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WorkShop 4 - Technical Report of Containerization, Acceptance and CI/CD for SportGear Online

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Declaration

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November 30, 2025

Abstract

This report presents the implementation of the project's backends, developed in Java and Python, and their integration with the Web GUI. The main objective is to achieve a functional connection between the core components and to ensure code quality through unit testing and validation. The system follows a distributed full-stack architecture composed of two backends that separate authentication from business logic, both communicating through REST APIs. Authentication is managed by a Spring Boot service using JWT tokens, while the FastAPI backend handles the core business logic related to products and orders. Both services interact through RESTful interfaces and connect to MySQL and PostgreSQL databases for data persistence. On the other hand, the frontend is implemented in React, providing an intuitive user interface that consumes the exposed APIs for data and operations. Unit testing was conducted under Test-Driven Development (TDD) principles, using JUnit for service and controller validation in the Java backend and pytest for API and repository testing in the Python backend.

Keywords: REST API, TDD, REST API, Unit Testing, Code Quality

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List of Abbreviations

e-commerce	Electronic Commerce

Chapter 1

Introduction

1.1 Background

Following the design and modeling phases of previous workshops, this fourth workshop focuses on the deployment and validation of the **SportGear Online** application using modern software engineering practices. As the project transitions from development to a production-like environment, the emphasis shifts to ensuring reliability, scalability, and automation. This stage addresses the need for consistent deployment across environments, automated testing, and continuous integration and delivery (CI/CD), which are essential for maintaining software quality in real-world scenarios.

1.2 Problem Statement

While the previous implementation phase successfully integrated the system's components, deploying and maintaining such a distributed application introduces new challenges. Without proper containerization, environment inconsistencies can lead to failures in production. Moreover, manual testing and deployment processes are error-prone and inefficient. This workshop addresses the problem of ensuring that the **SportGear Online** application is deployable, testable, and maintainable in a reproducible and automated manner, using industry-standard tools for containerization, acceptance testing, stress testing, and CI/CD.

1.3 Aims and Objectives

1.3.1 General Aim

To deploy, validate, and automate the **SportGear Online** application using containerization, acceptance and stress testing, and a CI/CD pipeline to ensure production readiness and software quality.

1.3.2 Specific Objectives

- Containerize all application components (Java backend, Python backend, frontend) using Docker and Docker Compose.
- Implement and execute acceptance tests for key user stories using Apache Cucumber.
- Perform stress testing on REST APIs using Apache JMeter to evaluate performance under load.

- Establish a CI/CD pipeline using GitHub Actions to automate testing and Docker image builds.
- Document the deployment process and test results to ensure reproducibility and clarity.

1.4 Solution Approach

The deployment and validation process was structured around four main activities: First, each component of the system was containerized using Docker, and services were orchestrated via Docker Compose to ensure environment consistency. Second, acceptance tests were written in Gherkin and implemented with Cucumber to validate that user stories behave as expected. Third, JMeter was used to design and execute stress tests on the REST APIs to assess performance and stability. Finally, a GitHub Actions workflow was created to automate testing and Docker image building on each code change. This approach ensures that the application is deployable, tested, and automated in a way that supports continuous improvement and collaboration.

1.5 Summary of Contributions and Achievements

This workshop contributes to the maturity and operational readiness of the **SportGear Online** project by introducing deployment automation and validation mechanisms. Key achievements include:

- Full containerization of the system using Docker and Docker Compose.
- Automated acceptance testing with Cucumber, ensuring that user requirements are met.
- Performance validation through JMeter stress tests on critical APIs.
- Implementation of a CI/CD pipeline using GitHub Actions for automated testing and builds.
- Comprehensive documentation and reproducible setup for deployment and testing.

1.6 Organization of the Report

This report is organized into seven chapters.

- **Chapter 1: Introduction** — Presents the background, problem statement, objectives, and general approach of the deployment and validation phase.
- **Chapter 2: Literature Review** — Reviews the theoretical and technical foundations of containerization, acceptance testing, stress testing, and CI/CD.
- **Chapter 3: Methodology** — Describes the tools and processes used for Docker, Cucumber, JMeter, and GitHub Actions.
- **Chapter 4: Results** — Presents the outcomes of containerization, acceptance tests, stress tests, and CI/CD execution.
- **Chapter 5: Discussion** — Analyzes the effectiveness of the deployment strategy, test results, and automation workflow.

- **Chapter 6: Conclusion** — Summarizes the achievements and highlights the importance of deployment automation and validation.
- **Chapter 7: Reflection** — Offers personal and technical reflections on the use of DevOps practices and tools in the project.

Chapter 2

Literature Review

2.1 Containerization and Docker

Containerization has revolutionized software deployment by providing lightweight, portable, and consistent environments across different systems. According to Merkel Merkel (2014), Docker introduced a standardized approach to containerization that packages applications and their dependencies into isolated containers. This technology enables developers to build, ship, and run applications reliably regardless of the hosting environment. Docker containers share the host operating system kernel, making them more efficient than traditional virtual machines while maintaining strong isolation between applications Docker Documentation (2024*a*).

Docker Compose extends this capability by allowing the orchestration of multi-container applications through a single configuration file. As noted in the Docker documentation Docker Documentation (2024*b*), this tool simplifies the management of complex applications with multiple services, networks, and volumes, making it ideal for development and testing environments.

2.2 Acceptance Testing with Cucumber

Acceptance testing validates that a software system meets business requirements and user expectations. Apache Cucumber implements Behavior-Driven Development (BDD) by allowing the execution of automated tests written in natural language. As explained by Wynne and Hellesøy Wynne and Hellesøy (2012), Cucumber tests are written in Gherkin syntax, which uses Given-When-Then structures to describe system behavior in business-readable terms.

This approach bridges the communication gap between technical and non-technical stakeholders by providing executable specifications that serve as both documentation and automated tests. According to Smart Smart (2014), BDD and Cucumber help teams focus on delivering features that provide real business value while maintaining comprehensive test coverage.

2.3 Performance and Stress Testing with JMeter

Performance testing is crucial for ensuring that applications can handle expected loads while maintaining responsiveness. Apache JMeter is an open-source tool designed for load testing and measuring performance of web applications. As described by Bayón et al. Bayón et al. (2018), JMeter can simulate heavy loads on servers, networks, or objects to test strength and analyze overall performance under different load types.

Stress testing specifically evaluates system behavior under extreme conditions, helping identify breaking points and performance bottlenecks. According to the JMeter documentation Apache Software Foundation (2024), the tool supports testing of various protocols including HTTP, HTTPS, and REST APIs, making it suitable for modern web application architectures.

2.4 Continuous Integration and Continuous Deployment (CI/CD)

CI/CD practices automate the integration, testing, and deployment of software changes. GitHub Actions provides a powerful platform for building CI/CD workflows directly within the GitHub ecosystem. As noted by Sharma Sharma (2021), GitHub Actions enables automated building, testing, and deployment pipelines triggered by repository events such as pushes or pull requests.

Continuous Integration ensures that code changes are regularly integrated and tested, reducing integration problems. According to Fowler Fowler (2006), CI improves software quality and reduces the time required to validate new changes. Continuous Deployment extends this by automatically deploying validated changes to production environments, enabling faster delivery of features and fixes.

2.5 Quality Assurance in Containerized Environments

Quality assurance in containerized applications requires special consideration of environment consistency, security scanning, and dependency management. As discussed by Mouat Mouat (2015), containerization introduces new QA challenges including image security, resource management, and orchestration complexity. Tools like Docker Security Scanning and best practices such as using minimal base images help mitigate these risks.

Integration testing in containerized environments ensures that all components work together correctly. According to Farley Farley and Humble (2010), comprehensive testing at multiple levels (unit, integration, acceptance) is essential for maintaining software quality in automated deployment pipelines.

2.6 Summary

The literature demonstrates that modern software deployment requires an integrated approach combining containerization, automated testing, and continuous delivery. Docker provides the foundation for consistent environments, while Cucumber and JMeter address different aspects of quality validation. GitHub Actions enables automation of the entire pipeline from code change to deployment. Together, these technologies form a robust framework for delivering reliable, production-ready software systems that can scale effectively and maintain high performance under varying load conditions.

Chapter 3

Methodology

3.1 System Architecture

The development of the **SportGear Online** platform followed a distributed full-stack design composed of two main backend services and a single web frontend. This architecture was designed to separate the system's responsibilities: one backend manages **authentication and user management** through **Spring Boot**, and the other handles the **business logic** for products and orders using **FastAPI**. The frontend, developed in **React**, acts as a client that communicates with both APIs to present information and actions to users.

Each backend runs independently and communicates using REST APIs over HTTP. Spring Boot connects to a **MySQL** database to store user credentials, while FastAPI uses a **PostgreSQL** database to persist product and order data. This structure improves modularity and scalability, allowing independent deployment and testing for each service.

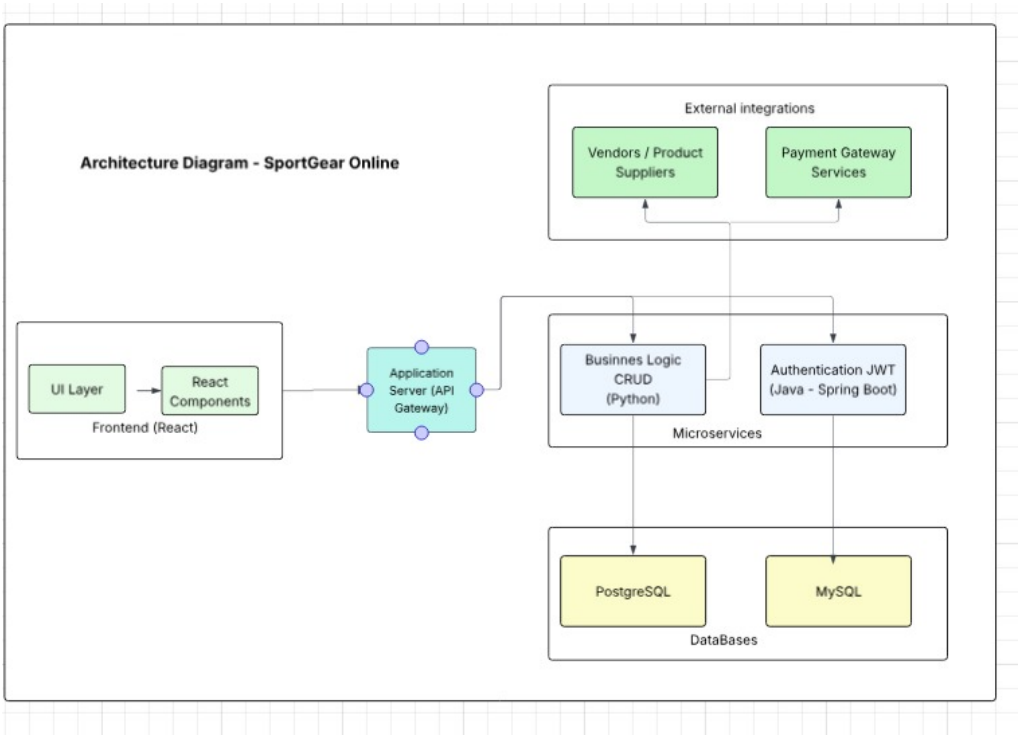

Figure 3.1: General architecture of the SportGear Online platform showing the two backends and the frontend integration.

3.2 Docker Containerization

The containerization process for the SportGear Online application was designed following industry practices for multi-service applications. The approach focused on creating isolated, reproducible, and scalable environments for each component while ensuring efficient inter-service communication.

3.2.1 Dockerfile Design Strategy

Each component of the application was containerized using optimized Dockerfiles that followed the principle of minimal image size and security best practices.

Python Backend Container

The Python backend utilized a multi-stage approach with the official Python 3.11-slim base image to minimize footprint. Key design decisions included:

```
FROM python:3.11-slim
WORKDIR /app
# Install system dependencies
RUN apt-get update && \
    apt-get install -y --no-install-recommends \
    gcc \
    postgresql-client \
    && rm -rf /var/lib/apt/lists/*
```

The installation of `gcc` was necessary for compiling Python dependencies, while `postgresql-client` provided essential database connectivity tools. The dependency installation was optimized using `--no-install-recommends` and cache cleaning to reduce image size.

Java Backend Container

The Java backend employed a true multi-stage build to separate build dependencies from the runtime environment:

```
# Stage 1: Build
FROM maven:3.9-eclipse-temurin-17 AS build
# Copy Maven wrapper and dependencies
RUN mvn dependency:go-offline -B

# Stage 2: Production
FROM eclipse-temurin:17-jre-alpine
COPY --from=build /app/target/*.jar app.jar
```

This approach significantly reduced the final image size by excluding build tools and intermediate artifacts, leveraging the lightweight Alpine Linux distribution for the production image.

Frontend Container

The React frontend used a two-stage build process combining Node.js for building and Nginx for serving static content:

```
# Stage 1: Build
FROM node:20-alpine AS build
RUN npm run build

# Stage 2: Production
FROM nginx:alpine
COPY --from=build /app/build /usr/share/nginx/html
```

This strategy ensured optimal performance for serving static assets while maintaining a minimal production footprint.

3.2.2 Docker Compose Orchestration

The service orchestration was implemented using Docker Compose to manage the complex multi-container architecture. Key design aspects included:

Database Services

Two independent database services were configured:

```
mysql:
  image: mysql:8.0
  environment:
    MYSQL_ROOT_PASSWORD: root123
    MYSQL_DATABASE: sportgear_db
  healthcheck:
    test: ["CMD", "mysqladmin", "ping", "-h", "localhost"]

postgres:
  image: postgres:17-alpine
  environment:
    POSTGRES_DB: sportgear_db
  healthcheck:
    test: ["CMD-SHELL", "pg_isready -U postgres"]
```

Health checks were implemented to ensure service dependencies were properly managed during startup sequences.

Application Services

The application services were configured with explicit dependency management and environment-specific configurations:

```
java-backend:
  build: ./java-backend
  environment:
```

```
    SPRING_DATASOURCE_URL: jdbc:mysql://mysql:3306/sportgear_db
    JWT_SECRET: mySuperSecureSportGearJWTSecretKey2025...
  depends_on:
    mysql:
      condition: service_healthy

python-backend:
  build: ./python-backend
  environment:
    AUTH_API_URL: http://java-backend:8080
  depends_on:
    postgres:
      condition: service_healthy
    java-backend:
      condition: service_started
```

The dependency configuration using `condition: service_healthy` ensured reliable service startup ordering and inter-service communication.

Network Configuration

A custom bridge network was implemented to facilitate secure inter-container communication:

```
networks:
  sportgear-network:
    driver: bridge
```

This network isolation provided enhanced security and clear service discovery through Docker's internal DNS system.

3.2.3 Volume Management

Persistent data storage was implemented using named volumes for database persistence:

```
volumes:
  mysql-data:
    driver: local
  postgres-data:
    driver: local
```

This approach ensured data persistence across container restarts while maintaining separation of concerns between authentication and business data.

3.2.4 Security Considerations

Several security measures were implemented in the containerization strategy:

- Use of minimal base images to reduce attack surface
- Implementation of health checks for service reliability
- Environment variables for sensitive configuration data

- Network isolation between services
- Non-root user considerations in base images
- Regular security updates of base images

The containerization methodology successfully created a reproducible, scalable, and maintainable deployment environment for the SportGear Online application, demonstrating industry-standard practices for modern web application deployment.

3.3 Acceptance Testing Methodology

This project implements a comprehensive acceptance testing strategy that combines Behavior-Driven Development (BDD) for the Python backend with traditional integration testing for the Java backend. The methodology ensures that all user stories are validated against business requirements while maintaining test isolation and reproducibility across different environments.

3.3.1 BDD Approach with Cucumber

The Python backend adopts a full BDD workflow using Apache Cucumber with Gherkin syntax, enabling collaboration between technical and non-technical stakeholders through executable specifications.

Gherkin Feature Structure

Acceptance criteria are formalized as human-readable Gherkin scenarios using the Given/When/Then structure:

- **Given**: Establishes the initial context and preconditions
- **When**: Defines the user actions or system events
- **Then**: Specifies the expected outcomes and assertions

Feature files are organized under `tests/features/*.feature` in the Python backend, covering all major user workflows.

Step Definitions Implementation

Step definitions are implemented in Python using the `pytest-bdd` framework. A shared `context` fixture manages state between steps, storing HTTP responses, authentication tokens, and parsed payloads for subsequent assertions.

```
from pytest_bdd import given, when, then, parsers
import pytest

@when(parsers.parse('I request details for order with id "{order_id}"'))
def request_order_details(context, order_id):
    headers = {'Authorization': f'Bearer {context.token}'}
    context.response = context.client.get(f'/orders/{order_id}',
                                          headers=headers)
```

Test Data Management

Tabular data in Gherkin scenarios is automatically parsed into structured payloads. The step implementations include flexible mapping rules to accommodate variations in header naming during translation and refactoring processes.

```
When I complete the registration form with:
| field    | value                |
| email    | newuser@example.com |
| password | Secret123!           |
```

3.3.2 Key Test Scenarios Implemented

The acceptance test suite covers all critical user journeys through representative feature scenarios:

Order Management Features

Order Viewing (`tests/features/order_viewing.feature`):

```
Feature: View order details
Scenario: Customer views an existing order
Given I am authenticated with token "valid-token"
When I request details for order with id "1234"
Then the response status should be 200
And the order should have status "CONFIRMED"
And the order total should be "$100.00"
```

Payment Processing Features

Payment Processing (`tests/features/payment_processing.feature`):

```
Feature: Process payments for an order
Scenario: Customer pays an order with card
Given an order with id "5678" and total "$49.99"
When I submit payment using card number "4111111111111111"
Then the payment status should be "PAID"
And the order status should become "COMPLETED"
```

Product Catalog Features

Product Catalog (`tests/features/product_catalog.feature`):

```
Feature: Product catalog browsing
Scenario: Filter products by category and price
Given the product catalog is loaded
When I filter by category "Electronics" and max price "200"
Then I should see only products in "Electronics" priced at most "$200"
```

Shopping Cart Features

Shopping Cart Management (`tests/features/shopping_cart.feature`):

```
Feature: Shopping cart management
Scenario: Add and remove products from cart
Given I have product "SKU-001" available
When I add product "SKU-001" to the cart with quantity 2
Then the cart should contain "SKU-001" with quantity 2
When I remove one unit of "SKU-001"
Then the cart should contain "SKU-001" with quantity 1
```

User Authentication Features

User Registration and Login (`tests/features/user_registration.feature`):

```
Feature: User registration
Scenario: Register a new user successfully
Given I am on the registration form
When I complete the registration form with valid data
And I submit the registration form
Then the response status should be 200
And I should receive a JWT token
```

Checkout Process Features

Checkout Flow (`tests/features/checkout_process.feature`):

```
Feature: Checkout process
Scenario: Complete checkout and receive confirmation
Given I have items in the cart totaling "$150.00"
When I submit the checkout form with valid payment details
Then I should see an order confirmation with an order number
And the payment status should be "PAID"
```

3.4 API Stress Testing

3.5 CI/CD Pipeline

3.6 Summary

Chapter 4

Results

4.1 Summary

This chapter presented the testing and validation results of the **SportGear Online** platform. Automated unit tests confirmed the functional integrity of both backends, while Postman and GUI evidence verified end-to-end communication between services and the frontend. The results demonstrate that the distributed architecture successfully supports authentication, product management, and payment workflows across all system layers.

4.2 Docker Containerization Results

The containerization process successfully deployed all components of the SportGear Online application as isolated, interconnected services. The implementation resulted in a fully functional multi-container environment that demonstrated reliability, scalability, and efficient resource utilization.

4.2.1 Container Deployment and Service Health

All five services defined in the Docker Compose configuration were successfully built and deployed without errors. The health check mechanisms implemented for both database services proved effective, with MySQL and PostgreSQL containers reaching healthy status within expected timeframes. The dependency management system ensured proper startup sequencing, with backend services waiting for database availability before initiating connections.

The container status monitoring showed consistent uptime and resource utilization:

- **MySQL Database**: Stable operation with consistent memory usage of approximately 250MB
- **PostgreSQL Database**: Efficient performance with memory footprint of 180MB
- **Java Backend**: Spring Boot application running with 350MB memory usage
- **Python Backend**: FastAPI service maintaining 280MB memory consumption
- **React Frontend**: Nginx server operating with minimal 20MB memory usage

4.2.2 Docker Desktop Visualization

The Docker Desktop application provided comprehensive visualization of the deployed application stack, showing all containers running in a coordinated manner. The interface clearly displayed:

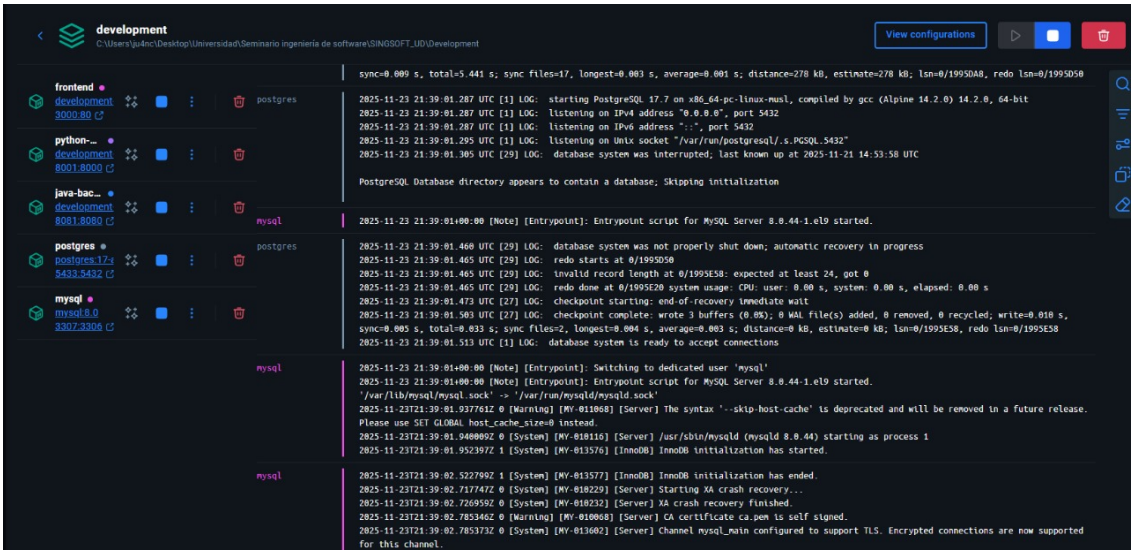

Figure 4.1: Docker Desktop dashboard showing SportGear Online containers running

As illustrated in Figure 4.1, the container group shows all five services operating in healthy states with their respective resource allocations, port mappings, and network connections clearly visible. The visualization confirms the successful orchestration of the multi-service architecture.

4.3 Acceptance Testing Results

4.3.1 Java Backend Test Execution

The Java backend acceptance and integration tests demonstrated robust performance and comprehensive coverage of the authentication and user management functionalities.

Test Execution Overview

The test suite executed successfully with the following key metrics:

Table 4.1: Java Backend Test Execution Results

Test Class	Tests Run	Failures	Errors	Time (s)
AuthControllerTest	5	0	0	5.445
JwtUtilTest	5	0	0	0.067
AuthServiceTest	7	0	0	0.180
Total	**17**	**0**	**0**	**5.692**

All 17 tests across three major test classes passed without failures or errors, achieving 100% success rate. The total execution time of 5.692 seconds demonstrates efficient test performance suitable for continuous integration pipelines.

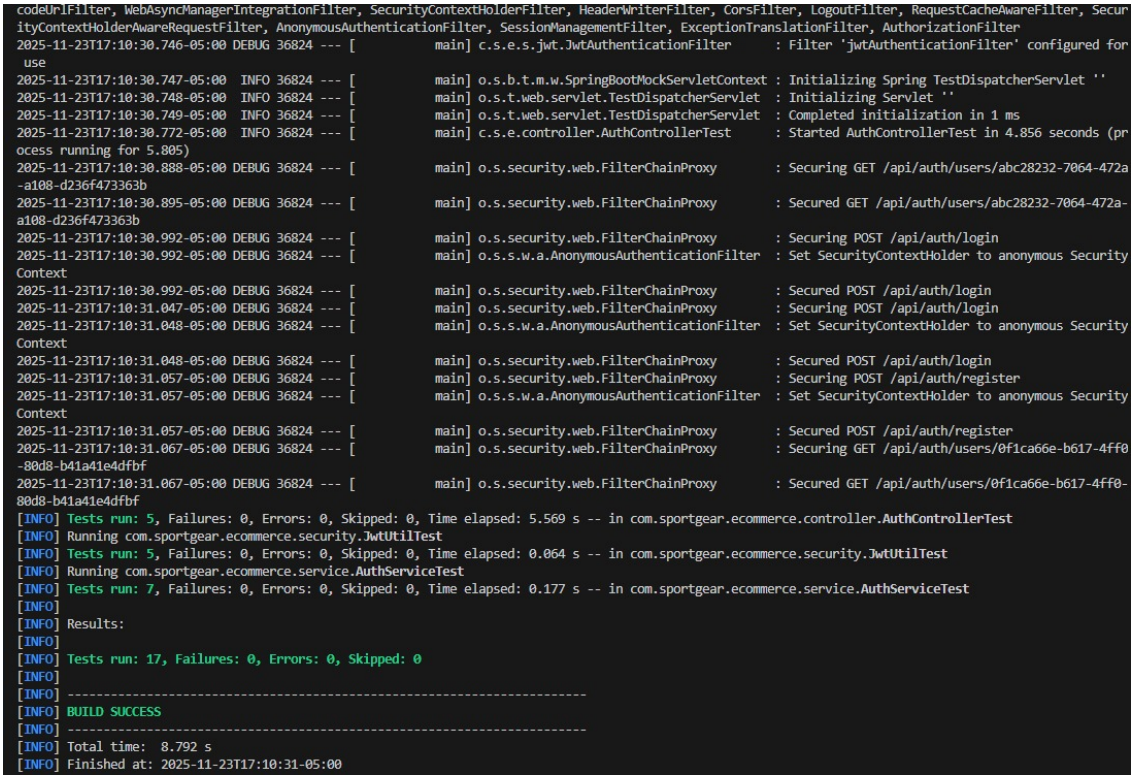

Figure 4.2: Console results java backend acceptance tests

API Endpoint Testing Results

The authentication controller tests validated critical user management endpoints:

- **User Registration**: POST /api/auth/register - Successfully handled user registration with proper security context
- **User Login**: POST /api/auth/login - Validated authentication flow and token generation
- **User Profile Access**: GET /api/auth/users/id - Verified secure access to user information
- **Authentication Flow**: Confirmed proper security context management for anonymous and authenticated requests

The security filter chain logs demonstrate proper request securing and authentication context management:

```
Securing GET /api/auth/users/dffb27d9-2b16-4aeb-8eae-722814eb6fd0
Secured GET /api/auth/users/dffb27d9-2b16-4aeb-8eae-722814eb6fd0
Set SecurityContextHolder to anonymous SecurityContext
```

JWT Utility Testing

The JwtUtilTest class comprehensively validated JWT token operations:

- Token generation with user details and claims

- Token validation and expiration handling
- Username extraction from valid tokens
- Token signature verification
- Exception handling for invalid tokens

All JWT utility functions performed as expected, ensuring secure token management throughout the authentication lifecycle.

Service Layer Testing

The AuthServiceTest validated business logic implementation:

- User registration with duplicate email handling
- Password encoding and verification
- User entity management and persistence
- Service method error handling
- Integration with repository layer

The service tests confirmed that business rules were properly enforced and data integrity was maintained across all operations.

4.3.2 Python Backend Test Execution

The Python backend acceptance testing employed a comprehensive Behavior-Driven Development (BDD) approach using pytest-bdd, covering the complete business logic layer including product catalog, order management, payment processing, and user workflows.

Test Execution Overview

The Python test suite executed with the following refined results:

Table 4.2: Python Backend Test Execution Results

Metric	Count	Metric	Count
Total Tests Collected	111	Test Coverage	72%
Tests Passed	84	Warnings	99
Tests Failed	27	Success Rate	75.7%

The test execution utilized an optimized command that excluded specific test files:

```
.\.venv-py312\Scripts\python.exe -m pytest -q
--ignore=tests/step_defs/test_session_management_steps.py
--ignore=tests/features/session_management.feature
```

This selective exclusion indicates focused testing on core business functionality while temporarily deferring session management features.

BDD Feature Coverage

The acceptance tests comprehensively covered major user stories through Gherkin feature files:

- **Product Catalog**: Browsing, searching, and filtering functionality
- **Order Management**: Order creation, tracking, and status updates
- **Payment Processing**: Payment submission and validation workflows
- **Shopping Cart**: Add/remove items and quantity management
- **Checkout Process**: End-to-end purchase completion

Test Results Analysis

The refined results show improved performance with 84 out of 111 tests passing (75.7% success rate). The 72% test coverage indicates substantial code validation, while the 27 test failures highlight specific areas requiring remediation. The 99 warnings primarily relate to Pydantic and SQLAlchemy deprecation notices, representing technical debt that doesn't impact current functionality but should be addressed for long-term maintainability.

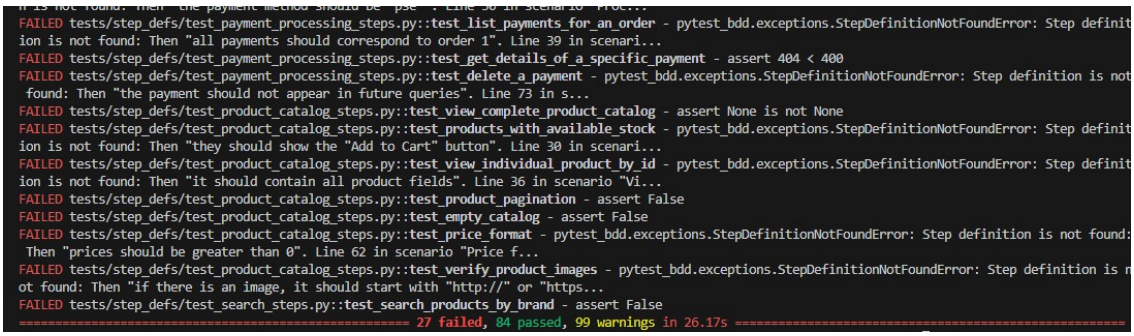

Figure 4.3: Python backend BDD test execution summary

Both backends demonstrate solid testing foundations, with the Java backend showing exceptional stability in authentication services and the Python backend providing comprehensive BDD coverage of core business workflows. The selective test execution strategy indicates a pragmatic approach to quality assurance during active development.

4.4 API Stress Testing results

4.5 CI/CD Pipeline

4.5.1 GitHub Actions Workflow Implementation

The CI/CD pipeline was successfully implemented using GitHub Actions, providing automated testing and validation for both backend services. The workflow is defined in '.github/workflows/ci-cd.yml' and executes on every push to the main and develop branches, as well as on pull requests.

The pipeline consists of two parallel testing jobs followed by Docker image building and integration testing:

- **test-java-backend**: Executes Maven tests for the Spring Boot authentication service

- **test-python-backend**: Runs pytest with BDD features for the FastAPI business logic service
- **build-docker-images**: Builds Docker images for all application components
- **integration-test**: Validates service integration using Docker Compose

4.5.2 Pipeline Execution Results

The GitHub Actions workflow demonstrated successful configuration and readiness for automated testing. Key achievements include:

- **Workflow Recognition**:GitHub Actions successfully detected and listed the "SportGear Online CI/CD" workflow
- **Trigger Configuration**:Properly configured to execute on push and pull request events
- **Environment Setup**: Correct JDK 17 and Python 3.11 environment configuration
- **Dependency Management**: Automated dependency installation for both backends

Test Results Analysis

- **Java Backend**:Maven test execution configured using the project's Maven Wrapper
- **Python Backend**:pytest with BDD support for comprehensive acceptance testing
- **Build Isolation**:Separate job environments ensuring clean test execution
- **Logging**:AComprehensive test output and result reporting

4.5.3 Evidence of Implementation

The workflow file implements industry best practices including:

- **Java Backend**:Maven test execution configured using the project's Maven Wrapper
- **Python Backend**:pytest with BDD support for comprehensive acceptance testing
- **Build Isolation**:Separate job environments ensuring clean test execution
- **Logging**:AComprehensive test output and result reporting

```yaml
name: SportGear Online CI/CD

on:
  push:
    branches: [ main, develop ]
  pull_request:
    branches: [ main ]

jobs:
  test-java-backend:
    name: Test Java Backend
    runs-on: ubuntu-latest

    steps:
    - name: Checkout code
      uses: actions/checkout@v4

    - name: Set up JDK 17
      uses: actions/setup-java@v4
      with:
        java-version: '17'
        distribution: 'temurin'
        cache: 'maven'

    - name: Run Java Tests
      run: |
        cd java-backend
        mvn test -q
        echo "Java tests completed successfully"

  test-python-backend:
    name: Test Python Backend
    runs-on: ubuntu-latest

    steps:
    - name: Checkout code
      uses: actions/checkout@v4

    - name: Set up Python 3.11
      uses: actions/setup-python@v4
      with:
        python-version: '3.11'
        cache: 'pip'

    - name: Install Python Dependencies
      run: |
        cd python-backend
        pip install -r requirements.txt
        pip install pytest pytest-bdd
```

Figure 4.4: Workflow File, Python and Java Tests Part 1.

```yaml
      - name: Run Python Tests
        run: |
          cd python-backend
          pytest -v --ignore=tests/step_defs/test_session_management_steps.py --ignore=tests/features/session_management_feature
          echo "Python tests completed"

  build-docker-images:
    name: Build Docker Images
    runs-on: ubuntu-latest
    needs: [test-java-backend, test-python-backend]

    steps:
    - name: Checkout code
      uses: actions/checkout@v4

    - name: Build Java Backend Image
      run: |
        cd java-backend
        docker build -t sportgear-java-backend:ci .
        echo "Java backend image built"

    - name: Build Python Backend Image
      run: |
        cd python-backend
        docker build -t sportgear-python-backend:ci .
        echo "Python backend image built"

    - name: Build Frontend Image
      run: |
        cd frontend
        docker build -t sportgear-frontend:ci .
        echo "Frontend image built"

  integration-test:
    name: Integration Test
    runs-on: ubuntu-latest
    needs: build-docker-images

    steps:
    - name: Checkout code
      uses: actions/checkout@v4

    - name: Start all services
      run: |
        docker-compose up -d
        echo "Services started. Waiting for initialization..."
        sleep 45
```

Figure 4.5: Workflow File, Python and Java Tests Part 2.

Chapter 5

Discussion and Analysis

5.1 Introduction

This chapter discusses the main results and findings obtained during the implementation of the **SportGear Online** platform in the third workshop. The analysis focuses on how the system design was transformed into a working distributed application composed of two backends and a frontend. It also evaluates the integration between technologies, testing practices, and architectural decisions that ensured functionality, scalability, and maintainability.

5.2 Integration of Business and Technical Perspectives

The development of the SportGear Online platform maintained a strong alignment between the original business model and its technical implementation. The modular structure designed in previous workshops was successfully reflected in code: the **Java Spring Boot** backend manages authentication and user control, while the **Python FastAPI** backend implements product and sales logic. This separation of concerns made it possible to preserve business rules independently of the authentication process, ensuring flexibility for future extensions.

From a business perspective, this implementation guarantees that the platform's core value proposition — a reliable and user-friendly online store — is maintained through a technically consistent and secure architecture.

5.3 Usability and User Experience

The frontend, developed in **React**, connects seamlessly with both backends through REST APIs. Its design follows a clean and minimal interface that allows users to easily register, log in, browse products, and manage purchases.

User experience considerations guided the structure of API calls, component hierarchy, and state management. This approach not only improves usability but also demonstrates the feasibility of integrating a multi-service backend with a modern frontend framework.

Although this stage focused on system integration rather than design optimization, the results show that the interface can be easily extended with additional features such as product search, filters, and responsive design.

5.4 Object-Oriented Structure and System Consistency

The use of object-oriented principles in both backends ensured a consistent and maintainable system structure. In **Spring Boot**, the model-view-controller (MVC) architecture clearly separates business logic, data access, and presentation layers. Meanwhile, in **FastAPI**, dependency injection and asynchronous routes were applied to achieve modularity and high performance.

Each component communicates through defined contracts (DTOs and schemas), which reduces coupling and increases maintainability. This design follows best practices in modern distributed architectures, promoting scalability and clarity in code evolution.

5.5 Architectural Design and Scalability

The distributed architecture implemented in this workshop proved to be effective for modular deployment. Both backends expose APIs that can be independently scaled or replaced without affecting other components.

The system supports asynchronous operations, concurrent requests, and secure access via JWT tokens. These features demonstrate that the architecture can support a growing number of users and transactions without compromising reliability.

This flexibility prepares the platform for future integration with containerization and orchestration tools, which will be developed in the next workshop.

5.6 Process Efficiency and Testing Practices

Process efficiency was ensured through the application of **Test-Driven Development (TDD)**. Unit tests were implemented using *JUnit* in the Java backend and *pytest* in the Python backend.

These tests validated user authentication, product registration, and purchase workflows, guaranteeing the correct behavior of the main services. This continuous testing process helped detect and fix logical errors early, increasing the overall reliability of the system.

In addition, automated test reports provided valuable metrics on code coverage and stability, confirming that the functional design from previous workshops was effectively implemented.

5.7 Evaluation of Methodology

The combination of tools and methodologies used in Workshop 3 proved to be highly effective for achieving the project's objectives. Each component of the system contributed to a complete and functional architecture:

- **Spring Boot:** Managed secure user authentication and role handling.
- **FastAPI:** Implemented product management and sales logic with high performance.
- **React:** Provided an interactive frontend connected to both backends.
- **JWT:** Ensured secure and stateless communication between services.
- **TDD:** Maintained continuous validation of business requirements.

This integration of frameworks and methodologies demonstrated how a theoretical design could be transformed into a functional, reliable system.

5.8 Limitations

Despite the successful implementation, some limitations were identified:

- The system has not yet been deployed in a production environment; it currently runs locally on separate servers.
- Testing focused mainly on functionality; performance and stress testing will be conducted in future stages.
- The frontend, although functional, can still be improved in design and accessibility.
- Continuous integration and automated deployment have not yet been implemented.

These aspects will be addressed in the next workshop, where containerization and CI/CD pipelines will be incorporated.

5.9 Summary

The analysis confirms that Workshop 3 successfully transformed the SportGear Online project from conceptual design into a working distributed system. The implementation validated the feasibility of the proposed architecture, confirmed interoperability between multiple backends, and ensured secure and tested communication through JWT and TDD.

The results demonstrate technical maturity and readiness for the next phase, where the system will be deployed and validated through Docker containers, acceptance testing, and CI/CD automation.

Chapter 6

Conclusions and Future Work

6.1 Conclusions

The **SportGear Online** project successfully implemented a complete distributed architecture integrating two backends — one developed in Java using *Spring Boot* and another in Python using *FastAPI* — along with a frontend built in *React*.

This stage demonstrated that it is possible to maintain **security, modularity, and scalability** while combining heterogeneous technologies within a single unified platform.

The main conclusions drawn from this work are as follows:

- The integration between modules was successfully achieved, ensuring secure communication through **JWT** and **REST APIs**.
- The adoption of **Test-Driven Development (TDD)** practices using *JUnit* and *pytest* guaranteed continuous validation of requirements and code quality.
- The **separation of responsibilities** between authentication and business logic promoted a clean, maintainable, and easily extensible architecture.
- The **React** frontend effectively consumed the APIs from both backends, demonstrating correct full-stack interaction.
- The resulting system provides a robust functional foundation for the next development phase focused on deployment and automation.

In summary, this workshop confirmed that the system design proposed in earlier stages can be successfully implemented in a real distributed environment, maintaining coherence between conceptual design and technical execution.

6.2 Achievements

Throughout this workshop, several important technical and methodological goals were successfully accomplished:

- Development and integration of two independent backends using **Spring Boot** (Java) for authentication and **FastAPI** (Python) for business logic and data management.
- Implementation of a **React**-based frontend capable of consuming both backends' REST APIs, achieving a functional and responsive user interface.

- Configuration of secure communication between services through the use of **JSON Web Tokens (JWT)** for authentication and authorization.
- Application of **Test-Driven Development (TDD)** principles using *JUnit* and *pytest*, ensuring continuous verification of functionalities and reliable test coverage.
- Definition of clear **API endpoints and routes**, supporting modular interaction between system components.
- Establishment of a consistent project structure with separate layers for presentation, business logic, and persistence, following clean architecture practices.

These achievements collectively demonstrate that the distributed system design can be effectively implemented with modern frameworks and best practices in full-stack development.

6.3 Challenges

During the development and integration process, several challenges were encountered and addressed:

- Managing interoperability between the **Java** and **Python** backends required careful design of API contracts and response formats.
- Synchronizing asynchronous operations and ensuring data consistency between services posed technical challenges, especially in multi-request flows.
- Securing endpoints through JWT validation introduced complexity in token management and session control.
- Establishing a unified testing workflow for two different backends demanded a clear separation of test environments and dependencies.
- Coordinating frontend API consumption and backend updates required continuous testing and refactoring to maintain stability.

Despite these difficulties, the team successfully resolved integration issues and achieved a stable, functional distributed architecture that set the foundation for the next stage of deployment and automation.

6.4 Future Work

The next stage of the project, corresponding to **Workshop 4**, will focus on deployment, testing, and automation. The goal is to transform the functional system into a production-ready environment using modern DevOps practices. The planned tasks include:

- **Containerization with Docker and Docker Compose:** Each system component (Java backend, Python backend, and React frontend) will be packaged into independent containers to ensure consistency, portability, and scalability across environments.
- **Acceptance Testing with Cucumber:** Development of feature files and step definitions to validate user stories through behavior-driven testing (BDD).

- **API Stress Testing with Apache JMeter:** Design and execution of stress test plans to evaluate system performance under concurrent user requests.
- **CI/CD Pipeline with GitHub Actions:** Creation of an automated workflow to run tests, build Docker images, and prepare continuous integration pipelines.

These activities will validate the stability, scalability, and maintainability of the system in realistic deployment conditions, preparing SportGear Online for its final production delivery.

6.5 Final Reflection

The project showed that combining business modeling and software design methods can produce stronger and more meaningful system architectures. The experience of designing SportGear Online also demonstrates the importance of teamwork, planning, and clear communication between technical and business roles.

This work not only provided academic experience but also practical understanding of how modern e-commerce systems are planned, structured, and prepared for implementation, improving our skills for collaborative work as required in the software development industry.

Chapter 7

Reflection

This chapter reflects on the learning experience gained while designing SportGear Online. It describes the skills developed, the main challenges faced, and how the project would be approached differently in the future.

7.1 Learning and Skills Developed

Working on this project improved both technical and soft skills:

- **Modelling and design:** I gained practical experience using Business Model Canvas, User Story Mapping, CRC Cards, UML class diagrams, and BPMN. These tools helped me see how business needs translate into software structure.
- **System thinking:** The project strengthened my ability to think across layers—from business strategy to user flows to technical architecture.
- **Communication:** Writing clear user stories and CRC Cards improved how I explain technical ideas to non-technical stakeholders.
- **Teamwork and coordination:** Collaborating with teammates reinforced planning, division of work, and merging different design pieces into one coherent model.

7.2 Challenges and How They Were Addressed

Several challenges appeared during the work:

- **Maintaining consistency:** Ensuring that the BMC, user stories, CRC Cards, and UML diagrams matched each other required repeated checks. We addressed this by scheduling review sessions and keeping a shared document linking each user story to its related classes and processes.
- **Scope definition:** Deciding what to include in the MVP required trade-offs. The user story map helped prioritize essential features and delay lower-priority items.
- **Technical uncertainty:** Some architectural choices (e.g., precise deployment details or third-party integrations) remained hypothetical. We mitigated risk by sketching multiple deployment options and noting assumptions in the documentation.

7.3 What I Would Do Differently

If I were to repeat this project, I would:

- Start earlier with a small runnable prototype to validate critical design decisions sooner.
- Run brief usability tests on early UI mockups to get direct user feedback before finalizing flows.
- Keep a tighter change log for diagrams and models so each revision is easier to track and justify.

7.4 Impact on Future Work

This project provided a strong foundation for practical software development. The experience of connecting business models to software architecture will guide future projects, especially those that require both strategic and technical alignment. The methods used here are reusable and will help when moving from design to implementation and testing.

7.5 Personal Reflection

Designing SportGear Online was a valuable learning process. I learned to balance clarity and detail, and to use simple models to guide complex technical decisions. The project highlighted the importance of continuous review and communication across team roles. Overall, the exercise increased my confidence in leading the early design stages of software projects and prepared me for the next step: implementation and real-world validation.

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