# CITS5501 Software Testing and Quality Assurance Graph-based testing

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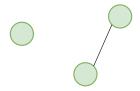
#### Overview

- Graph-based testing we identify inputs which will exercise particular paths through a graph representing the software in some way.
- The graph could represent
  - control flow through a program
  - data flow between variables
  - an activity diagram, showing the workflow when a user interacts with the system
  - a state diagram, showing states of a system and transitions between them

## Graph definition

#### A graph consists of:

- A set N of nodes
- A set E of edges, each edge being an "arrow" from one node to another



#### Graph-based testing

We will start by considering control flow. Our approach is:

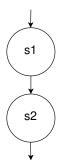
- Use the source code (or pseudocode) to produce a control flow graph.
- ② Using the graph produce a set of tests for the given program.

## Constructing the graph

- In a control flow graph, nodes represent points in the program control flow can go "from" or "to"
- Loops, thrown exceptions and gotos (in languages that have them) are locations control flow can go from – statements representing these spots are "sources"
- Locations control flow can go to are "sinks"

## Sequence control flow graphs

• The flow graph for a sequence of statements "s1; s2;" is

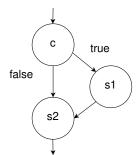


#### if-then control flow graphs

given pseudocode like

```
if c then:
    s1
s2
```

we get the following graph



#### if-then-else control flow graphs

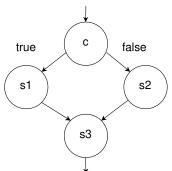
```
• if c then:

s1

else:

s2

s3
```

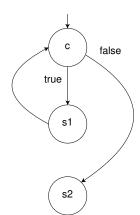


## What about loops?

 Edges will obviously go "backward" in the graph (usually, towards the "top")

#### while-do control flow graphs

```
• while c do:
s1
s2
```



#### other structures

 Most other control flow structures can be written into one of these forms (including "case" statements, breaking out of loops, "for" loops, etc)

#### other structures – example

```
A "case" statement:

case x of:

val1: s1; break

val2: s2; break

default: s3

s4

Can be written as nested if-else

if x == v1:

s1

else:

if x == v2:

s2

else:

s3

s4
```

## Using the graph

- To find a new test, examine the graph edges that haven't been exercised yet, and try to devise a test that exercises it
- In general, we'd actually like to find a test that exercises as few edges as possible
- why?

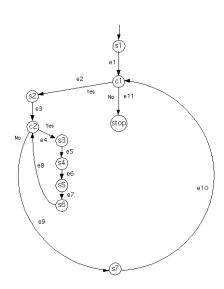
## Using the graph

- To find a new test, examine the graph edges that haven't been exercised yet, and try to devise a test that exercises it
- In general, we'd actually like to find a test that exercises as few edges as possible
- why?
  - Tests that exercise a large number of edges usually represent "common" scenarios – we'd actually like to find less common cases (i.e. get more "value" out of the test)
  - Ideally, we want tests to be small and independent, so that when something goes wrong, we can localize the fault.

#### Example – sorting algorithm

```
S1 i = 2
C1
   while (i \le n):
S2
   j = i - 1
C2
     while j \ge 1 and A[j] \ge A[j+1]:
S3
       temp = A[j]
S4
       A[j] = A[j+1]
S5
      A[j+1] = temp
S6
     j = j - 1
S7 i = i + 1
```

## Example – sorting algorithm (2)



#### Example – binary search

#### Inputs

- n, the length of the following array.
- A, an integer array with entries A[1], ..., A[n] such that A[i] < A[i+1] for i between 1 and n-1
  (i.e., it's sorted in ascending order, and 1-based)</li>
- key, an integer to search for (the "needle")

#### **Outputs**

- index, an integer between 0 and n such that:
  - if index = 0 then key does not equal any entry of the array A
  - if index is between 1 and n then A[index] = key

## Example – binary search (2)

```
found = false
low = 1
high = n
while ((low <= high) and not found):
  medium = floor((low + high)/2)
  if A[medium] == key:
     index = medium
     found = true
 else:
     if A[medium] < key then
       low = medium + 1
     else:
       high = medium - 1
if not found:
  index := 0
```

Graph-based testing criteria

#### Graph-based testing criteria

- Some possible criteria include:
  - node coverage our test set traverses every node (if using program control flow: statement coverage is similar, but coarser)
  - edge coverage we traverse every edge
  - egde-pair coverage we traverse every possible *pair* of edges
- We might use the informal heuristic of executing each loop 0 times, once, more than once (sometimes called "loop coverage")

#### Prime paths

#### Definitions:

- Simple path: A path from node ni to nj is simple if no node appears more than once, except possibly the first and last nodes are the same
  - No internal loops in our path
  - A loop is a simple path

#### Prime paths

#### Definitions:

- Simple path: A path from node ni to nj is simple if no node appears more than once, except possibly the first and last nodes are the same
  - No internal loops in our path
  - A loop is a simple path
- Prime path: A simple path that does not appear as a proper subpath of any other simple path

#### Prime path coverage

- Prime Path Coverage (PPC): Every prime path in the graph is visited.
- It subsumes node and edge coverage
- But not edge-pair coverage we code have nodes (m,n), where m loops to itself, and edge pair coverage requires the path (m,m,n) to be exercised.
- when it comes to devising tests, some tests may end up exercising multiple prime paths. But that's okay – as long as all prime paths are visited, we've satisfied the criterion.

#### Control flow graphs

In a control flow graph, different graph coverage criteria will correspond to:

- Node coverage: Execute every statement
   (in fact, node coverage is stronger, since one statement may
   expand to multiple nodes)
- Edge coverage: Execute every branch

Note that complex boolean conditions in branches are still treated as a single node. (Effectively, the boolean condition is a "black box".)

Logic coverage conditions (used, for instance, in avionics) look at these conditions in finer-grained detail.