Why is software always crashing?

Are we lazy or just not clever enough to code?

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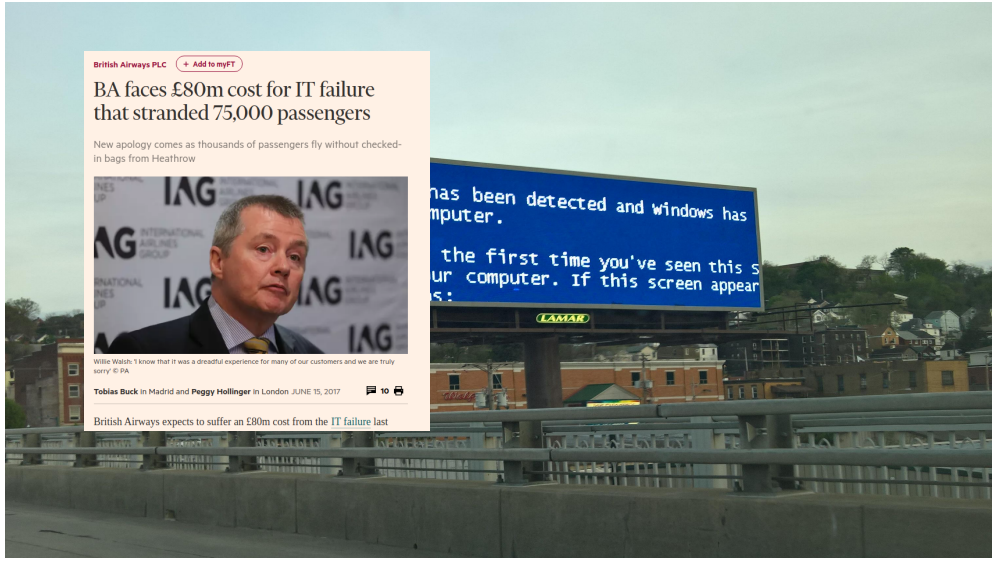

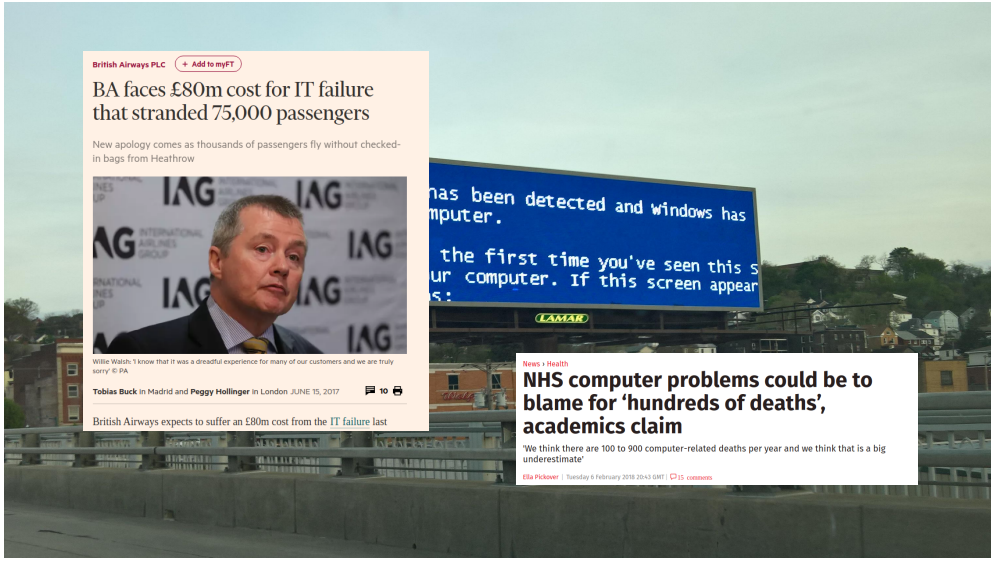

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Why?

A small example: what triangle do I have?

Our program

Given: The length of three lines
Answer: Do the three lines form a triangle?

```
> testTriangle(1,2,3);
val it = Error: triangle

> testTriangle(2,2,2);
val it = Equilateral: triangle

> testTriangle(1,2,2);
val it = Isosceles: triangle

> testTriangle(2,4,5);
val it = Scalene: triangle
```

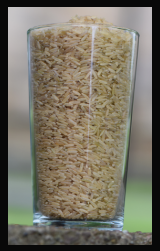
A small example what triangle do I have?

Is our program correct?

- We tested 4 different inputs …
- The program has 3 inputs, each can take

$$2^{64}$$

different values



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$$2^{64} = 1'844'6744'073'709'551'616$$

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$$2^{64} = 1'844'6744'073'709'551'616$$

different values

- Assume we can test 1'000'000 per second it takes 584'942 to test them all!
- But we have three nputs:

$$3^{2^{64}} = 11'790'184'577'738'583'171'520'872'861'$$
$$412'518'665'678'211'592'275'841'109'096'961$$

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A small example what triangle do I have?

Let's have a look at our program

```
datatype triangle = Equilateral | Scalene | Isosceles | Error

fun isTriangle(x:int, y:int , z:int)
    = ( (z < (x+y)) andalso  (x < (x+z)) andalso (y < (x+z)))

fun testTriangle(x:int, y:int, z:int)
    = if isTriangle(x,y,z) then
          if x=y then if y=z then Equilateral
                             else Isosceles
                 else if y=z then Isosceles
                             else if x=z
                                  then Isosceles
                                  else Scalene
        else Error
```


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        else Error
```

21 tests are sufficient, to cover all branches ...

Can 21 tests convince you that the program is correct?

Can we do better?

We can prove the correctness mathematically!

```
lemma isosceles:
  assumes "x = y"
  and     "z ≠ x"
  and     "isTriangle x y z"
shows "testTriangle x y z = isosceles"
  using assms testTriangle_def
  by auto
```

Can we do better?

We can prove the correctness mathematically!

Verification can show the correctness (for all possible inputs)!

```
lemma isosceles:
  assu
                  isTriangle x y z"
  shows "testTriangle x y z = isosceles"
  using assms testTriangle_def
  by auto
```


Ensuring correctness, security, and safety

(Inductive) Verification

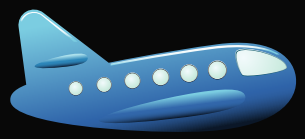
- Formal (mathematical) proof
- Can show absence of all failures relative to specification

Testing

- Execution of test cases
- Can show failures on real system

Is testing a "poor man's verification?"

Or: Why should I test if I verified my program (and vice versa)



- Fully formally verified
- Total number of flights: 0

- Fully tested
- Total number of flights: 1000

My vision

Combining testing and verification to ensure the security, safety, reliability, and correctness of (software) systems.

Any questions or remarks?

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