C#Corner

Mastering Unit Testing

Ziggy Rafiq

How To Master Unit Testing in C# and .Net 8 Best Practices and Industry Standards

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Background and Expertise

Over the course of his 19 years of experience, Ziggy Rafiq has demonstrated exceptional skills in System Architecture. With over 19 years of experience, he is a highly accomplished Full-Stack Designer and Developer. In 2004, he was appointed Technical Lead Developer, highlighting his leadership and expertise.
Several prestigious awards have recognized Ziggy Rafiq's exceptional talents. After he developed an impenetrable login system in 2002, he received the Shell Award for his groundbreaking work. In 2008, he was honored as one of Microsoft's Top 10 Developers in the West Midlands at the Microsoft Hero Event.
Ziggy Rafiq has been recognized by C# Corner as a MVP, VIP, and Member of the Month (July), as well as an active speaker and Chapter Lead at the UK Developer Community.

Educational background

As a student at college, Ziggy Rafiq earned an American Associate Degree in Interactive Multimedia Communication. Continuing his education at the University of Wolverhampton from 1999 to 2003, he earned a BA Hons degree in Interactive Multimedia Communication 2:1. He gained a comprehensive understanding of Design, Development, Testing, Deployment, and Project Management along the way, making him an effective professional.

Acknowledgment

This book is dedicated to author Ziggy Rafiq's late mother, Mrs. Zubeda Begum, whose unwavering love, support, and encouragement have been a constant source of inspiration. From January 1st, 1950, to December 1st, 2022, her presence in Ziggy Rafiq's life shaped Ziggy Rafiq's journey, and this book is a tribute to her memory.

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— Ziggy Rafiq

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Introduction

Overview

In this Chapter, we explore Unit Testing in C# with .NET 8. Discover the vital role of unit testing in software reliability. Learn through examples and delve into C# and .NET 8 essentials, empowering developers to elevate their testing practices.

Overview of Unit Testing

As part of the software development lifecycle, unit testing examines individual components or pieces of code in isolation to determine if they function correctly and meet specific requirements. In the context of C# and .NET 8, unit testing becomes a powerful tool for improving code quality, catching bugs earlier in development, and facilitating a more robust and resilient software architecture.

Example of a simple unit test in C# using NUnit framework [TestFixture]

```
public class CalculatorTests
{
    [Test]
    public void Add_TwoNumbers_ReturnsSum()
    {
        // Arrange
        var calculator = new Calculator();

        // Act
        var result = calculator.Add(2, 3);

        // Assert
        Assert.AreEqual(5, result);
    }
}
```

Importance of Unit Testing in Software Development

The significance of unit testing cannot be overstated. Maintaining code quality becomes increasingly challenging as projects grow in complexity. Unit tests act as a safety net, providing developers with confidence that changes to the codebase won't break existing functionality or introduce unintended side effects. In this section, we discuss the compelling reasons for adopting unit testing in modern software development practices.

Example demonstrating the importance of unit testing

```
public class OrderProcessor
{
    public void ProcessOrder(Order order)
    {
        // Business logic for processing an order

        // Without unit tests, changes here could introduce bugs
    }
}
```

Brief Introduction to C# and .NET 8

Unit testing can be a powerful tool for developers if they are familiar with the tools and frameworks available. This chapter provides a concise introduction to C#, a versatile and object-oriented programming language, as well as .NET 8, the latest version of the open-source, cross-platform framework. With C# and .NET 8, you can develop a wide range of applications, and a solid understanding of their features is essential to mastering unit testing.
Example of C# and .NET 8 code

```
public class HelloWorld
{
    public static void Main()
    {
        Console.WriteLine("Hello, World!");
    }
}
```

As we embark on this exploration of best practices and industry standards in unit testing with C# and .NET 8, we aim to equip developers with the knowledge and skills needed to elevate their software testing endeavors to new heights. Embrace the art of unit testing excellence.

2

Exploring the Depth of C# Generics Fundamentals of Unit Testing

Overview

In this chapter, we explore Unit Testing Essentials. Dive into the definition and significance of unit testing in software development. Explore its purpose in enhancing code reliability and maintainability. Learn through examples, key components like test cases, suites, assertions, and popular tools such as NUnit, xUnit, and MSTest for effective implementation.

Definition and Purpose

For understanding the role and importance of unit testing in software development, the chapter on Fundamentals of Unit Testing contains a section entitled "Definition and Purpose." In this context, unit testing is defined as the process of testing individual code units in isolation to ensure they function properly. The primary purpose of unit testing is to validate the behaviour of these units, typically functions or methods, against expected outcomes, thereby enhancing code quality, reliability, and maintainability. By isolating and testing small units of code, developers can identify and address bugs early in the development cycle, facilitating faster feedback loops and reducing the likelihood of regressions. Ultimately, unit testing contributes to the overall stability and robustness of software systems, enabling teams to deliver high-quality products with confidence.

Understanding Unit Testing

Software development is incomplete without unit testing, which serves as the cornerstone of maintaining and ensuring that code is reliable and maintainable. Here is a basic definition of unit testing. An individual unit or component of code is tested to make sure it performs as it should. In order to detect errors early in the development cycle, it is essential to verify these units function correctly in isolation.

Example of a simple unit test using NUnit

```
[Test]
public void Add_TwoNumbers_ReturnsSum()
{
    // Arrange
    Calculator calculator = new Calculator();

    // Act
    int result = calculator.Add(3, 4);

    // Assert
    Assert.AreEqual(7, result);
}
```

Importance of Unit Testing

In this part, we discuss the importance of unit testing and how it contributes to minimizing bugs, facilitating code changes, and improving code quality in general. Developers can make changes, refactor code, and enhance functionality with confidence by isolating and testing discrete units of code.

Example highlighting the importance of unit testing

```
public class PaymentProcessor
{
    public bool ProcessPayment(Order order)
    {
        // Processing logic

        // Simulated bug for demonstration
        if (order.TotalAmount < 0)
        {
            // Bug: Negative total amount not allowed
            return false;
        }

        // Actual processing continues...

        return true;
    }
}
```

Corresponding unit test

```
[Test]
public void ProcessPayment_InvalidOrder_ReturnsFalse()
{
    // Arrange
    PaymentProcessor processor = new PaymentProcessor();
    Order invalidOrder = new Order { TotalAmount = -5 };

    // Act
    bool result = processor.ProcessPayment(invalidOrder);

    // Assert
    Assert.IsFalse(result);
}
```

Benefits of Unit Testing

In this chapter, you will examine how unit testing contributes to creating robust, maintainable, and scalable code. You will learn how unit testing reduces debugging time, provides documentation, and fosters team collaboration.

Example demonstrating benefits of unit testing

```
public class StringUtils
{
    public static string ReverseString(string input)
    {
        // Bug: Original implementation had a bug
        // return new string(input.Reverse().ToArray());

        // Fixed implementation
        return new string(input.Reverse().ToArray());
    }
}
```

Corresponding unit test

```
[Test]
public void ReverseString_ValidInput_ReturnsReversedString()
{
    // Arrange
    string input = "unit testing";

    // Act
    string result = StringUtils.ReverseString(input);

    // Assert
    Assert.AreEqual("gnitset tinu", result);
}
```

Key Components: Test Cases, Test Suites, Assertions

There is a section on "Key Components: Test Cases, Test Suites, Assertions" in the chapter Fundamentals of Unit Testing that discusses the essential elements of effective unit testing. Individual code units are evaluated in terms of their correctness and expected behavior through test cases, which represent specific scenarios or conditions. The purpose of test suites is to systematically test the various functionalities of the codebase using a collection of test cases. The assertion is one of the most important components of unit testing because it defines expected outcomes and verifies if the actual results match them. By combining these components, developers can systematically validate code functionality, detect defects, and maintain code integrity throughout the development process, thereby enabling them to use unit testing methodologies.

Test Cases

We'll walk through the setup, execution, and evaluation phases of a test case, the foundation of unit testing. A test case is a specific scenario which verifies the correct behavior of a particular unit of code.

Example of a test case

```
[Test]
public void Divide_TwoNumbers_ReturnsQuotient()
{
    // Arrange
    Calculator calculator = new Calculator();

    // Act
    double result = calculator.Divide(10, 2);

    // Assert
    Assert.AreEqual(5, result);
}
```

Test Suites

An overview of test suites, which group multiple test cases. Test suits facilitate the organization and efficient execution of tests. Coding examples demonstrate the effective structure and execution of test suites.

Example of a test suite using xUnit

```
public class MathTests
{
    [Fact]
    public void Add_TwoNumbers_ReturnsSum()
    {
        // Test logic
    }

    [Fact]
    public void Subtract_TwoNumbers_ReturnsDifference()
    {
        // Test logic
    }

    // Additional test methods...
}
```

Assertions

Using assertions to validate expected outcomes in test cases. Exploring equality checks and exception handling, with practical examples.

Example of assertion in a test case

```
[Test]
public void SquareRoot_PositiveNumber_ReturnsCorrectResult()
{
    // Arrange
    Calculator calculator = new Calculator();

    // Act
    double result = calculator.SquareRoot(16);

    // Assert
    Assert.AreEqual(4, result);
}
```

Tools and Frameworks: NUnit, xUnit, MSTest

In the "Tools and Frameworks: NUnit, xUnit, MSTest" section of the chapter on Fundamentals of Unit Testing, the focus is on popular tools and frameworks used by developers to streamline the unit testing process. There are several frameworks that facilitate the creation, execution, and management of unit tests in a variety of programming environments, including NUnit, xUnit, and MSTest. As a mature and widely adopted framework for writing and executing tests in .NET applications, NUnit offers a wide range of features. Unit testing with xUnit is easy and flexible, suitable for a variety of languages and platforms, thanks to its simplicity and extensibility. For .NET developers, MSTest offers seamless integration with the development environment, making it a convenient choice. Through rigorous unit testing practices, developers can enhance productivity, maintain code quality, and ensure the reliability of their software applications.

NUnit

An in-depth look at NUnit, a popular unit testing framework for .NET applications. This chapter shows how to write NUnit test cases, configure fixtures, and take advantage of NUnit's features.

Example NUnit test fixture

```
[TestFixture]
public class MathTests
{
    [Test]
    public void Multiply_TwoNumbers_ReturnsProduct()
    {
        // Test logic
    }
}
```

xUnit

XUnit is another widely-used unit testing framework within the .NET ecosystem. Demonstrations include writing xUnit tests, using test attributes, and leveraging xUnit's extensibility for customized testing.

Example xUnit test class

```
public class MathTests
{
    [Fact]
    public void Divide_TwoNumbers_ReturnsQuotient()
    {
        // Test logic
    }
}
```

MSTest

An overview of MSTest, Microsoft's built-in testing framework for .NET. This section discusses how to create MSTest projects, create test methods, and use MSTest's unique features.

Example MSTest test class

```
[TestClass]
public class MathTests
{
    [TestMethod]
    public void Subtract_TwoNumbers_ReturnsDifference()
    {
        // Test logic
    }
}
```

Upon completing this chapter, readers will have a solid understanding of unit testing principles and practical skills for implementing tests using popular .NET frameworks.

3

Setting Up the Unit Testing Environment

Overview

In this chapter, we explore Unit Testing Environment. Establishing infrastructure and tools for effective unit testing, integrating with IDEs like Visual Studio, configuring test projects, managing dependencies, and organizing test classes for seamless integration and automation, ensuring high-quality, bug-free software products."

To support effective unit testing practices, the chapter "Setting Up the Unit Testing Environment" focuses on establishing the necessary infrastructure and tools. This process involves configuring the development environment with appropriate testing frameworks, such as NUnit, xUnit, and MSTest, and seamlessly integrating it with the chosen IDE. To ensure test isolation and simulate interactions with external components, developers use test dependencies, such as mocking libraries or test runners. By properly configuring build tools and version control systems, developers are able to automate test execution and seamlessly integrate testing into their development workflows, increasing the efficiency and reliability of the unit testing environment. Teams can contribute to high-quality, bug-free software products by setting up a robust unit testing environment that lays the groundwork for consistent and reliable software testing practices.

Integration with Visual Studio

As a kickstart to your journey to mastering unit testing with C# and .NET 8, this section examines how unit testing capabilities can be seamlessly integrated into Visual Studio. To enable and leverage Visual Studio's built-in features for efficient unit testing, we take you through the setup of test projects, configuring the test explorer, and using the test runner.

Example: Integration with Visual Studio

```
[TestClass]
public class MyUnitTest
{
    [TestMethod]
    public void TestMethod1()
    {
        // Arrange
        var calculator = new Calculator();

        // Act
        var result = calculator.Add(2, 3);

        // Assert
        Assert.AreEqual(5, result);
    }
}
```

Configuring Test Projects

This segment discusses how to set up C# and .NET 8 test projects in order to ensure a well-defined testing environment. We cover project settings, dependencies, and test-specific configurations. For a smooth testing experience, learn how to manage NuGet packages, handle dependencies, and set up project references.

Example: Configuring Test Projects

```
<Project Sdk="Microsoft.NET.Sdk">

  <PropertyGroup>
    <TargetFramework>netcoreapp3.1</TargetFramework>
  </PropertyGroup>

  <ItemGroup>
    <PackageReference Include="NUnit" Version="3.12.0" />
    <!-- Additional test-related packages -->
  </ItemGroup>

</Project>
```

Creating and Organizing Test Classes

We will discuss how to create and organize test classes effectively in the final part of this chapter. In order to ensure a clear and logical organization of tests, understand how to categorize and group them based on functionalities.
Example: Creating and Organizing Test Classes

```
[TestClass]
public class CalculatorTests
{
    [TestMethod]
    public void Add_TwoNumbers_ReturnsSum()
    {
        // Arrange
        var calculator = new Calculator();
        // Act
        var result = calculator.Add(2, 3);
        // Assert
        Assert.AreEqual(5, result);
    }

    [TestMethod]
    public void Subtract_TwoNumbers_ReturnsDifference()
    {
        // Arrange
        var calculator = new Calculator();

        // Act
        var result = calculator.Subtract(5, 3);

        // Assert
        Assert.AreEqual(2, result);
    }
}
```

As a result of this chapter, readers will be able to set up a robust unit testing environment, integrate seamlessly with Visual Studio, configure test projects, and organize test classes efficiently.

4

Writing Effective Unit Tests

Overview

In this chapter, we delve into Azure Cognitive Services, exploring its pre-made AI features for easier AI development and integration. We cover the basics of Cognitive Services, their functionalities, and their role in AI application development. The chapter includes a focus on Vision Services for image and video analysis, Language Services for natural language processing and chatbot intelligence, and Speech Services for speech recognition and interaction. We also discuss Decision and Anomaly Detection Services for personalized content and anomaly detection in various industries.

Characteristics of Good Unit Tests

A cornerstone of robust software development is the creation of effective unit tests. This section explains some of the characteristics that make a high-quality unit test. Examples illustrate how a test should be independent, clear, and concise. Below is an example of a test.

```
[TestMethod]

public void Add_TwoNumbers_ReturnsSum()

{

    // Arrange

    Calculator calculator = new Calculator();

    // Act

    int result = calculator.Add(3, 5);

    // Assert

    Assert.AreEqual(8, result);

}
```

Test Naming Conventions

As a result of consistent and descriptive test names, code is easy to read and maintain. This part outlines the naming conventions to adopt across projects, promoting a standardized approach.

```
[TestMethod]

public void Add_WhenAddingTwoNumbers_ReturnsSum()

{

    // Arrange

    Calculator calculator = new Calculator();

    // Act

    int result = calculator.Add(3, 5);

    // Assert

    Assert.AreEqual(8, result);

}
```

Test Data Management and Factories

Developing effective unit tests requires well-managed test data. This section examines ways to organize and manage test data, as well as using factories to simplify the test object creation process.

```
public static class TestDataFactory
{
    public static User CreateValidUser()
    {
        return new User
        {
            UserName = "TestUser",
            Email = "testuser@example.com",
            // ... other properties
        };
    }
}
```

[TestMethod]

```
public void RegisterUser_ValidUser_SuccessfulRegistration()
{
    // Arrange
    UserService userService = new UserService();
    User validUser = TestDataFactory.CreateValidUser();

    // Act
    bool registrationResult = userService.RegisterUser(validUser);

    // Assert
    Assert.IsTrue(registrationResult);
}
```

This comprehensive examination accompanied by illustrative code snippets will help developers create effective unit tests aligned with industry standards.

5

Test Execution and Lifecycle

Overview

In this chapter, we explore Characteristics of Effective Unit Tests. Explores key attributes of high-quality unit tests: independence, clarity, and conciseness. Covers test naming conventions for readability, data management techniques, and factories for streamlined test object creation, empowering developers to create robust and maintainable test suites."

Test Execution Workflow

Identifying the sequence of events during test execution is essential for mastering unit testing. This section explains the 'Arrange-Act-Assert' pattern.

```
[TestMethod]
public void Withdraw_ValidAmount_ReducesBalance()
{
    // Arrange
    Account account = new Account("John Doe", 1000);

    // Act
    account.Withdraw(500);

    // Assert
    Assert.AreEqual(500, account.Balance);
}
```

Test Discovery and Execution Order

An understanding of how tests are discovered and executed is critical to effective unit testing. This section examines how NUnit, xUnit, and MSTest discover and run tests. [TestMethod]

```
public void TestMethod1()
{
    // Test logic
}

[TestMethod]
public void TestMethod2()
{
    // Test logic
}

[TestMethod]
public void TestMethod3()
{
    // Test logic
}
```

Managing Test Dependencies

This section provides strategies for managing test dependencies, such as dependency injection and mocking frameworks. An example using Moq for mocking dependencies is provided.

```
[TestMethod]
public void PurchaseItem_InsufficientFunds_ReturnsErrorMessage()
{
    // Arrange
    var paymentServiceMock = new Mock<IPaymentService>();
    paymentServiceMock.Setup(ps =>
ps.AuthorizePayment(It.IsAny<decimal>()))
                      .Returns(false);

    ShoppingCart cart = new ShoppingCart(paymentServiceMock.Object);

    // Act
    string result = cart.PurchaseItem("Laptop", 1200);

    // Assert
    Assert.AreEqual("Insufficient funds", result);
}
```

Through real-world examples, this chapter guides developers through the intricacies of test execution, ensuring that they have a comprehensive understanding of the test lifecycle.

6

Mocking and Stubbing

Overview

In this chapter, we explore equipping developers with the skills and knowledge required to create high-quality unit tests. For writing robust, maintainable, and efficient unit tests, this chapter explains fundamental principles and best practices. Test cases are defined clearly, test suites are organized efficiently, and assertions are written to verify code behaviour by developers. This chapter also discusses strategies for isolating code units and facilitating thorough testing by handling test dependencies, such as mocking and stubbing. Developers can improve the quality of their code, identify defects early in the development process, and ensure their software applications are reliable and stable by mastering the art of writing effective unit tests.

Moq Example

```
// Arrange
var mockRepository = new Mock<IRepository>();
mockRepository.Setup(repo => repo.GetById(It.IsAny<int>()))
    .Returns(new SampleEntity { Id = 1, Name = "MockedEntity" });

// Act
var service = new SampleService(mockRepository.Object);
var result = service.GetEntityById(1);

// Assert
Assert.NotNull(result);
Assert.Equal("MockedEntity", result.Name);

NSubstitute Example:
// Arrange
var substituteRepository = Substitute.For<IRepository>();
substituteRepository.GetById(Arg.Any<int>())
    .Returns(new SampleEntity { Id = 1, Name = "SubstituteEntity" });

// Act
var service = new SampleService(substituteRepository);
var result = service.GetEntityById(1);

// Assert
Assert.NotNull(result);

Assert.Equal("SubstituteEntity", result.Name);
```

Creating Mock Objects

The purpose of this section is to demonstrate how to establish expectations, handle parameterized inputs, and verify interactions with mock objects using both Moq and NSubstitute. Mock Object Creation with Moq:

```
// Arrange
var mockLogger = new Mock<ILogger>();

// Act
var loggerService = new LoggerService(mockLogger.Object);
loggerService.Log("Mocking is powerful!");

// Assert
mockLogger.Verify(logger => logger.Log(It.IsAny<string>()),
Times.Once);

Mock Object Creation with NSubstitute:
// Arrange
```

```
var substituteLogger = Substitute.For<ILogger>();

// Act
var loggerService = new LoggerService(substituteLogger);
loggerService.Log("NSubstitute in action!");

// Assert
substituteLogger.Received(1).Log(Arg.Any<string>());
```

Stubbing External Dependencies

As part of this part, we explore the art of stubs, emphasizing the importance of isolating the system under test. By using code examples, we demonstrate how external calls can be replaced with controlled stubs, ensuring predictable behavior during a unit test.

```
// Arrange
var dataProvider = Substitute.For<IDataProvider>();
dataProvider.GetData().Returns(new List<string> { "stubbed", "data" });

// Act
var dataProcessor = new DataProcessor(dataProvider);
var result = dataProcessor.ProcessData();

// Assert
Assert.Equal("Processed: stubbed, data", result);
```

By the end of this chapter, readers will have a comprehensive understanding of mocking and stubbing, providing them with powerful tools for enhancing the effectiveness of their unit tests.

7

Understanding Code Coverage

Overview

In this chapter, we explore Visual Studio's Code Coverage and Code Analysis. Explores enabling and utilizing code coverage in Visual Studio, followed by code metrics measurement using tools like ReSharper. Readers learn to interpret results, identify areas for improvement, and refactor code to enhance coverage and maintainability, ensuring high-quality C# and .NET 8 applications.

Example Using Visual Studio's Code Coverage

- Enable code coverage in Visual Studio.
- Run tests with coverage analysis.
- Review the coverage results.

Sample Test

```
[TestMethod]
public void CalculateTotal_CorrectlyCalculatesTotal_CoverageExample()
{
    // Arrange
    var order = new Order { Items = new List<Item> { new Item { Price =
10 } } };

    // Act
    var total = order.CalculateTotal();

    // Assert
    Assert.AreEqual(10, total);
}
```

Measuring Code Metrics with Code Analysis Tools

This part introduces code analysis tools available in Visual Studio and other popular tools like ReSharper. Through hands-on examples, readers learn how to measure code metrics such as cyclomatic complexity, maintainability index, and more. The goal is to use these tools to identify code quality areas for improvement.

Using ReSharper to Analyze Code Metrics

- Install ReSharper extension.
- Run code analysis on the solution.
- Review and interpret code metrics.

Sample Code with High Cyclomatic Complexity

```
public string ProcessData(List<string> data)
{
    if (data == null || data.Count == 0)
    {
        return "No data to process.";
    }

    foreach (var item in data)
    {
        if (!string.IsNullOrEmpty(item))
        {
            ProcessItem(item);
        }
```

```
    }

    return "Data processed successfully.";
}
```

Interpreting Results and Improving Coverage

In this segment, readers learn how to interpret code coverage and metrics results and identify areas of low coverage and refactor code to improve coverage. The chapter concludes with best practices for achieving high coverage while writing effective tests.

```
// Low Coverage Area Identified
// Original Code
public bool ValidateInput(string input)
{
    return !string.IsNullOrEmpty(input) && input.Length > 5;
}

// Refactored Code
public bool ValidateInput(string input)
{
    return !string.IsNullOrEmpty(input) && input.Length > 3;
}
```

Upon completion of this chapter, readers will have a solid understanding of code coverage, code metrics, and how to use them to enhance the robustness and maintainability of their C# and .NET 8 applications.

8

Integrating Unit Tests into CI/CD Pipelines

Overview

In this Chapter, we explore Unit Tests into CI/CD Pipelines" emphasizes seamless unit testing automation within Continuous Integration/Continuous Deployment workflows. Through Jenkinsfiles and Azure Pipelines YAML, teams automate testing, ensuring rapid feedback, code quality maintenance, and collaboration enhancement. Cloud-based CI/CD services offer scalability and reliability, promoting robust software delivery.

Integrating Unit Tests into CI/CD Pipelines

The emphasis is on incorporating unit testing seamlessly into Continuous Integration/Continuous Deployment (CI/CD) workflows in this section, "Integrating Unit Tests into CI/CD Pipelines." The CI/CD pipeline enables developers to automate unit tests to ensure rapid feedback on code changes and early bug detection. Teams can maintain code quality, accelerate software delivery, and enhance collaboration across the development lifecycle by integrating unit tests into the pipeline.

Overview of CI/CD Integration

It highlights the use of Jenkinsfiles with Declarative Pipeline syntax to automate software delivery processes for continuous integration and continuous delivery. In this example, the pipeline consists of phases, including "Build" and "Test." The "Build" stage compiles the code, while the "Test" stage executes unit tests using the 'dotnet test' command. By automating the testing process, this integration ensures that code changes are thoroughly tested before deployment. A CI/CD approach can help teams deliver software faster, more reliably, improve collaboration, and reduce the risk of introducing bugs into production environments.

```
# Jenkinsfile (Declarative Pipeline)
pipeline {
    agent any

    stages {
        stage('Build') {
            steps {
                // Build steps
            }
        }
        stage('Test') {
            steps {
                // Execute unit tests
                sh 'dotnet test'
            }
        }
        // Additional stages for deployment, etc.
    }
}
```

Gain an understanding of the fundamental concepts and significance of CI/CD.

Modern software development practices require an understanding of CI/CD fundamentals and significance. CI (Continuous Integration) involves automating the integration of code changes into a shared repository multiple times a day, ensuring that changes are integrated smoothly and conflicts are detected as soon as possible. By automating the deployment of code changes to production or staging environments, CD (Continuous Delivery/Continuous Deployment) extends CI. Streamlining the development process reduces manual errors, enhances team collaboration, accelerates time to market, and improves software quality and customer satisfaction.

Discover how early integration of unit tests improves code quality.

Early integration of unit tests significantly enhances code quality by detecting bugs and issues at an early stage of development. Developers are able to identify new code changes as soon as possible by incorporating unit tests into the CI/CD pipeline. By detecting errors at an early stage of development or production, errors can be promptly debugged and resolved, preventing them from spreading to later stages. Additionally, unit tests serve as documentation for the expected behavior of individual code units, making code more maintainable and facilitating future modifications possible. The early integration of unit tests fosters the development of robust, reliable software products and promotes a culture of quality assurance.

Configuring CI/CD Pipelines

With the Azure Pipelines YAML configuration provided, a robust CI/CD pipeline can be configured for .NET projects. By automating the build, testing, and deployment processes, this pipeline ensures continuous integration and delivery when commits are made to the main branch. By specifying a 'windows-latest' virtual machine image, it ensures compatibility with Windows-based environments, common in .NET development. As part of the 'Build' job, essential tasks are executed, including fetching the latest code, installing the appropriate .NET SDK version, building the project in Release configuration, and running unit tests. By promptly detecting errors and verifying expected behaviour, automation not only speeds up development, but also improves code quality. Additionally, the YAML-based configuration offers version-controlled and reproducible setups, ensuring consistency and reliability across development, testing, and deployment environments. Using YAML scripts to configure continuous integration and continuous delivery pipelines can streamline software delivery, reduce manual effort, and ensure high-quality software delivery.

```
# Azure Pipelines YAML
trigger:
- main

pool:
  vmImage: 'windows-latest'

jobs:
- job: Build
  steps:
  - checkout: self
  - task: UseDotNet@2
    inputs:
      packageType: 'sdk'
      version: '3.1.x'
      installationPath: $(Agent.ToolsDirectory)/dotnet
  - script: dotnet build --configuration Release
  - script: dotnet test --configuration Release
  # Additional steps for deployment, etc.
```

Using Jenkins and Azure Pipelines, we will walk through configuring CI/CD pipelines.

As part of our exploration of Continuous Integration/Continuous Delivery pipelines, we will discuss how to configure and customize CI/CD workflows tailored to your specific project requirements using Jenkins and Azure Pipelines. Using Jenkins, an open-source automation server, and Azure Pipelines, a cloud-based Continuous Integration/Continuous Delivery service, we will cover the steps necessary to automate builds, tests, and deployments. With practical examples and walkthroughs, developers will learn how to build robust CI/CD pipelines that improve productivity, ensure code quality, and accelerate software development. This exploration aims to provide valuable guidance and expertise on how to set up efficient and effective CI/CD pipelines, whether you are an experienced developer or new to them.

Construct tests for different pipeline stages by scripting and configuring them

Through scripting and configuration, we will create tests tailored for the various pipeline stages as part of our journey of pipeline construction. We ensure comprehensive validation of code changes at each stage of the development process by crafting tests for different stages of the pipeline. Our goal is to demonstrate how to define and execute unit tests, integration tests, and end-to-end tests seamlessly within the Continuous Integration/Continuous Delivery pipeline. Software development lifecycles are rigorously tested to ensure functionality, performance, and reliability of code changes. In this course, developers will learn how to build tests that enhance the quality and robustness of their continuous integration/continuous delivery pipelines, leading to high-quality software delivery.

Leveraging CI/CD Platforms

In this section, we'll explore the seamless integration of unit tests into major CI/CD solutions and highlight the advantages of leveraging cloud-based CI/CD services for scalability and reliability. In this presentation, we will show how unit tests can be easily integrated into popular CI/CD platforms such as Jenkins, Azure Pipelines, and GitHub Actions, providing code examples and configurations for each platform. It reduces the risk of introducing bugs and promotes code quality by integrating unit tests into the CI/CD pipeline. Additionally, we'll provide an overview of the benefits offered by cloud-based CI/CD services, such as scalability, reliability, and ease of setup. Through practical demonstrations and insights, developers will gain a deeper understanding of how to harness the power of CI/CD platforms and cloud services to streamline their development workflows and deliver high-quality software with confidence.

```
# Jenkinsfile (Declarative Pipeline)
pipeline {
    agent any

    stages {
        stage('Build') {
            steps {
                // Build steps
            }
        }
```

```
        stage('Test') {
            steps {
                // Execute unit tests
                sh 'dotnet test'
            }
        }
        // Additional stages for deployment, etc.
    }
}

# Azure Pipelines YAML
trigger:
- main

pool:
  vmImage: 'windows-latest'

jobs:
- job: Build
  steps:
  - checkout: self
  - task: UseDotNet@2
    inputs:
      packageType: 'sdk'
      version: '3.1.x'
      installationPath: $(Agent.ToolsDirectory)/dotnet
  - script: dotnet build --configuration Release
  - script: dotnet test --configuration Release
  # Additional steps for deployment, etc.

# GitHub Actions Workflow
name: CI

on:
  push:
    branches:
      - main

jobs:
  build:
    runs-on: windows-latest

    steps:
    - name: Checkout code
      uses: actions/checkout@v2

    - name: Setup .NET
      uses: actions/setup-dotnet@v1
```

```
      with:
        dotnet-version: '3.1.x'

    - name: Build
      run: dotnet build --configuration Release

    - name: Test
      run: dotnet test --configuration Release
```

Continuing from the code examples, these snippets demonstrate how unit tests can be integrated into CI/CD pipelines using various platforms. Unit tests are executed as part of the automated pipeline in the Jenkinsfile, which uses a dedicated 'Test' stage. Likewise, Azure Pipelines YAML configuration uses the dotnet test command to run unit tests. A 'Test' job is defined in the GitHub Actions workflow to execute unit tests after the project has been built. Unit testing ensures that code changes are thoroughly validated, allowing for early detection of bugs and maintaining code quality. Cloud-based CI/CD services provide additional benefits, including scalability and reliability. Teams can scale their CI/CD infrastructure as needed using on-demand resources, and redundancy and monitoring are built in for enhanced reliability. With these platforms, developers can focus on developing quality software while CI/CD infrastructure handles the heavy lifting of building, testing, and deploying applications.

Real-world CI/CD Scenarios

Our goal in this section is to explore the diverse testing scenarios that can be handled seamlessly by CI/CD pipelines in the real world. We'll provide concrete examples of how CI/CD pipelines can be configured to execute different types of tests, such as unit tests, integration tests, end-to-end tests, and performance tests. We'll illustrate how each type of test contributes to software quality and reliability through practical demonstrations and code examples. Moreover, we will show strategies for optimizing pipeline execution times by parallelizing tests and leveraging cloud-based resources. Developers can significantly shorten the time it takes to run tests by distributing them across multiple parallel jobs or stages, speeding up the feedback loop and enabling code changes to be delivered more quickly. We will demonstrate how to implement parallel test execution in CI/CD pipelines using popular platforms such as Jenkins, Azure Pipelines, and GitHub Actions, providing code examples and best practices.

```
# Jenkinsfile (Declarative Pipeline)
pipeline {
    agent any

    stages {
        stage('Build') {
            steps {
                // Build steps
            }
        }
        stage('Test') {
            parallel {
                stage('Unit Tests') {
                    steps {
```

```
                        // Execute unit tests
                        sh 'dotnet test --filter Category=Unit'
                    }
                }
                stage('Integration Tests') {
                    steps {
                        // Execute integration tests
                        sh 'dotnet test --filter Category=Integration'
                    }
                }
            }
        }
        // Additional stages for deployment, etc.
    }
}

# Azure Pipelines YAML
trigger:
- main

pool:
  vmImage: 'windows-latest'

jobs:
- job: Build
  steps:
  - checkout: self
  - task: UseDotNet@2
    inputs:
      packageType: 'sdk'
      version: '3.1.x'
      installationPath: $(Agent.ToolsDirectory)/dotnet
  - script: dotnet build --configuration Release

- job: Test
  dependsOn: Build
  parallelStrategy:
    matrix:
      Unit:
        displayName: 'Run Unit Tests'
        script: dotnet test --configuration Release --filter
Category=Unit
      Integration:
        displayName: 'Run Integration Tests'
        script: dotnet test --configuration Release --filter
Category=Integration
#GitHub Actions Workflow
name: CI
```

```
on:
  push:
    branches:
      - main

jobs:
  build:
    runs-on: windows-latest

    steps:
    - name: Checkout code
      uses: actions/checkout@v2

    - name: Setup .NET
      uses: actions/setup-dotnet@v1
      with:
        dotnet-version: '3.1.x'

    - name: Build
      run: dotnet build --configuration Release

  test:
    needs: build
    runs-on: windows-latest
    strategy:
      matrix:
        category: ['Unit', 'Integration']
    steps:
    - name: Checkout code
      uses: actions/checkout@v2

    - name: Setup .NET
      uses: actions/setup-dotnet@v1
      with:
        dotnet-version: '3.1.x'

    - name: Run Tests
      run: dotnet test --configuration Release --filter
Category=$category
```

By utilizing parallelization, these code examples demonstrate how to configure CI/CD pipelines to handle different testing scenarios. These strategies allow developers to test their applications thoroughly while minimizing the time it takes to deliver code changes.
CI/CD pipelines can effectively handle various testing scenarios in real-world CI/CD environments to ensure software application quality and reliability. In unit tests, for example, individual components or units of code are tested in isolation to ensure they behave as expected. The integration test identifies issues arising from the integration of different

components or services. By simulating user interactions and ensuring seamless functionality across the system, end-to-end tests validate the entire application workflow. Performance tests are also used to identify performance bottlenecks and optimize resource utilization by assessing the scalability and responsiveness of applications under different load conditions.
In order to optimize pipeline execution times, it is crucial to parallelize tests. Large-scale projects with extensive test suites can benefit from accelerating the feedback loop by distributing tests across multiple parallel jobs or stages. This is particularly helpful on large-scale projects. As shown in the examples, Jenkins' parallel directive, Azure Pipelines' parallelStrategy property, and GitHub Actions' matrix strategy are used to parallelize tests. Iteration cycles can be shortened by running tests in parallel, enabling developers to validate code changes faster.
Closing off this section, leveraging CI/CD pipelines for real-world scenarios helps developers ensure the quality, reliability, and performance of their software applications. Developers can streamline development processes, accelerate delivery, and deliver high-quality software products by optimizing execution times through parallelization and configuring pipelines to handle diverse testing scenarios. In today's fast-paced software development world, teams can drive innovation, respond to customer feedback, and remain competitive through continuous testing and iteration.

Automated Testing in Build Processes

In the "Automated Testing in Build Processes" section, we explore the seamless integration of automated testing into CI/CD pipelines' build processes. To ensure software reliability and quality, automated testing is essential, catching bugs early in development. By using code examples, we show how various tests, such as unit, integration, and end-to-end tests, can be run as part of the build process, ensuring comprehensive coverage. To optimize test execution time, we also discuss strategies such as parallelization and cloud resources. It is possible to accelerate software development cycles, ensure software quality, and meet modern software delivery demands effectively by integrating automated testing into build processes.

Role of Automated Tests in Builds

The provided code snippet illustrates the role of automated tests in builds, utilizing MSBuild to build and run tests within a .NET project. The dotnet build command compiles the project, while the dotnet test command executes automated tests. By identifying any regressions or defects early in the development process, code changes are not only compiled successfully but also rigorously tested, thereby helping maintain code quality.
Automated testing is crucial within the build process as it serves as a gatekeeper for code quality. By automatically executing tests upon each build, developers can identify and rectify any issues introduced by recent changes in the code. The project is only integrated with high-quality, reliable code as a result of this culture of continuous quality assurance.
Through practical examples, the importance of automated tests in maintaining code quality is also stressed. A developer can ensure that new code changes do not introduce regressions or break existing functionality by running automated tests as part of the build process. As a result of this proactive testing approach, defects are caught early, which reduces the risk of shipping defective software.
By enforcing code quality standards and identifying issues early in the development lifecycle, automated testing plays an essential role in builds. Development workflows can be streamlined, code reliability can be improved, and high-quality software products can be delivered with confidence when automated tests are integrated into the build process.

```
# MSBuild with Test Execution
dotnet build
dotnet test
```

Dotnet build is used in this example above to compile the project, ensuring that all code changes are successfully compiled. In addition to running automated tests following the build process, dotnet test also ensures that the code changes maintain quality and meet the expected functionality.

Configuring Build Scripts

In the provided code snippet, you will see a typical MSBuild project (.csproj) used to configure the build process of a .NET project. The file contains various elements that describe the project's settings, dependencies, and configurations. The OutputType element specifies the project's output type, while the TargetFramework element specifies the version of the .NET framework the project is targeting. Moreover, the <PackageReference> elements specify the NuGet packages required for testing purposes, including Microsoft.NET.Test.Sdk, xunit, and xunit.runner.visualstudio. A standardized and reproducible build environment ensures consistency across different development environments, facilitating seamless collaboration between team members and ensuring consistency across development environments. By centralizing project configurations within the .csproj file, developers can streamline the build process, mitigate compatibility issues, and maintain code quality and reliability throughout the project's lifecycle.

```
<!-- MSBuild Project File (.csproj) -->
<Project Sdk="Microsoft.NET.Sdk">

  <PropertyGroup>
    <OutputType>Exe</OutputType>
    <TargetFramework>net5.0</TargetFramework>
  </PropertyGroup>

  <ItemGroup>
    <PackageReference Include="Microsoft.NET.Test.Sdk" Version="16.7.1"
/>
    <PackageReference Include="xunit" Version="2.4.1" />
    <PackageReference Include="xunit.runner.visualstudio"
Version="2.4.3" />
  </ItemGroup>

</Project>
```

Key Takeaways

- Exercising unit tests automatically can be achieved by configuring build scripts.
- Examine the integration of build tools with testing frameworks, such as MSBuild.

Test Parallelization

"Test Parallelization" explores strategies for parallelizing tests and balancing parallelization with resource constraints to improve feedback speed. In projects with extensive test suites, parallelizing tests is imperative for accelerating feedback speed. Developers can reduce the overall test execution time by running tests concurrently, resulting in faster feedback and shorter iteration cycles on code changes.
Using the built-in features provided by testing frameworks or developing custom parallelization techniques can help developers develop effective strategies for parallelizing tests. It is possible to run parallel tests across multiple threads or processes using testing frameworks such as NUnit, xUnit, and JUnit, for example. Furthermore, developers can utilize parallel execution features provided by CI/CD platforms or implement custom parallelization strategies using tools like TestNG.
However, it's crucial to consider how parallelization can be balanced with resource constraints, such as CPU and memory limitations. Inadequate parallelization can lead to performance degradation or system instability if too many tests are run concurrently. Therefore, developers should carefully configure parallelization settings to ensure optimal resource utilization and avoid resource contention.

The following code examples demonstrate how to parallelize tests using popular testing frameworks:

```
// NUnit Parallelization Example
[TestFixture]
[Parallelizable(ParallelScope.All)]
public class MyTests
{
    [Test]
    public void Test1()
    {
        // Test code
    }

    [Test]
    public void Test2()
    {
        // Test code
    }
}

// TestNG Parallelization Example
public class MyTests {
    @Test
    public void test1() {
        // Test code
    }

    @Test
```

```
    public void test2() {
        // Test code
    }
}
```

Using NUnit and TestNG, these code examples demonstrate how tests can be annotated or configured to run in parallel. Developers can speed up test execution, improve feedback speed, and enhance overall development efficiency by judiciously applying parallelization techniques and considering resource constraints.

Build-time Code Quality Checks

In the "Build-time Code Quality Checks" section, we'll explore how to implement code quality checks during the build process and integrate static code analysis tools. Throughout development, these checks ensure that the codebase adheres to best practices and maintains a high level of quality.
The most common way to implement code quality checks during the build process is by using a task runner or build automation tool such as MSBuild, Gradle, or Maven. These tools allow developers to define custom build tasks that execute code quality checks.

MSBuild is a popular build automation tool for .NET projects. Let's take a look at an example:

```
<!-- Example MSBuild configuration for code quality checks -->
<Project>
  <Target Name="CodeQualityChecks" AfterTargets="Build">
    <!-- Execute static code analysis using Roslyn Analyzers -->
    <Exec Command="dotnet analyze" />

    <!-- Execute code formatting using a tool like Prettier -->
    <Exec Command="prettier --check src/*.js" />

    <!-- Execute other code quality checks as needed -->
    <!-- For example, running unit tests, checking for code
duplication, etc. -->
  </Target>
</Project>
```

As an example, we define a "CodeQualityChecks" MSBuild target that executes after the "Build" target. Within this target, Roslyn Analyzers and Prettier are used to run static code analysis and code formatting. A variety of other code quality checks can be incorporated, including running unit tests and checking for duplication.
Developers can identify potential issues early and enforce coding standards consistently across the codebase by integrating static code analysis tools such as Roslyn Analyzers and ESLint into the build process. By taking a proactive approach to code quality, you help maintain a clean and maintainable codebase, which leads to better software quality and developer productivity.

Key Takeaways

- Demonstrate the implementation of code quality checks during build time.
- Discuss the integration of static code analysis tools.

Handling Continuous Deployment Challenges

As part of continuous deployment, various complexities arise that require a strategic approach. Maintaining system stability and minimizing downtime is one of the biggest challenges associated with ensuring a seamless transition of code changes from development to production environments. It is possible to mitigate risks associated with deploying new code by implementing robust deployment pipelines with automated testing, canary releases, and feature toggles. In addition, managing configuration drift, dependency versioning, and environment inconsistencies across different deployment targets is challenging. By adopting infrastructure-as-code (IaC) practices and containerization technologies like Docker, deployments across diverse environments can be consistent and reproducible. Furthermore, monitoring and observability solutions play a crucial role in detecting and responding to deployment issues in real-time, enabling rapid rollback or remediation when needed. Companies can streamline their continuous deployment processes and achieve faster, more reliable deployments while maintaining system integrity by addressing these challenges proactively and utilizing automation and monitoring tools effectively.

Deployment Challenges Overview

```
# Deploy Stage with Rollback Strategy (Azure Pipelines)
- stage: Deploy
  dependsOn: Test
  jobs:
  - deployment: DeploymentJob
    pool:
      vmImage: 'windows-latest'
    environment: 'production'
    strategy:
      runOnce:
        deploy:
          steps:
          - task: AzureRmWebAppDeployment@4
            inputs:
              ConnectionType: 'AzureRM'
              azureSubscription: 'YourAzureSubscription'
              appType: 'webApp'
              WebAppName: 'YourWebAppName'
              packageForLinux:
'$(System.DefaultWorkingDirectory)/**/*.zip'
```

- Examine the challenges associated with continuous application deployment.
- Examine the importance of thorough testing before deployment.

Environment-specific Configurations

```
// appsettings.json
{
  "ConnectionStrings": {
```

```
    "DefaultConnection":
"Server=(localdb)\\mssqllocaldb;Database=MyDatabase;Integrated
Security=True;"
  },
  "Logging": {
    "LogLevel": {
      "Default": "Information",
      "Microsoft": "Warning",
      "Microsoft.Hosting.Lifetime": "Information"
    }
  }
}
```

- Manage environment-specific configuration challenges.
- Provide solutions for maintaining consistency across different deployment environments.

Canary Releases and Feature Toggles

- As a strategy for controlled deployment, introduce canary releases and feature toggles.
- Describe scenarios where these strategies would be beneficial.

Rollback Strategies

- If a test fails post-deployment, provide insights into handling rollback strategies.
- To detect deployment issues, monitoring and alerting are essential.

Readers will encounter hands-on code examples illustrating C# and .NET 8 CI/CD best practices throughout the chapter. Developers will gain practical insights into building robust, automated, and reliable CI/CD pipelines by the end of the course.

9

Test Maintenance and Refactoring

Overview

In this Chapter, we explore Identify and Refactor Fragile Tests, developers tackle the challenge of maintaining robust test suites by understanding and refactoring fragile tests. Strategies include using mock data, isolating dependencies, and regular test reviews. Versioning test data and adhering to best practices ensure lasting test effectiveness and code quality.

Identifying and Refactoring Fragile Tests

In pursuit of robust test suites, identifying and refactoring fragile tests stands as a pivotal task. Maintaining a reliable testing ecosystem is difficult with fragile tests, which are susceptible to breaking with even minor changes to application code. An understanding of what constitutes fragile tests and practical strategies for refactoring them is presented in this section. With code examples and insights, developers gain valuable insight into how to isolate dependencies, utilize mock data, and enhance test resilience, ensuring their test suites remain effective and adaptable despite evolving codebases.

Understanding Fragile Tests

A fragile test breaks easily when the application code changes. Maintaining a robust test suite requires identifying and refactoring them.

```
// Fragile Test Example
[Test]
public void TestLogin()
{
    // Existing test code...
    Assert.AreEqual("Welcome", userService.Login("john", "password"));
}
```

Refactoring Fragile Test

The test can be refactored to use mock data or isolate dependencies, reducing its sensitivity to changes.

```
[Test]
public void TestLogin()
{
    // Refactored test code...
    var mockUserService = new Mock<IUserService>();
    mockUserService.Setup(u => u.Login(It.IsAny<string>(),
It.IsAny<string>())).Returns("Welcome");

    var result = mockUserService.Object.Login("john", "password");

    Assert.AreEqual("Welcome", result);
}
```

Strategies for Test Maintenance

Adopting effective strategies for test maintenance is crucial to maintaining the integrity and relevance of test suits. As applications evolve, this section explores a variety of strategies for ensuring that tests remain effective and lasting. It discusses various strategies for aligning tests with code changes, versioning test data to ensure consistency across environments, and

adhering to best practices for testing code quality. Developers can promote stability and reliability throughout the software development lifecycle by implementing these strategies.

Regularly Reviewing Tests

The tests should be reviewed and updated on a regular basis to ensure that they remain relevant and effective as the application evolves.

```
# Schedule test review in CI/CD pipeline
schedule:
- cron: "0 0 * * *"
  branches:
    include:
    - main
```

Versioning Test Data

Keep track of changes and maintain consistency across environments by version controlling test data.

```
// testdata.json
{
  "users": [
    {"username": "john", "password": "password"},
    {"username": "alice", "password": "secure123"}
  ]
}
```

Best Practices for Test Code Quality

In striving for optimal test code quality, adhering to best practices is paramount. This section delves into essential guidelines and principles to uphold when crafting test code. Using the Arrange-Act-Assert (AAA) pattern makes tests clear and structured, improving readability and maintainability. It is also beneficial to incorporate code reviews into development processes to foster collaboration and maintain high standards for test code. By focusing on meaningful names, edge case coverage, and adherence to established patterns, developers can elevate the quality of their test suites, bolstering confidence in the reliability of their software.

Follow Arrange-Act-Assert (AAA) Pattern

Readability and maintainability are ensured with structured tests based on the AAA pattern.

```
// AAA Pattern Example
[Test]
public void TestCalculateTotal()
{
    // Arrange
    var cart = new ShoppingCart();
    cart.AddProduct(new Product("Laptop", 1000));
```

```
    // Act
    var total = cart.CalculateTotal();

    // Assert
    Assert.AreEqual(1000, total);
}
```

Code Reviews for Test Code

Test code reviews should be incorporated into the development process to ensure that test code is high-quality.

Code Review Checklist

- Does the test focus on a single function?
- Do variables and methods have meaningful names?
- Is the test designed to cover edge cases?

For ensuring the longevity and effectiveness of your unit tests in a C# and .NET 8 environment, Chapter IX explores test maintenance and refactoring, offering practical strategies and best practices. To enhance the quality of your test suite, these code examples demonstrate how to identify, refactor, and maintain tests.

10

Performance and Load Testing

Overview

In this chapter, we will explore an essential part of software testing is Performance Testing, which evaluates an application's responsiveness, stability, and scalability under various conditions. An overview of Performance Testing is provided in this section, emphasizing its importance in ensuring optimal application performance. Testing an application's performance, such as load testing, stress testing, and scalability testing, is an important step in identifying potential bottlenecks and optimizing it. Developers gain a solid understanding of Performance Testing and its role in delivering high-quality software solutions through practical examples and insights.

Understanding Performance Testing

A performance test measures the responsiveness, stability, and scalability of an application under various conditions.

```
// Sample Performance Test
[PerformanceTest]
public void TestApplicationResponseTime()
{
    // Test setup code...
    var stopwatch = new Stopwatch();

    // Measure response time
    stopwatch.Start();
    applicationService.ProcessRequest();
    stopwatch.Stop();

    // Assert within acceptable response time
    Assert.Less(stopwatch.ElapsedMilliseconds, 100);
}
```

Types of Performance Tests

Examine different types of performance testing, such as load testing, stress testing, and scalability testing.

```
// Load Testing Example
[LoadTest]
public void TestApplicationUnderLoad()
{
    // Load test setup code...
    Parallel.For(0, 100, i => applicationService.ProcessRequest());
}
```

Integrating Performance Tests with Unit Tests

A strategic approach to building comprehensive software development testing suites is to integrate performance tests with unit tests. In order to ensure that their codebase is functional and efficient, developers can seamlessly combine performance evaluations with unit tests. Several practical examples of how performance tests can be incorporated into existing unit testing frameworks are presented in this section, which explains the benefits and methodologies of this integration. With this unified approach, developers are able to evaluate both the functionality and performance aspects of their applications, resulting in a higher level of software quality and reliability.

Combining Performance and Unit Tests

A comprehensive testing suite can be built by seamlessly integrating performance tests with unit tests.

```
// Combined Unit and Performance Test
[Test]
[PerformanceTest]
public void TestApplicationPerformanceAndFunctionality()
{
    // Unit test setup code...
    Assert.AreEqual(42, calculatorService.Add(20, 22));

    // Performance test setup code...
    var stopwatch = new Stopwatch();
    stopwatch.Start();
    applicationService.ProcessRequest();
    stopwatch.Stop();

    // Assert within acceptable response time
    Assert.Less(stopwatch.ElapsedMilliseconds, 100);
}
```

Utilizing Performance Testing Tools

Simulate real-world scenarios with tools such as Apache JMeter or Microsoft's Visual Studio Load Test.

```
<!-- Visual Studio Load Test Configuration -->
<LoadTest>
  <Scenario>
    <ConstantLoadProfile>
      <NumberOfUsers>100</NumberOfUsers>
      <Duration>600</Duration>
    </ConstantLoadProfile>
  </Scenario>
</LoadTest>
```

Analyzing and Optimizing Test Performance

To ensure the effectiveness and efficiency of software testing efforts, it is essential to analyse and optimize test performance. This section discusses strategies for interpreting performance test results to identify bottlenecks and areas for improvement. To pinpoint performance issues within their applications, developers are guided through the process of analysing metrics such as total requests, average response time, and throughput. Moreover, practical examples demonstrate techniques for optimizing test performance, including code refinement, database query optimization, and algorithm optimization. Developers can improve the reliability and scalability of their software applications by performing proactive analysis and optimization.

Analyzing Performance Test Results

Identification of bottlenecks and areas for improvement can be achieved by interpreting performance test results.

Total Requests: 1000

Average Response Time: 50ms
Throughput: 20 requests/s

Optimizing Test Performance

Enhance the efficiency of code by refining algorithms, addressing database queries, and refining algorithms.

```
// Optimized Code Example
public int Add(int a, int b)
{
    return a + b;
}
```

Chapter X provides a comprehensive guide to incorporating performance and load testing into your C# and .NET 8 projects. The included code examples demonstrate the implementation of performance tests, the integration with unit tests, and the utilization of performance testing tools to evaluate and enhance the performance of your applications.

11

Future Trends and Best Practices

Overview

In this Chapter, we explore Address Security Concerns in Unit Testing, developers prioritize application robustness by integrating security testing into unit testing frameworks. Tests target vulnerabilities like SQL injection, secure data transmission, and authentication mechanisms. By embedding secure coding practices and continuous security testing, developers fortify applications against cyber threats and ensure data integrity.

Addressing Security Concerns in Unit Testing

For software applications to be robust and integrity, it is imperative to address security concerns in unit testing. To identify and mitigate potential vulnerabilities proactively, this section emphasizes the importance of integrating security testing into unit testing frameworks. As a result, developers gain an understanding of how unit tests can prevent SQL injection attacks, verify secure data transmission, and evaluate authentication mechanisms. Developers can make their applications more secure by incorporating security tests into their unit testing workflows.

Importance of Security in Unit Testing

Learn how unit testing can help ensure your application's robustness by addressing security concerns.

```
// Security Unit Test Example
[Test]
[SecurityTest]
public void TestSecureDataTransmission()
{
    // Security test setup code...
    var secureDataService = new SecureDataService();

    // Ensure secure transmission
    Assert.IsTrue(secureDataService.TransmitDataSecurely());
}
```

Identifying Security Vulnerabilities

Develop unit tests that target specific security vulnerabilities, such as data leaks and injection attacks.

```
// SQL Injection Unit Test
[Test]
[SecurityTest]
public void TestSqlInjectionPrevention()
{
    // SQL Injection test setup code...
    var databaseService = new DatabaseService();

    // Attempt SQL injection
    Assert.IsFalse(databaseService.IsSqlInjectionDetected("'; DROP
TABLE Users; --"));
}
```

Incorporating Security Practices in Test Cases

Fortifying software applications against potential security threats requires incorporating security practices into test cases. Throughout the development lifecycle, security considerations can be embedded by integrating secure coding practices directly into unit tests. Input data is validated,

authentication and authorization mechanisms are assessed, and continuous security testing practices are implemented within the test suite by developers. By adopting these security-focused testing methodologies, developers can enhance the resilience of their applications and mitigate the risk of security breaches.

Secure Coding Practices

Fortify your application against potential security threats by integrating secure coding practices directly into your unit tests.

```
// Secure Coding Practice in Unit Test
[Test]
[SecurityTest]
public void TestSecurePasswordStorage()
{
    // Secure password storage test setup code...
    var authenticationService = new AuthenticationService();

    // Ensure secure password hashing
    Assert.IsTrue(authenticationService.ValidatePassword("user123",
"hashedPassword"));
}
```

Authentication and Authorization Tests

Assess the effectiveness of authentication and authorization mechanisms by developing unit tests.

```
// Authentication Unit Test
[Test]
[SecurityTest]
public void TestUserAuthentication()
{
    // Authentication test setup code...
    var authenticationService = new AuthenticationService();

    // Ensure successful user authentication
    Assert.IsTrue(authenticationService.AuthenticateUser("username",
"password"));
}
```

Common Security Pitfalls and Solutions

Software development security pitfalls are addressed in this section, along with effective solutions. Common problems include inadequate input validation, insecure authentication and authorization, neglecting encryption, handling errors poorly, and ignoring security updates. Among the solutions are robust input validation, robust authentication methods, data encryption, comprehensive error handling, and regular security updates. It is possible to enhance the security of software applications and protect against cyber threats by implementing these measures.

Handling Input Validation

By validating input data, unit tests can prevent security pitfalls such as buffer overflows and injection attacks.

```
// Input Validation Unit Test
[Test]
[SecurityTest]
public void TestInputValidation()
{
    // Input validation test setup code...
    var dataValidationService = new DataValidationService();

    // Ensure proper input validation
    Assert.IsTrue(dataValidationService.IsValidInput("safeInput"));
}
```

Continuous Security Testing

Maintain a proactive security posture by implementing continuous security testing practices in your unit testing framework.

```
// Continuous Security Testing
[Test]
[SecurityTest]
public void TestContinuousSecurityScanning()
{
    // Continuous security testing setup code...
    var securityScanner = new SecurityScanner();

    // Run continuous security scans
    Assert.IsTrue(securityScanner.ScanForVulnerabilities());
}
```

Chapter XI delves into the crucial domain of security testing within the context of unit testing for C# and .NET 8 applications. Through code examples, this chapter guides developers in addressing security concerns, incorporating security practices, and fortifying their code against common security pitfalls.

12

Real-world Case Studies

Overview

This chapter delves into Examining Successful Unit Testing Implementations, real-world case studies illuminate effective strategies and lessons learned in unit testing. From successful Test-Driven Development (TDD) stories to achieving high test coverage and debugging failures, developers gain insights into adapting best practices and scaling unit testing in diverse projects. Seamless integration into CI/CD pipelines is also explored, empowering teams to enhance code quality and project stability.

Examining Successful Unit Testing Implementations

In this chapter, we delve into real-world case studies that demonstrate successful implementations of unit testing. We analyze a variety of projects and scenarios in order to gain insight into the strategies, techniques, and best practices used by successful teams to integrate and execute unit testing effectively. Each case study provides valuable insights and practical lessons learned on identifying key challenges and implementing robust testing frameworks. The reader gains a better understanding of unit testing and how it contributes to the success of software development projects by examining these case studies. These real-world examples provide invaluable resources for improving your unit testing practices and improving the quality and reliability of your codebase, whether you're a novice or seasoned developer.

Successful Test-Driven Development (TDD) Stories

Examine real-world examples of how Unit Testing and Test-Driven Development contributed to project success.

```
// Test-Driven Development Success Story
[TestFixture]
public class ShoppingCartTests
{
    [Test]
    public void Adding_Products_Increases_TotalPrice()
    {
        // Arrange
        var shoppingCart = new ShoppingCart();
        var product = new Product("Laptop", 1000);

        // Act
        shoppingCart.AddProduct(product);

        // Assert
        Assert.AreEqual(1000, shoppingCart.TotalPrice);
    }
}
```

Achieving High Test Coverage

Providing real-world examples of how projects have achieved and maintained a high level of unit testing, resulting in improved code quality and fewer bugs.

```
// High Test Coverage Example
[TestFixture]
public class UserServiceTests
{
    [Test]
    public void GetUser_ReturnsCorrectUser()
    {
        // Arrange
        var userService = new UserService();
```

```
        var userId = 1;

        // Act
        var user = userService.GetUser(userId);

        // Assert
        Assert.IsNotNull(user);
    }
}
```

Learning from Common Pitfalls and Failures

By examining common pitfalls and failures encountered in real-world scenarios, we dissect the intricacies of unit testing. By examining these challenges, we gain valuable insights into areas where unit testing implementations often falter and uncover strategies to mitigate risks effectively. Analysing failed attempts and their underlying causes enables us to navigate potential obstacles and elevate our unit testing practices to new heights.

Case Studies on Test Failures

Develop lessons about enhancing test suites based on situations where unit tests failed to catch critical issues.

```
// Failing Test Example
[TestFixture]
public class CurrencyConverterTests
{
    [Test]
    public void ConvertToUSD_ReturnsCorrectValue()
    {
        // Arrange
        var currencyConverter = new CurrencyConverter();
        var amount = 100;
        var sourceCurrency = "EUR";
        var targetCurrency = "USD";

        // Act
        var result = currencyConverter.ConvertToUSD(amount,
sourceCurrency);

        // Assert (Incorrect assertion to simulate a failure)
        Assert.AreEqual(120, result);
    }
}
```

Debugging and Fixing Unit Test Failures

Describe how developers diagnosed and fixed failing unit tests to improve overall project stability in real-world scenarios.

```
// Debugging and Fixing Test
[TestFixture]
public class AuthenticationServiceTests
{
    [Test]
    public void AuthenticateUser_ReturnsTrueForValidCredentials()
    {
        // Arrange
        var authenticationService = new AuthenticationService();
        var username = "user";
        var password = "pass";

        // Act
        var result = authenticationService.AuthenticateUser(username,
password);

        // Assert (Initially fails due to a bug)
        Assert.IsTrue(result);
    }
}
```

Adapting Best Practices to Real-world Projects

In this section, we explore the practical application of best practices in real-world software projects. In order to effectively implement industry-standard practices in diverse development environments, we bridge the gap between theoretical concepts and project realities. We demonstrate how best practices can be customized to suit each project's unique needs and constraints through case studies and practical examples. To achieve success in software development, we empower teams to leverage proven methodologies and techniques by embracing flexibility and adaptability.

Scaling Unit Testing Practices

Find out how teams have successfully scaled unit testing practices to accommodate large and complex codebases.

```
// Scaling Unit Testing Example
[TestFixture]
public class LargeProjectTests
{
    [Test]
    public void HandleLargeDataSets_Efficiently()
    {
        // Arrange
        var largeDataSetProcessor = new LargeDataSetProcessor();
        var dataSet = GetLargeDataSet();

        // Act
        var result = largeDataSetProcessor.Process(dataSet);
```

```
        // Assert
        Assert.IsNotNull(result);
    }

    private List<Data> GetLargeDataSet()
    {
        // Code to generate a large dataset
    }
}
```

Integrating with CI/CD Pipelines

The seamless integration of unit tests into Continuous Integration and Continuous Deployment pipelines is demonstrated in case studies.

```
// CI/CD Integration Example
[TestFixture]
public class CI_CDTests
{
    [Test]
    public void RunTestsInCI_CD_Pipeline()
    {
        // CI/CD pipeline setup code...
        var ci_cdService = new CI_CDService();

        // Act
        var result = ci_cdService.RunTests();

        // Assert
        Assert.IsTrue(result);
    }
}
```

Real-world case studies are examined in Chapter XII, including both successful implementations and failures. Developers gain insight into adapting best practices to diverse real-world projects through code examples, improving their ability to create effective and resilient unit tests.

13

Emerging Trends and Future Considerations

Overview

In this Chapter, we explore cutting-edge trends in unit testing, including advancements in frameworks like NUnit 4.0+. Discover how AI is revolutionizing test automation and learn about microservices testing and DevOps integration. Stay updated through continuous learning via community involvement and online resources. Embrace emerging trends to ensure robust and adaptable testing strategies in modern software development.

Latest Developments in Unit Testing

As software development practices evolve, so do the techniques and tools used for unit testing. In this section, we examine the latest developments and emerging trends in unit testing. Automation, integration with continuous integration/continuous deployment (CI/CD) pipelines, and the adoption of machine learning (ML) and artificial intelligence (AI) for testing purposes are among the areas examined. Additionally, we discuss the increasing importance of testing in microservices architecture and containerized environments, as well as how DevOps practices affect testing workflows. Developers can anticipate future challenges and opportunities in unit testing by staying informed of these emerging trends, ensuring that their testing strategies remain effective and adaptable in an ever-changing software development environment.

Advances in Testing Frameworks

Check out the latest features and updates in popular testing frameworks, showcasing their benefits for unit testing.

```
// NUnit 4.0+ Feature Example
[TestFixture]
public class AdvancedNUnitTests
{
    [Test]
    public void NewConstraintSyntax_ImprovesReadability()
    {
        // Arrange
        var calculator = new Calculator();

        // Act
        var result = calculator.Add(3, 5);

        // Assert (Using new constraint syntax)
        Assert.That(result, Is.EqualTo(8));
    }
}
```

Integration of AI in Test Automation

Learn how artificial intelligence is being integrated into unit testing to optimize test case creation and execution.

```
// AI-Enhanced Testing Example
[TestFixture]
public class AITestAutomation
{
    [Test]
    public void AI_GeneratesOptimalTestCases()
    {
        // Arrange
        var aiTestGenerator = new AITestGenerator();
        var systemUnderTest = new AdvancedSystem();
```

```
        // Act
        var testCases =
aiTestGenerator.GenerateTestCases(systemUnderTest);

        // Assert
        Assert.IsNotNull(testCases);
    }
}
```

Industry Trends and Innovations

The current state of unit testing is shaped by industry trends and innovations, which we explore in this section. As software development continues to evolve, organizations are adopting new technologies and methodologies to enhance their testing processes. This paper examines trends such as behaviour-driven development (BDD) and acceptance test-driven development (ATDD), which emphasize collaboration between developers, testers, and stakeholders in order to define testable requirements. Additionally, we discuss the rise of cloud-based testing solutions and the integration of artificial intelligence (AI) and machine learning (ML) algorithms for test automation and predictive analytics. In addition, we examine how emerging programming languages and frameworks have affected unit testing practices, as well as the importance of security testing and performance testing in software development today. Organizations can deliver high-quality, reliable software products to their customers by staying abreast of these industry trends and innovations.

Microservices Testing Strategies

Find out how unit testing for microservices architectures is evolving, including strategies for testing distributed systems effectively.

```
// Microservices Testing Example
[TestFixture]
public class MicroservicesTesting
{
    [Test]
    public void TestMicroserviceIntegration()
    {
        // Arrange
        var microserviceClient = new MicroserviceClient();
        var requestData = new RequestData { /* Data initialization */
};

        // Act
        var response = microserviceClient.SendRequest(requestData);

        // Assert
        Assert.IsNotNull(response);
    }
}
```

DevOps Integration for Seamless Testing

In modern software development, unit testing facilitates continuous integration and continuous testing while aligning with DevOps practices.

```
// DevOps Integration Example
[TestFixture]
public class DevOpsUnitTesting
{
    [Test]
    public void RunUnitTestsInContinuousIntegrationPipeline()
    {
        // Arrange
        var devOpsPipeline = new DevOpsPipeline();
        var unitTestProject = new UnitTestProject();

        // Act
        var result = devOpsPipeline.RunTests(unitTestProject);

        // Assert
        Assert.IsTrue(result);
    }
}
```

Recommendations for Staying Updated

There are several proactive steps developers and organizations can take to stay on top of the newest trends in unit testing. Firstly, they should regularly follow industry blogs, websites, and forums dedicated to software development and testing, where valuable insights and discussions about emerging trends are often shared. Furthermore, attending conferences, workshops, and webinars related to software testing provides an opportunity to network with peers and learn from experts. The third way to access relevant information and insights is to join online communities, and subscribe to newsletters, podcasts, and YouTube channels dedicated to software testing. Additionally, developers should remain open to experimenting with new tools, technologies, and methodologies in unit testing, continuously expanding their skill set. Lastly, committing to continuous learning through online courses, books, and certifications ensures that developers stay abreast of the latest developments in unit testing and maintain their competitive edge in the field of software development. By following these recommendations, developers and organizations can effectively navigate the evolving landscape of unit testing and improve the quality and reliability of their software products.

Continuous Learning and Community Involvement

Learn about the latest trends through continuous learning, active participation in communities, and attendance at relevant conferences.

```
// Continuous Learning Example
[TestFixture]
public class ContinuousLearningTests
{
```

```
    [Test]
    public void StayUpdatedThroughCommunityInvolvement()
    {
        // Arrange
        var learner = new ContinuousLearner();

        // Act
        var knowledgeLevel = learner.StayUpdated();

        // Assert
        Assert.GreaterOrEqual(knowledgeLevel, 5); // Rating on staying
updated
    }
}
```

Leveraging Online Resources and Documentation

Make use of online resources, documentation, and official release notes to keep up with the latest advancements.

```
// Online Resources Example
[TestFixture]
public class OnlineResourcesUsage
{
    [Test]
    public void ExploreNewFeaturesUsingDocumentation()
    {
        // Arrange
        var developer = new UnitTestDeveloper();
        var testingFramework = new LatestTestingFramework();

        // Act
        var features = developer.ExploreNewFeatures(testingFramework);

        // Assert
        Assert.IsNotNull(features);
    }
}
```

The chapter discusses future unit testing trends and considerations. Developers gain insights into adapting testing strategies for evolving software landscapes by exploring the latest developments, industry trends, and innovative practices. Readers are provided with valuable resources and strategies for continuous learning in the dynamic field of unit testing through recommendations for staying updated.

14

Wrapping Up

Overview

In this Chapter, we emphasize core unit testing practices such as test-driven development (TDD) and continuous integration (CI). By adhering to industry standards and fostering a culture of collaborative testing, teams can ensure code quality and reliability. Encouraging continuous learning and adopting new tools promotes ongoing improvement in unit testing practices, leading to resilient software development.

Recap of Best Practices and Industry Standards

As a conclusion to the book, we summarize the best practices and industry standards discussed. To ensure code quality and reliability, we emphasize the importance of adhering to established practices such as test-driven development (TDD), continuous integration and continuous deployment (CI/CD), and behavior-driven development (BDD). Additionally, we emphasize the importance of writing clean, maintainable code and performing thorough unit tests to catch bugs early in the development process. In order to build robust, scalable software applications that meet the needs of users and stakeholders, developers need to follow these best practices and industry standards. To stay informed about emerging trends and advancements in software development, we encourage readers to incorporate these practices into their workflows. As a comprehensive guide to unit testing, the book provides readers with practical insights and strategies for improving their testing practices and delivering high-quality software.

Reviewing Core Unit Testing Practices

Summarize the fundamental best practices covered throughout the book, emphasizing key principles for writing maintainable, effective unit tests.

```
// Core Practices Recap Example
[TestFixture]
public class BestPracticesRecap
{
    [Test]
    public void ReviewCorePractices()
    {
        // Arrange
        var tester = new UnitTestingEnthusiast();
        var testProject = new TestProject();

        // Act
        var recapResult = tester.RecapBestPractices(testProject);

        // Assert
        Assert.IsTrue(recapResult);
    }
}
```

Highlighting Industry Standards

Employing a common set of testing conventions demonstrates the importance of industry-standard practices in producing robust software.

```
// Industry Standards Highlight Example
[TestFixture]
public class IndustryStandardsHighlight
{
    [Test]
    public void EmphasizeStandardConventions()
```

```
    {
        // Arrange
        var developmentTeam = new AgileDevelopmentTeam();
        var unitTestingStandards = new UnitTestingStandards();

        // Act
        var adherenceResult =
developmentTeam.AdhereToStandards(unitTestingStandards);

        // Assert
        Assert.IsTrue(adherenceResult);
    }
}
```

Encouraging a Culture of Unit Testing

As we emphasize, unit testing is more than just a technical practice; it is a mindset that fosters collaboration, accountability, and continuous improvement within development teams and organizations. By encouraging developers to write tests alongside their code, team members can catch bugs earlier, improve code quality, and foster a sense of pride and ownership in their work. Moreover, we emphasize the role of leadership in championing unit testing initiatives and providing support, resources, and training to empower developers to adopt best practices. In addition to enhancing project success, building a culture where unit testing is valued and prioritized leads to more resilient, maintainable software. To conclude, we encourage our readers to lead by example, share their knowledge and experiences, and advocate for the importance of unit testing.

Promoting Collaborative Testing Efforts

Encourage collaboration and shared responsibility within development teams by fostering a culture of unit testing.

```
// Collaborative Testing Example
[TestFixture]
public class CollaborativeTestingCulture
{
    [Test]
    public void PromoteTeamCollaboration()
    {
        // Arrange
        var teamLead = new TestingAdvocate();
        var developmentTeam = new AgileDevelopmentTeam();

        // Act
        var collaborationResult =
teamLead.PromoteCollaboration(developmentTeam);

        // Assert
        Assert.IsTrue(collaborationResult);
```

```
    }
}
```

Incentivizing Unit Testing Practices

Develop approaches to reward and incentivize developers who maintain high unit test coverage and adhere to best practices.

```
// Incentivizing Testing Practices Example
[TestFixture]
public class IncentivizingTesting
{
    [Test]
    public void RecognizeTestingContributions()
    {
        // Arrange
        var manager = new TestingAdvocacyManager();
        var developer = new UnitTestingDeveloper();

        // Act
        var recognitionResult = manager.RecognizeDeveloper(developer);

        // Assert
        Assert.IsTrue(recognitionResult);
    }
}
```

Looking Forward: Continuous Improvement in Unit Testing Practices

Embracing Continuous Learning

Stay abreast of evolving technologies and adapt unit testing practices accordingly by encouraging developers to embrace a continuous learning mindset.

```
// Continuous Learning Example
[TestFixture]
public class ContinuousLearningConclusion
{
    [Test]
    public void AdvocateContinuousImprovement()
    {
        // Arrange
        var advocate = new ContinuousImprovementAdvocate();
        var developmentTeam = new AgileDevelopmentTeam();

        // Act
        var improvementResult =
advocate.PromoteContinuousImprovement(developmentTeam);
```

```
        // Assert
        Assert.IsTrue(improvementResult);
    }
}
```

Adopting New Tools and Techniques

Demonstrate the benefits of adopting new tools and techniques when it comes to increasing the efficiency and effectiveness of unit testing.

```
// New Tools Adoption Example
[TestFixture]
public class NewToolsAdoption
{
    [Test]
    public void IntegrateLatestTools()
    {
        // Arrange
        var toolsExpert = new ToolsIntegrationExpert();
        var testingProject = new LatestTestingProject();

        // Act
        var integrationResult =
toolsExpert.IntegrateNewTools(testingProject);

        // Assert
        Assert.IsTrue(integrationResult);
    }
}
```

The book concludes with Chapter XIV, which summarizes the best practices and industry standards discussed. By emphasizing collaborative testing efforts, promoting a unit testing culture, and looking ahead to continuous improvement, developers can create resilient and high-quality software through effective unit testing practices.

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