QuviQ

Software Testing with QuickCheck

Lecture 1

Properties and Generators

Testing

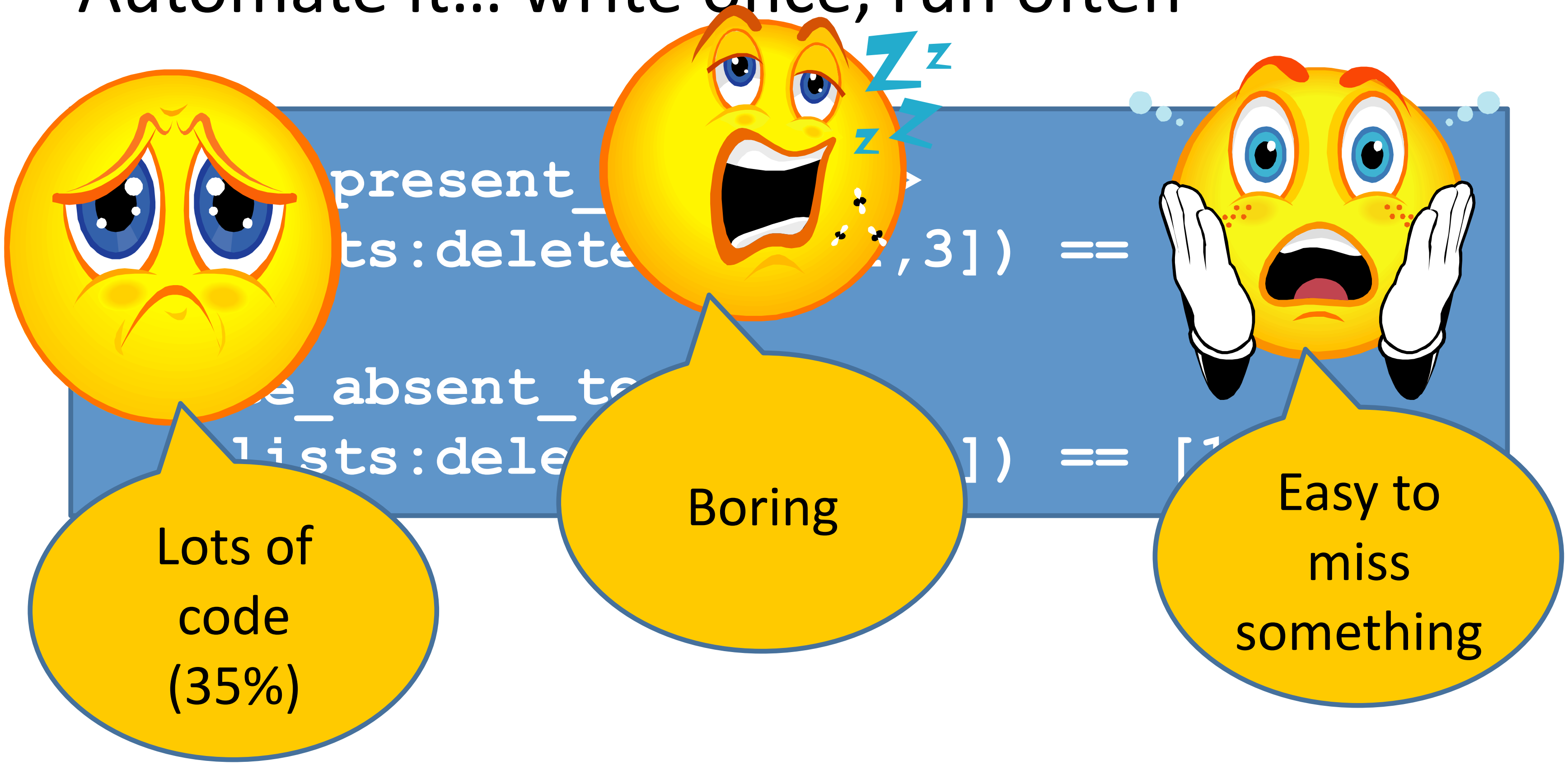
- How do we know software works?
  - We test it!
- ”lists:delete removes an element from a list”

```
4> lists:delete(2,[1,2,3]).
[1,3]
5> lists:delete(4,[1,2,3]).
[1,2,3]
```

- … seems to work!

Automated Testing

- Testing accounts for ~50% of software cost!
- Automate it… write once, run often



Lots of code (35%)

Boring

Easy to miss something

Property-based testing

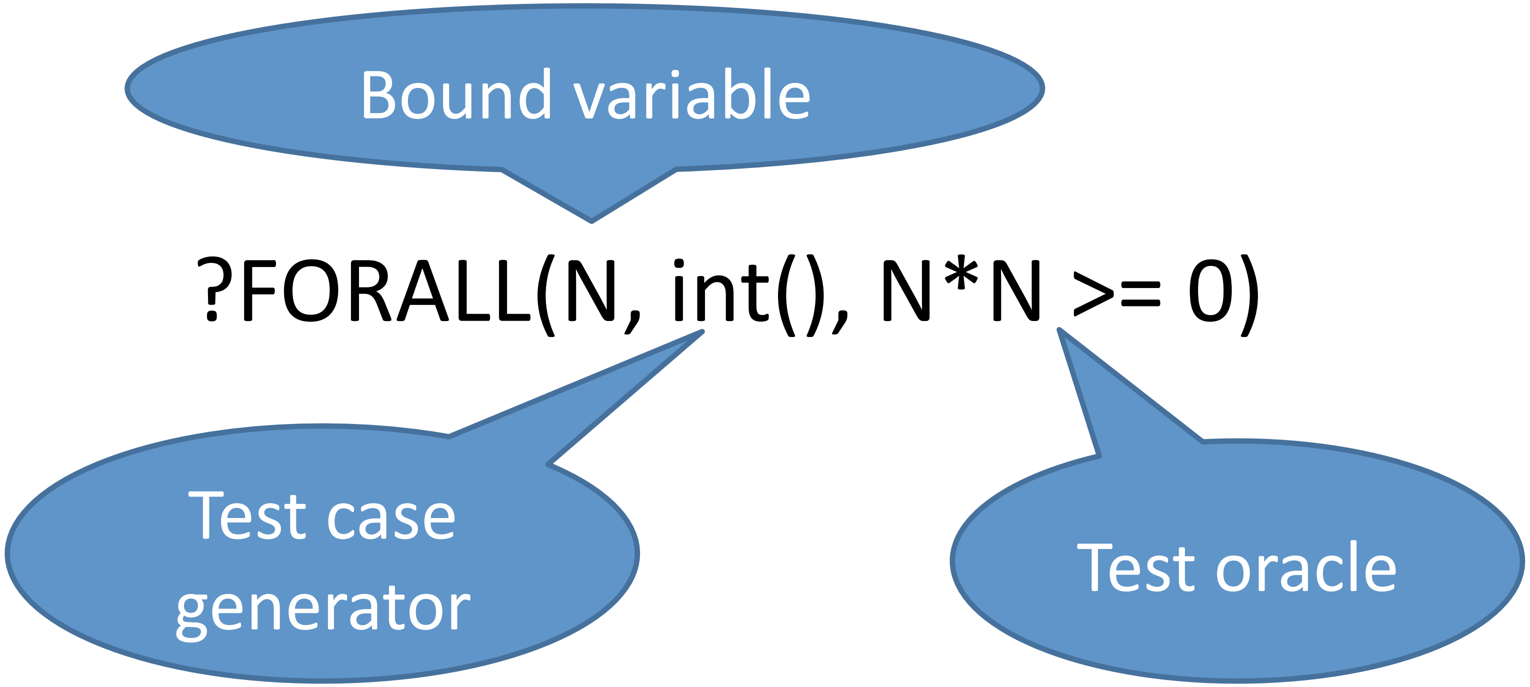
- Generalise test cases

$$\forall \{I,L\} \in \mathrm{int}() \times \mathrm{list}(\mathrm{int}())$$

```
prop_delete() ->
  ?FORALL({I,L},
          {int(),list(int())},
          not lists:member(I,
                lists:delete(I,L))).
```

```
21> eqc:quickcheck(examples:prop_delete()).
....................................................
................................................
OK, passed 100 tests
```

Properties



Bound variable

```
?FORALL(N, int(), N*N >= 0)
```

Test case generator

Test oracle

- We test directly against a formal specification

More tests…

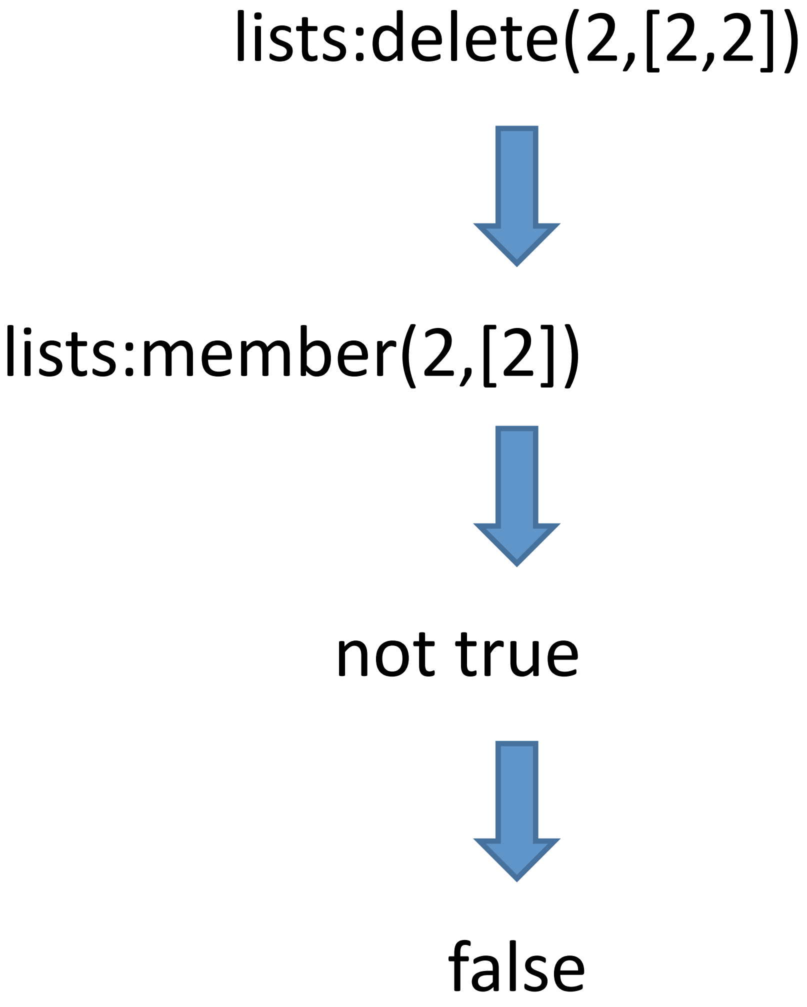
```
29> eqc:quickcheck(eqc:numtests(1000,examples:prop_delete())).
..........................................................
..........................................................
..........................................................
..........................................................
..........................................................
..........................................................
...Failed! After 346 tests.
{2,[-7,-13,-15,2,2]}
Shrinking.(1 times)
{2,[2,2]}
false
```

A failed test

A simplest failing test

c.f. **?FORALL({I,L},…,…)**

The fault explained



lists:delete(2,[2,2])

lists:member(2,[2])

not true

false

Properties with pr ditions

- The property h duplicates

```
no_duplicates(L) ->
    lists:usort(L)
 == lists:sort(L).
```

```
prop_delete() ->
    ?FORALL({I,L},
            {int(),list(int())},
            ?IMPLIES(no_duplicates(L),
                     not lists:member(I,lists:delete(I,L)))).
```

```
39> eqc:quickcheck(examples:prop_delete()).
.....................x.........x....................x.x
......xx...........x....x....xx....x..x...........x.
x.........x..
OK, passed 100 tests
```

Skipped tests

Custom generators

- Why not *generate* lists without duplicates in the first place?

```
ulist(Elem) ->
    ?LET(L,list(Elem),
         lists:usort(L)).
```

First: generate a list **L**

Then: sort it and remove duplicates

- Use as **?FORALL(L,uli** **)**
- Generators are an *abstrac* **?LET** for sequencing

Why was the error hard to find?

- $I \in \mathrm{int}()$
- $L \in \mathrm{list}(\mathrm{int}())$

What is the probability that *I* occurs in *L*—*twice*?

```
prop_delete() ->
    ?FORALL({I,L},
            {int(),list(int())},
            collect(lists:member(I,L),
                      not lists:member(I,lists:delete(I,L)))).
```

```
34> eqc:quickcheck(examples:prop_delete()).
.................................................................
......................................
OK, passed 100 tests
88% false
12% true
true
```

Usually `I` doesn't even occur *once*

Generate relevant tests

- Ensure that **`I`** *is* a member of **`L`**
  - Generate it *from* **`L`**

```
prop_delete_2() ->
   ?FORALL(L,list(int()),
      ?IMPLIES(L /= [],
        ?FORALL(I,elements(L),
          not lists:member(I,lists:delete(I,L))))).
```

```
45> eqc:quickcheck(examples:prop_delete_2()).
.xx.x.x.xx...x.x...x....x.......xx.....Failed! After 28 tests.
[-8,0,7,0]
0
Shrinking...(3 times)
[0,0]
0
```

Generate relevant tests

- Ensure that **`I`** *is* a member of **`L`**
  - Only works if **`L`** is non-empty
  - **`?SUCHTHAT`** like **`?IMPLIES`** but for generators
  - **`non_empty(G) -> ?SUCHTHAT(X,G,X /= []).`**

```
prop_delete_2() ->
  ?FORALL(L,non_empty(list(int())),

      ?FORALL(I,elements(L),
        not lists:member(I,lists:delete(I,L)))).
```

Documenting misconceptions

- Useful to record that an expected property is *not* true

```
prop_delete_misconception() ->
  fails(
    ?FORALL(L,non_empty(list(int())),
      ?FORALL(I,elements(L),
          not lists:member(I,lists:delete(I,L))))).
```

```
49> eqc:quickcheck(examples:prop_delete_misconception()).
..................OK, failed as expected. After 19 tests.
```

Good distribution ensures we falsify the property quickly

Remember!

- We test against a formal specification!
  - Often it is the *specification* which is wrong!

- We don’t see the test data!
  - 100 passing tests can give a false sense of security

- Collect statistics!
  - Ensure a good test case distribution

Exercises