Bad Pairs in Software Testing

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Bad Pairs: Intuition

a	b	c	P/F
1	0	0	P
1	2	1	P
1	**2**	**3**	F
⋮	⋮	⋮	⋮
2	0	0	P
2	1	1	P
3	**2**	**3**	F
⋮	⋮	⋮	⋮
4	0	0	P
5	1	3	P
7	**2**	**3**	F
⋮	⋮	⋮	⋮

Overview

- Open questions
  - What is a useful formalization of *bad pair*?
  - How common are bad pairs?
  - What is the effect of input selection on bad pairs?
  - What is the relationship between faults and bad pairs?
- Experiments: triangle, TCAS
- Case study: industrial network vulnerability testing
- Powerful new theory result: error-locating arrays

Test Table, Singleton, and Pair

Test Table

Input Table			**Results Vector**
a	*b*	*c*	P/F
1	0	0	P
1	2	1	P
1	2	3	F
2	0	0	P
2	1	1	P
3	2	3	F
4	0	0	P
5	1	3	P
7	2	3	F
⋮	⋮	⋮	⋮

Bad Singleton

Test Table

Input Table			Results Vector
a	**b**	c	P/F
⋮	⋮	⋮	⋮
0	0	2	P
3	**1**	2	**F**
1	**1**	3	**F**
4	**1**	3	**F**
3	**1**	3	**F**
1	**1**	4	**F**
1	2	3	P
⋮	⋮	⋮	⋮

Dependent Bad Pair

Test Table

Input Table			Results Vector
a	**b**	**c**	P/F
⋮	⋮	⋮	⋮
0	0	2	P
3	1	2	F
1	**1**	**3**	**F**
4	**1**	**3**	**F**
3	**1**	**3**	**F**
1	1	4	F
1	2	3	P
⋮	⋮	⋮	⋮

Independent Bad Pair

Test Table

Input Table			**Results Vector**
a	**b**	**c**	P/F
⋮	⋮	⋮	⋮
0	2	2	P
⋮	⋮	⋮	⋮
3	2	2	F
1	**2**	**3**	**F**
4	**2**	**3**	**F**
3	**2**	**3**	**F**
1	2	4	P
⋮	⋮	⋮	⋮
1	3	3	P
⋮	⋮	⋮	⋮

Triangle: Experimental Design

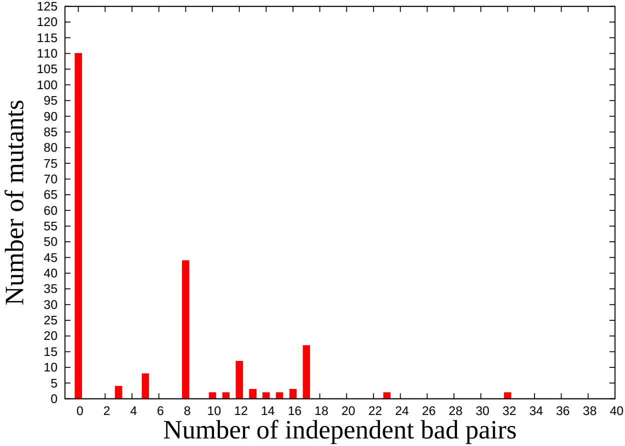
- Gold code: triangle program, hand-translated to Java
- Input table (216): $[0..5] \times [0..5] \times [0..5]$
- Mutants: single (213), double (212)
- Execution pseudocode

for each mutant M
    open log file L_M
    for each test case t
        run M with input t
        run the gold code with input t
        if M and the gold code produce the same output
            write t followed by 'P' to L_M
        else
            write t followed by 'F' to L_M
    close log file L_M

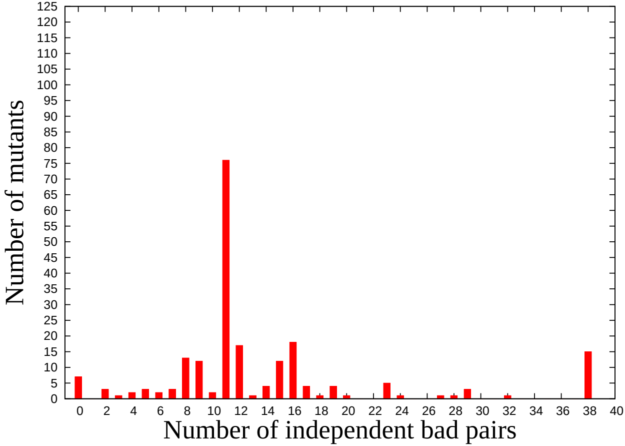
Triangle: source code

```
public static String triangle(
    int side1, int side2, int side3)
{
    int triang;
    if (side1 <= 0 || side2 <= 0 || side3 <= 0) {
        return "illegal";
    }
    triang = 0;

    if (side1 == side2) {
        triang = triang + 1;
    }
    if (side1 == side3) {
        triang = triang + 2;
    }
    if (side2 == side3) {
        triang = triang + 3;
    }

    if (triang == 0) {
        if (side1 + side2 <= side3 ||
            side2 + side3 <= side1 ||
            side1 + side3 <= side2) {
            return "illegal";
        } else {
            return "scalene";
        }
    }

    if (triang > 3) {
        return "equilateral";
    } else if (triang == 1 && side1 + side2 > side3) {
        return "isosceles";
    } else if (triang == 2 && side1 + side3 > side2) {
        return "isosceles";
    } else if (triang == 3 && side2 + side3 > side1) {
        return "isosceles";
    }

    return "illegal";
}
```

Triangle: Single Mutation Results



Triangle: Double Mutation Results: ROR



TCAS Experiments

- Gold code: TCAS program, hand-translated to Java
  - Seven functions; 109 LOC
- Input table
  - input parameters (12): values selected with equivalence partitioning
  - cross product: roughly 6 million elements
  - selected inputs (34): two-cover of the cross product
- Mutants (250): single mutation only
- Execution pseudocode: identical to Triangle

Network Vulnerability Testing: Case Study

- Gold code: object code in a programmable logic controller
  - no information on source code: language, size or structure
- Test table
  - packet capture file with 4734 IP packets
  - input parameters (11): field values extracted from IP header
  - two of the IP packets caused failures
- Which pairs in the two packets caused the failures?
  - each failed packet contains a single independent bad pair:
    1. (protocol:TCP, total length:0)
    2. (protocol:ICMP, total length:0)

Graph-based algorithms for bad pairs generation

- *Error-locating test case*: a test case containing exactly one independent bad pair
- *Error-locating array*: an input table containing at least one error-locating test case for each parameter pair

Conclusions

- Open questions
  - What is a useful formalization of *bad pair*?
  - How common are bad pairs?
  - What is the effect of input selection on bad pairs?
  - What is the relationship between faults and bad pairs?
- Triangle experiments
- TCAS Experiments
- Case study: industrial network vulnerability testing
- Powerful new theory result: error-locating arrays