

Debugging

- finding problems
 - the scientific method
 - verification, assessment, triage
 - confident problem identification
 - debugging tools
- fixing problems
 - root cause analysis
- psychological issues in debugging
 - how to become a better debugger
- bug reports and tracking

Bugs and Debugging

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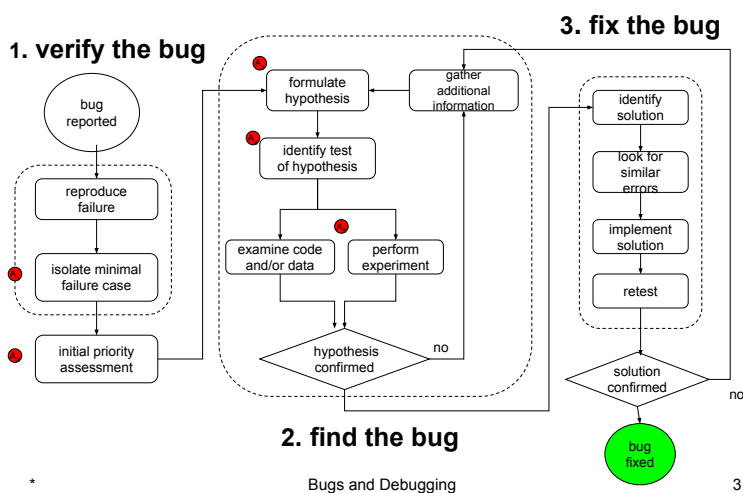
What makes debugging hard?

- programs are not as simple as theorems
 - much larger, nowhere nearly as well designed
- complex causes
 - faults may have very complex preconditions
 - interactions between components & people
 - relative timing of complex events
 - some causal elements may seem unrelated
- complex cause/symptom relationships
 - symptoms result from a cascade of events
 - symptoms may occur long after cause
 - symptoms may appear in unrelated areas

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the scientific debugging process



Bugs and Debugging

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when it doesn't make sense ...

- get more information
 - identify more failure (and non-failure) cases
 - use tracers or debuggers
 - instrumentation to catch errors sooner
 - try everything on McConnell's brute force list
- write down all the facts you know
 - spread them out on the wall or a white board
- ask for help
 - more eyes and brains in the analysis
 - suggestions for additional instrumentation

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information - program output

- programs often produce progress output
 - files processed, actions, events received
 - may have to be enabled w/verbose options
- many programs have diagnostic options
 - enable more detailed activity traces
 - request dumps of internal tables
- this can help us understand the problem
 - what is happening when the problem occurs
 - interesting state associated with the event

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debugger stack traces

simple gdb stack trace

```
#0 0x080483cb in function_2 ()
#1 0x080483b4 in function_1 ()
#2 0x08048385 in main ()
#3 0x4003ddc6 in __libc_start_main () from /lib/libc.so.6
```

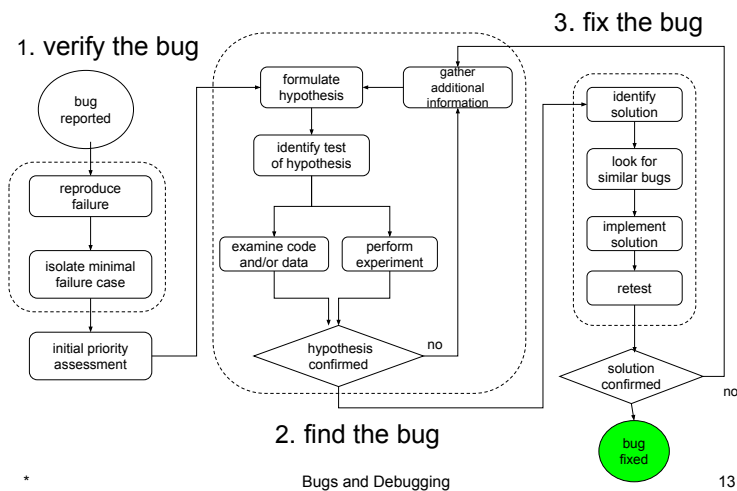
gdb backtrace with parameters and source info

```
#0 0x080ca21b in _efree (ptr=0xbffdb9b) at zend_alloc.c:240
#1 0x080d691a in _zval_dtor (zvalue=0x8186b94) at zend_variables.c:44
#2 0x080cfab3 in _zval_ptr_dtor (zval_ptr=0xbffdbfc) at zend_execute_API.c:274
#3 0x080f1cc4 in execute (op_array=0x816c670) at zend_execute.c:1605
```

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the scientific debugging process



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reviewing fixes

- original code clearly needed more review
 - original developer did not get it right
 - original reviewers did not find the error
 - original test cases did not find the error
- bug fixes almost always require review
 - correctness of code is clearly not obvious
 - bug fixers are often not original developer
 - they often have less familiarity with the code
 - they often have less programming experience
- how did this get past us before?
 - add regression tests

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Root Cause Analysis

- some bugs may be essentially random
 - software is complex, people are fallible
- many bugs turn out not to be random
 - people keep repeating the same mistakes
 - inadequate training, tools & methodology
- after a problem has been found and fixed
 - identify the root cause of the defect
 - understand how we made and failed to find it
- do statistical studies of root causes
 - identify clusters, find ways to eliminate them

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Psychological Issues

- We assume what we think we know
 - we do not see our work as it actually is
 - rather, we see it as we intended it to be
- We assume we are better than we are
 - we believe in our abilities and methodology
 - we don't like to believe ourselves error-prone
 - we suspect problems come from elsewhere
- These blind us to many hypotheses
 - which impairs our coding & debugging

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Inconceivability

- It is possible that the bug isn't your fault
 - operating systems are not perfect
 - they do contain bugs, especially new releases
 - compilers sometimes generate incorrect code
 - I've personally tracked down a few of these
 - computers can even mis-execute instructions
 - in 50 years, I have encountered one instance
 - and 2-3 mis-behaving I/O devices
- these may be conclusions you come to
 - they should never be assumptions you make

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Becoming a Better Debugger

- Keep an open mind
 - there are none so blind as those who will not see
- Learn from our programming mistakes
 - what did I do wrong?
 - why didn't I notice it sooner?
- Learn from our debugging mistakes
 - what clues were there, but we missed them?
 - what dead-ends did we wind up following?
- Learn from others
 - questions they ask, details they notice
 - tools and techniques they use

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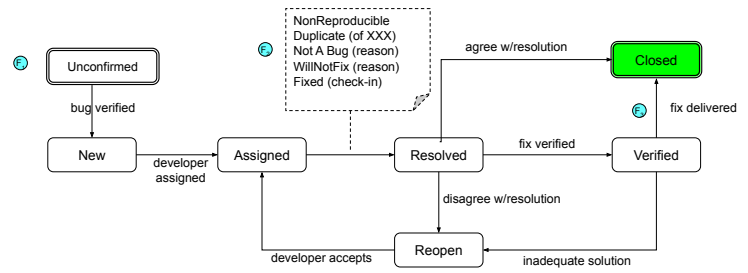
Key Attributes of a Bug Report

- ID (assigned automatically)
- Title (one line description of bug)
- Status
 - current state, severity, priority, owner
- Description
 - suspected component at fault
 - platform, symptoms, how to cause
 - diagnosis, work-arounds, and fix location
- History
 - log of all associated operations & comments

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Bug Report Life Cycle (simplified typical model)



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Good Bug Reports

- Clearly describe the problem
 - what should have happened, what did happen
- Clearly describe the impact
 - consequences to the affected users
- Clearly describe the affected systems
 - what platforms, what versions of what software
- Clearly describe how to cause the problem
 - ideally with a relatively simple test case
 - developing minimal failure cases is work
- Dispassionate, separate facts from opinions

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Bug Tracking Systems

- List of open tasks for developers
 - what work needs to be done
 - communication between developers & users
- Current status of product/development
 - what known problems are there (#, severity)
 - what is the status of each
- Support database
 - known problems and work-arounds
- Project management database
 - defect detection rates, fix rates
 - number of problems discovered
 - regression and not-a-bug rates

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bug triage and priority

- in emergency, sort patients into 3 groups
 - those who can wait a few hours
 - those who will die no matter what
 - those who need immediate attention
- bugs are prioritized in a similar fashion
 - disastrous bugs, must fix ASAP
 - they render the product unacceptable
 - serious bugs, should fix before shipment
 - they significantly compromise value of the product
 - minor bugs, fixes can be deferred to later

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For Next Lecture

- McConnell, chapter 29
 - overview of basic integration strategies
- Kampe, Integration Strategy
 - integration, architecture, testing, and schedule
- Fowler, Continuous Integration
 - good advice for a more rational process
- Kampe, Solaris Train Model
 - incremental integration for existing products
- Wikipedia, Test Driven Development
 - introduction to a useful agile development practice
- Kampe, Test Harnesses
 - introduction to a general class of testing tools
- CUnit, JUnit, Python unit test (just skim)
 - instances of a noble family of testing harnesses

Test Cases and Testability

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Supplementary Slides

bug verification

- reproduce the reported error
 - find a test case that reliably causes error
 - it is difficult to fix a problem one cannot observe
 - confirm that we observe reported behavior
 - we may have misunderstood the report
 - enable a preliminary assessment
 - does this, indeed, appear to be an error
- verify that program behavior is wrong
 - problem may be user-error or documentation
 - user may have unreasonable expectations

minimal failure cases

- some failures are complex or subtle
 - failure occurs after millions of operations
 - failure depends on environmental factors
 - failure isn't always in the same place
- find a simple case that fails solidly
 - isolate the contributing factors
 - find minimal combination that fails reliably
- this makes problem easier to reproduce, and easier to debug