CISC327 - Software Quality Assurance

Lecture 19

Regression Testing
Administrative

- **Friday:** Mini-Exam #2, on **testing** (white box, black box), **Lectures 8–16 inclusive** + readings
  - **Not** including last Friday’s Lectures 17–18 (mutation testing) and today (Lecture 19); 17–19 could be on Mini-Exam #3
  - Intended to be harder than Mini-Exam #1
  - I have intended this in the past and failed, but prior failure is no guarantee against success

- A1 has been reviewed by TAs; we are adjusting final marks to release today or Wed.
  - **Pay attention** to A1 feedback
  - A3 will be to **test** your A2 implementation; due **next** Fri.
• For logistical reasons, Computing is considering changes to 327 in future:
  – add an accelerated introduction to C++
  – mandate C++ for the project
• Comments?
Regression Testing

• Today we look at regression testing
• Purpose of regression testing
• Method
  – Establishing a regression test set
  – Maintaining a regression test set
  – Observable artifacts
Regression Testing

- regression:
  1. a return to a former or less developed state
Regression Testing

• Purpose
  – Ensure that existing functionality and behaviour is not broken by changes in new versions
  – Ensure that intended changes to functionality and behaviour are actually observed
  – Catch accidental or unintentional changes in functionality and behaviour before deployment, reducing costs
Regression Testing

• **Method**
  
  – Maintain a *regression set* of test inputs designed to exhibit existing functionality and behaviour
  
  – Choose a set of *observable artifacts* of computation that demonstrate desired aspects of functionality and behaviour (*not just output!*)
  
  – Maintain a *history* of the observable artifacts for each version of the software
  
  – **Compare** observable artifacts of each *new* version of software to *previous* version to ensure that differences are intentional
Regression Testing

• Regression Series
  – It's really called regression testing because we incrementally compare the results (functionality and behaviour) of tests for each new version of the software only to the previous version
  – And that one was compared to the one before it, and so on, forming a regression series based on the original software


  – It's a sort of inductive proof that we still have the behaviour we want to maintain
Regression Testing

• It's also called regression testing because to keep the total number of tests to be run at a practical level, we replace old tests with new ones to "cover" the same cases but to include testing of new/changed functionality.

• This sequence of replaced tests covering previous tests also forms a (more complex) regression series of test cases based on the original test set:
  – Where old tests are retired from the set as new tests are added to "cover" them.

• The reasoning that the tests have not lost anything is also an induction:
  – New tests cover retired old tests, which in turn cover previous older tests, and so on, back to the original validated test set.
Establishing a Baseline

• Begin with the original functionality test suite, plus early failure tests (if any), plus first operational tests
• Validate that these tests all run correctly
• Choose the set of observable artifacts to be tracked
  – These should characterize the functionality and behaviour we want to maintain across versions (more on this later)
• Run these first tests and save the observable artifacts in an easy to compare form (more on this later also)
Adding and Retiring Tests

• Whenever functionality is added or changed in the software, **add and validate** new tests for the new or changed functionality, and retire the tests for the replaced old functionality.

• Some practitioners retire **failure** tests after a fixed number of new versions do not exhibit the failure, as a way to keep the number of failure tests from growing too large.
Adding and Retiring Tests

• **Operational** tests must also be maintained, and retired or replaced when they no longer reflect current functionality.
Choosing Observable Artifacts

• Observable artifacts include at least the direct outputs of the software, but also other indicators of behaviour

• Because many programs have multiple kinds, streams, or files of output, we normally include all of them together in the observable artifacts

• Because subtle unintended changes in behaviour may not be immediately visible in direct test output, we normally turn on all debugging, tracing, and instrumenting flags the software may have when running regression tests, in order to have more detail in observable artifacts
Choosing Observable Artifacts

• Because performance is part of the user-visible behaviour of software, we usually measure time and space when running regression tests
  – Add these to the observable artifacts in order to observe unintended changes in performance

• Most systems provide some kind of external performance measuring tools
  – E.g., Unix "time" command, which can be used to give us this information

• To allow easy differencing, we normally translate all observable artifacts to text in the stored test results
Combining Observable Artifacts

• To allow easy differencing and archival, the entire set of observable artifacts resulting from running all of the tests in the entire set of regression tests is often combined into a single text file.

• This file includes the direct and indirect output, tracing, and debugging information, time and space statistics, and all other observable artifacts resulting from running each test, all concatenated together in a fixed order into one text file.

• This file forms a kind of behavioural signature for the version of the software, storing every observable characteristic of behaviour on the test set in one file.
Comparing Signatures

- The actual **regression** aspect of the test is implemented by looking at the difference between the signature files for the **previous version** and the **new version**

- If we're careful, this difference can be implemented by simple tools such as Unix's "**diff**"

```
  diff -b OldSignatureFile NewSignatureFile
  314c314
  < 0.3u 0.0s 0:00 97% 359+781k 0+0io 0pf+0w
  ---
  < 0.7u 0.0s 0:01 95% 361+770k 0+0io 0pf+0w
  2721c2721,2722
  < End of run - goodbye!
  ---
  > *** Error: invalid command 'create'
  > End of run - goodbye!
```
Normalizing Signatures

• To allow easy differencing, it is important that irrelevant or intentional differences between versions be factored out
• Since the signature file is all text, this can be automated using editor scripts to normalize signature files to reduce or eliminate non-behavioural or intended differences

  – Example: If the previous version of the software did all output in upper case and the new version (intentionally) outputs mixed case instead, the new signature can be normalized to upper case before differencing
Establishing the Baseline

• The **baseline** is the signature file of the version used to establish regression testing (the "original" version)

• The baseline signature **must** be carefully examined line by line **by hand** to ensure that every artifact is as it should be (a lot of work)

• Once established, only **differences** need to be examined for future versions
Regression Test Harness

• The regression test harness is the implementation of a procedure for automating the running, collection of observable artifacts, and differencing of versions for regression testing a product

• Should be developed such that it adapts automatically to addition or deletion of test cases or individual tests

• Again, requires care in planning and implementation, but once established, requires very little work
Regression Test Signatures

• The output of the entire run of the regression test script, including all test output, diagnostic output, and time and memory resource usage is saved in a single (large) signature file named for the version of the program being tested.

• The signature file is diff'ed against the previous version's signature file to check for differences in behaviour, and saved for comparison with the next version.
Regression Testing: TXL

• The **TXL interpreter** is a software product that implements the *TXL* programming language (http://www.txl.ca)

• It takes as input a TXL program “*foo.Txl*” and an input file to the program “*bar.foo*”, and compiles and runs the program on the input

• It produces two output streams:
  1. compiler and run time error messages on the **standard error stream**,  
  2. output of the program on the **standard output stream**
The TXL Regression Tests

• The regression tests for the TXL interpreter are organized into one large directory in which subdirectories contain test cases.

• Test case directories are named to indicate the kind and source of the test case they cover (functionality tests, failure tests or operational tests).

• Each test case directory contains a number of test inputs, each named beginning with the letters “eg” (standing for “example”) to make them easy to find automatically, as well as a README file explaining the original source and intentions of the test case.
The TXL Regression Tests

Regression Test Directory

<table>
<thead>
<tr>
<th>Permissions</th>
<th>Owner</th>
<th>Group</th>
<th>Size</th>
<th>Date/Time</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>drwxr--r--</td>
<td>4</td>
<td>cordy</td>
<td>512</td>
<td>Apr 01 17:11</td>
<td>ASDT/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>3</td>
<td>cordy</td>
<td>512</td>
<td>Apr 01 17:11</td>
<td>ASDT2/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>2</td>
<td>cordy</td>
<td>512</td>
<td>Nov 07 1997</td>
<td>ASTI-issue/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>2</td>
<td>cordy</td>
<td>512</td>
<td>Nov 27 1997</td>
<td>ASTI_issue/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>3</td>
<td>cordy</td>
<td>512</td>
<td>Apr 01 17:11</td>
<td>Abacus/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>2</td>
<td>cordy</td>
<td>512</td>
<td>Apr 13 1996</td>
<td>AndCondition/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>2</td>
<td>cordy</td>
<td>512</td>
<td>Jun 02 1996</td>
<td>Andy/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>2</td>
<td>cordy</td>
<td>512</td>
<td>Apr 29 1997</td>
<td>Apr97Bugs/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>2</td>
<td>cordy</td>
<td>512</td>
<td>Apr 13 1996</td>
<td>Backtrack/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>3</td>
<td>cordy</td>
<td>512</td>
<td>Apr 13 1996</td>
<td>Booster/</td>
</tr>
<tr>
<td>drwxr--r--</td>
<td>2</td>
<td>cordy</td>
<td>512</td>
<td>Jun 24 1996</td>
<td>C2T/</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>. . .</td>
</tr>
</tbody>
</table>

./Abacus:

```
  total 11
  -rw-r--r-- 1 cordy penguin  898 Jun 30 1993 README
  drwxr--r-- 2 cordy penguin  512 Dec 23 1994 Txl/
  -rw-r--r-- 1 cordy penguin  487 Jun 30 1993 eg.Compound
  -rw-r--r-- 1 cordy penguin   34 Jun 30 1993 eg1.Cascade
  -rw-r--r-- 1 cordy penguin  375 Jun 30 1993 eg2.Cascade
  -rw-r--r-- 1 cordy penguin 2102 Oct 16 1997 txltrace.out
```
Running the TXL Regression Tests

**TXL Regression Test Harness**

- The TXL regression tests are run by a **C-shell script** that walks through each subdirectory (test case) in the regression test directory, and runs each test input through TXL.

```csh
#!/bin/csh
# NewTestAll - the TXL regression script
foreach i (*)
    if -d $i then
        echo "====== $i ======
        cd $i
        foreach j (eg*.*)
            time newtxl -v $j
        end
        cd ..
    endif
end
```

- Each Test Case Directory
- Separator Message for each Test Case in Signature
- Each Input in the Test Case Directory
- Run with Unix “time” command to Measure Time and Memory Use
- Turn on All Verbose Diagnostic Messages
Running the TXL Regression Tests

TXL Regression Test Signatures

• The output of the entire run of the regression test script, including all test output, diagnostic output, and time and memory resource usage, is saved in a single (large) signature file named for the version of TXL being tested.

• The signature file is diff'ed against the previous version's signature file to check for differences in behaviour, and saved for comparison with the next version.

# Run TXL regression tests
NewTestAll >& NTAout2.42

Run Putting All Direct and Diagnostic Output in Signature File
Example TXL Regression Signature

===== Abacus =====
TXL Pro-LS 2.5d3b (22.7.98) Copyright 1995-1998 Legasys Corp.

Bootstrapping TXL ...
... used 348 trees and 229 kids.
Scanning the TXL program Txl/Compound.Txl
Parsing the TXL program
... used 1445 trees and 2270 kids.
Making the object language grammar tree
TXL ERROR : (Warning) Declaration of define 'choice'
previous declaration
... used 72 trees and 49 kids.
Making the rule table
... used 252 trees and 261 kids.
Scanning the input file eg.Compound
Parsing the input file
... used 158 trees and 266 kids.
Applying the transformation rules
Forced to copy 16 local vars (27%)
... used 93 trees and 158 kids.
Generating transformed output
Used a total of 2368 trees (0%) and 3233 kids (0%)

True = true ! True + setFalse ? False + setTrue ? True
False = false ! False + setTrue ? True + setFalse ? False
Negate = false ! Negate1
Negate1 = true ? Negate2 + setTrue ! nil
Negate2 = setFalse ! nil
And = false ? And1
And1 = true ? And2 + setFalse ! nil
And2 = true ? setTrue ! nil + false ? setFalse ! nil
[True & Negate]

0.0u 0.0s 0:00 109% 150+103k 0+0io 0pf+0w
## TXL Regression Differencing

<table>
<thead>
<tr>
<th>Version</th>
<th>Message</th>
<th>Difference</th>
<th>Performance</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2c2</td>
<td>TXL Pro-LS 2.4d8 (9.4.98) Copyright 1995-1998 Legasys Corp.</td>
<td>314c314</td>
<td>&lt; 0.3u 0.0s 0:00 97% 359+781k 0+0io 0pf+0w</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>TXL Pro-LS 2.5d3b (22.7.98) Copyright 1995-1998 Legasys Corp.</td>
<td>316c316</td>
<td>&gt; 0.3u 0.0s 0:00 83% 350+773k 0+0io 0pf+0w</td>
<td>---</td>
</tr>
<tr>
<td>2970,2971</td>
<td>TXL Pro-LS 2.4d8 (9.4.98) Copyright 1995-1998 Legasys Corp.</td>
<td>2971c2970</td>
<td>&lt; 1.1u 0.1s 0:01 100% 400+1395k 0+0io 0pf+0w</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>TXL Pro-LS 2.5d3b (22.7.98) Copyright 1995-1998 Legasys Corp.</td>
<td>2971</td>
<td>&gt; 1.2u 0.1s 0:01 98% 395+1369k 0+0io 1pf+0w</td>
<td>---</td>
</tr>
<tr>
<td>7039,7040</td>
<td>TXL Pro-LS 2.4d8 (9.4.98) Copyright 1995-1998 Legasys Corp.</td>
<td>7040c7039</td>
<td>&lt; 1.7u 0.1s 0:01 100% 413+1289k 0+0io 0pf+0w</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>TXL Pro-LS 2.5d3b (22.7.98) Copyright 1995-1998 Legasys Corp.</td>
<td>7040</td>
<td>&gt; 1.7u 0.1s 0:01 100% 410+1275k 0+0io 0pf+0w</td>
<td>---</td>
</tr>
<tr>
<td>9787,9788</td>
<td>TXL Pro-LS 2.4d8 (9.4.98) Copyright 1995-1998 Legasys Corp.</td>
<td>9788c9787</td>
<td>&lt; 1.8u 0.1s 0:01 100% 413+1427k 0+0io 0pf+0w</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>TXL Pro-LS 2.5d3b (22.7.98) Copyright 1995-1998 Legasys Corp.</td>
<td>9788</td>
<td>&gt; 1.7u 0.1s 0:01 98% 410+1431k 0+0io 0pf+0w</td>
<td>---</td>
</tr>
</tbody>
</table>
TXL Regression Differencing

```
32514c32532
< Preprocessor directives  58
---
> Preprocessor directives  58
32516c32534
< Declarations    91
---
> Declarations    91
   ... 

15010c15010
< TXL Pro-LS 2.4d2 (9.12.97) Copyright 1995-1997 Legasys Corp.
---
> TXL Pro-LS 2.5d3b (22.7.98) Copyright 1995-1998 Legasys Corp.
27888c27888
<  8.1u 1.1s 0:09  99%  372+6375k  0+0io  11pf+0w
---
>  7.7u  0.4s 0:08  99%  421+6965k  0+0io  0pf+0w
27891c27891
< TXL Pro-LS 2.4d2 (9.12.97) Copyright 1995-1997 Legasys Corp.
---
> TXL Pro-LS 2.5d3b (22.7.98) Copyright 1995-1998 Legasys Corp.
27942c27942
<    ... used 425 trees and 519 kids.
---
>    ... used 423 trees and 519 kids.
41066c41066
<    Used a total of 490839 trees (16%) and 998275 kids (22%).
---
>    Used a total of 490837 trees (16%) and 998275 kids (22%).
   ... 
```

 Significant Performance Difference (But an Improvement)

 Output Spacing Difference (Bug!)

 Internal Diagnostic Difference
Regression Testing

• Advantages
  – Previous *functionality* never accidentally lost
  – Previously fixed *bugs* never reappear in production
  – Virtually all *accidental* bugs are caught before deployment
  – Virtually no *unintentional changes* in behaviour slip into production
  – Users observe very high level of *quality*
Regression Testing

• Disadvantages
  – Regression set must be maintained with a high degree of discipline and care
    • At least as carefully as the software itself
  – Establishing the baseline and regression testing harness requires significant effort
    • But it pays off in ease of use later

• Bottom Line
  – High-quality software shops all do it, because the difference in confidence and observed quality is easily worth it
Summary

• Regression Testing
  – Ensure that existing functionality and behaviour is not broken by changes in new versions
  – Maintain regression set of tests designed to exhibit existing functionality and behaviour
  – Compare observable artifacts of each new version of software to previous version to ensure that differences are intentional

• Wednesday
  – Review for Mini-Exam #2

• Friday
  – Mini-Exam #2, Lectures 8–16 inclusive + readings

• Then
  – Begin Inspections