Testing

CS 346 Application Development

Why do we test?

The goal of testing is to ensure that the software that we produce meets our objectives, *specifically* when deployed into the environment where it will be used.

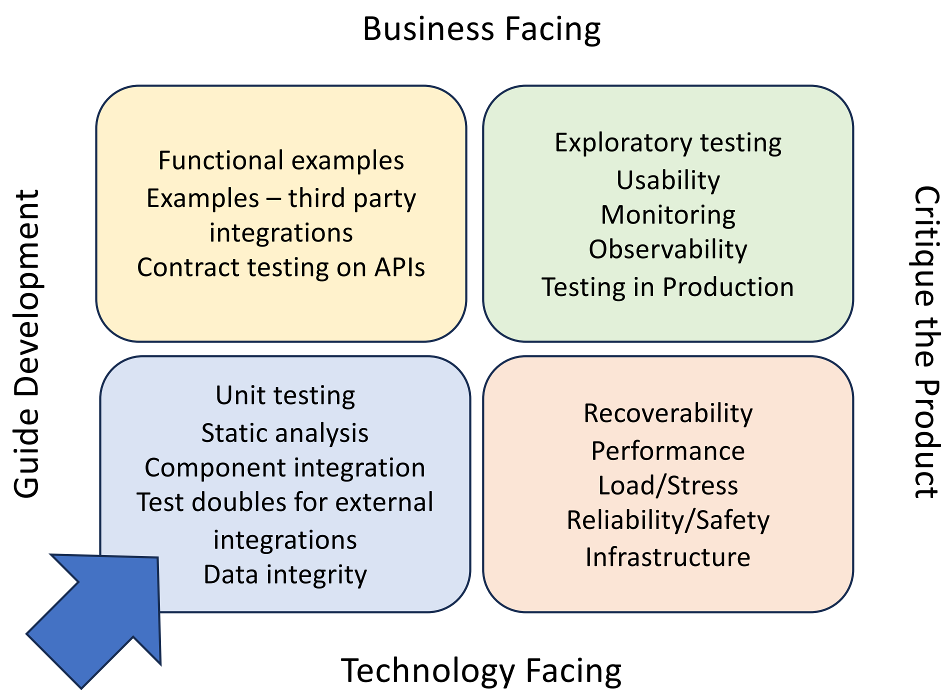
Purpose of testing?

- Find problems aka bugs and address them before shipping.
- Find design flaws and incrementally improve the product.

Benefits of testing?

- Improve confidence that you have met your goals.
- Occasionally find defects, deficiencies or design flaws from our tests.
- Produce an improved design, sometimes as a by-product of testing.

Agile Testing



The testing quadrants demonstrate different concerns. We need different types of tests for each quadrant!

Where will we focus our attention?

We will focus on the left-hand side of this matrix:
tests that benefit development. Types will include:

- **Unit tests**
  - operating at the class level; low-level interfaces.
  - Test doubles include “fake” classes - *more later*

Produce as part of a feature.
MANY of these! Cheap to produce.

- **Functional tests (aka Integration tests)**
  - classes or collections of classes that provide features.
  - check user-level functionality; end-to-end feature testing.
  - third-party integration includes databases, cloud.
- **System tests**
  - Test how features interact with one another.

Produce as part of a release.
FEW of these! Expensive to produce.

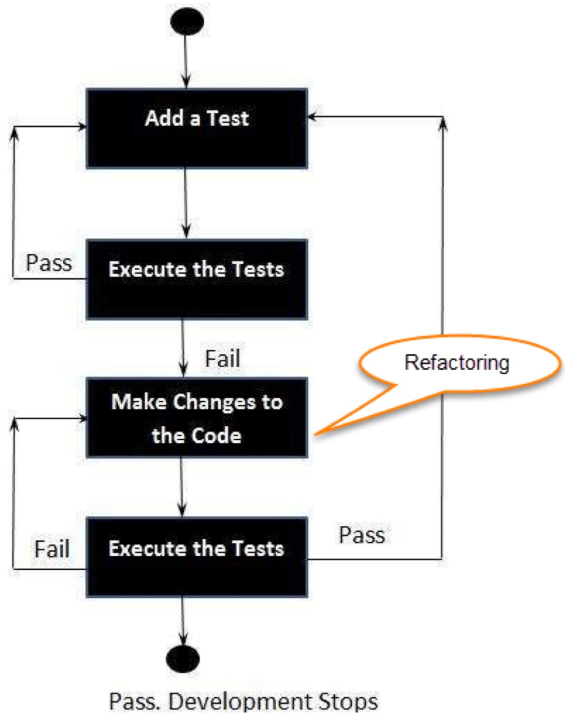
Test-Driven Development (TDD)

Promoted by Kent Beck around 2002 as an **Extreme Programming (XP) practice**.

- The basic idea is that you write tests *before* writing the corresponding implementation code.
- The test defines a contract that your code satisfies.

TDD development cycle

1. Define an interface or specification for your class or module.
2. Write a test against that interface.
3. Write the implementation code that causes the test to pass.
4. Repeat until completed.



Advantages of TDD?

Early bug detection. You are building up a set of tests *as you write code*.

- Your tests should be comprehensive so that you catch bugs *immediately*.
- By the time your implementation is complete, you have a full set of tests.

Better designs. Writing tests forces you to write clean code. e.g., improved interfaces, clean separation of concerns, cohesive classes.

- Code must be well-implemented to be testable.

Confidence to refactor. *Refactoring* is improving your code incrementally.

- To refactor, you need to verify that you haven’t “broken anything” in the process.
- TDD helps you have the confidence to refactor!

Simplicity. Code that is built-up deliberately tends to be simpler & maintainable.

Unit testing configuration

Setup the Kotlin test framework for unit testing.

Installing test dependencies

Kotlin has a cross-platform test framework.

- Similar to Junit (Java standard) but works across all platforms
- Make sure that you have these lines in your `build.gradle.kts` file.

```
dependencies {
    testImplementation(kotlin("test"))
}
tasks.test {
    useJUnitPlatform() // use Junit as the test runner when possible
}
```

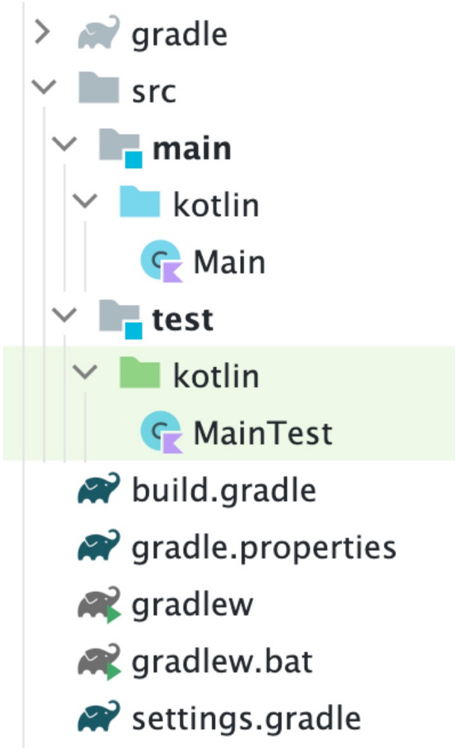
Unit tests are just functions

Unit tests are just Kotlin classes and functions that check inputs and outputs for what they are testing.

- Unit tests should be placed under `src/test/kotlin`.
- It's best practice to have one test class for each class that you want to test. e.g., classes `Main` and `MainTest`.
- Unit tests are automatically executed with `gradle build` or can be executed manually with `gradle test`.

```
$ gradle build
BUILD SUCCESSFUL in 928ms
8 actionable tasks: 8 up-to-date // this includes tests

$ gradle test
BUILD SUCCESSFUL in 775ms
3 actionable tasks: 3 up-to-date
```



A Simple Unit Test

1. Create a class to test under `src/main/kotlin`.

```
class Sample() {
    fun sum(a: Int, b: Int): Int {
        return a + b
    }
}
```

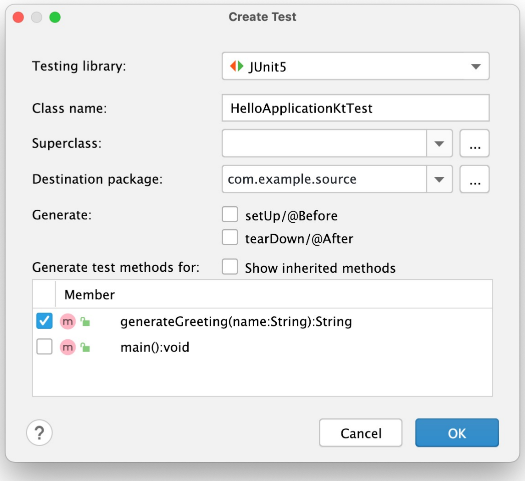
2. Create a test class under `src/test/kotlin`. Add functions as tests.

```
import kotlin.test.Test
import kotlin.test.assertEquals

internal class SampleTest {
    @Test
    fun testSum() {
        private val testSample: Sample = Sample()
        assertEquals(42, testSample.sum(40, 2))
    }
}
```

Internal means not-visible outside the file. Prevents production code from using test functions.

Running tests

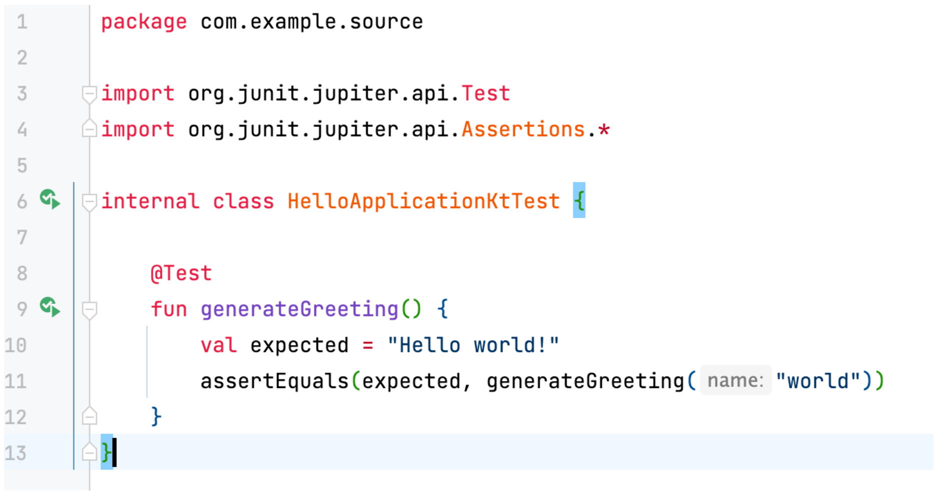


Create Test

Testing library:	JUnit5
Class name:	HelloApplicationKtTest
Superclass:	
Destination package:	com.example.source
Generate:	[ ] setUp/@Before [ ] tearDown/@After
Generate test methods for:	[ ] Show inherited methods

	Member
✓	generateGreeting(name:String):String
	main():void

Press Cmd-N to generate a new test for a selected class.



```
package com.example.source

import org.junit.jupiter.api.Test
import org.junit.jupiter.api.Assertions.*

internal class HelloApplicationKtTest {

    @Test
    fun generateGreeting() {
        val expected = "Hello world!"
        assertEquals(expected, generateGreeting( name: "world"))
    }
}
```

In the test class, you can execute a particular test by clicking the Run icon in the gutter.

Assertions

We call utility functions to assert how the function should successfully perform.

Function	Purpose
assertEquals	Provided value matches the actual value
assertNotEquals	The provided and actual values do not match
assertFalse	The given block returns false
assertTrue	The given block returns true

Test Annotations

The @Test annotation tells the compiler that this is a unit test function. The `kotlin.test` package provides annotations to mark test functions, and denote how they are managed:

Annotation	Purpose
@AfterTest	Marks a function to be invoked after each test
@BeforeTest	Marks a function to be invoked before each test
@Ignore	Mark a function to be ignored
@Test	Marks a function as a test

Writing Unit Tests

What are the characteristics of well-written tests?

Unit Test Characteristics

A unit test is a test that meets the following three requirements:

1. Verifies a single unit of behaviour,
2. Does it quickly, and
3. Does it in isolation from other tests.

Unit tests are the lowest-level tests that you can write:

- Tests should be small and quick to execute and return results.
- Each test focuses on a specific class or component, tested in isolation.
- Tests cannot have dependencies on other tests! i.e., can execute in any order.
- As an author, favour many small tests that each check a single thing over monolithic tests.

If a test exercises more than a single class, it's not a unit test.

Unit Test Composition

Every unit test should be a separate function, with the following steps:

1. Arrange:

- Setup the conditions for your test.
- Initialize variables, load data, setup any dependencies that you might need.
- Do NOT reuse anything from a different test.

2. Act:

- Execute the functionality that you want to test and capture the results.

3. Assert:

- Check that the actual and expected results match.
- Use asserts appropriately - see next page.

```
class CalcTest {
@Test
fun validPlus() {
   val input = arrayOf("1", "+" , "2")
   val results = Calc().calculate(input)}
   assertEquals(3, results)
}

@Test
fun invalidPlus() {
   val input = arrayOf("1", "+", "2")
   val results = Calc().calculate(input)
   assertNotEquals(5, results)
}


@Test
fun insufficientArguments() {
   try {
      val input = arrayOf("1", "+")
      Calc().calculate(input)
   } catch (e:Exception) {
      assertTrue(true)
   }
}
```

Test valid input conditions.
Create a unit test like this for each operation or function.

Test invalid input conditions.
Create a unit test like this for each operation or function to ensure that you handle input errors correctly. Choose representative values (or important outliers)

Special-purpose unit test to check a specific error condition.

Integration Tests

The next step; handling more complex interactions.

Integration tests

"Unit tests are great at verifying business logic, but it's not enough to check that logic in a vacuum. You have to validate how different parts of it integrate with each other and external systems: the database, the message bus, and so on." — Khorikov (2020).

- A **unit test** is a test that verifies a single unit of failure, in isolation.
- An **integration test** is a test with a broader scope.
  - It checks multiple potential units of failure.
  - **Seeks to understand the interaction between components**.
  - **Tests component *dependencies*.**

This is the primary distinction vs. unit testing.

What is a dependency?

- When you are examining a software component, we say that your component may be dependent on one or more other software entities to be able to run successfully. e.g. a library, or a different class, or a database. Each of these represents code that affects how the code being tested will execute.
- **We often call the external software component or class a dependency**. That word describes the relationship (classes dependent on one another), and the type of component (a dependency with respect to the original class).
- *A key strategy when testing is to figure out how to control these dependencies, so that you're exercising your class independently of the influence of other components.*

Dependencies

Managed vs. unmanaged dependencies. Distinction between dependencies that we control (managed), and those that may be shared (unmanaged).

- A managed dependency suggests that we directly control the state.
- e.g., A database could be single-file and used only for your application (managed) or shared among different applications (unmanaged).

Internal vs. external dependencies. Distinction between running in the context of our process (internal) or out-of-process (external).

- *External intrinsically means unmanaged (and usually untrusted)*.
- e.g., A library is internal. If statically linked, we manage its state.
- e.g., An external library is external and probably unmanaged.

An unmanaged dependency cannot be tested directly.

- How can we trust that its state isn't changing independently?

Test Doubles (aka Mocks)

How do you test unmanaged dependencies?

1. You test to the interface and not the concretion.
2. You can also create a “mock” or a test double that substitutes for the concretion in testing.

A **mock** is a fake object that holds the expected behaviour of a real object but without any genuine implementation. For example, we can have a mock File System that would report a file as saved but would not actually modify the underlying file system.

Mocks, or test doubles, remove dependencies and allow for controlled testing. They are extremely useful!

Mocking & Dependency Injection

Dependency injection is the practice of supplying dependencies to an object in its argument list instead of allowing the object to create them itself.

Problem: Here’s a class that manages the underlying database connection. How do you test it separately from the database?

```
class Persistence {
  val repo = UserRepository() // Create the required repo instance

  fun saveUserProfile(val user: User) {
    repo.save(user)
  }
}

val persist = Persistence()
persist.saveUserProfile(user) // saves using the real hard-coded database
```

Example: Mock DB

Solution: change the Persistence class so that we pass in the dependency. This allows us to control how the repository is created and even replace it with a mock for testing.

```
class Persistence(val repo: IUserRepository) {   // pass in the repo
    fun saveUserProfile(val user: User) {
    repo.save(user)
  }
}
class MockRepo : IUserRepository {
    // body with functions that mirror how the repo would work
    // but simpler/fake implementation
}

val mock = MockRepo()
val persist = Persistance(mock)
persist.saveUserProfile(user)   // save using the mock database
```

User Interface Testing

Considerations when writing unit tests for desktop applications.

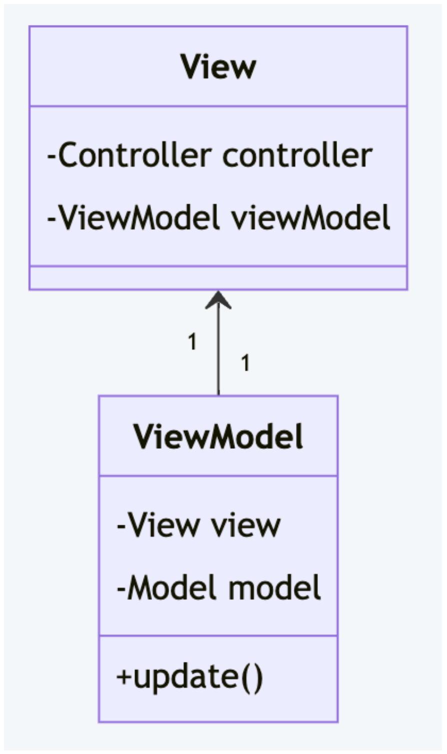
Adding GUI testing

Guidelines from earlier still apply.

- `Domain`, `Model`, `Service` already covered.

What do we need to add to our tests?

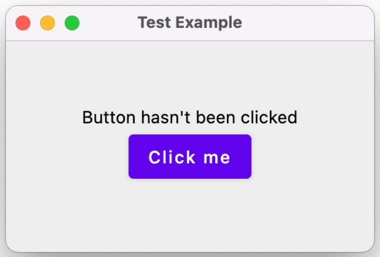
- Testing interaction & output (View)
- Test UI state (ViewModel)



```
fun main() {
    application {
        Window(title = "Test Example", onCloseRequest = ::exitApplication)
         {
            var text by remember { mutableStateOf("Button hasn't been clicked") }

            Column(
                horizontalAlignment = Alignment.CenterHorizontally,
                verticalArrangement = Arrangement.Center,
                modifier = Modifier.fillMaxSize().padding(10.dp)
            ) {
                Text(
                    text = text,
                )
                Button(
                    onClick = { text = "Clicked!" },
                ) {
                    Text("Click me")
                }
            }
        }
    }
}
```

We want to test this interaction i.e. click on the button and see how the UI changes.



lectures/compose -> run **UI Test** main method

```
class ExampleTest {
    @get:Rule
    val rule = createComposeRule()

    @Test
    fun myTest(){
          rule.setContent {
            var text by remember { mutableStateOf("Button hasn't been clicked") }

            Column(
                horizontalAlignment = Alignment.CenterHorizontally,
                verticalArrangement = Arrangement.Center,
                modifier = Modifier.fillMaxSize().padding(10.dp).testTag("column") // tag
            )
            {
                Text(
                    text = text,
                    modifier = Modifier.testTag("text") // tag
                )
                Button(
                    onClick = { text = "Clicked!" },
                    modifier = Modifier.testTag("button") // tag
                ) {
                    Text("Click me")
                }
            }
        }

        // Tests the declared UI with assertions and actions of the JUnit-based testing API
        rule.onNodeWithTag("text").assertTextEquals("Button hasn't been clicked")
        rule.onNodeWithTag("button").performClick()
        rule.onNodeWithTag("text").assertTextEquals("Clicked!")
    }
}
```

$\}$ Test actions performed in-order.

What actions can you test?

rule

- onNodeWithTag
- onNodeWithText
- onNode
- onAllNodes
- onRoot

- performClick()
- performKeyPress()
- performKeyInput ()
- performMouseInput ()
- performMouseMultiModal ()
- performScrollTo()
- performFirstLinkClick()

- assertExists
- assertDoesNotExist
- assertDeactivated
- assertTextEquals
- assertTextContains
- assertHasClickAction
- assertIsDisplayed
- assertIsEnabled
- assertHasFocus

References

- JetBrains. 2025. kotlin-test documentation.
- Khorikov. 2020. Unit Testing Principles, Practices, and Patterns. Manning. ISBN ISBN 978-1617296277.