# Fine-Tuning Spectrum Based Fault Localisation with Frequent Method Item Sets

**Gulsher Laghari**, Alessandro Murgia and Serge Demeyer

ASE`2016 - September 6, 2016

Ansymo
Antwerp Systems & Software Modelling
University of Antwerp

Universiteit Antwerpen

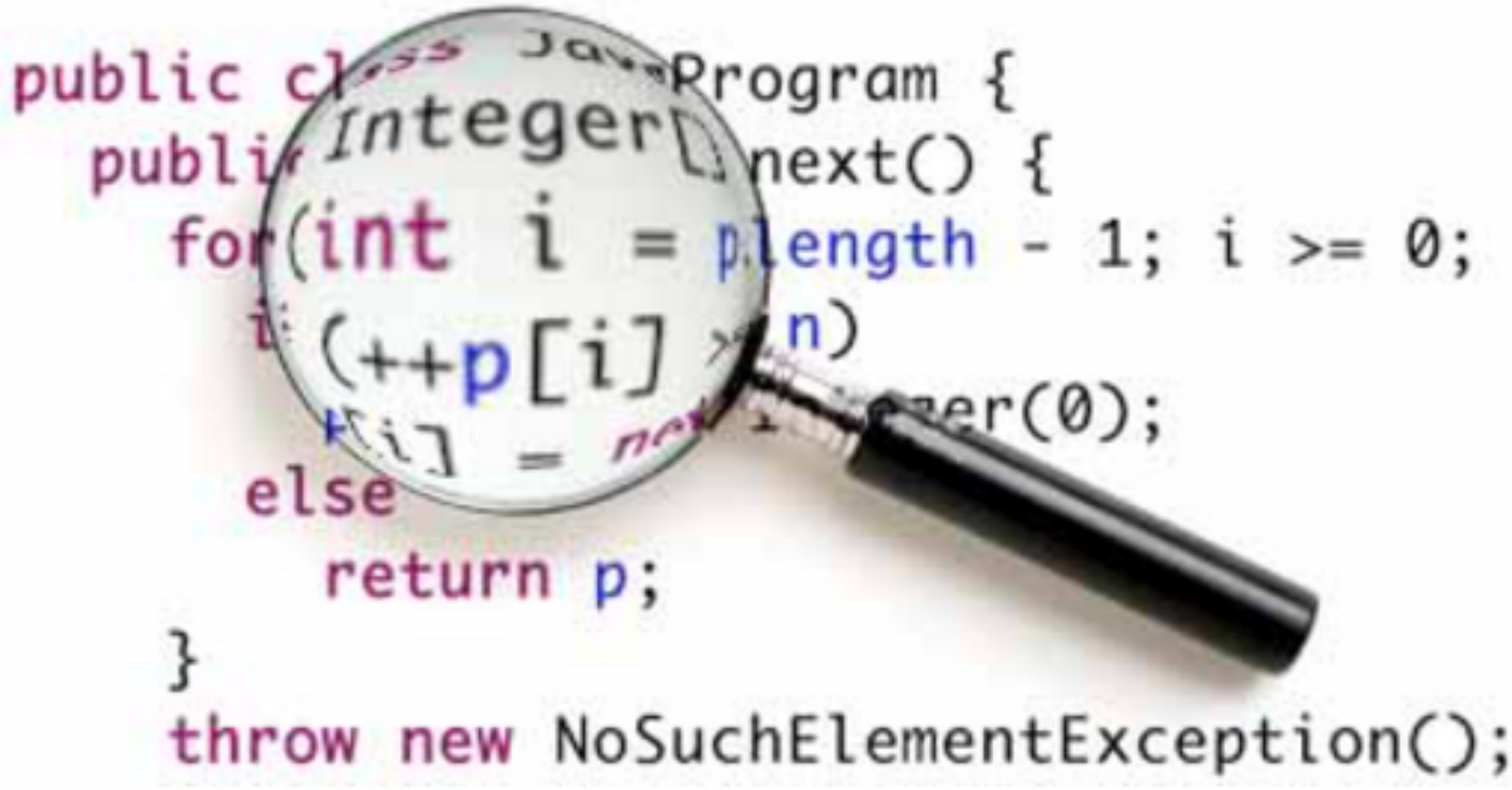
# Overview


CHANGES
CHANGES
CHANGES
CHANGES

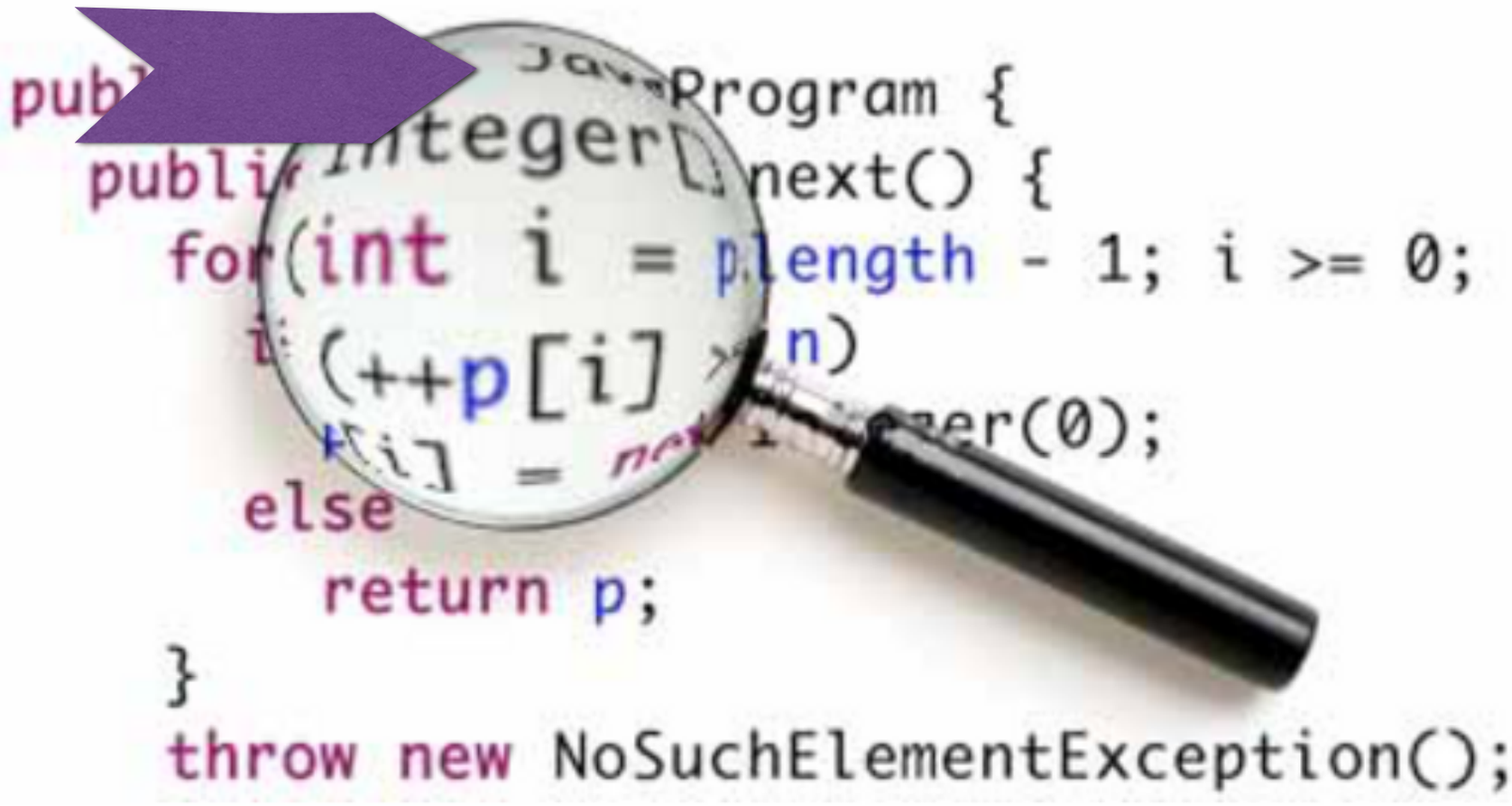

class
class
class Token{
char
char

# Fault Localisation

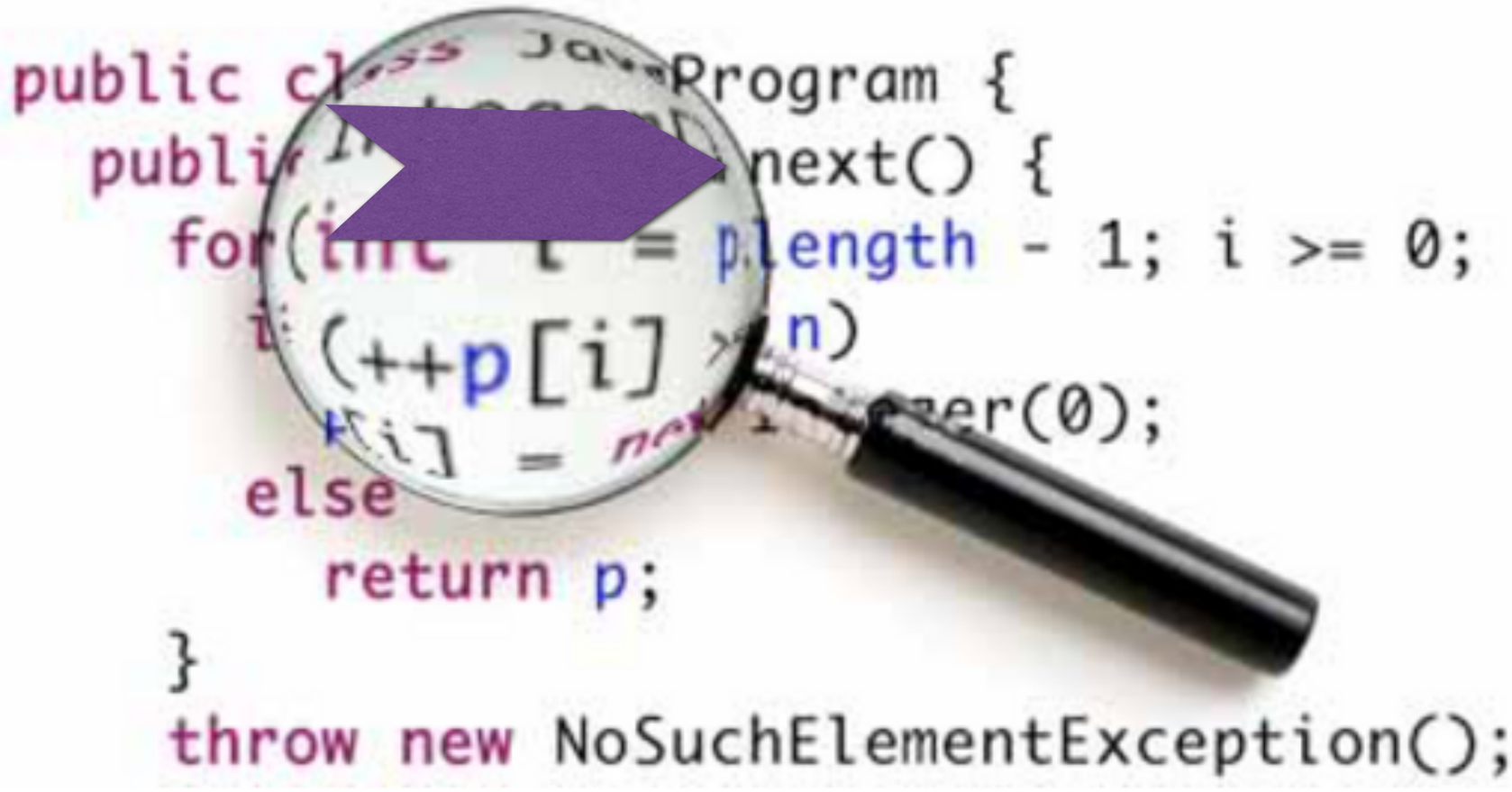
## Fault Localisation an important step in the Debugging



# Fault Localisation

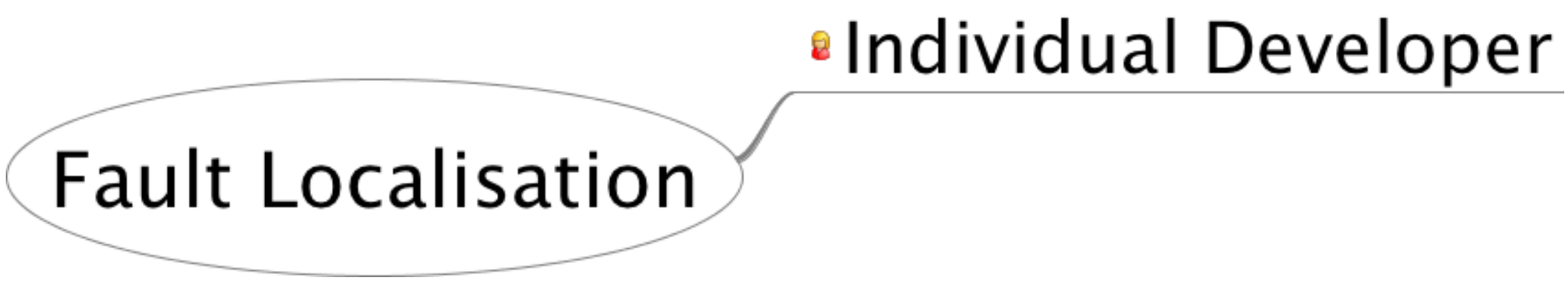


# Fault Localisation

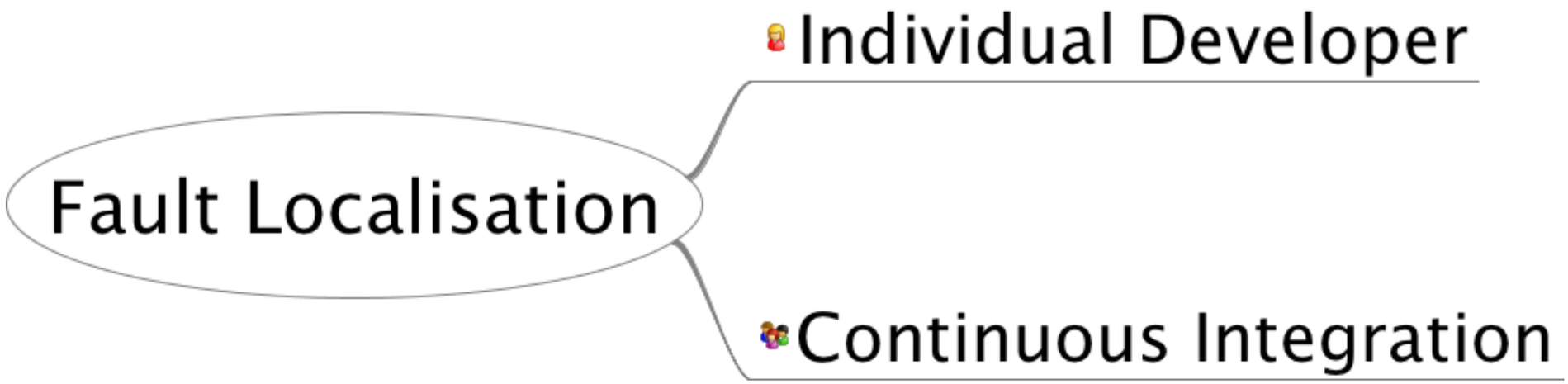


# Fault Localisation

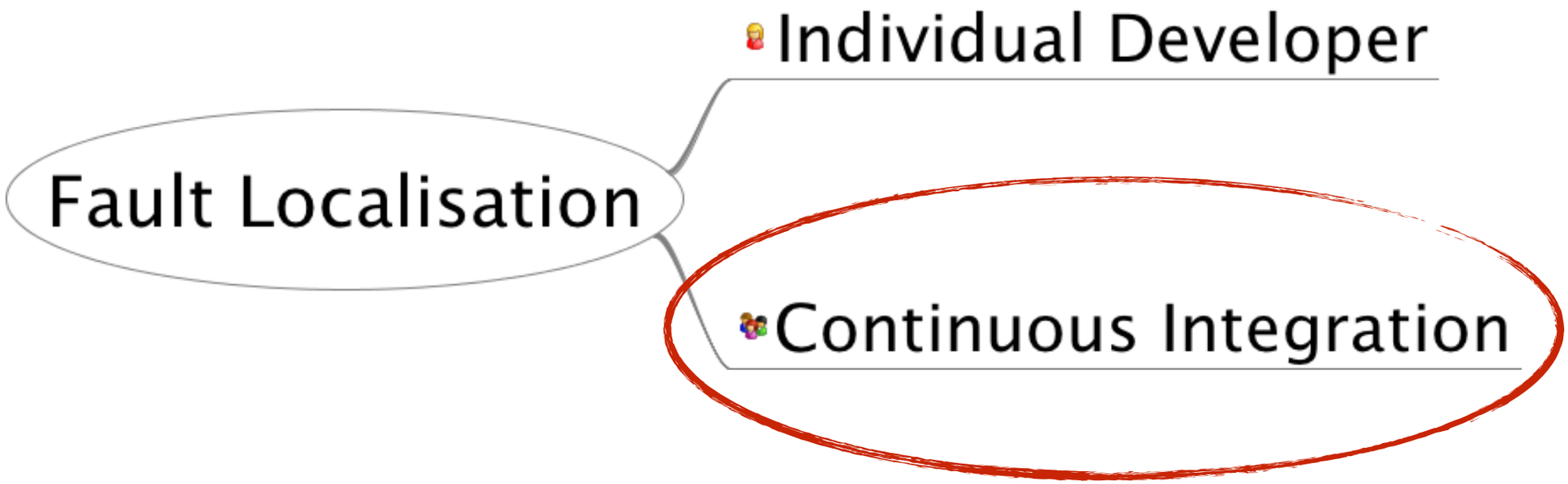
# Fault Localisation Applications



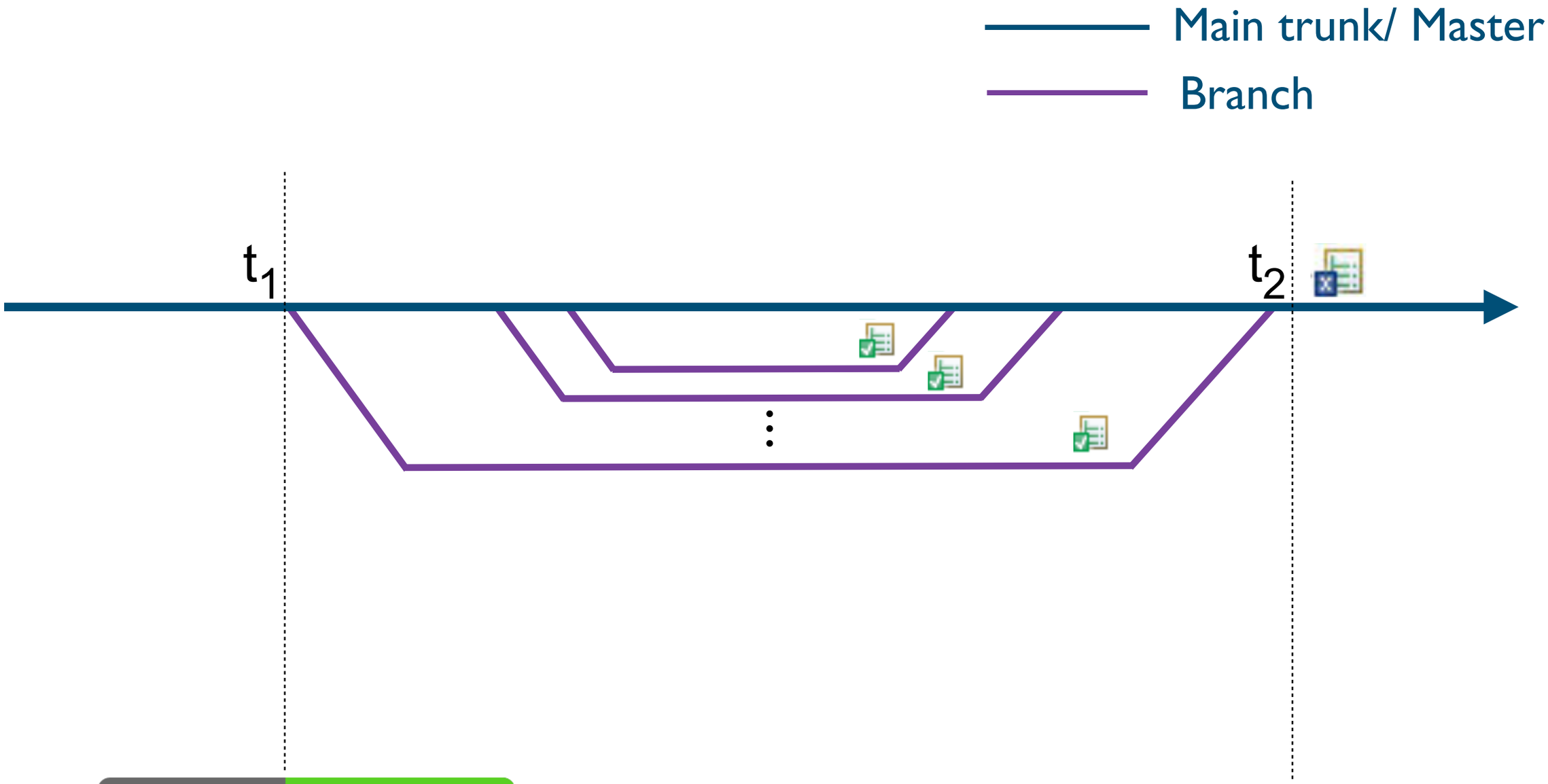
# Fault Localisation Applications



# Fault Localisation Applications



# Continuous Integration Scenario




build passing

Nightly build fail

# Spectrum Based Fault Localisation

## 1. Input

Faulty Program


Test code

## 2. Process

1 Run Tests and Collect traces

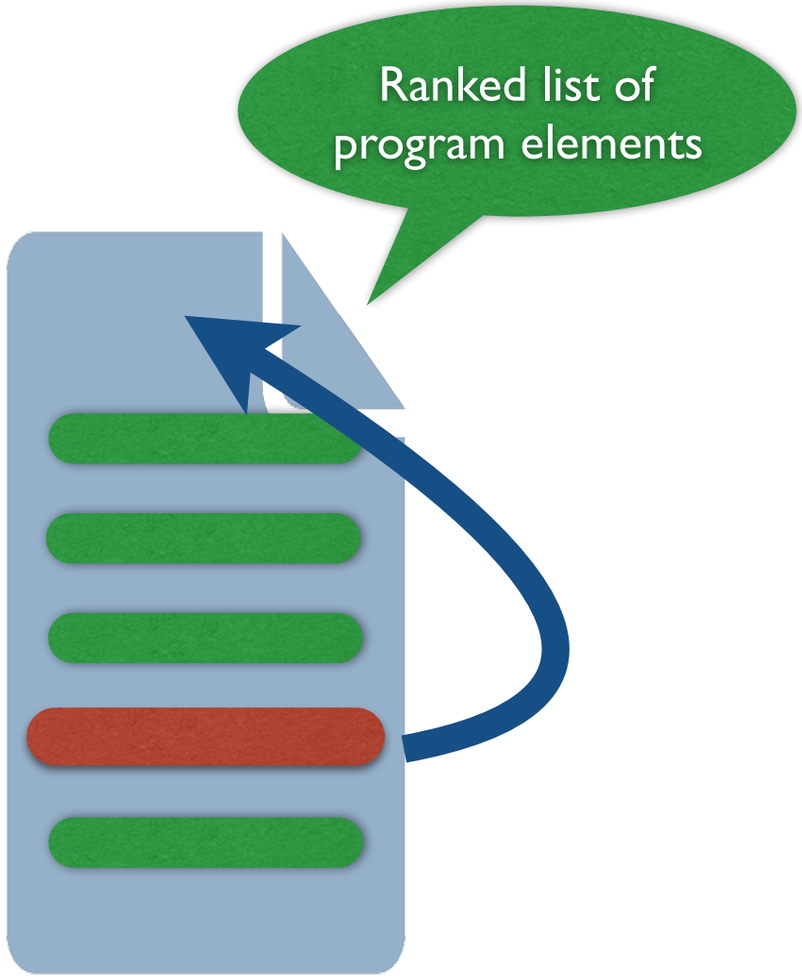
2 Build Program Spectrum

3 Rank Program Elements

## 3. Output

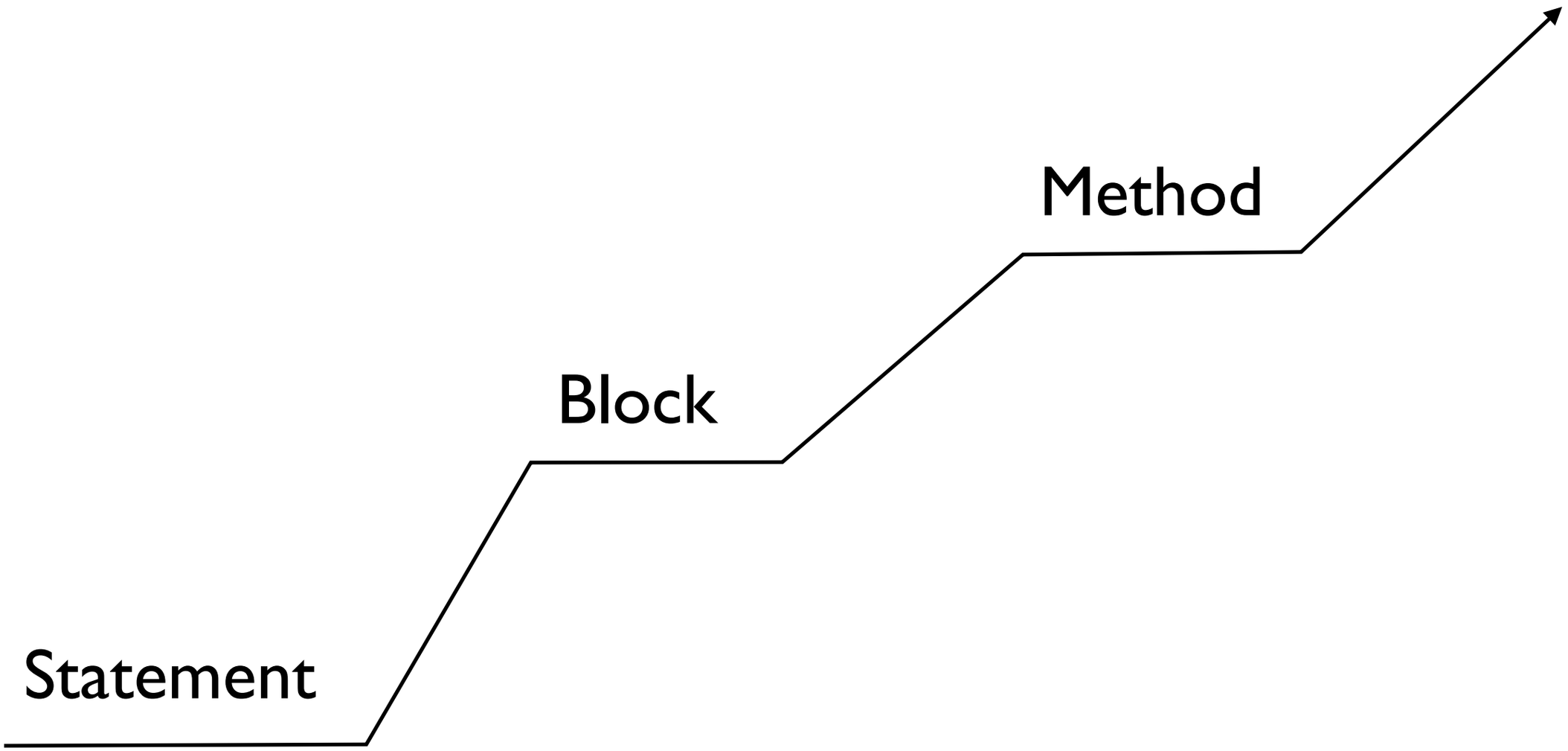
Ranked list of program elements

# Spectrum Based Fault Localisation

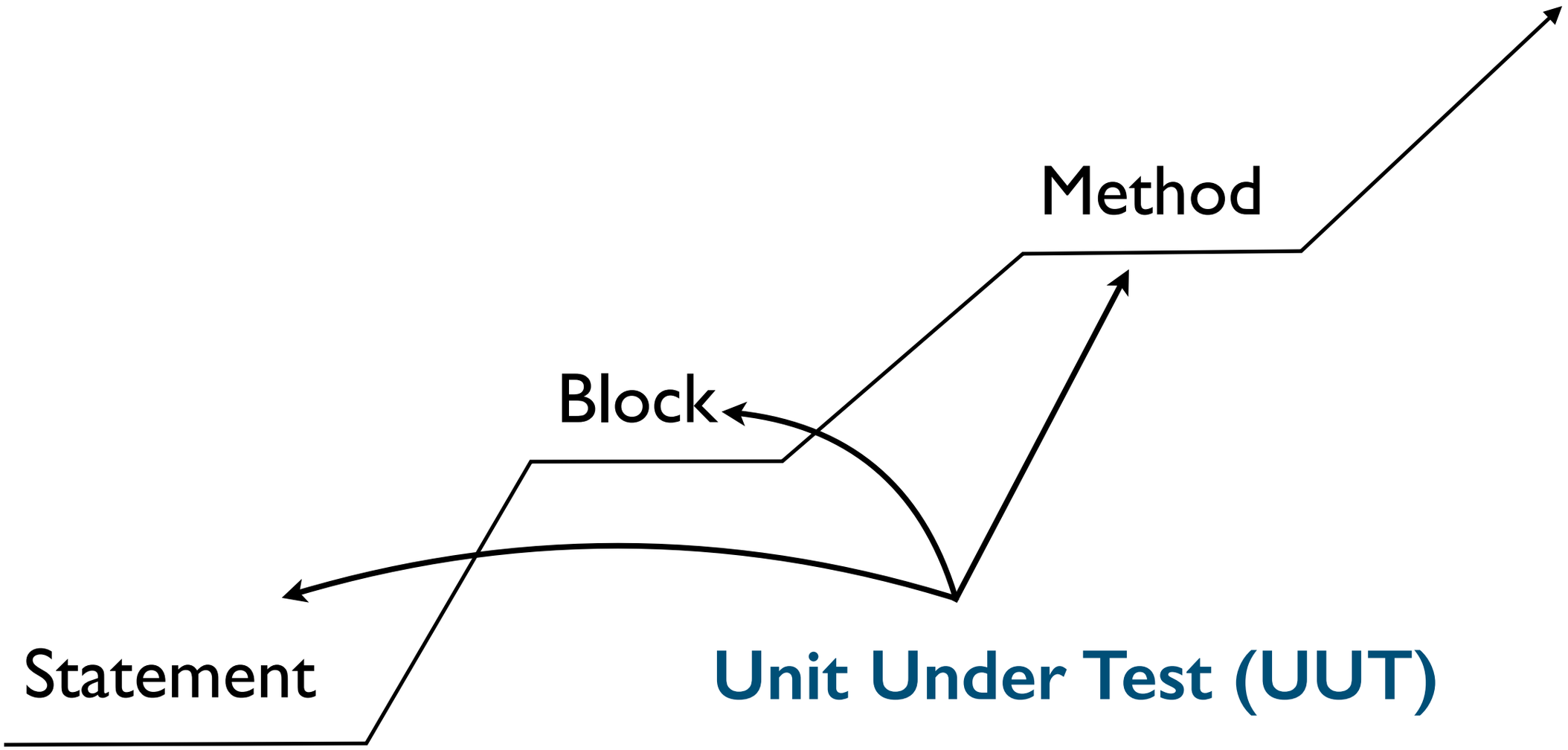
# Spectrum Based Fault Localisation

## Program Element Granularity



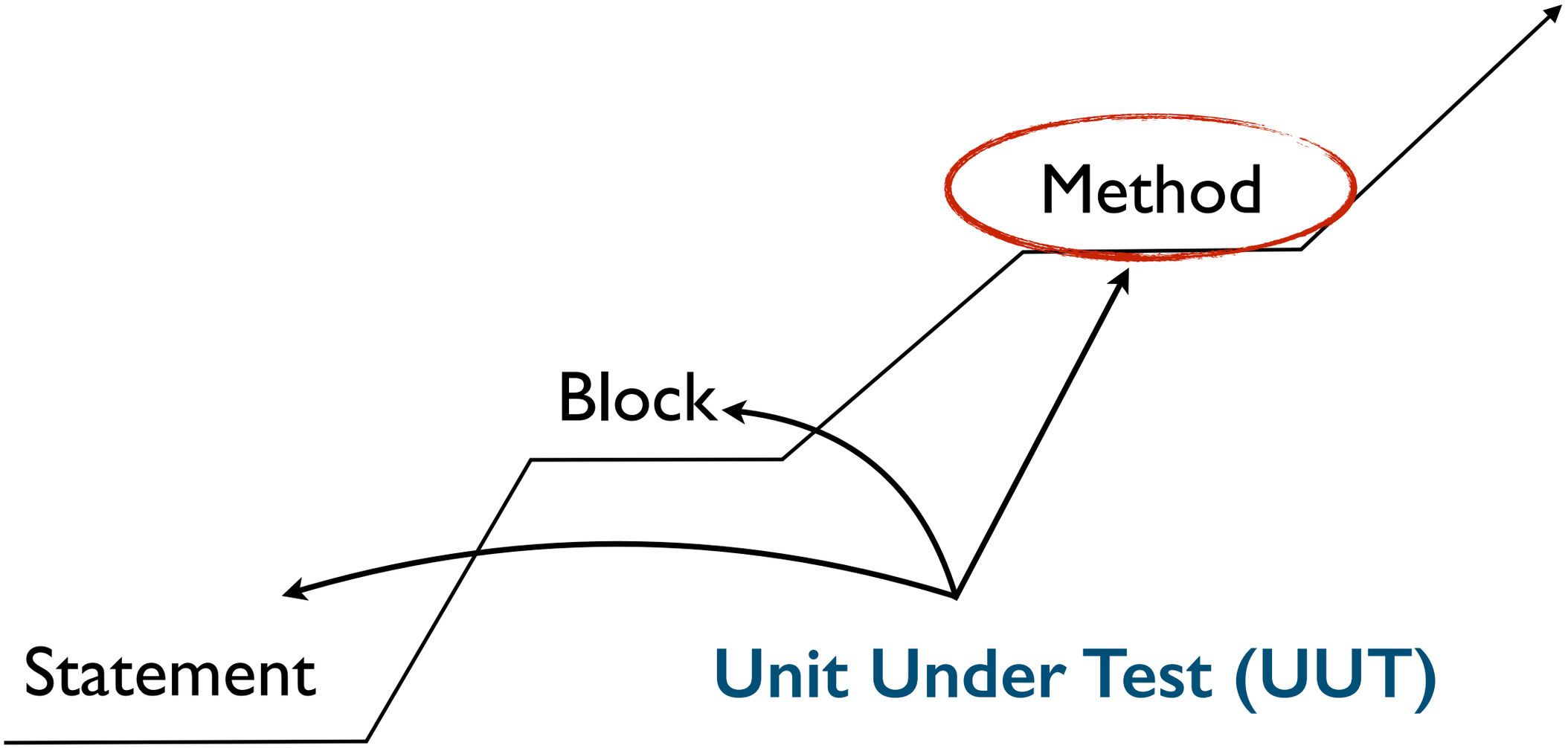
# Spectrum Based Fault Localisation

## Program Element Granularity



# Spectrum Based Fault Localisation

## Program Element Granularity



# Spectrum Based Fault Localisation

## Hit Spectrum

$$\text{UUT} = (e_f, e_p, n_f, n_p)$$

$e_f$ = number of failing test cases that execute the UUT

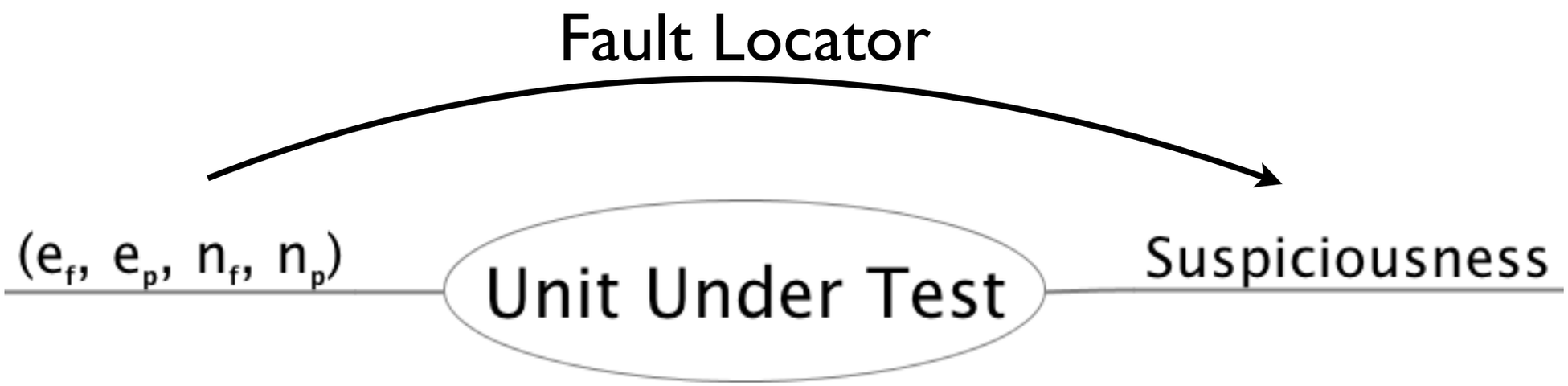
$e_p$ = number of passing test cases that execute the UUT

$n_f$ = number of failing test cases that do *not* execute the UUT

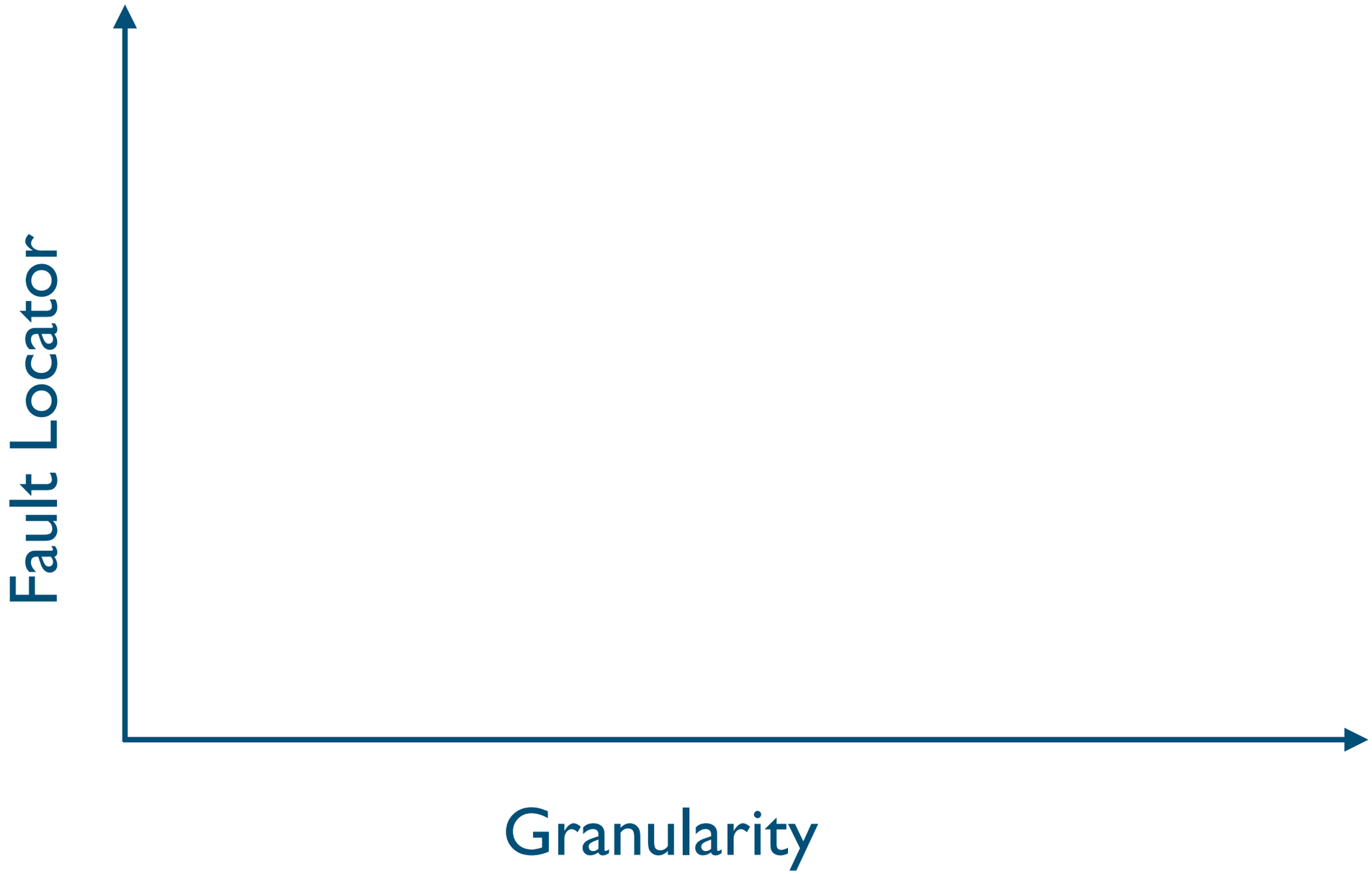
$n_p$ = number of passing test cases that do *not* execute the UUT

# Spectrum Based Fault Localisation

## Fault Locator



# Spectrum Based Fault Localisation



# Spectrum Based Fault Localisation

# Spectrum Based Fault Localisation

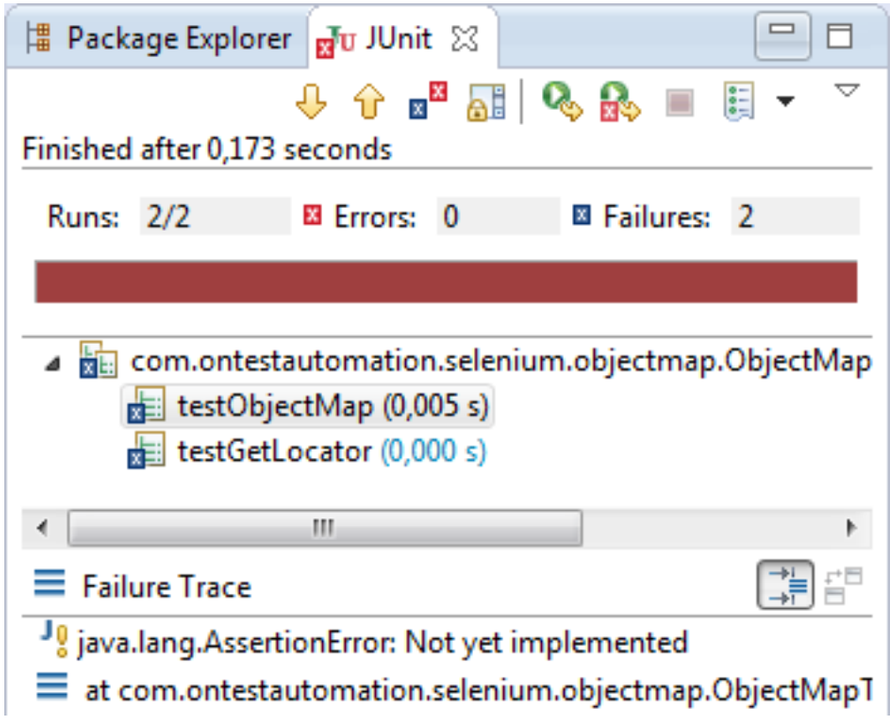
## Missing

Fault

```
public void method1(){
        ……
        methodA()
        methodB()
        if(condition){
          return
        }
        ……
        methodC()
        ……
}
```

# Spectrum Based Fault Localisation

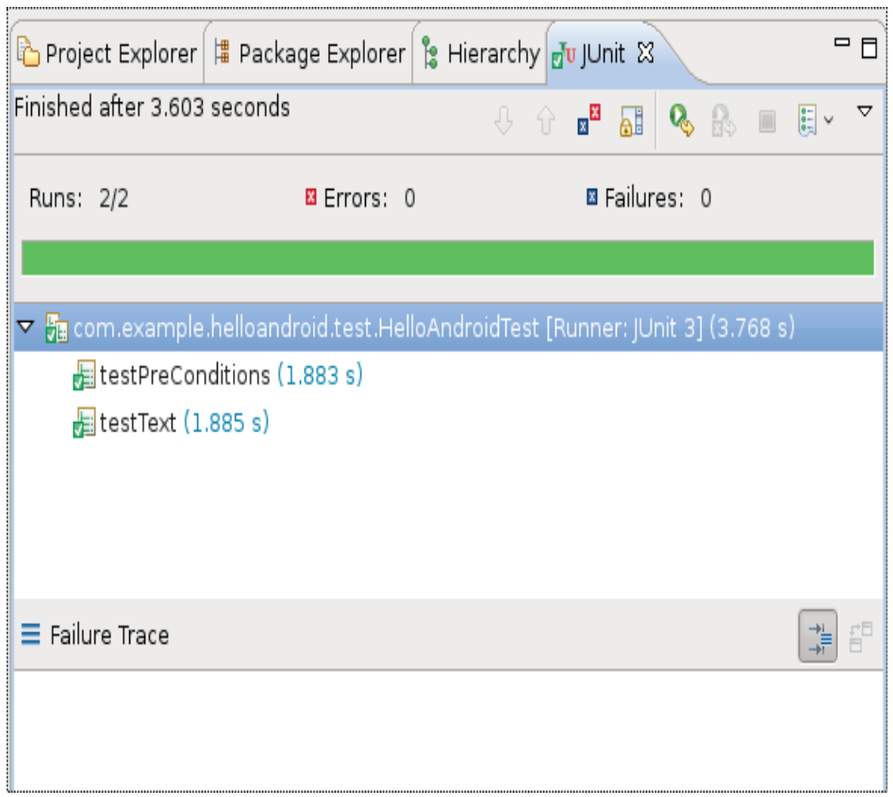
## Missing




```
public void method1(){
        ……….
        methodA()
        methodB()
        if(condition){
           return
        }
        ……….
        methodC()
        ……….
}
```

# Spectrum Based Fault Localisation

## Missing




```
public void method1(){
    ..........
    methodA()
    methodB()
    if(condition){
        return
    }
    ..........
    methodC()
    ..........
}
```

# Spectrum Based Fault Localisation

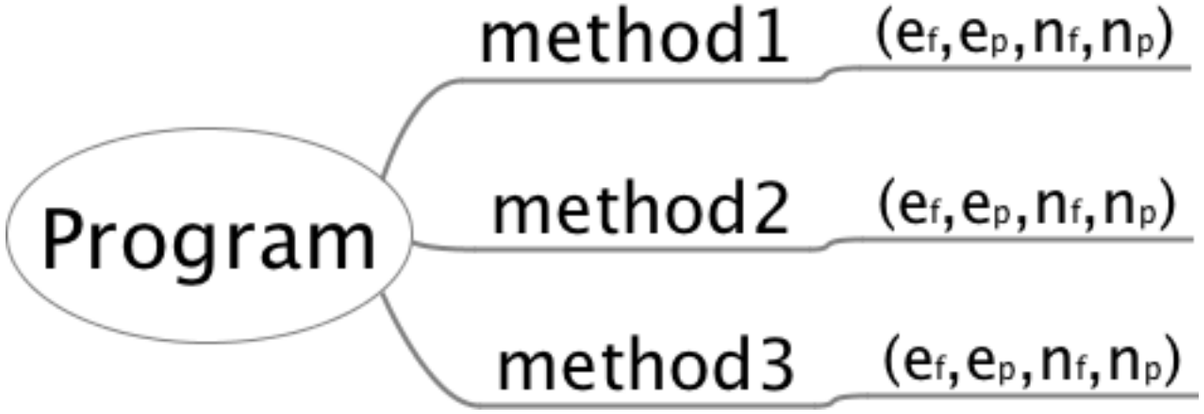
## Missing

```
public void method1(){
        ..........
          methodA()
          methodB()
          if(condition){
            return
          }
          ..........
          methodC()
          ..........
}
```

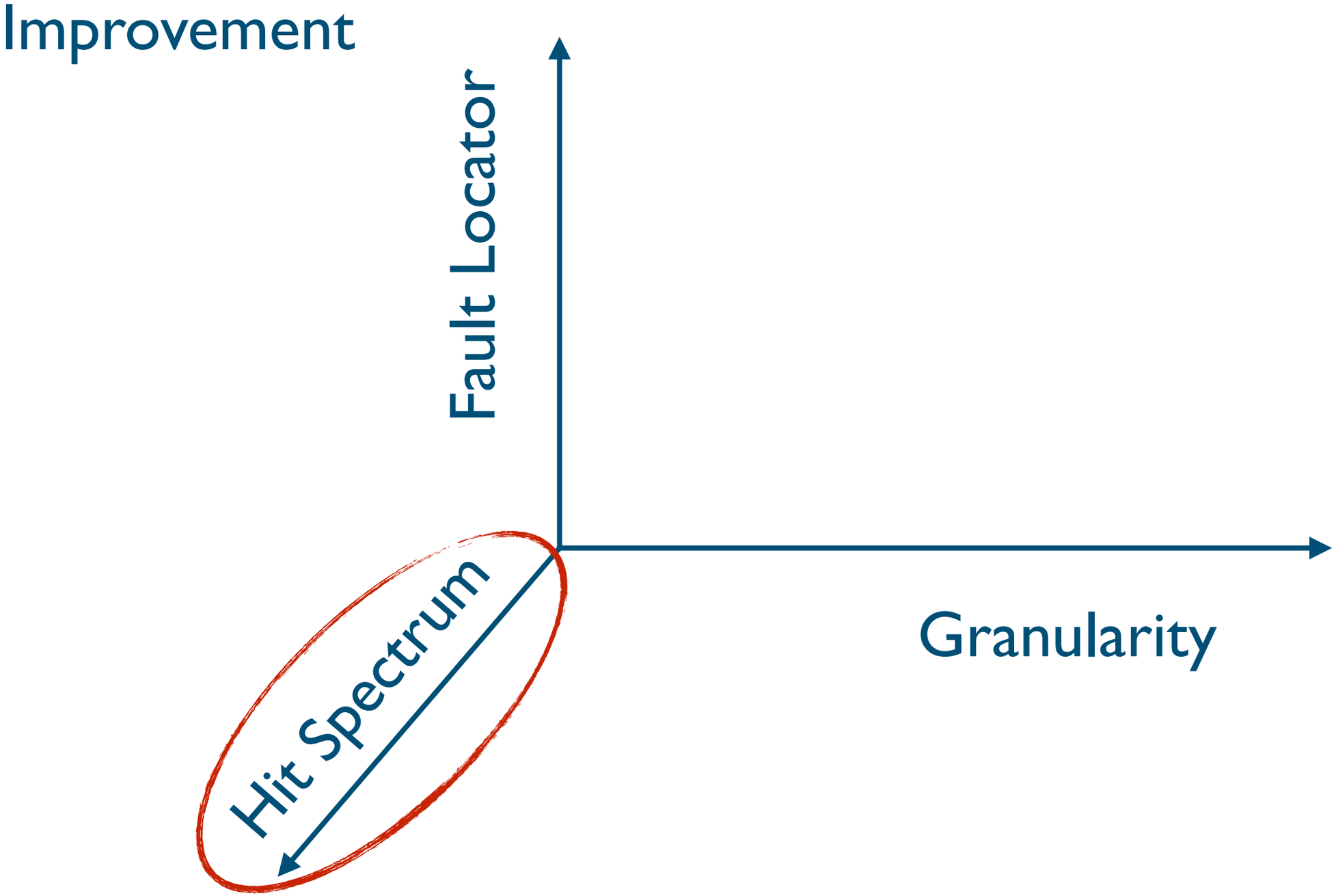
# Spectrum Based Fault Localisation

## Missing

Raw Spectrum Analysis

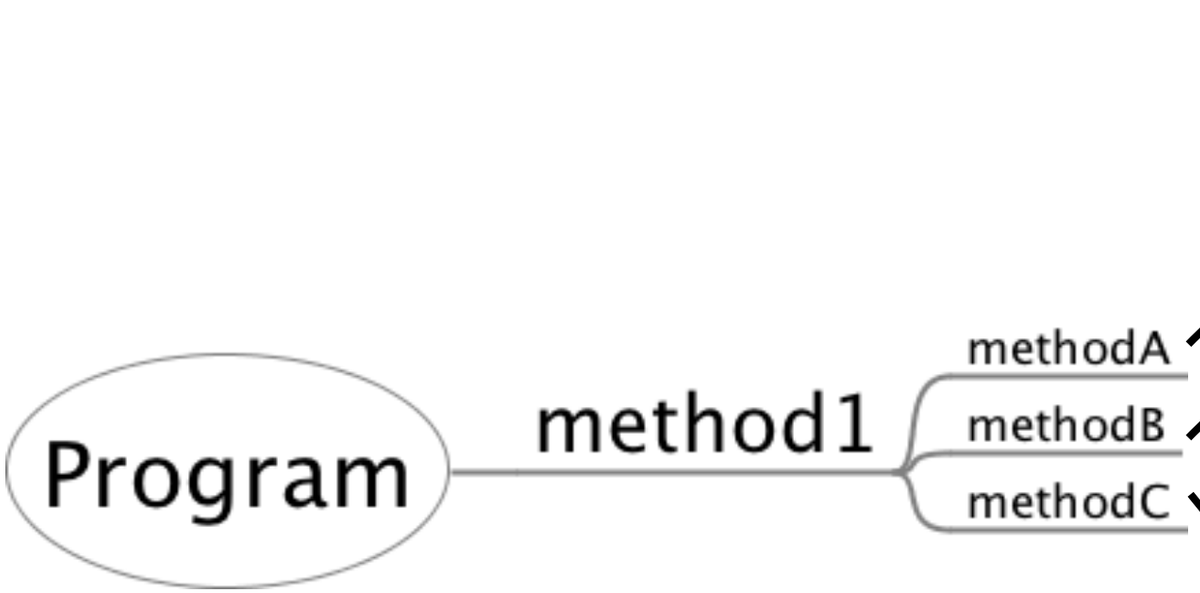


# Spectrum Based Fault Localisation



# Spectrum Based Fault Localisation

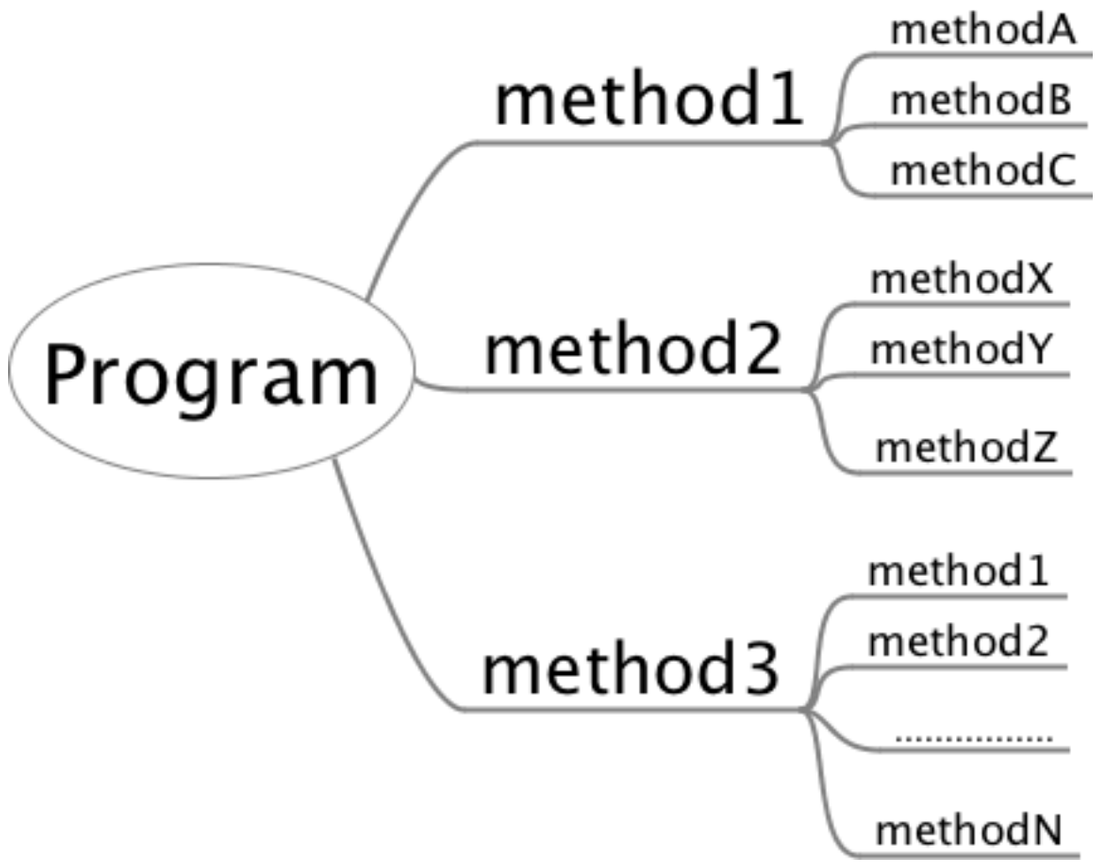
## Improvement




```
public void method1(){
    ..........
    methodA()
    methodB()
    if(condition){
       return
    }
    ..........
    methodC()
    ..........
}
```

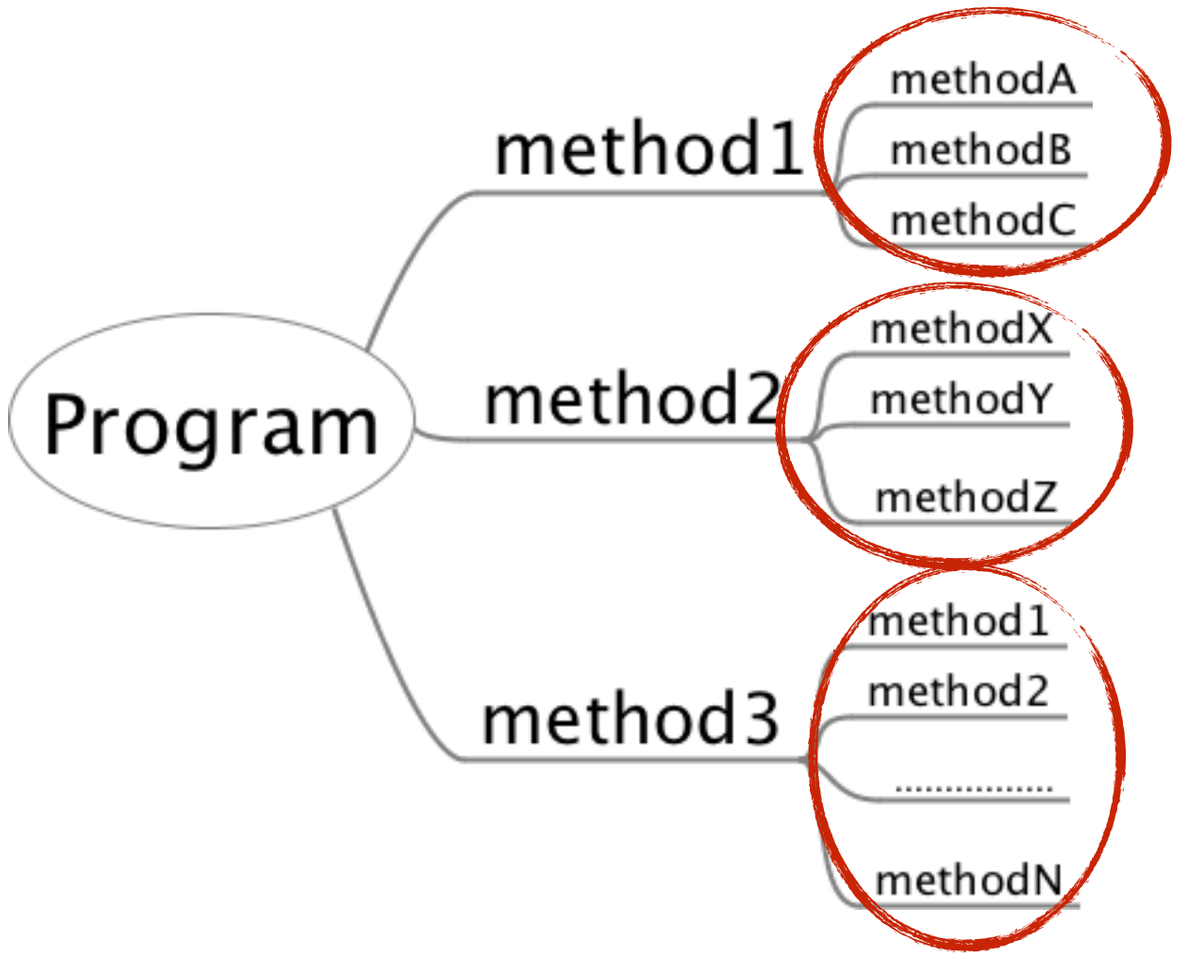
# Spectrum Based Fault Localisation

## Improvement



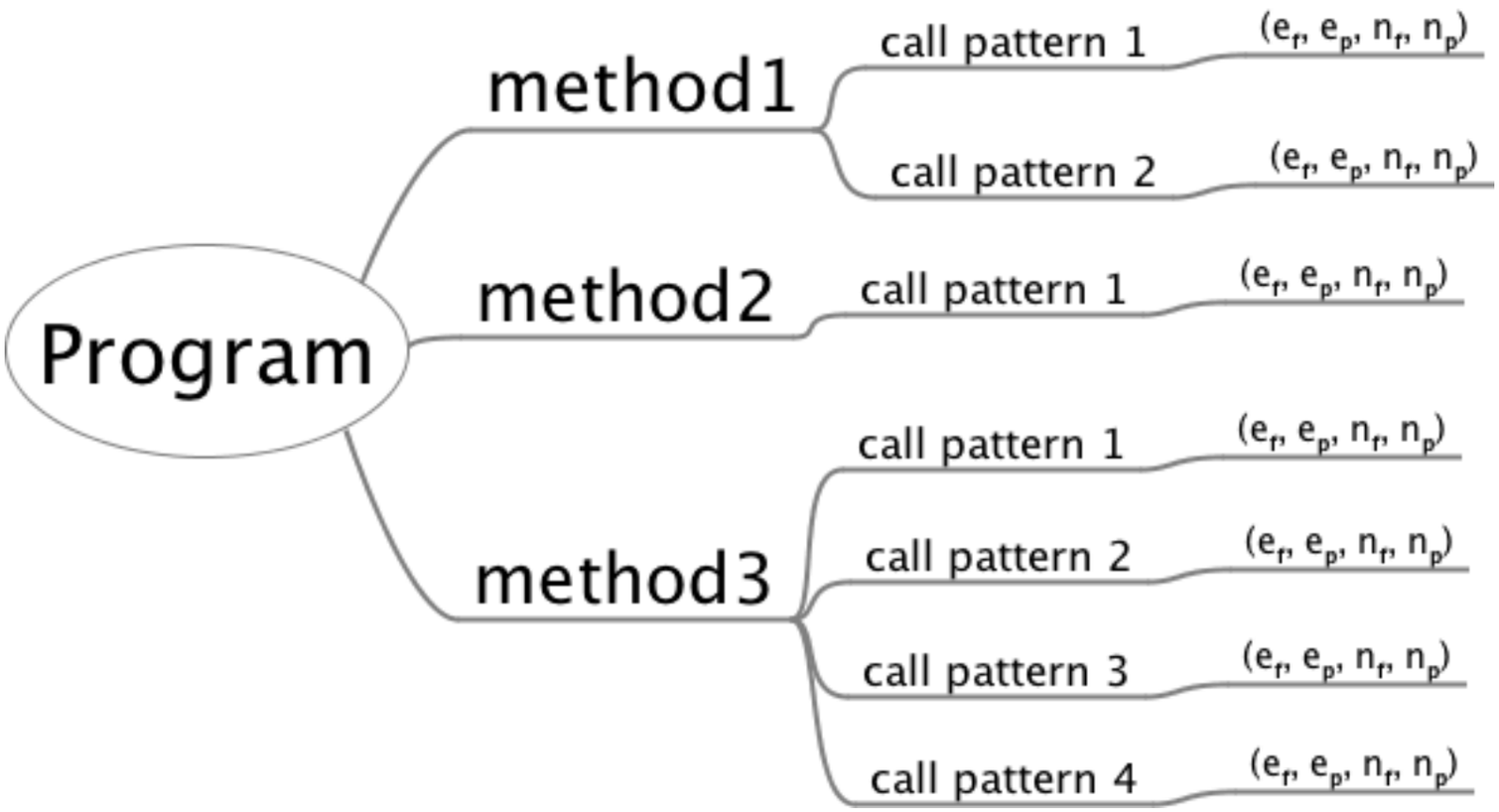
# Spectrum Based Fault Localisation

## Improvement



# Spectrum Based Fault Localisation

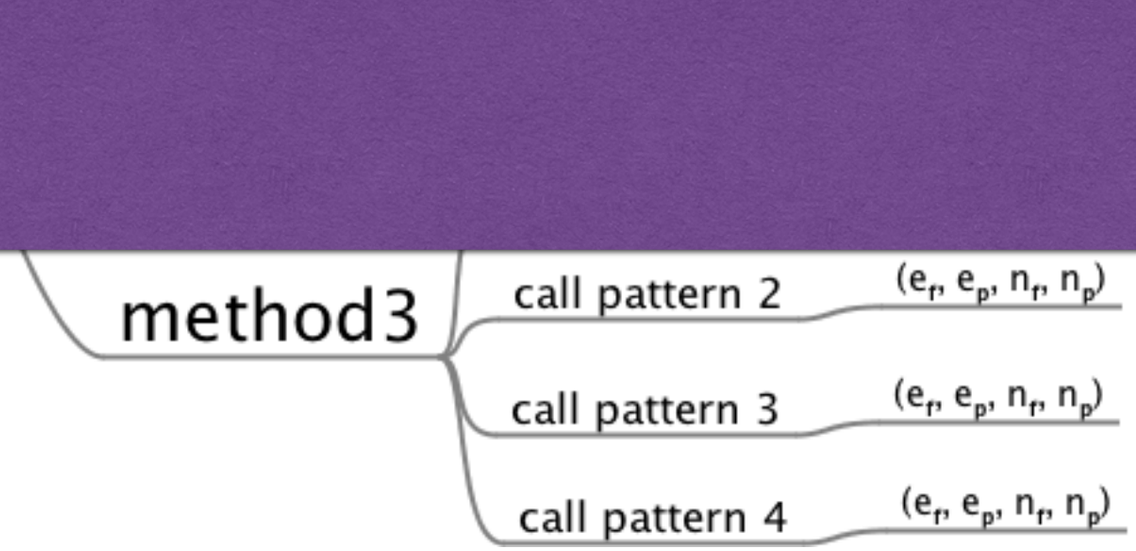
## Improvement



# Spectrum Based Fault Localisation

## Improvement

### Patterned Spectrum Analysis



# Case Study

# Case Study

## Dataset: Defects4J


| Project | Bugs | Source KLoC | Test KLoC | Tests | Methods Triggered (μ) | Methods Triggered (σ ) |
|---|---|---|---|---|---|---|
| **Math** | 104 | 85 | 19 | 3602 | 153 | 141 |
| **Lang** | 62 | 22 | 6 | 2245 | 89 | 55 |
| **Time** | 26 | 28 | 53 | 4130 | 586 | 210 |
| **Chart** | 26 | 96 | 50 | 2205 | 307 | 408 |
| **Closure** | 133 | 90 | 83 | 7927 | 2043 | 1228 |

# Case Study

## Evaluation metric



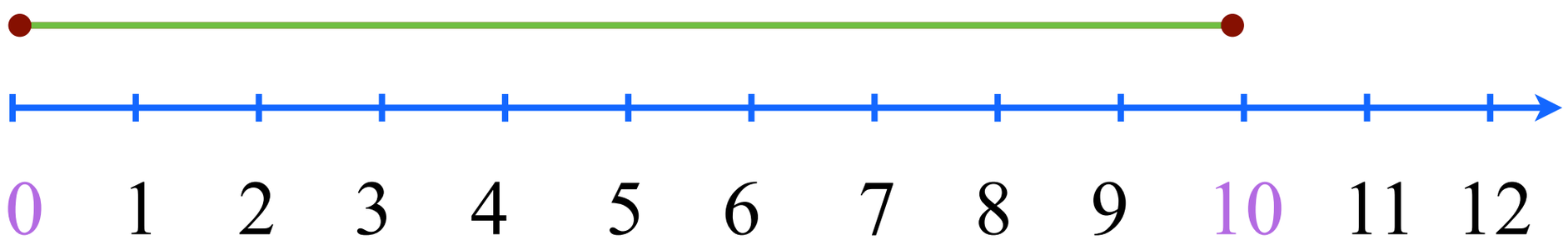
Wasted effort

# Case Study


**RQ1.** Which analysis provides the lowest wasted effort?

# Case Study


**RQ2.** How often the two analyses provide the wasted effort ≤ 10?

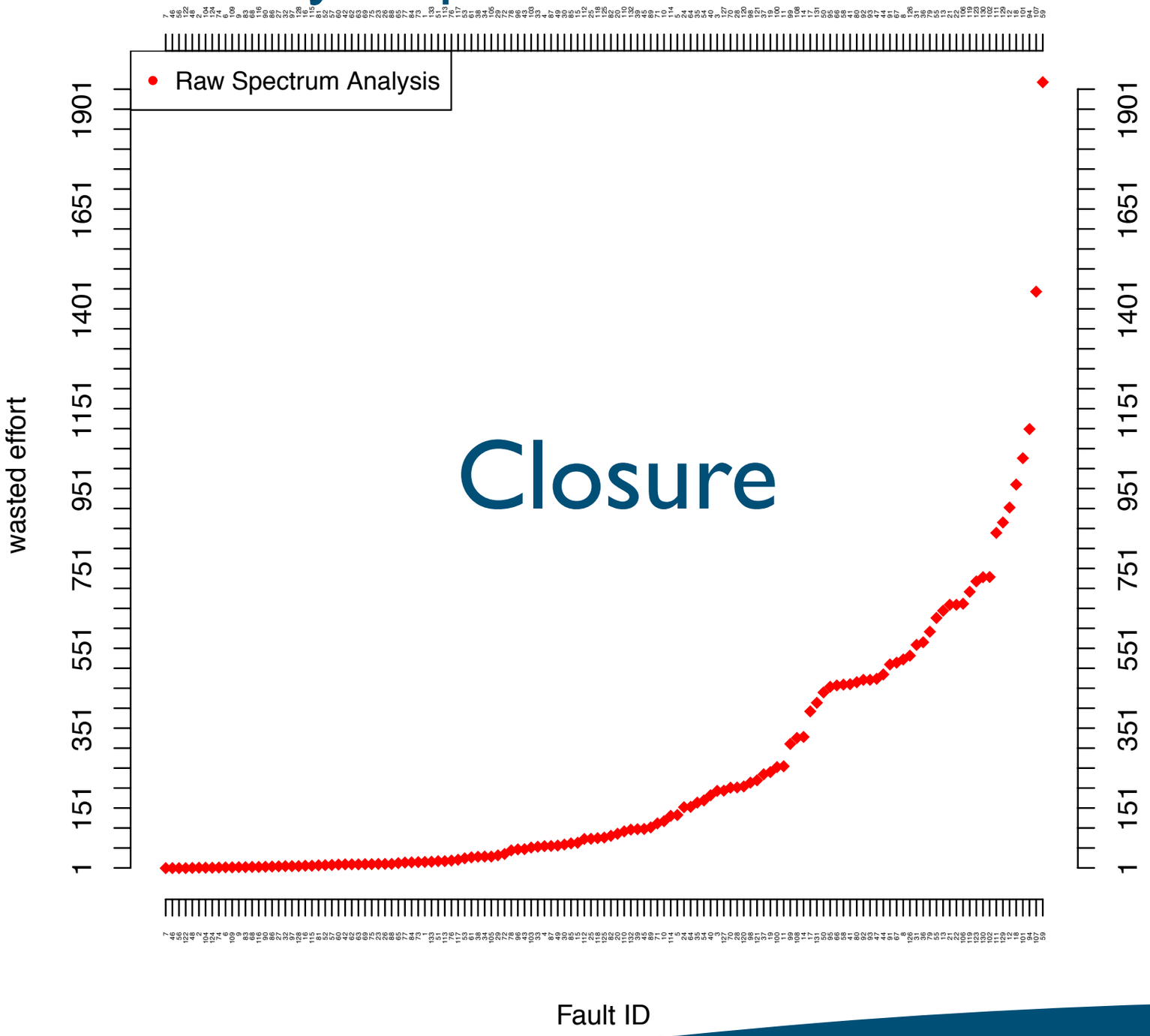


# Case Study


**RQ3.** How does the number of triggered methods affect the wasted effort?

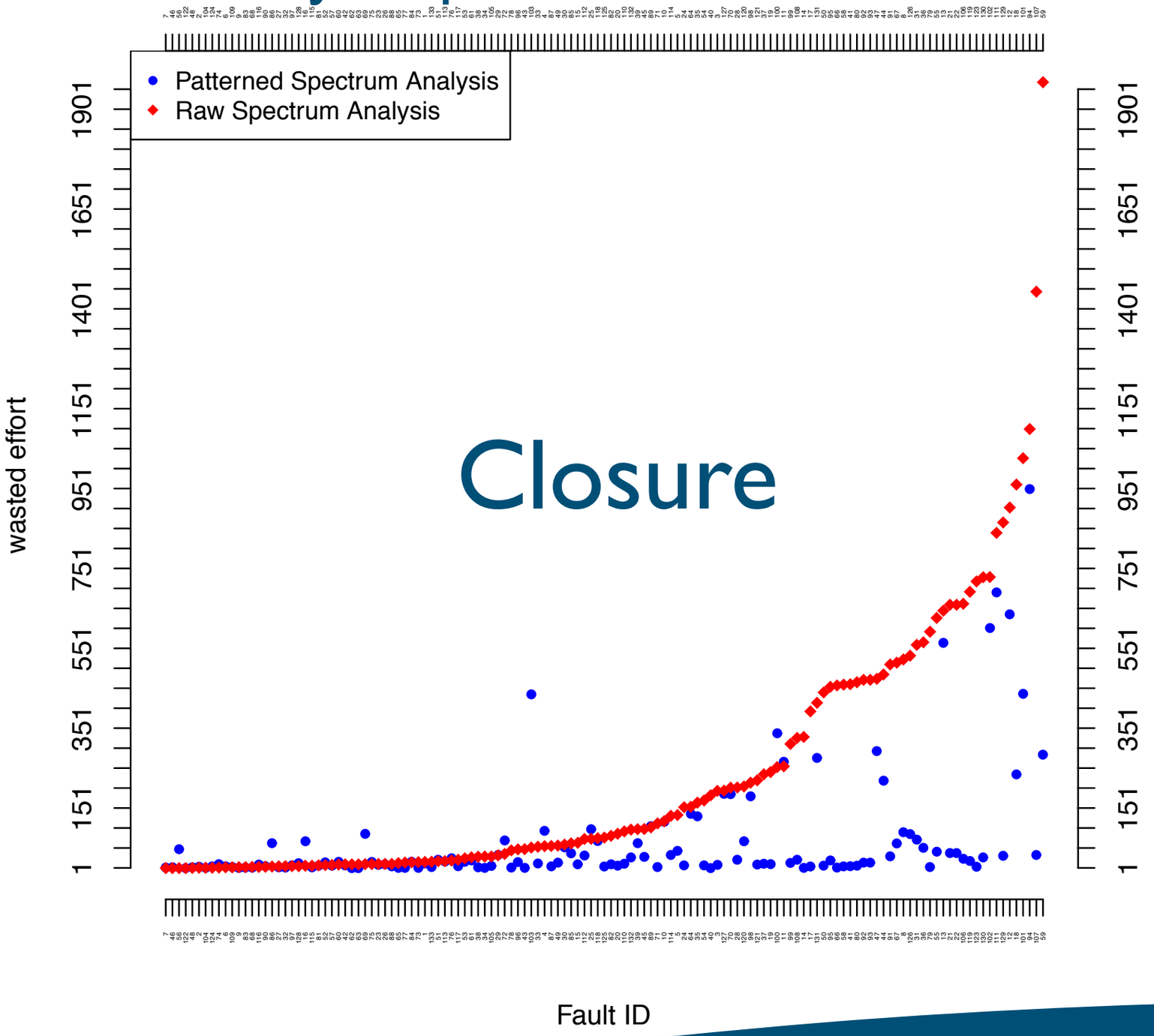
# Results

## **RQ1.** Which analysis provides the lowest wasted effort?



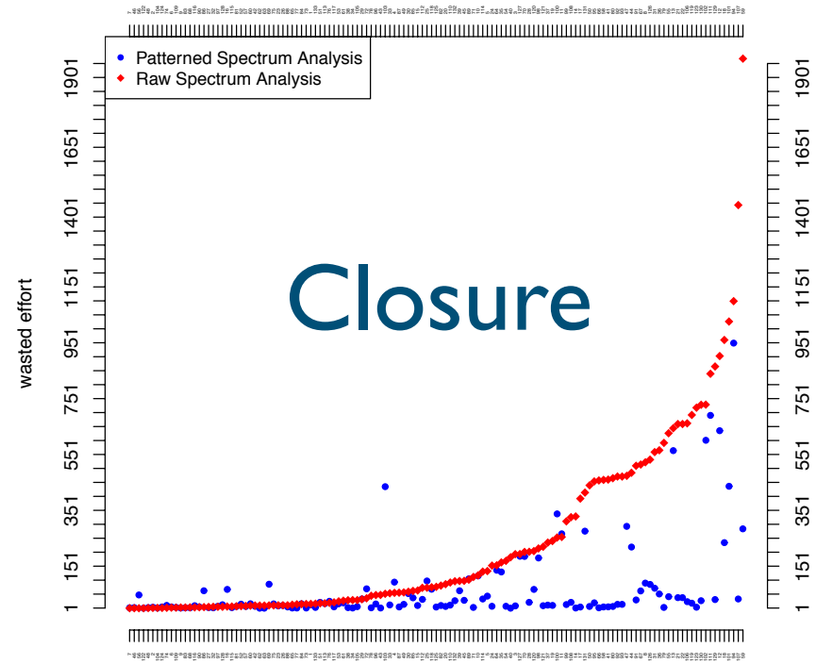
# Results

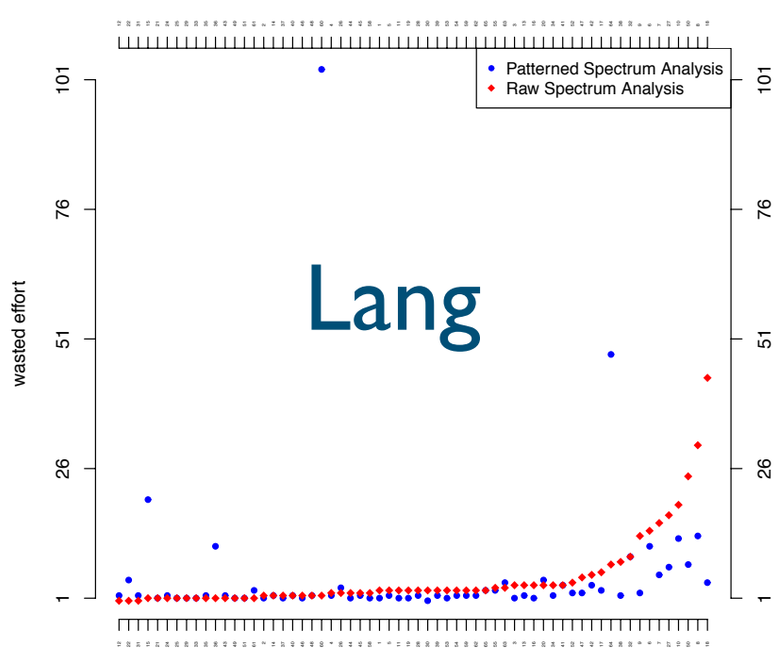
## **RQ1.** Which analysis provides the lowest wasted effort?

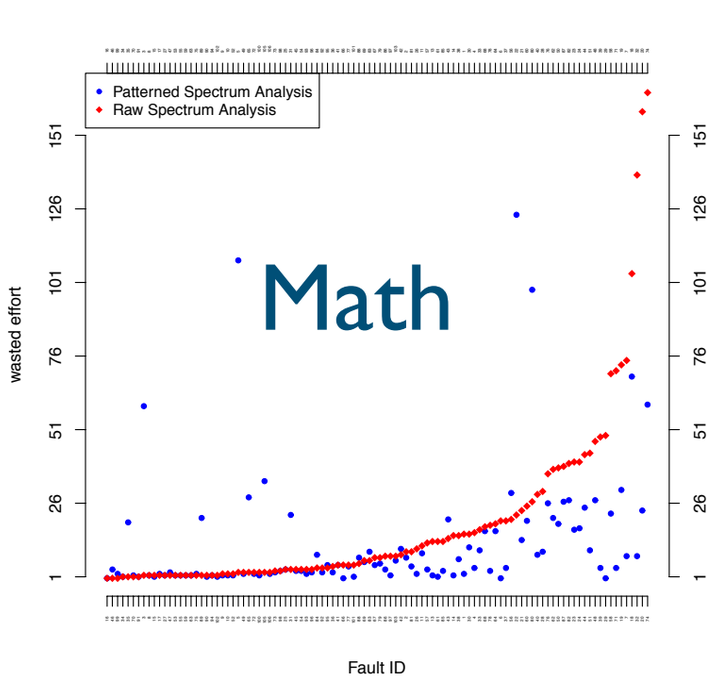


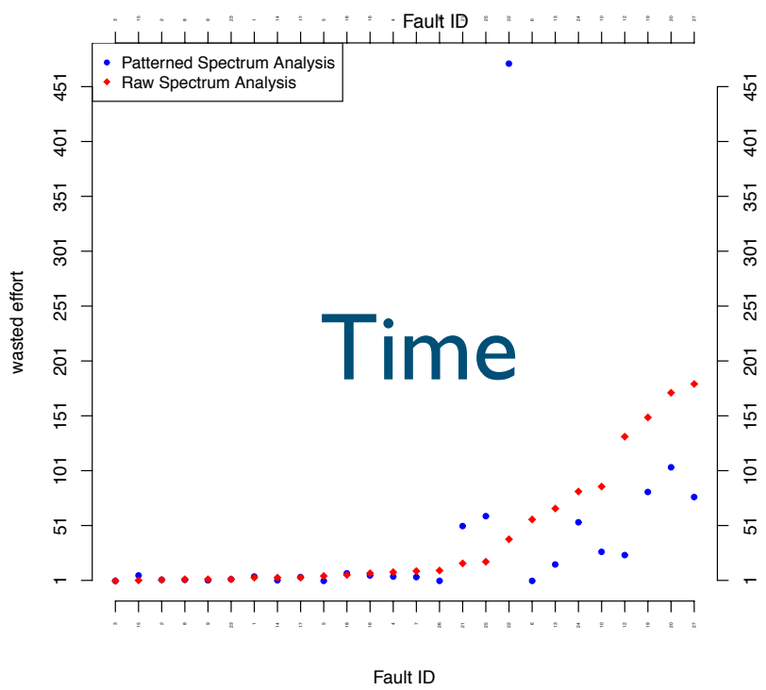
# Results

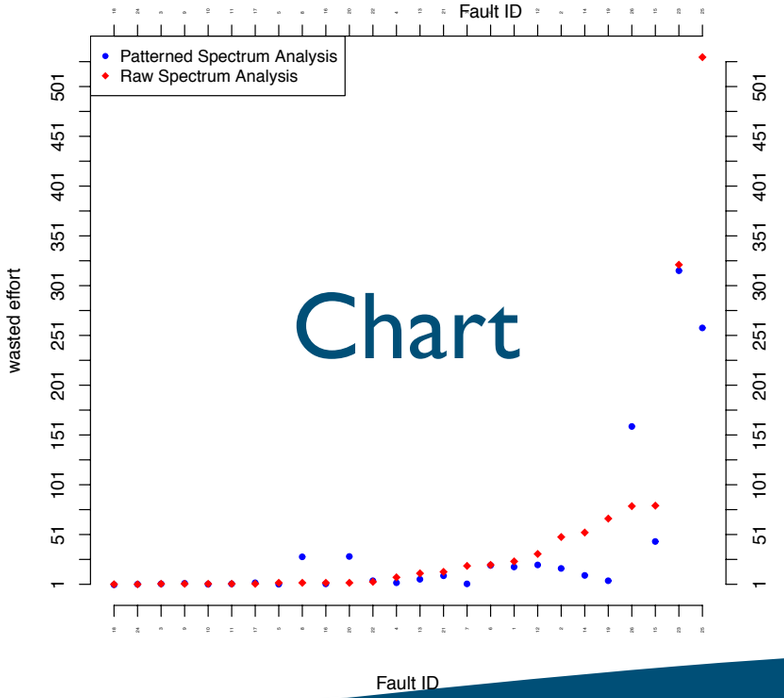
## **RQ1.** Which analysis provides the lowest wasted effort?



# Results

## **RQ1.** Which analysis provides the lowest wasted effort?

### Patterned Spectrum Analysis vs Raw Spectrum Analysis

| Project | < | > | = | Total |
|---|---|---|---|---|
| Math | 69 (66%) | 22 (21%) | 13 (13%) | 104 |
| Lang | 36 (58%) | 14 (23%) | 12 (19%) | 62 |
| Time | 16 (62%) | 7 (27%) | 3 (12%) | 26 |
| Chart | 16 (62%) | 7 (27%) | 3 (12%) | 26 |
| Closure | 101 (76%) | 30 (23%) | 2 (2%) | 133 |
| **Total** | **238** (68%) | **80** (23%) | **33** (9%) | **351** |

# Results

## **RQ1.** Which analysis provides the lowest wasted effort?

### Patterned Spectrum Analysis vs Raw Spectrum Analysis

| Project | < | > | = | Total |
|---|---|---|---|---|
| Math | 69 (66%) | 22 (21%) | 13 (13%) | 104 |
| Lang | 36 (58%) | 14 (23%) | 12 (19%) | 62 |
| Tim | | | | 26 |
| Ch | | | | 26 |
| Closure | 101 (76%) | 30 (23%) | 2 (2%) | 133 |
| **Total** | **238** (68%) | **80** (23%) | **33** (9%) | **351** |

238 (68%)

80 (23%)

# Results

**RQ2.** How often the two analyses provide the wasted effort ≤ 10?

# of faults where wasted effort ≤ 10

| Project | Patterned Spectrum Analysis | Raw Spectrum Analysis | Total |
|---|---|---|---|
| Math | 73 (70%) | 59 (57%) | 104 |
| Lang | 55 (89%) | 54 (87%) | 62 |
| Time | 16 (62%) | 14 (54%) | 26 |
| Chart | 16 (62%) | 13 (50%) | 26 |
| Closure | 56 (42%) | 30 (23%) | 133 |
| **Total** | **216** (62%) | **170** (48%) | **351** |

# Results

**RQ2.** How often the two analyses provide the wasted effort ≤ 10?

# of faults where wasted effort ≤ 10

| Project | Patterned Spectrum Analysis | Raw Spectrum Analysis | Total |
|---|---|---|---|
| Math | 73 (70%) | 59 (57%) | 104 |
| Lang | 55 (89%) | 54 (87%) | 62 |
| Time | 16 (62%) | 14 (54%) | 26 |
| Chart | | | 6 |
| Closure | | | 3 |
| **Total** | **216** (62%) | **170** (48%) | **351** |

216 (62%)

170 (23%)

# Results

**RQ3.** How does the number of triggered methods affect the wasted effort?

Triggered Methods vs wasted effort

| Bin | Patterned Spectrum Analysis | | | Raw Spectrum Analysis | | |
|---|---|---|---|---|---|---|
| | Q1 | Median | Q3 | Q1 | Median | Q3 |
| 4-43 | | | | | | |
| 44-71 | | | | | | |
| 72-91 | | | | | | |
| 92-134 | | | | | | |
| 137-202 | | | | | | |
| 204-397 | | | | | | |
| 423-892 | | | | | | |
| 917-1262 | | | | | | |
| 1273-1721 | | | | | | |
| 1752-2464 | | | | | | |
| 2523-5825 | | | | | | |

# Results

**RQ3.** How does the number of triggered methods affect the wasted effort?

Triggered Methods vs wasted effort

| Bin | Patterned Spectrum Analysis | | | Raw Spectrum Analysis | | |
|---|---|---|---|---|---|---|
| | Q1 | Median | Q3 | Q1 | Median | Q3 |
| 4-43 | 1.0 | 1.5 | 2.5 | 1.0 | 1.8 | 2.9 |
| 44-71 | 1.5 | 3.0 | 6.8 | 2.2 | 2.8 | 8.5 |
| 72-91 | 1.5 | 2.8 | 9.1 | 2.4 | 5.2 | 13.0 |
| 92-134 | 1.5 | 2.8 | 11.5 | 1.5 | 3.8 | 17.6 |
| 137-202 | 1.5 | 3.2 | 9.1 | 1.5 | 3.2 | 15.5 |
| 204-397 | 2.0 | 8.0 | 23.5 | 3.5 | 20.0 | 73.0 |
| 423-892 | 1.9 | 5.0 | 51.4 | 3.5 | 9.0 | 70.8 |
| 917-1262 | 5.8 | 14.0 | 38.5 | 10.4 | 263 | 511.6 |
| 1273-1721 | 8.2 | 20.8 | 56.4 | 33.9 | 97.8 | 203.1 |
| 1752-2464 | 2.5 | 11.2 | 40.9 | 12.4 | 50.0 | 196.0 |
| 2523-5825 | 5.0 | 24.0 | 77.5 | 11.0 | 115.5 | 561.1 |

# Results

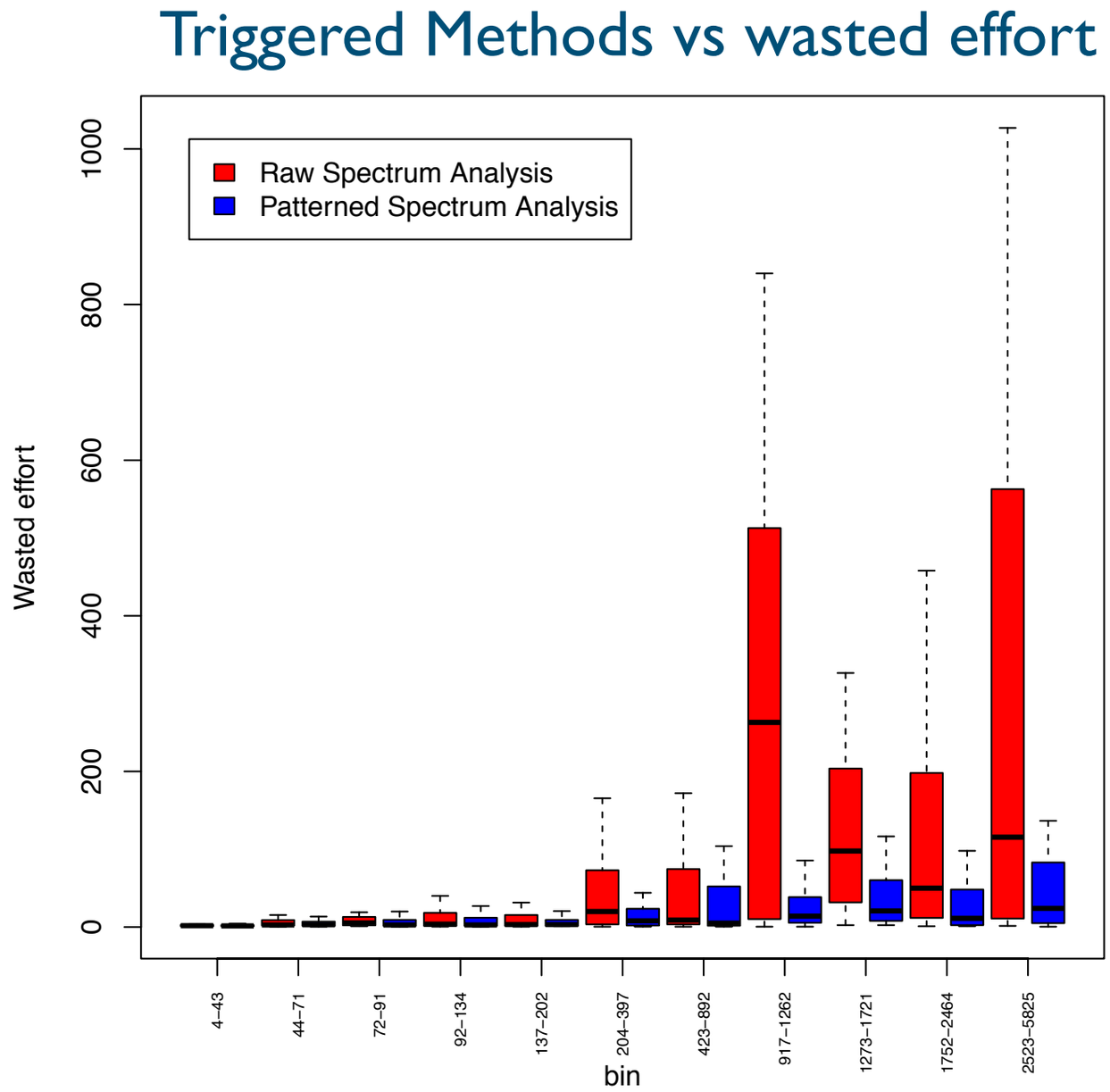
**RQ3.** How does the number of triggered methods affect the wasted effort?

Triggered Methods vs wasted effort

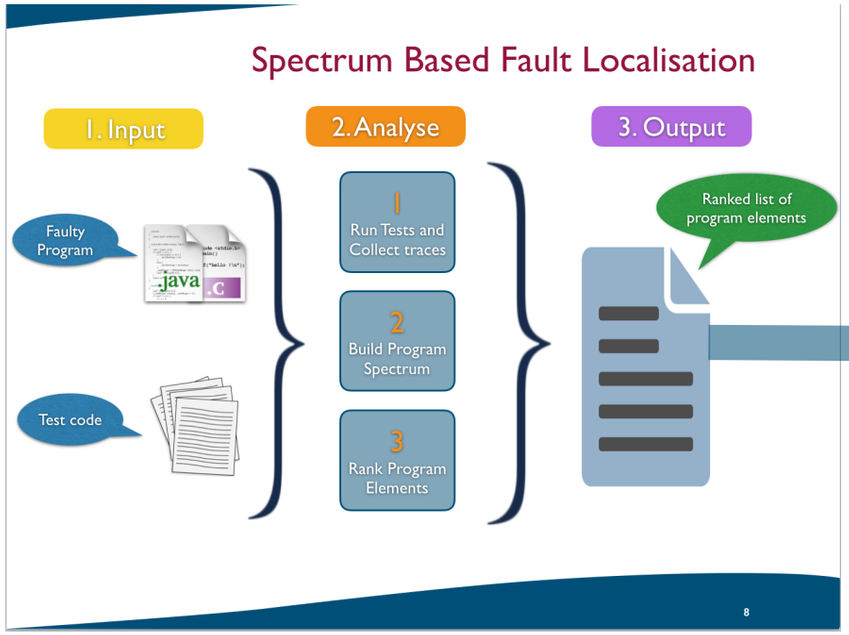
| Bin | Patterned Spectrum Analysis | | | Raw Spectrum Analysis | | |
|---|---|---|---|---|---|---|
| | Q1 | Median | Q3 | Q1 | Median | Q3 |
| 4-43 | 1.0 | 1.5 | 2.5 | 1.0 | 1.8 | 2.9 |
| 44-71 | 1.5 | 3.0 | 6.8 | 2.2 | 2.8 | 8.5 |
| 72-91 | 1.5 | 2.8 | 9.1 | 2.4 | 5.2 | 13.0 |
| 92-134 | 1.5 | 2.8 | 11.5 | 1.5 | 3.8 | 17.6 |
| 137-202 | 1.5 | 3.2 | 9.1 | 1.5 | 3.2 | 15.5 |
| 204-397 | 2.0 | 8.0 | 23.5 | 3.5 | 20.0 | 73.0 |
| 423-892 | 1.9 | 5.0 | 51.4 | 3.5 | 9.0 | 70.8 |
| **917-1262** | 5.8 | 14.0 | **38.5** | 10.4 | 263 | **511.6** |
| **1273-1721** | 8.2 | 20.8 | **56.4** | 33.9 | 97.8 | **203.1** |
| **1752-2464** | 2.5 | 11.2 | **40.9** | 12.4 | 50.0 | **196.0** |
| **2523-5825** | 5.0 | 24.0 | **77.5** | 11.0 | 115.5 | **561.1** |

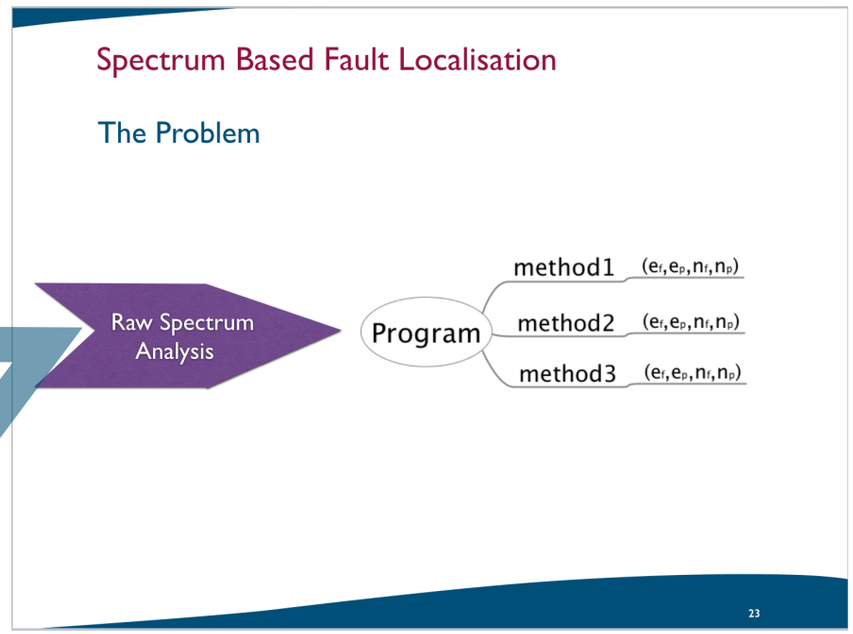
# Results

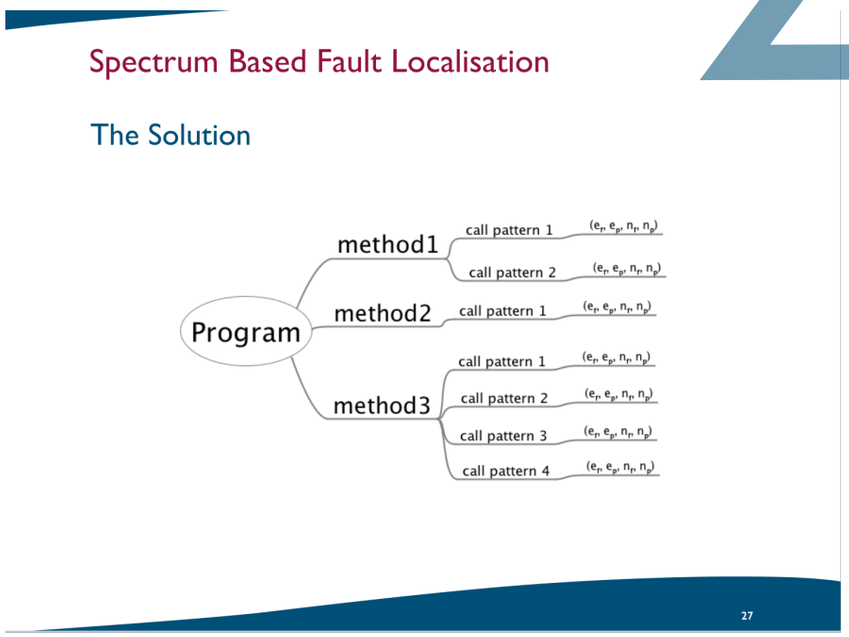
**RQ3.** How does the number of triggered methods affect the wasted effort?

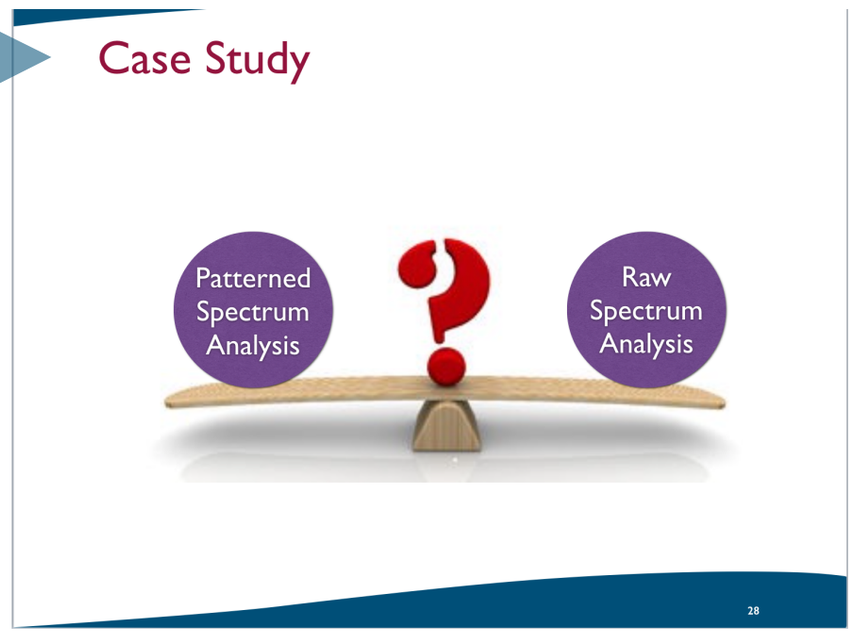


# Summary


Spectrum Based Fault Localisation
1. Input
2. Analyse
3. Output
Faulty Program
Test code
1 Run Tests and Collect traces
2 Build Program Spectrum
3 Rank Program Elements
Ranked list of program elements
8


Spectrum Based Fault Localisation
The Problem
Raw Spectrum Analysis
Program
method1 (ef, ep, nf, np)
method2 (ef, ep, nf, np)
method3 (ef, ep, nf, np)
23


Spectrum Based Fault Localisation
The Solution
Program
method1
call pattern 1 (ef, ep, nf, np)
call pattern 2 (ef, ep, nf, np)
method2
call pattern 1 (ef, ep, nf, np)
method3
call pattern 1 (ef, ep, nf, np)
call pattern 2 (ef, ep, nf, np)
call pattern 3 (ef, ep, nf, np)
call pattern 4 (ef, ep, nf, np)
27


Case Study
Patterned Spectrum Analysis
Raw Spectrum Analysis
28