Visualization of Test Information to Assist Fault Localization

James A. Jones, Mary Jean Harrold, John Stasko

Georgia Institute of Technology

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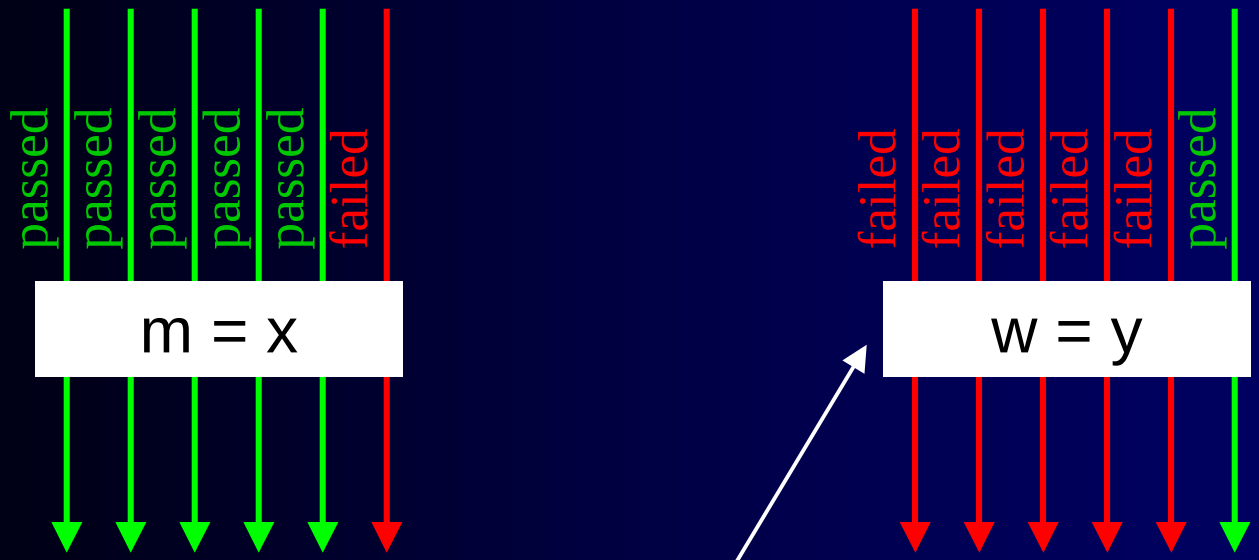
Information Interfaces

Outline

- Approach
- Demonstration of Prototype
- Case studies
- Related Work
- Conclusions & Future Work

Approach

Consider two statements



Approach

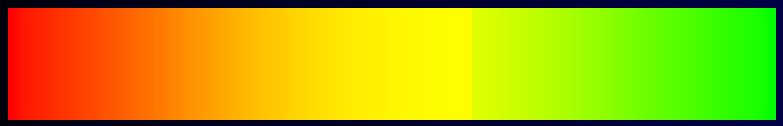
- Utilizes
  - pass/fail results of executing test cases
  - coverage provided by those test cases
  - source code of program under test
- Provides visualization of program statements that summarizes pass/fail status of test cases that covered them

Approach

For statement *s*:

Hue summarizes pass/fail results of test cases that executed *s*

Brightness presents the "confidence" of the hue assigned to *s*



Hue

- Summarizes pass/fail results
  - executed mostly by failed test cases → red
  - executed evenly by passed and failed → yellow
  - executed mostly by passed test cases → green
- Uses percentages of passed and failed test cases

$\frac{10}{10}$ failed test cases = 100%

```
m = y;
```

$\frac{20}{200}$ passed test cases = 10 %

$$\text{hue(s)} = \text{low hue (red)} + \frac{\%\text{passed(s)}}{\%\text{passed(s)} + \%\text{failed(s)}} * \text{hue range}$$

Hue

$\frac{10}{10}$ failed test cases = 100%

$\frac{0}{10}$ passed test cases = 0%

```
a = b;
```

$\frac{1}{10}$ failed test cases = 10%

$\frac{0}{10}$ passed test cases = 0%

```
c = d;
```

$\frac{10}{10}$ failed test cases = 100%

```
m = y;
```

$\frac{20}{200}$ passed test cases = 10 %

$$\text{hue(s)} = \text{low hue (red)} + \frac{\%\text{passed(s)}}{\%\text{passed(s)}+\%\text{failed(s)}} * \text{hue range}$$

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Brightness

- Shows the amount of coverage for a statement
- Uses greater percentage of passed and failed to show confidence in hue assigned

$\frac{10}{10}$ failed test cases = 100%

```
m = y;
```

$\frac{20}{200}$ passed test cases = 10 %

$$\text{bright}(s) = \max(\%\ \text{passed}(s), \%\ \text{failed}(s))$$

Example

```
   mid() {
    int x,y,z,m;
1:  read("Enter 3 numbers:",x,y,z);
2:  m = z;
3:  if (y<z)
4:     if (x<y)
5:           m = y;
6:     else if (x<z)
7:           m = y;
8:  else
9:     if (x>y)
10:          m = y;
11:    else if (x>z)
12:          m = x;
13: print("Middle number is:", m);
   }
```

	Test Cases					
	3,3,5	1,2,3	3,2,1	5,5,5	5,3,4	2,1,3
1	•	•	•	•	•	•
2	•	•	•	•	•	•
3	•	•	•	•	•	•
4	•	•			•	•
5		•				
6	•				•	•
7	•					•
8			•	•		
9			•	•		
10			•			
11				•		
12						
13	•	•	•	•	•	•
Pass Status:	P	P	P	P	P	F

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Example

```
   mid() {
    int x,y,z,m;
1:  read("Enter 3 numbers:",x,y,z);
2:  m = z;
3:  if (y<z)
4:     if (x<y)
5:        m = y;
6:     else if (x<z)
7:        m = y;
8:  else
9:     if (x>y)
10:       m = y;
11:    else if (x>z)
12:       m = x;
13: print("Middle number is:", m);
   }
```

Test Cases	3,3,5	1,2,3	3,2,1	5,5,5	5,3,4	2,1,3
1:	•	•	•	•	•	•
2:	•	•	•	•	•	•
3:	•	•	•	•	•	•
4:	•	•			•	•
5:		•				
6:	•				•	•
7:	•					•
8:			•	•		
9:			•	•		
10:			•			
11:				•		
12:						
13:	•	•	•	•	•	•
Pass Status:	P	P	P	P	P	F

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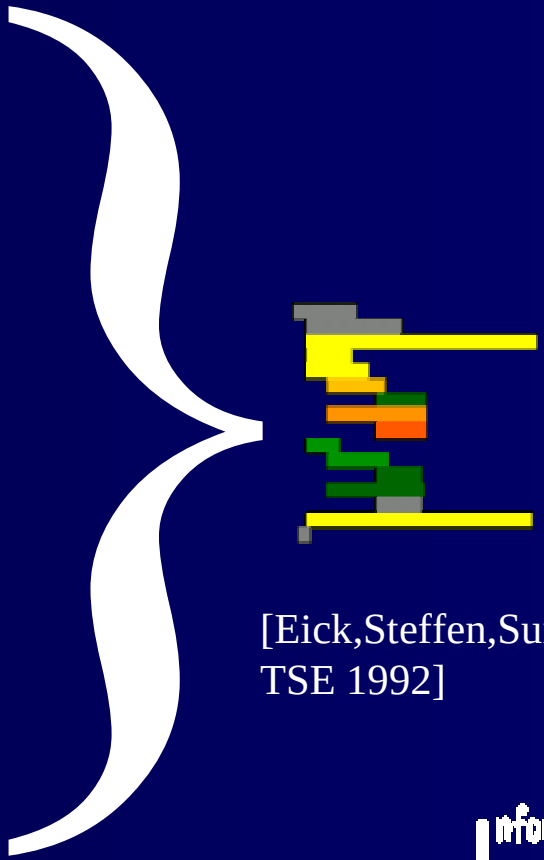
Scalability

- Large programs difficult to display
- Use the line-of-pixels, SeeSoft, view
- Each character in the source is displayed as a pixel

```
mid() {
 int x,y,z,m;
 read("Enter 3 numbers:",x,y,z);
 m = z;
 if (y<z)
    if (x<y)
           m = y;
    else if (x<z)
           m = y;
 else
    if (x>y)
           m = y;
    else if (x>z)
           m = x;
 print("Middle number is:", m);
}
```



[Eick,Steffen,Sumner, TSE 1992]

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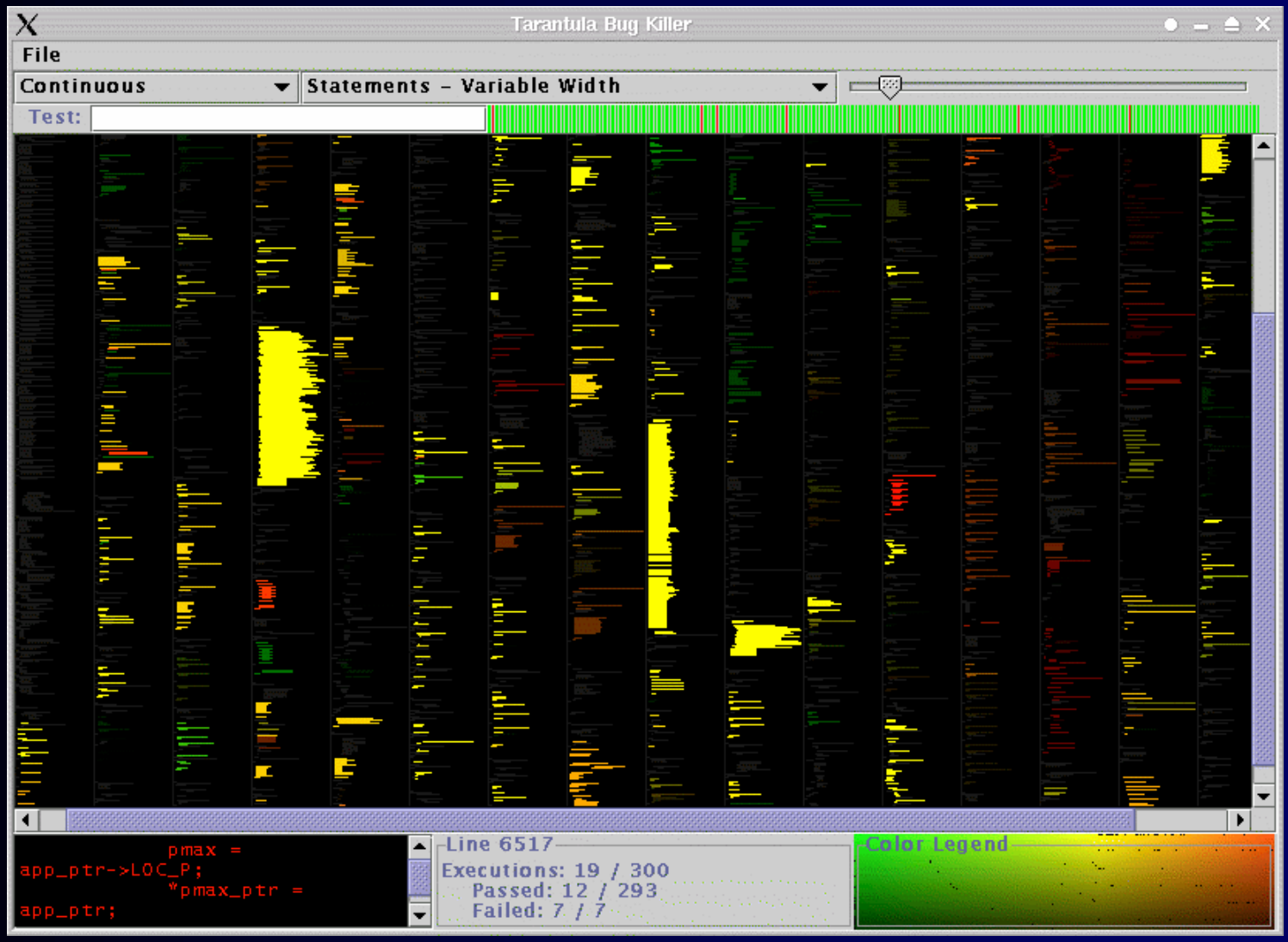
Tarantula



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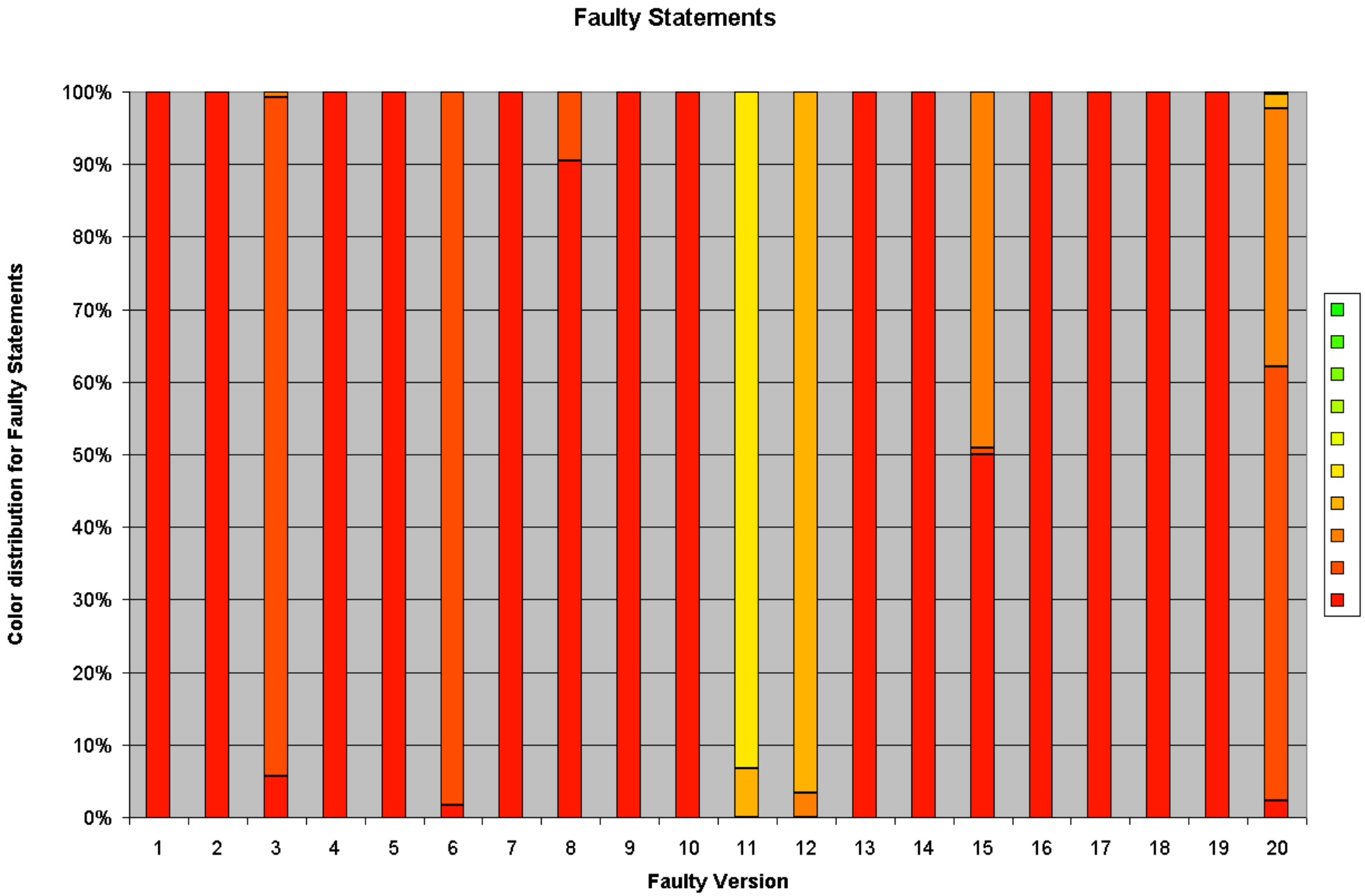
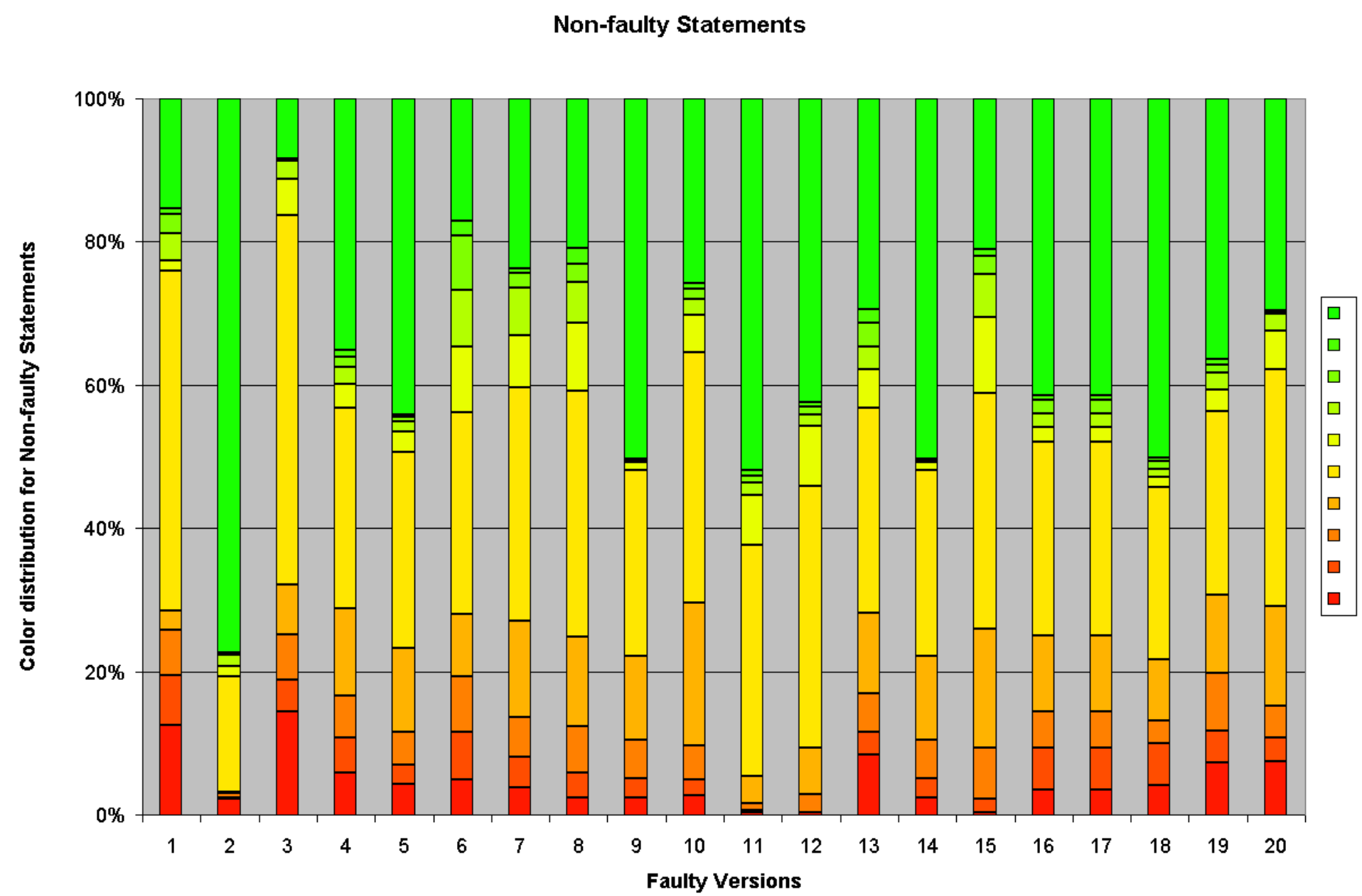
Case Studies

- Two initial studies
  - How red are the faulty statements?
  - How red are the non-faulty statements?
- Subject program: Space
  - 8000 lines of executable code
  - 1000 coverage-based test suites of size 156-4700 test cases
  - 20 faulty versions


Faulty Statements
Color distribution for Faulty Statements
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Faulty Version


Non-faulty Statements
Color distribution for Non-faulty Statements
100%
80%
60%
40%
20%
0%
1
2
3
4
5
6
7
8
9
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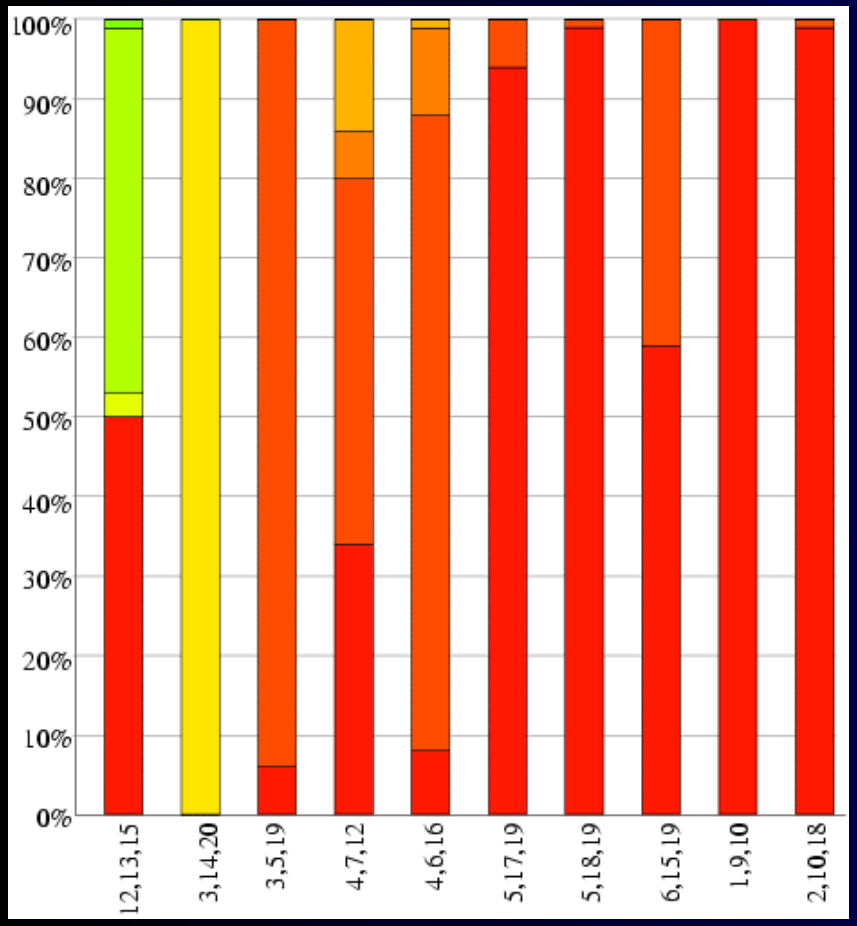
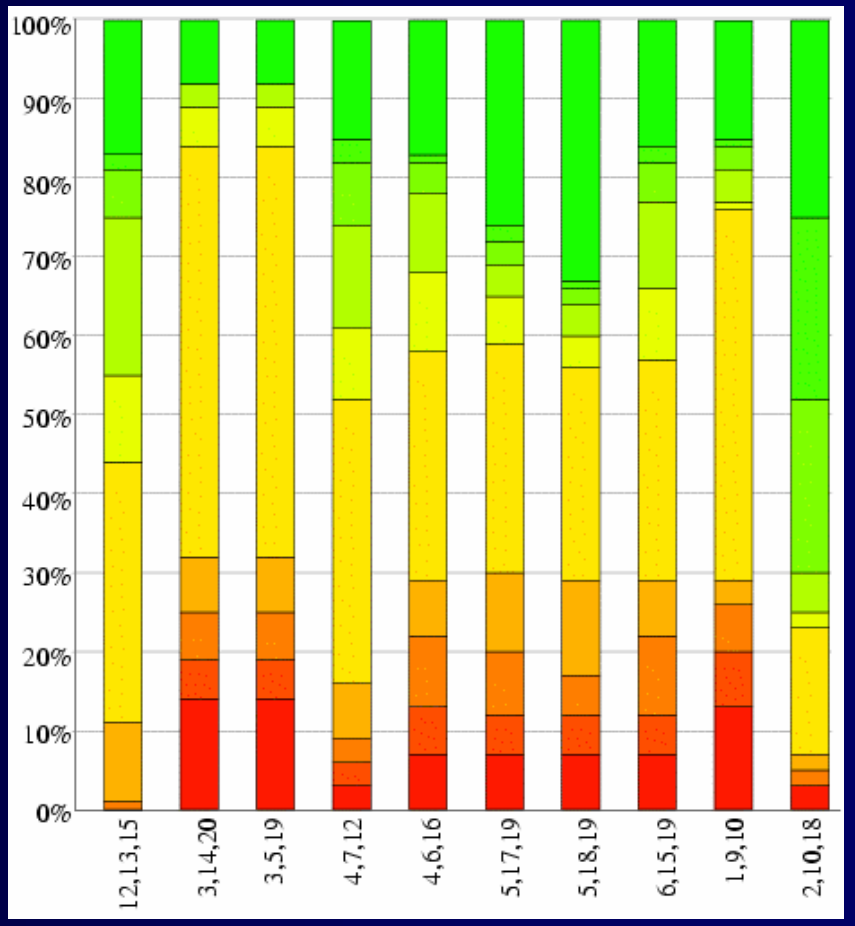
11
12
13
14
15
16
17
18
19
20
Faulty Versions

Three Faults



Faulty statements



Non-faulty statements

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Related Work

- Eick, et al. [TSE92]: SeeSoft visualizes coverage and slices
- Agrawal, Horgan, et al. [ISSRE95]: uses set arithmetic to compute dice for fault localization
- Leon, Podgurski, et al. [ICSE00]: visualize test case behavior using multivariate analysis

Conclusion & Future Work

- New technique that efficiently narrows search space for faults using commonly available information
- Promising results from studies

- Perform more empirical studies
- Create techniques to help when no statements are red
- Provide editing and dynamic update capabilities