Lecture 18: Structure-based Testing

Test Case First Strategy

White box testing:

- Statement Coverage
- Branch Coverage
- Condition Coverage
- Data Path Coverage

Black box testing:

- Use Cases as Test Cases
- Testing with good and bad data

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Developer Testing

Write the test cases first

- minimize the time to defect discovery
- forces you to think carefully about the requirements first
- exposes requirements problems early
- supports a "daily smoke test"

Limitations of Developer Testing

- Emphasis on clean tests (vs. dirty tests)
  - immature organisations have 1 dirty : 5 clean
  - mature organisations have 5 dirty : 1 clean
- Developers overestimate test coverage
- Developers tend to focus on statement coverage rather than …

Summary:

- Test-case first strategy is extremely valuable
- Test-case first strategy is not enough

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Random testing isn't enough

Source: Adapted from Horton, 1999

Structurally…

```
boolean equal (int x, y) {
/* effects: returns true if
   x=y, false otherwise
*/
if (x == y)
  return(TRUE)
else
  return(FALSE)
}
```

Test strategy: pick random values for x and y and test 'equals' on them

But:

...we might never test the first branch of the 'if' statement

Functionally…

```
int maximum (list a)
/* requires: a is a list of
   integers
   effects: returns the maximum
   element in the list
*/
```

Try these test cases:

Input	Output	Correct?
3 16 4 32 9	32	Yes
9 32 4 16 3	32	Yes
22 32 59 17 88 1	88	Yes
1 88 17 59 32 22	88	Yes
1 3 5 7 9 1 3 5 7	9	Yes
7 5 3 1 9 7 5 3 1	9	Yes
9 6 7 11 5	1	Yes
5 11 7 6 9	1	Yes
561 13 1024 79 86 222 97	1024	Yes
97 222 86 79 1024 13 561	1024	Yes

Why is this not enough?

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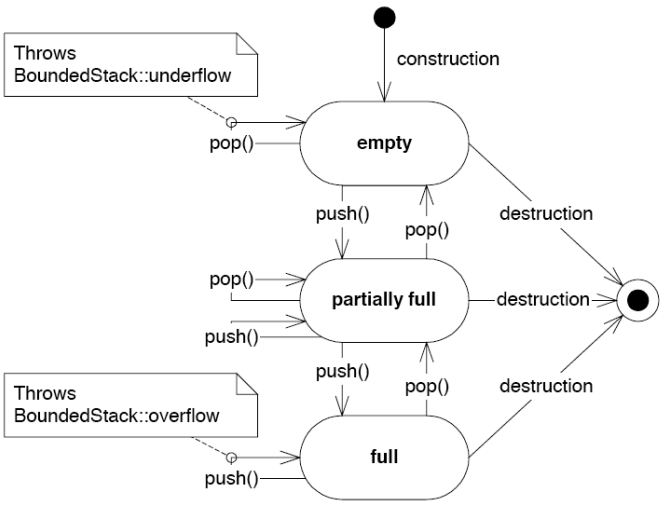
Testing in every state?



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Structured Basis Testing

Source: Adapted from McConnell 2004, p506-508

The minimal set of tests to cover every branch

How many tests?

start with 1 for the straight path
add 1 for each of these keywords: if, while, repeat, for, and, or
add 1 for each branch of a case statement

Example

```
int midval (int x, y, z) {
/* effects: returns median
   value of the three inputs
*/
if (x > y) {
  if (x > z) return x
  else return z }
else {
  if (y > z) return y
  else return z } }
```

Count 1 + 3 'if's = 4 test cases

Now choose the cases to exercise the 4 paths:

e.g. x=3, y=2, z=1
x=3, y=2, z=4
x=2, y=3, z=2
x=2, y=3, z=4

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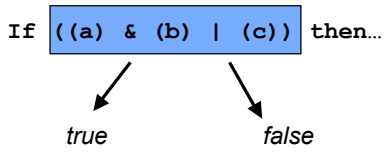
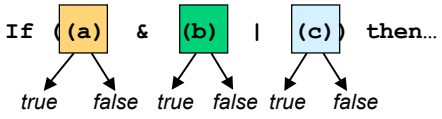
Complex Conditions

Source: Adapted from Christopher Ackermann's slides

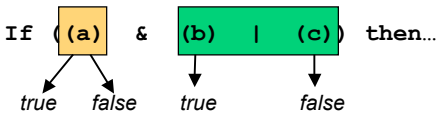
Branch Coverage:



Condition Coverage:



But can you show that each part has an independent effect on the outcome?



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MC/DC Coverage

Source: Adapted from Christopher Ackermann's slides

Show that each basic condition can affect the result

```
If ((a)  &  (b)  |  (c)) then…
```

number	ABC	result	A	B	C
1	TTT	T	5		
2	TTF	T	6	4	
3	TFT	T	7		4
4	TFF	F		2	3
5	FTT	F	1		
6	FTF	F	2		
7	FFT	F	3		
8	FFF	F			

Choose a minimal set:
Eg. {2, 3, 4, 6}
or {2, 3, 4, 7}

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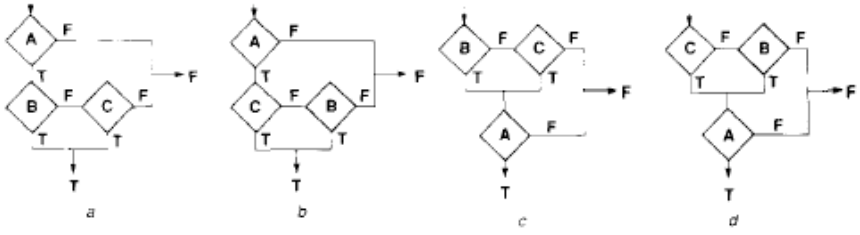
MC/DC versus Branch Coverage

Source: Adapted from Christopher Ackermann's slides

Compiler can translate conditions in the object code:



Test sets for condition/decision coverage:

{1, 8} or {2, 7} or {3, 6}

Covers all paths in the source code, but not all paths in the object code

Test sets for Modified Condition/Decision Coverage

{2, 3, 4, 6} or {2, 3, 4, 7}

Covers all paths in the object code

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About MC/DC

Advantages:

- Linear growth in the number of conditions
- Ensures coverage of the object code
- Discovers dead code (operands that have no effect)

Mandated by the US Federal Aviation Administration

- In avionics, complex boolean expressions are common
- Has been shown to uncover important errors not detected by other test approaches

It's expensive

- E.g. Boeing 777
- approx 4 million lines of code, 2.5 million newly developed
- approx 70% of this is Ada (rest is C or assembler)
- Total cost of aircraft development: $5.5 billion
- Cost of testing to MC/DC criteria: approx $1.5 billion

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Dataflow testing

Source: *Adapted from McConnell 2004, p506-508*

Things that happen to data:

- Defined - data is initialized but not yet used
- Used - data is used in a computation
- Killed - space is released
- Entered - working copy created on entry to a method
- Exited - working copy removed on exit from a method

Normal life:

- Defined once, Used a number of times, then Killed

Potential Defects:

- D-D: variable is defined twice
- D-Ex, D-K: variable defined but not used
- En-K: destroying a local variable that wasn't defined?
- En-U: for local variable, used before it's initialized
- K-K: unncessary killing - can hang the machine!
- K-U: using data after it has been destroyed
- U-D: redefining a variable after is has been used

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Testing all D-U paths

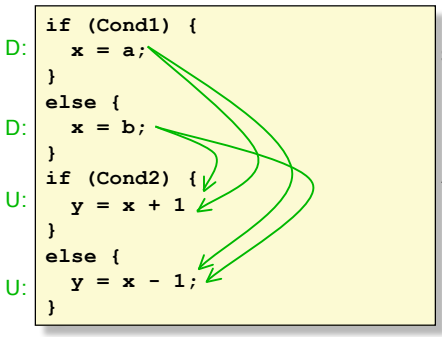
Source: Adapted from McConnell 2004, p506-508

The minimal set of tests to cover every D-U path

How many tests?

1 test for each path from each definition to each use of the variable

Example



Structured Basis Testing:

2 test cases is sufficient

Case 1: Cond1=true, Cond2=true

Case 2: Cond1=false, Cond2=false

All DU testing:

Need 4 test cases

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Boundary Checking

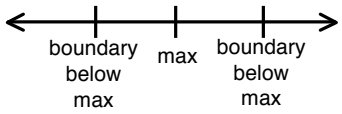
Source: Adapted from McConnell 2004, p506-508

Boundary Analysis

Every boundary needs 3 tests:

Example:

```
if (x < MAX) {
  … }
```



test for MAX+1, MAX-1 and MAX

Compound Boundaries

When several variables have combined boundaries

```
for (i=0; i<Num; i++) {
  if (a[i] < LIMIT) {
    y = y+a[i];
  }
}
```

Test when lots of array entries are close to the max?

Test when lots of entries are close to zero?

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Data Classes

Source: Adapted from McConnell 2004, p506-508

Classes of Bad Data

- Too little data (or no data)
- Too much data
- The wrong kind of data (invalid data)
- The wrong size of data
- Uninitialized data

Classes of Good Data

- Nominal cases - middle of the road, expected values
- Minimum normal configuration
- Maximum normal configuration
- Compatibility with old data

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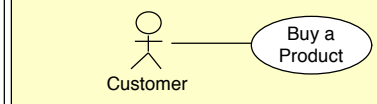
Generating Tests from Use Cases



Buy a Product

Precondition: Customer has successfully logged in

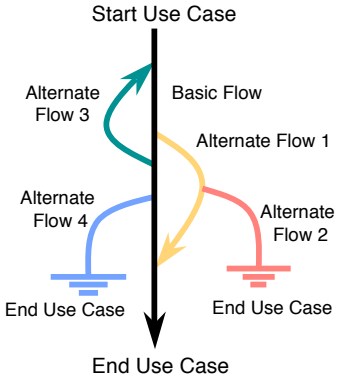
Main Success Scenario:
Customer browses catalog and selects items to buy
Customer goes to check out
Customer fills in shipping information (address, next-day or 3-day delivery)
System presents full pricing information
Customer fills in credit card information
System authorizes purchase
System confirms sale immediately
System sends confirming email to customer

Postcondition: Payment was received in full, customer has received confirmation

Extensions:
3a: Customer is Regular Customer
.1 System displays current shipping, pricing and billing information
.2 Customer may accept or override these defaults, returns to MSS at step 6
6a: System fails to authorize credit card
.1 Customer may reenter credit card information or may cancel

1 Test the Basic Flow

2 Test the Alternate Flows



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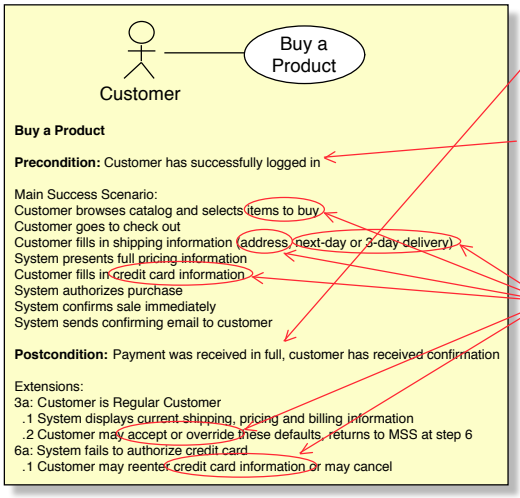
Generating Tests from Use Cases



3 Test the Postconditions

- Are they met on all paths through the use case?
- Are all postconditions met?

4 Break the Preconditions

- What happens if this is not met?
- In what ways might it not be met?

5 Identify options for each variable

- select combinations of options for each test case

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Classes of input variables

values that trigger alternative flows
- e.g. invalid credit card
- e.g. regular customer

trigger different error messages
- e.g. text too long for field
- e.g. email address with no "@"

inputs that cause changes in the appearance of the UI
- e.g. a prompt for additional information

inputs that causes different options in dropdown menus
- e.g. US/Canada triggers menu of states/provinces

cases in a business rule
- e.g. No next day delivery after 6pm

border conditions
- if password must be min 6 characters, test password of 5,6,7 characters

Check the default values
- e.g. when cardholder's name is filled automatically

Override the default values
- e.g. when the user enters different name

Enter data in different formats
- e.g. phone numbers:
- (416) 555 1234
- 416-555-1234
- 416 555 1234

Test country-specific assumptions
- e.g. date order: 5/25/08 vs. 25/5/08

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Limits of Use Cases as Test Cases

Use Case Tests good for:

- User acceptance testing
- "Business as usual" functional testing
- Manual black-box tests
- Recording automated scripts for common scenarios

Limitations of Use Cases

- Likely to be incomplete
- Use cases don't describe enough detail of use
- Gaps and inconsistencies between use cases
- Use cases might be out of date
- Use cases might be ambiguous

Defects you won't discover:

- System errors (e.g. memory leaks)
- Things that corrupt persistent data
- Performance problems
- Software compatibility problems
- Hardware compatibility problems

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