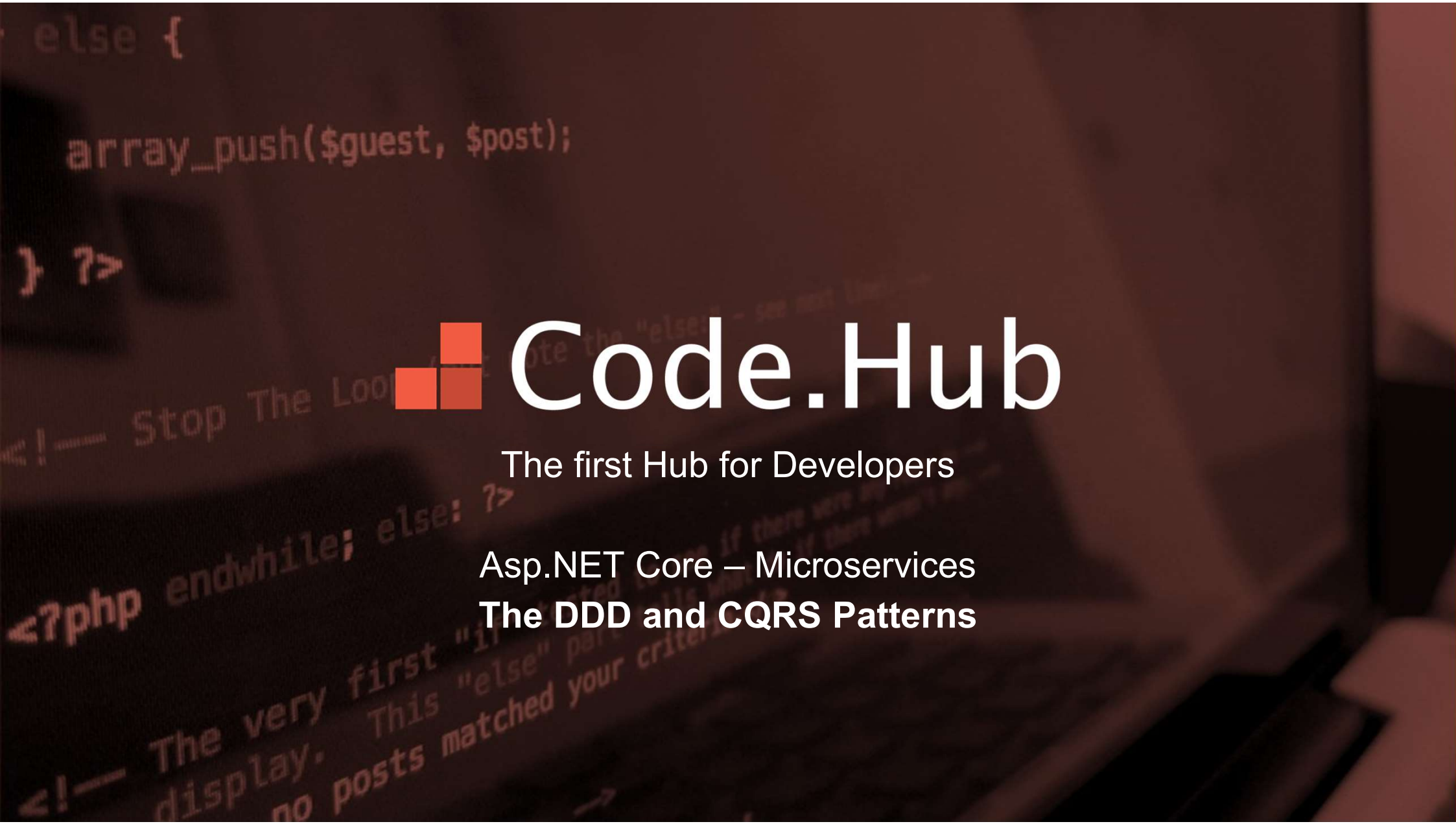
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Asp.NET Core – Microservices
The DDD and CQRS Patterns

- Designing a DDD-oriented microservice
- Designing a microservice domain model
- Implementation in .NET
- The CQRS Pattern
- Applying the patterns in microservices
- Implementing reads/queries
- Value objects and DTOs

Overview

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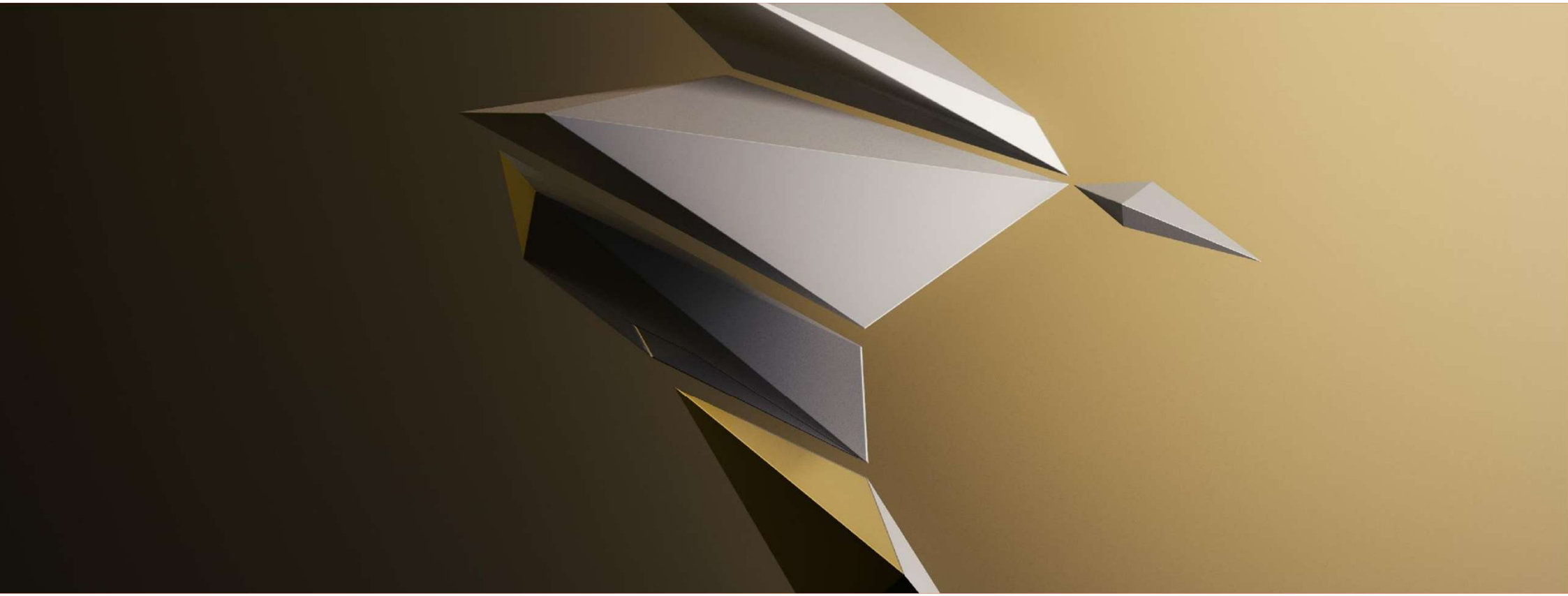

The DDD and CQRS Patterns

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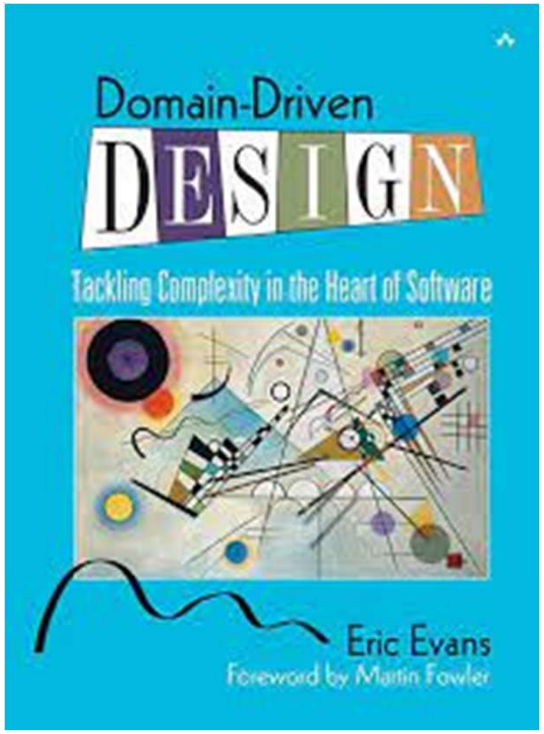
Domain-Driven Design Intro



Domain-Driven Design (DDD)

understanding and modeling the domain

Introduced by Eric Evans in his book

"Domain-Driven Design: Tackling Complexity in the Heart of Software."

Example of DDD

Let's assume the blogging application has the following core concepts:

User: Represents a user of the blogging platform.
Post: Represents a blog post created by a user.
Comment: Represents a comment left by a user on a specific blog post.

Definition and Principles of DDD

1. **Ubiquitous Language:**
   - Language shared between domain experts, stakeholders, and developers.
   - Helps bridge the gap between technical jargon and business terminology.
   - Everyone involved speaks the same language when discussing the domain model and its concepts.
2. **Model-Driven Design:**
   - Developers focus on building a rich and expressive domain model that accurately reflects the problem domain.
   - This model serves as a direct representation of the business processes, rules, and entities that make up the core of the application's purpose.
3. **Bounded Contexts:**
   - The domain is divided into "bounded contexts."
   - Each bounded context is a self-contained area with its own models, entities, and rules.
   - Bounded contexts help manage complexity by providing clear boundaries between different parts of the domain.
4. **Entities and Value Objects:**
   - Two key concepts: entities and value objects.
   - Entities have identity and are mutable over time, while value objects are immutable and defined by their attributes.
5. **Aggregates:**
   - Clusters of related entities and value objects treated as a single unit.
   - They help maintain consistency and enforce business rules within a bounded context.
   - Aggregates are crucial for defining transactional boundaries and ensuring data integrity.

Definition and Principles of DDD

1. **Ubiquitous Language, independence of specific technology**
2. **Model-Driven Design**
3. **Bounded Contexts**
4. **Entities and Value Objects**
5. **Aggregates**

Importance of DDD

Domain modeling is the process of abstracting and representing the core concepts and relationships within a specific problem domain. It serves as the backbone of a software solution built using DDD. The importance of domain modeling lies in the following aspects which are crucial for defining transactional boundaries and ensuring data integrity.

1. **Shared Understanding:** Domain modeling facilitates effective communication between domain experts and developers. By using a ubiquitous language and visual representations (e.g., diagrams), stakeholders can validate and verify the model, ensuring it accurately represents the problem domain.
2. **Complexity Management:** Modeling the domain allows developers to break down complex business processes into manageable components. Bounded contexts and aggregates help in isolating and handling complexity within specific areas of the domain.
3. **Flexibility and Adaptability:** A well-designed domain model is flexible and adaptable to changes in business requirements. By aligning the software with the actual domain, DDD enables easier evolution and maintenance of the system as the business evolves.
4. **Reduced Cognitive Load:** Domain modeling simplifies the mental model required to understand the software system. With a clear and well-organized domain model, developers can more easily reason about the behavior and interactions of the application's components.
5. **Quality and Validations:** By using the domain model as a reference, developers can validate the correctness and completeness of their implementation. The domain model acts as a quality assurance tool, ensuring that the software reflects the intended business rules and logic.

Importance of DDD

Domain Driven Design, DDD

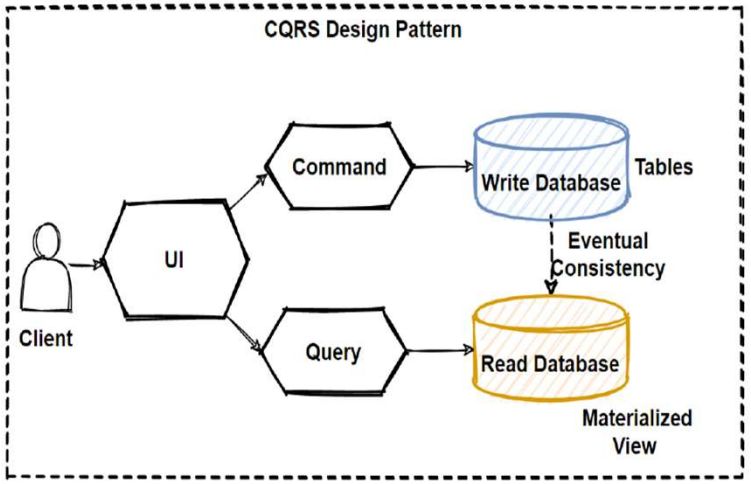
- process of abstracting and
- represents the core concepts and relationships
- defines transactional boundaries and
- ensures data integrity.

Main features

1. **Shared Understanding**
2. **Complexity Management**
3. **Flexibility and Adaptability**
4. **Reduced Cognitive Load**
5. **Quality and Validations**

Command Query Responsibility Segregation (CQRS) Overview

CQRS is a design pattern that separates the responsibilities of handling read (query) and write (command) operations into separate components. Unlike traditional monolithic architectures where the same model is used for both read and write operations, CQRS advocates using distinct models for each operation. It was popularized by Greg Young as a way to address scalability and performance challenges in complex systems.



Explanation of CQRS Pattern

In the CQRS pattern, the application is divided into two main parts: the Command side and the Query side.

1. **Command Side:** This side deals with operations that modify the system's state. Commands represent intentions to change the domain model and are handled by command handlers. Command handlers enforce business rules, validate data, and update the domain model accordingly. The focus is on consistency and ensuring that commands are processed correctly.
2. **Query Side:** The query side is responsible for reading data from the system without modifying its state. Read requests are served by specialized query handlers that retrieve data from read models (often optimized for query performance) and return results to clients. The focus is on query optimization and providing timely responses to read operations.

The core idea behind CQRS is that read and write operations have different usage patterns, and optimizing them separately can lead to improved performance, scalability, and maintainability.

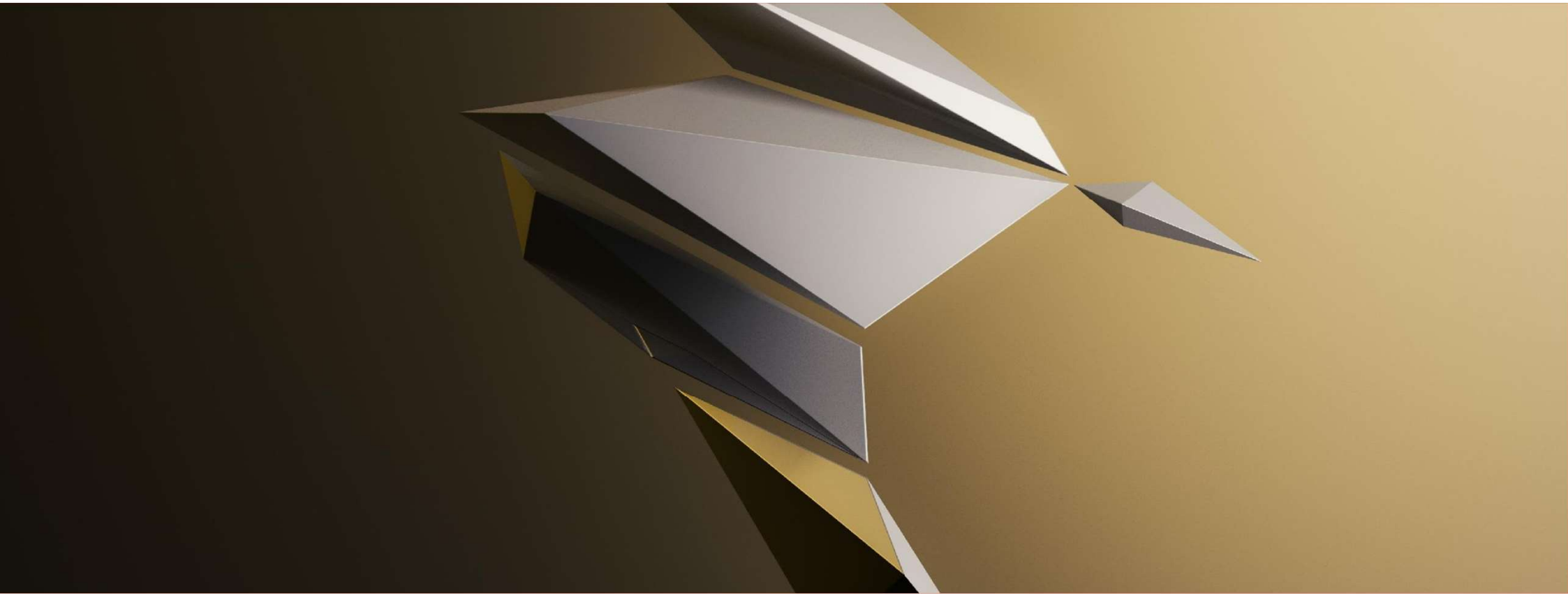
Advantages of CQRS:

1. **Scalability and Performance:** By segregating read and write operations, CQRS allows independent scaling of the query and command sides. This is particularly useful in systems where read operations significantly outnumber write operations. Read models can be optimized for specific queries, improving response times and reducing the load on the write side.
2. **Domain Model Simplification:** The separation of concerns in CQRS leads to a clearer and more focused domain model for each side. Command handlers can focus on enforcing business rules and maintaining consistency, while query handlers can concentrate on data retrieval and presentation.
3. **Flexibility in Data Storage:** CQRS enables the use of different data storage solutions for read and write operations. For example, the write side may use an event store for event sourcing, while the query side may leverage a traditional relational or NoSQL database. This flexibility allows choosing the best storage technology for each use case.
4. **Improved User Experience:** Since read models are designed to cater to specific queries, user interfaces can be tailored to provide a better user experience. Complex queries can be optimized, and data can be denormalized for faster retrieval.
5. **Simplified Scaling Strategies:** CQRS provides a straightforward approach to scaling different parts of the application independently. It allows allocating resources where they are most needed, reducing resource wastage and cost.
6. **Event Sourcing Integration:** CQRS aligns well with event sourcing, another pattern that stores domain events as the source of truth. Event sourcing can be easily combined with CQRS to ensure reliable data synchronization between the read and write sides.

CQRS Use Cases

CQRS is especially beneficial in the following scenarios

- Systems with high read and write workloads, where read performance is critical.
- Complex domains with different models for write and read operations.
- Systems that require fine-grained control over data retrieval and presentation.
- Situations where eventual consistency is acceptable or preferable for read operations.
- Projects where scalability and performance are paramount, and traditional monolithic approaches may not suffice.



Applying CQRS and DDD patterns in microservices

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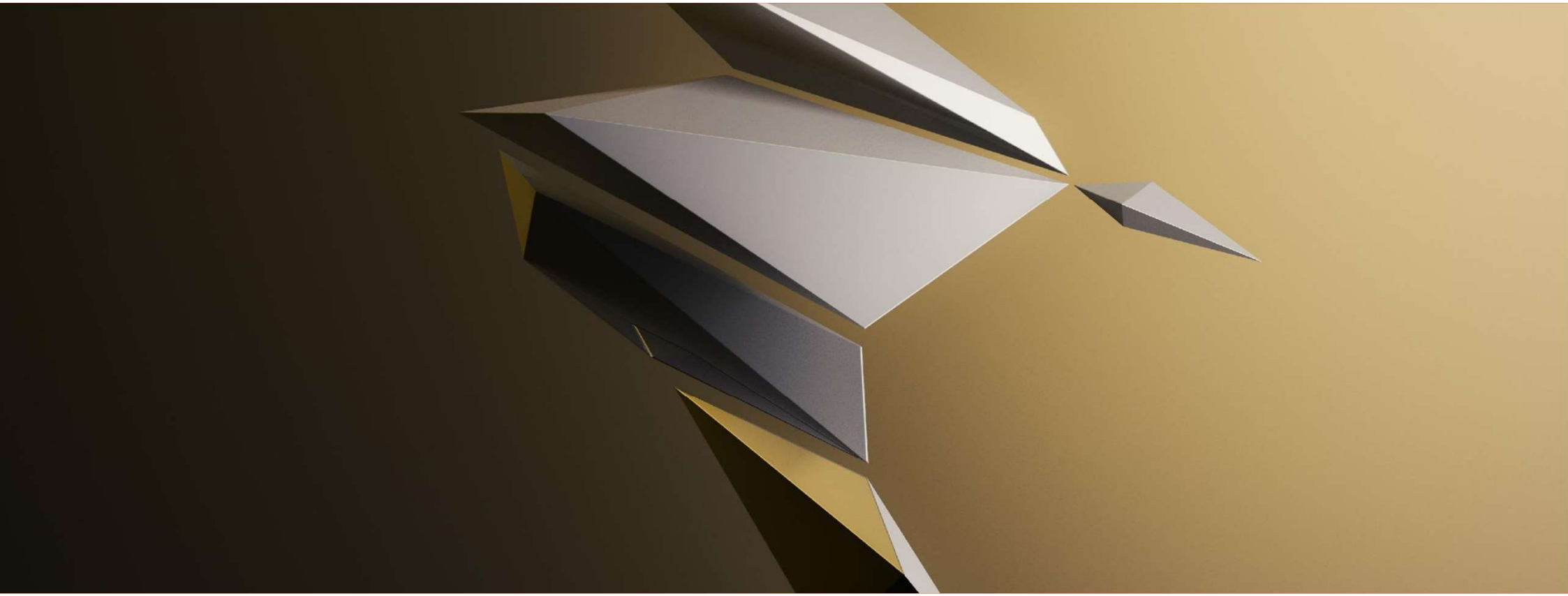
Applying CQRS and DDD patterns in microservices

Let's explore how these patterns can be effectively applied in a microservices context:

1. Bounded Contexts in Microservices
2. Microservices and CQRS
3. Aggregates, Entities, and Value Objects
4. Event-Driven Architecture (EDA) and Event Sourcing
5. Read Models and Query Optimization:
6. Consistency and Eventual Consistency:
7. API Gateway and Choreography vs. Orchestration



Implementing reads/queries in CQRS microservices

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Implementing reads/queries in CQRS microservices

Implementing reads/queries in CQRS microservices with .NET involves **designing and developing** the query side of the application. Let's explore the steps and best practices to implement read models and handle query requests using .NET technologies:

1)Designing Read Models:

- Define Read Models: Identify the specific data requirements for query operations. Design read models that store denormalized and precomputed data optimized for efficient data retrieval. Each read model should represent a specific query or view.
- Read Model Data Store: Choose an appropriate data store for read models. Depending on the use case, you can use relational databases, NoSQL databases, or in-memory data stores. Consider factors such as query performance, scalability, and data consistency.

2)Implementing Query Handlers:

- Create query handlers responsible for processing read requests and returning the required data. Each query handler should be specialized for a specific read model or query.
- Use MediatR or other similar libraries to implement the mediator pattern for handling queries. This promotes decoupling between the query handlers and the query controllers, leading to better maintainability.

Implementing reads/queries in CQRS microservices

3. Query API Endpoints:

- Design RESTful API endpoints to handle query requests. Use meaningful resource URIs and adhere to standard HTTP methods (GET, POST, etc.).
- Create controllers that receive query requests from clients and delegate the request to the appropriate query handler using MediatR.

4. Asynchronous Query Processing:

- Consider implementing asynchronous query handlers, especially if the read models involve time-consuming data processing or external service calls. Asynchronous processing enhances responsiveness and scalability.
- Use async/await with the Task-based Asynchronous Pattern (TAP) for efficient handling of asynchronous operations in .NET.

5. Caching and Query Optimization:

- Implement caching mechanisms to store frequently accessed query results. Use in-memory caches like Redis or distributed caching solutions to improve query performance and reduce the load on the data store.
- Consider cache invalidation strategies to keep the cached data up-to-date with the changes in the write side of the application. Events from the write side can trigger cache invalidation.

Implementing reads/queries in CQRS microservices

6. Error Handling and Fault Tolerance:

- Implement proper error handling in query handlers to handle exceptional cases gracefully. Return appropriate error responses to clients when queries cannot be processed successfully.
- Consider using the Circuit Breaker pattern to protect the query side from potential cascading failures. Circuit breakers help in failing fast and providing fallback responses during unstable conditions.

7. Security Considerations:

- Apply authorization mechanisms to ensure that only authorized users can access specific read models and query data.
- Implement data masking or data filtering techniques to ensure that sensitive information is not exposed in query responses.

8. Testing:

- Write unit tests for query handlers to validate their correctness and ensure proper data retrieval.
- Perform integration testing to verify the interaction between the query API endpoints, controllers, and query handlers.

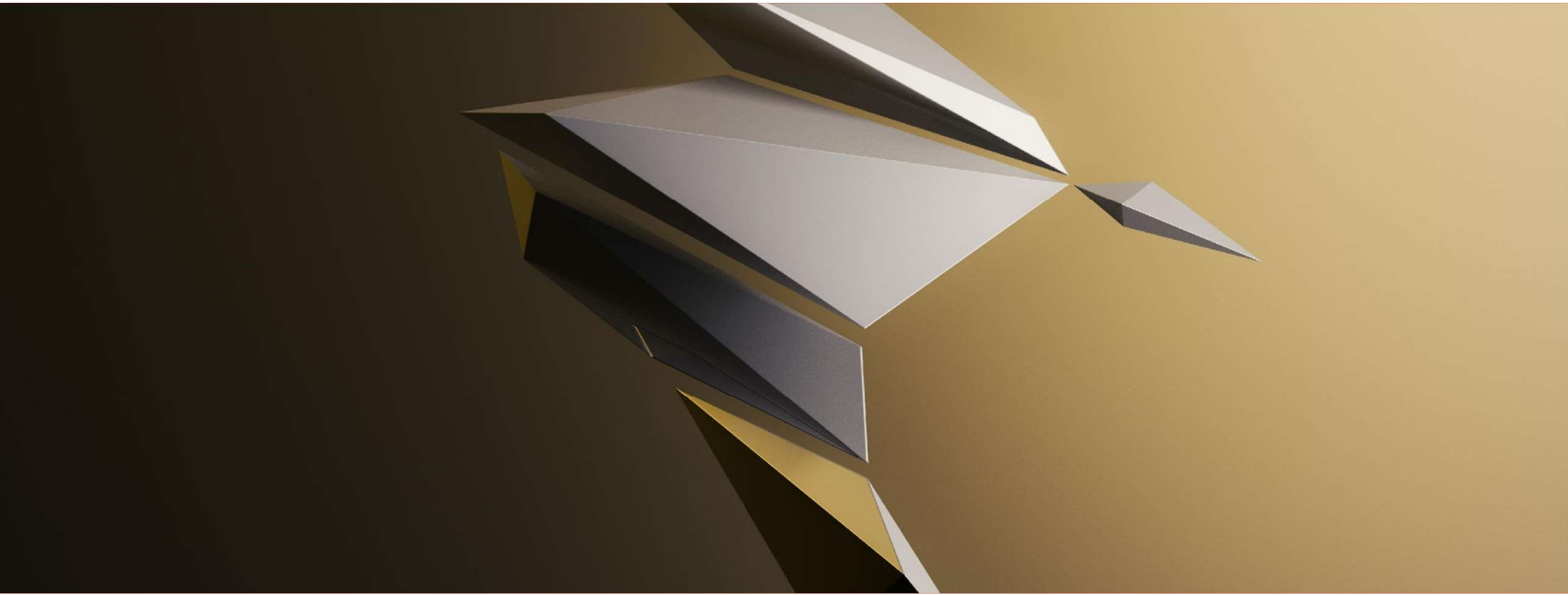
Implementing reads/queries in CQRS microservices

9. Monitoring and Logging:

Implement logging and monitoring to gain insights into the query side's performance, identify potential bottlenecks, and troubleshoot issues.

10. Load Balancing:

Set up load balancing for query API endpoints to distribute the query load evenly across multiple instances, enhancing scalability and fault tolerance.



Designing a DDD-oriented microservice

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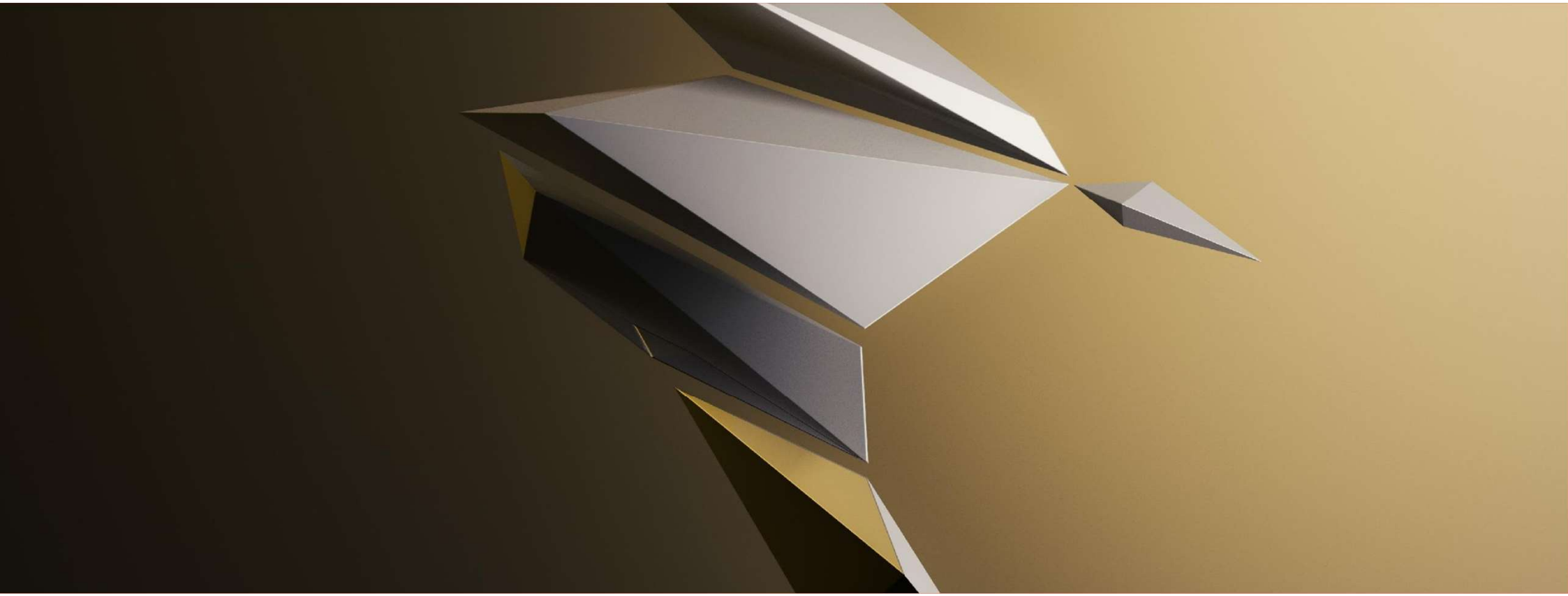
Designing a DDD-oriented microservice

Designing a Domain-Driven Design (DDD)-oriented microservice involves creating a microservice **that aligns closely** with the principles and concepts of DDD. The goal is to **model the microservice around the core business domain**, ensuring that it **captures and reflects the business logic accurately**. Below are the steps and key considerations for designing a DDD-oriented microservice:

1. Define Bounded Context
2. Develop the Domain Model
3. Establish a Shared Ubiquitous Language
4. Define Commands and Domain Events
5. Implement Command Handlers and Event Handlers
6. Design Data Persistence and Implement Repositories
7. Define Context Mapping
8. Design RESTful API and Implement API Controllers
9. Perform Thorough Unit and Integration Testing
10. Implement Asynchronous Communication



Designing a Microservice Domain Model

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Designing a DDD-oriented microservice

Designing a microservice domain model involves creating a well-defined and cohesive representation of the business domain within the microservice. The domain model should encapsulate the core business logic and data structures while adhering to Domain-Driven Design (DDD) principles. Below are the steps and key considerations for designing a microservice domain model:

1. Identify Bounded Context
2. Identify Domain Entities and Value Objects
3. Define Aggregates (Group Related Entities and Aggregate Roots)
4. Model Relationships and Invariants
5. Implement Business Logic
6. Use Domain Events
7. Implement Data Persistence and Repositories
8. Perform Thorough Validation and Error Handling (Input Validation, Gracefully handle exceptional cases)
9. Adopt TDD (Test-Driven Development)
10. Refine Your Model Continuously as per evolving business requirements

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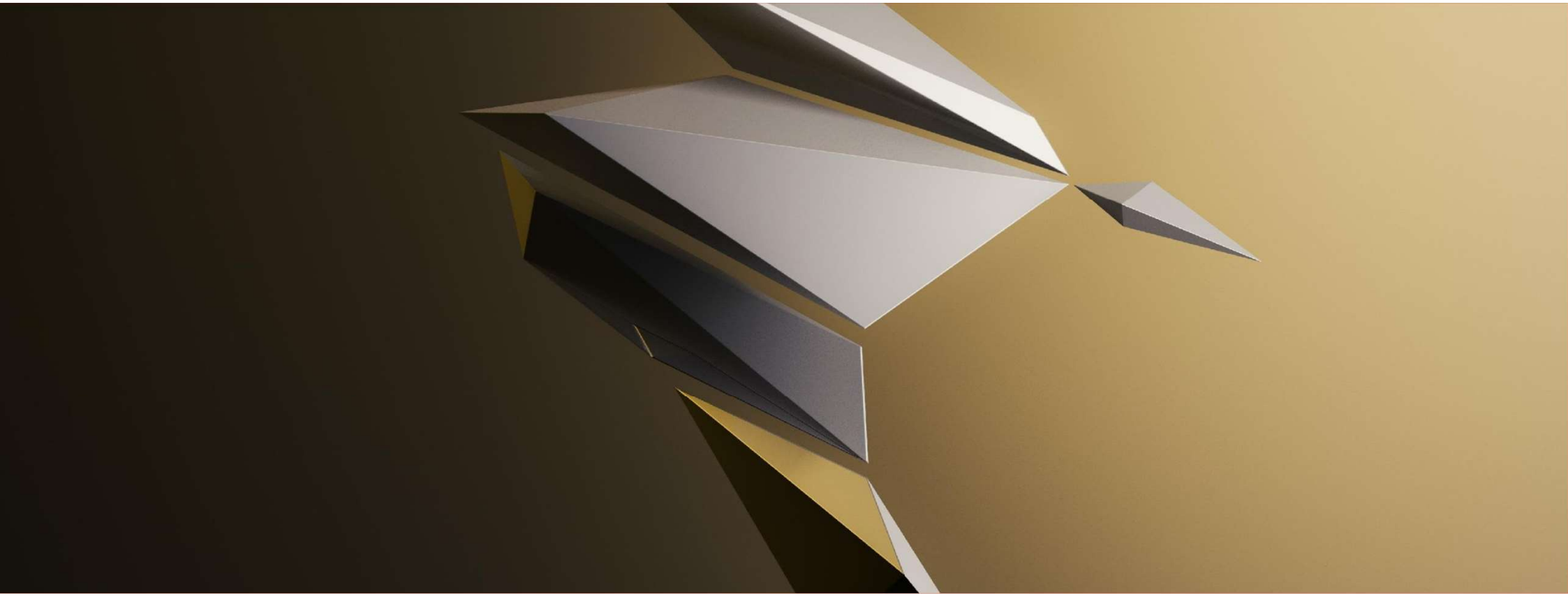

Implementing a microservice domain model in .NET

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Implementing a microservice domain model in .NET

Let's walk through a detailed example of implementing a simple microservice domain model for an online shopping application using .NET Core. We'll create a microservice for managing customer orders. The example will cover the creation of entities, value objects, aggregates, and domain events.

Step 1: Defining our entities and Value Objects

```
// Entity: Order
public class Order
{
    public int Id { get; private set; }
    public int CustomerId { get; private set; }
    public List<OrderItem> Items { get; private set; }
    public decimal TotalAmount => Items.Sum(item => item.Quantity * item.UnitPrice);

    // Private constructor for Entity creation
    private Order(int customerId)
    {
        CustomerId = customerId;
        Items = new List<OrderItem>();
    }

    // Factory method to create a new Order
    public static Order Create(int customerId)
    {
        return new Order(customerId);
    }

    // Method to add an item to the order
    public void AddItem(Product product, int quantity)
    {
        var item = OrderItem.Create(product.Id, product.Name, product.Price, quantity);
        Items.Add(item);
    }
}
```

```
// Value Object: OrderItem
public class OrderItem
{
    public int ProductId { get; private set; }
    public string ProductName { get; private set; }
    public decimal UnitPrice { get; private set; }
    public int Quantity { get; private set; }
    public decimal TotalPrice => UnitPrice * Quantity;

    // Private constructor for Value Object creation
    private OrderItem(int productId, string productName, decimal unitPrice, int
quantity)
    {
        ProductId = productId;
        ProductName = productName;
        UnitPrice = unitPrice;
        Quantity = quantity;
    }

    // Factory method to create a new OrderItem
    public static OrderItem Create(int productId, string productName, decimal
unitPrice, int quantity)
    {
        return new OrderItem(productId, productName, unitPrice, quantity);
    }
}
```

Implementing in .NET

Step 2: Implementing the Aggregates of our domain Model

```
// Aggregate Root: OrderAggregate
public class OrderAggregate
{
    private readonly List<Order> _orders;
    public OrderAggregate()
    {
        _orders = new List<Order>();
    }

    // Method to create a new order
    public Order CreateOrder(int customerId)
    {
        var order = Order.Create(customerId);
        _orders.Add(order);
        return order;
    }

    // Method to add an item to an existing order
    public void AddItemToOrder(int orderId, Product product, int quantity)
    {
        var order = _orders.FirstOrDefault(o => o.Id == orderId);
        if (order == null)
        {
            throw new ArgumentException($"Order with ID {orderId} not found.");
        }
        order.AddItem(product, quantity);
    }

    // Method to retrieve an order by its ID
    public Order GetOrderById(int orderId)
    {
        return _orders.FirstOrDefault(o => o.Id == orderId);
    }
    // Other methods for managing orders, such as canceling an order, etc.
}
```

Implementing a microservice domain model in .NET

Step 3: Implementing our Domain Events

```
// Domain Event: OrderCreatedEvent
public class OrderCreatedEvent
{
    public int OrderId { get; private set; }
    public int CustomerId { get; private set; }
    public DateTime CreationDate { get; private set; }

    public OrderCreatedEvent(int orderId, int customerId, DateTime creationDate)
    {
        OrderId = orderId;
        CustomerId = customerId;
        CreationDate = creationDate;
    }
}
```

Implementing a microservice domain model in .NET

Step 4: Testing the Domain Model

```
// Unit Tests: OrderAggregateTests
[TestFixture]
public class OrderAggregateTests
{
    private OrderAggregate _orderAggregate;

    [SetUp]
    public void SetUp()
    {
        _orderAggregate = new OrderAggregate();
    }

    [Test]
    public void CreateOrder_ShouldCreateNewOrder()
    {
        // Arrange
        var customerId = 123;

        // Act
        var order =
_orderAggregate.CreateOrder(customerId);

        // Assert
        Assert.AreEqual(customerId, order.CustomerId);
        Assert.IsEmpty(order.Items);
    }

    [Test]
    public void
AddItemToOrder_ShouldAddItemToExistingOrder()
    {
        // Arrange
        var productId = 456;
        var productName = "Product A";
        var unitPrice = 10.50m;
        var quantity = 2;
        var product = new Product(productId, productName,
unitPrice);
        var order = _orderAggregate.CreateOrder(789);

        // Act
        _orderAggregate.AddItemToOrder(order.Id, product,
quantity);

        // Assert
        Assert.AreEqual(1, order.Items.Count);
        var orderItem = order.Items.First();
        Assert.AreEqual(productId, orderItem.ProductId);
        Assert.AreEqual(productName, orderItem.ProductName);
        Assert.AreEqual(unitPrice, orderItem.UnitPrice);
        Assert.AreEqual(quantity, orderItem.Quantity);
    }
}
```

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Thank you!

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