Mutation testing

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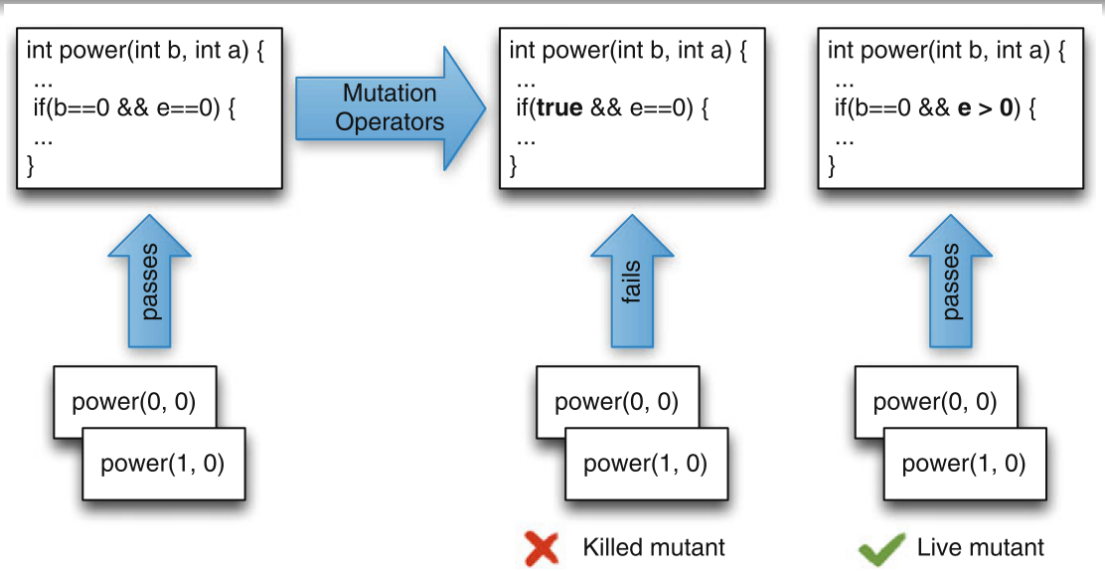
Mutation testing in brief

1. Mutation testing, also known as fault-based testing targets explictly the software faults
2. To evalute the tests, their quality is **NOT** measured in terms of coverage of structural elements
3. Instead, faults are injected in the code and tests are evaluated in terms of how many injected faults are detected

mutation process



Overview of the mutation testing process:

- Mutation operators are applied to the program under test to produce mutants.
- Tests are executed on all mutants; if a test fails on a mutant but passes on the original program, then the mutant is killed.
- If there is no test that kills the mutant, the mutant is alive, and likely reveals a weakness in the test suite

An example - power method

```
1  int power(int b, int e){
2   if (e < 0) throw new Exception("Negative exponent"
3   if ((b == 0) && (e == 0)) throw new Exception("Und
4   int r = 1;
5   while (e > 0){
6    r = r * b; e = e - 1;
7   }
8   return r;
9  }
10 @Test
11 public void testPowerOf2() {
12  int result = power(2, 2);
13  assertEquals(4, result);
14 }
```

mutant example

```
1  int power(int b, int e){
2    if (e < 0) throw new Exception("Negative exponent"
3    if ((true) && (e == 0)) throw new Exception("Undefi
4    int r = 1;
5    while (e > 0){
6      r = r * b;
7      e = e - 1;
8    }
9    return r;
10 }
```

- Mutant by applying the COR operator (Conditional Operator Replacement) to line number 4
- The original test case assertEquals(4,power(2, 2)); won't fail - the mutant is NOT killed - the faults is not found

Survived mutants

1. Survived mutants are a sign of weakness of the test suiste (a fault that cannot be found)
2. New tests must be added
3. Note 1: (survived) mutants can be very many ...

mutant example

```
1  int power(int b, int e){
2   //... as before
3   if ((true) && (e == 0))
4    throw new Exception("Undefined");
5   //... as before
6  }
```

- To detect this fault we need a test in which we call power with e = 0 and b != 0. something like:

```
1  @Test public void test0PowerOf2() {
2   int result = power(2, 0);
3   assertEquals(1, result);
4  }
```

- test0PowerOf2 will pass on the original code but it will fail with the mutant -> mutant is killed

Equivalent mutants

1. A limitation of mutation testing lies in the existence of equivalent mutants.
2. A mutant is equivalent when, although syntactically different, it is semantically equivalent to the original program.
3. There is NO test that kills an equivalent mutant - they will always survive
4. It is very difficult to say if a mutant has survived beacuase a test is missing or because it is equivalent

equivalent mutants

```
int power(int b, int e){
  if (e < 0)
    throw new Exception("Negative exponent");
  if ((b == 0) && (e == 0))
    throw new Exception("Undefined");
  int r = 1;
  while (e != 0){
    r = r * b; e = e - 1;
  }
  return r;
}
```

- This mutant cannot be killed by any test since it is equivalent.

Tools for mutation testing

- There are many tools that perform mutation testing
- DEMO with PIT test: https://pitest.org/