234: Rythmos_complicatedExample_belos_1_MPI_1 ..... Passed 0.52 sec
234/237 Test #234: Rythmos_complicatedExample_belos_1_MPI_1 ..... Passed 0.52 sec
Start 235: Rythmos_complicatedExample_belos_nox_bdf_MPI_1 ..... Passed 0.52 sec
235/237 Test #235: Rythmos_complicatedExample_belos_nox_bdf_MPI_1 ..... Passed 0.52 sec
Start 236: Rythmos_simpleAdjoint_amesos_0_MPI_1 ..... Passed 0.52 sec
236/237 Test #236: Rythmos_simpleAdjoint_amesos_0_MPI_1 ..... Passed 0.52 sec
Start 237: Rythmos_simpleAdjoint_amesos_1_MPI_1 ..... Passed 0.52 sec
237/237 Test #237: Rythmos_simpleAdjoint_amesos_1_MPI_1 ..... Passed 0.52 sec

98% tests passed, 4 tests failed out of 237

Label Time Summary:
Anasazi    = 100.15 sec
NOX        = 165.35 sec
Rythmos   = 124.19 sec

Total Test time (real) = 389.89 sec

The following tests FAILED:
  56 - Anasazi_Tpetra_TraceMin_smallest_proj_test_MPI_4 (Failed)
  57 - Anasazi_Tpetra_TraceMin_smallest_schur_test_MPI_4 (Failed)
  58 - Anasazi_Tpetra_TraceMin_largest_standard_test_MPI_4 (Failed)
  59 - Anasazi_Tpetra_TraceMinDavidson_largest_standard_test_MPI_4 (Failed)

Errors while running CTest
[amklinv@s995692 MPI_DEBUG]$ 
```

The log file tells us which tests were broken

# Trilinos automated testing

Project									
Project	Configure			Build			Test		
	Error	Warning	Pass	Error	Warning	Pass	Not Run	Fail	Pass
Trilinos 	1	531	530	0	272	257	0	14	3976
SubProjects									
Project	Configure			Build			Test		
	Error	Warning	Pass	Error	Warning	Pass	Not Run	Fail	Pass
Teuchos	0	21	21	0	12	9	0	0	227
ThreadPool	0	1	1	0	0	1			
Sacado	0	2	2	0	2	0	0	0	564
RTOp	0	20	20	0	0	20			
Kokkos	0	19	19	0	0	19	0	0	9
Epetra	0	21	21	0	12	9	0	1	244
Zoltan	0	21	21	0	13	8	0	0	135
Shards	0	1	1	0	0	1			
GlobiPack	0	1	1	0	0	1			

# Trilinos automated testing

Nightly

Site	Build Name	Update		Configure		Build		Test				
		Files	↑	Error	Warn	Error	Warn	Not Run	Fail	Pass	Build Time	Labels
artemis.srn.sandia.gov	Linux-intel-15.0.2-MPI_RELEASE_DEV_DownStream_ETI_SERIAL-OFF_OPENMP-ON_PTHREAD-OFF_CUDA-OFF_COMPLEX-OFF	68	1	140	0	216	0	3	1256		6 hours ago	(44 labels)
lightsaber.srn.sandia.gov	Linux-GCC-4.7.2-RELEASE_DEV_MueLu_Matlab	69	0	111	0	51	0	0	431		10 hours ago	(25 labels)
enigma.sandia.gov	Linux-GCC-4.8.3-OPENMPI_1.6.4_DEBUG_DEV_MueLu_Basker	69	0	227	0	117	0	0	96		9 hours ago	(25 labels)
hansel.sandia.gov	Linux-GCC-4.4.7-MPI_OPT_DEV_XYCE	121	0	70	0	28	0	0	553		9 hours ago	(13 labels)
enigma.sandia.gov	Linux-GCC-4.8.3-OPENMPI_1.6.4_DEBUG_DEV_MueLu_KLU2	69	0	225	0	91	0	0	73		8 hours ago	(25 labels)
enigma.sandia.gov	Linux-GCC-4.8.3-OPENMPI_1.6.4_DEBUG_DEV_MueLu_ExtraTypes_EI	69	0	227	0	117	0	0	97		8 hours ago	(25 labels)
enigma.sandia.gov	Linux-GCC-4.8.3-SERIAL_DEBUG_DEV_MueLu_ExtraTypes	69	0	227	0	117	0	3	94		7 hours ago	(25 labels)
enigma.sandia.gov	Linux-GCC-4.8.3-SERIAL_RELEASE_DEV_MueLu_Experimental	69	0	227	0	113	0	4	107		6 hours ago	(25 labels)

# Trilinos automated testing

- Several Amesos2 (direct solver) tests are broken.

SubProject Dependencies										
Project	Configure			Build			Test			Last submission
	Error	Warning	Pass	Error	Warning	Pass	Not Run	Fail	Pass	
Teuchos	0	22	22	0	13	9	0	0	227	2016-06-06 09:01:20
Epetra	0	22	22	0	13	9	0	1	244	2016-06-06 09:02:05
Triutils	0	22	22	0	0	21	0	0	2	2016-06-06 09:02:16
Tpetra	0	20	20	0	18	2	0	0	285	2016-06-06 08:10:13
EpetraExt	0	21	21	0	3	18	0	0	26	2016-06-06 08:11:16
ThreadPool	0	1	1	0	0	1				2016-06-06 02:51:44
Amesos	0	21	21	0	1	20	0	0	41	2016-06-06 08:16:59

- Are any of its dependencies broken?
  - Yes, there is a broken Epetra (basic linear algebra) test
  - Maybe this broke Amesos2

# Trilinos automated testing

- Which tests were broken in Amesos2?

Testing started on 2016-06-06 07:42:35

**Site Name:**enigma.sandia.gov

**Build Name:**Linux-GCC-4.8.3-SERIAL\_DEBUG\_DEV\_MueLu\_ExtraTypes

**Total time:**16s 840ms

**OS Name:**Linux

**OS Platform:**x86\_64

**OS Release:**3.10.0-229.4.2.el7.x86\_64

**OS Version:**#1 SMP Fri Apr 24 15:26:38 EDT 2015

**Compiler Version:**unknown

3 tests failed.

Name	Status	Time	Details	Labels	Summary
Amesos2_Epetra_RowMatrix_Adapter_UnitTests_MPI_4	Failed	1s 860ms	Completed (Failed)	Amesos2	Broken
Amesos2_Epetra_MultiVector_Adapter_UnitTests_MPI_4	Failed	1s 980ms	Completed (Failed)	Amesos2	Broken
Amesos2_Tpetra_CrsMatrix_Adapter_UnitTests_MPI_4	Failed	1s 900ms	Completed (Failed)	Amesos2	Broken

# Trilinos automated testing

- If you may have broken something, you will get an email about it

 CDash <trilinos-regression@sandia.gov> 4:05 AM (5 hours ago)     
to anasazi-regres. 

A submission to CDash for the project Trilinos has failing tests.  
You have been identified as one of the authors who have checked in changes that are part of this submission or you are listed in the default contact list.

Details on the submission can be found at <http://testing.sandia.gov/cdash/buildSummary.php?buildid=2469557>

Project: Trilinos

SubProject: Anasazi

Site: [artemis.srn.sandia.gov](http://artemis.srn.sandia.gov)

Build Name: Linux-intel-15.0.2-MPI\_RELEASE\_DEV\_DownStream\_ETI\_SERIAL-OFF\_OPENMP-ON\_PTHREAD-OFF\_CUDA-OFF\_COMPLEX-OFF

Build Time: 2016-06-06T03:59:42 MDT

Type: Nightly

Tests failing: 1

\*Tests failing\*

Anasazi\_Epetra\_MVOPTester\_MPI\_4 (<http://testing.sandia.gov/cdash/testDetails.php?test=33891492&build=2469557>)

# How do you motivate somebody to write all those tests?



- Tests protect YOU from other people from breaking your work
  - If someone else's changes break your code, they are responsible for fixing it
- You may already have some
  - Drivers for generating conference or paper results
    - Just reduce the problem size
  - User submitted bugs
    - Ask for a file that reproduces the issue
    - These make great regression tests
  - Examples
    - Add a pass/fail condition and you have a test

# How do I determine what other tests I need?



- Code coverage tools
  - Expose parts of the code that aren't being tested
  - gcov
    - standard utility with the GNU compiler collection suite
    - counts the number of times each statement is executed
  - lcov
    - a graphical front-end for gcov
    - available at <http://ltp.sourceforge.net/coverage/lcov.php>

# How to use lcov

- Compile and link your code with --coverage flag
  - It's a good idea to disable optimization
- Run your test suite
- Collect coverage data using lcov
- Generate html output using genhtml

# A simple example

```
#include<iostream>
#include "isEven.hpp"

int main()
{
    int num = 8;

    if(isEven(num))
        std::cout << num << " is an even number.\nTEST PASSED";
    else
        std::cout << num << " is an odd number.\nTEST FAILED";

    return 0;
}

bool isEven(int x)
{
    if(x%2 == 0)
        return true;
    return false;
}
```

# A simple example

- Compile and link with --coverage flag
  - `g++ --coverage evenExample.cpp -o evenExample`
  - This creates a file called `evenExample.gcno`
- Run the test
  - `./evenExample`
  - This creates a file called `evenExample.gcda`
- Collect coverage data using lcov
  - `lcov --capture --directory . --output-file evenExample.info`
  - This creates `evenExample.info`
- Generate html output using genhtml
  - `genhtml evenExample.info --output-directory evenHTML`
  - This generates html files in the directory `evenHTML`

# A simple example

## LCOV - code coverage report

Current view: [top level](#) - /home/amklinv/IDEAS/testingTalk/examples/simpleExample

Test: evenExample.info

Date: 2016-05-24 14:13:07

	Hit	Total	Coverage
Lines:	9	11	81.8 %
Functions:	4	4	100.0 %

Filename	Line Coverage	Functions
evenExample.cpp	85.7 %	100.0 %
isEven.hpp	75.0 %	100.0 %

Generated by: LCOV version 1.12-4-g04a3c0e

This is the file we're testing



# A simple example

## LCOV - code coverage report

Current view: [top level](#) - [home/amklinv/IDEAS/testingTalk/examples/simpleExample](#) - `isEven.hpp` (source / [functions](#))

Test: evenExample.info

Date: 2016-05-24 14:13:07

	Hit	Total	Coverage
Lines:	3	4	75.0 %
Functions:	1	1	100.0 %

### Line data      Source code

1	1 : bool isEven(int x)
2	: {
3	1 : if(x%2 == 0)
4	1 : return true;
5	:
6	0 : return false;
7	: }

We never tested this line of code  
(which activates when x is odd)

# Let's add another test

```
#include<iostream>
#include "isEven.hpp"

int main()
{
    int num = 7;

    if(isEven(num))
        std::cout << num << " is an even number.\nTEST FAILED";
    else
        std::cout << num << " is an odd number.\nTEST PASSED";

    return 0;
}

bool isEven(int x)
{
    if(x%2 == 0)
        return true;
    return false;
}
```

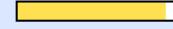
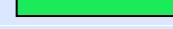
# A simple example

- Compile and link with --coverage flag
  - `g++ --coverage oddExample.cpp -o oddExample`
  - This creates a file called `oddExample.gcno`
- Run the test
  - `./oddExample`
  - This creates a file called `oddExample.gcda`
- Collect coverage data for BOTH TESTS using lcov
  - `lcov --capture --directory . --output-file twoExamples.info`
  - This creates `twoExamples.info`
- Generate html output using genhtml
  - `genhtml twoExamples.info --output-directory totalHTML`
  - This generates html files in the directory `totalHTML`

# A simple example

## LCOV - code coverage report

Current view:	<a href="#">top level</a>	-	/home/amklinv/IDEAS/testingTalk/examples/simpleExample	Hit	Total	Coverage
Test:	<a href="#">twoExamples.info</a>			Lines:	16	18 <b>88.9 %</b>
Date:	2016-05-24 15:17:38			Functions:	7	7 <b>100.0 %</b>

Filename	Line Coverage	Functions
evenExample.cpp	 85.7 %	6 / 7 <b>100.0 %</b>
isEven.hpp	 100.0 %	4 / 4 <b>100.0 %</b>
oddExample.cpp	 85.7 %	6 / 7 <b>100.0 %</b>

Generated by: [LCOV version 1.12-4-g04a3c0e](#)

This is the file we're testing

# A simple example

## LCOV - code coverage report

Current view: [top level](#) - [home/amklinv/IDEAS/testingTalk/examples/simpleExample](#) - `isEven.hpp` (source / functions)

Test: `twoExamples.info`

Date: 2016-05-24 15:17:38

	Hit	Total	Coverage
Lines:	4	4	100.0 %
Functions:	1	1	100.0 %

### Line data      Source code

1	2 : bool isEven(int x)
2	: {
3	2 : if(x%2 == 0)
4	1 : return true;
5	:
6	1 : return false;
7	: }

We tested every line of this function

# A real example - xSDKTrilinos

- Part of the Trilinos library, developed at SNL as part of the IDEAS project
- Contains the interfaces between Trilinos, PETSc, and hypre
- Available at <https://github.com/trilinos/xSDKTrilinos>
- Ten automated tests are run nightly
  - Six are actually examples that were converted into tests
- Did we leave anything out?

# A real example - xSDKTrilinos

- Step 1: Modify our CMake configuration file to use the --coverage flag to compile and link

trilinos-build : vim

```

\ -D TPL_ENABLE_PETSC:BOOL=ON \
\ -D PETSC_LIBRARY_DIRS:FILEPATH="${PETSC_LIB_DIR}" \
\ -D PETSC_INCLUDE_DIRS:FILEPATH="${PETSC_INCLUDE_DIR}" \
\ -D TPL_ENABLE_ParMETIS:BOOL=ON \
\ -D ParMETIS_LIBRARY_DIRS:FILEPATH="${SUPERLU_LIB_DIR}" \
\ -D ParMETIS_INCLUDE_DIRS:FILEPATH="${SUPERLU_INCLUDE_DIR}" \
\ -D TPL_ENABLE_HYPRE:BOOL=ON \
\ -D HYPRE_LIBRARY_DIRS:FILEPATH="${HYPRE_LIB_DIR}" \
\ -D HYPRE_INCLUDE_DIRS:FILEPATH="${HYPRE_INCLUDE_DIR}" \
\ -D TPL_ENABLE_SuperLUDist:BOOL=ON \
\ -D SuperLUDist_LIBRARY_DIRS:FILEPATH="${SUPERLU_LIB_DIR}" \
\ -D SuperLUDist_INCLUDE_DIRS:FILEPATH="${SUPERLU_INCLUDE_DIR}" \
\ -D Trilinos_ENABLE_Amesos2:BOOL=ON \
\ -D Trilinos_ENABLE_xSDKTrilinos:BOOL=ON \
\ -D CMAKE_CXX_FLAGS:STRING="--coverage" \
\ -D CMAKE_C_FLAGS:STRING="--coverage" \
\ -D CMAKE_EXE_LINKER_FLAGS:STRING="--coverage" \
\ -D Trilinos_ENABLE_Fortran:BOOL=OFF \
\ ${TRILINOS_HOME}
-- INSERT --

```

# A real example - xSDKTrilinos

- Build Trilinos (including xSDKTrilinos)
  - ./do-configure
  - make -j
- This will create a whole bunch of .gcno files
- This will also build the xSDKTrilinos tests because the configure file included
  - -D Trilinos\_ENABLE\_TESTS:BOOL=ON
  - -D Trilinos\_ENABLE\_EXAMPLES:BOOL=ON
  - -D Trilinos\_ENABLE\_ALL\_OPTIONAL\_PACKAGES=ON

# A real example - xSDKTrilinos

- Run the tests using ctest
  - Note that this is not prohibitively slow

File Edit View Scrollback Bookmarks Settings Help

trilinos-build : ctest

```
[amklinv@s995692 trilinos-build]$ ctest
Test project /home/amklinv/IDEAS/testingTalk/trilinos-build
  Start 1: Amesos2_KLU2_UnitTests_MPI_4
1/18 Test #1: Amesos2_KLU2_UnitTests_MPI_4 ..... Passed    1.46 sec
  Start 2: Amesos2_SuperLU_DIST_Solver_Test_MPI_4
2/18 Test #2: Amesos2_SuperLU_DIST_Solver_Test_MPI_4 ..... Passed    2.80 sec
  Start 3: Amesos2_SolverFactory_UnitTests_MPI_4
3/18 Test #3: Amesos2_SolverFactory_UnitTests_MPI_4 ..... Passed    1.46 sec
  Start 4: Amesos2_Tpetra_MultiVector_Adapter_UnitTests_MPI_4
4/18 Test #4: Amesos2_Tpetra_MultiVector_Adapter_UnitTests_MPI_4 ... Passed    1.36 sec
  Start 5: Amesos2_Tpetra_CrsMatrix_Adapter_UnitTests_MPI_4
5/18 Test #5: Amesos2_Tpetra_CrsMatrix_Adapter_UnitTests_MPI_4 .... Passed    1.42 sec
  Start 6: Amesos2_Epetra_MultiVector_Adapter_UnitTests_MPI_4
6/18 Test #6: Amesos2_Epetra_MultiVector_Adapter_UnitTests_MPI_4 ... Passed    1.35 sec
  Start 7: Amesos2_Epetra_RowMatrix_Adapter_UnitTests_MPI_4
7/18 Test #7: Amesos2_Epetra_RowMatrix_Adapter_UnitTests_MPI_4 .... Passed    1.35 sec
  Start 8: Amesos2_CrsMatrix_Adapter_Conistency_Tests_MPI_4
8/18 Test #8: Amesos2_CrsMatrix_Adapter_Conistency_Tests_MPI_4 .... Passed    1.47 sec
  Start 9: xSDKTrilinos_PETScAIJMatrix_MPI_4
9/18 Test #9: xSDKTrilinos_PETScAIJMatrix_MPI_4 ..... Passed    1.42 sec
  Start 10: xSDKTrilinos_PETSc_Amesos2_example_MPI_4
10/18 Test #10: xSDKTrilinos_PETSc_Amesos2_example_MPI_4 ..... Passed    1.42 sec
  Start 11: xSDKTrilinos_PETSc_Anasazi_example_MPI_4
11/18 Test #11: xSDKTrilinos_PETSc_Anasazi_example_MPI_4 ..... Passed    2.71 sec
  Start 12: xSDKTrilinos_PETSc_Itpack2_example_MPI_4
12/18 Test #12: xSDKTrilinos_PETSc_Itpack2_example_MPI_4 ..... Passed    1.47 sec
  Start 13: xSDKTrilinos_PETSc_MueLu_example_MPI_4
```

47

...ilinos-build : ctest

# A real example - xSDKTrilinos

- All tests passed. Yay!
  - This also created a bunch of .gcda files

```

trilinos-build : ctest
File Edit View Scrollback Bookmarks Settings Help
Start 10: xSDKTrilinos_PETSc_Amesos2_example_MPI_4
10/18 Test #10: xSDKTrilinos_PETSc_Amesos2_example_MPI_4 ..... Passed 1.42 sec
Start 11: xSDKTrilinos_PETSc_Anasazi_example_MPI_4
11/18 Test #11: xSDKTrilinos_PETSc_Anasazi_example_MPI_4 ..... Passed 2.71 sec
Start 12: xSDKTrilinos_PETSc_Itpack2_example_MPI_4
12/18 Test #12: xSDKTrilinos_PETSc_Itpack2_example_MPI_4 ..... Passed 1.47 sec
Start 13: xSDKTrilinos_PETSc_MueLu_example_MPI_4
13/18 Test #13: xSDKTrilinos_PETSc_MueLu_example_MPI_4 ..... Passed 2.34 sec
Start 14: xSDKTrilinos_example_TpetraKSP_MPI_4
14/18 Test #14: xSDKTrilinos_example_TpetraKSP_MPI_4 ..... Passed 1.50 sec
Start 15: xSDKTrilinos_example_EpetraKSP_MPI_4
15/18 Test #15: xSDKTrilinos_example_EpetraKSP_MPI_4 ..... Passed 1.37 sec
Start 16: xSDKTrilinos_HYPRETest_MPI_4
16/18 Test #16: xSDKTrilinos_HYPRETest_MPI_4 ..... Passed 1.42 sec
Start 17: xSDKTrilinos_HYPRE_Belos_example_MPI_4
17/18 Test #17: xSDKTrilinos_HYPRE_Belos_example_MPI_4 ..... Passed 1.38 sec
Start 18: xSDKTrilinos_HYPRE_Solve_example_MPI_4
18/18 Test #18: xSDKTrilinos_HYPRE_Solve_example_MPI_4 ..... Passed 1.36 sec

100% tests passed, 0 tests failed out of 18

Label Time Summary:
Amesos2      = 12.67 sec (8 tests)
xSDKTrilinos = 16.39 sec (10 tests)

Total Test time (real) = 29.11 sec
[amklinv@s995692 trilinos-build]$ █

```

# A real example - xSDKTrilinos

- Collect coverage data for the tests using lcov
  - `lcov --capture --directory . --output-file xSDKTrilinos.info`
  - This creates `xSDKTrilinos.info`
  - lcov processes 634 gcda files in this step, so this does take a few minutes

# A real example - xSDKTrilinos

- Generate html output using genhtml
  - `genhtml xSDKTrilinos.info --output-directory xSDKTrilinos`
  - This generates html files in the directory xSDKTrilinos
  - This step takes a few minutes too

# A real example - xSDKTrilinos

## **LCOV - code coverage report**

Current view:	<a href="#">top level</a> - xSDKTrilinos/petsc/src <th>Hit</th> <th>Total</th> <th>Coverage</th>	Hit	Total	Coverage
Test:	xSDKTrilinos.info	Lines:	342	420 <span style="background-color: yellow;">81.4 %</span>
Date:	2016-06-02 15:36:10	Functions:	77	117 <span style="background-color: red;">65.8 %</span>

Filename	Line Coverage	Functions
<a href="#">BelosPETScSolMgr.hpp</a>	<div style="width: 84.7%;">84.7 %</div> 166 / 196	<span style="background-color: red;">68.2 %</span> 30 / 44
<a href="#">Tpetra_PETScAIJGraph.hpp</a>	<div style="width: 75.3%;">75.3 %</div> 67 / 89	<span style="background-color: red;">62.5 %</span> 20 / 32
<a href="#">Tpetra_PETScAIJMatrix.hpp</a>	<div style="width: 80.7%;">80.7 %</div> 109 / 135	<span style="background-color: red;">65.9 %</span> 27 / 41

Generated by: [LCOV version 1.12-4-g04a3c0e](#)

Let's take a look at the solver interface.

```
766 : //=====
767 : template<class ScalarType, class MV, class OP>
768 : PetscErrorCode PETScSolMgr<ScalarType,MV,OP>::applyPrec(PC M, Vec x, Vec Mx)
769 : {
770 :     using Teuchos::RCP;
771 :     typedef PETScSolMgrHelper<ScalarType,MV,OP> Helper;
772 :
773 :     PetscErrorCode ierr;
774 :     const PetscScalar * xData;
775 :     PetscScalar * MxData;
776 :     void * ptr;
777 :
778 :     // Get the problem out of the context
779 :     ierr = PCShellGetContext(M,&ptr); CHKERRQ(ierr);
780 :     LinearProblem<ScalarType,MV,OP> * problem = (LinearProblem<ScalarType,MV,OP>*)ptr;
781 :
782 :     // Rip the raw data out of the PETSc vectors
783 :     ierr = VecGetArrayRead(x, &xData); CHKERRQ(ierr);
784 :     ierr = VecGetArray(Mx, &MxData); CHKERRQ(ierr);
785 :
786 :     // Wrap the PETSc data in a Trilinos Vector
787 :     RCP<MV> trilinosX, trilinosMX;
788 :     Helper::wrapVector(const_cast<PetscScalar*>(xData), *problem->getLHS(), trilinosX);
789 :     Helper::wrapVector(MxData, *problem->getLHS(), trilinosMX);
790 :
791 :     // Perform the multiplication
792 :     if(problem->isLeftPrec()) {
793 :         problem->applyLeftPrec(*trilinosX, *trilinosMX);
794 :     }
795 :     else {
796 :         problem->applyRightPrec(*trilinosX, *trilinosMX);
797 :     }
798 :
799 :     // Unwrap the vectors; this is necessary if we copied data in the wrap step
800 :     Helper::unwrapVector(MxData, trilinosMX);
801 :
802 :     // Restore the PETSc vectors
803 :     ierr = VecRestoreArrayRead(x,&xData); CHKERRQ(ierr);
804 :     ierr = VecRestoreArray(Mx,&MxData); CHKERRQ(ierr);
805 :
806 :     192 :     return 0;
807 :     : }
```

# A real example - xSDKTrilinos

```
791      :    // Perform the multiplication
792      192 :    if(problem->isLeftPrec()) {
793      192 :      problem->applyLeftPrec(*trilinosX, *trilinosMX);
794      :    }
795      :    else {
796      0 :      problem->applyRightPrec(*trilinosX, *trilinosMX);
797      :    }
```



Oops. I never tested the RIGHT preconditioning branch.

# DOCUMENTATION

# Why is documentation important?



- To identify the purpose of the software and its requirements
- To clarify what each component does, what is needed to maintain it, and how it can be reused elsewhere
- To provide user support
  - Minimizes unnecessary handholding of users
- To ensure that software is used within its region of validity
  - Minimizes possibility of producing spurious scientific results

# Categories of documentation

- Users guide
- Reference manual
  - List of the interfaces and routines and explanation of functionality
  - Can be generated automatically from code
- Readme files
- Installation guide
- Tutorials

All software needs documentation  
Not all software needs a users guide

# How does Trilinos handle documentation?

- Each package does it differently
- User manuals
  - MueLu (algebraic multigrid)
  - AztecOO (Krylov solvers)
  - Teuchos RCP (reference counted pointers)
- Publicly available tutorials, presentations, and slides
  - Tpetra (MPI+X linear algebra)
  - Kokkos\*
- Well commented examples
- Automatically generated html documentation

# Doxxygen

- One approach to producing “reference manual”-like documentation
- Automatically generates html documentation from comments in source code
- Easy to update documentation when source code is updated
- doxywizard - GUI frontend for doxygen

# A simple doxygen example

- Add some comments to isEven.hpp

```
/**  
 * @file isEven.hpp  
 * Contains a function for detecting whether a number is even or odd  
 * @author Alicia Klinvex  
 * @example oddExample.cpp  
 * @example evenExample.cpp  
 */  
  
/**  
 * Detects whether an integer is even or odd  
 * @param[in] x an integer which may be even or odd  
 * @return  
 * - true if x is even  
 * - false otherwise  
 */  
bool isEven(int x)  
{  
    if(x%2 == 0)  
        return true;  
  
    return false;  
}
```

# A simple doxygen example

- Create an index page (index.doc)

```
/*! \mainpage EvenOdd: a revolutionary new function
\section intro Introduction
This page provides the documentation for the %EvenOdd project.
*/
```

# A simple doxygen example

Doxygen GUI frontend (/home/amklinv/IDEAS/testingTalk/examples/simpleExample/Doxyfile)

File Settings Help

Step 1: Specify the working directory from which doxygen will run  
/home/amklinv/IDEAS/testingTalk/examples/simpleExample

Step 2: Configure doxygen using the Wizard and/or Expert tab, then switch to the Run tab to generate the documentation

Wizard Expert Run

Topics

Project

Mode

Output

Diagrams

Provide some information about the project you are documenting

Project name: EvenOdd

Project version or id:

Specify the directory to scan for source code

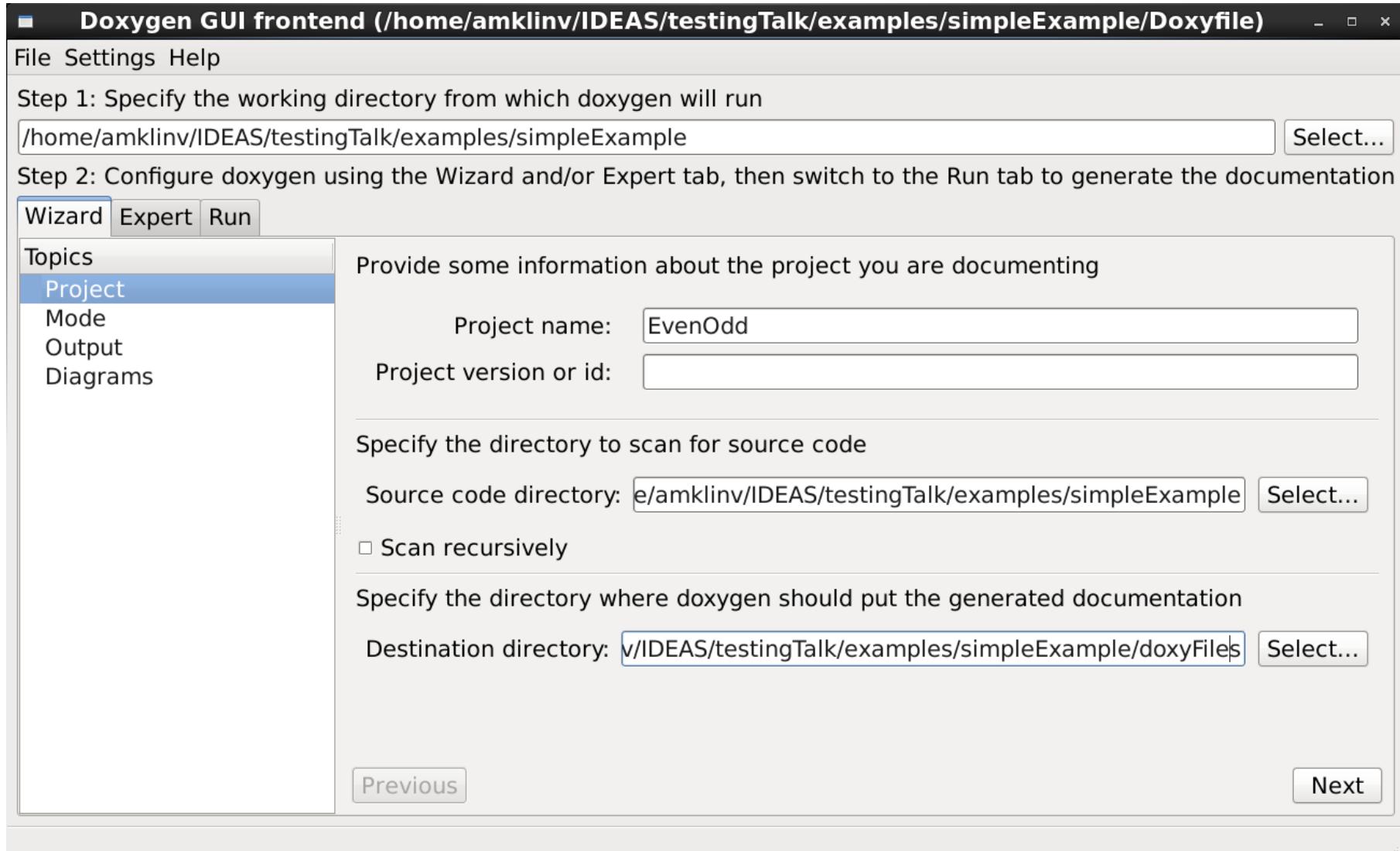
Source code directory: /home/amklinv/IDEAS/testingTalk/examples/simpleExample

Scan recursively

Specify the directory where doxygen should put the generated documentation

Destination directory: /IDEAS/testingTalk/examples/simpleExample/doxyFiles

Previous



# A simple doxygen example

Doxygen GUI frontend (/home/amklinv/IDEAS/testingTalk/examples/simpleExample/Doxyfile)

File Settings Help

Step 1: Specify the working directory from which doxygen will run

/home/amklinv/IDEAS/testingTalk/examples/simpleExample

Step 2: Configure doxygen using the Wizard and/or Expert tab, then switch to the Run tab to generate the documentation

**Wizard** Expert Run

Topics

Project  
Mode  
**Output**  
Diagrams

Select the output format(s) to generate

**HTML**  
 plain HTML  
 with frames and a navigation tree  
 prepare for compressed HTML (.chm)  
 With search function (requires PHP enabled web server)

**LaTeX**  
 as intermediate format for hyperlinked PDF  
 as intermediate format for PDF  
 as intermediate format for PostScript  
 Man pages  
 Rich Text Format (RTF)  
 XML

# A simple doxygen example

Doxygen GUI frontend + (/home/amklinv/IDEAS/testingTalk/examples/simpleExample/Doxyfile)

File Settings Help

Step 1: Specify the working directory from which doxygen will run

/home/amklinv/IDEAS/testingTalk/examples/simpleExample

Step 2: Configure doxygen using the Wizard and/or Expert tab, then switch to the Run tab to generate the documentation

**Wizard** Expert Run

**Topics**

- Project
- Build
- Messages
- Input**
- Source Browser
- Index
- HTML
- LaTeX
- DTE

**INPUT**

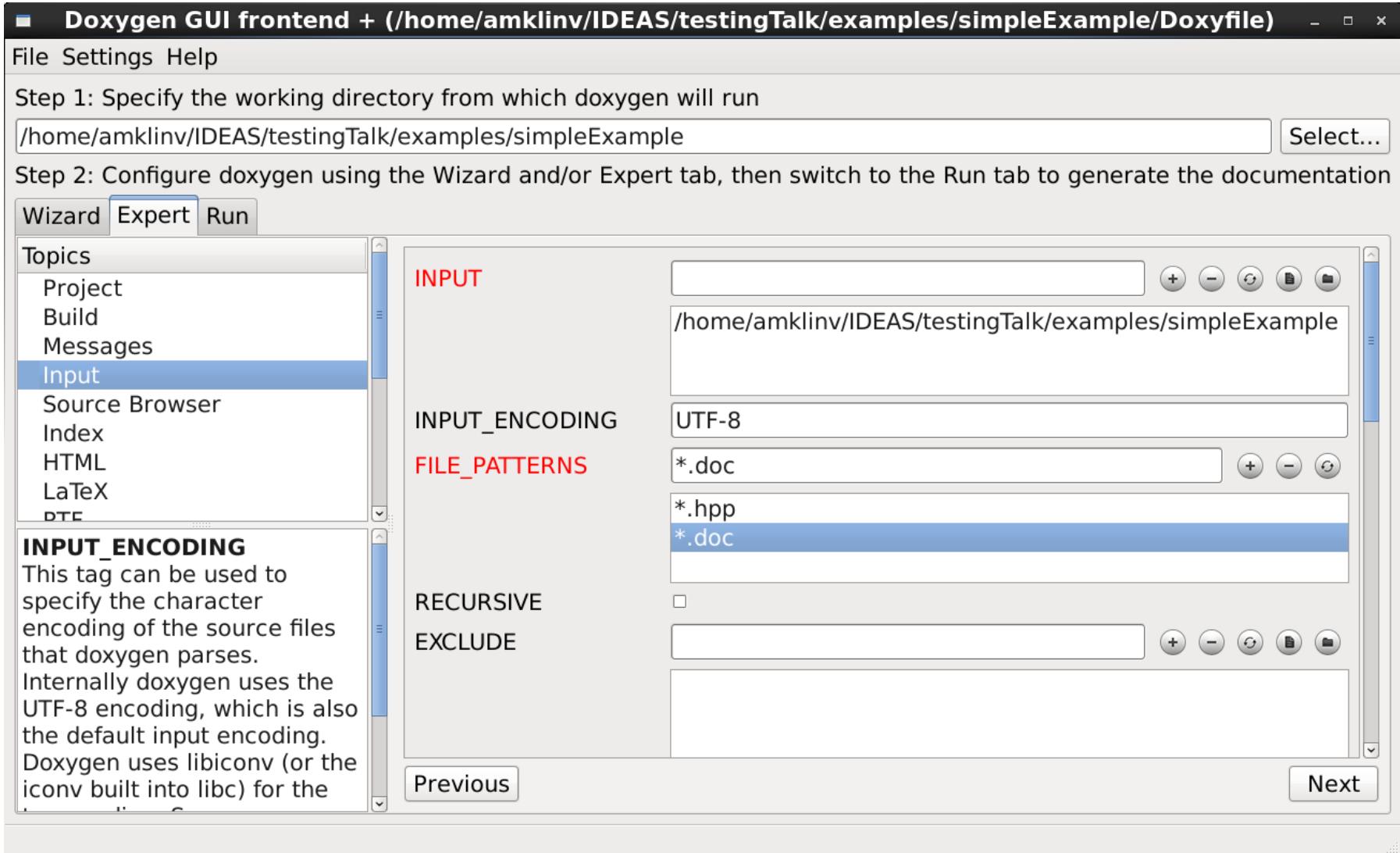
INPUT\_ENCODING

FILE\_PATTERNS

RECURSIVE

EXCLUDE

Previous



# A simple doxygen example

■ Doxygen GUI frontend + (/home/amklinv/IDEAS/testingTalk/examples/simpleExample/Doxyfile) - □ ×

File Settings Help

Step 1: Specify the working directory from which doxygen will run

/home/amklinv/IDEAS/testingTalk/examples/simpleExample

Step 2: Configure doxygen using the Wizard and/or Expert tab, then switch to the Run tab to generate the documentation

**Wizard** Expert Run

Topics

- Project
- Build
- Messages
- Input**
- Source Browser
- Index
- HTML
- LaTeX
- DTC

**EXAMPLE\_PATH**

.

**EXAMPLE\_PATTERNS**

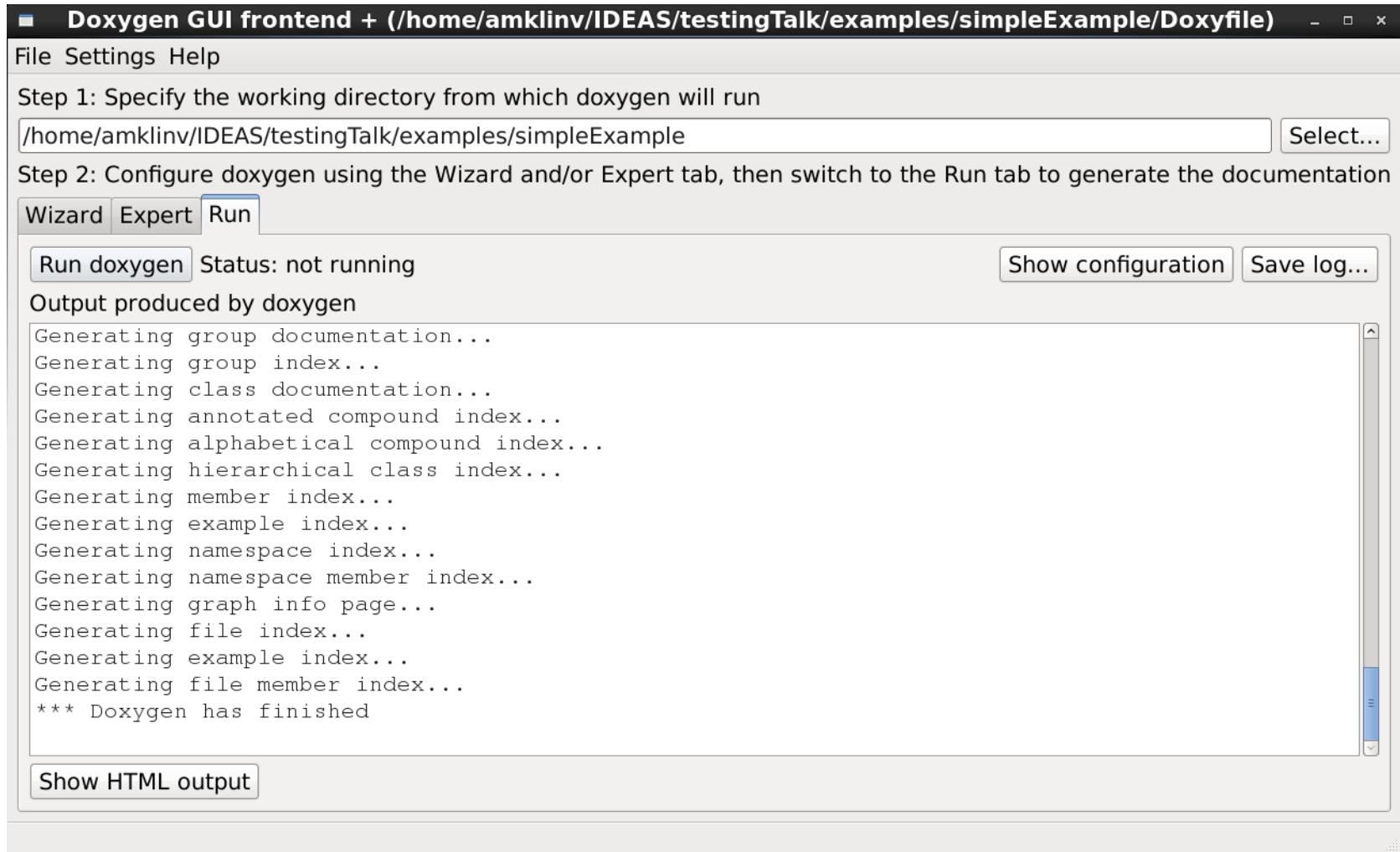
\*Example.cpp

**EXAMPLE\_RECURSIVE**

**IMAGE\_PATH**

**EXAMPLE\_PATTERNS**  
 If the value of the EXAMPLE\_PATH tag contains directories, you can use the EXAMPLE\_PATTERNS tag to specify one or more wildcard pattern (like \*.cpp and \*.h) to filter out the source-files in the directories. If left blank all files are included.

# A simple doxygen example



The screenshot shows the Doxygen GUI frontend window. The title bar reads "Doxygen GUI frontend + (/home/amklinv/IDEAS/testingTalk/examples/simpleExample/Doxyfile)". The menu bar includes "File", "Settings", and "Help". The main area displays the following steps:

- Step 1: Specify the working directory from which doxygen will run. The input field contains "/home/amklinv/IDEAS/testingTalk/examples/simpleExample" with a "Select..." button.
- Step 2: Configure doxygen using the Wizard and/or Expert tab, then switch to the Run tab to generate the documentation.

The "Run" tab is selected. The status message says "Run doxygen Status: not running". To the right are "Show configuration" and "Save log..." buttons. Below this, the "Output produced by doxygen" section shows the command-line output of the doxygen build process:

```
Generating group documentation...
Generating group index...
Generating class documentation...
Generating annotated compound index...
Generating alphabetical compound index...
Generating hierarchical class index...
Generating member index...
Generating example index...
Generating namespace index...
Generating namespace member index...
Generating graph info page...
Generating file index...
Generating example index...
Generating file member index...
*** Doxygen has finished
```

At the bottom left is a "Show HTML output" button.

# A simple doxygen example



## EvenOdd: a revolutionary new function

### Introduction

This page provides the documentation for the EvenOdd project.

---

Generated on 6 Jun 2016 for EvenOdd by

 1.6.1

# A simple doxygen example

Main Page   [Files](#)   [Examples](#)

[File List](#)   [File Members](#)

 Search

## isEven.hpp File Reference

[Go to the source code of this file.](#)

### Functions

bool [isEven](#) (int x)

### Detailed Description

Contains a function for detecting whether a number is even or odd

### Author:

Alicia Klinvex

# A simple doxygen example

Main Page   Files   Examples

File List   File Members

 Search

## isEven.hpp

Go to the documentation of this file.

```
00001
00016 bool isEven(int x)
00017 {
00018     if(x%2 == 0)
00019         return true;
00020
00021     return false;
00022 }
```

# A simple doxygen example

```
/**  
 * Detects whether an integer is even or odd  
 * @param[in] x an integer which may be even or odd  
 * @return  
 * - true if x is even  
 * - false otherwise  
 */
```

## Function Documentation

### `bool isEven ( int x )`

Detects whether an integer is even or odd

#### Parameters:

[in] x an integer which may be even or odd

#### Returns:

- true if x is even
- false otherwise

#### Examples:

[evenExample.cpp](#), and [oddExample.cpp](#).

# Summary

- Testing and documentation are very important
- There are many different types of tests that should be included in your test suite
- Code coverage tools can help you figure out where existing testing is insufficient
- Documentation does not have to mean “user manual”
- Tools such as doxygen can help you write documentation

# Thanks for Participating!

- Make sure you get counted. Please visit <http://bit.ly/hpcbp-s04>
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- Slides and a recording will be available from the OLCF training web site:  
<https://www.olcf.ornl.gov/training-event/webinar-series-best-practices-for-hpc-software-developers>

## Next Webinar

### **Session 5: How the HPC Environment is Different from the Desktop (and Why)**

Date: Wednesday, July 14, 2016

Time: 1:00-2:00 pm ET

Presenter: Katherine Riley, Argonne Leadership Computing Facility

**SC16 Tutorial: “Testing of HPC Scientific Software”**

For updates, please register (if you haven't already)

<https://www.olcf.ornl.gov/training-event/webinar-series-best-practices-for-hpc-software-developers>