Fixing the Defect

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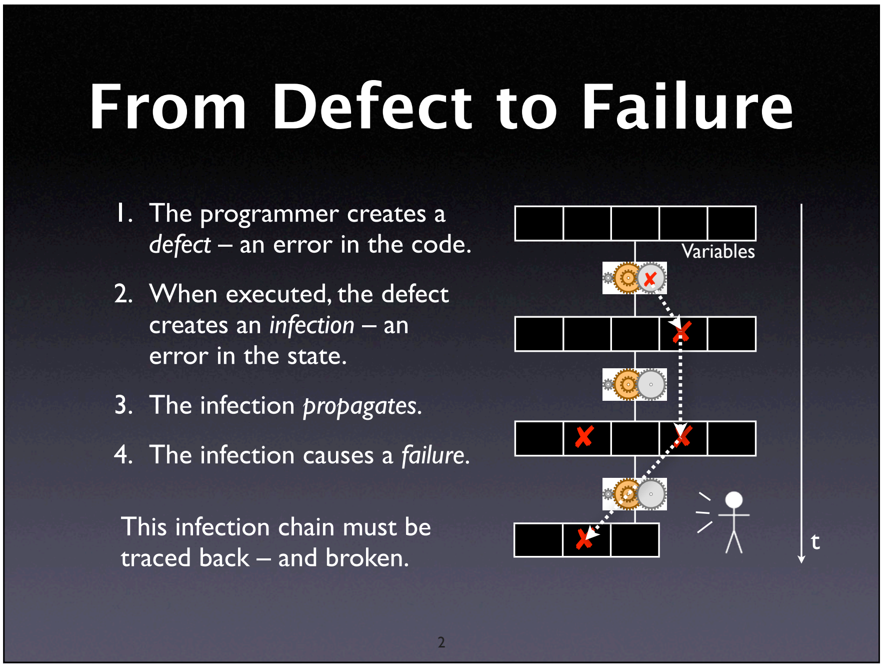
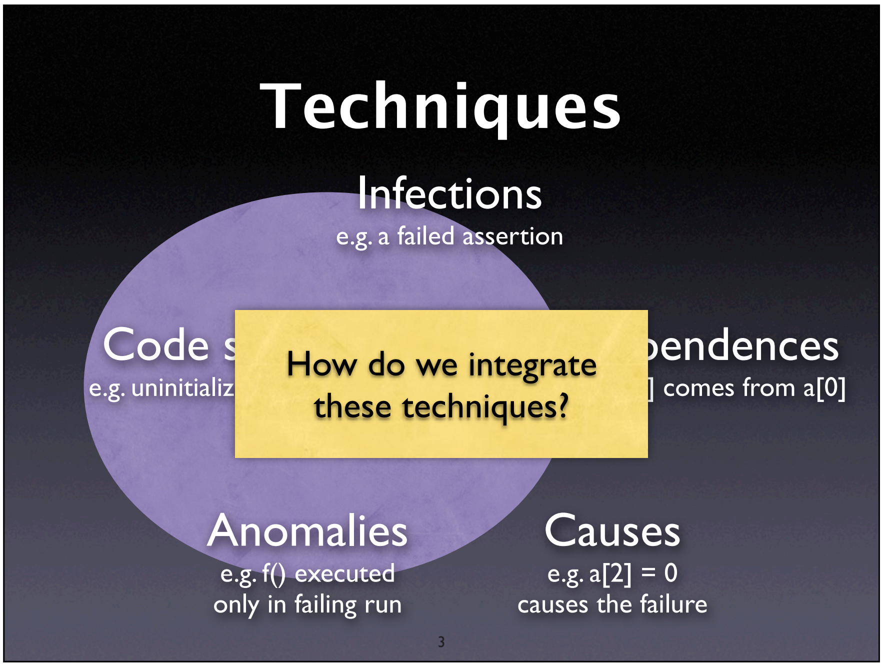


From Defect to Failure

1. The programmer creates a *defect* – an error in the code.
2. When executed, the defect creates an *infection* – an error in the state.
3. The infection *propagates*.
4. The infection causes a *failure*.

This infection chain must be traced back – and broken.



Techniques

Infections
e.g. a failed assertion

Code s
e.g. uninitializ

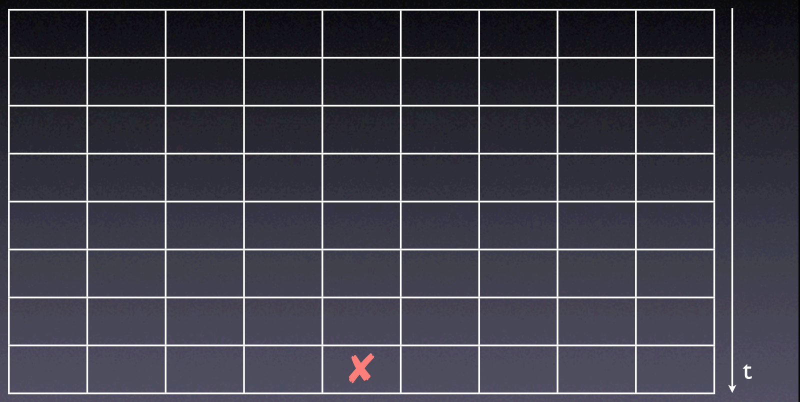
pendences
] comes from a[0]

How do we integrate these techniques?

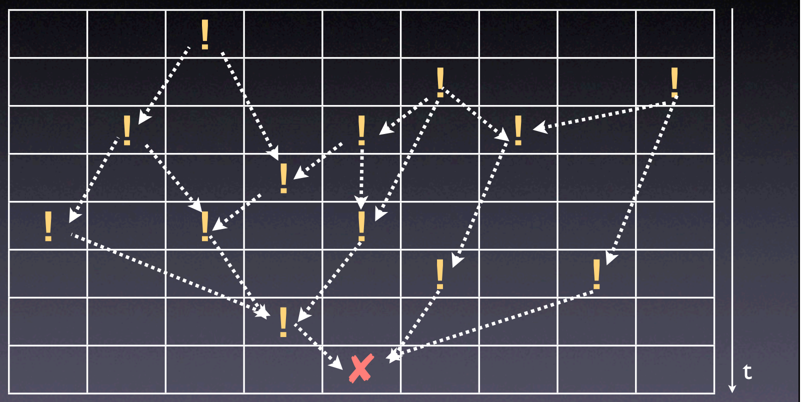
Anomalies
e.g. f() executed only in failing run

Causes
e.g. a[2] = 0 causes the failure

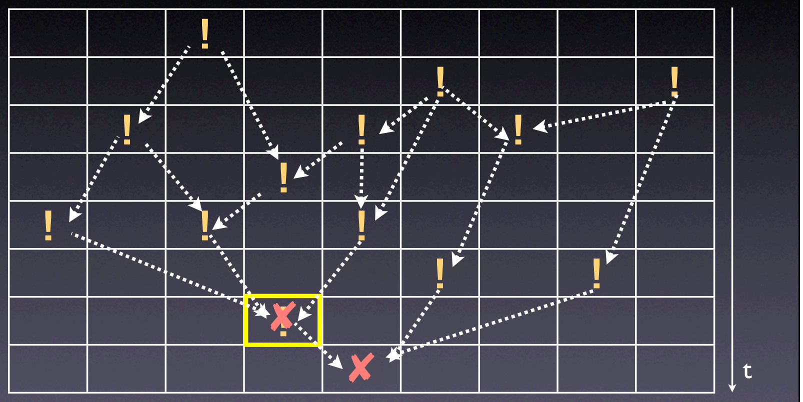
All Techniques



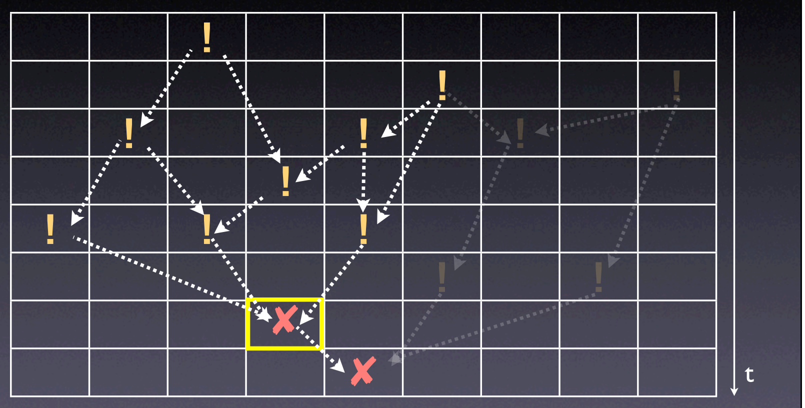
Dependencies



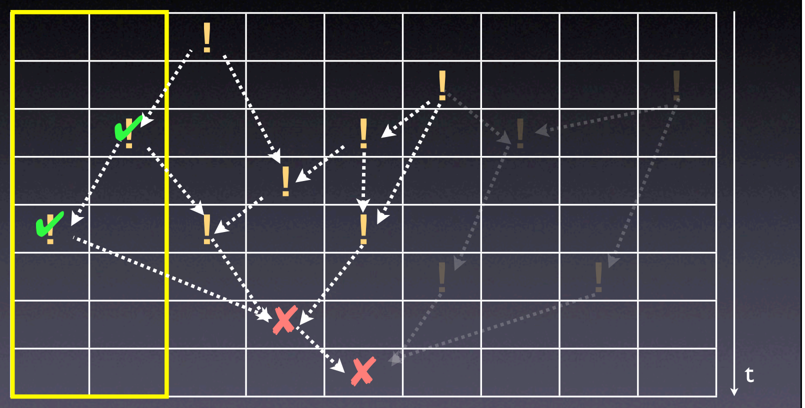
Observation



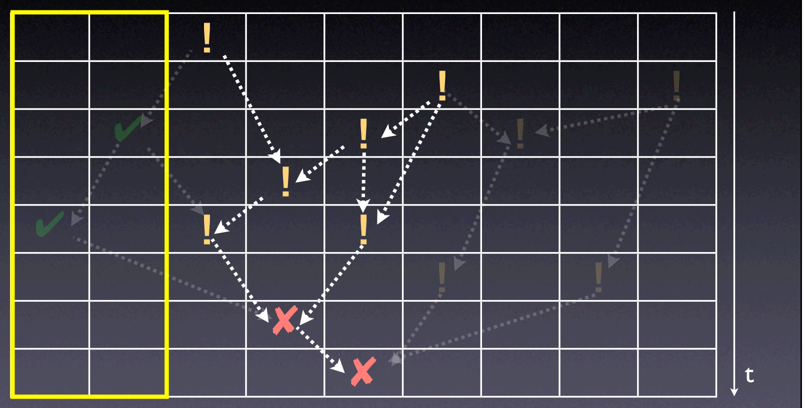
Observation



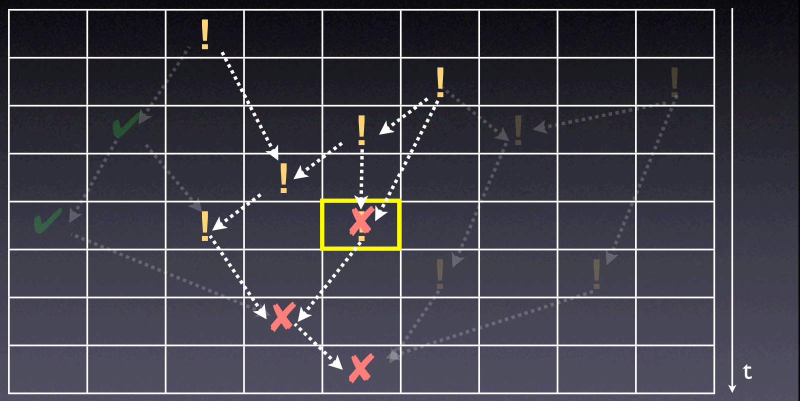
Assertion



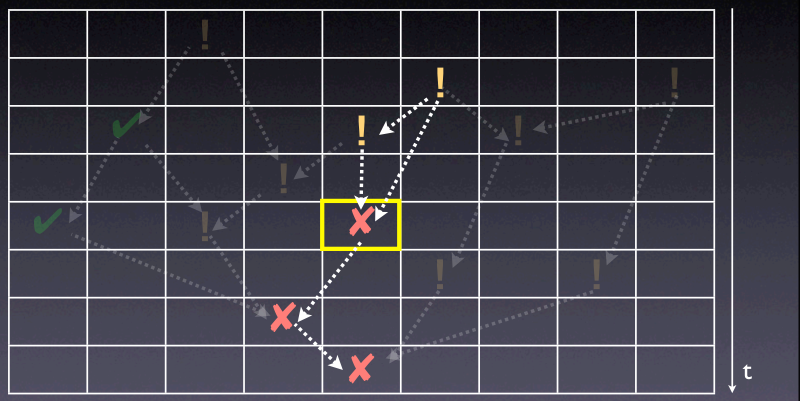
Assertion



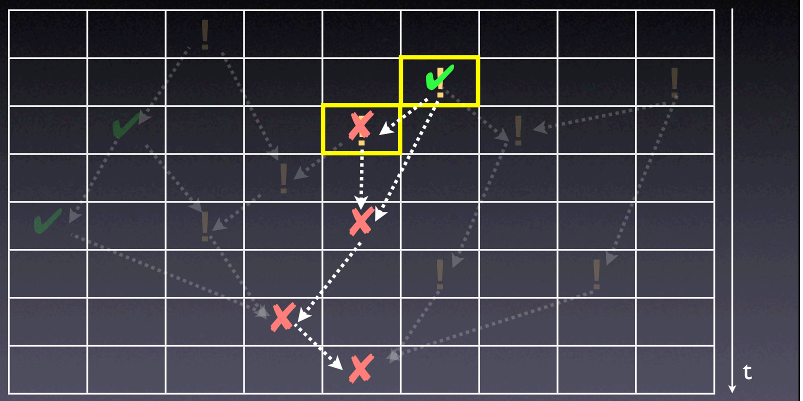
Anomaly



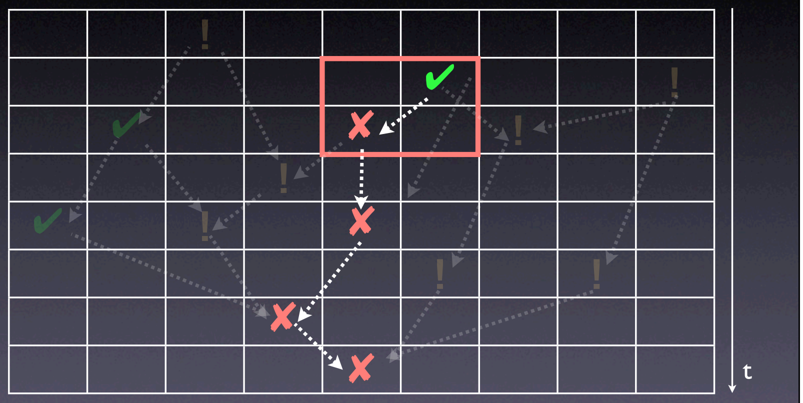
Anomaly



Cause Transition



The Defect



The Traffic Principle

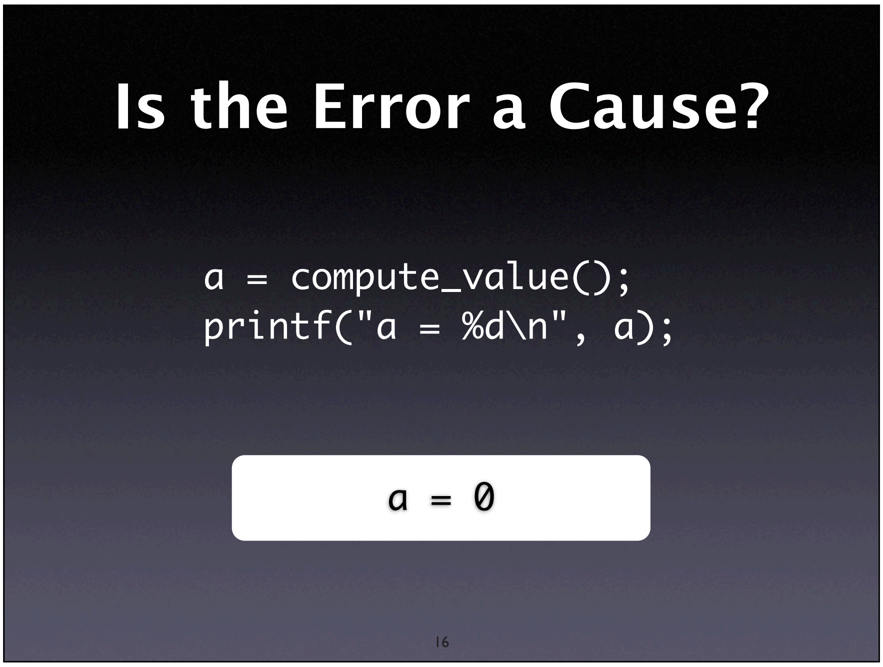
T rack the problem
R eproduce
A utomate
F ind Origins
F ocus
I solate
C ure

Validating the Defect

Any element of the infection chain must be

- *infected* – i.e., have an incorrect value
- *a failure cause* – i.e., changing it causes the failure to no longer occur

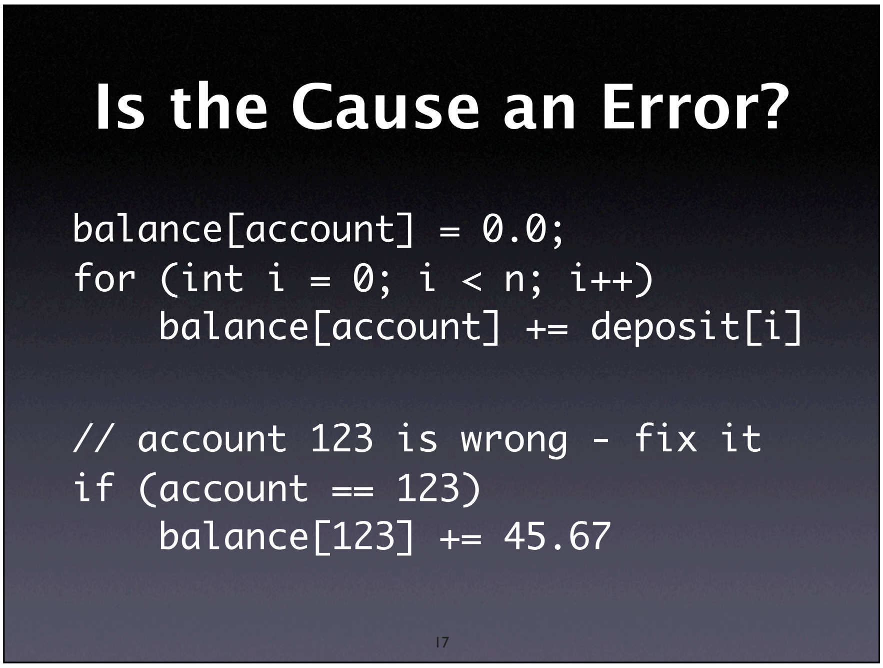
Demonstrate by experiments and observation



Is the Error a Cause?

```
a = compute_value();
printf("a = %d\n", a);
```

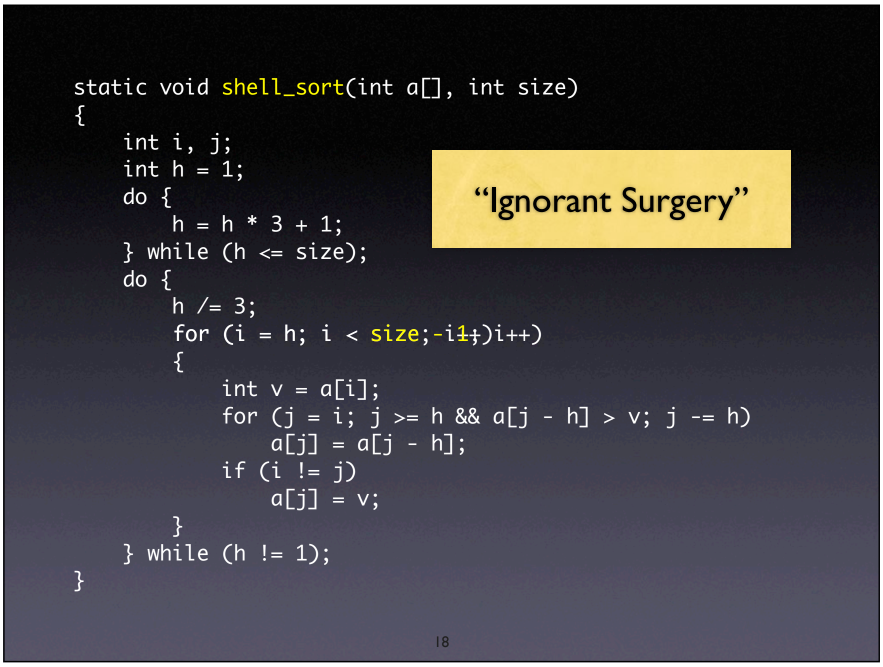
```
a = 0
```



Is the Cause an Error?

```
balance[account] = 0.0;
for (int i = 0; i < n; i++)
    balance[account] += deposit[i]

// account 123 is wrong - fix it
if (account == 123)
    balance[123] += 45.67
```



```
static void shell_sort(int a[], int size)
{
    int i, j;
    int h = 1;
    do {
        h = h * 3 + 1;
    } while (h <= size);
    do {
        h /= 3;
        for (i = h; i < size;-i1;)i++)
        {
            int v = a[i];
            for (j = i; j >= h && a[j - h] > v; j -= h)
                a[j] = a[j - h];
            if (i != j)
                a[j] = v;
        }
    } while (h != 1);
}
```

“Ignorant Surgery”

To tell whether something is an error means to have a **correction** in mind – but these examples are not corrections, they just fix the problem at hand.

Validating Causality

- In principle, we must show causality for *each element of the infection chain*
- However, a successful correction *retrospectively validates causality:*
  - Since the failure has gone, we have proven that the defect caused the failure
- Yet, we must not fall into ignorant surgery

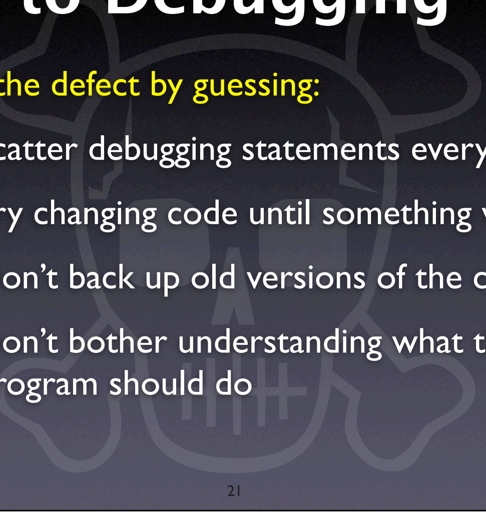
Think before you code

Before applying a fix, you must understand

- how your code change will *break* the infection chain, and
- how this will make the failure (as well as other failures) no longer occur

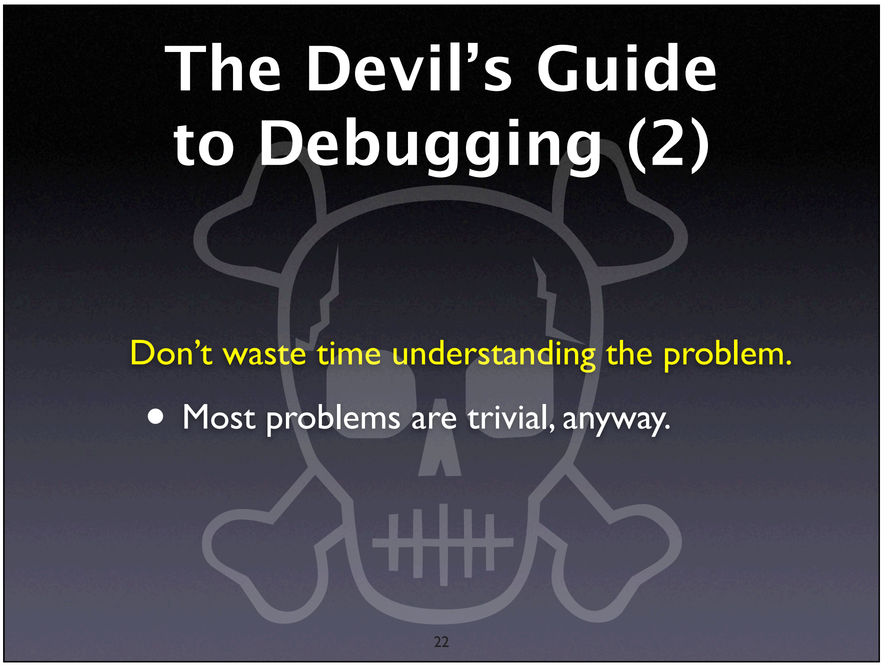
In fact, you have a theory about the defect

The Devil's Guide to Debugging



Find the defect by guessing:

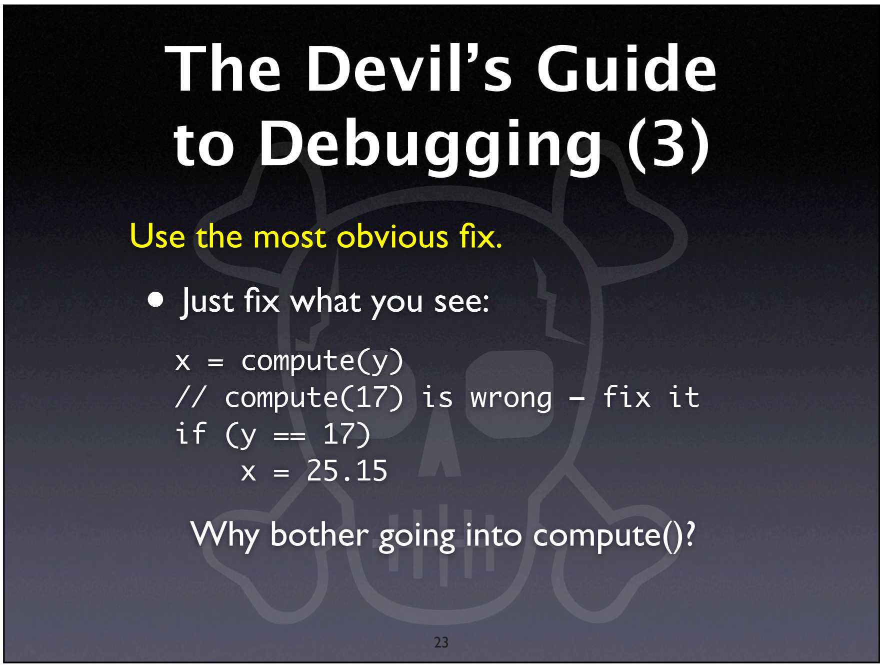
- Scatter debugging statements everywhere
- Try changing code until something works
- Don't back up old versions of the code
- Don't bother understanding what the program should do



The Devil’s Guide to Debugging (2)

Don’t waste time understanding the problem.

- Most problems are trivial, anyway.



The Devil’s Guide to Debugging (3)

Use the most obvious fix.

- Just fix what you see:

```
x = compute(y)
// compute(17) is wrong – fix it
if (y == 17)
    x = 25.15
```

Why bother going into compute()?

Correcting the Defect

Correcting the code can be a great moment. After having reproduced
the failure, observed the execution, carefully tracked back the infection chain, and having gained complete understanding of what was
going on---all this has prepared us for this very moment, the actual correcting of the code

Homework

Does the failure no longer occur?

- If the failure is still there, this should
  - leave you astonished
  - cause self-doubt + deep soul-searching
  - happen rarely
- Note that there may be a second cause

Homework (2)

Did the correction introduce new problems?

- Have corrections peer-reviewed
- Have a regression test to detect unintended changes in behavior
- Check each correction individually

Homework (3)

Was the same mistake made elsewhere?

- Check for other defects caused by the same mistake
  - Other code of the same developer
  - Code involving the same APIs

Homework (4)

Did I commit the change?

- Be sure to commit your change to
  - the version control system
  - the bug tracking system

Workarounds

Correcting the defect may be impossible:

- Unable to change
- Risks
- Design flaw

A *workaround* solves the problem at hand – but mark it as a temporary solution

The Blues

Where's the next open problem?

Concepts

- ★ To isolate the infection chain, transitively work backwards along the infection origins.
- ★ To find the most likely origins, focus on
  - failing assertions
  - causes in state, code, and input
  - anomalies
  - code smells

Concepts (2)

- ★ To correct the defect, wait until you have a theory about how the failure came to be
- ★ Check that the correction solves the problem and does not introduce new ones
- ★ To avoid introducing new problems, use code review and regression tests