



Integration Testing with Docker and Testcontainers



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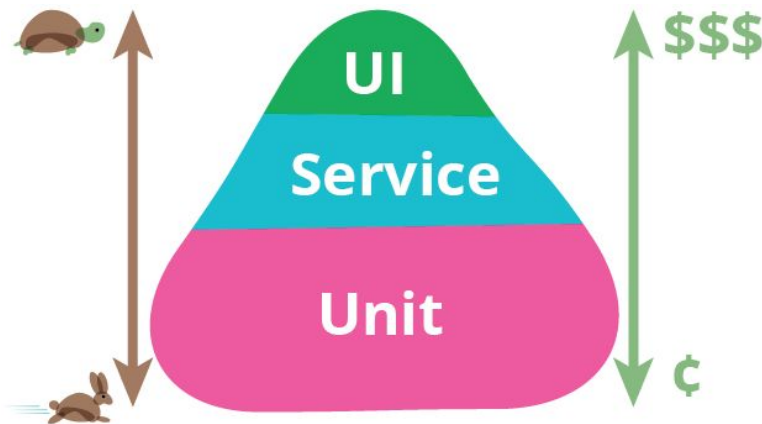
[automatedascent.com](#)

Challenges and Benefits of Integration Testing

Understanding Testcontainers and the Problems it Solves

The Testing Pyramid

Distribution, cost, and execution times per type



[Post on Martin Fowler's blog](#)



Integration Tests Are A Must

12 unit tests, 0 integration tests



DISCUSSION

Typical Problems with
Integration Testing?



Problems with Integration Testing

Integration tests interact with other parts of the system

- Reproducible environment
- Slow startup times
- Isolated environment
- Cross-platform support



What is Testcontainers?

Library for managing containers in tests with Docker

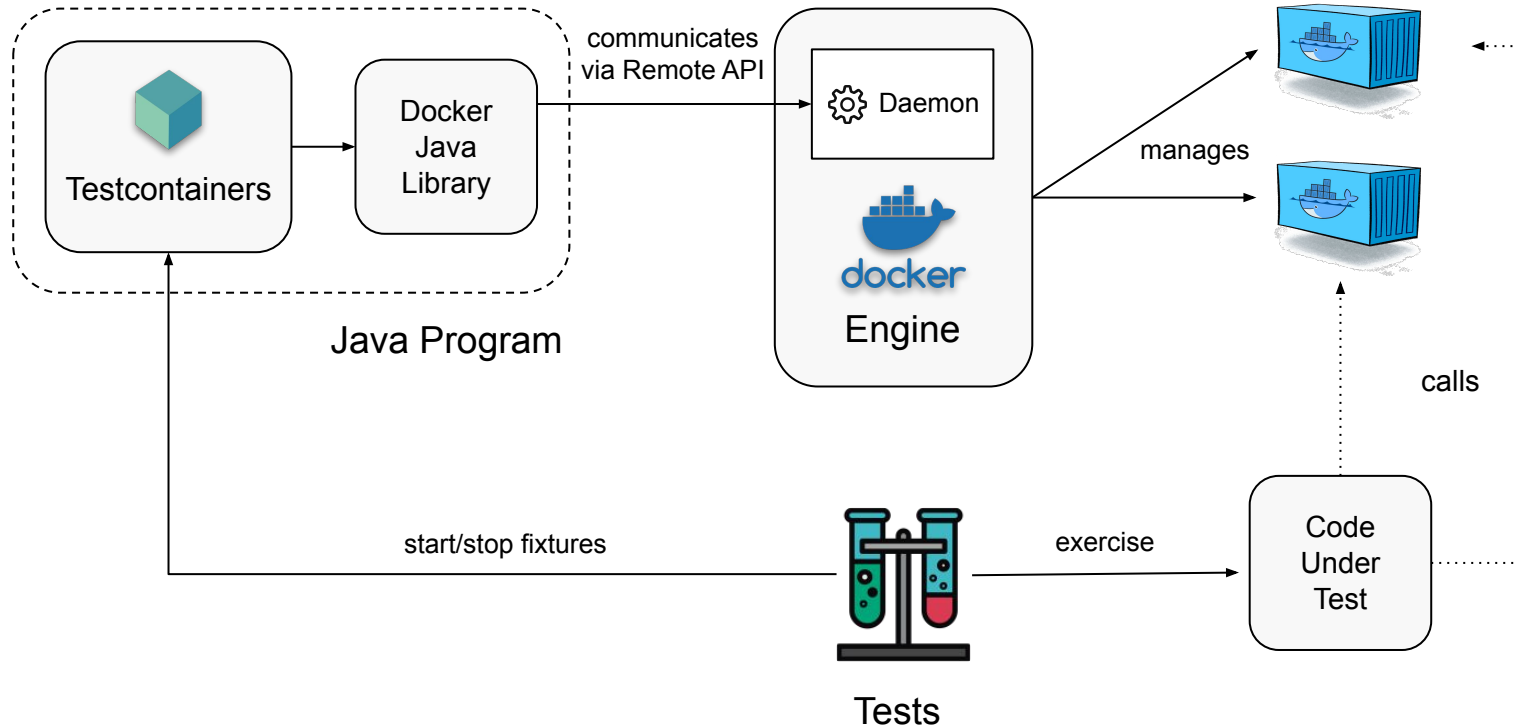
- Creates disposable Docker containers as test fixtures
- Support for different programming languages
- Most prominent implementation is based on Java/JUnit 4 & 5



[User documentation](#)



High-Level Architecture



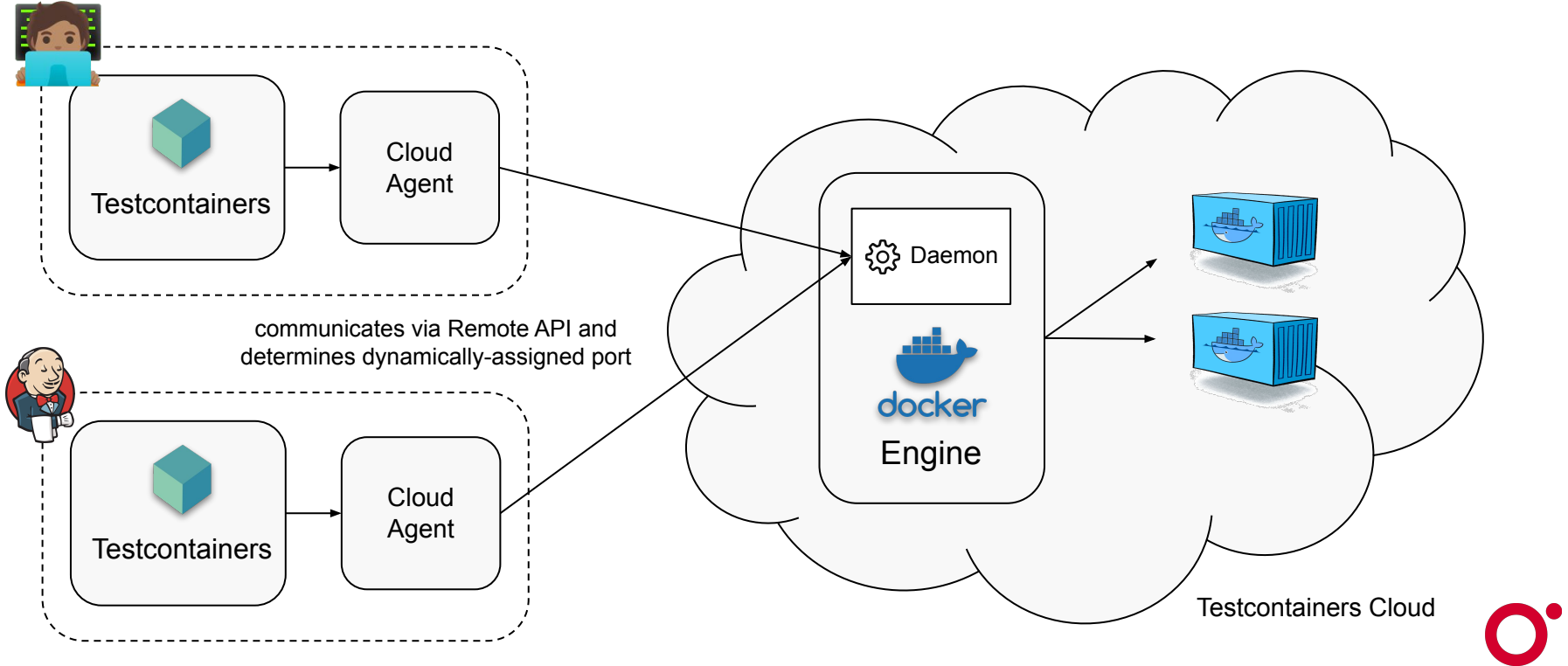
Interaction with Docker

Docker Java handles low-level communication

- Docker Engine communication via [docker-java library](#)
 - Doesn't require Docker executable to be installed
 - No support for [buildx](#) functionality
- Docker environment discovery
 - Detection of environment variables like `DOCKER_HOST`
 - Reads and uses credentials from `~/.docker/config.json`
- Automatic container cleanup via [Moby Ryuk](#) container



Testcontainers Cloud



Testcontainers Cloud

Decouples container interaction for test machine

- Cloud environment handles container creation
 - Early phase and requires signup
 - Developer or CI machine initiates container creation and interacts with it
- Almost no additional configuration needed
 - Mandatory Installation of Testcontainers Cloud agent
 - Dynamic port leasing handled by Cloud agent



Dependencies in Maven

pom.xml

```
<dependency>
  <groupId>org.testcontainers</groupId>
  <artifactId>testcontainers</artifactId>
  <version>1.16.3</version>
  <scope>test</scope>
</dependency>
```



TestContainers libraries [available on Maven Central](#)



Dependencies in Gradle

build.gradle

```
repositories {  
    mavenCentral()  
}  
  
dependencies {  
    testImplementation 'org.testcontainers:junit-jupiter:1.16.3'  
    testImplementation 'org.testcontainers:postgresql:1.16.3'  
    testRuntime 'org.postgresql:postgresql:42.2.24'  
}
```

Duplicated version definition



Using the Bill of Materials

build.gradle

```
dependencies {  
    testImplementation platform('org.testcontainers:testcontainers-bom:1.16.3')  
    testImplementation 'org.testcontainers:mysql'  
}
```

Bill of Materials (BOM)

A POM that defines compatible versions for a set of dependencies



JUnit 5 (Jupiter) Dependencies

build.gradle

```
dependencies {  
    def junitJupiterVersion = '5.4.2'  
    testImplementation "org.junit.jupiter:junit-jupiter-api:$junitJupiterVersion"  
    testImplementation "org.junit.jupiter:junit-jupiter-params:$junitJupiterVersion"  
    testRuntimeOnly "org.junit.jupiter:junit-jupiter-engine:$junitJupiterVersion"  
    testImplementation "org.testcontainers:testcontainers:1.16.3"  
    testImplementation "org.testcontainers:junit-jupiter:1.16.3"  
}
```

Requires declaration of Jupiter and Testcontainers dependencies!



Creating a Container

```
import org.testcontainers.containers.PostgreSQLContainer;
import org.testcontainers.junit.jupiter.Container;
import org.testcontainers.junit.jupiter.Testcontainers;

@Testcontainers
public class DatabaseIntegrationTest {

    @Container
    private static PostgreSQLContainer container =
        new PostgreSQLContainer("postgres:9.6.10-alpine")
            .withUsername("username")
            .withPassword("pwd")
            .withDatabaseName("todo");
}
```



Using a Private Registry

```
private static PostgreSQLContainer container =  
    new PostgreSQLContainer(  
        DockerImageName.parse(  
            "my-company-docker-local.jfrog.io/postgres:9.6.10-alpine"  
        ).asCompatibleSubstituteFor( "postgres")  
    ).withUsername( "username")  
    .withPassword( "pwd")  
    .withDatabaseName( "todo");
```

Automatic substitution for all image is possible for easy migration



Using a Remote Docker Daemon

~/docker-java.properties

```
DOCKER_HOST=tcp://DOCKER_HOST_IP:2375  
DOCKER_TLS_VERIFY=0
```

~/testcontainers.properties

```
docker.client.strategy=org.testcontainers.dockerclient.EnvironmentAndSystemPropertyClientProviderStrategy
```



Restarted vs. Shared Container

```
// Restarted for all test methods of class
```

```
@Container
```

```
private final PostgreSQLContainer container =  
    new PostgreSQLContainer("postgres:9.6.10-alpine")  
        .withUsername("username")  
        .withPassword("pwd")  
        .withDatabaseName("todo");
```

← Instance field

```
// Reused across all test methods of class
```

```
@Container
```

```
private static final PostgreSQLContainer container =  
    new PostgreSQLContainer("postgres:9.6.10-alpine")  
        .withUsername("username")  
        .withPassword("pwd")  
        .withDatabaseName("todo");
```

← Static field



Container Runtime Information

```
private CustomerRepository repository;
```

```
@BeforeEach
```

```
public void setUp() {
```

```
    String jdbcUrl = container.getJdbcUrl();
```

```
    int port = container.getFirstMappedPort();
```

```
    String username = container.getUsername();
```

```
    String password = container.getPassword();
```

```
    repository = new CustomerRepository(jdbcUrl, username,  
password);  
}
```

← Accessing container
runtime information

↑ Injecting values into code under test



EXERCISE

Using
TestContainers for
a Java-based
Project with JUnit 5



Q & A



5 mins





BREAK



Implementing Typical Integration Test Scenarios

Database Services, Multi-Services, Generic
Containers

Testing Database Services

A common challenge for business applications

- Avoid using a local or shared, remote test database with state
- Testcontainers provides a wide range of database implementations as container images
- Seed data can be populated for each test scenario
- Managing the lifecycle of such a container is not as performant as H2



Adding the Dependency

Requires Testcontainers dependency and JDBC driver

build.gradle

```
dependencies {  
    testImplementation 'org.testcontainers:mysql:1.16.3'  
    runtimeOnly 'mysql:mysql-connector-java:8.0.26'  
}
```



Database Container Object

API gives access to runtime connection information

```
import org.testcontainers.containers.MySQLContainer;  
  
@Container  
private final MySQLContainer container = new MySQLContainer();
```




```
String jdbcUrl = container.getJdbcUrl();  
String username = container.getUsername();  
String password = container.getPassword();
```



Creating Seed Data

Test cases require the database to be in a specific state

```
@Container
private final MySQLContainer container = new MySQLContainer()
    .withDatabaseName("accounting")
    .withInitScript("schema.sql");
```



```
CREATE TABLE customer(customer_id INT NOT NULL AUTO_INCREMENT,
    firstname VARCHAR(100) NOT NULL,
    lastname VARCHAR(100) NOT NULL,
    PRIMARY KEY (customer_id));
```





EXERCISE

Using a Database
Module



Testing Multiple Services

Test scenarios may involved multiple services

- Testcontainers does not restrict your test to a single container
- Communication between containers can be established by setting up a network
- Docker Compose helps with defining multi-service setups in YAML



Instantiating Multiple Containers

Simply create multiple instances

```
@Container
private final GenericContainer container1 =
    new GenericContainer("...");

@Container
private final GenericContainer container2 =
    new GenericContainer("...");
```




Shared Network Communication

Restricted to a single network per container

```
private final Network network = Network.newNetwork();

@Container
private final GenericContainer container1 =
    new GenericContainer("...").withNetwork(network);

@Container
private final GenericContainer container2 =
    new GenericContainer("...").withNetwork(network);
```



Can talk to
each other



Docker Compose Container

Launches temporary Compose client

```
@Testcontainers
public class DockerComposeIntegrationTest {

    private final static File PROJECT_DIR = new File(System.getProperty("project.dir"));
    private final static String POSTGRES_SERVICE_NAME = "database_1";
    private final static int POSTGRES_SERVICE_PORT = 5432;

    @Container
    public static DockerComposeContainer environment = createComposeContainer();

    private static DockerComposeContainer createComposeContainer() {
        return new DockerComposeContainer(new File(PROJECT_DIR,
            "src/test/resources/compose-test.yml"))
            .withExposedService(POSTGRES_SERVICE_NAME, POSTGRES_SERVICE_PORT);
    }
}
```



Example Docker Compose File

Doesn't follow Compose YAML specification 100%

compose-test.yml

```
database:
  image: "postgres:9.6.10-alpine"
  environment:
    - POSTGRES_USER=postgres
    - POSTGRES_PASSWORD=postgres
    - POSTGRES_DB=todo
elasticsearch:
  image: "elasticsearch"
```

Compose allows
defining one or more
shared networks or
use the default
network



Accessing Runtime Information

Ambassador container makes port accessible to tests

```
private static String getPostgresServiceUrl() {  
    String postgresHost =  
        environment.getServiceHost( POSTGRES_SERVICE_NAME,  
                                    POSTGRES_SERVICE_PORT );  
  
    Integer postgresPort =  
        environment.getServicePort( POSTGRES_SERVICE_NAME,  
                                    POSTGRES_SERVICE_PORT );  
  
    StringBuilder postgresServiceUrl = new StringBuilder();  
    postgresServiceUrl.append( "jdbc:postgresql://" );  
    postgresServiceUrl.append( postgresHost );  
    postgresServiceUrl.append( ":" );  
    postgresServiceUrl.append( postgresPort );  
    postgresServiceUrl.append( "/todo" );  
    return postgresServiceUrl.toString();  
}
```

← IP address the container
is listening to

← Exposed container port



Container Startup Timeout

Default to 60 secs per container but configurable

```
private final DockerComposeContainer environment =
    new DockerComposeContainer(new File(PROJECT_DIR,
        "src/test/resources/compose-test.yml"))
        .withExposedService(POSTGRES_SERVICE_NAME,
            POSTGRES_SERVICE_PORT,
            Wait.forListeningPort()
                .withStartupTimeout(Duration.ofSeconds(120)));
```

Logic can also probe for HTTP endpoint or a log message





EXERCISE

Using Multiple
Modules



Creating Generic Containers

Test scenarios may involved multiple services

- While there a specialized container implementations you may bring up any image in a container as a test fixture e.g. web servers, NoSQL database, or images built by other teams
- Testcontainers can build an image on-the-fly and use it
- Needs to provide the image at a minimum



Generic Container Usage

Use any container image you need

```
private static final DockerImageName IMAGE =  
  
DockerImageName.parse("bmuschko/java-hello-world:1.0.0");  
  
private final GenericContainer container =  
    new GenericContainer(IMAGE).withExposedPort(8080);
```



Building an Image On-The-Fly

For test cases from the end user's perspective

```
@Container
private final GenericContainer appContainer = createContainer();

private static GenericContainer createContainer() {
    return new GenericContainer(buildImageDockerfile())
        .withExposedPorts(8080)
        .waitingFor(Wait.forHttp("/actuator/health")
            .forStatusCode(200));
}

private static ImageFromDockerfile buildImageDockerfile() {
    return new ImageFromDockerfile()
        .withFileFromFile(ARCHIVE_NAME, new File(DISTRIBUTION_DIR, ARCHIVE_NAME))
        .withDockerfileFromBuilder(builder -> builder
            .from("openjdk:jre-alpine")
            .copy(ARCHIVE_NAME, "/app/" + ARCHIVE_NAME)
            .entryPoint("java", "-jar", "/app/" + ARCHIVE_NAME)
            .build());
}
```



EXERCISE

Using the Generic
Container Module



Q & A



5 mins





BREAK



Going Further

Comparing Test Frameworks, Continuous Integration, Support for Other Languages

Test Framework Integration

TestContainers supports a wide range of options

- JUnit 4 - the legacy test framework which is still widely used
- JUnit 5 (Jupiter) - the current industry standard
- Spock framework - a powerful BDD test framework that requires the use Groovy for writing tests



JUnit 4 Implementation

No superclass, annotation on container object

```
public class DatabaseIntegrationTest {  
  
    @Rule // or @ClassRule  
    public final PostgreSQLContainer container =  
        new PostgreSQLContainer("postgres:9.6.10-alpine");  
  
    @Test  
    public void testAccessDatabase() {  
        // test case implementation  
    }  
}
```



Adding the Spock Dependency

Implemented as Spock extension

build.gradle

```
dependencies {  
    testImplementation 'org.testcontainers:spock:1.16.0'  
}
```



Spock Test Implementation

Extend Specification, mark with @Testcontainers

```
@Testcontainers
class DatabaseIntegrationTest extends Specification {

    @Shared
    PostgreSQLContainer container = new PostgreSQLContainer("postgres:9.6.10-alpine");

    def "can access database"() {
        given:
            // set up scenario

        when:
            // execute scenario

        then:
            // verify assertions
    }
}
```



Continuous Integration (CI)

Trigger an automated build for every commit

- Integrates changes into master/main branch
- Fast feedback by executing the build
- Use the same build tool as on a developer machine
- Standardizes on Gradle/Maven runtime version used



The CI Product GitHub Actions

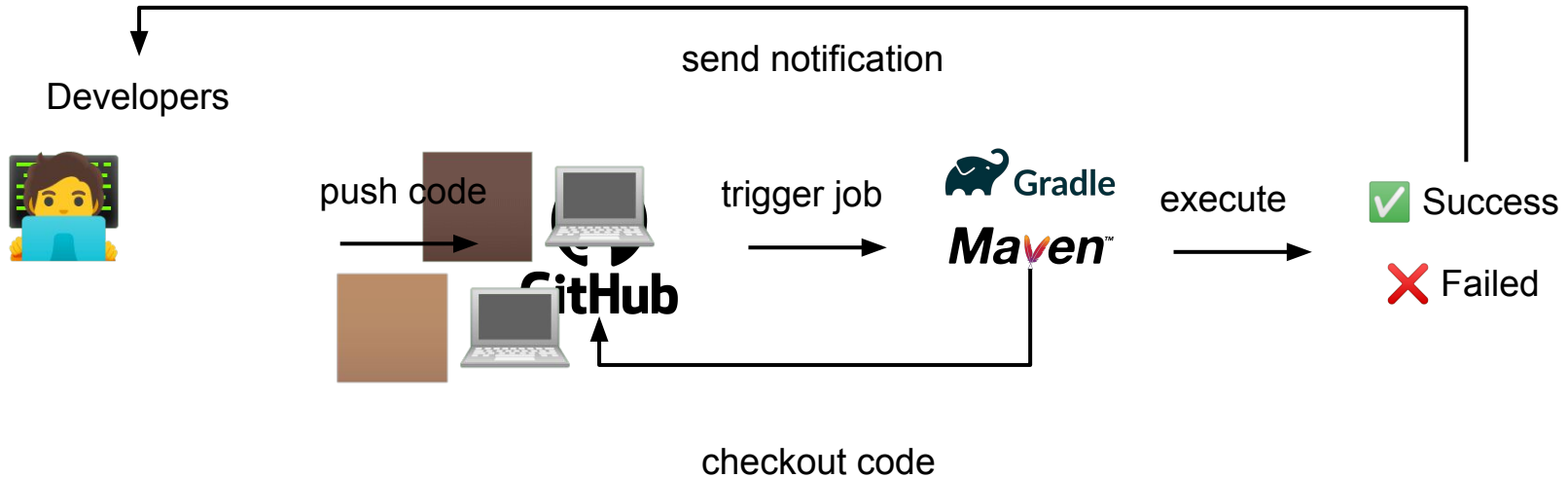
Fully-integrated CI solution with GitHub repository

- Definition of build using a “configuration as code” approach
- Fast feedback by executing the build upon pushing a commit
- Use the same build tool and logic as on a developer machine



Basic Workflow

GitHub Actions reacts on an emitted repository event



Terminology

Essential for understanding a workflow definition

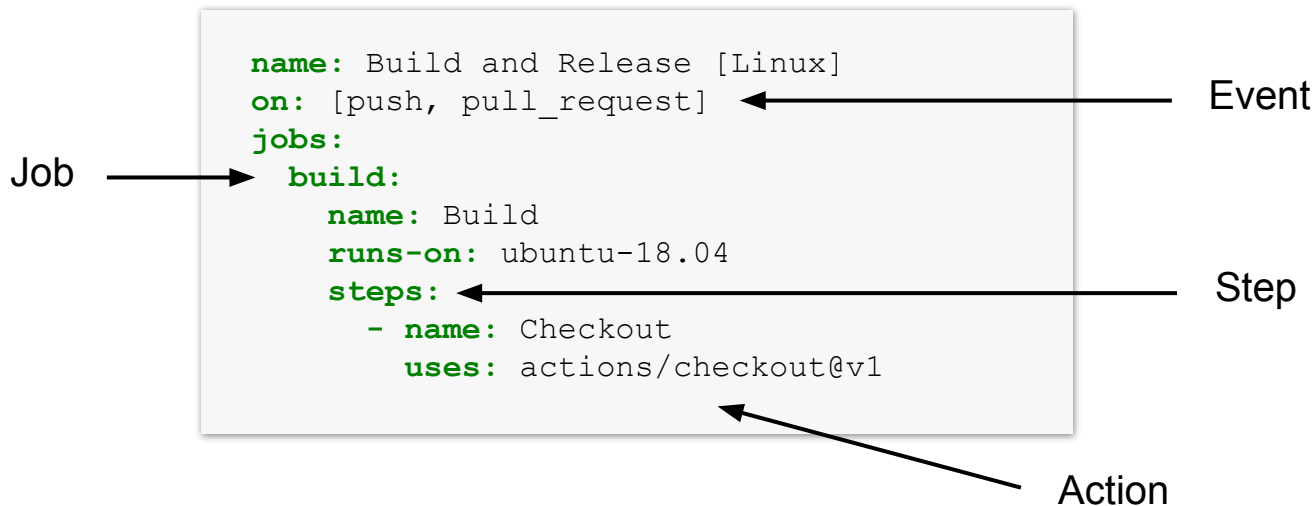
- **Event:** Repository activity that triggers a workflow
- **Job:** Set of steps that execute automation logic
- **Step:** Task that can run a command in a job
- **Action:** Reusable functionality provided by GitHub community



Typical Elements of Workflow File

Defines automation logic checked in GitHub repository

.github/workflows/build.yml



Using a Build Tool Action

Downloads and uses Gradle runtime

.github/workflows/build.yml

```
steps:
- uses: actions/checkout@v2
- uses: actions/setup-java@v1
  with:
    java-version: 11
- uses: gradle/gradle-build-action@v2
  with:
    arguments: build
```



Actions in the Repository

Click on “Actions” tab at the top

The screenshot shows the GitHub Actions interface for the repository `bmuschko/redis-generic-container`. The `Actions` tab is selected in the top navigation bar. On the left, under the `Workflows` section, the `Build [Linux]` workflow is listed. The main area displays `All workflows` with a search bar and a table of workflow runs.

Workflows

- [All workflows](#)
- [New workflow](#)

`Build [Linux]`

All workflows

Showing runs from all workflows

Filter workflow runs

3 workflow runs		Event ▾	Status ▾	Branch ▾	Actor ▾
✓	Fix command Build [Linux] #3: Commit b13e0b0 pushed by bmuschko	master	1 minute ago 52s	...	
✗	Add Maven build Build [Linux] #2: Commit a7b713d pushed by bmuschko	master	3 minutes ago 50s	...	
✓	first commit Build [Linux] #1: Commit 12498b9 pushed by bmuschko	master	7 minutes ago 1m 1s	...	



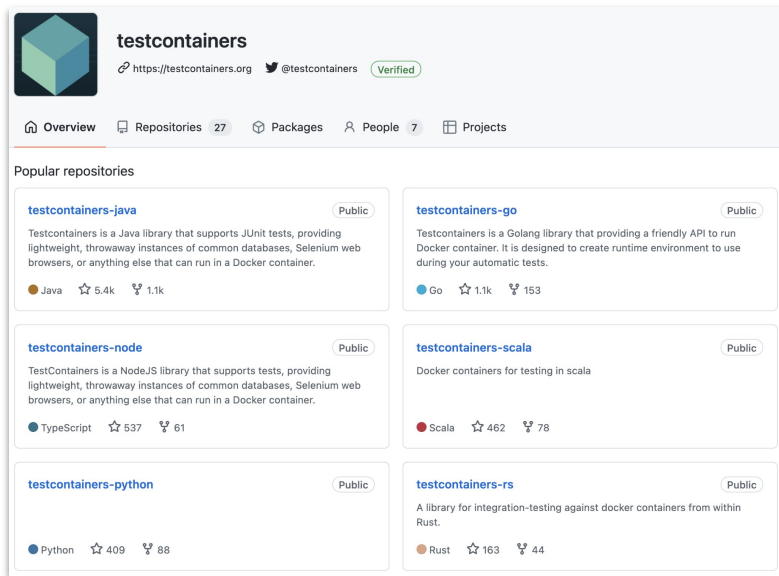
EXERCISE

Using
Testcontainers on
GitHub Actions



More Than Just Java

Support for other languages and ecosystems



The screenshot shows the GitHub profile for testcontainers, which is a verified account. The profile includes a header with the testcontainers logo, name, website (https://testcontainers.org), and Twitter handle (@testcontainers). Below the header are navigation tabs for Overview, Repositories (27), Packages, People (7), and Projects. The main section displays 'Popular repositories' with a grid of six repository cards. Each card shows the repository name, a brief description, and statistics for stars, forks, and downloads.

Repository	Description	Stars	Forks	Downloads
testcontainers-java	Testcontainers is a Java library that supports JUnit tests, providing lightweight, throwaway instances of common databases, Selenium web browsers, or anything else that can run in a Docker container.	5.4k	1.1k	
testcontainers-go	Testcontainers is a Golang library that providing a friendly API to run Docker container. It is designed to create runtime environment to use during your automatic tests.	1.1k	153	
testcontainers-node	TestContainers is a NodeJS library that supports tests, providing lightweight, throwaway instances of common databases, Selenium web browsers, or anything else that can run in a Docker container.	537	61	
testcontainers-scala	Docker containers for testing in scala	462	78	
testcontainers-python		409	88	
testcontainers-rs	A library for integration-testing against docker containers from within Rust.	163	44	




Installing the Go Module

In your project, add library to Go Modules definition

```
$ go init github.com/bmuschko/redis-go  
$ go get github.com/testcontainers/testcontainers-go
```

go.mod



```
module github.com/bmuschko/redis-go  
  
go 1.17  
  
require (  
    github.com/testcontainers/testcontainers-go  
    v0.11.1  
)
```



Using Testcontainers Go

Container lifecycle needs to be controlled manually

```
func TestWithRedis(t *testing.T) {  
    ctx := context.Background()  
    req := testcontainers.ContainerRequest{  
        Image:      "redis:latest",  
        ExposedPorts: []string{"6379/tcp"},  
        WaitingFor:  wait.ForLog("Ready to accept connections"),  
    }  
    redisC, err := testcontainers.GenericContainer(ctx, testcontainers.GenericContainerRequest{  
        ContainerRequest: req,  
        Started:          true,  
    })  
    if err != nil {  
        t.Error(err)  
    }  
    defer redisC.Terminate(ctx)  
}
```

Creation

Disposal



Q & A



5 mins



Wrap Up

Summary and Lessons Learned

O'REILLY®

Thank you

