



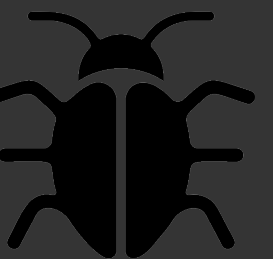
COM 3529

# SOFTWARE TESTING & ANALYSIS

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## 3.2 White Box Coverage Criteria based on Logic Analysis

```
public static int daysBetweenTwoDates(int year1, int month1, int day1,  
                                       int year2, int month2, int day2) {  
    ...  
    if ((year2 < year1) ||  
        (year2 == year1 && month2 < month1) ||  
        (year2 == year1 && month2 == month1 && day2 < day1)) {  
        int t = month2;  
        month2 = month1;  
        month1 = t;  
        t = day2;  
        day2 = day1;  
        day1 = t;  
        t = year2;  
        year2 = year1;  
        year1 = t;  
    }  
    ...  
}
```



Disjunct 1

Disjunct 2

Disjunct 3

```
public static int daysBetweenTwoDates(int year1, int month1, int day1,  
                                       int year2, int month2, int day2) {  
    ...  
    if ((year2 < year1) ||  
        (year2 == year1 && month2 < month1) ||  
        (year2 == year1 && month2 == month1 && day2 < day1)) {  
        int t = month2;  
        month2 = month1;  
        month1 = t;  
        t = day2;  
        day2 = day1;  
        day1 = t;  
        t = year2;  
        year2 = year1;  
        year1 = t;  
    }  
    ...  
}
```

Disjunct 1

Disjunct 2

Disjunct 3

```
public static int daysBetweenTwoDates(int year1, int month1, int day1,  
                                       int year2, int month2, int day2) {
```

```
    ...
```

```
    if ((year2 < year1) ||
```

```
        (year2 == year1 && month2 < month1) ||
```

```
        (year2 == year1 && month2 == month1 && day2 < day1)) {
```

```
        int t = month2;
```

```
        month2 = month1;
```

```
        month1 = t;
```

```
        t = day2;
```

```
        day2 = day1;
```

```
        day1 = t;
```

```
    }
```

```
    ...
```

```
}
```

```
...
```

Branch Coverage does not ensure each  
disjunct is exercised as true and false:

| Test<br>Case | Example Input |        |      |       |        |      | Disjunct |   |   | Branch<br>Predicate |
|--------------|---------------|--------|------|-------|--------|------|----------|---|---|---------------------|
|              | year1         | month1 | day1 | year2 | month2 | day2 | 1        | 2 | 3 |                     |
| 1            | 2019          | 12     | 13   | 2018  | 4      | 25   | T        | F | F | T                   |
| 2            | 2018          | 4      | 25   | 2019  | 12     | 13   | F        | F | F | F                   |

# Analysing the Logic of a Predicate

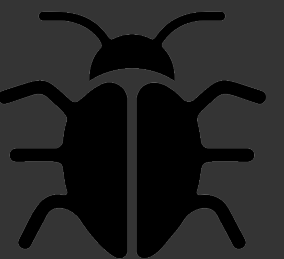
## Logical Operators

| Operator Name | Mathematical Symbol | Typical Programming Language Symbol |
|---------------|---------------------|-------------------------------------|
| not           | $\neg$              | !                                   |
| and           | $\wedge$            | &&                                  |
| or            | $\vee$              |                                     |

A **condition** is a boolean expression that is a component of a more complex predicate that does not contain any logical operators

```
if ((year2 < year1) ||  
    (year2 == year1 && month2 < month1) ||  
    (year2 == year1 && month2 == month1 && day2 < day1)) {  
    ...  
}
```

How many  
conditions are there  
in this if statement?



# Analysing the Logic of a Predicate

```
if ((year2 < year1) ||  
    (year2 == year1 && month2 < month1) ||  
    (year2 == year1 && month2 == month1 && day2 < day1)) {  
    ...  
}
```

How many  
conditions are there  
in this if statement?

| Condition |                  | Disjunct |
|-----------|------------------|----------|
| 1         | year2 < year1    | 1        |
| 2=        | year2 == year1   | 2        |
| 3         | month2 < month1  | 2        |
| 2=        | year2 == year1   | 3        |
| 4         | month2 == month1 | 3        |
| 5         | day2 < day1      | 3        |





# Condition Coverage

Exercise each condition as true and false

```
if ((year2 < year1) ||  
    (year2 == year1 && month2 < month1) ||  
    (year2 == year1 && month2 == month1 && day2 < day1)) {  
    ...  
}
```

| Condition |                  | Disjunct |
|-----------|------------------|----------|
| 1         | year2 < year1    | 1        |
| 2=        | year2 == year1   | 2        |
| 3         | month2 < month1  | 2        |
| 2=        | year2 == year1   | 3        |
| 4         | month2 == month1 | 3        |
| 5         | day2 < day1      | 3        |

| Test Case | Condition |   |   |   |   | Branch Predicate | Example Input |        |      |       |        |      |
|-----------|-----------|---|---|---|---|------------------|---------------|--------|------|-------|--------|------|
|           | 1         | 2 | 3 | 4 | 5 |                  | year1         | month1 | day1 | year2 | month2 | day2 |
| 1         | T         | F | F | T | T | T                | 2019          | 1      | 2    | 2018  | 1      | 1    |
| 2         | F         | T | T | F | F | T                | 2019          | 2      | 1    | 2019  | 1      | 1    |



# Multiple Condition Coverage

Exercise each possible combination of truth values for each condition

$n$  conditions =  $2^n$  test requirements

| Condition |                  | Disjunct |
|-----------|------------------|----------|
| 1         | year2 < year1    | 1        |
| 2=        | year2 == year1   | 2        |
| 3         | month2 < month1  | 2        |
| 2=        | year2 == year1   | 3        |
| 4         | month2 == month1 | 3        |
| 5         | day2 < day1      | 3        |

5 unique conditions =  
32 test requirements

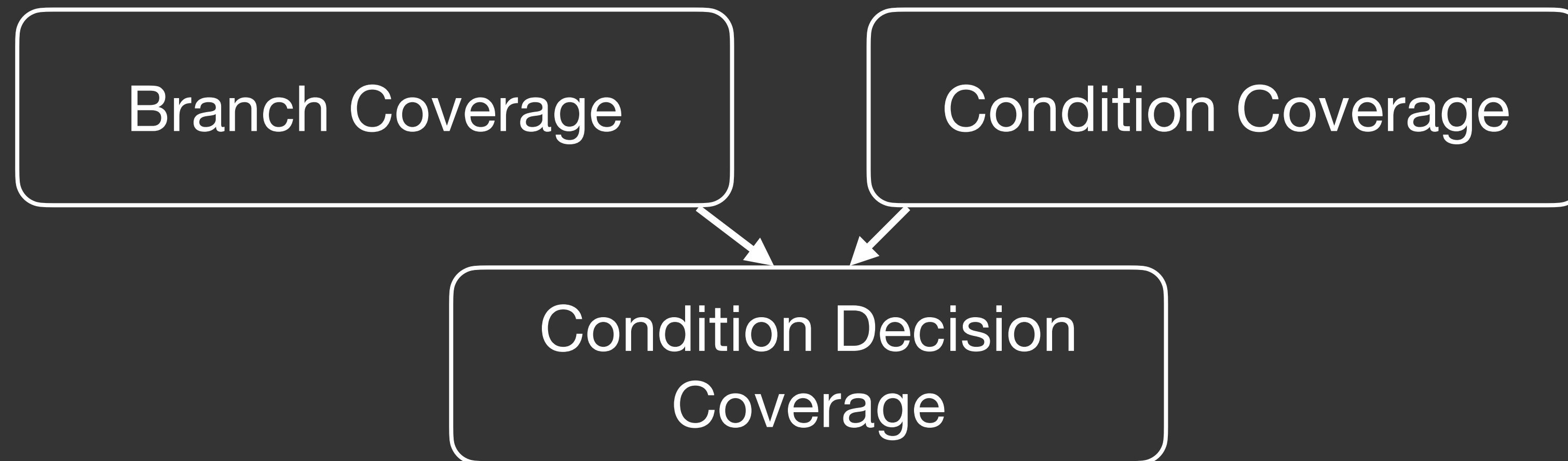
But not all combinations  
are feasible





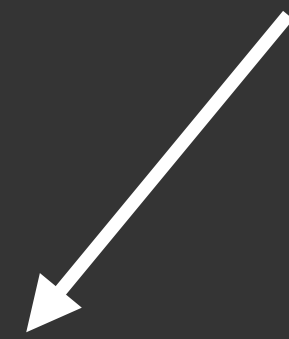
# Condition Decision Coverage

Exercise each condition as true and false, as well as the overall branch predicate



# Modified Condition Decision Coverage (MCDC)

Exercise each condition as true and false. When the condition flips truth value, the branch predicate must also flip



The “major” condition

Truth values of the remaining “minor” conditions set so that flipping the major condition flips the predicate

The major condition will then determine the predicate

| Condition |                  | Disjunct |
|-----------|------------------|----------|
| 1         | year2 < year1    | 1        |
| 2=        | year2 == year1   | 2        |
| 3         | month2 < month1  | 2        |
| 2=        | year2 == year1   | 3        |
| 4         | month2 == month1 | 3        |
| 5         | day2 < day1      | 3        |



# Restricted MCDC

The truth values of the minor conditions are fixed as the major condition and the predicate flip

Condition 1 is major:

| Test Case | Condition |   |   |   |   | Branch Predicate | Example Input |        |      |       |        |      |
|-----------|-----------|---|---|---|---|------------------|---------------|--------|------|-------|--------|------|
|           | 1         | 2 | 3 | 4 | 5 |                  | year1         | month1 | day1 | year2 | month2 | day2 |
| 1         | T         | F | F | F | F | T                | 2019          | 1      | 1    | 2018  | 2      | 1    |
| 2         | F         | F | F | F | F | F                | 2018          | 1      | 1    | 2019  | 2      | 1    |

| Condition |                  | Disjunct |
|-----------|------------------|----------|
| 1         | year2 < year1    | 1        |
| 2=        | year2 == year1   | 2        |
| 3         | month2 < month1  | 2        |
| 2=        | year2 == year1   | 3        |
| 4         | month2 == month1 | 3        |
| 5         | day2 < day1      | 3        |

Condition 2 is major:

| Test Case | Condition |   |   |   |   | Branch Predicate | Example Input |        |      |       |        |      |
|-----------|-----------|---|---|---|---|------------------|---------------|--------|------|-------|--------|------|
|           | 1         | 2 | 3 | 4 | 5 |                  | year1         | month1 | day1 | year2 | month2 | day2 |
| 3         | F         | T | T | F | F | T                | 2019          | 2      | 1    | 2019  | 1      | 1    |
| 4         | F         | F | T | F | F | F                | 2018          | 2      | 1    | 2019  | 1      | 1    |



# Correlated MCDC

The truth values of the minor conditions do not need to be fixed as the major condition and the predicate flip

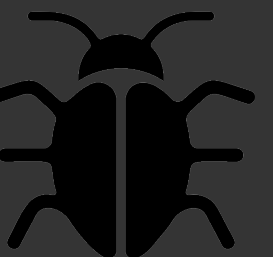
| Test Case | Condition |   |   |   |   | Branch Predicate | Example Input |        |      |       |        |      |
|-----------|-----------|---|---|---|---|------------------|---------------|--------|------|-------|--------|------|
|           | 1         | 2 | 3 | 4 | 5 |                  | year1         | month1 | day1 | year2 | month2 | day2 |
| 1         | T         | F | F | T | T | T                | 2019          | 1      | 2    | 2018  | 1      | 1    |
| 2         | F         | T | T | F | F | T                | 2019          | 2      | 1    | 2019  | 1      | 1    |
| 3         | F         | F | F | F | F | F                | 2018          | 1      | 1    | 2019  | 2      | 1    |



# Correlated MCDC

The truth values of the minor conditions do not need to be fixed as the major condition and the predicate flip

| Test Case | Condition |   |   |   |   | Branch Predicate | Example Input |        |      |       |        |      |
|-----------|-----------|---|---|---|---|------------------|---------------|--------|------|-------|--------|------|
|           | 1         | 2 | 3 | 4 | 5 |                  | year1         | month1 | day1 | year2 | month2 | day2 |
| 1         | T         | F | F | T | T | T                | 2019          | 1      | 2    | 2018  | 1      | 1    |
| 2         | F         | T | T | F | F | T                | 2019          | 2      | 1    | 2019  | 1      | 1    |
| 3         | F         | F | F | F | F | F                | 2018          | 1      | 1    | 2019  | 2      | 1    |





# Correlated MCDC

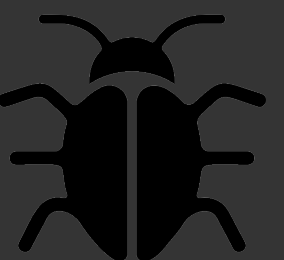
The truth values of the minor conditions do not need to be fixed as the major condition and the predicate flip

| Test Case | Condition |   |   |   |   | Branch Predicate | Example Input |        |      |       |        |      |
|-----------|-----------|---|---|---|---|------------------|---------------|--------|------|-------|--------|------|
|           | 1         | 2 | 3 | 4 | 5 |                  | year1         | month1 | day1 | year2 | month2 | day2 |
| 1         | T         | F | F | T | T | T                | 2019          | 1      | 2    | 2018  | 1      | 1    |
| 2         | F         | T | T | F | F | T                | 2019          | 2      | 1    | 2019  | 1      | 1    |
| 3         | F         | F | F | F | F | F                | 2018          | 1      | 1    | 2019  | 2      | 1    |

| Condition |                  | Disjunct |
|-----------|------------------|----------|
| 1         | year2 < year1    | 1        |
| 2=        | year2 == year1   | 2        |
| 3         | month2 < month1  | 2        |
| 2=        | year2 == year1   | 3        |
| 4         | month2 == month1 | 3        |
| 5         | day2 < day1      | 3        |

```
if ((year2 < year1) ||  
    (year2 == year1 && month2 < month1) ||  
    (year2 == year1 && month2 == month1 && day2 < day1)) {  
    ...  
}
```

Disjunct 3 not actually exercised as true





Decision Coverage  
Predicate Coverage  
Edge Coverage

Branch Coverage

Condition Coverage

Clause Coverage

Condition Decision  
Coverage

Correlated Active Clause Coverage  
Modified Condition Decision Coverage  
Multiple Condition Decision Coverage

*Correlated*  
Modified Condition  
Decision Coverage

Restricted Active Clause Coverage  
Modified Condition Decision Coverage  
Multiple Condition Decision Coverage

*Restricted*  
Modified Condition  
Decision Coverage

Complete Condition Coverage  
Complete Clause Coverage  
Combinatorial Coverage

Multiple Condition  
Coverage



# Some General Observations

- MCDC variants offer the best trade-off in terms of number of test requirements v. test thoroughness
- Correlated MCDC tends to result in smaller test suites than Restricted
- Multiple Condition Coverage yields too many test requirements
- Condition Coverage does not subsume Branch Coverage



# Consider this...

```
...
boolean yearSame = year2 == year1;
boolean yearAndMonthSame = yearSame && month2 == month1;

boolean secondDateBeforeFirstByYear = year2 < year1;
boolean secondDateBeforeFirstByMonth = yearSame && month2 < month1;
boolean secondDateBeforeFirstByDay = yearAndMonthSame && day2 < day1;

boolean secondDateBefore = secondDateBeforeFirstByYear ||
                           secondDateBeforeFirstByMonth || secondDateBeforeFirstByDay;

if (secondDateBeforeFirst) {
    ...
}
...
```



# MCDC and Testing Standards

- **ISO 26262** – “Road Vehicles – Functional Safety”  
[https://en.wikipedia.org/wiki/ISO\\_26262](https://en.wikipedia.org/wiki/ISO_26262)
- **EN 50128** – a functional safety standard used in the rail industry  
<https://www.adacore.com/industries/rail/en50128>
- **DO-178B** and **DO-178C** – “Software Considerations in Airborne Systems and Equipment Certification”  
<https://en.wikipedia.org/wiki/DO-178B>  
<https://en.wikipedia.org/wiki/DO-178C>
- **IEC 61508**, a basic functional safety standard applicable to all industries.  
[https://en.wikipedia.org/wiki/IEC\\_61508](https://en.wikipedia.org/wiki/IEC_61508)

