A Series of Unfortunate Bugs

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CppCon 2019

I love debugging! 💖

Developers spend half their programming time debugging

Reversible Debugging Software,University of Cambridge

How am I going to solve this!

Don’t know what the code does!

Nobody knows what the code does!

This doesn’t make sense!

I have never done this before!

Is the compiler wrong?

What if I can’t solve this bug?!

What happens if I change this?!

How do we get better at debugging unfortunate bugs?

Unfortunate Bugs

Difficult to debug, Critical, Stressful, Often Avoidable, Often **Simple** Fixes

Simple Bugs
Complex Behaviors

4 Bugs

🐞🔍🔧💖

🐞 # 1

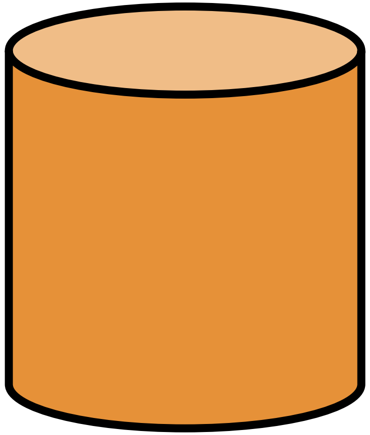
Crash in ancient code!

- An assertion failure

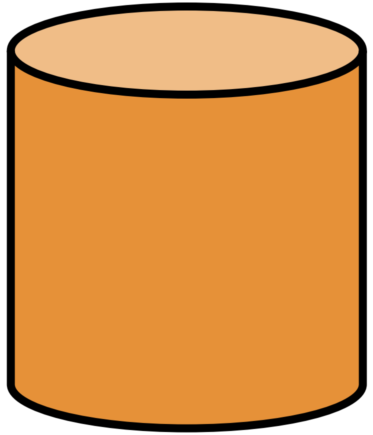
```
void Format::Decode(DBEntry* entry) {
    assert(mSomeNumber > 0);
    ...
```

- Nobody knew about the code
- Ran for hours
- Nothing obviously wrong

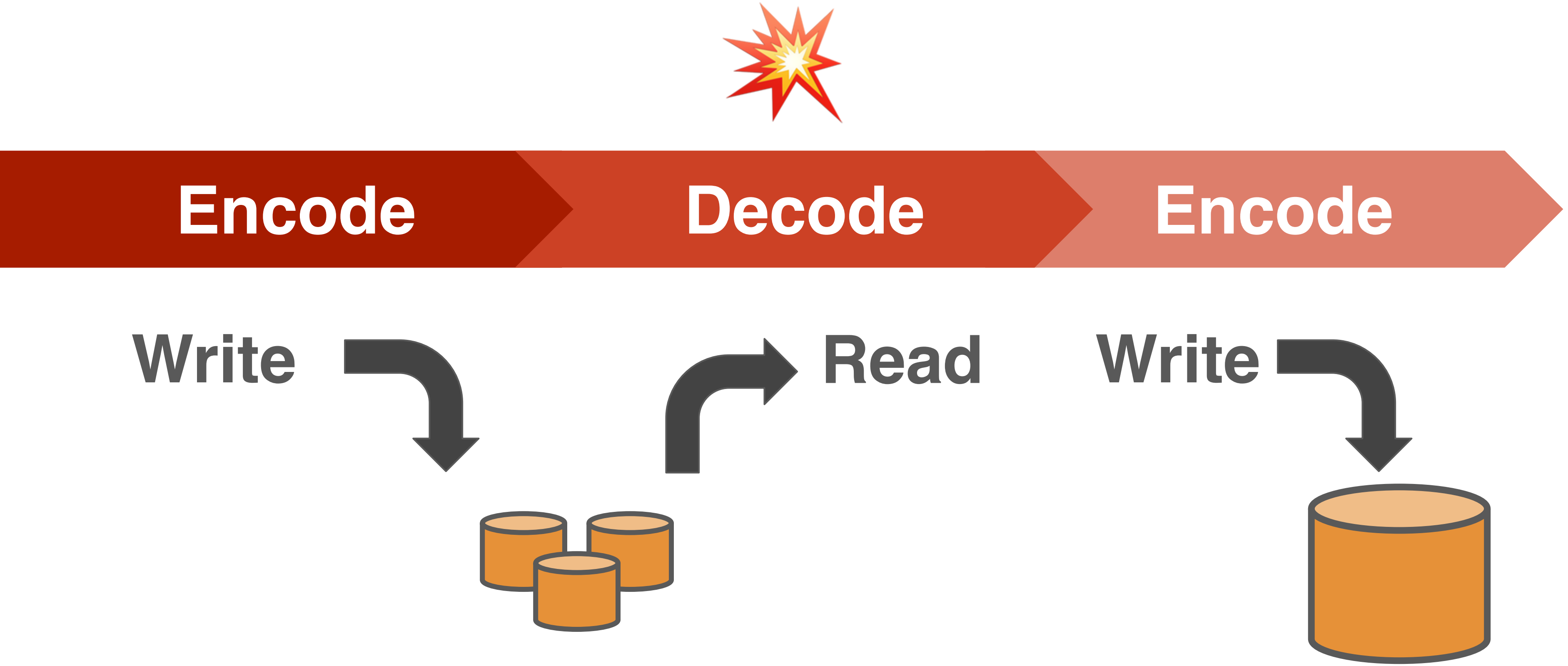
- **A database storing key-value pairs**
  - Fast
  - Compact
  - Many bitwise operations

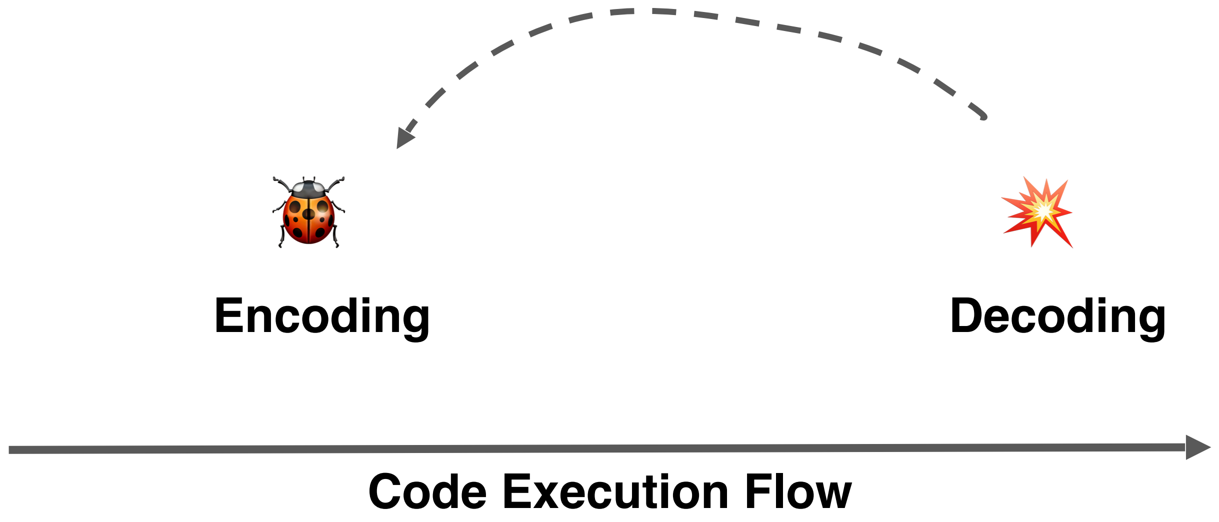


- **A database storing key-value pairs**
  - Believed to be working fine
  - Until one day it didn’t!
  - Nobody’s code



Understand somebody else’s code!


Encode
Decode
Encode
Write
Read
Write


Encoding
Decoding
Code Execution Flow

```c
unsigned int putBits(unsigned int val, int posn) {
    int right = 32 - posn;
    val = val >> right;
    return val;
}
```

Undefined behavior

```
int main() {
    int val = 127;

    val = shiftBits(val, 0);
    std::cout << "Value "
              << val
              << '\n';

    val = shiftBits(val, 1);
    std::cout << "Value "
              << val
              << '\n';
    return 0;
}
```

```
Value 127
Value 0
```

gcc, x86_64

A simple bug
A simple fix!

What did I learn?

- Positive mindset/Growth mindset
- Throw away assumptions
- Make the test case smaller
- Understand the system

Set yourself up for success, **use the right tools!**

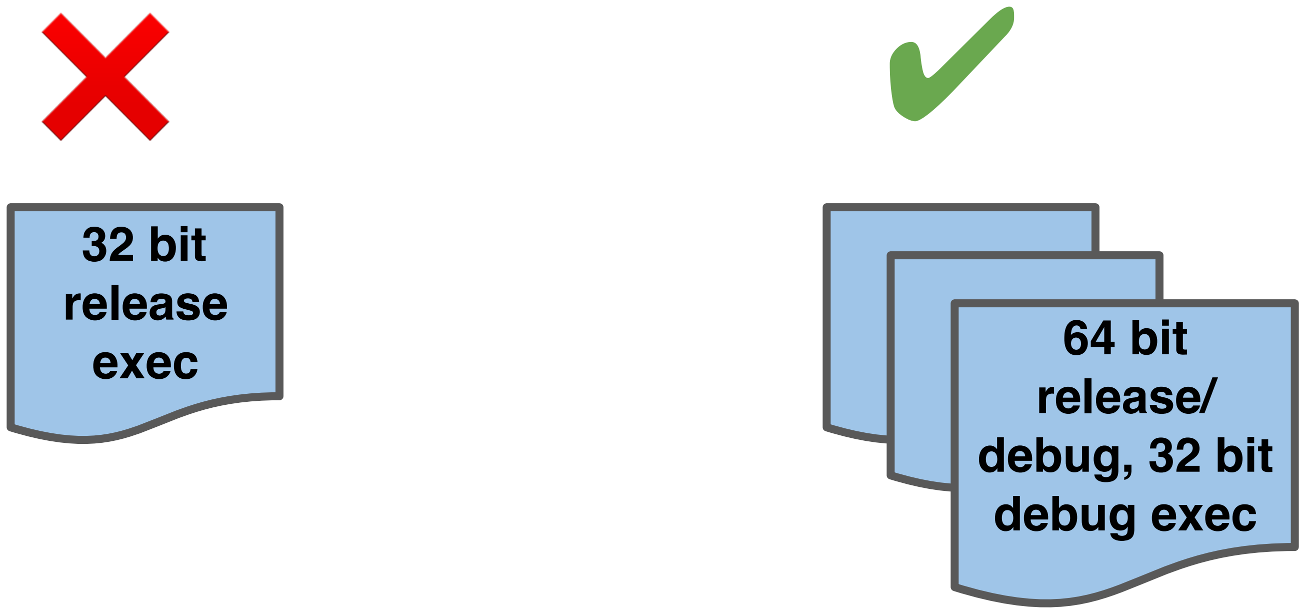
```
g++ -fsanitize=undefined UBshift.cpp
```

```
UBshift.cpp:6:13: runtime error: shift
exponent 32 is too large for 32-bit type
'unsigned int'
Value 127
Value 0
```

Have **helpful** logs!

🐞 # 2

Crash before the release!


✗
32 bit release exec
✓
64 bit release/ debug, 32 bit debug exec

No memory error reported by Valgrind!

Compiler optimizations: -O3, Symbols: Stripped

Debugging an optimized executable is...

Difficult!

```
SomeValue theCrashyFunction(SomeParam& param) {
    ...
    AList* pList = nullptr;
    initializeList(&pList);
    ...
    aStruct->mList = pList;
    if (cond) {
        callAFunction(aStruct);
    } else {
        callAnotherFunction(aStruct);
    }

    unsigned int size = pList->size(); 💥
```

No **obvious** write to pList!

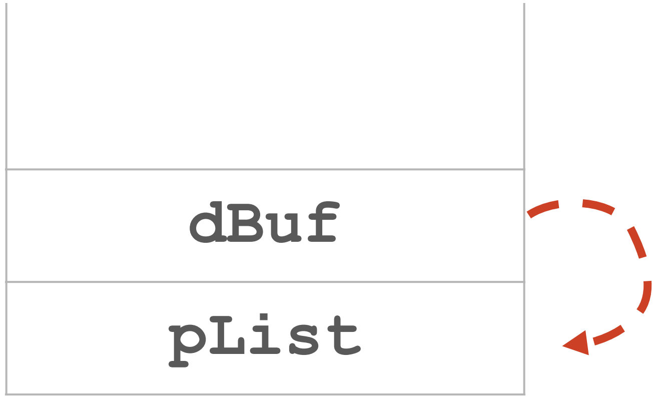
```
aStruct->mList = pList;
if (cond) {
    callAFunction(aStruct);
} else {
    callAnotherFunction(aStruct);
}
size = pList->size(); 💥
```

A static buffer overflow!

```
char dBuf[4 * sizeof(long unsigned)];
sprintf(dBuf, “\,,/(^_^)\,,/-%lx”,
        (long unsigned) dpt);
```

Compiler inlined both the functions!

```
SomeValue theCrashyFunction(SomeParam&
param) {
    ...
    AList* pList = nullptr;
    initializeList(&pList);
    ...
    aStruct->mList = pList;
    if (cond) {
        char dBuf[4 *
                  sizeof(long unsigned)];
        sprintf(dBuf, "\,,/(^_^)\,,/%lx",
                (long unsigned) dpt);
        ...
    } else {
        ...
```



Right tools & safer coding!

No shotgun debugging!
No back-seat driving!

Recurse Center

www.recurse.com

🐞 # 3

Deadlock in code!

-- Benjamin Dow
Software Engineer
Amazon

- **A multi-threaded program**
  - Sometimes hangs on startup
  - Stack traces of hang at different places
  - No inconsistencies in locking

• **Stack traces** - 2 different low level locks

```
Thread 2 (Thread 0xf7763b70 (LWP 28839)):
#0  0x00c25430 in __kernel_vsyscall ()
#1  0x00d181b9 in __lll_lock_wait () from /lib/libpthread.so.0
#2  0x00d1355e in _L_lock_731 () from /lib/libpthread.so.0
```

```
Thread 1 (Thread 0xf77646c0 (LWP 28720)):
#0  0x00c25430 in __kernel_vsyscall ()
#1  0x00d181b9 in __lll_lock_wait () from /lib/libpthread.so.0
#2  0x00d13550 in _L_lock_677 () from /lib/libpthread.so.0
#3  0x00d13421 in pthread_mutex_lock () from /lib/libpthread.so.0
#4  0x080488f4 in SleepLock::SleepLock (this=0x8476098) at thread.cpp:10
```

- **Heavy use of singleton pattern**

```
static Thing& getInstance() {
  static Thing instance
  return instance;
}
```

- **Is this thread-safe?**

```
static Thing& getInstance() {
  static Thing instance;
  return instance;
}
```

C++ 11: Yes, Older C++: ?

G++ 4.2 $\longrightarrow$ **G++ 4.3**

Thread 1	Thread 2
Acquires user space lock	
	Initializes a local static variable
Initializes a local static variable	
	Acquires user space lock

```
class SleepLock {
public:
  SleepLock() {
    usleep(5000);
    pthread_mutex_lock(&mutex);
    pthread_mutex_unlock(&mutex);
  }
};

int main(int, char*[]) {
  pthread_t tid;
  pthread_create(&tid, 0,
                 &thread_1, 0);
  static SleepLock obj;
  void* result;
  pthread_join(tid, &result);
  return 0;
}
```

```
void* thread_1(void*) {
  pthread_mutex_lock(&mutex);
  usleep(5000);
  static Noop* obj = new Noop();
  pthread_mutex_unlock(&mutex);
  return 0;
}
```

Difficult to reason

Code review or tools **not helpful**

Talk about your **bugs!**

Perils of forgetting after fixing it!

Memory helps you find creative solution to a problem

Smart Thinking

Art Markman, Cognitive Scientist

🐞 # 4

Refactoring bug!

Cargo Cult Software Engineering

Steve McConnell

Author of Code Complete

```
bool someLongFunc(Type1 var1, Type2 var2,
                  Type3 var3, Type4 var4,
                  ...) {
  ...
  // Do some things
  ...
  jmp_buf env;
  int status = setjmp(env);
  ...
  // Do some things
  ...
  longjmp(env, someValue);
  ...
}
```

```
bool someLongFunc(Type1 var1, Type2 var2,
                  Type3 var3, Type4 var4,
                  ...) {
  ...
  // Do some things
  ...
  jmp_buf env;
  int status = setjmp(env);
  ...
  // Do some things
  ...
  longjmp(env, someValue);
  ...
}
```

```
bool notLongFunc1(Type1 var1,
                  Type2 var2,
                  Type3 var3,
                  Type4 var4,
                  ...) {
  ...
  // Do some things
  ...
  jmp_buf env;
  int status = setjmp(env);
  ...
  // Do some things
}
```

```
bool notLongFunc(Type1 var1,
                 Type2 var2,
                 Type3 var3,
                 Type4 var4,
                 ...) {
  ...
  // Do some things
  ...
  longjmp(env, someValue);
  ...
}
```

```
bool ok = someLongFunc(var1,
                       var2,
                       var3,
                       ...);
```

```
bool ok1 = notLongFunc1(var1,
                        var2,
                        ...);
bool ok2 = notLongFunc2(var1,
                        var2,
                        ...);
```

Crash
in the optimized executable!

```
bool someLongFunc(Type1 var1, Type2 var2,
                  Type3 var3, Type4 var4,
                  ...) {
   ...
   // Do some things
   ...
   jmp_buf env;
   int status = setjmp(env);
   .
   // Do some things
   ...
   longjmp(env, someValue);
   ...
}
```

Undefined behavior

💥

Perseverance + Methodical approach

Debugging Principles

- Understand the System
- Make it Fail
- Quit Thinking and Look
- Divide and Conquer
- Change One Thing at a Time
- Keep an Audit Trail
- Check the Plug
- Get a Fresh View
- If You Didn't Fix it, It Ain't Fixed

… by David Agans

Deliberate Practice

K Anders Ericsson,
Psychologist, Author of “Peak: Secrets from the New Science of Expertise”

Want to get great at something, get a coach

Atul Gawande

Surgeon, Public Health Professor, Writer

“C++ is for smart people”

C++ is for hard working people

Bugs are great **learning opportunities!**

Start talking

Stop the culture of blaming

Believe that you can fix the bug

Love your Bugs,

Allison Kaptur, PyCon 2018

The Debugging Mindset,

Devon H. O’Dell, CACM, June 2017

See an unfortunate bug?

Thanks to -

- Ben Dow
- Debamitro Chakraborti
- Hirak Ray
- Kelson Gent
- Ken Crouch
- Stephen Richardson

… For helping and giving feedback on the slides.

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