**Domain-Driven Design Approaches in Cloud-Native Services Architecture**

Jordan Jordanov 1, Pavel Petrov 2

*1* *University of Economics – Varna, Varna, Bulgaria (jordanov.jordan@ue-varna.bg)*

*2* *University of Economics – Varna, Varna, Bulgaria (petrov@ue-varna.bg)*

*Abstract –* With the proliferation of cloud-native services, the need for efficient software design strategies has become of the utmost importance. This paper gives a brief overview of domain-driven, cloud-based software development activities and how they fit into a well-known process. It emphasizes multiple techniques for expressing complex business logic by facilitating greater scalability, flexibility, and maintainability. The significance of the system's availability, reliability, and resilience may prevent an organization from experiencing failure and support its growth. This article examines the fundamental components of domain-driven design, their integration with cloud-native technologies, and their benefits and challenges. In addition, the study aims to contribute to the growing body of knowledge in this field and to aid software architects and developers

*Keywords –* domain-driven design, cloud-native services, scalability, maintainability, modularity, distributed systems, software architecture.

1. **Introduction**

Cloud-native services have revolutionized the production and deployment of software systems. These services take advantage of the agility, adaptability, and fault tolerance that cloud platforms offer. Even so, there are unique challenges associated with leading organizations to developing and operating applications in a dynamic environment.

DOI: 10.18421/TEMxx-xx

<https://doi.org/10.18421/TEMxx-xx>

**Corresponding author:** *Pavel Petrov,*

*University of Economics - Varna, Varna, Bulgaria*

**Email:** *petrov@ue-varna.bg*

*Received: -----.*

*Revised: -----.*

*Accepted: -----.*

*Published: -----.*

© 2023. ----; published by UIKTEN. This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License.

The article is published with Open Access at <https://www.temjournal.com/>

Domain-driven design (DDD) is a software development methodology that emphasizes the application domain, its concepts, and their relationships as the motivating factors for architecture design [37], [38]. From a business perspective, a domain is defined as “[a] field | industry in which a business operates, composed of multiple subdomains.” There are three categories of subdomains: generic, core, and supporting. Businesses invest in software to meet specific requirements or address specific problems. For an in-depth understanding of the problem, architects must first grasp the domain. Core DDD principles include capturing valuable domain knowledge in code models, which can include both structural and behavioral aspects, in a collaborative mode between domain experts and software engineers. DDD provides conditions and activities for constructing a domain model as the primary artifact [2]. This article examines the potential of DDD as a guiding principle for designing cloud-native services in an effort to optimize development processes.

A list of essential concepts for designing robust, scalable, and secure cloud-based systems is presented in Table 1. Each principle may be used as a solution to a commonly occurring problem.

*Table 1. List of key design principles.*

|  |  |
| --- | --- |
| **Name** | **Description** |
| Separation of Concerns | A design guideline for dividing distinct sections of a computer program. Each module and object must have its own purpose and context. This leads to more opportunities for module development, reuse, and autonomy. |
| Encapsulation | A way to restrict direct access to certain segments of an element so that people cannot view the state values of all of an object's variables. Encapsulation can be used to cover up both the data members and the data functions or methods. |
| Single Responsibility | The basic concept asserting that "[a] module should only be accountable to a single actor." [40] To put it another way, each piece in the design must have a single purpose. Single responsibility is closely related to the concepts of coupling and cohesion. |
| Dependency Inversion | Research by R. C. Martin [29], [30] shows that this principle is a specific way to loosely connect software modules. In accordance with this approach, the typical dependence connections between high-level, policy-setting modules and low-level, dependency modules are reversed, making high-level modules independent of the implementation details of low-level modules. |
| “You Are Not Going to Need It” (YAGNI) | A fundamental principle of extreme programming [29], [30]. YAGNI says, “Do not add functionality unless it is considered required.” In other words, create the code required for the given circumstance. One must not add anything that is unneeded. For the time being, when adding logic to the code, one should not take into account what may be required in the future. |
| “Keep It Short and Simple” (KISS) | This idea relates to the simplification of functionality implementation. Less complicated code is easier to read and hence easier to maintain. |
| Factory | This is one of the well-known Gang of Four design patterns [23]. It offers an interface for constructing objects without specifying their classes. It encapsulates the logic of object construction within a distinct factory class. |

When creating a cloud solution, one of the first decisions to make is which service(s) to utilize in order to operate the applications [33]. Table 2 shows the choices for which cloud services are best for which types of applications.

*Table 2. Cloud services’ suitability for various application types (Source: Rob Caron Sr. Product Marketing Manager, Barry Luijbregts, Microsoft Azure, 2022)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Web service | Mobile service | Serverless | Virtual Machine | Microservices |
| Monolithic and N-Tier app | **✓** |  |  | **✓** |  |
| Mobile app back end | **✓** | **✓** |  |  | **✓** |
| Distributed system |  |  | **✓** |  | **✓** |
| Business process workflow |  |  | **✓** | **✓** |  |

One of the simplest and most effective solutions for managing cloud-based apps is the HTTP-based service for hosting web applications. Some examples of this service are Azure App Hosting Service, AWS Elastic Beanstalk, and Google App Engine. They provide a set of hosting services that cover the complexity of the operating system and infrastructure while hosting an application [10]. They are highly available by default and are operational at least 99.95% of the time. They share potent characteristics such as automatic scaling, zero-downtime deployments, and straightforward authentication and authorization [9]. Some of them enable debugging the application while it is in production, using tools such as Snapshot Debugger [33].

When developing a mobile application, a backend that the application can connect to is required. Typically, this is an API that the application can utilize to access and store data. Azure Mobile Apps and AWS Amplify provide such solutions with unique capabilities. For example, there is an offline sync that enables a mobile app to keep functioning if there is no connection to the backend, and the sync is refreshed whenever the connection is re-established [21]. Another feature is sending push notifications to the mobile apps, regardless of the platform they run on (iOS or Android), with services such as Firebase Cloud Messaging, Azure Notification Hubs, and Apple Push Notification Service.

Serverless functions, also known as “function as a service” (FaaS), are a cloud computing paradigm that allows developers to compose and deploy individual functions or code fragments without managing or provisioning servers [24]. In a serverless setup, the cloud provider handles server administration, scalability, and infrastructural duties, freeing developers to concentrate on writing and deploying code.

Existing applications could be lifted and relocated from virtual machines (VMs) operating in a local data center to VMs running in the cloud, making this a simple approach to getting started. There are many predefined VM images that are ready to use. Even so, running the application in a VM does not offer any optimizations. The operation staff is also accountable for maintaining the operating system and antivirus software [9]. Azure Virtual Machines, Amazon EC2, and Google Compute Engine are examples of such solutions.

All the aforementioned types are created individually as monolithic, large-core applications that contain all of the domain logic. It has components that communicate with one another directly within a single server process [41]. A monolithic application is a single, integrated unit, whereas microservices divide the application into several smaller units.

Microservices are an organizational and architectural approach to developing software. According to this approach, software is composed of loosely connected services that are organized around business capabilities and that can be independently deployed and tested [36]. These services communicate with one another via well-defined APIs. Large, sophisticated applications may be delivered quickly, consistently, and reliably. Microservices are technology- and language-agnostic, so it is quite possible for a single organization to utilize multiple runtime platforms. Modern cloud platforms have features such as scalability, availability, and resilience that can be used to their fullest potential by microservices [42]. Such cloud solutions include Azure Kubernetes Service, Amazon EC2 & EKS, Google Kubernetes Engine, Red Hat OpenShift, DigitalOcean, and many more. Microservices architecture is a catalyst and enabler for continuous business transformation.

1. **The features of domain-driven design in the context of cloud services**

A web service, whether a monolith or part of a distributed system, has certain features, the most important of which are the volume of data handled, performance requirements, business logic, and technological complexity. DDD strategies are beneficial for initiatives with a large number of complex business principles because they can simplify the business logic. In other words, the primary objective of DDD concepts is to deal with the complexity of domain logic, which consists of business rules, validations, and calculations.

The classic approach, as described by T. Erl in his book *SOA Principles of Service Design* [13], incorporates the separation of services based on their technical and functional characteristics. It focuses on core capabilities exposed as services. E. Evans [14], [15], on the other hand, states that DDD provides the key ideas needed to separate web services into different parts. The DDD approach provides a means of representing the real world in a structured representation of a solution that meets the requirements in the problem space. These characteristics lead to improved software architecture quality [25].

The focus should always be on the core domain. Business logic complexity is the first indicator of how complicated the problem domain in which software works is. A CRUD application that needs to perform fundamental “create,” “read,” “update,” and “delete” operations is not particularly complex. This situation can be handled with less complicated methods. Simultaneously, an order management system, [31] which automates a significant portion of a company's activity, must model all the processes upon which the company acts and therefore manage a large number of complex business responsibilities. This system's business logic complexity may be extremely high [9]. Another attribute is its technical complexity, a term that refers to the number of algorithms that need to be implemented to make the software work.

In the book *Patterns of Enterprise Application Architecture* [20], Martin Fowler presents a diagram (Figure 1) with time and cost on the Y axis and complexity on the X axis. In accordance with data-centric design patterns, the curve indicates that beyond a certain level of complexity, even a small increase in complexity results in a significant cost peak.



*Figure 1. Time and complexity diagram (adapted from Martin Fowler's book* Patterns of Enterprise Application Architecture*)*

On the other hand, the time and cost of a project designed from a domain-centric perspective tended to increase linearly with complexity, whereas the start-up costs were quite high. According to DDD, use cases should be modeled based on the way the business actually operates, which is always evolving.

DDD offers a variety of technical concepts and patterns to assist in internal implementation. Ubiquitous language, bounded context, and core domain are the strategic elements and the most important parts of DDD. The other ideas, such as entities, value objects, aggregates, and repositories, are the steps for building a software project. Some individuals view these technical rules and patterns as difficult-to-learn obstacles that make it challenging to employ DDD methodologies. However, the most critical aspect is arranging the code so that it matches the business problems [47].

Each industry and profession has its own terminology. To build complex systems, IT teams must learn the business terminology used by the relevant stakeholders. A core principle of DDD is to make it easier for domain experts and software engineers to talk to each other by defining an explicit ubiquitous (universal) language (UL). This language assists in bringing together the stakeholder, the designer, and the programmer so that they may construct the domain model(s) and then put them into action [3]. Code written in the UL can provide a hint for some edge cases that were not clear enough at the start, or it can rewrite the problem statement in a much cleaner and more concise manner. [48] For the idea of a UL to work, the code base needs to be in sync with the terminology, or, more specifically, classes and tables in the database need to be named after the terms in the UL. Common nomenclature facilitates the understanding of user requirements. Batista's research [3] indicates that this helps bridge the gap and establishes the foundation for effective communication. It seeks to develop a standard, business-oriented language, the basic objective of which is to prevent misunderstandings and incorrect assumptions. UL is utilized in documentation, conversations, app code, and testing code and is used by domain experts and delivery teams. UL evolves over time and may be managed on any knowledge collaboration platform. It helps identify focus areas for knowledge crunching, which is the process of “coping” the knowledge received from the experts into domain models.

The bounded context (BC) is a small area within the domain that gives each element of the UL its own meaning [31]. Quite often, an application's code base becomes unmanageable as its volume increases. Elements of code that make sense in one portion of the system may appear irrelevant in another. In this situation, the optimal solution would be to explicitly separate these components []. A BC illustrates how the program and its development were structured. Frequently, it corresponds to a subdomain, which indicates how the business or domain activity is divided. [24] Each BC is represented by its own domain and is developed independently. The domain model built for a BC is applicable only within its boundaries.

A context map facilitates the identification and management of interdependencies and collaborations among BCs [2]. It enables teams to comprehend the structure of the larger system and understand how their individual contexts integrate into the bigger picture.

Even though a DDD application is governed by behavior, objects are still required. DDD conveys distinct types of objects, characterized by their identities or values [39].

An **entity** represents a uniquely identifiable business object that encapsulates attributes and a well-defined domain behavior [2]. The definition of an entity consists of attributes and behavior. An entity is something that can be tracked, located, retrieved, and kept in long-term storage.

**Value objects** are small, simple objects whose equality is not based on identity [2]. They are items used to quantify, measure, or characterize a certain topic. Value objects may have methods and behaviors, but they should never have side effects. In his book, Vaughn Vernon [43] says that value objects should be used instead of entities if possible.

An **aggregate** is a collection of connected items that are modified as a single entity [16], [17]. Aggregates are treated as a unit for data changes. They consist of one or more entities and value objects that change together. Before making modifications, it is necessary to evaluate the consistency of the whole aggregate. Every aggregate must have an aggregate root, which is the parent object of all members. In some cases, the aggregate may have rules that ensure all of the objects’ data are consistent. Data changes in aggregates should adhere to ACID, which means they should be atomic, consistent, isolated, and long-lasting (Jovanovic & Benson, 2013). The factory pattern can be used for creating complex aggregates [2].

A **repository** is a collection of items of a particular type. Repositories offer a unified abstraction for all persistence-related problems [34]. This makes it easy for clients to obtain and manage model objects. The public interface of a repository communicates design decisions very clearly. Only a few things should be directly accessible; repositories provide and regulate this access. An important benefit of repositories is that they make the code easier to test. They reduce the tight coupling with external resources such as databases and data providers, which would traditionally make unit testing challenging. When code for data access is wrapped in one or more well-known classes, it is easier and safer to use (Gorman, 2021).

Vaughn Vernon [44] describes **domain events**, saying they should be used to capture an occurrence of something that happened in the domain, and they should be part of the UL. Events are helpful because they signal that a certain thing has happened. A domain event is essentially a message, a record of something that happened in the past.

**Model-driven design** **(MDD)** provides a framework for the implementation of DDD-modeled systems [2]. The previously listed tactical patterns are the construction elements, which have a relationship. MDD expresses state and computation through value objects, identity through entities, and change through domain events. Repositories permit access to entities and aggregates. Except for the events, they can all be encapsulated in a factory.

1. **Managing the complexity issues in cloud services through a layered approach**

The most important aspect of designing and establishing a service is setting its boundaries. DDD patterns assist in understanding the domain's complexity. Each BC identifies the entities and value objects, characterizes them, and combines them. Choosing where to draw the border between BCs requires balancing two competing objectives. Creating a barrier around items that need cohesion is the first step. The second goal is to avoid “chatty” inter-unit communications. These objectives may conflict with each other. Balance should be accomplished by decomposing the system into the smallest units feasible [49]. In a single-bound context, cohesion is crucial. Another way to look at this aspect is to view it as autonomy. A unit is not completely autonomous if it relies on another unit to fulfill a request directly.

DDD concepts create a structure known as “onion architecture.” The word “onion” is used because the architecture has numerous layers and a central core. The top layers are dependent on the lower layers, yet the lower layers have no knowledge of the upper ones. Onion architecture illustrates that the core elements of the domain model should act in isolation from each other.



*Figure 2. Building blocks of domain-driven design in onion architecture (adapted from the book* Domain-Driven Design: Tackling Complexity in the Heart of Software*, 2003)*

The core part of this onion consists of the notions of “entity,” “value object,” “domain event,” and “aggregate.” The next layer consists of repositories, factories, and domain services. Application services go beyond that. The code working with the data storage must be gathered under the repositories in the domain model. These four elements – entities, value objects, domain events, and aggregates – are the most basic. They can refer to each other. For example, a value object can keep a reference to an aggregate root but cannot work with other DDD notions such as repositories and factories. Similarly, repositories, factories, and domain services can know about each other and the four basic elements, but they should not refer to the application services. The main reason for this isolation is to allow the separation of concerns.

Most enterprise applications with significant business and technical complexity are defined by multiple layers [13]. These layers are logical artifacts that help developers manage the complexity of the code. MDD isolates domain expression using layers. Those layers have nothing to do with the deployment of the service. When DDD principles are employed, the elements may be organized differently depending on the specific implementation. Nonetheless, as shown in Figure 3, there are a few common layers.



*Figure 3. Dependencies between layers in DDD* [11]

The **application layer** coordinates the execution flow between various domain objects/entities to solve problems. It also specifies the use cases and operations that can be carried out within the service, and it orchestrates interaction between the UI and the core elements. Commonly, the application layer is implemented as a web API project, which implements the interaction, remote network access, etc. The application layer depends on domains and infrastructure.

The **domain model layer** encapsulates the business logic and principles and constitutes the core of the service. It contains domain objects/entities, aggregates, value objects, and domain services. The domain layer concentrates on solving business problems and expresses the business domain's concepts and behaviors. Should have completely decoupled POCO classes, implementing “the heart of the software.” The domain layer does not depend on any other.

The **infrastructure layer** is responsible for providing the domain layer with the necessary technical facilities and support. The infrastructure layer's primary function is to abstract and encapsulate technical details and complexities. It provides implementations for multiple concerns, including data persistence, messaging, network communication, integration with external services, caching, and performance optimization.

1. **Using command and query responsibility segregation and event sourcing in cloud services**

Command and query responsibility segregation (CQRS) was introduced by Greg Young in 2010. Young based this idea on Bertrand Meyer's command-query separation principle. Command-query separation (CQS) states that every method must either be a command that executes an operation that modifies the state of the system or a query that provides data to the caller, but not both. Therefore, asking a question should not affect the outcome of the response. Methods should only return a value if they are referentially transparent and do not have any side effects, such as changing the state of an object or a file in the file system. To follow this principle, if a method changes some piece of state, it should always be of type void. This increases the readability of the code base. However, it is not always practical to stick to the CQS paradigm. There are occasions when it makes more sense for a method to have both a side effect and a return value. One example of this is the linear data structure “Stack.” Its “Pop” method removes the element last pushed into the stack and returns it to the caller. This solution violates the CQS concept, yet separating these duties into two distinct functions is illogical.

The relationship between CQS and CQRS is that the latter extends the same notion as the former to a higher level, and CQRS is seen as an architectural pattern. Instead of focusing on methods such as CQS, CQRS applies the same principles by facilitating the separation of a single, unified domain model into two distinct entities: one for command management, or “writes,” and the other for query processing, or “reads.” CQRS is an object-oriented expression of the domain and is frequently associated with more complex business contexts [10].

Typically, it is difficult to create one specific unified model since the command and query sides have very distinct needs. By concentrating on each case individually, one can develop a different strategy that makes the most sense. In the end, there are two models, each of which specializes in a certain purpose. The separation aspect is achieved by grouping query activities into one composition and commands into another. Each one has a unique data model. The application layer turns any input into a command or a query and sends it to a shared communication channel (message handler). Commands, queries, and events are three categories of messages in an application. They are all part of the core domain model, located in the center of the onion architecture. Commands tell the application to do something; queries ask it about something; and events are informational messages. Commands trigger a reaction in the domain model, while events are the result of that reaction. Naming guidelines are associated with ubiquitous language and all three types of messages, with commands always being in the imperative tense, queries usually starting with the word “get,” and events always being in the past tense.

In addition, the query and command handlers can be implemented within the same tier or on distinct services so that they can be optimized and scaled independently without affecting one another, offloading the complexity from the code base [11]. This can be seen as the single responsibility principle being used at the architectural level.

The CAP theorem and CQRS have a close relationship. The CAP theorem, also known as Brewer's theorem, [8] is a fundamental principle in distributed computing that asserts that it is impossible for a distributed system to guarantee all three of the following properties simultaneously: consistency, availability, and performance. If consistency is maintained, every read operation returns the most recent write or an error. Availability, on the other hand, implies that every request receives a response, even if all system nodes are down. With partition tolerance, the system continues to function even when communications are lost or delayed across network nodes. Due to the impossibility of choosing all three options, it is necessary to reach a compromise. CQRS is effective because it provides numerous opportunities by emphasizing optimal decision-making in various circumstances.

By adopting CQRS, developers can design cloud-native services that efficiently handle high query loads while ensuring data consistency through strict command processing. CQRS is commonly referred to as an interim stage preceding event sourcing. Event sourcing complements CQRS by capturing all changes to the system's state as a sequence of events.

**Event sourcing** is a design technique based on the concept that all changes to the state of an application throughout its lifetime are recorded as a series of events. As a result, serialized events become the fundamental building blocks of the application. In the event sourcing approach, the programs store transactions but not their respective states. When a state is needed, all transactions from the beginning of time are applied [29], [30]. Nothing is deleted or updated from the data repository. Because of this, there cannot be any concurrent updating issues. Most applications work by storing the current state of domain entities and starting business transactions. Instead of storing all the information in the columns of a single record or in the properties of a single object, the state of the entities is described by the sequence of events. This is an event-based representation of an entity. As described above, an “event” is something that occurred in the past and is an expression of the UL.

As objects, domain events are an integral component of a BC. They provide a way to talk about important things that happen or change in the system, and then loosely connected parts of the domain can respond to these events [21]. In this manner, the objects that raise the events do not need to consider the action that must occur when the event occurs. Similarly, event-handling objects do not need to know where the event originated.

Event storage may be relational, document-based, or graph-based; therefore, events may be stored in an SQL or NoSQL database such as PostgreSQL, MySQL, MongoDB, or Apache Cassandra, or they may be stored using a specific solution such as “RavenDB” or “FaunaDB” [4]. Table 3 presents some examples of cloud-based options.

*Table 3. Suitability of cloud-based storage options for various business cases*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Relational | Unstructured | Semi-Structured | Tunable Consistency | Geo-Replication | Large Data |
| Azure SQL | **✓** |  |  |  | **✓** |  |
| Azure Cosmos |  | **✓** | **✓** | **✓** | **✓** | **✓** |
| Azure Blob |  | **✓** |  |  | **✓** | **✓** |
| Amazon RDS | **✓** |  |  |  | **✓** | **✓** |
| Amazon Dynamo |  | **✓** | **✓** | **✓** | **✓** | **✓** |
| Amazon S3 |  | **✓** |  |  | **✓** | **✓** |
| Google SQL | **✓** |  |  |  | **✓** | **✓** |
| Google Firestore |  | **✓** | **✓** | **✓** | **✓** | **✓** |

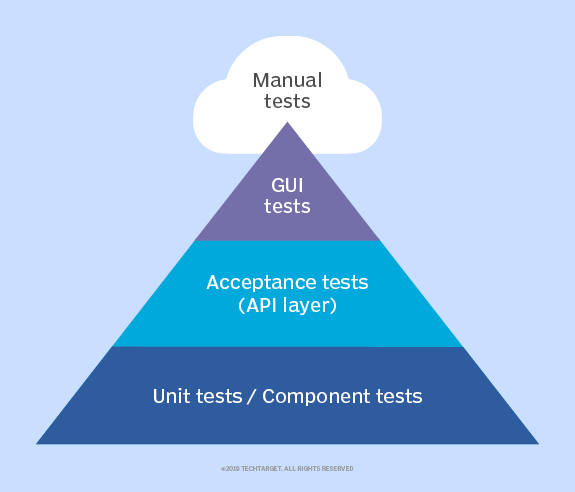
To obtain the entire state, it is necessary to replay the program timeline from the beginning. Using recorded events, it is possible to reconstruct the state of an aggregate. This may sometimes require the management of huge volumes of data. In this case, snapshots, which represent the state of the entity at a certain point in time, may be specified (Baptista & Abbruzzese, 2022b). Once stored, events are immutable. It is possible to duplicate and repeat events for scalability reasons. The replay algorithm involves examining the data and using logic to retrieve the relevant information. Other, more intriguing situations, such as business intelligence, statistical analysis, and tracking the history of a resource, may be addressed by *ad hoc* projections. Events also provide a powerful and efficient approach to data warehousing, supported by cloud services such as Amazon Redshift, Google BigQuery, and Azure Synapse Analytics.

1. **Applying test-driven development practice in cloud services**

Test-driven development (TDD) and DDD are two potent methodologies that, when combined, can increase the quality of cloud services and the development process. By employing these practices, developers and quality assurance engineers can create a system that is more robust and reliable. TDD encourages a rigorous testing process in which tests are written prior to the implementation code; this process follows best practices, ensuring that the intended functionality is met. There is a three-step procedure known as “red, green, and refactor.” Creating a failing test for a piece of functionality is the initial step. The second phase is the “green step,” during which sufficient production code is created to make the failed test pass. Refactoring is the last phase, in which both test and production code are enhanced to maintain high quality [32]. This cycle is repeated for each piece of functionality in order of increasing complexity in each method and class until the entire feature is finished. Using TDD ensures that the testing process is what guides the design. Testable code is what produces maintainable code [5].

In the field of software testing, there are several different sorts of tests. Some tests are subject-matter-based – e.g., unit, integration, component service, and user interface testing. Meanwhile, others are determined by the purpose of the test – e.g., functional tests, acceptance tests, smoke tests, and exploratory testing. Still others are determined by how they are being tested – e.g., automated, semi-automated, and manual tests.

The test automation pyramid (Figure 4) was first described by Mike Cohn in his book *Succeeding with Agile: Software Development Using Scrum* [1]. The pyramid depicts the types of tests that should be performed at various stages of the software development lifecycle and how often they should occur in a testing suite to ensure the quality of the program. The notion behind the pyramid is that testers should devote more effort to basic tests before moving on to more complicated ones.



*Figure 4. The agile test automation pyramid by Mike Cohn* [1]

In Figure 4, four different kinds of test are identified:

1) Unit tests – automated tests that check how well a single piece of code works on its own;

2) Service tests – automated tests that check how well a group of classes and methods that provide a service to users works;

3) UI tests – automated tests that check that the entire application works (from the user interface to the database); and

4) Manual tests – tests performed by a person which also check the full application's functionality.

The test automation pyramid captures the essence of how each type of test becomes more expensive. As a result, the system should have many low-cost tests and a small number of high-cost tests.

By implementing TDD, programmers have the ability to identify potential problems early on and validate the veracity of the domain models. In addition, the iterative nature of TDD enables frequent feedback, which facilitates continuous refinement and adaptability in cloud service development [37].

**Limitations**

The DDD patterns presented in this article should not be applied universally. They introduce constraints that provide benefits such as higher quality over time. Time and effort are required to properly comprehend and implement the numerous DDD layers, patterns, and concepts, which can be overwhelming. The learning curve for DDD is steep, particularly for inexperienced coders [11]. It is important to emphasize that CQRS and most DDD patterns are not architectural styles but merely architectural patterns. Microservices and SOA are examples of architectural styles, while CQRS and DDD patterns describe something inside a single system or component [11]. At an architectural level, the design of each element in a system shows its own trade-offs and internal design decisions.

**Conclusion**

All the aforementioned patterns, techniques, and principles are geared toward the design and development of simple, intuitive, flexible, testable, and maintainable cloud software architectures. The architectures have a high level of abstraction and a long-term focus for solution components. Their design is comprehensive and implementation-focused. “Clean architecture” [] is a philosophy of architectural essentialism and operates mainly according to a cost-benefit analysis. Users’ use cases and mental models need to be reflected in the system, and that is what clean architecture focuses on. It builds only what is necessary when it is necessary and optimizes it for maintainability. The topic of clean architecture is also connected to the notion of “clean code.” Clean code is simple and direct and reads like well-written prose. Clean code never obscures the designer’s intent but is full of crisp abstractions and straightforward lines of control [6].

In conclusion, DDD approaches have emerged as a valuable methodology for building cloud-native service architectures. By focusing on the core business domain and encapsulating it in a well-defined bounded context, DDD helps to create modular, scalable, and maintainable systems. By combining these two approaches, organizations can build systems that are not only technically robust but also aligned with their business goals, requirements, and objectives. Ultimately, the adoption of DDD and cloud-native architectures can help organizations innovate faster, reduce costs, deliver better value to their customers, and stay competitive in a rapidly changing digital landscape.

The cleaner the domain model is kept, the easier it is to extend it later. The inability to maintain proper separation of concerns in enterprise-level applications is one of the biggest reasons why code bases become a mess, leading to delays and even project failure. As this article focuses mostly on the relevant foundations, a case study on the domain-driven software development process could be presented as a continuation.

Acknowledgements

This research is financially supported by NPD-XX/2023 from the University of Economics – Varna Science Fund.

**References**

1. Ashbacher, C. (2010). Succeeding with agile: Software development using Scrum, by Mike Cohn. *The Journal of Object Technology*, *9*(4). https://doi.org/10.5381/jot.2010.9.4.r1
2. Avram, A. (2007). *Domain-driven design quickly*. Lulu.com.
3. Batista, F. (2019). *Developing the ubiquitous language*. https://thedomaindrivendesign.io/developing-the-ubiquitous-language/
4. Betts, D., Dominguez, J., Melnik, G., Simonazzi, F., & Subramanian, M. (2012). *Exploring CQRS and event sourcing: A journey into high scalability, availability, and maintainability with Windows Azure*. Microsoft patterns & practices.
5. Bissi, W., Neto, A. T., & Emer, M. C. F. P. (2016). The effects of test driven development on internal quality, external quality and productivity: A systematic review. *Information & Software Technology*, *74*, 45–54. https://doi.org/10.1016/j.infsof.2016.02.004
6. Booch, G., Maksimchuk, R. A., Engle, M. W., Young, B. J., Conallen, J., & Houston, K. (2007). *Object-Oriented Analysis and Design with Applications* (3rd ed.). Pearson Education.
7. Braun, S., Bieniusa, A., & Elberzhager, F. (2021). Advanced domain-driven design for consistency in distributed data-intensive systems. European *Conference on Computer Systems. PaPoC '21: Proceedings of the 8th Workshop on Principles and Practice of Consistency for Distributed*, 1–12. https://doi.org/10.1145/3447865.3457969
8. Brewer, E. (2012). *Pushing the CAP: Strategies for consistency and availability*. *IEEE Computer*, *45*(2), 23–29. http://dx.doi.org/10.1109/MC.2012.37
9. Caron, R. (2018). *Get the Azure quick start guide for .NET developers*. Microsoft. https://azure.microsoft.com/en-us/blog/get-the-azure-quick-start-guide-for-net-developers/
10. De La Torre, C. (2022, February 9). *Containerized docker application lifecycle with Microsoft platform and tools*. Microsoft Learn. https://learn.microsoft.com/en-us/dotnet/architecture/containerized-lifecycle/
11. De La Torre, C., Wagner, B., & Rousos, M., (2023, March 22). .*NET Microservices. Architecture for Containerized .NET Applications*. Microsoft Learn. https://learn.microsoft.com/en-us/dotnet/architecture/microservices/
12. Debski, A., Szczepanik, B., Malawski, M., Spahr, S., & Muthig, D. (2018). In search for a scalable & reactive architecture of a cloud application: CQRS and event sourcing case study. *IEEE Software*, *35*(2), 62–71. https://doi.org/10.1109/ms.2017.265095722
13. Erl, T. (2007). *SOA principles of service design.* Prentice Hall.
14. Evans, E. (2014). *Domain-driven design reference: Definitions and pattern summaries.* Dog Ear Publishing*.*
15. Evans, E. (2014). *Domain-driven Design: Tackling Complexity in the Heart of Software*. Addison-Wesley Professional.
16. Fields, J., Harvie, S., Fowler, M., & Beck, K. (2009). *Refactoring: Ruby edition*. Pearson Education.
17. Fowler, M. (2010). *Domain-specific languages*. Pearson Education.
18. Fowler, M. (2012). *Pattern Enterprise Application Architecture*. Addison-Wesley.
19. Garverick, J., & McIver, O. D. (2023). *Implementing event-driven microservices architecture in .NET 7: Develop event-based distributed apps that can scale with ever-changing business demands using C# 11 and .NET 7*. Packt Publishing.
20. Hippchen, B., Giessler, P., Steinegger, R. H., Schneider, M., & Abeck, S. (2017). Designing microservice-based applications by using a domain-driven design approach. *International Journal on Advances in Software*, *10*, 432–445. https://www.thinkmind.org/articles/soft\_v10\_n34\_2017\_22.pdf
21. Huang, D., Xing, T., & Wu, H. (2013). Mobile cloud computing service models: a user-centric approach. *IEEE Network*, *27*(5), 6–11. https://doi.org/10.1109/mnet.2013.6616109
22. Indrasiri, K., & Suhothayan, S. (2021). *Design patterns for cloud native applications: Patterns in practice using APIs, data, events, and streams*. O’Reilly Media.
23. Khononov, V. (2021). *Learning domain-driven design: Aligning software architecture and business strategy*. O’Reilly Media.
24. Kumar, V., & Agnihotri, K. (2021). *Serverless computing using Azure functions: Build, deploy, automate, and secure serverless application development with Azure functions (English Edition)*. BPB Publications.
25. Landre, E., Wesenberg, H., & Olmheim, J. (2007). Agile enterprise software development using domain-driven design and test first. In Association for Computing Machinery (Ed.), *Companion to the 22nd ACM SIGPLAN conference on Object-oriented programming systems and applications companion* (pp. 983–993). Association for Computing Machinery. https://doi.org/10.1145/1297846.1297967
26. Martin, R. C. (2008). *Clean code: A Handbook of agile software craftsmanship*. Pearson Education.
27. Martin, R. C. (2018). *Clean architecture: A craftsman’s guide to software structure and design*. Prentice Hall.
28. Meyer, B. (1997). *Object-oriented software construction*. Prentice Hall.
29. Millett, S., & Tune, N. (2015). *Patterns, principles, and practices of domain-driven design*. John Wiley & Sons.
30. Myers, B. (2021, August 12). *Red, green, tefactor. What is test-driven development.* https://medium.com/codecastpublication/red-green-refactor-what-is-test-driven-development-302794e06c
31. Nguyen, P., Song, H., Chauvel, F., Muller, R., Boyar, S., & Levin, E. (2019). Using microservices for non-intrusive customization of multi-tenant SaaS.In Association for Computing Machinery (Ed.), *ESEC/FSE 2019: Proceedings of the 2019 27th ACM joint meeting on European software engineering conference and symposium on the foundations of software engineering* (pp. 905–915). Association for Computing Machinery. https://doi.org/10.1145/3338906.3340452
32. Nilsson, J. (2006). *Applying domain-driven design and patterns: With examples in C# and.* Addison-Wesley Professional.
33. Oukes, P., Van Andel, M., Folmer, E., Bennett, R., & Lemmen, C. (2021). Domain-driven design applied to land administration system development: Lessons from the Netherlands. *Land Use Policy*, *104*, 105379. https://doi.org/10.1016/j.landusepol.2021.105379
34. Palermo, J. (2019). *.NET DevOps for Azure: A Developer’s Guide to DevOps Architecture the Right Way*. Apress.
35. Rademacher, F., Sachweh, S., & Zündorf, A. (2017). Towards a UML Profile for Domain-Driven Design of Microservice Architectures. In A. Cerone & M. Roveri (Eds.), *Software engineering and formal methods: SEFM 2017 collocated workshops: DataMod, FAACS, MSE, CoSim-CPS, and FOCLASA, Trento, Italy, September 4-5, 2017* (pp. 230–245). Springer International Publishing. https://doi.org/10.1007/978-3-319-74781-1\_17
36. Rademacher, F., Sorgalla, J., & Sachweh, S. (2018). Challenges of domain-driven microservice design: A model-driven perspective. *IEEE Software*, *35*(3), 36–43. https://doi.org/10.1109/ms.2018.2141028
37. Steinegger, R. H., Giessler, P., Hippchen, B., & Abeck, S. (2017). Overview of a domain driven design approach to build microservice-based applications. Conference: *Third International Conference on Advances and Trends in Software Engineering (SOFTENG 2017)*, 79–87. https://www.thinkmind.org/articles/softeng\_2017\_4\_30\_64138.pdf
38. Stuckenberg, S. (2014). *Exploring the organizational impact of software-as-a-service on software vendors: The role of organizational integration in software-as-a-service development and operation*. Peter Lang.
39. Uludağ, Ö., Hauder, M., Kleehaus, M., Schimpfle, C., & Matthes, F. (2018). *Supporting large-scale agile development with domain-driven design*. In J. Garbajosa, X. Wang, & A. Aguiar (Eds.), *Agile processes in software engineering and extreme programming 19th international conference, XP 2018, Porto, Portugal, May 21–25, 2018, Proceedings* (pp. 232–247). Springer. https://doi.org/10.1007/978-3-319-91602-6\_16
40. Vernon, V. (2013). *Implementing domain-driven design*. Addison-Wesley.
41. Vernon, V. (2016). *Domain-driven design distilled*. Addison-Wesley Professional.
42. Vettor, R., & Smith, S. (2023). *Architecting cloud native .NET applications for Azure*. Microsoft Learn. https://learn.microsoft.com/en-us/dotnet/architecture/cloud-native/
43. Villaça, L. A., Azevedo, L. G., & Baião, F. A. (2018). *Query strategies on polyglot persistence in microservices.* In Association for Computing Machinery (Ed.), *SAC '18: proceedings of the 33rd annual ACM symposium on applied computing* (pp. 1725–1732). Association for Computing Machinery. https://doi.org/10.1145/3167132.3167316
44. Wlaschin, S. (2018). *Domain modeling made functional: Tackle software complexity with domain-driven design and F#*. Pragmatic Bookshelf.
45. Young, G. (2011). *Event centric: Finding simplicity in complex systems*. Addison-Wesley Professional.
46. Zimarev, A. (2019). *Hands-on domain-driven design with .NET Core: Tackling complexity in the heart of software by putting DDD principles into practice*. Packt Publishing.