Introduction to Software Testing
Logic Coverage (Ch. 8.1.2)

Software Testing & Maintenance
SWE 437
http://go.gmu.edu/swe437

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Combinatorial Coverage (CoC)

This is simple, neat, clean, and comprehensive …
But can be **expensive**
- Impractical for predicates with more than 3 or 4 clauses
The literature has lots of suggestions – some confusing
The general idea is simple:

Test each clause independently from the other clauses

Getting the details right is hard
What exactly does “independently” mean?
The book presents this idea as “**making clauses active**” …
Active Clauses (8.1.2)

Clause coverage has a weakness: The values do not always make a difference.

Consider the CC tests for $P = (a \& (b \mid c))$:

- Test 1: $(true \& (true \mid true))$
- Test 2: $(false \& (false \mid false))$

Clauses b and c are ignored!

To really test the results of a clause, the clause should be the determining factor in the value of the predicate.
Active Clauses — Determination

Clause $c_i$ determines the value of its predicate when the other clauses have certain values.

If $c_i$ is changed, the value of the predicate changes

$c_i$ is called the major clause

Other clauses are minor clauses

This is called making the clause active.
Determining Predicates

\[ P = A \lor B \]

if \( B = \text{true} \), \( p \) is always true.
so if \( B = \text{false} \), \( A \) determines \( p \).
if \( A = \text{false} \), \( B \) determines \( p \).

\[ P = A \land B \]

if \( B = \text{false} \), \( p \) is always false.
so if \( B = \text{true} \), \( A \) determines \( p \).
if \( A = \text{true} \), \( B \) determines \( p \).

**Goal:** Find tests for each clause when the clause determines the value of the predicate.

This is formalized in a **family of criteria** that have subtle, but very important, differences.
In-class Exercise

Making clauses active

\[ P = (a \& (b \mid c)) \]

Write truth values for \( b \) and \( c \) that make clause \( a \) active

*For example: \( P_a : b=?? \) or \( c=?? \)*

Write truth values for \( a \) and \( c \) that make clause \( b \) active

Write truth values for \( a \) and \( b \) that make clause \( c \) active
In-class Exercise

Making clauses active

\[ P = (a \& (b \mid c)) \]

Write truth values for \( b \) and \( c \) that make clause \( a \) active

For example: \( Pa : b=?? \) or \( c=?? \)

Write truth values for \( a \) and \( c \) that make clause \( b \) active

Write truth values for \( a \) and \( b \) that make clause \( c \) active

\( Pa : (b=true \text{ or } c=true \text{ compactly: } (b \text{ or } c) \)
\( Pb : (a \text{ and } !c) \)
\( Pc : (a \text{ and } !b) \)
Active Clause Coverage (ACC): For each clause $c_i$ in each predicate $p$, choose values for the other clauses to make $c_i$ active.

Create two tests, one where $c_i$ evaluates to true and the other where $c_i$ evaluates to false.

<table>
<thead>
<tr>
<th>$p = a \lor b$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1) $a = \text{true}$, $b = \text{false}$</td>
<td></td>
</tr>
<tr>
<td>2) $a = \text{false}$, $b = \text{false}$</td>
<td></td>
</tr>
<tr>
<td>3) $a = \text{false}$, $b = \text{true}$</td>
<td></td>
</tr>
<tr>
<td>4) $a = \text{false}$, $b = \text{false}$</td>
<td></td>
</tr>
</tbody>
</table>

This is a form of MCDC, which is required by the FAA for safety critical software.
ACC Ambiguity

Do the minor clauses have to have the same values for both tests?

**Restricted ACC:** They do

**Correlated ACC:** They do not, but the *predicate has to have different values*

**General ACC:** They do not, and the *predicate does not have to have different values* either

The FAA requires **MCDC** (modified condition decision coverage) for flight critical software

Original definition of MCDC was GACC

For years, some inspectors required RACC, some CACC.

**MCDC is now equivalent to CACC.**

We are skipping GACC and RACC.
### CACC Example

|   | a | b | c | a & (b | c) |
|---|---|---|---|---------|
| 1 | T | T | T | T       |
| 2 | T | T | F | T       |
| 3 | T | F | T | T       |
| 4 | T | F | F | F       |
| 5 | F | T | T | F       |
| 6 | F | T | F | F       |
| 7 | F | F | T | F       |
| 8 | F | F | F | F       |

For **a** to determine the value of the predicate:

\[ P_a : b=true \text{ or } c = true \]

So we can use ANY OF the 9 pair of rows: (1,5), (1,6), (1,7), (2,5),(2,6),(2,7), (3,5),(3,6),(3,7)

For **b** to determine the value of the predicate:

\[ P_b : a=true \text{ and } c = false \]

Rows 2 and 4

For **c** to determine the value of the predicate:

\[ P_c : a=true \text{ and } b = false \]

Rows 3 and 4
Extra Credit!

Making clauses active

\[ P = ((a \& b) \mid c \mid (d \& e)) \]

Pick any one of the 5 clauses (call it \( c_i \))

Solve for \( c_i \)

Answer by giving truth values for the other 4 clauses that make your \( c_i \) determine the value of the predicate

Show your work!
In-class Exercise

Making clauses active

\[ P = ((a \& b) \mid c \mid (d \& e)) \]

Pick any one of the 5 clauses (call it \( c_i \))
Solve for \( c_i \)
Answer by giving truth values for the other 4 clauses that make your \( c_i \) determine the value of the predicate

\[ \begin{align*}
Pa &= b \text{ and } !c \text{ and } !(d \text{ and } e) \\
&= b \text{ and } !c \text{ and } (!d \text{ or } !e) \\
Pb &= a \text{ and } !c \text{ and } !(d \text{ and } e) \\
&= a \text{ and } !c \text{ and } (!d \text{ or } !e) \\
Pc &= !(a \text{ and } b) \text{ and } !(d \text{ and } e) \\
&= (!a \text{ or } !b) \text{ and } (!d \text{ or } !e) \\
Pd &= !(a \text{ and } b) \text{ and } !c \text{ and } e \\
&= (!a \text{ or } !b) \text{ and } !c \text{ and } e \\
Pe &= !(a \text{ and } b) \text{ and } !c \text{ and } d \\
&= (!a \text{ or } !b) \text{ and } !c \text{ and } d
\]