Introduction to Software Testing
Test Driven Development (TDD)

Software Testing & Maintenance
SWE 437
http://go.gmu.edu/swe437

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Growing importance of testing

Philosophy of traditional software development methods

- **Upfront** analysis
- Extensive **modeling**
- Reveal **problems** as early as possible

More work must be revised
Scaling assumptions

Traditional assumptions are...

1. *Modeling and analysis can identify potential problems early in development*

2. *Savings implied by the cost-of-change curve justify the cost of modeling and analysis over the life of the project*

These are true if requirements are always complete and current.

But customers always change their minds!

- Humans are naturally good at approximating
- But pretty bad at perfecting

These two assumptions have made software engineering frustrating and difficult for decades.

Thus, agile methods...
Why be agile?

Agile methods start by recognizing that neither assumption is valid for many current software projects

- Software engineers are not good at developing requirements
- We do not anticipate many changes
- Many of the changes we do anticipate are not needed

Requirements (and other “non-executable artifacts”) tend to go out of date very quickly

- We seldom take time to update them
- Many current software projects change continuously

Agile methods expect software to start small and evolve over time

- Embraces software evolution instead of fighting it
Supporting evolutionary design

Traditional design advice says to anticipate changes.

Designers often anticipate changes that don’t happen.

Both anticipated and unanticipated changes affect design.
The test harness as guardian

(4.2)

What is correctness?

Traditional Correctness
(Universal)
\( \forall x, y, x \geq y \)

Agile Correctness
(Existential)

\[
\{ 
(1, 1) \rightarrow T \\
(1, 0) \rightarrow T \\
(0, 1) \rightarrow F \\
(10, 5) \rightarrow T \\
(10, 12) \rightarrow F 
\} 
\]
Supporting evolutionary design

In traditional methods, we try to define all correct behavior completely, at the beginning

- What is correctness?
- Does “correctness” mean anything in large engineering products?
- People are VERY BAD at completely defining correctness

In agile methods, we redefine correctness to be relative to a specific set of tests

- If the software behaves correctly on the tests, it is “correct”
- Instead of defining all behaviors, we demonstrate some behaviors
- Mathematicians may be disappointed at lack of completeness

But software engineers ≠ mathematicians!
In-class Exercise

Discuss

limited correctness

Do you understand the distinction?

How does limited correctness related to evolutionary design?
Verifying “correctness”

A test harness runs all automated tests and reports results to the developer.

Tests must be automated
- Test automation is a prerequisite to test driven development.

Every test must include a test oracle that can evaluate whether that test executed correctly.

The tests replace the requirements.

Tests must be high quality and must run quickly.

We run tests every time we make a change to the software.
Continuous integration

Agile methods work best when the current version of the software can be run against all tests at any time.

A *continuous integration server* rebuilds the system, returns, and re-verifies tests whenever *any* update is checked into the repository.

Mistakes are caught earlier.

Other developers are aware of changes early.

The rebuild and reverify must happen as soon as possible.

- Thus, tests need to execute quickly.

A *continuous integration server* doesn’t just run tests, it decides if a modified system is *still correct*. 

**Travis CI**

**Jenkins**
Continuous integration reduces risk

TDD encourages incremental integration of functionality

Non-integrated functionality is dangerous
Build it right: TDD

The heart-beat of TDD = Test-Code-Refactor

- The rule: **only write code to fix a failing test**
- Traditional development cycle

![Design → Code → Test](image)

- Test-driven development cycle

![Test → Code → Refactor](image)

Sometimes called red-green-refactor
Build it right: TDD

First, we write a test

This really amounts to design by example
  - We make decisions about how the Application Programmer Interface (API) works
    - Class name, method names, return results, etc.
    - This is essentially the user interface
  - We’re thinking hard about how code is used
  - We’re taking a client perspective
  - We’re working at a very small scale

Example for a stack

Start with one concrete client interaction

```java
stack = ... ;
stack.push (x);
y = stack.pop();
assertEquals (x, y);
```
In-class Exercise

You are asked to write a program to **merge two lists**

Design the **FIRST test case** (test values and expected output)

Do NOT consider software design, or details of the behavior that are not needed for the first test
Build it right: TDD

Then we write just enough code
  - We don’t write more code
  - All we want is to make the test pass
    - It should be a very small step
    - Implementation probably not optimal
    - We don’t care (yet)

Goal: Make code base (just) pass test suite
Build it right: TDD

And then we refactor

TDD without refactoring just makes ugly code
  - Maintenance debt

We have numerous transformations to address this

Developing with small steps
  - The code always runs!
    - Changes are small enough to fit in our heads
    - Time-frame is minutes to (maybe) hours

- Evolutionary design
  - Anticipated vs unanticipated changes
  - Many “anticipated changes” turn out to be unnecessary
Build it right: TDD

Keeping code healthy with refactoring

**Refactoring:** A *disciplined technique for restructuring an existing body of code, and altering its internal structure without changing its external behavior*

- Refactoring is disciplined
  - Wait for a problem before solving it
- Refactorings are transformations
  - Many refactorings are simply applications of patterns
- Refactorings alter internal structure
- Refactorings preserve behavior

Focus is on current code, not future code.
User stories

A user story is a few sentences that capture what a user will do with the software

- In the language of the end user
- Usually small in scale with few details
- Not archived

Withdraw money from checking account

Support technician sees customer’s history on demand

Agent sees a list of today’s interview applicants
In-class Exercise

In assignment 3, you added new functionality.

Each individual in your group:
write a user story that would start the need for that functionality

Share the user stories in your group and critique them
- Are they the right size?
- Are they in the user’s vocabulary?
Acceptance tests with agile

User Story

Acceptance Test (Failing)

Acceptance Test (Passing)

TDD Test 1

Change software & Refactor

Continue adding TDD tests until acceptance test passes

TDD Test 2

Change software & Refactor

Refactoring avoids

Tests archived
The caveat

Do TDD tests (acceptance or otherwise) test the software well?
- Do the tests achieve good coverage on the code?
- Do the tests find most of the faults?
- If software passes, should management feel confident the software is reliable?

NO!
Why not?

Most agile tests focus on “happy paths”
- What should happen under normal use

They often miss things like
- **Confused**-user paths
- **Creative**-user paths
- **Malicious**-user paths

The agile methods literature does not give much guidance
Summary – take small steps

More companies are putting testing first

This can dramatically decrease cost and increase quality

A different view of “correctness”
  - Restricted but practical

Embraces evolutionary design

TDD is definitely not test automation
  - Test automation is a prerequisite to TDD

TDD tests aren’t enough