Intro to Software Testing
Chapter 8.1.4 & 8.1.5

Logic Coverage

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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

$P = A \lor B$	$P = A \land B$
if ***B* = *true***, *p* is always true.	if ***B* = *false***, *p* is always false.
so if ***B* = *false***, *A* determines *p*.	so if ***B* = *true***, *A* determines *p*.
if ***A* = *false***, *B* determines *p*.	if ***A* = *true***, *B* determines *p*.

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

Infeasibility & Subsumption (8.1.4)

Consider the predicate:

$(a > b \wedge b > c)$

Realize the abstract test tt into a concrete test by finding values for a, b, and c that create the truth assignments tt

$a=9, b=7, c=5$

Now consider the predicate:

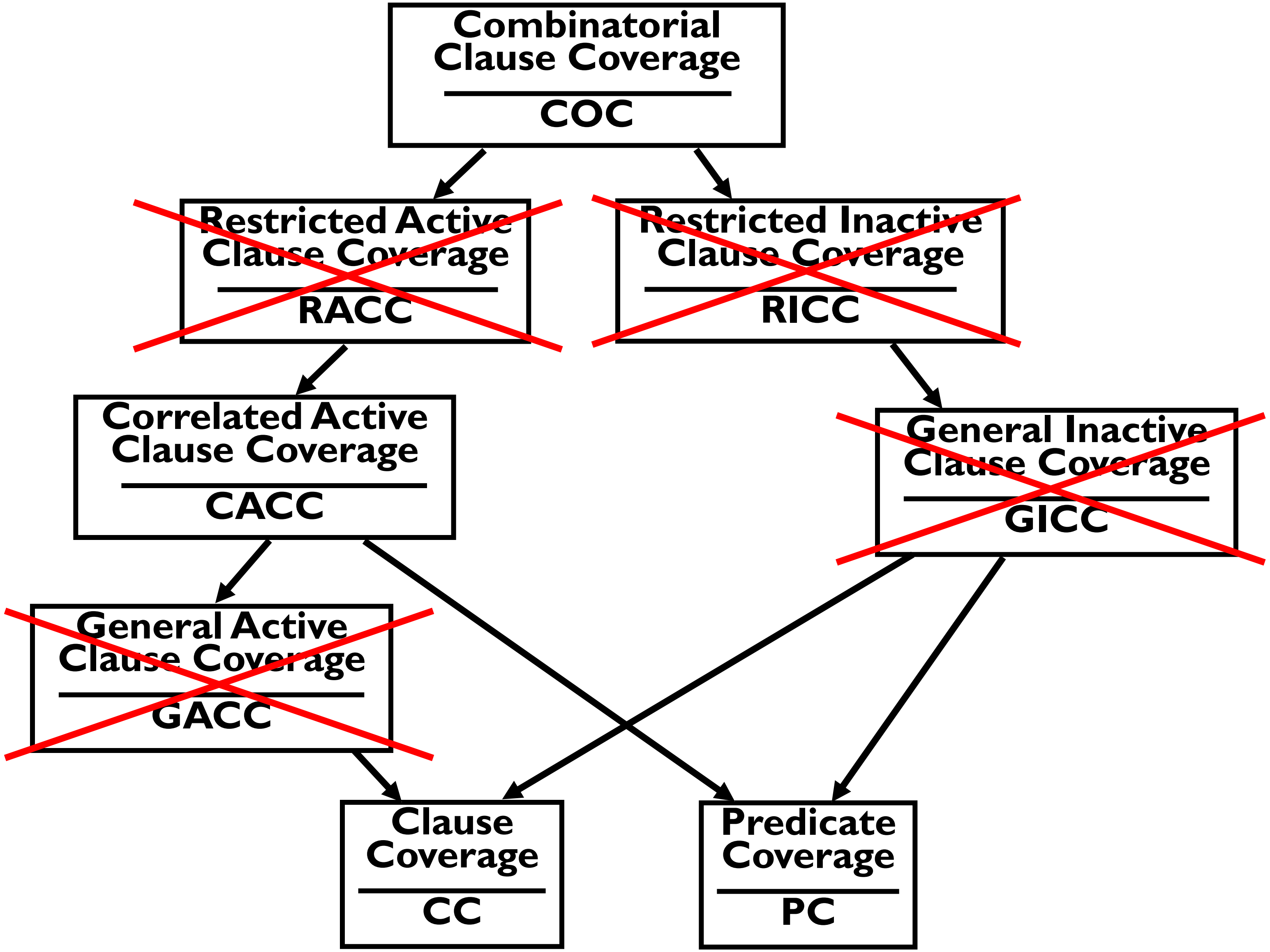
$(a > b \wedge b > c) \vee c > a$

Realize the abstract test ttt into a concrete test by finding values for a, b, and c that create the truth assignments ttt

Impossible!

- Infeasible test requirements are recognized and ignored
- Recognizing infeasible test requirements is generally undecidable
  - Thus usually done by hand

Logic Criteria Subsumption



Making Clauses Determine a Predicate

Three techniques

1. Informal **by inspection**
    - This is what we've been doing
    - Fast, but mistake-prone and does not scale—for experts
2. **Tabular** method
    - Very simple by hand
    - Few mistakes, slower, scales well to 5 or 6 clauses
3. **Definitional** method
    - More mathematical
    - Scales arbitrarily

Tabular Method

Find pairs of rows in the truth table

	a	b	P=a $\wedge$ b	p_a	p_b
1	T	T	T	●	●
2	T	F	F		●
3	F	T	F	●	
4	F	F	F		

For Pa, find a **pair** of rows where

- **b is the same** in both
- **a is different**
- **P is different**

For Pb, find a **pair** of rows where

- **a is the same** in both
- **b is different**
- **P is different**

Tabular Method

Find pairs of rows in the truth table

	a	b	$P = a \wedge b$	p_a	p_b
1	T	T	T	●	●
2	T	F	F		●
3	F	T	F	●	
4	F	F	F		

For Pa, find a **pair** of rows where
- **b is the same** in both
- **a is different**
- **P is different**

For Pb, find a **pair** of rows where
- **a is the same** in both
- **b is different**
- **P is different**

Now do the same for "or"

	a	b	$P = a \vee b$	p_a	p_b
1	T	T	T		
2	T	F	T	●	
3	F	T	T		●
4	F	F	F	●	●

In-class Exercise

Tabular method

Use the tabular method to solve for Pa, Pb, and Pc.
Give solutions as pairs of rows.

	a	b	c	$a \wedge (b \vee c)$	p_a	p_b	p_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			

In-class Exercise

Tabular method

b & *c* are the same, *a* differs, and *p* differs … thus TTT and FTT cause *a* to determine the value of *p*

Again, *b* & *c* are the same, so TTF and FTF cause *a* to determine the value of *p*

Finally, this third pair, TFT and FFT, also cause *a* to determine the value of *p*

For clause *b*, only one pair, TTF and TFF cause *b* to determine the value of *p*

Likewise, for clause *c*, only one pair, TFT and TFF, cause *c* to determine the value of *p*

	a	b	c	$a \wedge (b \vee c)$	p_a	p_b	p_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			

Three separate pairs of rows can cause *a* to determine the predicate.

Only one pair each for *b* and *c*.

Definitional Method

Scales better (more clauses), requires more math

Definitional approach:

- $\boldsymbol{p_{c=true}}$ is predicate *p* with every occurrence of *c* replaced by *true*
- $\boldsymbol{p_{c=false}}$ is predicate *p* with every occurrence of *c* replaced by *false*

To find values for the minor clauses, connect $\boldsymbol{p_{c=true}}$ and $\boldsymbol{p_{c=false}}$ with exclusive *OR*

$$p_c = p_{c=true} \oplus p_{c=false}$$

After solving, $\boldsymbol{p_c}$ describes exactly the values needed for ***c*** to determine ***p***

Definitional Method Examples

$p = a \vee b$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \vee b)$ XOR $(false \vee b)$

$=$ true XOR b

$= !\, b$

$p = a \wedge b$

Use the definitional approach to solve for Pa

Definitional Method Examples

$p = a \vee b$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \vee b)$ XOR $(false \vee b)$

$=$ true XOR b

$= !\,b$

$p = a \wedge b$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \wedge b) \oplus (false \wedge b)$

$= b \oplus false$

$= b$

Use the definitional approach to solve for Pa

Definitional Method Examples

$p = a \vee b$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \vee b)$ XOR $(false \vee b)$

$=$ true XOR b

$= !\, b$

$p = a \wedge b$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \wedge b) \oplus (false \wedge b)$

$= b \oplus false$

$= b$

Use the definitional approach to solve for Pa

$p = a \vee (b \wedge c)$

Use the definitional approach to solve for Pa

Definitional Method Examples

$p = a \vee b$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \vee b)$ XOR $(false \vee b)$

$=$ true XOR b

$= !\,b$

$p = a \wedge b$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \wedge b) \oplus (false \wedge b)$

$= b \oplus false$

$= b$

Use the definitional approach to solve for Pa

$p = a \vee (b \wedge c)$

$p_a = p_{a=true} \oplus p_{a=false}$

$= (true \vee (b \wedge c)) \oplus (false \vee (b \wedge c))$

$= true \oplus (b \wedge c)$

$= !\,(b \wedge c)$

$= !\,b \vee !\,c$

Use the definitional approach to solve for Pa

"*NOT b* $\vee$ *NOT c*" means either b or c must be false

XOR Identity Rules

Exclusive-OR (*xor*, ⊕) means both cannot be true

That is, A *xor* B means

"*A or B is true, but not both*"

$p = A \oplus A \wedge b$
$\quad = A \wedge \neg b$

$p = A \oplus A \vee b$
$\quad = \neg A \wedge b$

with fewer symbols …

p = A xor (A and b)
= A and !b

p = A xor (A or b)
= !A and b

Repeated Variables

The definitions in this chapter yield the same tests no matter how the predicate is expressed

$(a \vee b) \wedge (c \vee b) == (a \wedge c) \vee b$

$(a \wedge b) \vee (b \wedge c) \vee (a \wedge c)$

- Only has 8 possible tests, not 64

Use the simplest form of the predicate, and ignore contradictory truth table assignments

A More Subtle Example

$$p = (a \wedge b) \vee (a \wedge ! b)$$

$$p_a = p_{a=true} \oplus p_{a=false}$$
$$= ((true \wedge b) \vee (true \wedge ! b)) \oplus ((false \wedge b) \vee (false \wedge ! b))$$
$$= (b \vee ! b) \oplus false$$
$$= true \oplus false$$
$$= true$$

$$p = (a \wedge b) \vee (a \wedge \neg b)$$

$$p_b = p_{b=true} \oplus p_{b=false}$$
$$= ((a \wedge true) \vee (a \wedge ! true)) \oplus ((a \wedge false) \vee (a \wedge ! false))$$
$$= (a \vee false) \oplus (false \vee a)$$
$$= a \oplus a$$
$$= false$$

- *a* always determines the value of this predicate
- *b* never determines the value – *b* is irrelevant !

Logic Coverage Summary

Predicates are often **very simple**—in practice, most have less than 3 clauses

- In fact, most predicates only have one clause !
- With only clause, PC is enough
- With 2 or 3 clauses, CoC is practical
- Advantages of ACC and ICC criteria significant for large predicates
  - CoC is impractical for predicates with many clauses

Control software often has many complicated predicates, with lots of clauses

In-Class Exercise

Definitional method

P = (a | b) & (a | c) & d

Use the definitional method to solve for Pa
First step: ((T | b) & (T | c) & d) xor ((F | b) & (F | c) & d)

In-Class Exercise

Definitional method

P = (a | b) & (a | c) & d

Use the definitional method to solve for Pa
First step: ((T | b) & (T | c) & d) xor ((F | b) & (F | c) & d)

Pa = ((T | b) & (T | c) & d) xor ((F | b) & (F | c) & d)
= (T & T & d) xor (b & c & d)
= d xor (b & c & d)

Using the identity: A xor (A & b) == A and !b
= d & !(b & c)
= d & (!b | !c)