Testing (Part 1/3)

Martin Kellogg

Testing (part 1)

Today's agenda:

- **Reading Quiz**
- What is testing?
- How to write tests
- Different kinds of tests and how to use them
- Continuous integration (or: why most of your tests should be automated)

Reading Quiz: testing (1)

Q1: **TRUE** or **FALSE**: an important activity in TDD is writing tests that fail

Q2: The example's first test case was:

```
assertEquals(1, qs.count());
```

How did the author implement the `qs.count()` function to get this test to pass the first time? (Answers that describe the technique or give a complete implementation are OK.)

Reading Quiz: testing (1)

Q1: **TRUE** or **FALSE**: an important activity in TDD is writing tests that fail

Q2: The example's first test case was:

```
assertEquals(1, qs.count());
```

How did the author implement the `qs.count()` function to get this test to pass the first time? (Answers that describe the technique or give a complete implementation are OK.)

Reading Quiz: testing (1)

Q1: **TRUE** or **FALSE**: an important activity in TDD is writing tests that fail

Q2: The example's first test case was:

```
assertEquals(1, qs.count()
```

How did the author implement th
to pass the first time? (Answers t
complete implementation are OK

Hardcoded it to always return 1:

```
public int count() {
    return 1;
}
```

(Anything close gets full credit)

Testing (part 1)

Today's agenda:

- Reading Quiz
- **What is testing?**
- How to write tests
- Different kinds of tests and how to use them
- Continuous integration (or: why most of your tests should be automated)

What is testing?

Definition: a ***test*** executes a given input on a program (the ***system under test*** or ***SUT***) and compares the SUT's output to a given oracle

What is testing?

Definition: a ***test*** executes a given input on a program (the ***system under test*** or ***SUT***) and compares the SUT's output to a given oracle

Aside: testing is the canonical example of a ***dynamic analysis***, which is program analysis that requires running the program

What is testing?

Definition: a ***test*** executes a given input on a program (the ***system under test*** or ***SUT***) and compares the SUT's output to a given oracle

```
./prog < input > output && diff output oracle
```

What is testing?

Definition: a ***test*** executes a given input on a program (the ***system under test*** or ***SUT***) and compares the SUT's output to a given oracle

```
./prog < input > output && diff output oracle
```

SUT

What is testing?

Definition: a ***test*** executes a **given input** on a program (the ***system under test*** or ***SUT***) and compares the SUT's output to a given oracle

```
./prog < input > output && diff output oracle
```

input

What is testing?

Definition: a ***test*** executes a **given input** on a program (the ***system under test*** or ***SUT***) and compares the SUT's **output** to a given oracle

```
./prog < input > output && diff output oracle
```

output

What is testing?

Definition: a *test* executes a **given input** on a program (the ***system under test*** or ***SUT***) and **compares** the SUT's **output** to a given oracle

```
./prog < input > output && diff output oracle
```

comparator

What is testing?

Definition: a ***test*** executes a **given input** on a program (the ***system under test*** or ***SUT***) and **compares** the SUT's **output** to a given **oracle**

```
./prog < input > output && diff output oracle
```

oracle

What is testing?

Definition: a *test* executes a **given input** on a program (the *system under test* or *SUT*) and **compares** the SUT's **output** to a given **oracle**

```
./prog < input > output && diff output oracle
```

SUT **input** **output** **comparator** **oracle**

Building a test case

- You usually know the SUT

Building a test case

- You usually know the SUT
- **You choose** inputs (**how?**)

Building a test case

- You usually know the SUT
- **You choose** inputs (**how?**)
- Run the SUT on the chosen inputs to produce the output

Building a test case

- You usually know the SUT
- **You choose** inputs (**how?**)
- Run the SUT on the chosen inputs to produce the output
- **You choose** the comparator (**how?**)

Building a test case

- You usually know the SUT
- You choose inputs (how?)
- Run the SUT on the chosen inputs to produce the output
- You choose the comparator (how?)
- You choose the oracle (how?)

Building a test case

- You usually know the SUT
- You choose inputs (how?)
- Run the SUT on the chosen inputs to produce the output
- You choose the comparator (how?)
- You choose the oracle (how?)

Ideal situation: you can test every input ("**exhaustive testing**")

Building a test case

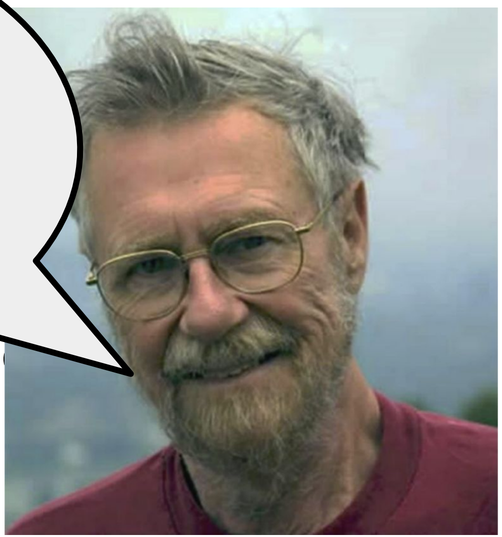
- You usually know the SUT
- **You choose** inputs (**how?**)
- Run the SUT on the chosen inputs to produce the output
- **You choose** the comparator (**how?**)
- **You choose** the oracle (**how?**)

Ideal situation: you can test every input ("**exhaustive testing**")

- in practice, rarely possible: **input space is too large**

Building a test cas

> "Tests can show the presence of bugs, but not their absence"



- You usually know th
- You choose inputs (ho
- Run the SUT on the chosen ... produ
- You choose the comparator (how?)
- You choose the oracle (how?)

Ideal situation: you can test every input ("**exhaustive testing**")

- in practice, rarely possible: **input space is too large**

Building a test case

- You usually know the SUT
- You choose inputs (how?)
- Run the SUT on the chosen inputs to produce the output
- You choose the comparator (how?)
- You choose the oracle (how?)

Ideal situation: you can test every input ("

- in practice, rarely possible: input spac

We'll talk about these out of order:

- comparators
- oracles
- inputs

Testing (part 1)

Today's agenda:

- Reading Quiz
- What is testing?
- **How to write tests**
- Different kinds of tests and how to use them
- Continuous integration (or: why most of your tests should be automated)

Choosing a comparator

- Most common: **exact match** (often a good choice!)

Choosing a comparator

- Most common: exact match (often a good choice!)
- Also common:
  - over-approximation (“is the output one of these good values”, or, more commonly, “is there any output at all”)

Choosing a comparator

- Most common: exact match (often a good choice!)
- Also common:
  - over-approximation (“is the output one of these good values”, or, more commonly, “is there any output at all”)
  - under-approximation (“does the output contain this expected value”)

Choosing a comparator

- Most common: exact match (often a good choice!)
- Also common:
  - **over-approximation** ("is the output one of these good values", or, more commonly, "is there any output at all")
  - **under-approximation** ("does the output contain this expected value")
- But, could be an **arbitrarily-complex boolean** function
  - must be boolean, because test needs to either pass or **fail**

Choosing a comparator

- Most common: exact match (often a g
- Also common:
  - over-approximation ("is the outp
    values", or, more commonly, "is th
  - under-approximation ("does the
    expected value")
- But, could be an **arbitrarily-complex boolean** function
  - must be boolean, because test needs to either pass or **fail**

Choosing a comparator is easy for programs that read and write text. For programs that e.g., have a GUI, this can be a very difficult problem.

Choosing an oracle

- As a human, you get this from the **specification**
    - ask yourself: “what should the program do with this input?”

Choosing an oracle

- As a human, you get this from the specification
  - ask yourself: "what should the program do with this input?"
  - advice: always **write down the oracle**
    - common (low quality) oracle: add a `printf` statement to the program, run it, check by hand that the output is what you expect

Choosing an oracle

- As a human, you get this from the **specificatior**
  - ask yourself: “what should the program do
  - advice: always **write down the oracle**
    - common (low quality) oracle: add a `printf` statement to the program, run it, check by hand that the output is what you expect

Don’t do this!

Choosing an oracle

- As a human, you get this from the **specification**
  - ask yourself: "what should the program do with this input?"
  - advice: always **write down the oracle**
    - common (low quality) oracle: add a `printf` statement to the program, run it, check by hand that the output is what you expect
- Choosing an oracle automatically is **very hard**
  - key problem in automated test generation
  - we'll talk about this in more detail later

Choosing inputs

- When writing tests by hand, this is often the hardest part

Choosing inputs

- When writing tests by hand, this is often the hardest part
- Strategies:
  - choose at random (avoid when writing by hand)
  - edge cases
  - partition testing

Choosing inputs

- When writing tests by hand, this is often the hardest part
- Strategies:
  - choose at random (avoid when writing by hand)
  - **edge cases**
  - partition testing

Edge case examples:

- 0, 1, -1
- null
- empty list
- empty file
- etc.

Choosing inputs

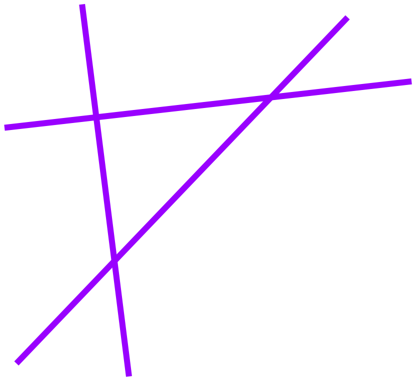
- When writing tests by hand, this is often the hardest part
- Strategies:
  - choose at random (avoid when writing by hand)
  - edge cases
  - **partition testing**

Partition testing

Key idea: split up the input space into redundant "regions"

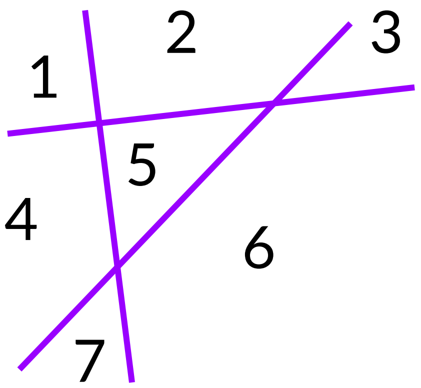
Partition testing

Key idea: split up the input space into redundant “regions”



Partition testing

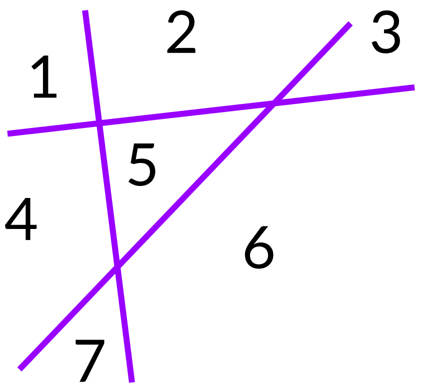
Key idea: split up the input space into redundant "regions"



- write one test **for each region**

Partition testing

Key idea: split up the input space into redundant "regions"

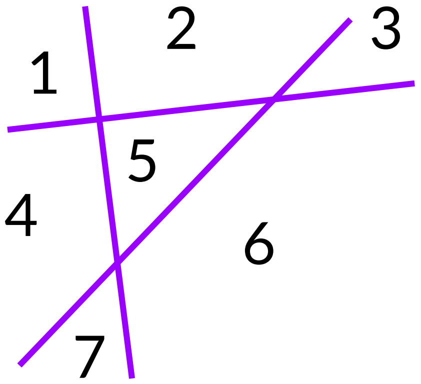


- write one test **for each region**
- possible ways to split up the input:
  - parity (even, odd)
  - positive, negative, zero
  - jpg files vs png files
  - correctly-formatted input vs incorrectly-formatted input

Partition testing

Key idea: split up the input space into

Common technique: split up input space k ways, write 2^k tests



- write one test **for each region**
- possible ways to split up the input:
  - parity (even, odd)
  - positive, negative, zero
  - jpg files vs png files
  - correctly-formatted input vs incorrectly-formatted input

Testing (part 1)

Today's agenda:

- Reading Quiz
- What is testing?
- How to write tests
- **Different kinds of tests and how to use them**
- Continuous integration (or: why most of your tests should be automated)

Kinds of tests

Many ways to classify tests:

Kinds of tests

Many ways to classify tests:

- by size: **how many resources** do the tests need?
- by scope: **what sort of thing** is the SUT?
- by purpose: **why** are we testing?
- by manner: **how** is testing performed?

Kinds of tests

Many ways to classify tests:

- by size: **how many resources** do the tests need?
- by scope: **what sort of thing** is the SUT?
- by purpose: **why** are we testing?
- by manner: **how** is testing performed?

All valid ways to classify tests!

Kinds of tests

We'll discuss the following important kinds of tests:

- **unit** tests
- **integration** tests
    - with a discussion of **mocking**
- **regression** tests

Kinds of tests: unit tests

Definition: a ***unit test*** tests individual “units” of source code: procedures, methods, classes, modules, etc.

Kinds of tests: unit tests

Definition: a ***unit test*** tests individual "units" of source code: procedures, methods, classes, modules, etc.

- unit tests are characterized by **scope**: you can tell a test is a unit test because it tests only a single component

Kinds of tests: unit tests

Definition: a ***unit test*** tests individual “units” of source code: procedures, methods, classes, modules, etc.

- unit tests are characterized by **scope**: you can tell a test is a unit test because it tests only a single component
- typically they should be **small and fast**

Kinds of tests: unit tests

Definition: a ***unit test*** tests individual “units” of source code: procedures, methods, classes, modules, etc.

- unit tests are characterized by **scope**: you can tell a test is a unit test because it tests only a single component
- typically they should be **small and fast**
- tests features **in isolation**, which makes debugging easier

Kinds of tests: unit tests

Definition: a ***unit test*** tests individual “units” of source code: procedures, methods, classes, modules, etc.

- unit tests are characterized by **scope**: you can tell a test is a unit test because it tests only a single component
- typically they should be **small and fast**
- tests features **in isolation**, which makes debugging easier
- modern frameworks are often based on SUnit (for Smalltalk)
    - e.g., JUnit (Java), unittest (Python), googletest (C++), etc.

Kinds of tests: unit tests

Definition: a ***unit test*** tests individual "units" of source code: procedures, methods, classes, modules, etc.

- unit tests are characterized by **scope**; you can tell a test is a unit test because it tests only a single
- typically they should be **small and**
- tests features **in isolation**, which
- modern frameworks are often based on SUnit (for Smalltalk)
  - e.g., JUnit (Java), unittest (Python), googletest (C++), etc.

Collectively referred to as **xUnit** frameworks

Kinds of tests: unit tests: xUnit

- Test cases “look like other code”
  - They are special methods written to return a boolean or raise assertion failures

Kinds of tests: unit tests: xUnit

- Test cases “look like other code”
  - They are special methods written to return a boolean or raise assertion failures
- A test case **discoverer** finds all such tests
  - Special naming scheme, dynamic reflection, etc.

Kinds of tests: unit tests: xUnit

- Test cases “look like other code”
  - They are special methods written to return a boolean or raise assertion failures
- A test case **discoverer** finds all such tests
  - Special naming scheme, dynamic reflection, etc.
- A test case **runner** chooses which tests to run

Kinds of tests: unit tests: xUnit

- Test cases “look like other code”
  - They are special methods written to return a boolean or raise assertion failures
- A test case **discoverer** finds all such tests
  - Special naming scheme, dynamic reflection, etc.
- A test case **runner** chooses which tests to run
- Each test is run in a “fresh” environment
  - A **test fixture** specifies which code to run before/after the test case to setup/teardown the right environment

Kinds of tests

We'll discuss the following important kinds of tests:

- **unit** tests
- **integration** tests
  - with a discussion of **mocking**
- **regression** tests

Kinds of tests: integration tests

Definition: an ***integration test*** tests that multiple sub-components of a software system work correctly when combined

Kinds of tests: integration tests

Definition: an ***integration test*** tests that multiple sub-components of a software system work correctly when combined

- **Goal**: answer the question "Does our application work from start to finish?"

Kinds of tests: integration tests

Definition: an ***integration test*** tests that multiple sub-components of a software system work correctly when combined

- **Goal**: answer the question “Does our application work from start to finish?”
- Typically **combined with unit testing**: unit test individual components, then test that they integrate together properly

Kinds of tests: integration tests vs unit tests

Question: what determines whether a test is a **unit test** of a module, or an **integration test** of its sub-components?

Kinds of tests: integration tests vs unit tests

Question: what determines whether a test is a **unit test** of a module, or an **integration test** of its sub-components?

Answer: perspective!

Remember, all of computer science is based on **abstractions**. An integration test for layer *n* of a software stack might be a unit test for layer *n+1*

Kinds of tests: integration tests vs unit tests

Question: what determines whether a test is a **unit test** of a module, or an **integration test** of its sub-components?

Answer: perspective!

Remember, all of computer science is based on **abstractions**. An integration test for layer *n* of a software stack might be a unit test for layer *n+1*

This also promotes a modular, decoupled design

Testing SUTs that are hard to test

What if we want to write unit or integration tests for some SUT, but the SUT has **expensive dependencies**?

Exercise: take one minute and, in pairs, generate three examples of things that are hard to test because of their dependencies or other expense factors.

Mocking

Definition: ***Mock objects*** are simulated objects that mimic the behavior of real objects in controlled ways.

In testing, **mocking** uses a mock object to test the behavior of some other object.

- analogy: use a crash test dummy instead of real human to test automobiles

Mocking example: Web API Dependency

- Suppose we're writing a single-page web app
- The API we'll use (e.g., Speech to Text, an LLM, etc.) hasn't been implemented yet or costs money to use
- We want to be able to write our frontend (website) code without waiting on the server-side developers to implement the API and without spending money each time
- What should we do?

Mocking example: Web API Dependency

- Solution: make our own "fake" ("mock") implementation of the API
- For each method the API exposes, write a substitute for it that just returns some **hardcoded data** (or any other approximation)
    - Why does this work?

Mocking example: Error Handling

- Suppose we're writing some code where certain kinds of errors will occur **sporadically once deployed**, but “never” in development
  - Out of memory, disk full, network down, etc.

Mocking example: Error Handling

- Suppose we're writing some code where certain kinds of errors will occur **sporadically once deployed**, but “never” in development
  - Out of memory, disk full, network down, etc.
- We'd like to apply the same strategy: write a fake version of the function ...
  - But that sounds difficult to do manually, because many functions would be impacted
  - Example: many functions use the disk

Mocking example: Error Handling

- Strategy one: **static** (= “before running the program”) mocking
  - Move all disk access to a wrapper API, use mocking there at that one point (coin flip fake error)
  - Combines modularity/encapsulation with mocking

Mocking example: Error Handling

- Strategy one: **static** (= “before running the program”) mocking
  - Move all disk access to a wrapper API, use mocking there at that one point (coin flip fake error)
  - Combines modularity/encapsulation with mocking
- Strategy two: **dynamic** (= “while running the program”) mocking
  - While the program is executing, have it **rewrite itself** and replace its existing code with fake or mocked versions
  - this approach is common but has serious downsides, so let’s explore it in a little more detail

Dynamic mocking

- Some languages provide **dynamic mocking libraries** that allow you to substitute objects and functions at runtime

Dynamic mocking

- Some languages provide **dynamic mocking libraries** that allow you to substitute objects and functions at runtime
  - For one test, we could use a mocking library to force another line of code inside our target function to throw an exception when reached

Dynamic mocking

- Some languages provide **dynamic mocking libraries** that allow you to substitute objects and functions at runtime
  - For one test, we could use a mocking library to force another line of code inside our target function to throw an exception when reached
- This feature is available in modern dynamic languages with reflection (Python, Java, etc.)
  - the Jest library used by Covey.Town supports this

Dynamic mocking library uses

- Track how many times a function was called and/or with what arguments ("***spying***")
    - How would you do this with dynamic mocking?

Dynamic mocking library uses

- Track how many times a function was called and/or with what arguments ("***spying***")
  - How would you do this with dynamic mocking?
- Add or remove side effects
  - Exceptions are considered a side effect by mocking libraries

Dynamic mocking library uses

- Track how many times a function was called and/or with what arguments ("***spying***")
  - How would you do this with dynamic mocking?
- Add or remove side effects
  - Exceptions are considered a side effect by mocking libraries
- Test locking in multithreaded code
  - e.g., force a thread to stall after acquiring a lock

Dynamic mocking library disadvantages

Dynamic mocking library disadvantages

- Test cases with dynamic mocking can be **very fragile**
  - What if someone moves or removes the call to the operation you mocked?

Dynamic mocking library disadvantages

- Test cases with dynamic mocking can be **very fragile**
  - What if someone moves or removes the call to the operation you mocked?
- Dynamic mocking **requires good integration tests**
  - If we mock dependencies, we need to be extra careful that our data structures play nicely together

Dynamic mocking library disadvantages

- Test cases with dynamic mocking can be **very fragile**
  - What if someone moves or removes the call to the operation you mocked?
- Dynamic mocking **requires good integration tests**
  - If we mock dependencies, we need to be extra careful that our data structures play nicely together
- Dynamic mocking libraries have a **learning curve**
  - Many language-specific caveats, based on the implementation of the library
  - Error messages are often cryptic (modified program)

Kinds of tests

We'll discuss the following important kinds of tests:

- **unit** tests
- **integration** tests
  - with a discussion of **mocking**
- **regression** tests

Kinds of tests: regression tests

Definition: a ***regression test*** tests that the system no longer suffers from a specific bug

Kinds of tests: regression tests

Definition: a ***regression test*** tests that the system no longer suffers from a specific bug

- prevents old bugs from being **reintroduced**
    - by you or someone else

Kinds of tests: regression tests

Definition: a ***regression test*** tests that the system no longer suffers from a specific bug

- prevents old bugs from being **reintroduced**
  - by you or someone else
- theory: **monotonically increasing** software quality

Kinds of tests: regression tests

Definition: a ***regression test*** tests that the system no longer suffers from a specific bug

- prevents old bugs from being **reintroduced**
  - by you or someone else
- theory: **monotonically increasing** software quality
- **best practice**: when you fix a bug, add a test that specifically exposes that bug
  - that test is a regression test

How to use tests

How to use tests

- as **acceptance criteria**
  - for a feature or bug-fix: ***test driven development***

How to use tests

- as **acceptance criteria**
  - for a feature or bug-fix: ***test driven development***
  - or for a customer accepting the work is done:
    - “if these tests pass, we agree the project is finished”

How to use tests

- as **acceptance criteria**
  - for a feature or bug-fix: ***test driven development***
  - or for a customer accepting the work is done:
    - “if these tests pass, we agree the project is finished”
- to **prevent** the recurrence of **past mistakes**
  - ***regression testing***

How to use tests

- as **acceptance criteria**
  - for a feature or bug-fix: ***test driven development***
  - or for a customer accepting the work is done:
    - “if these tests pass, we agree the project is finished”
- to **prevent** the recurrence of **past mistakes**
  - ***regression testing***
- as a **gatekeeper** to prevent breaking changes to the system
  - ***continuous integration***

Test driven development

Definition: ***test driven development*** (TDD) is a software development process that relies on the repetition of a very short development cycle: requirements are turned into very specific test cases, then the software is improved so that the tests pass.

Test driven development

Definition: ***test driven development*** (TDD) is a software development process that relies on the repetition of a very short development cycle: requirements are turned into very specific test cases, then the software is improved so that the tests pass.

- **key idea**: using TDD **guarantees** that you have a test for each line of code that you write

Test driven development

Definition: ***test driven development*** (TDD) is a software development process that relies on the repetition of a very short development cycle: requirements are turned into very specific test cases, then the software is improved so that the tests pass.

- **key idea**: using TDD **guarantees** that you have a test for each line of code that you write
- research shows that TDD **dramatically improves** software quality (as measured by defect density)
  - implication: **always use TDD** if possible

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”

requirement: the test must **fail** when first written!

- “run your entire suite of tests and watch the new test fail”

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”

requirement: the test must **fail** when first written!

- “run your entire suite of tests and watch the new test fail”
- what if your new test ***doesn’t*** fail?

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”

requirement: the test must **fail** when first written!

- “run your entire suite of tests and watch the new test fail”
- what if your new test ***doesn’t*** fail?
    - actually a very common problem!
    - when reporting a bug, this is why you should try to provide a failing test case

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”
2. write the test and **observe** the test failure

Test driven development: steps

1. "think of a test that will **force** you t
   production code"
2. write the test and **observe** the test failure

Common mistake: don't actually run the tests, just assume that your test will fail

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”
2. write the test and **observe** the test failure
3. write **just enough** code to get the test to pass

Test driven development: steps

1. “think of a test that will **force** you t
   production code”
2. write the test and **observe** the test failure
3. write **just enough** code to get the test to pass

> Don’t worry too much about elegance - goal in step 3 is to get back to **working code**

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”
2. write the test and **observe** the test failure
3. write **just enough** code to get the test to pass
4. **refactor** your code to improve its quality/elegance, re-running the test after each change to make sure that it still passes

Test driven development: steps

1. "think of a test that will **force** you to add the next few lines of production code"
2. write the test and **observe** the test failure
3. write **just enough** code to get the test to pass
4. **refactor** your code to improve its quality/elegance, re-running the test after each change to make sure that it still passes
5. commit the new code **and the test**; make a PR

Test driven development: steps

1. “think of a test that will **force** you to add the next few lines of production code”
2. write the test and **observe** the test failure
3. write **just enough** code to get the test to pass
4. **refactor** your code to improve its quality/elegance, re-running the test after each change to make sure that it still passes
5. commit the new code **and the test**; make a PR
6. go back to step 1

Why does TDD improve code quality?

Why does TDD improve code quality?

- every behavior has a **regression test** immediately

Why does TDD improve code quality?

- every behavior has a **regression test** immediately
- fast **edit-test-debug cycle**

Why does TDD improve code quality?

- every behavior has a **regression test** immediately
- fast **edit-test-debug cycle**

Definition: the ***edit-test-debug cycle*** is the main loop of software development:

- edit the code
- test to make sure it works
- debug why it doesn't

Research shows that having a fast edit-test-debug cycle is critical for programmer productivity.
Advice: Try to avoid "test" steps of > 30 seconds.

Why does TDD improve code quality?

- every behavior has a **regression test** immediately
- fast **edit-test-debug cycle**

Definition: the ***edit-test-debug cycle*** is the main loop of software development:

- edit the code
- test to make sure it works
- debug why it doesn't

Research shows that having a **fast edit-test-debug cycle** is critical for programmer productivity.

Why does TDD improve code quality?

- every behavior has a **regression test** immediately
- fast **edit-test-debug cycle**

Definition: the ***edit-test-debug cycle*** is the main loop of software development:

- edit the code
- test to make sure it works
- debug why it doesn't

Research shows that having a **fast edit-test-debug cycle** is critical for programmer productivity.

Advice: Try to **avoid** "test" steps of **> 10 seconds**.

Why does TDD improve code quality?

- every behavior has a **regression test** immediately
- fast **edit-test-debug cycle**
- code is **working most of the time** (TDD and Agile are closely related: almost all Agile methodologies advocate for TDD)

Why does TDD improve code quality?

- every behavior has a **regression test** immediately
- fast **edit-test-debug cycle**
- code is **working most of the time** (TDD and Agile are closely related: almost all Agile methodologies advocate for TDD)
  - we'll come back to this in the "Process" lecture

Testing (part 1)

Today's agenda:

- Reading Quiz
- What is testing?
- How to write tests
- Different kinds of tests and how to use them
- **Continuous integration** (or: why most of your tests should be automated)

Continuous integration

A few slides ago, I mentioned that it's a good idea to avoid edit-test-debug cycles with > 10 second "test" steps

- but what if your tests **take longer** than that to run?

Continuous integration

A few slides ago, I mentioned that it's a good idea to avoid edit-test-debug cycles with > 10 second "test" steps

- but what if your tests **take longer** than that to run?
- answer: move them from the developer's machine to a **continuous integration** server

Continuous integration

Definition: ***continuous integration*** (CI) “is a software development practice where developers regularly merge their code changes into a central repository, after which automated builds and tests are run”

[https://aws.amazon.com/devops/continuous-integration/]

Continuous integration

Definition: ***continuous integration*** (CI) "is a software development practice where developers regularly merge their code changes into a central repository, after which automated builds and tests are run"

- use of CI is **practically mandatory** in industry

[https://aws.amazon.com/devops/continuous-integration/]

Continuous integration

Definition: ***continuous integration*** (CI) "is a software development practice where developers regularly merge their code changes into a central repository, after which automated builds and tests are run"

- use of CI is **practically mandatory** in industry
- **best practices**:
  - use CI for every project, even very small ones
  - all changes to a project should be gated by CI tests passing
  - run all tests (and other quality checks) automatically in CI

[https://aws.amazon.com/devops/continuous-integration/]

Continuous integration

Definition: ***continuous integration*** (CI) "is a software development practice where developers regularl[y] central repository, after which aut[o]

- use of CI is **practically mandat[e]**
- **best practices**:
  - use CI for every project, ev
  - all changes to a project sho
  - run all tests (and other quality

Advice: be very concerned about any project that:

- doesn't have a CI setup
- doesn't run all tests in CI
- lets CI builds regularly fail for long periods of time
  - a failing CI build is an **emergency**

[https://aws.amazon.com/devops/continuous-integration/]

Takeaways

- A test is an input + a comparator + an oracle
- Use strategies like partition testing when writing test cases by hand
- Different kinds of tests serve different purposes
  - understand the difference between unit, integration tests
  - regression testing prevents bugs (especially when combined with TDD + CI)
- Use TDD + CI to improve software quality
- Next time: test suite quality and mutation testing