Test Driven Development in R

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What is Test Driven Development?

- It is important to stress, Test Driven Development (TDD) is a **development** methodology, not a testing methodology.

- The key idea is to write the tests for code before writing the code itself.

- It turns around the usual approach to software development from starting with “What code do I need to write to solve this problem?” to starting with “How will I know if I’ve solved the problem”?

Test Driven Development cycle

- Write test
  - The new tests should be testing something not yet written – i.e. the new tests should fail
- Run tests
- Write code
  - The new code should ensure that the new tests now pass
- Run tests
- Refactor code
- Run tests
- One thing this cycle suggests is that the tests should be simple and efficient.

Refactoring

- Refactoring is defined by Fowler (1999) as

  “a change made to the internal structure of software to make it easier to understand and cheaper to modify without changing its observable behaviour”.

- Examples given of this include
  - Removing duplicated code (probably the most important)
  - Shortening long methods / functions
  - Extracting a fragment of code into a separate function

A few simple principals for TDD

- Write tests first!
- KISS – Keep it simple, stupid
  - Don’t use clever features of code if you don’t need them
- YAGNI – You ain’t gonna need it
  - Only write the code you need to pass the test; don’t add lots of clever features that you MIGHT need in the future.
- DRY – Don’t repeat yourself
  - Don’t have more than one representation of anything, so if you have two bits of code doing the same thing then eliminate one of them.

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How to do it in R

- There are two packages for unit testing in R
- rUnit (https://sourceforge.net/projects/runit/)
- svUnit (http://www.sciviews.org/SciViews-K/index.html)
- In this case I run the example using svUnit as this works well with Komodo Edit and SckViews-K to produce a development environment (see the SciViews website for instructions on how to install the various software packages).

Getting started

- For a simple example type the following code in the editor:

```
add <- function (x, y) return (x + y)
test (add) <- function ()
{
    checkEquals (2, add (1, 1))
    checkException (add (1, "Fred"))
}

subtract <- function (x, y) return (x - y)
test (subtract) <- function ()
{
    checkEquals (2, subtract (3, 1))
    checkEquals (3, subtract (2, 1))
}
```

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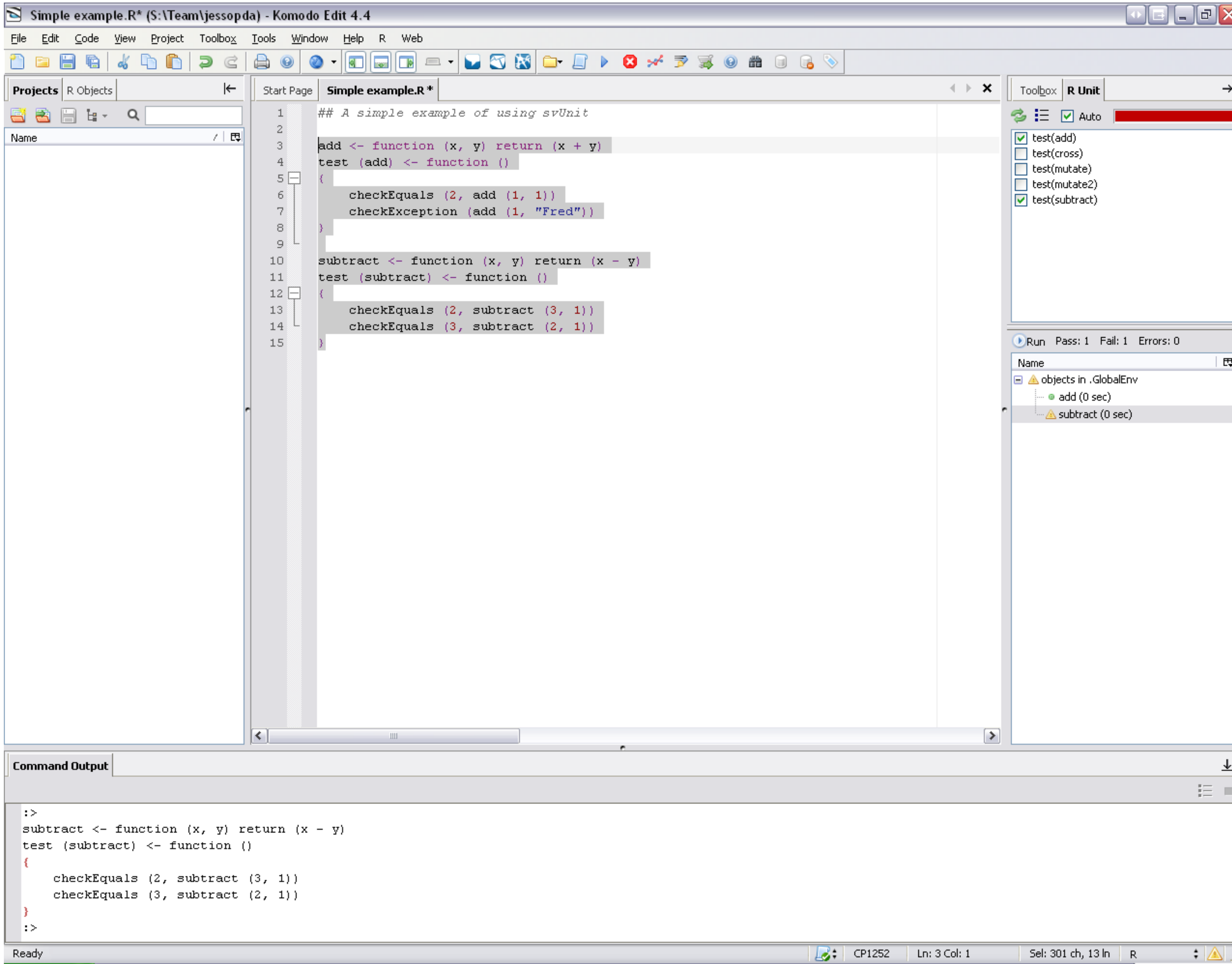
Getting started (2)



Source: UBS, Komodo

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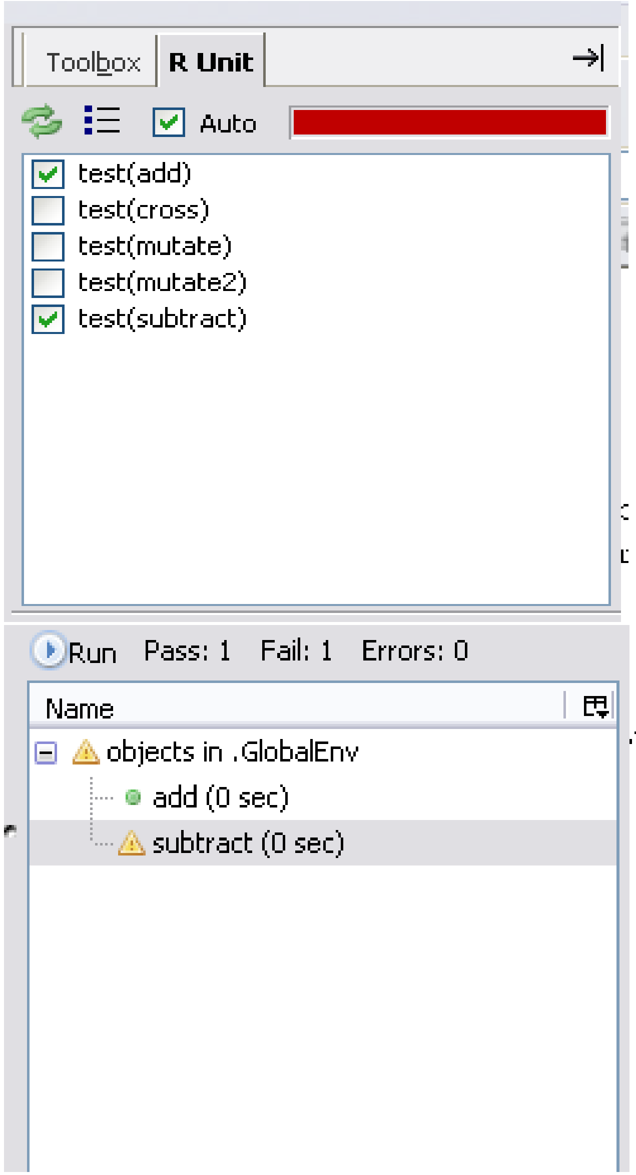
Getting started (3)

- The advantage of this development environment is that the tests and their outcome appear in the editor, as can be seen on the right.
- Here we see that we have run two tests, one passing and one failing.



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Source: UBS, Komodo

Getting started (4)

- We can get more details with the Log() function:

```
= A svUnit test suite run in less than 0.1 sec with:

* testadd ... OK
* testsubtract ... **FAILS**

== testadd (in runitobjects.R) run in less than 0.1 sec: OK

//Pass: 2 Fail: 0 Errors: 0//

== testsubtract (in runitobjects.R) run in less than 0.1 sec:
   **FAILS**

//Pass: 1 Fail: 1 Errors: 0//

* : checkEquals(3, subtract(2, 1)) run in less than 0.001 sec ...
   **FAILS**
Mean relative difference: 0.6666667
 num 1
```

An example

- We were developing a package to calculate various risk statistics for a portfolio, using a linear factor model.
- The package used a DLL for the calculations as we want to use the same library in other places and for it to be fast.
- The inputs to all the calculations are
  - a vector of weights, w
  - a matrix of factor sensitivities, B
  - a matrix of factor covariances, F
  - a vector (or diagonal matrix) of stock specific risks, D

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An example (2)

- Although there are a number of statistics we wish to calculate, we will focus on developing two, the risk calculation and the portfolio’s factor sensitivities.

- The risk is defined as

$$w^T B F B^T w + w D w$$

- This is calculated efficiently by first calculating $w^T B$ and then using this in the above calculation.

- The factor sensitivities are equal to $w^T B$

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An example (3)

- The basic structure of the C code is

```
void getStatistic (char *name, double *data, int *retCode)
{
   // Check for errors

   switch ( lookup(name) )
   {
         default:
                  retCode [0] = ERR_INVALID_NAME;
                  data [0] = INVALID_DATA;
   }
}
```

- There is a simple R wrapper which calls this routine and checks for the value of retCode. If it's none zero then we generate an error.

- There are other routines to pass the risk model and the portfolio data that we won't consider here.

An example (4)

- The first test routine that we wrote to get to this point was:

```
test (getStatistic) <- function ()
{
    fmp (beta, fcov, specific)
    loadPortfolio (test1, test2)

    checkException (getStatistic ("rubbish"))
}
```

- This test passes. We now add an additional test

```
checkEquals (getStatistic ("activerisk", dataLength = 3), riskCheck
   (active, fcov, beta, specific))
```

- which is designed to fail!

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An example (5)

- We edit the C code to have the structure

```
void getStatistic (char *name, double *data, int *retCode)
{
   // Check for errors

   switch ( lookup(name) )
   {
         case ITEM_ARISK:
                  // Calculate w^TBFB^Tw + wDw and return values in
   *data
                  // Details skipped for clarity
         default:
                  retCode [0] = ERR_INVALID_NAME;
                  data [0] = INVALID_DATA;
   }
}
```

- Note that the `lookup (name)` function maps the string in name to an integer.

- Now our new test passes.

An example (6)

- We now add another test routine, again designed to fail:

```
test (getStatistic) <- function ()
{
   fmp (beta, fcov, specific)
   loadPortfolio (test1, test2)

   checkException (getStatistic ("rubbish"))

   checkEquals (getStatistic ("activerisk", dataLength = 3),
                              riskCheck (active, fcov, beta, specific))
   checkEquals (getStatistic ("activebetas", dataLength = 3),
                                         as.vector (active %*% beta))
}
```

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An example (7)

- We edit the C code to have the structure

```
void getStatistic (char *name, double *data, int *retCode)
{
   // Check for errors

   switch ( lookup(name) )
   {
         case ITEM_ARISK:
                  // Calculate wTBFBTw + wDw and return values in
   *data
         case ITEM_ABETAS:
                  // Calculate wTB and return values in *data
         default:
                  retCode [0] = ERR_INVALID_NAME;
                  data [0] = INVALID_DATA;
   }
}
```

- Now our new test passes.

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An example (8)

- We note that we are calculating the vector $w^T B$ more than once
- In terms of speed (if nothing else) we should calculate this once and store the value
- So we refactor our code to do this, running the tests when we've finished to ensure we haven't changed the external behaviour of the routines.

Is it worthwhile?

- What are the benefits of TDD?

- Some of the benefits stated by the proponents of TDD include:
  - Better code design
  - Fewer errors in code
  - Efficiency
  - The tests themselves
  - Reducing defect injection i.e. reducing errors from fixes and “small” code changes.

- There is little academic evidence however to back up these assertions. What evidence there is does seem to back the view that TDD code contains fewer errors, and that test coverage is greater than from a “test last” approach, but there is little evidence for the other benefits.

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Is it worthwhile? (2)

- Nagappan et al (2008) in a study of four separate development teams (from IBM and Microsoft) find that "all the teams demonstrated a significant drop in defect density", with the falls being between 40% and 90%.

- They also have some recommendations based on their experience rather than on specific empirical evidence. These include:
  - Start TDD from the beginning of projects
  - Convince the developer(s) to add new tests every time a problem is found
  - Tests should be run frequently, and definitely as part of a daily automated build process
  - Encourage fast unit test execution and efficient unit test design

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Is it worthwhile? (3)

- Siniaalto (2006) summarises the conclusions of 13 studies carried out in both an industrial and an academic context.
- In the industrial context “it is especially significant that all [the] case studies reported considerably reduced defect rates, as much as 40-50%. The productivity effects were not that obvious”.
- In the academic context (i.e. studies carried out using undergraduate students), the results were less conclusive. One caveat the author raises is that real software projects are often orders of magnitude bigger than the experiments carried out with students.
- She concludes “TDD seems to improve software quality” but that “the productivity effects of TDD were not very obvious”.

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Summary

- Test Driven Development is a development methodology, not a testing methodology
- R + Komodo + svUnit provides a good environment for programming in this way
- In my view, not every project benefits from this approach, but packages or for code that is re-used it provides a useful framework.
- The academic evidence is mixed, but does seem to suggest that it improves the error rate of code, although it may not improve productivity.

References

- Astels, David (2003) Test Driven Development: A Practical Guide, Prentice Hall
- Erdogmus, H (2005) On the Effectiveness of Test-first Approach to Programming, Proceedings of the IEEE Transactions on Software Engineering, 31(1)
- Fowler, M, (1999), Refactoring: Improving the Design of Existing Code, Addison Wesley
- Kent, Beck (2002) Test Driven Development: By Example, Addison-Wesley
- Komodo Edit (http://www.activestate.com/komodo_edit/)
- König, T., K. Jünemann & M. Burger, 2007. RUnit – A unit test framework for R. Vignette of the package RUnit available on CRAN
- Muller, M. M. and F Padberg (2003) About the Return on Investment of Test-Driven Development. In: International Workshop on Economics-Driven Software Engineering Research (EDSER), Portland, Oregon, USA (2003)
- Nagappan, N., E. M. Maximillien, T Bhat, L Williams (2008) Realizing quality improvement through test driven development: results and experiences of four industrial teams, Journal of Empirical Software Engineering, 13:289-302
- SciViews-K (http://www.sciviews.org/SciViews-K/index.html)
- Siniaalto, M. (2006) Test driven development: empirical body of evidence. Technical report, ITEA, Information Technology for European Advancement.
- Proffitt, Jacob, TDD Proven Effective! Or is it? (http://theruntime.com/blogs/jacob/archive/2008/01/22/tdd-proven-effective-or-is-it.aspx)

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