Testing, Debugging, and Verification re-exam
DIT082/TDA567

Day: 12 April 2017 Time: $14^{00} - 18^{00}$

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Results:	Will be published mid May or earlier
Extra aid:	Only dictionaries may be used. Other aids are *not* allowed!
Grade intervals:	**U**: 0 – 18p, **3**: 19 – 24 p, **4**: 25 – 29p, **5**: 30 –37p, **G**: 19 – 29p, **VG**: 30 – 37p, **Max.** 37p.

Please observe the following:

- This exam has 7 numbered pages.
  Please check immediately that your copy is complete
- Answers must be given in English
- Please use page numbering on your pages
- Please write clearly
- Fewer points are given for unnecessarily complicated solutions
- Indicate clearly when you make assumptions that are not given in the assignment
- Answers to the exam will be published on the course website tomorrow.

Good luck!

1 Testing

Assignment 1 Continuous integration (2p)

→ Briefly explain what continuous integration is.

Assignment 2 Logic coverage (3p)

Consider the following piece of java code:

```
if (a > b && (x || c == 0) )
   return a;
else
   return b;
```

→ Construct a set of test-cases for the code snippet above, which satisfies *modified condition decision coverage (MCDC).*

Assignment 3 Mutation testing (3p)

Consider the following Java method which counts the number of elements which are present in both input arrays:

```
/*

requires: input left and right are non-null arrays which are sorted
          in non-decreasing order
ensures: output is the number of elements that are present in
         both arrays
*/
public static int inBoth(int[] left, int[] right){
  int il = 0, ir = 0, res = 0;
  while(il < left.length && ir < right.length){
    if(left[il] == right[ir]) {
       il += 1; ir += 1; res += 1;
    } else if(left[il] < right[ir]) {
       il += 1;
    } else {
      ir += 1;
    }
  {
  return res;
}
```

Ludvig has constructed a set of tests for this method which consists of the following tests (in shorthand):

```
inBoth({6,8,10},{}) == 0
inBoth({6,6,7},{4,5,6}) == 1
inBoth({3,4,5},{1,2,3,4}) == 2
inBoth({},{2,3,5}) == 0
```

Ludvig thinks that he does not need more tests: he cannot imagine a bug that he has not tested for. You, as a fresh expert on testing, do not agree with Ludvig.

→ Show that Ludvig is wrong: construct a mutant of the method that does not conform to the specification, but that is not killed by Ludvig's test set.

Assignment 4 Framing (2p)

In Dafny, it is required to state which variables are read (for functions) and which variables are modified (for methods).

→ Why does Dafny need this information?

Assignment 5 Logic and property based testing (4p)

(a) Explain briefly what a SAT solver is. (2p)

(b) Many efficient SAT-solvers are available. How would you use property based testing, namely testing the pointwise equivalence of functions to test a SAT solver? Specify what you generate and when you detect that something is wrong. (2p)

Assignment 6 Minimization (3p)

Suppose we have a method `f` which takes an array of characters as input, and suppose that this method computes the output incorrectly if the input contains two consequetive occurances of the letter `v`.

→ Simulate a run of the `ddMin` algorithm and compute a 1-minimal failing input from the following initial failing input: `[a,b,c,v,v,c,b,a]`. Clearly state what happens at *each step* of the algorithm and what the final result is.

Assignment 7 Formal Specification (1) (3p)

The seL4 microkernel is a *verified* microkernel (a microkernel is the minimal core of an operating system).

→ Briefly explain what it means that the seL4 microkernel is verified. Use at least the following words in your answer: implementation, specification, refinement, executable specification, proof.

Assignment 8 Formal Specification (2) (7p)

In this question you are going to specify and implement a method that takes two non-null arrays of the same length and "zips" them. This means that the method will return an array, as long as both input arrays together, where the elements alternately come from the first and the second input array.

For example, the result of running the method on the input arrays `[1,2,3,4]` and `[11,12,13,14]` will be a new array containing `[1,11,2,12,3,13,4,14]`.

The header of the method is as follows:

```
method zip(a : array<int>, b : array<int>) returns (c : array<int>)
requires ?
ensures ?
```

(a) Make the informal specification of `zip` formal by filling in the `requires` and `ensures` fields. (3p)

(b) Implement the `zip` method. Use a `while` loop and provide a loop invariant and decrease clauses such that Dafny will be able to prove total correctness. (It is not allowed to use a parallel for loop.) (4p)

Assignment 9 (Formal Verification) (10p)

In this question, you are going to prove that a simple division method is correct using the weakest-precondition calculus. The following method implements the division of natural numbers:

```
method div(n : nat, d : nat) returns (q : nat, r : nat)
requires d > 0
ensures q * d + r == n && r < d
{
  r := n;
  q := 0;
  while r >= d
  invariant r + q * d == n
  decreases r
  {
      r := r - d;
      q := q + 1;
  }
}
```

The method only deals with whole numbers. The result q gives the number of times d fits in n and r is the remainder after division.

→ Prove total correctness (including termination) for the above program.

You can assume that any variable with type `nat` is always bigger or equal to 0.

(total 37p)