# ggcov

# A Practical Guide To Making Your Test Suite Suck Less

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# Overview

- Scope
- What is test coverage?
- How does test coverage work?
- How to interpret results
- What to expect
- What **NOT** to expect
- Extra topics

# Scope

- GNU Compiler Collection 4.1
- C and C++
- UNIX-like platforms
- Similar techniques apply to
  - other platforms
  - other compilers
  - other languages
- Licence neutral (IANAL)

# What is test coverage?

- Measuring how much of your code is run ("covered") when your code's test suite runs

# Why do test coverage?

- Working code can stop working
  - due to changes to the environment, other code
  - sometimes code works “by accident”
- => code must be tested regularly
  - untested code is buggy code
- => need a test suite which is run regularly
- A test suite is only useful if it runs your code
  - Test coverage provides one measure of that

# Just Do It!

- Test coverage is sorely underused
- Testing is often "2nd class"
  - management pays lip service
  - but nothing actually happens
- "Our test suite takes 8 hours to run, it must be good!"
  - 1000s of runs of the same 2% of the code
- The first coverage study is often a shock
  - but it **WILL** improve code quality

# How does coverage work?

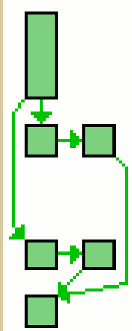
- Three phases
  - build time
  - run time
  - analysis time

# How does it work: build time

- Add a special *make* target
  - adds --*coverage* gcc option
    - interesting compile lines
    - all link lines
    - gcc<4.0: *-fprofile-arcs -ftest-coverage (**both**)*
  - adds -g, removes -O
- Compiler adds *instrumentation* to object files
  - code at basic block boundaries to counter++
  - array of counters, 1 per bb->bb arc
  - descriptor for the file & counters
    - global c'tor registers descriptor before *main*

# Sidebar: what's a basic block?

- Obscure internal compiler unit
- A sequence of instructions ending at a change of control flow



```
int
function_one(int x)
{
    if (x & 1)
        x += function_two(x);
    else
        x += function_three(x);
    return x;
}
```

# How does it work: build time (2)

- Compiler writes *graph file*
  - *foo.gcno* in the same directory as *foo.o*
  - contains extra information
    - more detailed than normal debug info
    - line numbers <-> basic blocks
    - basic block graph per function
  - gcc<3.4: *foo.bbg*

# How does it work: run time

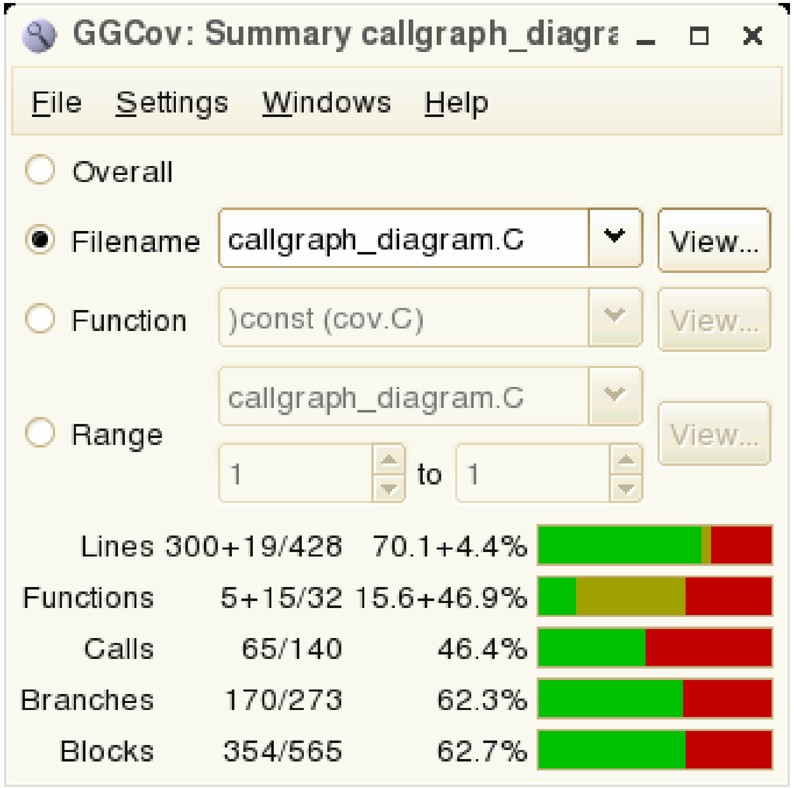
- Instrumented code counter++ as it's run
- Special *atexit* handler
  - writes counters to a *data file* per source file
  - *foo.gcda* in the same directory as *foo.o*
  - also on *fork* and *execve.*

# How does it work: analysis time

- Post processor reads *.gcno, .gcda* and source to build a report
  - *gcov:* text tool, comes with gcc
  - *lcov:* massages *gcov* output into HTML
  - *ggcov:* a GUI (by me)
- Report shows which code was run
- The art is in figuring out what to do with all that information

# How to interpret results

- *ggcov* Summary window
  - don't read too much into these numbers, yet



# Suggested procedure (1)

- Get the latest ggcov from SourceForge
- Run the entire test suite to completion, once
- Do not try to focus on individual tests (yet)
- Open *ggcov*'s File List window
- Sort on the Lines column
- Start with the file with the lowest Lines %

# Example: Files Window

- An example of *ggcov*'s Files Window

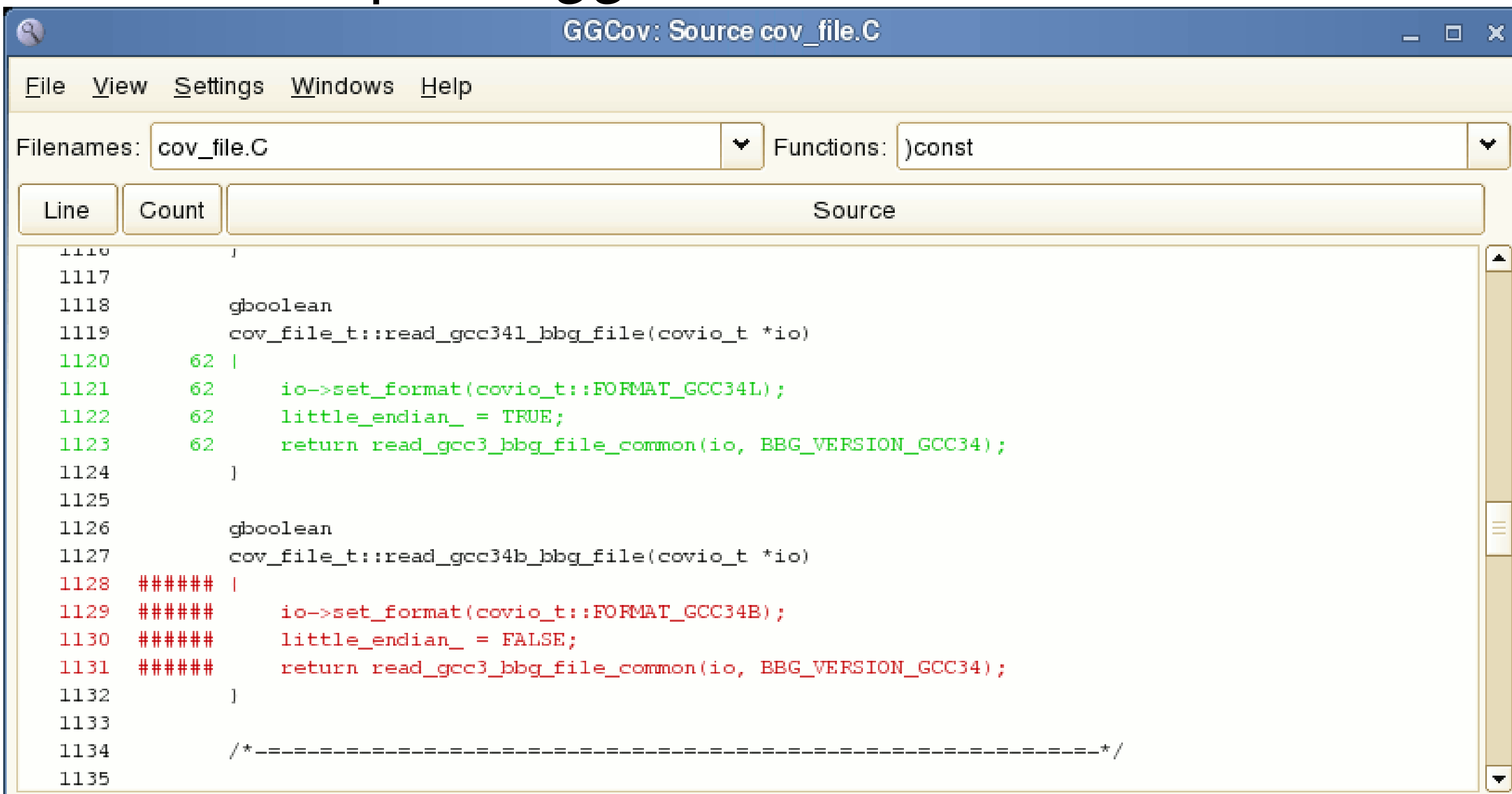

| File | Blocks | Lines | Functions | Calls | Branches |
|---|---|---|---|---|---|
| report.C | 0.00 | 3.36 | 33.33 | 0.00 | 0.00 |
| cov_dwarf2.C | 0.56 | 3.88 | 14.29 | 1.04 | 0.00 |
| cov_elf.C | 1.06 | 4.63 | 18.18 | 1.79 | 0.00 |
| mvc.c | 7.14 | 10.00 | 22.22 | 3.85 | 7.41 |
| cov_stab32.C | 2.22 | 10.64 | 40.00 | 3.45 | 0.00 |
| common.c | 8.70 | 12.00 | 37.50 | 8.33 | 7.69 |

# Suggested procedure (2)

- For each interesting file...
- Open the file in the Source window
- Scroll through looking for large fragments coloured red = code not run

# Example: Source Window

- An example of *ggcov*'s Source Window



# Suggested procedure (3)

- Using your knowledge of the code, map red fragments back to 1 or more of:
  - a software feature
  - a user action
  - a configuration option
  - possible input data
  - an environmental effect (compiler, libc)
  - an error condition
- As you go, keep a list of the untested features etc
  - this is your list of new test cases to write

# Why do it this way?

- In your first coverage study, there will be large amounts of untested code
- You want to improve the test suite as fast as possible
- The suggested procedure aims to test more code in broad brush strokes first
- No tool to merge data from separate runs (!)

# Example: Lego Diagram

- An alternative way of finding files to focus on

# What to expect

- Setting up your first study will take lots of time & effort
  - but worth it...persevere!
- Your test suite sucks
  - probably more than you think
  - the first numbers are usually pretty frightening
  - e.g. Samba4: 17%
- Entire features of your code are not tested
  - even if your coverage numbers are good
  - e.g. XFS QA: 70% but RT volumes not tested!

# What NOT to expect (1)

- Don't expect perfect numbers
  - bugs and corner cases in the toolchain
  - compiler optimisation does strange things
  - other effects (more on this later)
  - so, concentrate on finding **uncovered code**
  - look for the red code!
  - and don't sweat the details
    - “OMG, this line was executed 3 times instead of 4!!”

# What NOT to expect (2)

- Don't aim for 100% coverage
  - you will **never** exercise 100% of real world code
  - beyond the point of diminishing returns
  - don't waste time trying
    - unless they pay you by the hour
- *assert()* problem
  - macro generates code which in a correct program is **never** run
    - spuriously reduces coverage counts

# What NOT to expect (3)

- *malloc()/new* failure branches
  - in most programs, the only useful way to handle this is *exit()*.
  - unless you have external resources which need cleaning up, there is no point testing these paths
- C++ exception paths
  - compiler adds hidden code to functions
    - stack unwinding, calling d'tors
    - many of these simply won't happen
    - spuriously reduces coverage counts

# What NOT to expect (4)

- No coverage tool will tell you when to stop testing
  - if it does, don't believe it
  - fundamentally an economic choice
  - suggested criteria:
    - every user-input option tested
    - every source fragment >= 3 lines is tested
    - but not error paths

# What NOT to expect (5)

- Coverage will not write tests for you
  - programmers still needed, yay
- *ggcov* will not help you reduce your test suite
  - coverage does not provide enough information to make this decision wisely
  - you probably have too **few** tests anyway
- Coverage will not help you write test001
  - but you already know that **all** your code is untested...

# Extra topics

- Separate test machine
- Performance impact
- Build system integration
- Multi-process programs
- Multi-threaded programs
- Linux kernel

# Separate test machine

- Instrumented code writes *.gcda* files into the **source** directory
  - using an absolute path
  - source directory needs to be visible, writable from test machine
- Solutions:
  - NFS mount the source on the same path
  - Make a dummy directory and copy the *.gcda* files back before analysis
- Cross-platform problematic
  - use same arch for analysis as runtime

# Performance impact

- Actually, quite light
- Instrumentation is sparse
  - only arcs between blocks
  - not all the arcs (spanning tree)
- Instrumentation is cheap
  - increment of a 64b or 32b global variable
- Impact << *valgrind, Purify*.
- Disabling optimisation may have an effect

# Build system integration

- Depends on your build system
- A single make target to instrument all code
  - larger projects may want to be more specific
- One target to enable all the compile options
  - add --coverage
  - remove -O etc
  - add -g
  - don't strip executables
  - e.g. overrides $CCOVFLAGS, normally empty, used in $CFLAGS and $LDFLAGS

# Multi-process programs

- Works fine
- When writing *.gcda* files, instrumented code takes file locks and **accumulates** counts

# Multi-threaded programs

- On a single CPU, works fine
- On multiple CPUs, doesn't work
  - instrumented code increments global counts non-atomically
  - spanning tree => one corrupted count breaks the whole function
- GCC patch to do atomic increments
  - gcc bug#28441
  - waiting on paperwork

# Linux kernel (1)

- IBM patch
  - allows kernel code to be built with *--coverage*
  - exports counts via `/proc`
  - ability to zero counts
  - compiler version specific
- Issues on SMP
  - need gcc atomic increment patch
  - or disable all except 1 CPU
  - or run a UP kernel

# Linux kernel (2)

- If coveraging filesystems, ensure all instances are **unmounted** before extracting data
  - => / should be a different fs
- Some core *fs/* or *mm/* code is nearly impossible to coverage properly

# References

- http://ggcov.sourceforge.net/
- gcc docs
  - http://gcc.gnu.org/onlinedocs/gcc4.1.1/gcc/Gcov.html
- IBM kernel coverage patch
  - http://ltp.sf.net/coverage/gcov-kernel.readme.php
- Linux Test Project
  - http://ltp.sf.net/