Introduction to Software Testing
Chapter 8.3
Logic Coverage for Source Code

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Logic Expressions from Source

- Predicates are derived from decision statements
- In programs, most predicates have less than four clauses
  - Wise programmers actively strive to keep predicates simple
- When a predicate only has one clause, COC, ACC, ICC, and CC all collapse to predicate coverage (PC)
- Applying logic criteria to program source is hard because of reachability and controllability:
  - *Reachability* : Before applying the criteria on a predicate at a particular statement, we have to get to that statement
  - *Controllability* : We have to find input values that indirectly assign values to the variables in the predicates
  - Variables in the predicates that are not inputs to the program are called *internal variables*
- Illustrated through an example in the following slides …

Thermostat (*pg 1 of 2*)

```
// Jeff Offutt & Paul Ammann—September 2014
// Programmable Thermostat
import java.io.*;
public class Thermostat
{
   private int curTemp;                 // Current temperature reading
   private int thresholdDiff;           // Temp difference until heater on
   private int timeSinceLastRun; // Time since heater stopped
   private int minLag;                  // How long I need to wait
   private boolean Override;            // Has user overridden the program
   private int overTemp;                // OverridingTemp
   private int runTime;                 // output of turnHeaterOn–how long to run
   private boolean heaterOn;            // output of turnHeaterOn – whether to run
   private Period period;               // morning, day, evening, or night
   private DayType day;                 // week day or weekend day
   // Decide whether to turn the heater on, and for how long.
   public boolean turnHeaterOn (ProgrammedSettings pSet)
   {
```

Thermostat (*pg 2 of 2*)

```
    int dTemp = pSet.getSetting (period, day);
    if (((curTemp < dTemp - thresholdDiff) ||
        (Override && curTemp < overTemp - thresholdDiff)) &&
        (timeSinceLastRun > minLag))
    {  // Turn on the heater
      // How long? Assume 1 minute per degree (Fahrenheit)
      int timeNeeded = curTemp - dTemp;
      if (Override)
        timeNeeded = curTemp - overTemp;
      setRunTime (timeNeeded);
      setHeaterOn (true);
      return (true);
    }
    else
    {
      setHeaterOn (false);
      return (false);
    }
} // End turnHeaterOn
```

The full class is in the book and on the book website.

Two Thermostat Predicates

**28-30 : (((curTemp < dTemp - thresholdDiff) ||
(Override && curTemp < overTemp - thresholdDiff)) &&
timeSinceLastRun > minLag))**

34 : (Override)

Simplify

a : curTemp < dTemp - thresholdDiff

b : Override

c : curTemp < overTemp - thresholdDiff

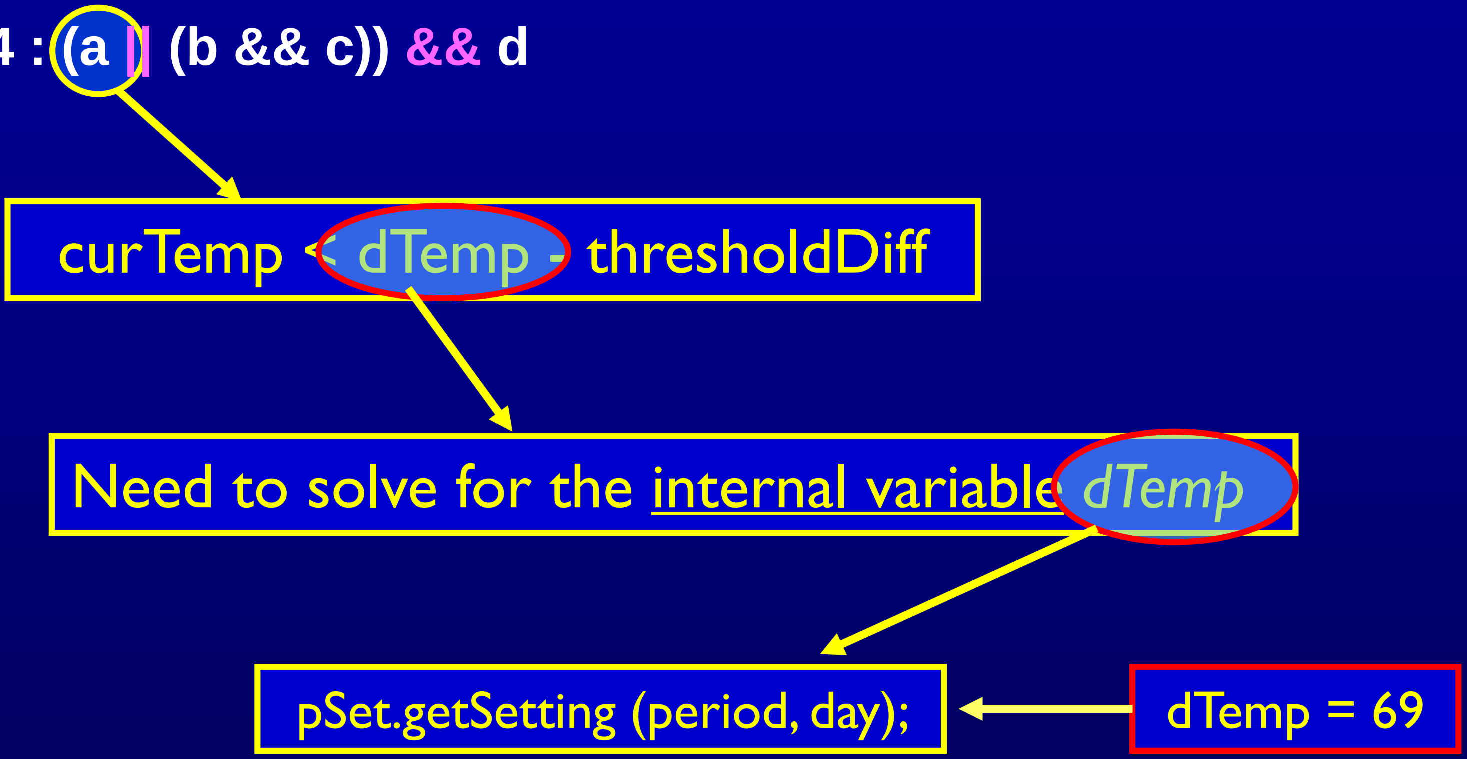
d : timeSinceLastRun > minLag)

28-30 : (a || (b && c)) && d

34 : b

Reachability for Thermostat Predicates

28-30 : True



34 : (a || (b && c)) && d

curTemp < dTemp - thresholdDiff

Need to solve for the internal variable *dTemp*

pSet.getSetting (period, day);

dTemp = 69

```
setSetting (Period.MORNING, DayType.WEEKDAY, 69);
setPeriod (Period.MORNING);
setDay (DayType.WEEKDAY);
```

Predicate Coverage (*true*)

(8.3.1)

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

a : true b : true
c : true d : true

a: curTemp < dTemp – thresholdDiff : true
b: Override : true
c: curTemp < overTemp – thresholdDiff : true
d: timeSinceLastRun > (minLag) : true

```
thermo = new Thermostat();  // Needed object
settings = new ProgrammedSettings();  // Needed object
settings.setSetting (Period.MORNING, DayType.WEEKDAY, 69);  // dTemp
thermo.setPeriod (Period.MORNING);  // dTemp
thermo.setDay (DayType.WEEKDAY);  // dTemp
thermo.setCurrentTemp (63);  // clause a
thermo.setThresholdDiff (5);   // clause a
thermo.setOverride (true);  // clause b
thermo.setOverTemp (70);  // clause c
thermo.setMinLag (10);  // clause d
thermo.setTimeSinceLastRun (12);  // clause d
assertTrue (thermo.turnHeaterOn (settings));   // Run test
```

Correlated Active Clause Coverage

(1 of 6)

(8.3.3)

P_a = ((a || (b && c)) && d) ⊕ ((a || (b && c)) && d)

((T || (b && c)) && d) ⊕ ((F || (b && c)) && d)

(T && d) ⊕ ((b && c) && d)

d ⊕ ((b && c) && d)

T ⊕ ((b && c) && T)

!(b && c) && d

(!b || !c) && d

Check with the logic coverage web app
http://cs.gmu.edu:8080/offutt/coverage/LogicCoverage

Correlated Active Clause Coverage

(1 of 6) (8.3.3)

P_b = ((a || (b && c)) && d) ⊕ ((a || (b && c)) && d)

((a || (T && c)) && d) ⊕ ((a || (F && c)) && d)

((a || c) && d) ⊕ ((a || F) && d)

((a || c) && d) ⊕ (a && d)

(((a || c) && d) && !(ad)) || (!((a || c) && d) && ad)

(((a || c) && d) && (!a || !d) || !a && !c && d && ad

!a && c && d

Check with the logic coverage web app
http://cs.gmu.edu:8080/offutt/coverage/LogicCoverage

Correlated Active Clause Coverage

(2 of 6)

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

	a	b	c	d
P_a :	T	t	f	t
	F	t	f	t
P_b :	f	T	t	t
	f	F	t	t
P_c :	~~f~~	~~t~~	~~T~~	~~t~~
	~~f~~	~~t~~	~~F~~	~~t~~
P_d :	t	t	t	T
	t	t	t	F

duplicates

Six tests needed for CACC on Thermostat

Correlated Active Clause Coverage

(3 of 6)

	curTemp	dTemp	thresholdDiff
a=t : curTemp < dTemp - thresholdDiff	63	69	5
a=f : !(curTemp < dTemp - thresholdDiff)	66	69	5

dTemp:

```
   settings.setSettings (Period.MORNING, DayType.WEEKDAY, 69)
   thermo.setPeriod (Period.MORNING);
   thermo.setDay (Daytype.WEEKDAY);
```

	Override
b=t : Override	T
b=f : !Override	F

These values then need to be placed into calls to turnHeaterOn() to satisfy the 6 tests for CACC

	curTemp	overTemp	thresholdDiff
c=t : curTemp < overTemp - thresholdDiff	63	72	5
c=f : !(curTemp < overTemp - thresholdDiff)	66	67	5

	timeSinceLastRun	minLag
d=t : timeSinceLastRun > minLag	12	10
d=f : !(timeSinceLastRun > minLag)	8	10

Correlated Active Clause Coverage

(4 of 6)

dTemp = 69 (period = MORNING, daytype = WEEKDAY)

1. T t f t

```
thermo.setCurrentTemp (63);
thermo.setThresholdDiff (5);
thermo.setOverride (true);
thermo.setOverTemp (67); // c is false
thermo.setMinLag (10);
thermo.setTimeSinceLastRun (12);
```

2. F t f t

```
thermo.setCurrentTemp (66); // a is false
thermo.setThresholdDiff (5);
thermo.setOverride (true);
thermo.setOverTemp (67); // c is false
thermo.setMinLag (10);
thermo.setTimeSinceLastRun (12);
```

Correlated Active Clause Coverage

(5 of 6)

dTemp = 69 (period = MORNING, daytype = WEEKDAY)

3. f T t t

```
thermo.setCurrentTemp (66); // a is false
thermo.setThresholdDiff (5);
thermo.setOverride (true);
thermo.setOverTemp (72); // to make c true
thermo.setMinLag (10);
thermo.setTimeSinceLastRun (12);
```

4. F f T t

```
thermo.setCurrentTemp (66); // a is false
thermo.setThresholdDiff (5);
thermo.setOverride (false); // b is false
thermo.setOverTemp (72);
thermo.setMinLag (10);
thermo.setTimeSinceLastRun (12);
```

Correlated Active Clause Coverage

(6 of 6)

dTemp = 69 (period = MORNING, daytype = WEEKDAY)

5. t t t T

```
thermo.setCurrentTemp (63);
thermo.setThresholdDiff (5);
thermo.setOverride (true);
thermo.setOverTemp (72);
thermo.setMinLag (10);
thermo.setTimeSinceLastRun (12);
```

6. t t t F

```
thermo.setCurrentTemp (63);
thermo.setThresholdDiff (5);
thermo.setOverride (true);
thermo.setOverTemp (72);
thermo.setMinLag (10);
thermo.setTimeSinceLastRun (8); // d is false
```

Program Transformation Issues

(8.3.4)

```
if ((a && b) || c)
{
    S1;
}
else
{
    S2;
}
```

Transform (1) ?

```
if (a) {
    if (b)
        S1;
    else {
        if (c)
            S1;
        else
            S2;
    }
}
else {
    if (c)
        S1;
    else
        S2;
}
```

Problems With Transformation 1

- We trade one problem for two problems :
  - Maintenance becomes harder
  - Reachability becomes harder
- Consider coverage :
  - CACC on the original requires four rows marked in the table
  - PC on the transformed version requires five different rows

a	b	c	$(a \wedge b) \vee c$	CACC	PC_T
T	T	T	T		X
T	T	F	T	X	
T	F	T	T	X	X
T	F	F	F	X	X
F	T	T	T		X
F	T	F	F	X	
F	F	T	T		
F	F	F	F		X

- PC on the transformed version has two problems :
  1. It does not satisfy CACC on the original
  2. It is more expensive (more tests)

Program Transformation Issue 2

```
if ((a && b) || c)
{
     S1;
}
else
{
     S2;
}
```

→ Transform (2) ?

```
d = a && b;
e = d || c;
if (e)
{
     S1;
}
else
{
     S2;
}
```

Problems With Transformation 2

- We move complexity into computations
  - Logic criteria are not effective at testing computations
- Consider coverage :
  - CACC on the original requires four rows marked in the table
  - PC on the transformed version requires only two

a	b	c	$(a \wedge b) \vee c$	CACC	PC_T
T	T	T	T		X
T	T	F	T	X	
T	F	T	T	X	
T	F	F	F	X	
F	T	T	T		
F	T	F	F	X	
F	F	T	T		
F	F	F	F		X

- PC on the transformed version becomes equivalent to clause coverage on the original
  - Not an effective testing technique

Transforming Does Not Work

Logic coverage criteria exist to help us make better software

Circumventing (規避) the criteria is unsafe

Side Effects in Predicates(8.3.5)

- Side effects occur when a value is changed while evaluating a predicate (e.g., multi-thread programs)
  - – A clause appears twice in the same predicate
  - – A clause in between changes the value of the clause that appears twice
- Example :

  A && (B || A) **B is : changeVar (A)**

  - – Evaluation : Runtime system checks *A*, then *B*, if *B* is false, check *A* again
  - – But now *A* has a different value! (during predicate evaluation)
  - – How do we write a test that has two different values for the same predicate?
- No clear answers to this controllability problem

We suggest a social solution : Go ask the programmer

Summary : Logic Coverage for Source Code

- Predicates appear in decision statements (if, while, for, etc.)
- Most predicates have less than four clauses
  - But some programs have a few predicates with many clauses
- The hard part of applying logic criteria to source is usually resolving the internal variables
  - Sometimes setting variables requires calling other methods
- Non-local variables (class, global, etc.) are also input variables if they are used
- If an input variable is changed within a method, it is treated as an internal variable thereafter
- Avoid transformations that hide predicate structure