Specification-based Testing 2

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Slides thanks to Stuart Anderson

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Overview

- We consider issues in the generation of test cases – in particular defining coverage criteria that reduce the combinatorial complexity of test case generation.
- We then go on to consider model-based black-box testing where we have some model of the system and use that to decide how to exercise the sysem. Typical examples of models include:
  - Decision trees/graphs
  - Workflows
  - Finite State Machines
  - Grammars
- All of these models provide some kind of abstraction of the system's behaviour – we can use this both to explore the system's behaviour and check that it agrees with the abstraction.

Reducing the number of testcases

Display Mode full-graphics text-only limited-bandwidth	**Language** English French Spanish Portuguese	**Fonts** Minimal Standard Document-loaded
Color Monochrome Color-map 16-bit True-color	**Screen size** Hand-held Laptop Full-size	

P&Y p.190: Table 11.3

Coverage Criterion

- If our tests just took a simple approach to exhaustive testing inputs drawn from Display Mode, Fonts, and Screen Size we would need to consider 27 test cases.
- With large numbers of categories this becomes prohibitive (e.g. n categories each of size k has k^n possible cases.
- We can reduce this by just requiring that the input set cover all possible m-tuples of each subset of m variables drawn from n.
- For example in the case above we might require that we just ensure all pairs of (Display Mode, Fonts), (Fonts, Screen Size) and (Display Mode, Screen Size) are covered in the test set.
- The next slide demonstrates this reduces the test set from 27 combinations to 9.

Ensuring all Pairs are Covered

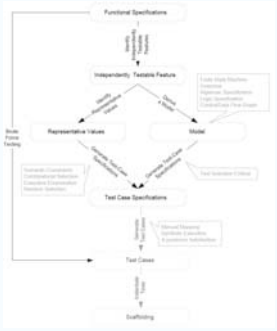
Display mode × Screen size		*Fonts*
Full-graphics	Hand-held	Minimal
Full-graphics	Laptop	Standard
Full-graphics	Full-size	Document-loaded
Text-only	Hand-held	Standard
Text-only	Laptop	Document-loaded
Text-only	Full-size	Minimal
Limited-bandwidth	Hand-held	Document-loaded
Limited-bandwidth	Laptop	Minimal
Limited-bandwidth	Full-size	Standard

P&Y p.191: Table 11.4

Summary

- Generally enumerating all possible combinations is exhaustive but probably infeasible given cost constraints.
- Alternative is to choose some systematic way of reducing the space.
- In this case we chose to find all pairs.
- Other criteria are possible – see the reading.

Model-based Testing



P&Y p.169: Figure 10.3

Models

- Models typically provide some abstract representation of the behaviour of the system.
- Typical notations are:
  - Algebraic Specifications
  - Control/Data Flow Graphs
  - Logic-based specification
  - Finite State Machine Specification
  - Grammar-based Specification

Control Flow Graphs (e.g. UML Activity Diagrams)

- Often specify the human process the system is intended to support.
- Can be used to represent both "normal" and "erroneous" behaviours (and recovery behaviour).
- Abstract away from internal representations.
- Focus on interactions with the system

Shipping Order Process

P&Y p.259: Figure 14.7

Different Adequacy Criteria Are Applicable

- Node coverage – ensure that test cases cover all the nodes in the flow graph.
- Branch coverage – ensure we branch in both directions at each decision node.
- Mutations – we might also consider introducing mutations where the user does not follow the control graph:
  - can provide explanations of "automation surprises" (see Rushby paper in readings).
  - Machines are often better at remembering state than humans (recall "cruise control" example from first year?)

Coverage Criteria

P&Y p.260: Figures 14.8 & 14.9

T-node

Case	Too small	Ship where	Ship method	Cust type	Pay method	Same addr	CC valid
TC-1	No	Int	Air	Bus	CC	No	Yes
TC-2	No	Dom	Air	Ind	CC	–	No (abort)

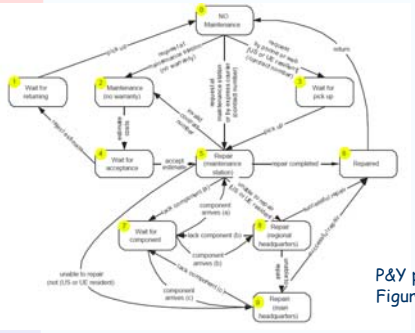
T-branch

Case	Too small	Ship where	Ship method	Cust type	Pay method	Same addr	CC valid
TC-1	No	Int	Air	Bus	CC	No	Yes
TC-2	No	Dom	Land	–	–	–	–
TC-3	Yes	–	–	–	–	–	–
TC-4	No	Dom	Air	–	–	–	–
TC-5	No	Int	Land	–	–	–	–
TC-6	No	–	–	Edu	Inv	–	–
TC-7	No	–	–	–	CC	Yes	–
TC-8	No	–	–	–	CC	–	No (abort)
TC-9	No	–	–	–	CC	–	No (no abort)

Finite State Machines

- Good at describing interactions in systems with a small number of modes.
- Good at describing transducers (via finite state machines).
- Widely used in industry (via Statecharts (see Harel reference in the Readings) + associated tools).
- Most systems are "infinite state" (or effectively so), but many systems are finite state + parameters – there are a finite set of states that control the way data is moved around.
- Good examples are systems like communication protocols or many classes of control systems (e.g. automated braking, flight control systems).
- Transitions are generally made on inputs (e.g. the discovery of some state of affairs – e.g. that the wheels are locked in a braking system)
- Good for describing interactive systems that rarely reach a final state

Example Finite State Machine



P&Y p.248: Figure 14.2

Designing tests

- Sequence of inputs that drives the system though some sequence of transitions.
- We use coverage criteria to measure how successful we are in exploring the specification.
- The simplest criterion is that we have covered all transitions.

T-Cover

TC-1	0 – 2 – 4 – 1 – 0
TC-2	0 – 5 – 2 – 4 – 5 – 6 – 0
TC-3	0 – 3 – 5 – 9 – 6 – 0
TC-4	0 – 3 – 5 – 7 – 5 – 8 – 7 – 8 – 9 – 7 – 9 – 6 – 0

P&Y p.249: Table 14.1

Other Coverage Criteria

- Implementations of FSM specification often have more state than the specification (i.e. they may exhibit history sensitivity). Typically because we introduce extra management into the system (e.g. the possibility to undo some number of transitions).
- As a result we often use other coverage criteria that explore the behaviour more thoroughly, e.g.:
  - Single state path coverage: collection of paths that cover the states:
  - Single transition path coverage: collection of paths that cover all transitions.
  - Boundary interior loop coverage: criterion on number of times loops are exercised.
- Errors included by adding an Error state.
- We can consider mutation to discover how the system responds to unexpected inputs.
- We can use probabilistic automata to represent distributions of inputs if we want to do randomised testing.

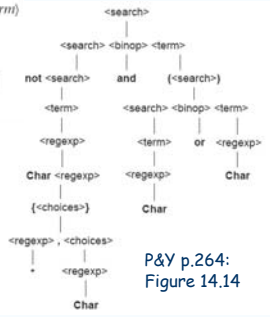
Grammar-based Testing

- Grammars are used to describe well-formed inputs to systems.
- We might want to know the system responds correctly to all such inputs.
- We can use grammars to generate sample inputs.
- We can use coverage criteria on a test set to see that all constructs are covered.
- We can use probabilistic CFGs to capture distributions on particular inputs.
- As XML is used increasingly to define transfer formats etc grammar-based testing is becoming increasingly important.
- Grammar-based testing is fairly easy to automate.

A Sample Grammar and Test Case

⟨search⟩ ::= ⟨search⟩ ⟨binop⟩ ⟨term⟩ | not ⟨search⟩ | ⟨term⟩
⟨binop⟩ ::= and | or
⟨term⟩ ::= ⟨regexp⟩ | (⟨search⟩)
⟨regexp⟩ ::= Char ⟨regexp⟩ | Char | { ⟨choices⟩ } | •
⟨choices⟩ ::= ⟨regexp⟩ | ⟨regexp⟩ , ⟨choices⟩

P&Y p.261: Figure 14.11



P&Y p.264: Figure 14.14

Generating Tests

- Coverage criteria are important, e.g.:
  - Every production at least once
  - Boundary conditions on recursive productions – 0, 1, many
- Probabilistic CFGs allow us to prioritise heavily used constructs.
- Probabilistic CFGs can be used to capture and abstract real-world data.
- We can easily generate erroneous data using simple mutations in the rules or final sentential forms.
- CFGs can be used to model interaction and low level detail in GUIs.

Choice Criteria

- What form does the specification take?
- Experience of the team in different methods.
- Availability and quality of tools
- Cost/benefit analysis on the range of techniques and the available budget (some approaches may require too much infrastructure