Oops, I did it again - Funny Programming Fails

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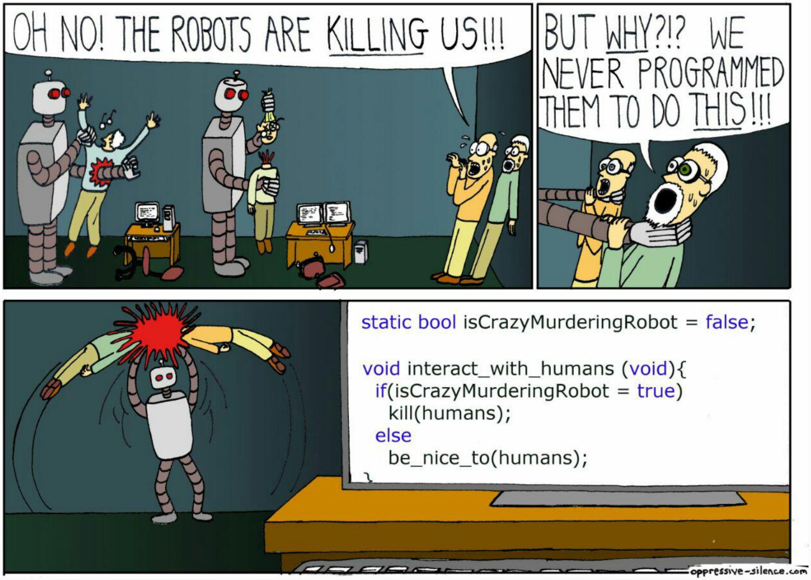
Funny Programming Fails


OH NO! THE ROBOTS ARE KILLING US!!!
BUT WHY?!? WE NEVER PROGRAMMED THEM TO DO THIS!!!
oppressive-silence.com

```
static bool isCrazyMurderingRobot = false;

void interact_with_humans (void){
 if(isCrazyMurderingRobot = true)
   kill(humans);
 else
   be_nice_to(humans);
}
```

Outline

How to accidentally cheat PABS

Toyota - Nothing is Impossible, even Code that Kills

A Story of Knights and Farmers

Funny Takeouts

Broken by Optimization

Santas Sled

How to accidentally cheat PABS

The Assignment

Implement the MergeSort algorithm for arrays of `int` in Java

PABS Tests

```java
@Test
public void testMergeSortSorted() {
    int[] testArray = {1, 2, 3, 4, 5, 6};
    MergeSort.sort(testArray);
    assertArrayEquals("Array not sorted",
            new int[] {1, 2, 3, 4, 5, 6}, testArray);
}

@Test
public void testMergeSortSortedDesc() {
    int[] testArray = {6, 5, 4, 3, 2, 1};
    MergeSort.sort(testArray);
    assertArrayEquals("Array not sorted",
            new int[] {1, 2, 3, 4, 5, 6}, testArray);
}
```

More PABS Tests

```
// testMergeSort:
int[] testArray = {1, 3, 7, 5, 2, 9};
// [...]

// testMergeSort2:
int[] testArray = {16, 22, 38, 27, 85, 38, 60};
// [...]

// testMergeSort3:
int[] testArray = {7, 75, 24, 20, 12, 54, 19,
                    42, 73, 81};
// [...]
// testMergeSort4:
int[] testArray = {8, 12, 69, 31, 49, 49, 40, 3, 53,
                    13, 84, 36, 86, 72, 89, 94, 70};
```

Seems legit ...

The following code passes ALL six tests:

Accepted Solution

```java
public static void sort(int[] arr) {
    if (arr.length < 2) return;
    sort(arr, 0, arr.length - 1);
    merge(arr, 0, arr.length / 2, arr.length - 1);
}

static void sort(int[] arr, int start, int end) {
    if (end - start == 1) return;
    int mid = (start + end + 1) / 2;
    sort(arr, start, mid);
    sort(arr, mid, end);
    merge(arr, start, mid, end);
}
```

Accepted Solution

```java
static void merge(int[] arr, int start,
                  int mid, int end) {
    while (start < end || mid < end) {
        if (arr[start] <= (arr[mid])) {
            if (start < mid) start++;
            else mid++;
        } else {
            int tmp = arr[mid];
            arr[mid] = arr[start];
            arr[start++] = tmp;
        }
    }
}
```

Accepted Solution

Try this example:

`sort(new int[] {3, 4, 1, 2})`

Invariant for `merge(...)`:

Both Parts are sorted ⇒ The whole becomes sorted

Debugging

```
//  {3, 4, 1, 2}       0         2        3
merge(int[] arr, int start, int mid, int end) {
//              true
    while (start < end || mid < end) {
//              3             1
        if (arr[start] <= (arr[mid])) {
            if (start < mid) start++;
            else mid++;
        } else { // => swap(0, 2); start++
            int tmp = arr[mid];
            arr[mid] = arr[start];
            arr[start++] = tmp;
        }
    }
}
```

Debugging

```
//  {1, 4, 3, 2}       1          2         3
merge(int[] arr, int start, int mid, int end) {
//               true
    while (start < end || mid < end) {
//               4              3
        if (arr[start] <= (arr[mid])) {
            if (start < mid) start++;
            else mid++;
        } else { // => swap(1, 2); start++
            int tmp = arr[mid];
            arr[mid] = arr[start];
            arr[start++] = tmp;
        }
    }
}
```

Debugging

```
//  {1, 3, 4, 2}       2          2         3
merge(int[] arr, int start, int mid, int end) {
//               true
    while (start < end || mid < end) {
//               4              4
        if (arr[start] <= (arr[mid])) {
            if (start < mid) start++; // false
            else mid++;
        } else {
            int tmp = arr[mid];
            arr[mid] = arr[start];
            arr[start++] = tmp;
        }
    }
}
```

Debugging

```
//  {1, 3, 4, 2}       2          3         3
merge(int[] arr, int start, int mid, int end) {
//               true
    while (start < end || mid < end) {
//               4              2
        if (arr[start] <= (arr[mid])) {
            if (start < mid) start++;
            else mid++;
        } else { // => swap(2, 3); start++
            int tmp = arr[mid];
            arr[mid] = arr[start];
            arr[start++] = tmp;
        }
    }
}
```

Debugging

```
//  {1, 3, 2, 4}       3          3         3
merge(int[] arr, int start, int mid, int end) {
//              false        false
    while (start < end || mid < end) {
//
        if (arr[start] <= (arr[mid])) {
            if (start < mid) start++;
            else mid++;
        } else {
            int tmp = arr[mid];
            arr[mid] = arr[start];
            arr[start++] = tmp;
        }
    }
}
```

Conclusion

- This `merge(...)` method is totally crap!
- Result of `sort({3, 4, 1, 2})` is `{2, 1, 3, 4}`
- Six JUnit tests failed to detect this!
- One of them testing a 17 elements array

Toyota - Nothing is Impossible, even Code that Kills

Unintended Acceleration

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- Toyota cars suddenly accelerate at full power
- Breakting does NOT stop the acceleration
- Only way to stop is handbrake
  Breaking distance up to 100 meters!!!

Unintended Acceleration

- Toyota cars suddenly accelerate at full power
- Breakting does NOT stop the acceleration
- Only way to stop is handbrake
  Breaking distance up to 100 meters!!!
- **81 deaths so far!**

First Investigation

- Acceleration code investigated by NASA
    - Did not find a “smoking gun”
    - But
        - tight timeline
        - limited information / access (trade secrets)
        - no exoneration of the system

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“We enlisted the best and brightest engineers to study Toyota’s electronic systems, and the verdict is in. There is no electronic-based cause for unintended high-speed acceleration in Toyotas.”

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- **Lesson:** Politicians do not know jack shit about software.

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  Only main CPU software analyzed.
- Toyota told NASA they had EDAC (Error Detection and Correction)
- **But:** There was no EDAC for the RAM

Code “Architecture”

256’600	Non-Commented Lines C Source
39’000	Non-Commented Lines C Headers (Main CPU only)
???	Proprietary Monitor Chip Software

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Code only for acceleration!

Software Testing @ Toyota

Testing only at vehicle level.

No

- Unit Testing
- Integration testing

Vehicle Testing not Enough

- Vehicle level testing useful and important
    - Unexpected component interactions
    - Environment influences in real-world application

- Complete testing at vehicle level unpractical
    - Too many combinations of possible conditions, timings
    - Too many possible sources for failures
        - Two faults can counter each other
        - Source of defects hard to locate

Toyota Coding Rules

- **11** of **35** rules suggested for road vehicles found in coding rules
- Rules last updated **1998**
- Those weren't followed:
  105 of **343** `switch` keywords without `default`
- **14** of **35** rules violated, **7'134** violations
  - Macros
  - Use of `#undef`

Static Code Analysis

- Coverity

97	variables declared but not referenced
5	include recurision

- Codesonar

2272	global variable declared with different types
333	cast alters value
99	condition contains side-effect
64	multiple declaration of global variable
22	uninitialized variables

- Uno

89	possibly uninitialized variable
2	array of 16 byte initialized with 17 bytes

Code Complexity

Spaghetti Code

- McCabe Cyclomatic Complexity Metric
  - Number of “eyes” in flow control graph
  - Unit tests harder with complex graph
  - Over 50 considered “untestable”
- Toyota Code
  - 67 functions with complexity over 50
  - Throttle angle function: **146**
    1300 LOC, no test plan

Global Variables

- Ideal Number: ZERO
- Toyota: 9’273 - 11’528 global variables

6’971	local static sufficient
1’086	file static sufficient

Other Issues

- Poor isolation of task functions
- Many large functions
- Reviews informal and only on some modules
- No configuration management
- No bug tracking system
- No formal specification

Lesson

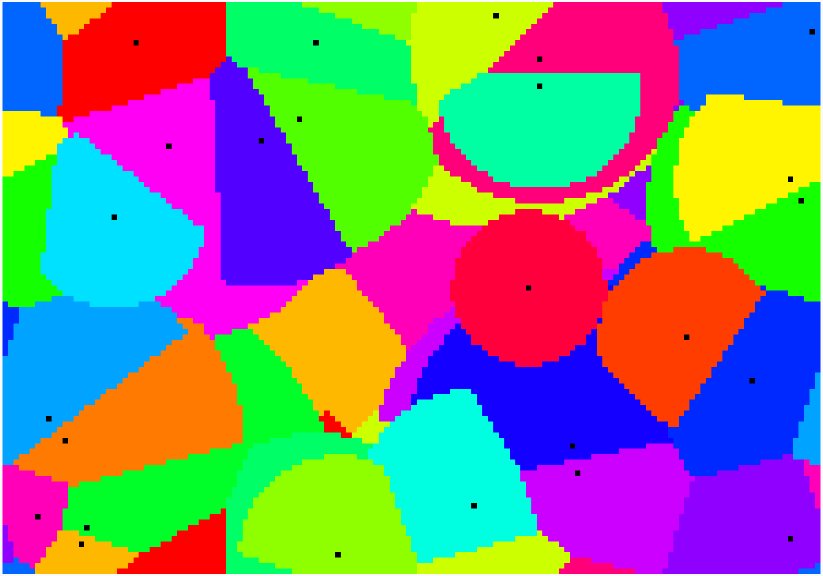
- Write code you can be confident of it being safe
- You should be able to sleep with the knowledge of software being used in production.

Personal Story

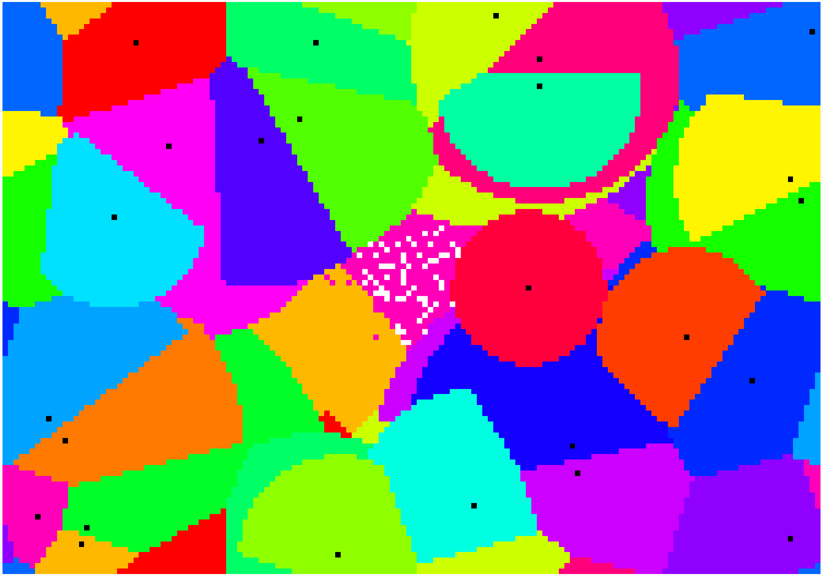
Personal Story

A Story of Knights and Farmers

Singlethreaded Algorithm



Multithreaded Algorithm



Multithreaded Algorithm

The graphic rendered by the multithreaded algorithm is corrupt:

- Some pixels have a different color than they should
- Some pixels have no color at all

$\Rightarrow$ We need sychronization :(

Synchronized Multithreaded Algorithm

```
private final Semaphore rendezvous;
private final Queue<Knight> knights;
// Implementation: ConcurrentLinkedQueue

public void runMT(int nThreads) {
    ExecutorService pool =
            Executors.newFixedThreadPool(nThreads);
    do {
        // do some preparation ... fill knight queue
        for (int i = 0; i < nThreads; i++) {
            pool.submit(this::run);
        }
        rendezvous.acquire(nThreads);
    } while (/*work to do*/);
    pool.shutdown();
}
```

Synchronized Multithreaded Algorithm

```
private void run() {
    while (!knights.isEmpty()) {
        Knight knight = knights.remove();
        while (!knight.isSatisfied()) {
            // do stuff ...
        }
    }
    rendezvous.release();
}
```

Synchronized Multithreaded Algorithm

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- It is way faster (factor 2.3 on an Intel Core i3 [2C + HTT])

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- It is way faster (factor 2.3 on an Intel Core i3 [2C + HTT])
- Rendering a 1080p scene randomly fails...
- Rendering a 4K scene always fails
- DEADLOCK

Debugging

- Deadlock occurs on heavy load
- The only blocking structure is that semaphore we added
- Debugging prints tell us the semaphore stucks because of too few `release()` calls
- $\Rightarrow$ some threads never finish

Broken Synchronized Multithreaded Algorithm

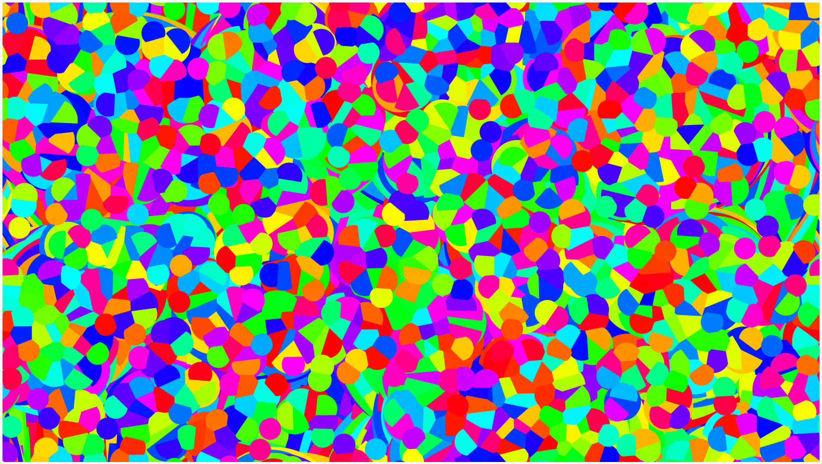
```
private void run() {
    // ----->
    while (!knights.isEmpty()) {
        Knight knight = knights.remove();
        // <------ IS NOT ATOMIC (but should!)

        while (!knight.isSatisfied()) {
            // do stuff ...
        }
    }
    rendezvous.release();
}
```

Fixed Synchronized Multithreaded Algorithm

```java
private void run() {
    Knight knight;
    while ((knight = knights.poll()) != null) {
        while (!knight.isSatisfied()) {
            // do stuff ...
        }
    }
    rendezvous.release();
}
```

Working 8K Example



Conclusions

- Threads can disappear when they throw an uncaught exception or error
- Threads from ThreadPools do not even log something to stdout/stderr when they die
- Check for exceptions on your own
- Use Rust

Funny Takeouts

Count it UP!

```
x = 0;
while x < 5
  x = x + 1;
end
%do something with x ...
```

Abbreviations can be tricky!

```
try {
  //...
} catch (SecurityException sex) {
  //...
}
```

Redeclaration

```
public class A {
  protected String foo;
  public void setFoo(String fooVal);
  public String getFoo();
  public void doSomething() {
    . . .
      foo = x.munge();
    . . .
}};

public class B extends A {
  /* redeclared here for clarity */
  protected String foo;
  public void doSomething() {
    . . .
      foo = x.munge();
    . . .
}}
```

Work for nothing?

```
int getRandomize(int randMax)
{
  srand ( time(NULL) );
  int randNum; = rand() % randMax + 1;
  return 2;
}
```

OMG - why?

```cpp
int multiplyBy10(int number)
{
    std::stringstream str;
    str << number << '0';
    str >> number;
    return number;
}
```

Correct result but ...

```c
void get_tomorrow_date( struct timeval *date )
{
  sleep( 86400 ); // 60 * 60 * 24
  gettimeofday( date, 0 );
}
```

Like code structure?

```
// Not a joke, I've really seen that
for ($i=0 ; $i<3 ; $i++) {
  switch($i) {
    case 1:
      // do some stuff
      break;
    case 2:
      // do some stuff
      break;;
    case 3:
      // do some stuff
      break;
  }
}
```

Double Kill

```
$('body *:visible').hide().show();
$('body *:not(:visible)').show().hide()
```

Broken by Optimization

Broken by Optimization

There is an ancient legend, every programmer knows, that aggressive compiler optimizations break your code

Broken by Optimization

This legend is true

The example

```
#include "stdio.h"

int main() {
    int i, j = 0;
    for (i = 1; i > 0; i += i)
        ++j;
    printf("%d\n", j);
}
```

Try the example

```
$ gcc example.c
$ ./a.out
31
$ ▯
```

At release...

```
$ gcc -O3 -Wall example.c
$ ./a.out
▯
```

At release...

```
$ gcc -O3 -Wall example.c
$ ./a.out
^C
$ ▯
```

gcc -O0 -S example.c

```c
#include "stdio.h"

int main() {
    int i, j = 0;
    for (i = 1; i > 0; i += i)
        ++j;
    printf("%d\n", j);
}
```

```asm
main:
# [...]
    movl    $0, -8(%rbp)
    movl    $1, -4(%rbp)
    jmp .L2
.L3:
    addl    $1, -8(%rbp)
    movl    -4(%rbp), %eax
    addl    %eax, %eax
    movl    %eax, -4(%rbp)
.L2:
    cmpl    $0, -4(%rbp)
    jg  .L3
    movl    -8(%rbp), %eax
    movl    %eax, %esi
    movl    $.LC0, %edi
    movl    $0, %eax
    call    printf
# [...]
```

gcc -O3 -S example.c

```c
#include "stdio.h"

int main() {
    int i, j = 0;
    for (i = 1; i > 0; i += i)
        ++j;
    printf("%d\n", j);
}
```

```asm
main:
.LFB11:
    .cfi_startproc
    .p2align 4,,10
    .p2align 3
.L2:
    jmp .L2
    .cfi_endproc
# [...]
```

Well then?

- OK - indeed `-O3` is very aggressive

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- Then `–O1` ?!

Well then?

- OK - indeed `–O3` is very aggressive
- Trying `–O2` …
- Same result (even same assembler code!)
- Then `–O1` ?!
- At least this one works:

gcc -O1 -S example.c

```c
#include "stdio.h"

int main() {
    int i, j = 0;
    for (i = 1; i > 0; i += i)
        ++j;
    printf("%d\n", j);
}
```

```asm
.main
# [...]
    movl    $0, %esi
    movl    $1, %eax
.L2:
    addl    $1, %esi
    addl    %eax, %eax
    testl   %eax, %eax
    jg  .L2
    movl    $.LC0, %edi
    movl    $0, %eax
    call    printf
    movl    $0, %eax
# [...]
```

What happened?

GCC signed integer overflow optimization

What happened?

GCC signed integer overflow optimization

`$ gcc -O3 -fno-strict-overflow example.c` produces nearly the same assembler code as `$ gcc -O1 example.c`

Broken by Optimization

This legend is true

But it’s all your own fault :)

Santas Sled

Santas Sled

Now, at the end of this talk, let’s have some look at Santa Claus’ sled management software:

- for every reindeer save their name and guide (the reindeer before them)
- save the christmas present for every reindeer
- list all reindeers with the present they get

Class Reindeer

```java
public class Reindeer {
    private final String name;
    private Reindeer guide;

    public Reindeer(String name) {...}
    public Reindeer getGuide() {...}
    public void setGuide(Reindeer guide) {...}
    public String getName() {...}

    @Override public boolean equals(Object o) {
        // [...]
        return Objects.equals(name, reindeer.name) &&
                Objects.equals(guide, reindeer.guide);
    }

    @Override public int hashCode() {
        return Objects.hash(name, guide);
    }
}
```

Class SantasPlan

```
public class SantasPlan {
    Map<Reindeer, String> presents = new HashMap<>();
    Reindeer leader;

    void prepareForChristmas() {
        Reindeer donner = new Reindeer("Donner");
        leader = donner;
        Reindeer comet = new Reindeer("Comet");
        comet.setGuide(donner);
        Reindeer blixen = new Reindeer("Blixen");
        blixen.setGuide(comet);

        presents.put(donner, "noise cancelling headphones");
        presents.put(comet, "a fitness tracker");
        presents.put(blixen, "new sunglasses");
    }
```

Class SantasPlan

```
    void foggyChristmasEve() {
        Reindeer rudolph = new Reindeer("Rudolph");
        leader.setGuide(rudolph);
        leader = rudolph;
        presents.put(rudolph, "tissues");
    }

    public static void main(String[] args) {
        SantasPlan plan = new SantasPlan();
        plan.prepareForChristmas();
        plan.foggyChristmasEve();
        for (Reindeer reindeer : plan.presents.keySet()) {
            System.out.println(reindeer.getName() +
                    " gets " + plan.presents.get(reindeer));
        }
    }
}
```

Guess what happens?

1. Everything runs well
2. Rudolph does not show up
3. Just Rudolph is shown nobody else
4. Every reindeer is printet but some loose their presents

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   Seriously? We're talking about FAILS!
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   Why shouldn't he?
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   Getting closer...
4. Every reindeer is printet but some loose their presents
   You got it!

Output of main

```
Blixen gets null
Rudolph gets tissues
Donner gets null
Comet gets null
```

Where is our bug?

```java
@Override
public int hashCode() {
    return Objects.hash(name, guide);
}
```

Where is our bug?

- Adding Rudolph as Donner’s guide alters Donners hashcode
- Altering Donner’s hashcode alters Comet’s hashcode …
- The HashMap stores the presents under the old hashcodes
- But looks them up calculating the new ones

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- Altering Donner’s hashcode alters Comet’s hashcode ...
- The HashMap stores the presents under the old hashcodes
- But looks them up calculating the new ones
- $\Rightarrow$ FAIL!

Merry Christmas