CITS5501 Software Testing and Quality Assurance
Model-based testing

Unit coordinator: Arran Stewart

Models and approaches

Approaches to testing

For most software components (and other artifacts, such as machinery, etc.), it's possible to consider them in two ways, when testing:

- knowing *nothing* about the internal workings of the component, we can focus on its intended functionality, and conduct tests that demonstrate each aspect of the functionality, and attempt to uncover any errors.
  - This approach is called "black-box" testing
- knowing the internal workings of the components, we can write tests that try to check the internal operations are correctly performed, and that all internal components have been adequately exercised.
  - This approach is called "white-box" testing

In reality, many testing approaches make use of aspects of both.

Approaches to testing

- Example of “black-box” testing:
  - The sorts of unit tests we have seen so far: they are derived from the *specifications* for methods, and treat the method as a “black box” that takes in input and produces output, without considering how it does it.
- Example of “white-box” testing:
  - Looking at the source code for a method, and ensuring that *paths* of execution through the method have been adequately tested.

Black-box testing

Signature of method, plus specification using Javadoc:

```
/** Remove/collapse multiple spaces.
*
* @param String string to remove multiple spaces from.
* @return String */
public static String collapseSpaces(String argStr)
```

Black-box testing

- Specifications need not be for *methods*, they can be for software components, or hardware, or whole systems

White-box testing

A Java method for collapsing sequences of blanks, taken from the `StringUtils` class of Apache Velocity (http://velocity.apache.org/), version 1.3.1.

```
/** Remove/collapse multiple spaces.
*
* @param String string to remove multiple spaces from.
* @return String */
public static String collapseSpaces(String argStr) {
  char last = argStr.charAt(0);
  StringBuffer argBuf = new StringBuffer();
  for (int cIdx = 0 ; cIdx < argStr.length(); cIdx++) {
    char ch = argStr.charAt(cIdx);
    if (ch != ' ' || last != ' ') {
      argBuf.append(ch);
      last = ch;
    }
  }
  return argBuf.toString();
}
```

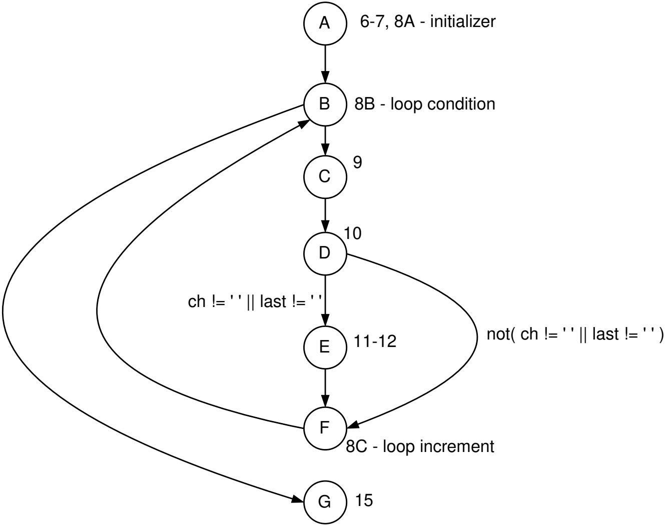
Control-flow testing outline

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”

Constructing the graph



Black-box techniques

- When we design tests based on the interface – "black-box" testing – we normally work off the *specification* for the item, we don't care about the details of the implementation
- Input space partition testing (this lecture). We don't need to look at the code *within* an item being tested – we just consider its parameters or inputs.

Other black-box techniques

- In the Pressman textbook you'll see mention of other black box techniques, e.g. "boundary value analysis"
  - i.e., include tests which have inputs at the "boundaries" of ranges of values
  - this helps detect, for instance "off-by-one" and "fencepost" errors
- Boundary value analysis is actually incorporated into the ISP testing procedure covered in this lecture
  - when "modeling the input domain", we identify valid values, invalid, boundaries, "normal use", and so on

Benefits of black box testing

- Helps find
  - functionality that is specified but not implemented
  - functionality that is implemented but incorrect

White-box testing

- We can also design tests by looking at the *internal* details of an item to be tested – “white-box” or “clear-box” testing.
- This is also sometimes called *structural testing*, since it looks at the internal structure of an item to be tested
- Here, we do care about the implementation

White-box testing – examples

- As part of white box testing, we might try to ensure that
  - all internal data structures have been checked
  - all loops have been checked
  - where there is some sort of branching statement (if-else, case, etc.), all the possible branches have been tested
  - . . . and so on.

Why perform white-box testing

- Why perform white-box testing?
  - Isn't black box enough? – after all, it tests the functionality

Why perform white-box testing (2)

- What if we've failed to identity some particular scenario (set of inputs) in black box testing, and not written a test for it?
  - It can be difficult to think of unusual inputs/scenarios
- What if the environment, or some other part of the system, changes?
  - code that was previously "dead code", and never executed, might now become "live" – and may contain errors
- Some sorts of errors (e.g. typos) are as likely to occur on unusual or uncommon paths of execution, as on anywhere else.
  - White box testing helps ensure we've considered those paths.

Why perform white-box testing (3)

- One question that is often asked is “Do we have enough tests?”
- White box testing may not answer that question – but it can identify parts of a system that *haven’t* been tested.

Types of white-box testing

- In practice and in the literature, many different techniques are identified:
  - branch/decision testing
    - have all branches in decisions been exercised?
    - have all parts of boolean expressions been exercised?
  - control flow testing
    - uses a program's control flow graph as a model
  - data flow testing
    - flow of data between variables – are there variables that are declared but not used, or vice versa? Declared multiply? Not initialized before use? Deallocated before use? Used before being validated?
  - statement coverage
    - is every statement executed at least once?
  - modified condition/decision coverage (used in avionics)
  - path testing
  - prime path testing

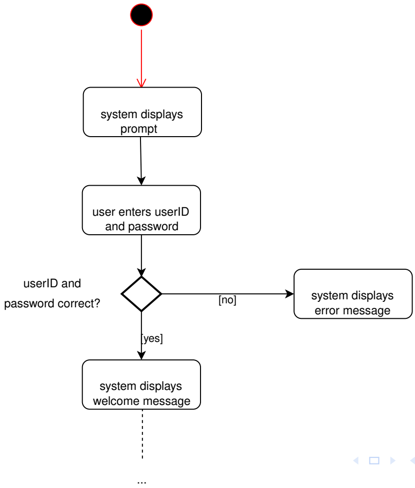
Alternative view – model-based testing

When doing white-box testing of the `collapseSpaces` function, we look at the control-flow *graph* for the function, and try to ensure our tests adequately exercise paths through the graph (called checking the *test coverage* of the graph).

But there are many other sorts of "graphs" we might want to check for test coverage, and not all are "internal", "white-box" views of something.

Activity diagrams

For instance, *activity diagrams* are way of modelling a user's interactions with a system.



Activity diagrams

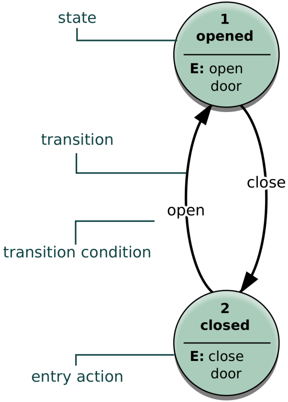
These too form a sort of graph, and we can ask whether out tests have exercised paths through the graph sufficiently.

Activity diagrams don't look at "source code" or the "inside" of a system – they consider the "outside" (a user's interaction with the system).

So they are a sort of "black-box" testing, yet the same methods we use for control-flow analysis – a form of "white-box" testing – are applicable.

State diagrams

State diagrams show states something can be in, and transitions between them.[1]



[1] Courtesy Wikipedia, https://en.wikipedia.org/wiki/State_diagram.

State diagrams

A state diagram also is a kind of graph, so we can look at whether our tests have exercised paths through it sufficiently.

Is it “black-box” or “white-box” testing?

Alternative view – model-based testing

Rather than classifying something as being "black-box" or "white-box" testing, a more useful approach is to consider various *models* of a software system, and ask "What sort of model is this? And what sort of testing techniques can be applied?"

Model-based testing – functions

- As we've seen – if we can treat the model as a *function* from inputs to outputs – then we can apply *input-space partitioning* to it.
  - Example: Unit tests based on Javadoc specification
  - Example: System testing based on specifications

Model-based testing – graphs

- If we can treat the model as a *graph* – a network of nodes – then we can apply *graph-based* techniques to it.
  - Example: Control flow analysis

Model-based testing – logic

If particular parts of the system make "choices" based on combinations of logical conditions, we can apply *logic-based* techniques to it.

- Example: Avionics systems are required to have a particular level of coverage of logic expressions
- Sample specification for a system [from Ammann]:

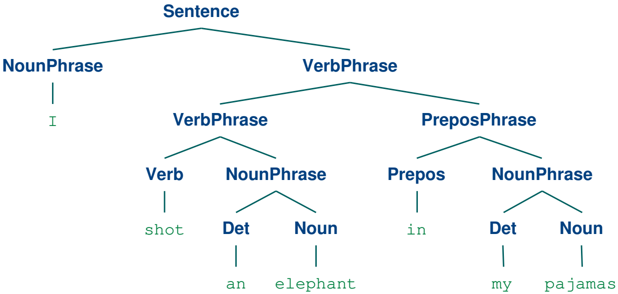
  If the moon is full and the sky is clear, release the monster.
  If the sky is clear and the wind is calm, release the monster.

Model-based testing – logic vs graphs

- Graph-based techniques look at what *edges* we traverse between nodes, they don't look "inside" the nodes –
- For any "decision node", however complex, graph-based techniques only consider "Which edge do we take out of the node?"
- By contrast, logic-based testing looks "inside" the parts of boolean expressions making up a "decision point", and asks whether we've tested those parts sufficiently thoroughly.

Model-based testing – syntax

- If the model can be treated as having a “syntax” (a sort of tree-like, potentially recursive structure), then we can apply *syntax-based* techniques to it.
- One example of things with “syntax” is, unsurprisingly, natural language sentences:[2]



[2] Diagram adapted from Bird *et al* (2009). Dialogue from “Animal Crackers” (1930, dir. V. Heerman).

Model-based testing – syntax

But other things that can be modelled as having a syntax are things like Java source code (a text format), or binary file formats (such as PNG graphics files or executable files).

Model-based testing

Our "models" don't have to be models of source code – they can be models of, say, database structure, or user interaction with a system, or class hierarchies, or any other way we find it useful to consider our system (or some part of it).