Testing Spring Boot Applications Demystified

Best Practices, Common Pitfalls, and Real-World Strategies

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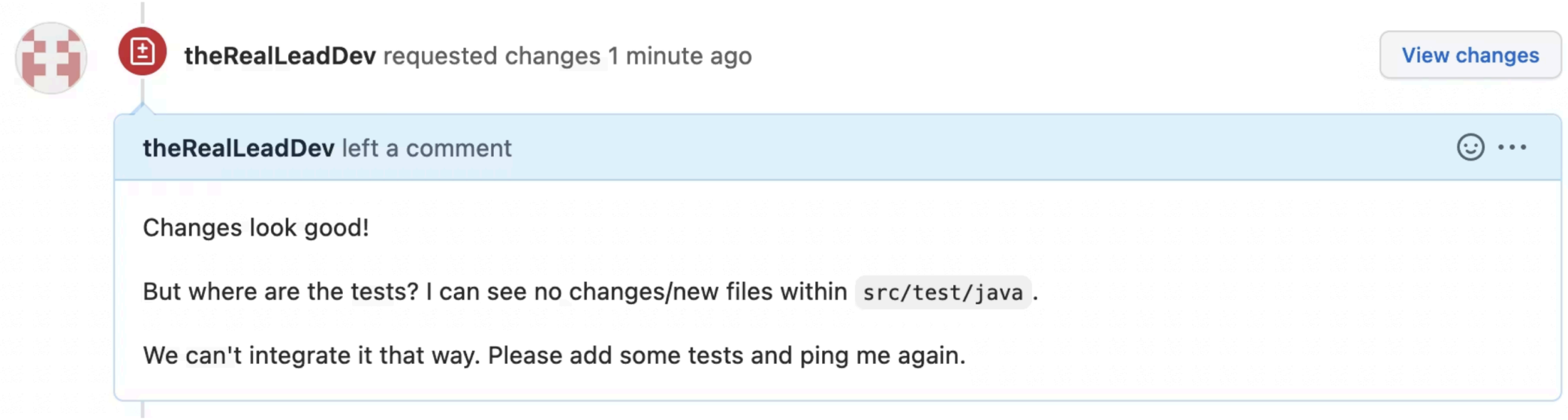
Getting Started with Testing

How It Started

Getting Used To Testing At Work



Goals For This Talk

- Lay the foundation for your Spring Boot testing success
- Introduction to Spring Boot’s excellent test support
- Showcase a mix of best practices and early pitfalls
- Convince you that testing is not an afterthought

About

- Self-employed IT consultant from Herzogenaurach, Germany (Bavaria) 🍻
- Blogging & content creation for more than five years. Since three years with a focus on testing Java and specifically Spring Boot applications 🍃
- Founder of PragmaTech GmbH - Enabling Developers to Frequently Deliver Software with More Confidence 🚤
- Enjoys writing tests 🧪
- @rieckpil on various platforms

Agenda

- Introduction
- Testing with Spring Boot
  - Spring Boot Testing 101
  - Unit Testing
  - Sliced Testing
  - Integration Testing
- Spring Boot Testing Best Practices
- Common Spring Boot Testing Pitfalls to Avoid
- Summary & Outlook

Spring Boot Testing 101

Naming Things Is Hard

Black Box Test

White Box Test

User Acceptance Tests

Smoke Tests

Load Tests

Stress Tests

Exploratory Tests

Unit Tests

Integration Tests

E2E Tests

Regression Test

Functional Test

System Tests

Performance Tests

Integrated Test

Fast Test

Mutation Tests

Contract Tests

Property-based Tests

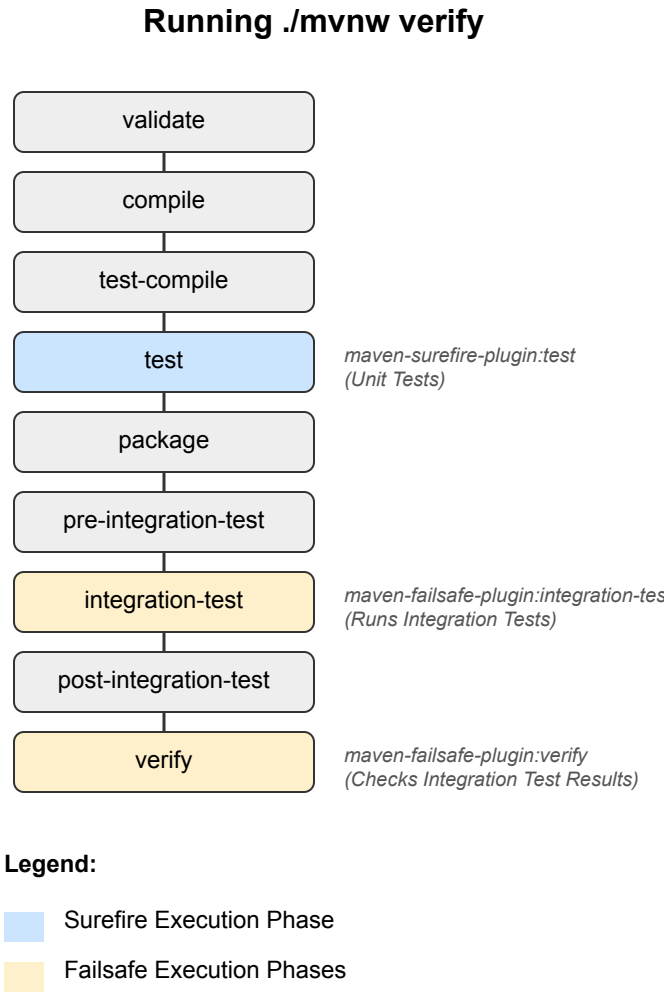
Boundary Value Testing

My Pragmatic Test Name Approach

1. **Unit Tests**: Tests that verify the functionality of a single, isolated component (like a method or class) by mocking or stubbing all external dependencies.
2. **Integration Tests**: Tests that verify interactions between two or more components work correctly together, with real implementations replacing some mocks.
3. **E2E**: Tests that validate the entire application workflow from start to finish, simulating real user scenarios across all components and external dependencies.

Maven Build Lifecycle

- Maven Surfire Plugin for unit tests: default postfix `*Test` (e.g. `CustomerTest`)
- Maven Failsafe Plugin for integration tests: default postfix `*IT` (e.g. `CheckoutIT`)
- Reason for splitting: parallelize, better grouping



Spring Boot Starter Test

- aka. "Testing Swiss Army Knife"
- Batteries-included for testing
- Dependency management for:
  - JUnit Jupiter
  - Mockito
  - AssertJ
  - Awaitility
  - etc.
- We can manually override the dependency versions

```
[INFO] +- org.springframework.boot:spring-boot-starter-test:jar:3.4.5:test
[INFO] |  +- org.springframework.boot:spring-boot-test:jar:3.4.5:test
[INFO] |  +- org.springframework.boot:spring-boot-test-autoconfigure:jar:3.4.5:test
[INFO] |  +- com.jayway.jsonpath:json-path:jar:2.9.0:test
[INFO] |  +- jakarta.xml.bind:jakarta.xml.bind-api:jar:4.0.2:test
[INFO] |  |  \- jakarta.activation:jakarta.activation-api:jar:2.1.3:test
[INFO] |  +- net.minidev:json-smart:jar:2.5.2:test
[INFO] |  |  \- net.minidev:accessors-smart:jar:2.5.2:test
[INFO] |  |     \- org.ow2.asm:asm:jar:9.7.1:test
[INFO] |  +- org.assertj:assertj-core:jar:3.26.3:test
[INFO] |  |  \- net.bytebuddy:byte-buddy:jar:1.15.11:test
[INFO] |  +- org.awaitility:awaitility:jar:4.3.0:test
[INFO] |  +- org.hamcrest:hamcrest:jar:2.2:test
[INFO] |  +- org.junit.jupiter:junit-jupiter:jar:5.11.4:test
[INFO] |  |  +- org.junit.jupiter:junit-jupiter-api:jar:5.11.4:test
[INFO] |  |  |  +- org.junit.platform:junit-platform-commons:jar:1.11.4:test
[INFO] |  |  |  \- org.apiguardian:apiguardian-api:jar:1.1.2:test
[INFO] |  |  +- org.junit.jupiter:junit-jupiter-params:jar:5.11.4:test
[INFO] |  |  \- org.junit.jupiter:junit-jupiter-engine:jar:5.11.4:test
[INFO] |  |     \- org.junit.platform:junit-platform-engine:jar:1.11.4:test
[INFO] |  +- org.mockito:mockito-core:jar:5.17.0:test
[INFO] |  |  +- net.bytebuddy:byte-buddy-agent:jar:1.15.11:test
[INFO] |  |  \- org.objenesis:objenesis:jar:3.3:test
[INFO] |  +- org.mockito:mockito-junit-jupiter:jar:5.17.0:test
[INFO] |  +- org.skyscreamer:jsonassert:jar:1.5.3:test
[INFO] |  |  \- com.vaadin.external.google:android-json:jar:0.0.20131108.vaadin1:test
[INFO] |  +- org.springframework:spring-core:jar:6.2.6:compile
[INFO] |  |  \- org.springframework:spring-jcl:jar:6.2.6:compile
[INFO] |  +- org.springframework:spring-test:jar:6.2.6:test
[INFO] |  \- org.xmlunit:xmlunit-core:jar:2.10.0:test
```

Unit Testing with Spring Boot

- Provide collaborators from outside (dependency injection) -> no `new` inside your code
- Develop small, single responsibility classes
- Test only the public API of your class
- Verify behavior not implementation details

Avoid Static Method Access

```
@Service
public class BirthdayService {

  public boolean isTodayBirthday(LocalDate birthday) {
    LocalDate today = LocalDate.now();

    return today.getMonth() == birthday.getMonth()
      && today.getDayOfMonth() == birthday.getDayOfMonth();
  }
}
```

Better Alternative

```
@Service
public class BirthdayServiceWithClock {

  private final Clock clock;

  public BirthdayServiceWithClock(Clock clock) {
    this.clock = clock;
  }

  public boolean isTodayBirthday(LocalDate birthday) {
    LocalDate today = LocalDate.now(clock);

    return today.getMonth() == birthday.getMonth()
      && today.getDayOfMonth() == birthday.getDayOfMonth();
  }
}
```

```java
@Test
void shouldReturnTrueWhenTodayIsBirthday() {
  // Arrange
  LocalDate fixedDate = LocalDate.of(2025, 5, 15);
  Clock fixedClock = Clock.fixed(
    fixedDate.atStartOfDay(ZONE_ID).toInstant(),
    ZONE_ID
  );

  BirthdayServiceWithClock cut = new BirthdayServiceWithClock(fixedClock);
  LocalDate birthday = LocalDate.of(1990, 5, 15); // Same month and day

  // Act
  boolean result = cut.isTodayBirthday(birthday);

  // Assert
  assertThat(result).isTrue();
}
```

Check Your Imports

- Nothing Spring-related here
- Rely only on JUnit, Mockito and an assertion library

```
import org.junit.jupiter.api.DisplayName;
import org.junit.jupiter.api.Nested;
import org.junit.jupiter.api.Test;
import org.junit.jupiter.api.extension.ExtendWith;
import org.junit.jupiter.params.ParameterizedTest;
import org.junit.jupiter.params.provider.CsvSource;
import org.mockito.Mock;
import org.mockito.junit.jupiter.MockitoExtension;

import static org.assertj.core.api.Assertions.assertThat;
```

Unify Test Structure

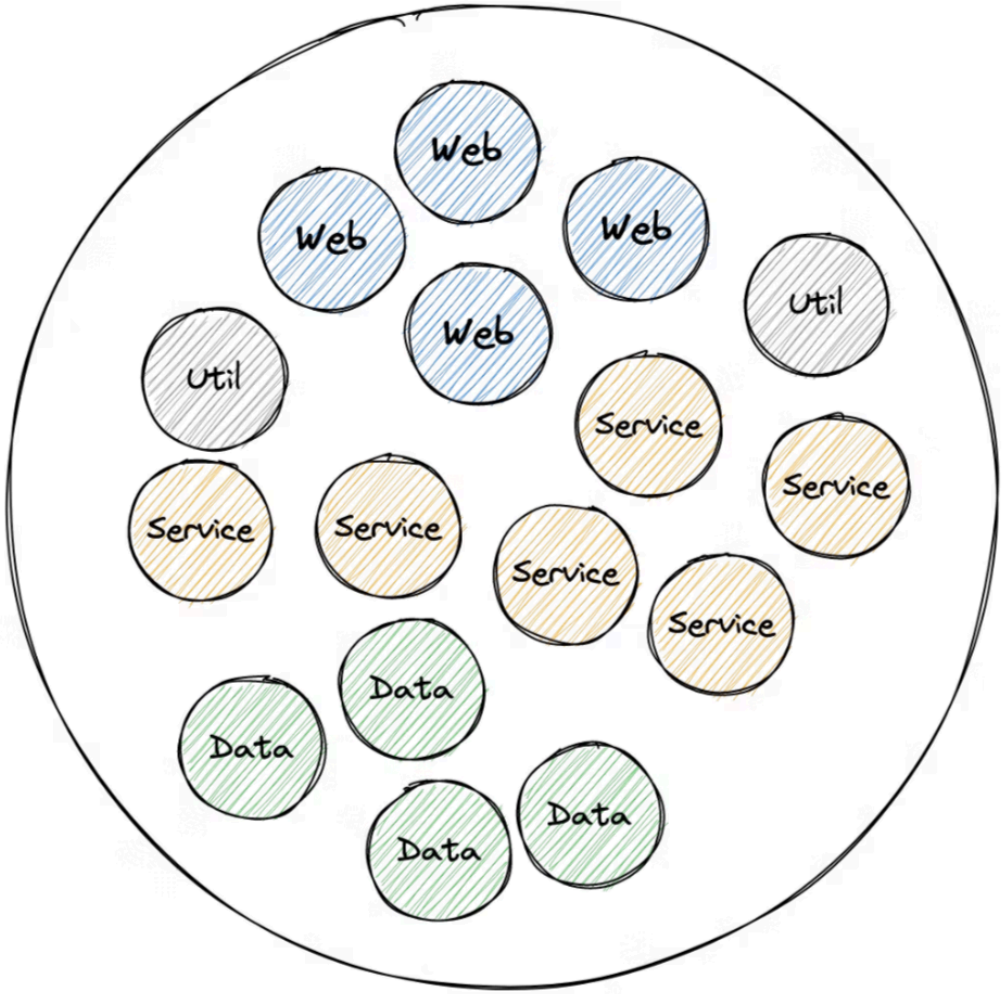
- Use a consistent test method naming: givenWhenThen, shouldWhen, etc.
- Structure test for the Arrange/Act/Assert test setup

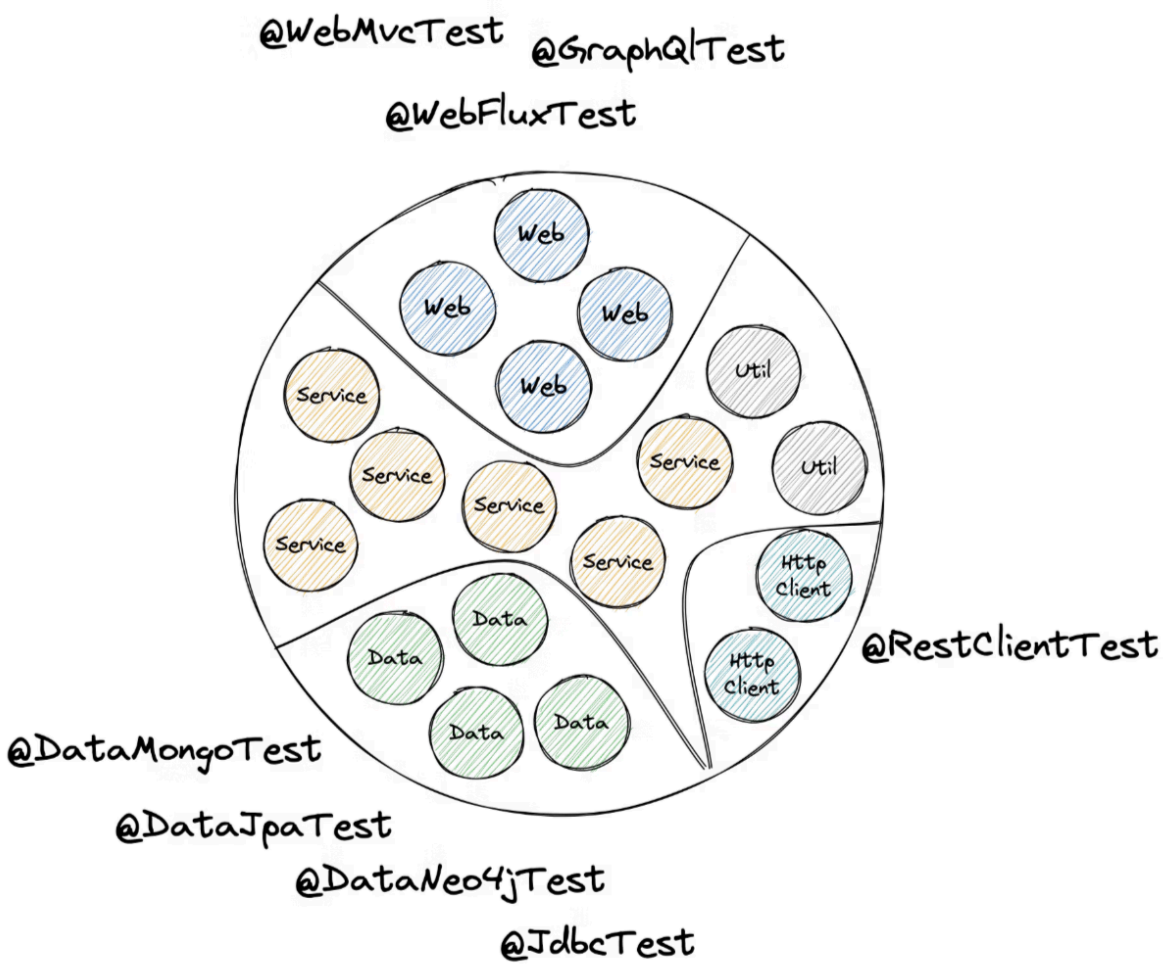
```
@Test
void should_When_() {

  // Arrange
  // ... setting up objects, data, collaborators, etc.

  // Act
  // ... performing the action to be tested on the class under test

  // Assert
  // ... verifying the expected outcome
}
```

Unit Testing Has Limits

- Unit test comes to break when e.g. controller
- Request Mapping: Does /api/users/{id} actually resolve to your method?
- Status Codes: Will a bad request return a 400 or an accidental 200?
- Headers: Are you setting Content-Type or custom headers correctly?
- Security: Is your @PreAuthorize rule enforced?

Sliced Testing with Spring Boot


Web
Web
Web
Web
Util
Util
Service
Service
Service
Service
Service
Service
Data
Data
Data
Data


@WebMvcTest
@GraphQlTest
@WebFluxTest
Web
Web
Web
Web
Service
Service
Service
Service
Service
Service
Util
Util
Http Client
Http Client
Data
Data
Data
Data
@RestClientTest
@DataMongoTest
@DataJpaTest
@DataNeo4jTest
@JdbcTest

Slicing Example: @WebMvcTest

- For some application parts it will become not beneficial
- best use cases web layer: show how we don't get far with a plain unit test -> validation, security, status code, mapping
- Same is true for DataJapTest
- There are more slices available
- You can write your own slice
- See `WebMvcTypeExcludeFilter`

@DataCouchbaseTest

@DataLdapTest

@RestClientTest

@JsonTest

@JooqTest

@WebFluxTest

@DataRedisTest

@WebMvcTest

@DataMongoTest

@DataCassandraTest

@GraphQlTest

@DataNeo4jTest

@WriteYourOwn*

@DataJpaTest

@SqsTest

@JdbcTest

@DataElasticsearchTest

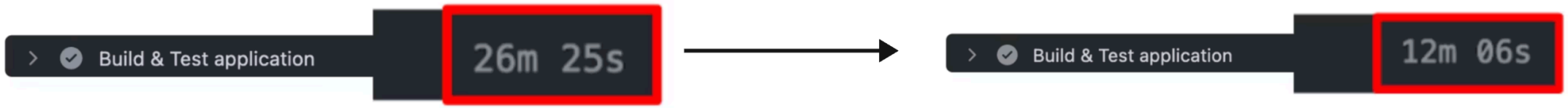
Integration Testing

- Start everything up
- BUto how? Testcontainers to the resuce
- Difference with PORT to start tomcat or not
- Difference between MockMvc and WebTestClient!
- Context Caching!
- Tips to make the most of context caching
    - avoid many different context setups
    - avoid @DirtiesContext
    - Measure the time it takes to start the context

Context Caching

- Part of Spring Test (automatically part of every Spring Boot project via `spring-boot-starter-test`)
- Spring TestContext Framework: caches an already started Spring context for later reuse
- Configurable cache size (default is 32) with LRU (least recently used) strategy

Speed up your build:

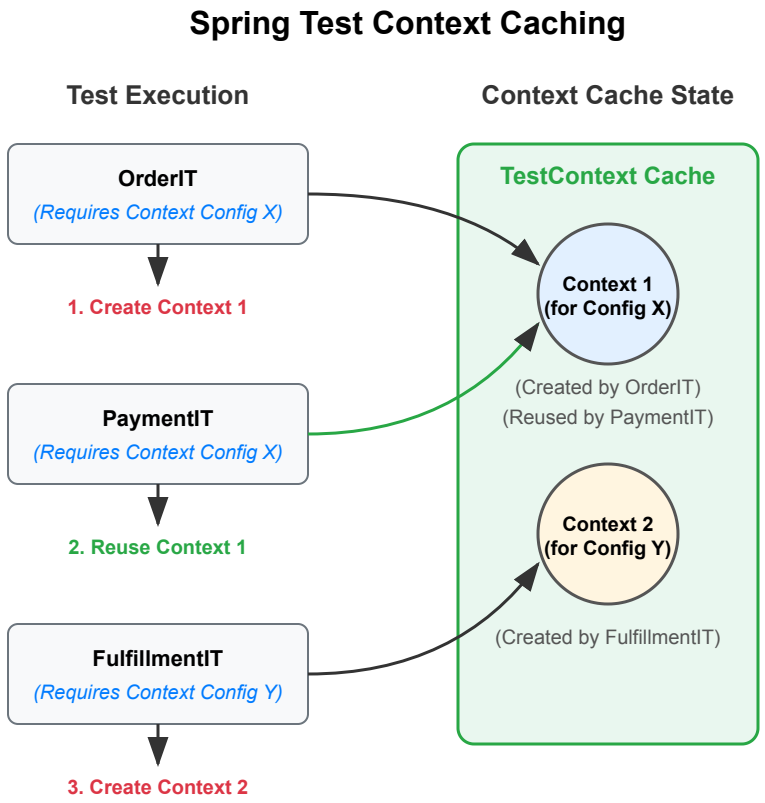


How the Cache Key is Built

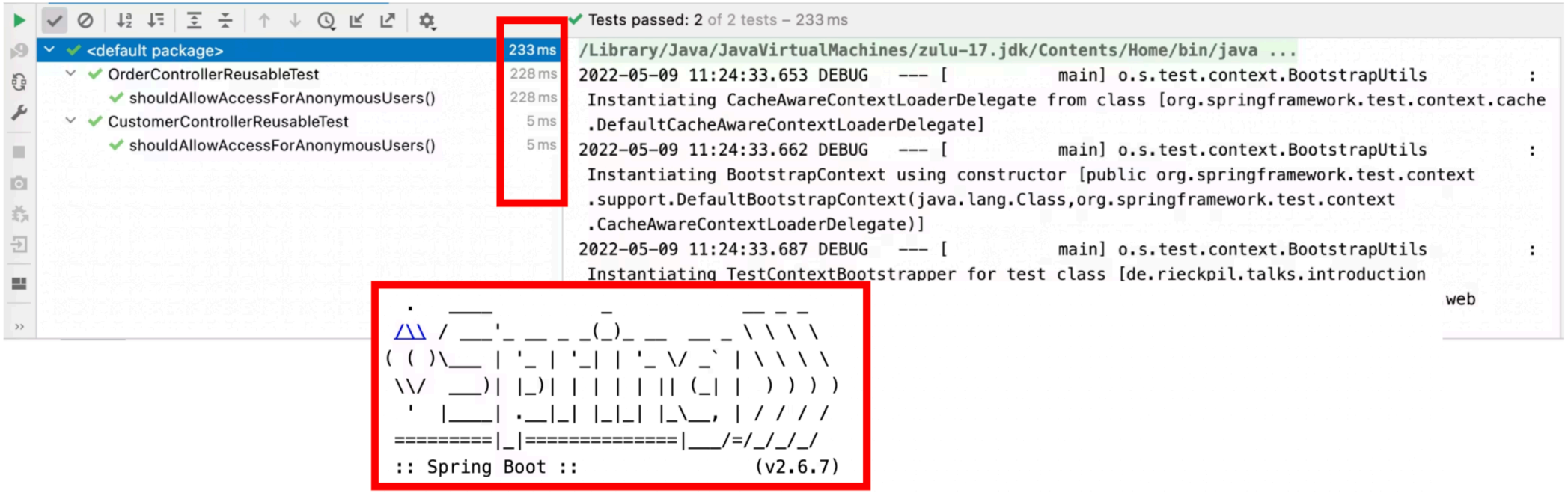
This goes into the cache key (`MergedContextConfiguration`):

- activeProfiles (`@ActiveProfiles`)
- contextInitializersClasses (`@ContextConfiguration`)
- propertySourceLocations (`@TestPropertySource`)
- propertySourceProperties (`@TestPropertySource`)
- contextCustomizer (`@MockitoBean` , `@MockBean` , `@DynamicPropertySource` , ...)

Caching Is King



Identify Context Restarts



Investigate the Logs

```
<logger name="org.springframework.test.context" level="TRACE" />
```

```
2022-05-05 14:27:38.136 DEBUG 42500 --- [           main] org.springframework.test.context.cache   : Spring test
 ApplicationContext cache statistics: [DefaultContextCache@68e62b3b size = 1, maxSize = 32, parentContextCount = 0,
 hitCount = 11, missCount = 1]
2022-05-05 14:27:38.136 DEBUG 42500 --- [           main] tractDirtiesContextTestExecutionListener : After test class:
 context [DefaultTestContext@325bb9a6 testClass = ApplicationIT, testInstance = [null], testMethod = [null], testException
  = [null], mergedContextConfiguration = [WebMergedContextConfiguration@1d12b024 testClass = ApplicationIT, locations =
 '{}', classes = '{class de.rieckpil.talks.Application}', contextInitializerClasses = '[]', activeProfiles = '{}',
 propertySourceLocations = '{}', propertySourceProperties = '{org.springframework.boot.test.context
 .SpringBootTestContextBootstrapper=true, server.port=0}', contextCustomizers = set[org.springframework.boot.test.context
 .filter.ExcludeFilterContextCustomizer@5215cd9a, org.springframework.boot.test.json
 .DuplicateJsonObjectContextCustomizerFactory$DuplicateJsonObjectContextCustomizer@9257031, org.springframework.boot.test
```

Spot the issues for Context Caching

```java
@DirtiesContext
@Testcontainers
@ActiveProfiles("integration-test")
@SpringBootTest(webEnvironment = SpringBootTest.WebEnvironment.RANDOM_PORT)
abstract class AbstractIntegrationTest {
```

What's "bad" for context caching here?

```java
@ActiveProfiles("integration-test")
@Import(SomeTestConfiguration.class)
@ContextConfiguration(initializers = CustomInitializer.class)
@SpringBootTest(properties = {"features.login-enabled=true", "custom.message=duke42"})
class ShowcaseIT {

  @MockBean
  private OrderService orderService;

  @SpyBean
  private CustomerService customerService;

  @Test
  void shouldInitializeContext(@Autowired ApplicationContext applicationContext) {
    assertThat(applicationContext)
            .isNotNull();
  }
}
```

Make the Most of the Caching Feature

- Avoid `@DirtiesContext` when possible, especially at `AbstractIntegrationTest` classes
- Understand how the cache key is built
- Monitor and investigate the context restarts
- Align the number of unique context configurations for your test suite

Spring Boot Testing Best Practices

Best Practice 1: Test Parallelization

Goal: Reduce build time and get faster feedback

Requirements:

- No shared state
- No dependency between tests and their execution order
- No mutation of global state

Two ways to achieve this:

- Fork a new JVM with Surefire/Failsafe and let it run in parallel -> more resources but isolated execution
- Use JUnit Jupiter's parallelization mode and let it run in the same JVM with multiple threads

Java Test Parallelization Options

Maven Surefire Fork-Based

(Multiple JVMs)

JVM Fork 1

- Test Class A
- Test Class B
- Test Class C

JVM Fork 2

- Test Class D
- Test Class E
- Test Class F

Maven (forkCount) Features:

- Each fork is a separate JVM process
- Isolated memory spaces
- Higher memory overhead
- High isolation (one DB per fork)
- Configuration: forkCount, reuseForks

JUnit Jupiter Thread-Based

(Single JVM)

Single JVM

Thread Pool

Thread 1	Thread 2
Test Method A1	Test Method A2
Test Method B1	Test Method B2
Test Class C	Test Class D

JUnit Jupiter Features:

- Uses threads within a single JVM
- Shared memory space
- Lower memory overhead
- Configuration: junit.jupiter.execution.parallel.*

Best Practice 2: Get Help from AI

- Diffblue Cover: #1 AI Agent for unit testing complex Java code at scale
- Agent vs. Assistant
- LLMs: ChatGPT, Claude, Gemini, etc.
- Claude Code
- TDD with an LLM?
- (Not AI but still useful) OpenRewrite for migrations
- Clearly define your requirements in e.g. `claude.md` or cursor rule files

Best Practice 3: Try Mutation Testing

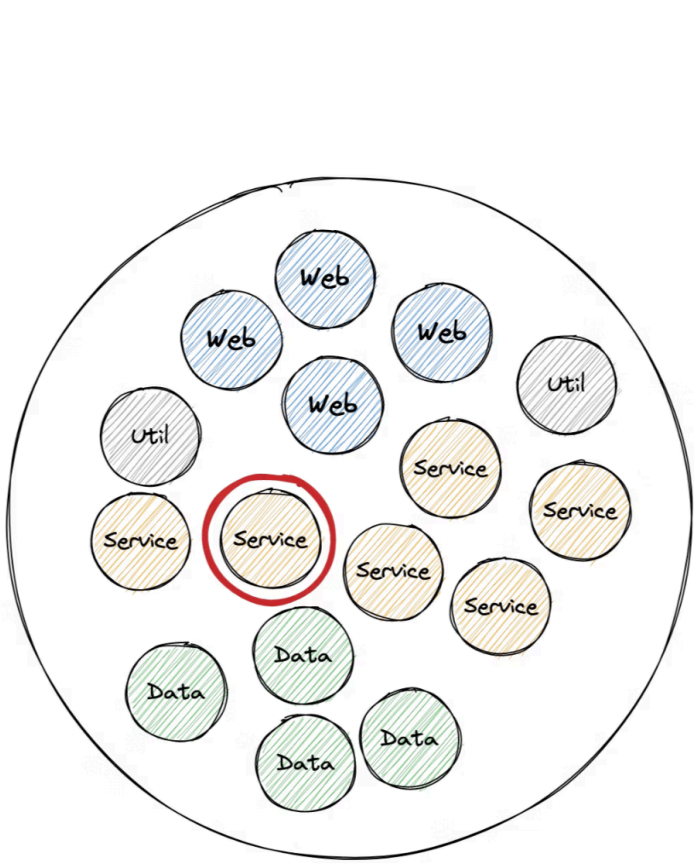
- Having high code coverage might give you a false sense of security
- Mutation Testing with PIT
- Beyond Line Coverage: Traditional tools like JaCoCo show which code runs during tests, but PIT verifies if your tests actually detect when code behaves incorrectly by introducing "mutations" to your source code.
- Quality Guarantee: PIT automatically modifies your code (changing conditionals, return values, etc.) to ensure your tests fail when they should, revealing blind spots in seemingly comprehensive test suites.
- Considerations for bigger projects: only run on the new code diffs, not on the whole codebase

Common Spring Boot Testing Pitfalls to Avoid

Testing Pitfall 1: `@SpringBootTest` Obsession

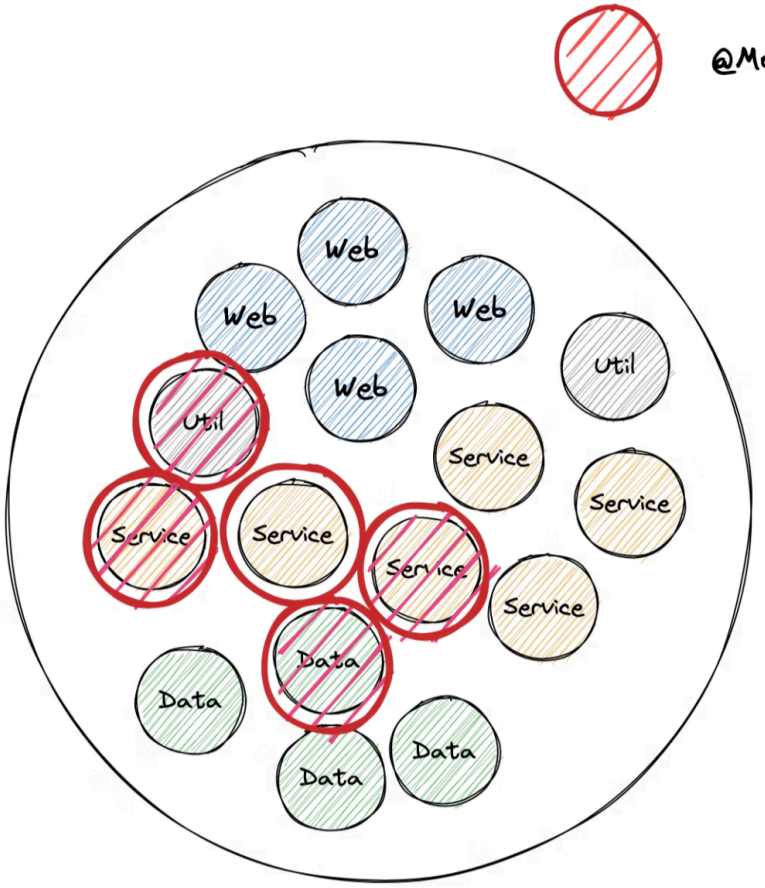
- The name could apply it's a one size fits all solution, but it isn't
- It comes with costs: starting the (entire) application context
- Useful for integration tests that verify the whole application but not for testing a single service in isolation
- Start with unit tests, see if sliced tests are applicable and only then use `@SpringBootTest`

@SpringBootTest Obsession Visualized



Testing every single class with @SpringBootTest

… results in a lot of different context setups and slows down the build



Testing Pitfall 2: @MockitoBean vs. @MockBean vs. @Mock

- `@MockBean` is a Spring Boot specific annotation that replaces a bean in the application context with a Mockito mock
- `@MockBean` is deprecated in favor of the new `@MockitoBean` annotation
- `@Mock` is a Mockito annotation, only for unit tests
- Golden Mockito Rules:
  - Do not mock types you don't own
  - Don't mock value objects
  - Don't mock everything
  - Show some love with your tests

Testing Pitfall 3: JUnit 4 vs. JUnit 5

- You can mix both versions in the same project but not in the same test class
- Browsing through the internet (aka. StackOverflow/blogs/LLMs) for solutions, you might find test setups that are still for JUnit 4
- Easily import the wrong `@Test` and you end up wasting one hour because the Spring context does not work as expected

JUnit 4	JUnit 5
@Test from org.junit	@Test from org.junit.jupiter.api
@RunWith	@ExtendWith/@RegisterExtension
@ClassRule/@Rule	-
@Before	@BeforeEach
@Ignore	@Disabled
@Category	@Tag

Summary & Outlook

- Spring Boot applications come with batteries-included for testing
- Spring and Spring Boot provides many excellent testing features
- Mature & rich Java testing ecosystem
- Consider the context caching feature for fast builds
- Get help from AI
- Still many new features are coming: `@ServiceConnection`, Testcontainers support, Docker Compose support, more AssertJ integrations, etc.

What's Next?

- Online Course: **Testing Spring Boot Applications Masterclass** (on-demand, 12 hours, 130+ modules)
- eBook: **30 Testing Tools and Libraries Every Java Developer Must Know**
- eBook: **Stratospheric - From Zero to Production with AWS**
- Spring Boot testing workshops (in-house/remote/hybrid)
- Consulting offerings, e.g. the Test Maturity Assessment

Joyful Testing!

Reach out any time via:

- LinkedIn (Philip Riecks)
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