

### Solution to Homework 3

Does criterion  $C_1$  subsume  $C_2$ ? That is, if a test set gives 100% coverage with respect to  $C_1$ , will it also give 100% coverage with respect to  $C_2$ ?

	block	statement	condition	decision	CD	MC	c-use	p-use	all-use
block		Yes (1)	No (2)	Yes (3)	Yes (4)	Yes (5)	No (6)	Yes (7)	Yes (8)
statement	Yes (1)		No (2)	Yes (3)	Yes (4)	Yes (5)	No (6)	Yes (7)	Yes (8)
condition	No (2)	No (2)		No (9)	Yes (10)	Yes (11)	No (12)	No (13)	No (14)
decision	No (3)	No (3)	No (9)		Yes (15)	Yes (16)	No (17)	Yes (18)	Yes (19)
CD	No (4)	No (4)	No (10)	No (15)		Yes (20)	No (21)	No (22)	No (23)
MC	No (5)	No (5)	No (11)	No (16)	No (20)		No (24)	No (25)	No (26)
c-use	No (6)	No (6)	No (12)	No (17)	No (21)	No (24)		No (27)	Yes (28)
p-use	No (7)	No (7)	No (13)	No (18)	No (22)	No (25)	No (27)		Yes (29)
all-use	No (8)	No (8)	No (14)	No (19)	No (23)	No (26)	No (28)	No (29)	

#### 1. block and statement

- 100% block coverage gives 100% statement coverage? → **Yes**

For each statement, it must belong to a block, so covering every block is equivalent to covering every statement.

- 100% statement coverage gives 100% block coverage? → **Yes**

For each block, it contains at least one statement, so covering every statement is equivalent to covering every block.

#### 2. block/statement and condition

- 100% block/statement coverage gives 100% condition coverage? → **No**

```

s1:    if (a > 0 && b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }

```

$t_1: \{a = 1, b = 1\}$  and  $t_2: \{a = 1, b = -1\}$  gives 100% block/statement coverage. To achieve 100% condition coverage, test cases need to make  $a > 0$  as true and false as well as  $b > 0$  as true and false. However,  $t_1$  and  $t_2$  fail to make  $a > 0$  as false so that the 100% condition coverage is not satisfied.

- 100% condition coverage gives 100% block/statement coverage? → **No**

```

s1:    if (a > 0 || b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }

```

$t_1: \{a = -1, b = 1\}$  and  $t_2: \{a = 1, b = -1\}$  gives 100% condition coverage (both  $a > 0$  and  $b > 0$  are evaluated as true and false). However,  $s_3$  and  $s_4$  are not covered since both test cases will make  $(a > 0 \parallel b > 0)$  as true.

### 3. block/statement and decision

- 100% block/statement coverage gives 100% decision coverage? → **No**

```

s1:      if (a > 0 && b > 0){
s2:          a++;
s3:          b++;
s4:      }

```

$t_1: \{a = 1, b = 1\}$  gives 100% block/statement coverage. However, the false branch is not taken so that the 100% decision coverage is not satisfied.

- 100% decision coverage gives 100% block/statement coverage? → **Yes**

Every block/statement must be part of a branch; or it will be covered by any test cases. So covering both true and false branches of all decisions makes every block/statement to be covered.

### 4. block/Statement and condition-decision

- 100% block/statement coverage gives 100% condition-decision coverage? → **No**

Since 100% block/statement coverage cannot guarantee 100% condition or decision coverage, it cannot give 100% condition-decision coverage (which subsumes condition coverage and decision coverage).

- 100% condition-decision coverage gives 100% block/statement coverage? → **Yes**

Since 100% decision coverage gives 100% block/statement coverage, 100% condition-decision (which subsumes condition coverage and decision coverage) also gives 100% block/statement coverage.

### 5. block/Statement and multiple-condition

- 100% block/statement coverage gives 100% multiple-condition coverage? → **No**

```

s1:      if (a > 0 && b > 0){
s2:          a++;
s3:      }else{
s4:          b++;
s5:      }

```

100% multiple-condition coverage requires test cases which make  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ .

$t_1: \{a = 1, b = 1\}$  and  $t_2: \{a = 1, b = -1\}$  gives 100% block/statement coverage. However, only  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$  and  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$  are covered.

- 100% multiple-condition coverage gives 100% block/statement coverage? → **Yes**

If 100% multiple-condition coverage is achieved, it means all program paths have been covered. Hence, all block/statement will also be covered.

#### 6. block/statement and c-use

- 100% block/statement coverage gives 100% c-use coverage? → **No**

```

s1:    if (a > 0) {
s2:        x = 1
s3:    }else{
s4:        x = 2;
s5:    }
s6:    if (b > 0) {
s7:        y = x + 1;
s8:    }else{
s9:        y = x - 1;
s10:   }
```

The define/c-use pair of variable  $x$  contains  $(s_2, s_7)$ ,  $(s_2, s_9)$ ,  $(s_4, s_7)$ ,  $(s_4, s_9)$ .

$t_1: \{a = -1, b = 1\}$  and  $t_2: \{a = 1, b = -1\}$  gives 100% block/statement coverage. However, only two pairs are covered  $(s_2, s_9)$ ,  $(s_4, s_7)$ .

- 100% c-use coverage gives 100% block/statement coverage? → **No**

```

s1:    input (a, b);
s2:    if (a > 0){
s3:        print (a + b);
s4:    }else{
s5:        print ("Hello World!");
s6:    }
```

$s_5$  does not contain c-use of any variable.  $t_1: \{a = 1, b = 1\}$  gives 100% c-use coverage. However,  $s_5$  is not covered.

#### 7. block/statement and p-use

- 100% block/statement coverage gives 100% p-use coverage? → **No**

```

s1:    input (x);
s2:    if (x > 0) {
s3:        y = x + 1;
s4:    }
s5:    print(y);
```

$t_1: \{x = 1\}$  gives 100% block/statement coverage. 100% p-use coverage requires define/p-use pairs  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$  to be covered. However, only one of them,  $(s_1, (s_2, s_3))$  is covered.

- 100% p-use coverage gives 100% block/statement coverage? → **Yes**

```

s1:    input (x, y);
s2:    if (x > 0) {
s3:        x++;
s4:    }
s5:    print(x);
s6:    if (y > 0) {
s7:        y++;
s8:    }
s9:    print(y);

```

100% p-use coverage guarantees that define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $x$  are covered and define/p-use pairs,  $(s_1, (s_6, s_7))$  and  $(s_1, (s_6, s_9))$ , of variable  $y$  are covered. It implies that all program branches are covered. Hence, all block/statements are also covered.

#### 8. block/statement and all-use

- 100% block/statement coverage gives 100% all-use coverage? → **No**

Since 100% block/statement coverage does not give 100% c-use coverage or 100% p-use coverage, it cannot give 100% all-use coverage (which subsumes c-use and p-use coverage).

- 100% all-use coverage gives 100% block/statement coverage? → **Yes**

Since 100% p-use coverage give 100% block/statement coverage, 100% all-use coverage also gives 100% block/statement coverage.

#### 9. condition and decision

- 100% condition coverage gives 100% decision coverage? → **No**

```

s1:    if (a > 0 || b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }

```

$t_1: \{a = -1, b = 1\}$  and  $t_2: \{a = 1, b = -1\}$  gives 100% condition coverage (both  $a > 0$  and  $b > 0$  are evaluated as true and false). However, these test cases cannot make  $(a > 0 || b > 0)$  as false so that 100% decision coverage cannot be achieved.

- 100% decision coverage gives 100% condition coverage? → **No**

```

s1:    if (a > 0 || b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }

```

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = -1, b = -1\}$  gives 100% decision coverage ( $(a > 0 \parallel b > 0)$  is evaluated as true and false). However, they cannot make condition  $a > 0$  as true so that 100% condition coverage cannot be achieved.

#### 10. condition and condition-decision

- 100% condition coverage gives 100% condition-decision coverage? → **No**

Since 100% condition cannot give 100% decision coverage, it also cannot give 100% condition-decision coverage (which subsumes condition and decision coverage).

- 100% condition-decision coverage gives 100% condition coverage? → **Yes**

Condition-decision coverage subsumes condition coverage and decision coverage.

#### 11. condition and multiple-condition

- 100% condition coverage gives 100% multiple-condition coverage? → **No**

```

s1:    if (a > 0 || b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }
```

100% Multiple-condition coverage requires test cases which cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ .

$t_1: \{a = -1, b = 1\}$  and  $t_2: \{a = 1, b = -1\}$  gives 100% condition coverage (both  $a > 0$  and  $b > 0$  are evaluated as true and false). However, they cannot cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$  and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ .

- 100% multiple-condition coverage gives 100% condition coverage? → **Yes**

```

s1:    if (a > 0 || b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }
```

100% Multiple-condition coverage requires test cases which cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ . If 100% multiple-condition coverage is satisfied then each condition must be evaluated as true and false.

## 12. condition and c-use

- 100% condition coverage gives 100% c-use coverage? → **No**

```
s1:    input (a, b); x = 0; y = 0;
s2:    if (a > 0 || b > 0){
s3:        a = x + 1;
s4:    }else{
s5:        b = y + 1;
s6:    }
```

The define/c-use pair of variable  $x$  contains  $(s_1, s_3)$ .

The define/c-use pair of variable  $y$  contains  $(s_1, s_5)$ .

$t_1: \{a = -1, b = 1\}$  and  $t_2: \{a = 1, b = -1\}$  gives 100% condition coverage. However, the define/c-use pair of  $y$  is not covered.

- 100% c-use coverage gives 100% condition coverage? → **No**

```
s1:    input (a, b);
s2:    if (a > 0){
s3:        print (a + b);
s4:    }else{
s5:        print ("Hello World!");
s6:    }
```

$s_5$  does not contain c-use of any variable.  $t_1: \{a = 1, b = 1\}$  gives 100% c-use coverage. However,  $t_1$  cannot make  $a > 0$  as false.

## 13. condition and p-use

- 100% condition coverage gives 100% p-use coverage? → **No**

```
s1:    input (a, b);
s2:    if (a > 0 || b > 0){
s3:        x ++;
s4:    }else{
s5:        y ++;
s6:    }
```

100% p-use coverage requires define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $a$  and define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $b$  to be covered.

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = 1, b = -1\}$  gives 100% condition coverage. However, only  $(s_1, (s_2, s_3))$  of  $a$  and  $(s_1, (s_2, s_3))$  of  $b$  are covered.

- 100% p-use coverage gives 100% condition coverage? → **No**

```
s1:    input (a, b);
s2:    if (a > 0 || b > 0){
s3:        x ++;
s4:    }else{
```

```

s5:      y ++;
s6:      }

```

100% p-use coverage requires define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $a$  and define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $b$  to be covered.

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = -1, b = -1\}$  gives 100% p-use coverage. However,  $a > 0$  cannot be true using these test cases.

#### 14. condition and all-use

- 100% condition coverage gives 100% all-use coverage? → **No**

Since 100% condition cannot give 100% p-use or 100% c-use coverage, it also cannot give 100% all-use coverage (which subsumes c-use and p-use coverage).

- 100% all-use coverage gives 100% condition coverage? → **No**

```

s1:      input (a, b, x, y);
s2:      if (a > 0 || b > 0){
s3:          x ++;
s4:      }else{
s5:          y ++;
s6:      }

```

100% p-use coverage requires define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $a$  and define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $b$  to be covered.

The define/c-use pair of variable  $x$  contains  $(s_1, s_3)$ . The define/c-use pair of variable  $y$  contains  $(s_1, s_5)$ .

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = -1, b = -1\}$  gives 100% all-use (100% c-use and 100% p-use) coverage. However,  $a > 0$  cannot be true using these test cases.

#### 15. decision and condition-decision

- 100% decision coverage gives 100% condition-decision coverage? → **No**

Since 100% decision cannot give 100% condition coverage, it also cannot give 100% condition-decision coverage (which subsumes condition and decision coverage).

- 100% condition-decision coverage gives 100% condition coverage? → **Yes**

Condition-decision coverage subsumes condition coverage and decision coverage.

#### 16. decision and multiple-condition

- 100% decision coverage gives 100% multiple-condition coverage? → **No**

```

s1:      if (a > 0 || b > 0){
s2:          a++;

```

```

s3:      }else{
s4:      b++;
s5:      }

```

100% Multiple-condition coverage requires test cases which cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ .

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = -1, b = -1\}$  gives 100% decision coverage. However, they cannot cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$  and  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ .

- 100% multiple-condition coverage gives 100% decision coverage? → **Yes**

```

s1:      if (a > 0 || b > 0){
s2:      a++;
s3:      }else{
s4:      b++;
s5:      }

```

100% Multiple-condition coverage requires test cases which cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ . If 100% multiple-condition coverage is satisfied then all decision must be evaluated as both true and false.

## 17. decision and c-use

- 100% decision coverage gives 100% c-use coverage? → **No**

```

s1:      if (a > 0) {
s2:      x = 1
s3:      }else{
s4:      x = 2;
s5:      }
s6:      if (b > 0) {
s7:      y = x + 1;
s8:      }else{
s9:      y = x - 1;
s10:     }

```

The define/c-use pair of variable  $x$  contains  $(s_2, s_7)$ ,  $(s_2, s_9)$ ,  $(s_4, s_7)$ ,  $(s_4, s_9)$ .

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = 1, b = -1\}$  gives 100% decision coverage. However, only two pairs are covered  $(s_2, s_9)$ ,  $(s_4, s_7)$ .

- 100% c-use coverage gives 100% decision coverage? → **No**

```

s1:      input (a, b);
s2:      if (a > 0){
s3:      print (a + b);
s4:      }else{
s5:      print ("Hello World!");
s6:      }

```



$s_5$  does not contain c-use of any variable.  $t_1: \{a = 1, b = 1\}$  gives 100% c-use coverage. However,  $t_1$  cannot make  $a > 0$  as false.

#### 18. decision and p-use

- 100% decision coverage gives 100% p-use coverage? → **No**

```

s1:    input (a);
s2:    if (a > 2) {
s3:        x = a * 2;
s4:    }else{
s5:        x = a + 6;
s6:    }
s7:    if (x > 7) {
s8:        y = x + 1;
s9:    }else{
s10:        y = x - 1;
s11:    }

```

100% p-use coverage requires define/p-use pairs,  $(s_3, (s_7, s_8))$ ,  $(s_3, (s_7, s_{10}))$ ,  $(s_5, (s_7, s_8))$ , and  $(s_5, (s_7, s_{10}))$  of variable  $x$  are covered.

$t_1: \{a = 4\}$ ,  $t_2: \{a = 1\}$  gives 100% decision coverage.

$t_1$  covers  $(s_3, (s_7, s_8))$  of  $x$ .

$t_2$  covers  $(s_5, (s_7, s_{10}))$  of  $x$ .

$(s_3, (s_7, s_{10}))$  and  $(s_5, (s_7, s_8))$  are not covered.

- 100% p-use coverage gives 100% decision coverage? → **Yes**

```

s1:    input (a);
s2:    if (a > 2) {
s3:        x = a * 2;
s4:    }else{
s5:        x = a + 6;
s6:    }
s7:    if (x > 7) {
s8:        y = x + 1;
s9:    }else{
s10:        y = x - 1;
s11:    }

```

100% p-use coverage requires define/p-use pairs,  $(s_3, (s_7, s_8))$ ,  $(s_3, (s_7, s_{10}))$ ,  $(s_5, (s_7, s_8))$ , and  $(s_5, (s_7, s_{10}))$  of variable  $x$  are covered.

$t_1: \{a = 4\}$ ,  $t_2: \{a = 1\}$ ,  $t_3: \{a = 3\}$ ,  $t_4: \{a = 2\}$  gives 100% p-use coverage. They also guarantee 100% decision coverage.

Generally speaking, for p-use coverage, every p-use must independently contribute to the decision taking both a true and false branch. So it guarantees decision coverage.

#### 19. decision and all-use

- 100% decision coverage gives 100% all-use coverage? → **No**

Since 100% decision coverage cannot give 100% p-use or 100% c-use coverage, it also cannot give 100% all-use coverage (which subsumes c-use and p-use coverage).

- 100% all-use coverage gives 100% decision coverage? → **Yes**

Since 100% p-use coverage gives 100% decision coverage, 100% all-use coverage (which subsumes p-use coverage) also gives 100% decision coverage.

## 20. condition-decision and multiple-condition

- 100% condition-decision coverage gives 100% multiple-condition coverage? → **No**

```

s1:    if (a > 0 || b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }

```

100% Multiple-condition coverage requires test cases which cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ .

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = -1, b = -1\}$ ,  $t_3: \{a = 1, b = -1\}$  gives 100% condition-decision coverage. However, they cannot cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ .

- 100% multiple-condition coverage gives 100% condition-decision coverage? → **Yes**

```

s1:    if (a > 0 || b > 0){
s2:        a++;
s3:    }else{
s4:        b++;
s5:    }

```

100% Multiple-condition coverage requires test cases which cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ .

If 100% multiple-condition coverage is satisfied, it implies all possible combinations of condition outcomes are covered so that 100% condition-decision coverage is achieved.

## 21. condition-decision and c-use

- 100% condition-decision coverage gives 100% c-use coverage? → **No**

```

s1:    if (a > 0) {
s2:        x = 1
s3:    }else{
s4:        x = 2;
s5:    }
s6:    if (b > 0) {
s7:        y = x + 1;
s8:    }else{
s9:        y = x - 1;

```

```
s10:    }
```

The define/c-use pair of variable  $x$  contains  $(s_2, s_7), (s_2, s_9), (s_4, s_7), (s_4, s_9)$ .

$t_1: \{a = -1, b = 1\}, t_2: \{a = 1, b = -1\}$  gives 100% condition-decision coverage. However, only two pairs are covered  $(s_2, s_9), (s_4, s_7)$ .

- 100% c-use coverage gives 100% condition-decision coverage? → **No**

```
s1:    input (a, b);
s2:    if (a > 0){
s3:        print (a + b);
s4:    }else{
s5:        print ("Hello World!");
s6:    }
```

$s_5$  does not contain c-use of any variable.  $t_1: \{a = 1, b = 1\}$  gives 100% c-use coverage. However,  $t_1$  cannot make  $a > 0$  as false.

## 22. condition-decision and p-use

- 100% condition-decision coverage gives 100% p-use coverage? → **No**

```
s1:    input (a);
s2:    if (a > 2) {
s3:        x = a * 2;
s4:    }else{
s5:        x = a + 6;
s6:    }
s7:    if (x > 7) {
s8:        y = x + 1;
s9:    }else{
s10:    y = x - 1;
s11:    }
```

100% p-use coverage requires define/p-use pairs,  $(s_3, (s_7, s_8)), (s_3, (s_7, s_{10})), (s_5, (s_7, s_8)),$  and  $(s_5, (s_7, s_{10}))$  of variable  $x$  are covered.

$t_1: \{a = 4\}, t_2: \{a = 1\}$  gives 100% condition-decision coverage.

$t_1$  covers  $(s_3, (s_7, s_8))$  of  $x$ .

$t_2$  covers  $(s_5, (s_7, s_{10}))$  of  $x$ .

$(s_3, (s_7, s_{10}))$  and  $(s_5, (s_7, s_8))$  are not covered.

- 100% p-use coverage gives 100% condition-decision coverage? → **No**

```
s1:    input (a, b);
s2:    if (a > 0 || b > 0){
s3:        x++;
s4:    }else{
s5:        y++;
s6:    }
```

100% p-use coverage requires define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $a$  and define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $b$  are covered.

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = -1, b = -1\}$  gives 100% p-use coverage. However,  $a > 0$  cannot be true using these test cases. So 100% condition-decision coverage is not satisfied.

## 23. condition-decision and all-use

- 100% condition-decision coverage gives 100% all-use coverage? → **No**

Since 100% condition-decision coverage cannot give 100% p-use or 100% c-use coverage, it also cannot give 100% all-use coverage (which subsumes c-use and p-use coverage).

- 100% all-use coverage gives 100% condition-decision coverage? → **No**

Since 100% all-use coverage cannot give 100% condition coverage, Hence 100% all-use coverage also cannot give 100% condition-decision coverage (which subsumes decision and condition coverage).

## 24. multiple-condition and c-use

- 100% multiple-condition coverage gives 100% c-use coverage? → **No**

```

s1:    if (a > 0) {
s2:        x = 1
s3:    }else{
s4:        x = 2;
s5:    }
s6:    if (b > 0) {
s7:        y = x + 1;
s8:    }else{
s9:        y = x - 1;
s10:    }

```

The define/c-use pair of variable  $x$  contains  $(s_2, s_7)$ ,  $(s_2, s_9)$ ,  $(s_4, s_7)$ ,  $(s_4, s_9)$ .

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = 1, b = -1\}$  gives 100% multiple-condition coverage. However, only two pairs are covered  $(s_2, s_9)$ ,  $(s_4, s_7)$ .

- 100% c-use coverage gives 100% multiple-condition coverage? → **No**

```

s1:    input (a, b);
s2:    if (a > 0){
s3:        print (a + b);
s4:    }else{
s5:        print ("Hello World!");
s6:    }

```

$s_5$  does not contain c-use of any variable.  $t_1: \{a = 1, b = 1\}$  gives 100% c-use coverage. However,  $t_1$  cannot make  $a > 0$  as false.

## 25. multiple-condition and p-use

- 100% multiple-condition coverage gives 100% p-use coverage? → **No**

```
s1:    input (a);
s2:    if (a > 2) {
s3:        x = a * 2;
s4:    }else{
s5:        x = a + 6;
s6:    }
s7:    if (x > 7) {
s8:        y = x + 1;
s9:    }else{
s10:        y = x - 1;
s11:    }
```

100% p-use coverage requires define/p-use pairs,  $(s_3, (s_7, s_8))$ ,  $(s_3, (s_7, s_{10}))$ ,  $(s_5, (s_7, s_8))$ , and  $(s_5, (s_7, s_{10}))$  of variable  $x$  are covered.

$t_1: \{a = 4\}$ ,  $t_2: \{a = 1\}$  gives 100% multiple-condition coverage.

$t_1$  covers  $(s_3, (s_7, s_8))$  of  $x$ .

$t_2$  covers  $(s_5, (s_7, s_{10}))$  of  $x$ .

$(s_3, (s_7, s_{10}))$  and  $(s_5, (s_7, s_8))$  are not covered.

- 100% p-use coverage gives 100% multiple-condition coverage? → **No**

```
s1:    input (a, b);
s2:    if (a > 0 || b > 0){
s3:        x ++;
s4:    }else{
s5:        y ++;
s6:    }
```

100% p-use coverage requires define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $a$  and define/p-use pairs,  $(s_1, (s_2, s_3))$  and  $(s_1, (s_2, s_5))$ , of variable  $b$  are covered.

$t_1: \{a = -1, b = 1\}$ ,  $t_2: \{a = -1, b = -1\}$  gives 100% p-use coverage. However, to satisfy 100% multiple condition coverage, test cases need to cover  $\{a > 0 \text{ as true}, b > 0 \text{ as true}\}$ ,  $\{a > 0 \text{ as true}, b > 0 \text{ as false}\}$ ,  $\{a > 0 \text{ as false}, b > 0 \text{ as true}\}$ , and  $\{a > 0 \text{ as false}, b > 0 \text{ as false}\}$ . Two test cases obviously cannot achieve such coverage.

## 26. multiple-condition and all-use

- 100% multiple-condition coverage gives 100% all-use coverage? → **No**

Since 100% multiple-condition coverage cannot give 100% p-use or 100% c-use coverage, it also cannot give 100% all-use coverage (which subsumes c-use and p-use coverage).

- 100% all-use coverage gives 100% multiple-condition coverage? → **No**

Since 100% all-use coverage cannot give 100% condition coverage, Hence 100% all-use coverage also cannot give 100% multiple-condition coverage.

## 27. c-use and p-use

- 100% c-use coverage gives 100% p-use coverage? → **No**

```
s1:    input (a, b);
s2:    if (a > 0){
s3:        print (a + b);
s4:    }else{
s5:        print ("Hello World!");
s6:    }
```

$s_5$  does not contain c-use of any variable.  $t_1: \{a = 1, b = 1\}$  gives 100% c-use coverage. However, define/p-use pair of variable  $a$ ,  $(s_1, (s_2, s_5))$ , is not covered.

- 100% p-use coverage gives 100% c-use coverage? → **No**

```
s1:    input (a, b)
s2:    if (a > 0) {
s3:        x = 1
s4:    }else{
s5:        x = 2;
s6:    }
s7:    if (b > 0) {
s8:        y = x + 1;
s9:    }else{
s10:        y = x - 1;
s11:    }
```

The define/c-use pair of variable  $x$  contains  $(s_3, s_8), (s_3, s_{10}), (s_5, s_8), (s_5, s_{10})$ .

The define/p-use pair of variable  $a$  contains  $(s_1, (s_2, s_3)), (s_1, (s_2, s_5))$

The define/p-use pair of variable  $b$  contains  $(s_1, (s_7, s_8)), (s_1, (s_7, s_{10}))$

$t_1: \{a = -1, b = 1\}, t_2: \{a = 1, b = -1\}$  gives 100% p-use coverage. However, two define/c-use pairs of  $x$  are not covered  $(s_3, s_8), (s_5, s_{10})$ .

## 28. c-use and all-use

- 100% c-use coverage gives 100% all-use coverage? → **No**

100% c-use does not give 100% p-use (which is subsumed by all-use).

- 100% all-use coverage gives 100% c-use coverage? → **Yes**

All-use subsumes c-use.

## 29. p-use and all-use

- 100% c-use coverage gives 100% all-use coverage? → **No**

100% p-use does not give 100% c-use (which is subsumed by all-use).

- 100% all-use coverage gives 100% c-use coverage? → **Yes**

All-use subsumes p-use.