CITS5501 Software Testing and Quality Assurance
Graph-based testing

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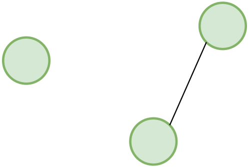
Overview

- 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:

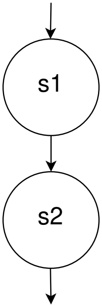
1. Use the source code (or pseudocode) to produce a control flow graph.
2. Using the graph produce a set of tests for the given program.

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

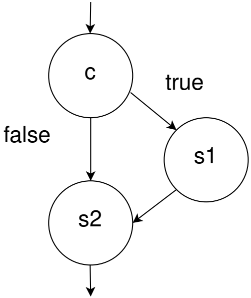


if-then control flow graphs

- given pseudocode like

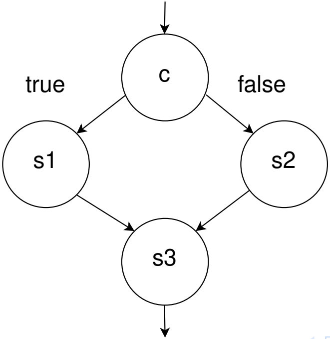
```
if c then:
  s1
s2
```

we get the following graph



`if-then-else` control flow graphs

- ```
  if c then:
    s1
  else:
    s2
  s3
  ```

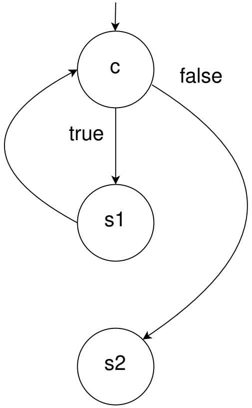

  ```

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, `break`ing 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?

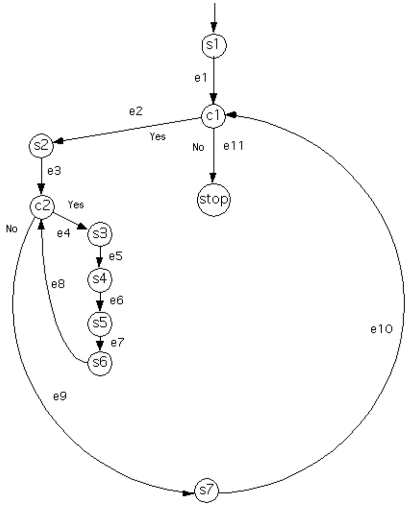
Using the graph

- 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 <= n):
S2    j = i - 1
C2    while j >= 1 and A[j] >= 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)
- `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.