Logic Coverage Active Clause Coverage

CS 3250 Software Testing

[Ammann and Offutt, "Introduction to Software Testing," Ch. 8]

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Active Clause Coverage (ACC)

 From the testing perspective, we would test each clause under circumstances where the clause determines the predicate

For each p in P and each major clause c_i in Cp, choose minor clauses c_j , j != i, so that c_i determines p. TR has two requirements for each c_i : c_i evaluates to true and c_i evaluates to false.

- Steps:
 - Analyze determination, i.e., making the clause active
 - Derive test requirements that evaluates the major clause to true and false
- This is a form of "Modified Condition Decision Coverage" (MCDC), which is required by the US Federal Aviation Administration (FAA) for safety critical avionics software

p = a ∨ b

- $p_a = p_{a=true} \oplus p_{a=false}$
 - = (true \lor b) \oplus (false \lor b)
 - = true ⊕ b

= ¬b

For clause a, a determines p if and only if b is false Thus, we have two test requirements {(a=true, b = false), (a=false, b= false)}

$$p_b = p_{b=true} \oplus p_{b=false}$$

= (a \ne true) \oplus (a \ne false)
= true \oplus a
= \ne na

For clause b, b determines p if and only if a is false Thus, we have two test requirements {(a=false, b = true), (a=false, b= false)}

TR = {(a=true, b = false), (a=false, b= false), (a=false, b = true), (a=false, b= false)

- Overlap is common
- n \leq number test requirements \leq 2n, where n = number clauses

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Ambiguity in ACC

p = **a** ∧ (**b** ∨ **c**)

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

- = (true \land (b \lor c)) \oplus (false \land (b \lor c))
- = $(b \lor c) \oplus false$
- $= b \lor c$ $a = T, a = F, {TT, TF, FT} -- is this allowed?$
- Do the minor clauses have to have the same values when the major clause is true and false?

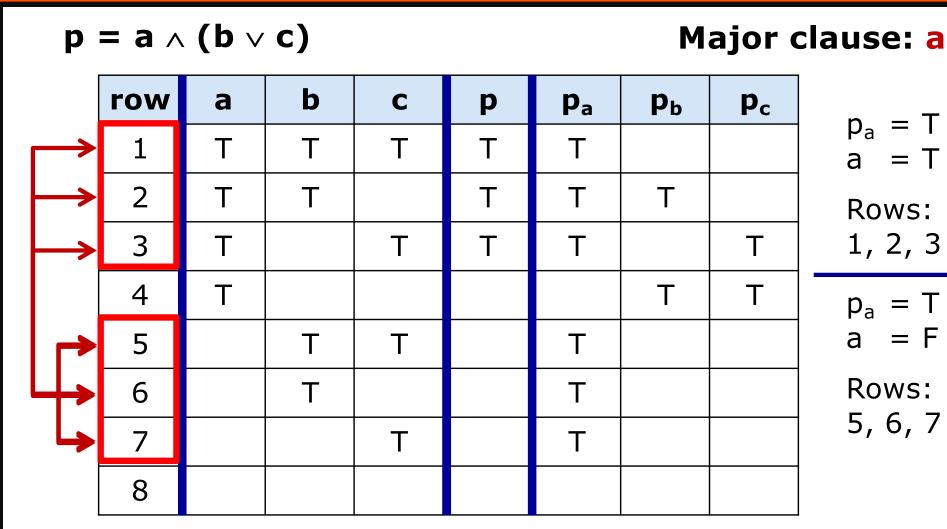
This leads to 3 separate criteria:

- 1. Minor clauses do not need to be the same (GACC)
- 2. Minor clauses must be the same and force the predicate to become both true and false (RACC)
- 3. Minor clauses force the predicate to become both true and false (CACC)

General Active Clause Coverage (GACC)

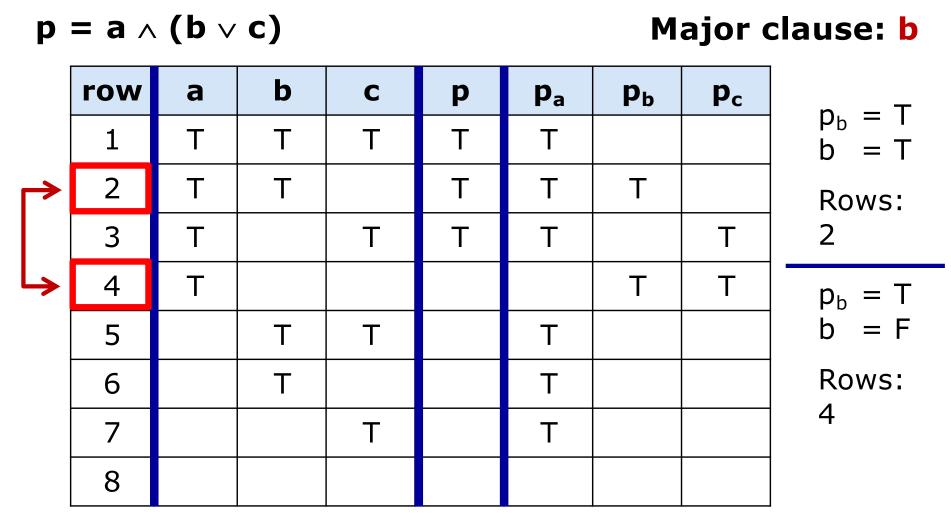
- For each major clause c, choose minor clauses such that c determines the predicate
- Clause c has to evaluate to true and false
- Minor clauses do not need to be the same

- Allow minor clauses to have different values
- Possible to satisfy GACC without satisfying predicate coverage
- We really want to cause predicates to be both true and false



Set of possible test requirements:

 $\{(1,5), (1,6), (1,7), (2,5), (2,6), (2,7), (3,5), (3,6), (3,7)\}$



Set of possible test requirements: {(2,4)}



Major clause: c

	row	а	b	С	р	p _a	p _b	p _c	
	1	Т	Т	Т	Т	Т			p _c = T c = T
	2	Т	Т		Т	Т	Т		Rows:
	3	Т		Т	Т	Т		Т	3
Ļ	4	Т					Т	Т	$p_c = T$
	5		Т	Т		Т			$p_c = T$ c = F
	6		Т			Т			Rows:
	7			Т		Т			4
	8								

Set of possible test requirements: {(3,4)}

Set of possible test requirements:

Major clause a: {(1,5), (1,6), (1,7), (2,5), (2,6), (2,7), (3,5), (3,6), (3,7)} Major clause b: {(2,4)}

Major clause c: $\{(3,4)\}$

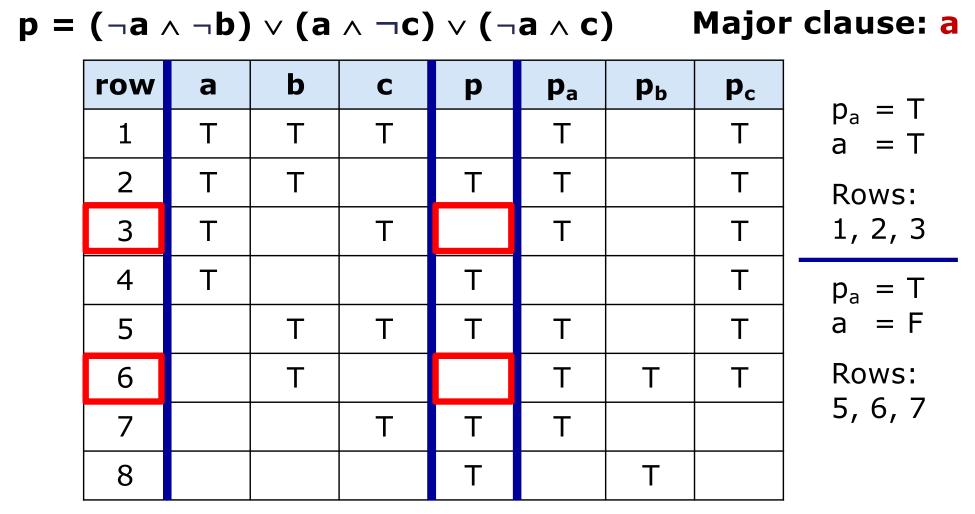
Give GACC-adequate test set (= minimal test set that satisfies GACC)

Based on the possible test requirements, select a smallest combination pairs (one for each clause)

(2, 5), (2, 4), (3, 4)

This means, we need at least 4 tests (i.e., test inputs) -- rows 2, 3, 4, 5 GACC-adequate test set = $\{2, 3, 4, 5\}$

GACC Does Not Subsume PC

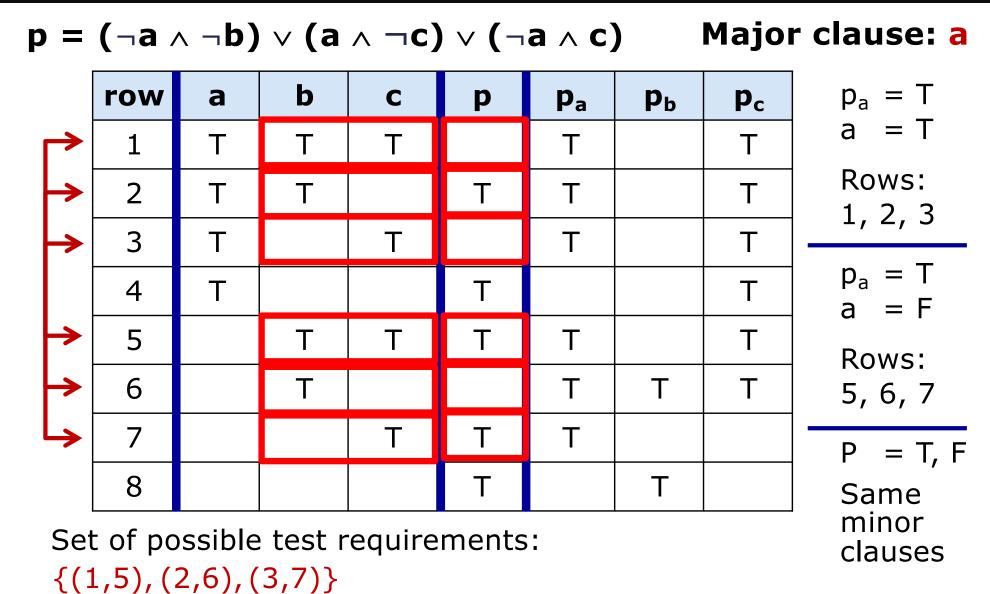


Set of possible test requirements:

 $\{(1,5), (1,6), (1,7), (2,5), (2,6), (2,7), (3,5), (3,6), (3,7)\}$

Restricted Active Clause Coverage (RACC)

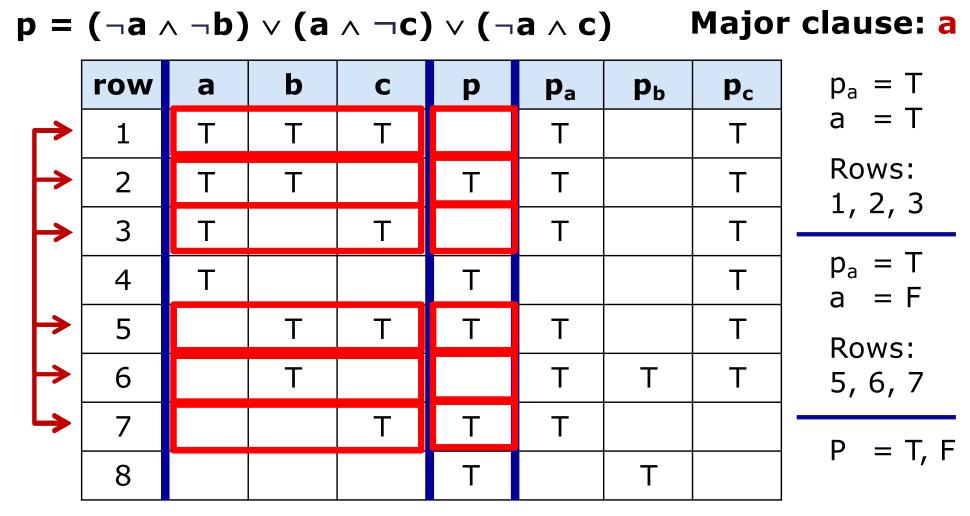
- For each major clause c, choose minor clauses such that c determines the predicate
- Clause c has to evaluate to true and false
- Predicate p has to evaluate to true and false
- Minor clauses must be the same
- This has been a common interpretation by aviation developers
- RACC often leads to infeasible test requirements
- Stricter version of CACC requires the same minor clause
- There is no logical reason for such a restriction



Then, derive tests for clauses b and c

Correlated Active Clause Coverage (CACC)

- For each major clause c, choose minor clauses such that c determines the predicate
- Clause c has to evaluate to true and false
- Predicate p has to evaluate to true and false
- Minor clauses do not need to be the same
- A more recent interpretation
- Implicitly allows minor clauses to have different values
- Explicitly satisfies (subsumes) predicate coverage
- Stricter version of GACC adds PC requirement to GACC



Set of possible test requirements: {(1,5), (1,7), (2,6), (3,5), (3,7)}

Then, derive tests for clauses b and c

CACC vs. RACC

- What is the difference between CACC and RACC?
 - RACC imposes more constraints on the truth values of minor clauses
 - RACC requires the the truth values for minor clauses are consistent between the two requirements
 - In practice?
 - There are fewer possible truth table row combinations that satisfy RACC
 - RACC leads to more infeasible test requirements than CACC

RACC Leads to Infeasible Requirements

- If clauses are independent, there is no problem
- If clauses are dependent, some combination of clauses become infeasible

Suppose a program has

$= a \land (b \lor c)$	Three clauses:			
	a = the valve is closed b = the system mode is operational c = the system mode is standby			

Assume the following constraints:

- A valve must be open in "operational" mode and closed in all other modes
- Mode cannot be in both "operational" and "standby" at the same time

Constraints: $\neg a \leftrightarrow b$ $\neg (b \land c)$

CACC and RACC – Infeasible TRs

 $p = a \land (b \lor c)$

Constraints: ¬a↔b

 $\neg (b \land c)$

row	а	b	С	р	Constraint violations
1	Т	Т	Т	Т	1,2
2	Т	Т	F	Т	1
3	Т	F	Т	Т	
4	Т	F	F	F	
5	F	Т	Т	F	2
6	F	Т	F	F	
7	F	F	Т	F	1
8	F	F	F	F	1

CACC: out of $\{1,2,3\} \times \{5,6,7\}$, only (3,6) is feasible RACC: out of (1,5), (2,6), (3,7), none are feasible

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Summary

- A clause is active if the other clauses have values that allow the active clause to determine the value of the predicate
- Active Clause Coverage (ACC) requires each clause to be made active, and then true and then false
- ACC comes with three different possible interpretations
 - General Active Clause Coverage (GACC)
 - Correlated Active Clause Coverage (CACC)
 - Restricted Active Clause Coverage (RACC)