Uma imagem com Gráficos, Tipo de letra, captura de ecrã, logótipo

Descrição gerada automaticamente

Quizzes Tutor  
Software Architecture Document (SAD)

Leonardo Monteiro Nº58250

Henrique Vale Nº58168

Gustavo Henriques Nº64361

Table 1: SAD update history

|  |  |  |
| --- | --- | --- |
| **DOCUMENT NUMBER** | **RELEASE/REVISION DATE** | **RELEASE/REVISION** |
| 1.0 | 28/10/2024 | **Purpose and Scope creation:** Defined *Purpose and Scope*. |
| 2.0 | 30/10/2024 | **Stakeholder and Viewpoint Definition:** Added *Stakeholder Representation* and initiate the development of *Viewpoint Definitions*. |
| 2.1 | 31/10/2024 | **Viewpoint 1:** Continue to work on the Viewpoint section. |
| 2.2 | 01/11/2024 | **Viewpoint 2:** Continue to work on the Viewpoints section. |
| 2.3 | 02/11/2024 | **Viewpoint 3:** Continue to work on the Viewpoints section. |
| 2.4 | 03/11/2024 | **Viewpoint 4:** Ended and revised the Viewpoints section. |
| 3.0 | 06/11/2024 | **Architecture Background:** Completed *Architecture Background* (*Problem Background*, *Goals and Context*, *Driving Requirements*). |
| 4.0 | 08/11/2024 | **Solution Background:** Began drafting Solution Background (Architectural Approaches and initial Analysis Results). |
| 5.0 | 09/11/2024 | **Analysis Results:** Understanding how to use SonarQube and start to analyze the results given. |
| 5.1 | 10/11/2024 | **Analysis Results 1:** Start to write in this document the analysis made in the SonarQube platform. |
| 5.2 | 11/11/2024 | **Analysis Results 2:** Ended and revised the analysis results section. |
| 6.0 | 13/11/2024 | **Requirements coverage and summary of background:** Completed requirements coverage and summary of background. |
| 7.0 | 15/11/2024 | **Module Views 1:** Documented *Module Views* (*Decomposition*). |
| 7.0.1 | 16/11/2024 | **Module Views 2:** Documented Module Views (Uses and Data Model). |
| 7.1 | 17/11/2024 | **Component-and-Connector Views:** Documented *Component-and-Connector Views* (*Call-Return*, *Repository*). |
| 7.2 | 21/11/2024 | **Allocation Views:** Documented *Allocation Views* (*Execution*). |
| 7.2.1 | 22/11/2024 | **Allocation Views:** Documented *Allocation Views* (*Development*). |
| 7.3 | 25/11/2024 | **Revisions and Relation Among Views:** Reviewed and refined all *Views* (*Module*, *Component-and-Connector*, and *Allocation*) and added *Relations Among Views*. |
| 8.0 | 26/11/2024 | **Relation Among Views, Referenced Materials and Glossary:** Finalized *Relations Among Views* and completed *Referenced Materials* and *Glossary*. |
| 9.0 | 28/11/2024 | **Final Revisions 1:** Conducted a full review of the project, ensuring all sections are aligned and coherent. Addressed outstanding issues and incorporated necessary adjustments. |
| 9.1 | 29/11/2024 | **Final Revision 2:** Finalized the review on all the sections of this project. |

Table of Contents

[1 Documentation Roadmap 3](#_Toc183540832)

[1.1 Document Management and Configuration Control Information 4](#_Toc183540833)

[1.2 Purpose and Scope of the SAD 4](#_Toc183540834)

[1.2.1 Purpose 4](#_Toc183540835)

[1.2.2 Scope 4](#_Toc183540836)

[1.3 How the SAD Is Organized 5](#_Toc183540837)

[1.4 Stakeholder Representation 6](#_Toc183540838)

[1.5 Viewpoint Definitions 7](#_Toc183540839)

[1.5.1 Module Viewpoint Definition 9](#_Toc183540840)

[1.5.1.1 Decomposition Viewpoint Definition 9](#_Toc183540841)

[**1.5.1.1.1** **Abstract** 9](#_Toc183540842)

[**1.5.1.1.2** **Stakeholders and Their Concerns Addressed** 9](#_Toc183540843)

[**1.5.1.1.3** **Elements, Relations, Properties and Constraints** 10](#_Toc183540844)

[**1.5.1.1.4** **Language(s) to Model/Represent Conforming Views** 10](#_Toc183540845)

[**1.5.1.1.5** **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria** 10](#_Toc183540846)

[**1.5.1.1.6** **Viewpoint Source** 10](#_Toc183540847)

[1.5.1.2 Uses Viewpoint Definition 10](#_Toc183540848)

[**1.5.1.2.1** **Abstract** 10](#_Toc183540849)

[**1.5.1.2.2** **Stakeholders and Their Concerns Addressed** 11](#_Toc183540850)

[**1.5.1.2.3** **Elements, Relations, Properties and Constraints** 11](#_Toc183540851)

[**1.5.1.2.4** **Language(s) to Model/Represent Conforming Views** 11](#_Toc183540852)

[**1.5.1.2.5** **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria** 11](#_Toc183540853)

[**1.5.1.2.6** **Viewpoint Source** 11](#_Toc183540854)

[1.5.1.3 Data Viewpoint Definition 11](#_Toc183540855)

[**1.5.1.3.1** **Abstract** 11](#_Toc183540856)

[**1.5.1.3.2** **Stakeholders and Their Concerns Addressed** 11](#_Toc183540857)

[**1.5.1.3.3** **Elements, Relations, Properties and Constraints** 12](#_Toc183540858)

[**1.5.1.3.4** **Language(s) to Model/Represent Conforming Views** 12](#_Toc183540859)

[**1.5.1.3.5** **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria** 12](#_Toc183540860)

[**1.5.1.3.6** **Viewpoint Source** 12](#_Toc183540861)

[1.5.2 Component-and-Connector Viewpoint Definition 12](#_Toc183540862)

[1.5.2.1 Call-Return Viewpoint Definition 12](#_Toc183540863)

[**1.5.2.1.1** **Abstract** 12](#_Toc183540864)

[**1.5.2.1.2** **Stakeholders and Their Concerns Addressed** 12](#_Toc183540865)

[**1.5.2.1.3** **Elements, Relations, Properties and Constraints** 13](#_Toc183540866)

[**1.5.2.1.4** **Language(s) to Model/Represent Conforming Views** 13](#_Toc183540867)

[**1.5.2.1.5** **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria** 13](#_Toc183540868)

[**1.5.2.1.6** **Viewpoint Source** 13](#_Toc183540869)

[1.5.2.2 Repository Viewpoint Definition 13](#_Toc183540870)

[**1.5.2.2.1** **Abstract** 13](#_Toc183540871)

[**1.5.2.2.2** **Stakeholders and Their Concerns Addressed** 13](#_Toc183540872)

[**1.5.2.2.3** **Elements, Relations, Properties and Constraints** 13](#_Toc183540873)

[**1.5.2.2.4** **Language(s) to Model/Represent Conforming Views** 14](#_Toc183540874)

[**1.5.2.2.5** **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria** 14](#_Toc183540875)

[**1.5.2.2.6** **Viewpoint Source** 14](#_Toc183540876)

[1.5.3 Allocation Viewpoint Definition 14](#_Toc183540877)

[1.5.3.1 Execution Viewpoint Definition 14](#_Toc183540878)

[**1.5.3.1.1** **Abstract** 14](#_Toc183540879)

[**1.5.3.1.2** **Stakeholders and Their Concerns Addressed** 14](#_Toc183540880)

[**1.5.3.1.3** **Elements, Relations, Properties and Constraints** 15](#_Toc183540881)

[**1.5.3.1.4** **Language(s) to Model/Represent Conforming Views** 15](#_Toc183540882)

[**1.5.3.1.5** **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria** 15](#_Toc183540883)

[**1.5.3.1.6** **Viewpoint Source** 15](#_Toc183540884)

[1.5.3.2 Development Viewpoint Definition 15](#_Toc183540885)

[**1.5.3.2.1** **Abstract** 15](#_Toc183540886)

[**1.5.3.2.2** **Stakeholders and Their Concerns Addressed** 15](#_Toc183540887)

[**1.5.3.2.3** **Elements, Relations, Properties and Constraints** 16](#_Toc183540888)

[**1.5.3.2.4** **Language(s) to Model/Represent Conforming Views** 16](#_Toc183540889)

[**1.5.3.2.5** **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria** 16](#_Toc183540890)

[**1.5.3.2.6** **Viewpoint Source** 16](#_Toc183540891)

[1.6 How a View is Documented (Este já fiz, a stora já tinha feito esta secção burro) 16](#_Toc183540892)

[1.7 Relationship to Other SADs 18](#_Toc183540893)

[1.8 Process for Updating this SAD 18](#_Toc183540894)

[2 Architecture Background 19](#_Toc183540895)

[2.1 Problem Background 19](#_Toc183540896)

[2.1.1 System Overview 19](#_Toc183540897)

[2.1.2 Goals and Context 19](#_Toc183540898)

[2.1.3 Significant Driving Requirements 20](#_Toc183540899)

[2.2 Solution Background 20](#_Toc183540900)

[2.2.1 Architectural Approaches 21](#_Toc183540901)

[2.2.2 Analysis Results 22](#_Toc183540902)

[2.2.2.1 Security Analysis 22](#_Toc183540903)

[2.2.2.2 Reliability Analysis 24](#_Toc183540904)

[2.2.2.3 Maintainability Analysis 26](#_Toc183540905)

[2.2.2.4 Test Coverage Analysis 28](#_Toc183540906)

[2.2.2.5 Duplication Analysis 29](#_Toc183540907)

[2.2.3 Requirements Coverage 30](#_Toc183540908)

[2.2.4 Summary of Background Changes Reflected in Current Version 31](#_Toc183540909)

[2.3 Product Line Reuse Considerations 32](#_Toc183540910)

[3 Views 33](#_Toc183540911)

[3.1 Module View 35](#_Toc183540912)

[3.1.1 View Description 35](#_Toc183540913)

[3.1.2 View Packet Overview 35](#_Toc183540914)

[3.1.3 Architecture Background 36](#_Toc183540915)

[3.1.4 Variability Mechanisms 36](#_Toc183540916)

[3.1.5 View Packets 36](#_Toc183540917)

[3.1.5.1 Frontend Module (View Packet #1) 36](#_Toc183540918)

[3.1.5.2 Backend Module (View Packet #2) 37](#_Toc183540919)

[3.1.5.3 Database Module (View Packet #3) 37](#_Toc183540920)

[3.2 Uses View 37](#_Toc183540921)

[3.2.1 View Description 37](#_Toc183540922)

[3.2.2 View Packet Overview 37](#_Toc183540923)

[3.2.3 Architecture Background 38](#_Toc183540924)

[3.2.4 Variability Mechanisms 38](#_Toc183540925)

[3.2.5 View Packets 38](#_Toc183540926)

[3.2.5.1 Frontend-Backend Dependency (View Packet #1) 38](#_Toc183540927)

[3.2.5.2 Backend-Database Dependency (View Packet #2) 39](#_Toc183540928)

[3.3 Data Model View 39](#_Toc183540929)

[3.3.1 View Description 39](#_Toc183540930)

[3.3.2 View Packet Overview 40](#_Toc183540931)

[3.3.3 Architecture Background 40](#_Toc183540932)

[3.3.4 Variability Mechanisms 40](#_Toc183540933)

[3.3.5 View Packets 40](#_Toc183540934)

[3.3.5.1 User Table (View Packet #1) 40](#_Toc183540935)

[3.3.5.2 Quizzes Table (View Packet #2) 41](#_Toc183540936)

[3.3.5.3 Results Table (View Packet #3) 41](#_Toc183540937)

[3.4 Call-Return View 42](#_Toc183540938)

[3.4.1 View Description 42](#_Toc183540939)

[3.4.2 View Packet Overview 42](#_Toc183540940)

[3.4.3 Architecture Background 42](#_Toc183540941)

[3.4.4 Variability Mechanisms 42](#_Toc183540942)

[3.4.5 View Packets 43](#_Toc183540943)

[3.4.5.1 User Interaction Component (View Packet #1) 43](#_Toc183540944)

[3.4.5.2 Backend Processing Component (View Packet #2) 43](#_Toc183540945)

[3.5 Repository View 44](#_Toc183540946)

[3.5.1 View Description 44](#_Toc183540947)

[3.5.2 View Packet Overview 44](#_Toc183540948)

[3.5.3 Architecture Background 44](#_Toc183540949)

[3.5.4 Variability Mechanisms 44](#_Toc183540950)

[3.5.5 View Packets 45](#_Toc183540951)

[3.5.5.1 Data Storage Component (View Packet #1) 45](#_Toc183540952)

[3.5.5.2 Backend Processing Component (View Packet #2) 45](#_Toc183540953)

[3.6 Execution View 46](#_Toc183540954)

[3.6.1 View Description 46](#_Toc183540955)

[3.6.2 View Packet Overview 46](#_Toc183540956)

[3.6.3 Architecture Background 46](#_Toc183540957)

[3.6.4 Variability Mechanisms 46](#_Toc183540958)

[3.6.5 View Packets 47](#_Toc183540959)

[3.6.5.1 Frontend Deployment (View Packet #1) 47](#_Toc183540960)

[3.6.5.2 Backend Deployment (View Packet #2) 47](#_Toc183540961)

[3.7 Development View 48](#_Toc183540962)

[3.7.1 View Description 48](#_Toc183540963)

[3.7.2 View Packet Overview 48](#_Toc183540964)

[3.7.3 Architecture Background 48](#_Toc183540965)

[3.7.4 Variability Mechanisms 48](#_Toc183540966)

[3.7.5 View Packets 49](#_Toc183540967)

[3.7.5.1 Source Code Organization (View Packet #1) 49](#_Toc183540968)

[3.7.5.2 API Documentation (View Packet #2) 49](#_Toc183540969)

[4 Relations Among Views 50](#_Toc183540970)

[4.1 General Relations Among Views 50](#_Toc183540971)

[4.2 View-to-View Relations 51](#_Toc183540972)

[5 Referenced Materials 52](#_Toc183540973)

[6 Directory 53](#_Toc183540974)

[6.1 Glossary 53](#_Toc183540975)

[6.2 Acronym List 55](#_Toc183540976)

List of Figures

[Figure 1 - Security Analysis of Sonarqube 24](#_Toc183185753)

[Figure 2 - Example of critical reliability issue 25](#_Toc183185754)

[Figure 3 - Example of major reliability issue 26](#_Toc183185755)

[Figure 4 - Example of minor reliability issue 26](#_Toc183185756)

[Figure 5 - Example of critical maintainability issue 27](#_Toc183185757)

[Figure 6 - Example of major maintainability issue 27](#_Toc183185758)

[Figure 7 - Example of minor maintainability issue 28](#_Toc183185759)

[Figure 8 - Plot of test coverage distribution 29](#_Toc183185760)

[Figure 9 - Plot of duplication density 30](#_Toc183185761)

List of Tables

[Table 1: SAD update history ii](#_Toc183529376)

[Table 2: Stakeholders and Relevant Viewpoints 9](#_Toc183529377)

[Table 3: Views of this sad 34](#_Toc183529378)

[Table 4: View Packets of Module View 35](#_Toc183529379)

[Table 5: View Packets of Uses View 38](#_Toc183529380)

[Table 6: View Packets of Data Model View 40](#_Toc183529381)

[Table 7: View Packets of Call-Return View 42](#_Toc183529382)

[Table 8: View Packets of Execution View 46](#_Toc183529383)

[Table 9: View Packets of Development View 48](#_Toc183529384)

[Table 10: Reference Materials 52](#_Toc183529385)

[Table 11: Glossary 53](#_Toc183529386)

[Table 12: Acronym List 55](#_Toc183529387)

# Documentation Roadmap

The Documentation Roadmap should be the first place a new reader of the SAD begins. But for new and returning readers, it is intended to describe how the SAD is organized so that a reader with specific interests who does not wish to read the SAD cover-to-cover can find desired information quickly and directly.

Sub-sections of Section 1 include the following.

* **Section 1.1 (“Document Management and Configuration Control Information”)** explains revision history. This tells you if you’re looking at the correct version of the SAD.
* **Section 1.2 (“Purpose and Scope of the SAD”)** explains the purpose and scope of the SAD, and indicates what information is and is not included. This tells you if the information you’re seeking is likely to be in this document.
* **Section 1.3 (“How the SAD Is Organized”)** explains the information that is found in each section of the SAD. This tells you what section(s) in this SAD are most likely to contain the information you seek.
* **Section 1.4 (“Stakeholder Representation”)** explains the stakeholders for which the SAD has been particularly aimed. This tells you how you might use the SAD to do your job.
* **Section 1.5 (“Viewpoint Definitions”)** explains the *viewpoints* (as defined by IEEE Standard 1471-2000) used in this SAD. For each viewpoint defined in Section 1.5, there is a corresponding view defined in Section 3 (“Views”). This tells you how the architectural information has been partitioned, and what views are most likely to contain the information you seek.
* **Section 1.6 (“How a View is Documented”)** explains the standard organization used to document architectural views in this SAD. This tells you what section within a view you should read in order to find the information you seek
* **Section 1.7 ("Relationship to Other SADs")** notes whether this SAD is related to other architecture documents. If no related documents exist, it simply states "Not applicable," clarifying whether additional architecture documents should be consulted.
* **Section 1.8 (“Process for Updating this SAD”)** describes how to report issues or inaccuracies in the SAD, providing contact details and steps for handling feedback to maintain document accuracy.

## Document Management and Configuration Control Information

* Revision Number: 7.0
* Revision Release Date: 28/11/2024
* Purpose of Revision: Final review of the document and implementation of minor necessary adjustments after the project evaluation.
* Scope of Revision: Performed a final assessment of all sections, ensuring readability, accuracy, and alignment with project objectives. Minor corrections and refinements were applied to improve clarity and coherence.

## Purpose and Scope of the SAD

### Purpose

The purpose of this Software Architecture Document (SAD) is to comprehensively document the architecture of Quizzes Tutor, an open-source platform for creating, managing, and evaluating educational quizzes. This SAD serves as a central reference for the system’s development, analysis, and maintenance, supporting effective stakeholder communication and ensuring a shared understanding of its design.

### Scope

This SAD outlines key architectural aspects of Quizzes Tutor, including:

**Stakeholders and Their Interests**: Identification of main stakeholders (teachers, students, development team, and system administrators), highlighting their specific needs and concerns to guide architectural decisions.

**Quality Requirements**: Definition of key quality attributes such as performance, security, scalability, and maintainability, supported by scenarios illustrating expected system behavior and performance benchmarks.

**Architectural Views**:

* **Module View:**
  + *Decomposition View*: Describes the hierarchy of modules and submodules, specifying their distinct responsibilities.
  + *Uses View*: Highlights functional dependencies between modules, showing key interactions.
  + *Data Model View*: Illustrates relationships between data entities to ensure consistency in data storage.
* **Component-and-Connector View:**
  + *Call-Return*: Focuses on control flow and function interactions between components.
  + *Repository*: Describes shared data storage and access mechanisms used by the system.
* **Allocation View:**
  + *Execution View*: Maps software components to physical or virtual infrastructure, ensuring scalability and reliability.
  + *Development View*: Outlines the organization of development artifacts, such as source code and dependencies, to facilitate collaboration and project management.

This document focuses on high-level architectural decisions and component interactions, leaving detailed technical specifications and implementation guidelines to supplementary documentation. This approach provides a top-down view, making the system’s architecture accessible without delving into low-level code details.

## How the SAD Is Organized

This SAD is organized into the following sections:

* **Section 1 (“Documentation Roadmap”) provides information about this document and its intended audience**. It provides the roadmap and document overview. Every reader who wishes to find information relevant to the software architecture described in this document should begin by reading Section 1, which describes how the document is organized, which stakeholder viewpoints are represented, how stakeholders are expected to use it, and where information may be found. Section 1 also provides information about the views that are used by this SAD to communicate the software architecture.
* **Section 2 (“Architecture Background”) explains why the architecture is what it is.** It provides a system overview, establishing the context and goals for the development. It describes the background and rationale for the software architecture. It explains the constraints and influences that led to the current architecture, and it describes the major architectural approaches that have been utilized in the architecture. It includes information about evaluation or validation performed on the architecture to provide assurance it meets its goals.
* **Section 3 (Views”) and Section 4 (“Relations Among Views”) specify the software architecture**. Views specify elements of software and the relationships between them. A view corresponds to a viewpoint (see Section 1.5), and is a representation of one or more structures present in the software (see Section 1.2).
* **Sections 5 (“Referenced Materials”) and 6 (“Directory”) provide reference information for the reader.** Section 5 provides look-up information for documents that are cited elsewhere in this SAD. Section 6 is a *directory*, which is an index of architectural elements and relations telling where each one is defined and used in this SAD. The section also includes a glossary and acronym list.

## Stakeholder Representation

This section provides an overview of the primary stakeholders involved in the development and use of the Quizzes Tutor system, along with their main concerns regarding the system’s architecture.

1. **Teachers**
   * **Role**: Creators and managers of quizzes.
   * **Main Concerns**:
     + Usability: An intuitive interface for creating and managing quizzes.
     + Reliability: System stability during usage to ensure smooth educational activities.
     + Performance Reporting: Access to reports tracking student progress and results.
2. **Students**
   * **Role**: End users who take quizzes.
   * **Main Concerns**:
     + Availability: Reliable access to the system at all times.
     + User Experience: A simple, user-friendly interface for completing quizzes.
     + Responsiveness: Fast response time, especially when submitting answers.
3. **Development Team**
   * **Role**: Engineers and developers responsible for system maintenance and expansion.
   * **Main Concerns**:
     + Modularity: An architecture that supports easy maintenance and future feature additions.
     + Scalability: The ability to handle an increase in users if necessary.
     + Documentation: Clear documentation to support ongoing development.
4. **System Administrators**
   * **Role**: Responsible for system deployment, stability, and monitoring.
   * **Main Concerns**:
     + Stability and Monitoring: Capability to monitor and resolve issues quickly.
     + Security: Protecting against unauthorized access and ensuring data integrity.
     + Resource Efficiency: Efficient management of server and storage resources.
5. **Project Manager**
   * **Role**: Supervisor ensuring project goals, timeline, and budget.
   * **Main Concerns**:
     + Schedule and Budget: Ensuring that the system is developed on time and within budget constraints.
     + Team Coordination: Facilitating collaboration among developers, designers, and stakeholders.
     + Architectural Flexibility: Ensuring that the architecture can adapt to changes or new requirements.

## Viewpoint Definitions

The SAD employs a stakeholder-focused, multiple view approach to architecture documentation, as required by ANSI/IEEE 1471-2000, the recommended best practice for documenting the architecture of software-intensive systems [IEEE 1471].

As described in Section 1.2, a software architecture comprises more than one software structure, each of which provides an engineering handle on different system qualities. A *view* is the specification of one or more of these structures, and documenting a software architecture, then, is a matter of documenting the relevant views and then documenting information that applies to more than one view [Clements 2002].

ANSI/IEEE 1471-2000 provides guidance for choosing the best set of views to document, by bringing stakeholder interests to bear. It prescribes defining a set of viewpoints to satisfy the stakeholder community. A viewpoint identifies the set of concerns to be addressed, and identifies the modeling techniques, evaluation techniques, consistency checking techniques, etc., used by any conforming view. A view, then, is a viewpoint applied to a system. It is a representation of a set of software elements, their properties, and the relationships among them that conform to a defining viewpoint. Together, the chosen set of views show the entire architecture and all of its relevant properties. A SAD contains the viewpoints, relevant views, and information that applies to more than one view to give a holistic description of the system.

For the Quizzes Tutor system, we have identified three primary viewpoints to capture essential system qualities and address the specific needs of stakeholders:

* **Module Viewpoint**: Focuses on the static structure, dividing the system into modules.

**Decomposition View:** Displays the hierarchy of modules and submodules, showing how each part of the system has a specific responsibility.

**Uses View:** Highlights functional dependencies between modules, illustrating essential interactions for system functionality.

**Data Model View:** Shows relationships between data entities, ensuring a clear and consistent structure for information storage.

* **Component-and-Connector Viewpoint**: Highlights runtime interactions, showing data flow and communication.

**Call-Return:** Components receive control and data from others, executing a function and then returning control to the invoker.

**Repository:** Large stores of persistent data managed centrally or across several databases, enabling shared access to data.

* **Allocation Viewpoint**: Maps software elements to their physical or virtual deployment infrastructure.

**Execution View**: Maps software components to the execution infrastructure, such as physical servers or cloud environments, to support real-time operation.

**Development View**: Shows the organization of development artifacts, like source code, to facilitate team coordination and management.

The following table summarizes the stakeholders in the Quizzes Tutor project and the viewpoints selected to address their specific concerns:

Table 2: Stakeholders and Relevant Viewpoints

| **Stakeholder** | **Viewpoint(s) that apply to that class of stakeholder’s concerns** |
| --- | --- |
| Teachers | |  | | --- | |  | | Module Viewpoint: Decomposition View | |
| Students | Component-and-Connector Viewpoint: Call-Return |
| Development Team | Module Viewpoint: Decomposition View, Uses View, Data Model View  Component-and-Connector Viewpoint: Call-Return  Allocation Viewpoint: Development View |
| System Administrators | |  | | --- | |  | | Component-and-Connector Viewpoint: Repository  Allocation Viewpoint: Execution View  Module Viewpoint: Data Model View | |
| Project Manager | Module Viewpoint: Decomposition View |

### Module Viewpoint Definition

#### Decomposition Viewpoint Definition

##### **Abstract**

The Decomposition View displays the system's hierarchy of modules and submodules, dividing it into distinct parts, each with specific responsibilities, to organize and structure the system.

##### **Stakeholders and Their Concerns Addressed**

**Project Managers:** Need a clear view of the modules to plan tasks and organize the team's work.

**Development Team**: Benefits from a clear modular structure to facilitate incremental development and maintenance.

**Teachers**: Require an understanding of the main modular functionalities to support their use of the system.

##### **Elements, Relations, Properties and Constraints**

**Elements**: Modules, submodules, and their specific functionalities.

**Relations**: “Is-part-of” relation representing the hierarchy and modular structure of the system.

**Properties**: Each module’s name, main function, and software interface.

**Constraints**: Each module should be responsible for a distinct function and not overlap responsibilities with other modules.

##### **Language(s) to Model/Represent Conforming Views**

**UML Class Diagrams** or **Component Diagrams** to illustrate hierarchical structure and relations of each module.

##### **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria**

**Consistency**: Each element should have only one parent module.

**Completeness**: The functionality of all modules combined should cover the system requirements.

**Evaluation Techniques**: Scenario-based analysis to ensure modularity allows changes with minimal impact.

##### **Viewpoint Source**

Clements, P., et al. *Documenting Software Architectures: Views and Beyond* (2002).

#### Uses Viewpoint Definition

##### **Abstract**

The *Uses View* highlights the functional dependencies between modules, illustrating how the functionality of one module depends on another, helping identify key system interactions.

##### **Stakeholders and Their Concerns Addressed**

**Development Team**: Needs to understand module dependencies to avoid integration issues.

##### **Elements, Relations, Properties and Constraints**

**Elements**: Modules with specific functions and functional dependencies.

**Relations**: “Depends-on” relations defining execution dependencies between modules.

**Properties**: Each module’s name, function, and associated dependencies.

**Constraints**: Dependent modules must be compatible in terms of interface and communication.

##### **Language(s) to Model/Represent Conforming Views**

**UML Dependency Diagrams** or **Sequence Diagrams** to show interactions and functional dependencies.

##### **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria**

**Consistency**: All listed dependencies should be valid and documented.

**Completeness**: All critical interactions for functionality should be represented.

**Evaluation Techniques**: Review dependencies to identify potential coupling issues.

##### **Viewpoint Source**

Clements, P., et al. *Documenting Software Architectures: Views and Beyond* (2002).

#### Data Viewpoint Definition

##### **Abstract**

The *Data Model View* shows relationships between the system’s data entities, providing a clear and consistent structure for storing and managing information.

##### **Stakeholders and Their Concerns Addressed**

**Development Team**: Requires a clear data structure to correctly implement and integrate storage and retrieval operations.

**System Administrators**: Concerned with data integrity and security to ensure proper system functioning.

##### **Elements, Relations, Properties and Constraints**

**Elements**: Data entities, such as tables and columns in the database.

**Relations**: “Association” and “dependency” relations between entities (e.g., foreign key).

**Properties**: Each entity’s attributes, including data types and constraints.

**Constraints**: All relationships must maintain referential integrity and data consistency.

##### **Language(s) to Model/Represent Conforming Views**

**Entity-Relationship Diagrams (ERD)** or **UML Class Diagrams** to represent the data structure and relationships between entities.

##### **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria**

**Consistency**: All data relationships should be consistent and follow integrity constraints.

**Completeness**: All necessary entities and relationships for data storage should be represented.

**Evaluation Techniques**: Referential integrity check and normalization analysis to avoid data redundancy.

##### **Viewpoint Source**

Clements, P., et al. *Documenting Software Architectures: Views and Beyond* (2002).

### Component-and-Connector Viewpoint Definition

#### Call-Return Viewpoint Definition

##### **Abstract**

The *Call-Return View* models interactions in which components receive control and data from others, execute a function, and then return control to the invoker. This style is typical in client-server or peer-to-peer architectures, where components rely on specific calls to perform tasks.

##### **Stakeholders and Their Concerns Addressed**

**Development Team**: Requires a clear understanding of component interactions and control flow to develop, debug, and optimize system performance.

**Students**: Interested in understanding how system components work together, which enhances their user experience during runtime.

##### **Elements, Relations, Properties and Constraints**

**Elements**: Components that act as invokers or receivers in control flows, such as clients and servers.

**Relations**: “Calls” relation, where an invoker component makes a call to another, transferring control and possibly data.

**Properties**: Each component’s role (invoker or receiver), and data involved in the call.

**Constraints**: Each call must follow a compatible interface for control and data exchange, and components should maintain state consistency.

##### **Language(s) to Model/Represent Conforming Views**

**Sequence Diagrams** or **Activity Diagrams** to show the sequence and flow of control and data exchange among components.

##### **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria**

**Consistency**: All control flows must be compatible with the designated interfaces.

**Completeness**: All necessary calls to achieve full functionality must be represented.

**Evaluation Techniques**: Performance analysis of control flows to ensure low-latency interaction; scenario-based testing to validate control dependencies.

##### **Viewpoint Source**

Based on standard client-server and peer-to-peer interaction models as described in *Documenting Software Architectures: Views and Beyond* by Clements et al.

#### Repository Viewpoint Definition

##### **Abstract**

The *Repository View* focuses on the system’s large stores of persistent data, managed centrally or across several databases, enabling shared access and data integrity. This view is crucial for understanding how data is stored, accessed, and maintained.

##### **Stakeholders and Their Concerns Addressed**

**System Administrators**: Concerned with the data repository's stability, integrity, and security to maintain overall system health.

##### **Elements, Relations, Properties and Constraints**

**Elements**: Central data repositories (e.g., databases), data access components, and storage structures.

**Relations**: “Stores” and “retrieves” relations showing interactions between data storage elements and components accessing them.

**Properties**: Each data repository’s storage type, access protocols, and security measures.

**Constraints**: All data access should ensure data integrity, security, and support for concurrent data requests without conflicts.

##### **Language(s) to Model/Represent Conforming Views**

**Entity-Relationship Diagrams (ERD)** or **UML Component Diagrams** to represent data storage structures and data flow between components and repositories.

##### **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria**

**Consistency**: All data access methods should comply with data repository constraints.

**Completeness**: The repository should include all essential data entities for system functionality.

**Evaluation Techniques**: Integrity checks, performance analysis to handle data load, and security analysis to prevent unauthorized access.

##### **Viewpoint Source**

Inspired by repository-centric designs for shared-data environments as documented in *Documenting Software Architectures: Views and Beyond* by Clements et al.

### Allocation Viewpoint Definition

#### Execution Viewpoint Definition

##### **Abstract**

The Execution View maps the system's software components to the underlying infrastructure, such as web servers, application servers, and databases, to ensure real-time operation, scalability, and reliability. This viewpoint ensures that the system can operate efficiently across distributed environments, leveraging cloud-based or on-premises infrastructure.

##### **Stakeholders and Their Concerns Addressed**

**System Administrators**: Need a clear understanding of deployment strategies, server configurations, and resource allocation to maintain the system's stability.

##### **Elements, Relations, Properties and Constraints**

**Elements**: Application servers, database servers, front-end components, and communication protocols.

**Relations**: "Is-deployed-on" relationship mapping software components to execution nodes and "communicates-with" relationships showing data flow between components.

**Properties**: Latency requirements, resource usage (e.g., CPU, memory), and database query performance.

**Constraints**: Infrastructure must meet high availability requirements to ensure quiz access and must support load balancing during peak times.

##### **Language(s) to Model/Represent Conforming Views**

UML Deployment Diagrams for mapping software to execution environments.

Infrastructure-as-Code (e.g., Docker Compose or Kubernetes YAML files) to represent cloud-based deployment configurations.

##### **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria**

**Consistency**: All components must be associated with an infrastructure node.

**Completeness**: Execution view should represent all components necessary for system functionality.

**Evaluation**: Load testing, scalability tests, and failover scenario simulations to ensure system stability and reliability.

##### **Viewpoint Source**

Derived from Quizzes Tutor deployment documentation and cloud architecture practices.

#### Development Viewpoint Definition

##### **Abstract**

The Development View organizes development artifacts, such as source code, modules, libraries, and build tools, to support team collaboration, modularity, and maintainability. This viewpoint facilitates efficient implementation, testing, and future system enhancements.

##### **Stakeholders and Their Concerns Addressed**

**Development Team**: Requires a well-structured codebase to manage dependencies and collaborate effectively.

##### **Elements, Relations, Properties and Constraints**

**Elements**: Front-end and back-end modules, APIs, database migration scripts, and test suites.

**Relations**: "Depends-on" relations between modules, libraries, and build tools.

**Properties**: Ownership of modules, versioning of artifacts, and coverage of test cases.

**Constraints**: Codebase must adhere to defined coding standards and avoid circular dependencies.

##### **Language(s) to Model/Represent Conforming Views**

UML Component Diagrams to represent dependencies and modular architecture.

Repository structure diagrams to model folder organization and version control branching.

##### **Applicable Evaluation/Analysis Techniques and Consistency/Completeness Criteria**

**Consistency**: Ensure no conflicting dependencies exist and version control is maintained.

**Completeness**: Ensure all required artifacts are included for implementation and testing.

**Evaluation**: Dependency analysis, CI/CD pipeline validation, and automated testing reports.

##### **Viewpoint Source**

Based on Quizzes Tutor development practices and project repository analysis.

## How a View is Documented (Este já fiz, a stora já tinha feito esta secção burro)

Section 3 of this SAD contains one view for each viewpoint listed in Section 1.5. Each view is documented as a set of view packets. A view packet is the smallest bundle of architectural documentation that might be given to an individual stakeholder.

Each view is documented as follows, where the letter *i* stands for the number of the view: 1, 2, etc.:

* Section 3.i: Name of view.
* Section 3.i.1: View description. This section describes the purpose and contents of the view. It should refer to (and match) the viewpoint description in Section 1.5 to which this view conforms.
* Section 3.i.2: View packet overview. This section shows the set of view packets in this view and provides rationale that explains why the chosen set is complete and non-duplicative. The set of view packets are shown in table to facilitate interpretation.
* Section 3.i.3: Architecture background. Whereas the architecture background of Section 2 pertains to those constraints and decisions whose scope is the entire architecture, this section provides any architecture background (including significant driving requirements, design approaches, patterns, analysis results, and requirements coverage) that applies to this view.
* Section 3.i.4: Variability mechanisms. This section describes any architectural variability mechanisms (e.g., adaptation data, compile-time parameters, variable replication, and so forth) described by this view, including a description of how and when those mechanisms may be exercised and any constraints on their use.
* Section 3.i.5: View packets. This section presents all of the view packets given for this view. Each view packet is described using the following outline, where the letter *j* stands for the number of the view packet being described: 1, 2, etc.
* Section 3.i.5.j: View packet #j.
* Section 3.i.5.j.1: Primary presentation. This section presents the elements and the relations among them that populate this view packet, using an appropriate language, languages, notation, or tool-based representation.
* Section 3.i.5.j.2: Element catalog. Whereas the primary presentation shows the important elements and relations of the view packet, this section provides additional information needed to complete the architectural picture. It consists of the following subsections:
* Section 3.i.5.j.2.1: Elements.This section describes each element shown in the primary presentation, details its responsibilities of each element, and specifies values of the elements’ relevant *properties*, which are defined in the viewpoint to which this view conforms.
* Section 3.i.5.j.2.2: Relations.This section describes any additional relations among elements shown in the primary presentation, or specializations or restrictions on the relations shown in the primary presentation.
* Section 3.i.5.j.2.3: Interfaces.This section specifies the software interfaces to any elements shown in the primary presentation that must be visible to other elements.
* Section 3.i.5.j.2.4: Behavior. This section specifies any significant behavior of elements or groups of interacting elements shown in the primary presentation.
* Section 3.i.5.j.2.5: Constraints: This section lists any constraints on elements or relations not otherwise described.
* Section 3.i.5.j.3: Context diagram. This section provides a context diagram showing the context of the part of the system represented by this view packet. It also designates the view packet’s scope with a distinguished symbol, and shows interactions with external entities in the vocabulary of the view.
* Section 3.i.5.j.4: Variability mechanisms. This section describes any variabilities that are available in the portion of the system shown in the view packet, along with how and when those mechanisms may be exercised.
* Section 3.i.5.j.5: Architecture background. This section provides rationale for any significant design decisions whose scope is limited to this view packet.
* Section 3.i.5.j.6: Relation to other view packets. This section provides references for related view packets, including the parent, children, and siblings of this view packet. Related view packets may be in the same view or in different views.

This organizational structure in Section 1.6 serves as a template for Section 3, ensuring consistency and clarity across all views in the SAD.

## Relationship to Other SADs

Not applicable.

## Process for Updating this SAD

Not applicable.

# Architecture Background

## Problem Background

The Quizzes Tutor system was developed to address specific needs in the educational field, particularly in simplifying quiz creation and management. This demand emerged from a gap in traditional assessment methods, which can be time-consuming and difficult to tailor for each class and subject. Quizzes Tutor aims to fulfill these needs by providing a practical, accessible, and secure digital platform.

### System Overview

The Quizzes Tutor project considers the following key constraints and influences on its architecture:

* **Flexibility and Ease of Use:** The system must allow teachers to create quizzes with various question types (e.g., multiple-choice, true/false) and provide an intuitive interface for both teachers and students.
* **Data Security:** Protecting user data and quiz results is a primary concern. The architecture must support data encryption and user authentication.
* **Performance and Scalability:** Given the potential for multiple simultaneous accesses, particularly during peak assessment periods, the architecture must support horizontal scalability and high availability.
* **Chosen Technologies:** The use of Vue.js for the frontend, Spring Boot for the backend, and PostgreSQL for the database influences architectural decisions, as each of these tools provides specific capabilities in modularity, performance, and security.

These combined factors form the background for the architectural choices made for Quizzes Tutor, ensuring the system effectively meets pedagogical and technical requirements.

### Goals and Context

This section outlines the main goals and contextual factors shaping the architecture of Quizzes Tutor. The system’s primary goal is to facilitate teaching and learning through interactive quizzes, ensuring that teachers can easily create and manage quizzes, while students have a seamless experience accessing and completing them. In the educational context, the system needs to be robust, focusing on usability, scalability, and security. The architecture of Quizzes Tutor plays a central role in the software lifecycle, aligning with system engineering artifacts and meeting both pedagogical and technical needs.

### Significant Driving Requirements

This section highlights the behavioral and quality requirements that drive the architecture of Quizzes Tutor. Performance requirements include the ability to handle high volumes of simultaneous requests, particularly during peak testing periods. Security requirements ensure that only authorized users have access to sensitive information. Other quality attributes, such as availability and maintainability, were evaluated using methods like ATAM, ensuring the system can support future adaptations and enhancements without compromising data integrity or user experience.

## Solution Background

This section outlines the rationale behind the architecture chosen for Quizzes Tutor and explains how it meets the defined behavioral and quality objectives.

**Architecture Goal**: Designed to be a robust, scalable, and user-friendly platform for creating and managing educational quizzes, supporting both teachers and students. The system must be intuitive, reliable, and maintain consistent performance.

**Behavioral Goals**:

**User Experience**: The Vue.js frontend offers an interactive and responsive interface, crucial for a positive user experience in educational environments, where usability is key.

**Reliability**: Ensures consistent execution of core functionalities (e.g., quiz creation, submission, and grading), minimizing disruptions.

**Quality Attributes**:

**Performance**: The frontend-backend separation optimizes each component’s performance, keeping the interface responsive while the backend manages business logic and data processing efficiently.

**Scalability**: Using PostgreSQL and a modular implementation supports the system's growth for increasing users, while preserving integrity and performance.

**Maintainability**: The modular architecture facilitates feature additions and updates without impacting the entire application, enabling continuous improvement.

### Architectural Approaches

This section discusses the key design decisions underlying Quizzes Tutor’s architecture, including adopted architectural styles, patterns, and considered alternatives.

**Architectural Styles and Patterns**:

**Separate Frontend-Backend Architecture**: Vue.js is used for the frontend, separate from the Spring Boot (in java) backend, creating a responsive and scalable interface independent of business logic and data processing.

**Client-Server Model**: Sensitive operations and data are securely processed on the server (backend), while the client (frontend) offers an interactive user experience.

**Data Persistence with PostgreSQL**: Chosen for its reliability, scalability, and compatibility with complex transactions, PostgreSQL is ideal for managing quiz and assessment data.

**Design Rationale**:

**Vue.js for Frontend**: Chosen for its quick development cycle and easy learning curve, enabling the team to build an intuitive interface.

**Spring Boot for Backend**: Selected for robustness and modularity, managing business logic and integrating well with PostgreSQL.

**PostgreSQL as Database**: Ensures data integrity and consistency, essential for educational systems.

**Considered and Rejected Alternatives**:

**Frontend Frameworks**: React and Angular were considered, but Vue.js was chosen for simplicity and ease of integration.

**Databases**: MySQL and MongoDB were reviewed, but PostgreSQL was selected for handling complex transactions and ensuring data consistency.

**COTS Issues**:

**Use of Open-Source Solutions**: The architecture leverages open-source solutions, like PostgreSQL, to meet quality requirements without significant added cost.

**IST Authentication Integration**: Integrated with the Instituto Superior Técnico’s authentication system to ensure secure and straightforward access for users.

### Analysis Results

SonarQube is a powerful tool for static code analysis, designed to assess and improve the quality of software projects. It provides insights into various aspects of code quality, including security, reliability, maintainability, test coverage, and code duplication. By identifying potential vulnerabilities, technical debt, and areas for optimization, SonarQube supports developers in building robust and high-quality software systems.

This section focuses on the analysis performed using SonarQube, detailing the project's strengths and weaknesses in key quality metrics. Each subsection will provide an in-depth examination of specific aspects, including recommendations for improvement, supported by relevant visualizations and examples from the analysis results.

#### Security Analysis

The security analysis performed by SonarQube identified several areas of concern categorized by review priority: High, Medium, and Low. These findings highlight potential vulnerabilities and areas that may require further inspection to ensure the application's resilience against threats.

**High-Priority Issues:**

Cross-Site Request Forgery (CSRF):

* + Occurrences: 2
  + Description: CSRF vulnerabilities allow attackers to trick authenticated users into performing unintended actions on a web application.
  + Impact: May compromise user accounts and application functionality.

Cross-Site Scripting (XSS):

* + Occurrences: 19
  + Description: XSS vulnerabilities can allow attackers to inject malicious scripts into web pages viewed by other users.
  + Impact: Can lead to theft of user data, session hijacking, or website defacement.

**Medium-Priority Issues**

Denial of Service (DoS):

* + Occurrences: 4
  + Description: DoS vulnerabilities can lead to resource exhaustion, rendering the application unresponsive.
  + Impact: May disrupt service availability for legitimate users.

Weak Cryptography:

* + Occurrences: 2
  + Description: Use of weak or outdated cryptographic algorithms.
  + Impact: Could compromise the integrity and confidentiality of sensitive data.

**Low-Priority Issues**

Encryption of Sensitive Data:

* + Occurrences: 8
  + Description: Potential areas where sensitive data encryption may not be properly enforced.
  + Impact: Could expose user information if intercepted.

Insecure Configuration:

* + Occurrences: 4
  + Description: Misconfigurations that may introduce security risks.
  + Uma imagem com texto, captura de ecrã, software, número

    Descrição gerada automaticamenteImpact: Could be exploited to gain unauthorized access or expose sensitive functionality.

Figure 1 - Security Analysis of Sonarqube

#### Reliability Analysis

The reliability analysis identified 230 open issues, distributed across various levels of severity. Below is a detailed breakdown:

**Severity distribution:**

* Critical: 4 issues
* Major: 223 issues
* Minor: 3 issues

**Examples of issues:**

**Critical Issues:**

**Improper Stream Handling**:

* Certain code sections do not properly close streams or ensure they are managed correctly.
* Example: stream() pipelines left open, leading to potential memory leaks or resource exhaustion.

**Null Pointer Dereference**:

* Code paths that dereference objects without null-checks, resulting in possible runtime exceptions.
* Uma imagem com texto, captura de ecrã, Tipo de letra, file

  Descrição gerada automaticamenteExample: A method assumes a variable is non-null without proper validation, which could crash during edge cases.

Figure 2 - Example of critical reliability issue

**Major Issues:**

**Redundant Resource Management**:

* Several instances where resources are not released in a timely manner, though not as critical as open streams.

**Inconsistent Exception Handling**:

* Areas where exceptions are either swallowed silently or handled inconsistently across the codebase.

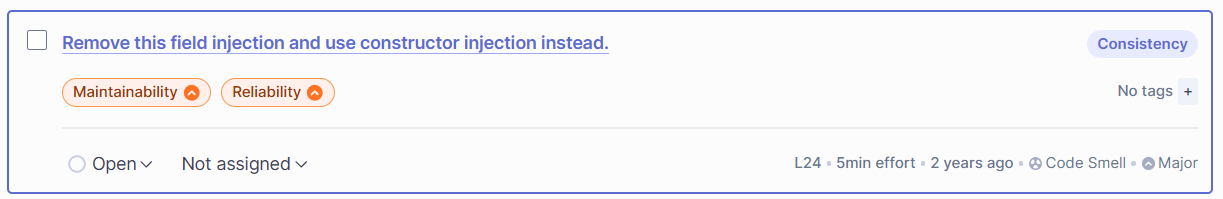


Figure 3 - Example of major reliability issue

**Minor Issues**

**Code Formatting and Readability**:

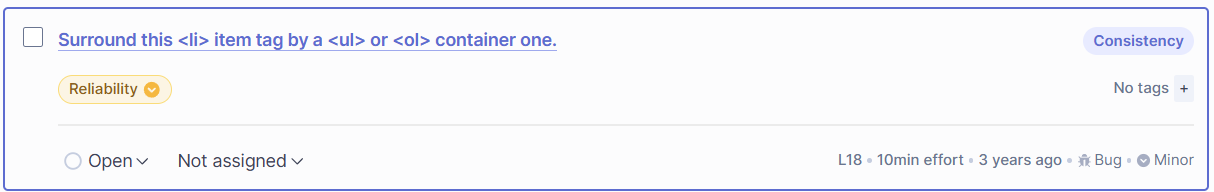
* Minor concerns with inconsistent formatting or redundant code snippets.
* Example: Excessively long methods with inline logic that could benefit from modularization for better clarity.

Figure 4 - Example of minor reliability issue

#### Maintainability Analysis

The maintainability analysis highlights 484 open issues, which are distributed across different severities as follows:

**Severity distribution:**

* **Critical**: 28 issues
* **Major**: 270 issues
* **Minor**: 186 issues

**Examples**:

**Critical Issues:**

**Improper Use of Serialization**:

* + Classes such as CodeFillInAnswer, CodeOrderAnswer, and MultipleChoiceAnswer are flagged for not being properly marked as transient or serializable.
  + **Example**: In CodeFillInStatementAnswerDetailsDto.java, serialization warnings indicate potential data leakage or issues in object state persistence.

**Hard-Coded Literals**:

* + Repeated occurrences of hard-coded values (e.g., email addresses) without being defined as constants.
  + Uma imagem com texto, Tipo de letra, file, captura de ecrã

    Descrição gerada automaticamente**Example**: The literal "rito.silva@tecnico.ulisboa.pt" is duplicated three times in AnswerService.java.

Figure 5 - Example of critical maintainability issue

**Major Issues:**

**Field Injection Over Constructor Injection**:

* + Instances where fields are injected directly, rather than using constructor-based dependency injection.
  + **Example**: Classes such as TutorApplication and AdminController are flagged for this practice, which reduces testability and increases coupling.

**Complex Conditionals**:

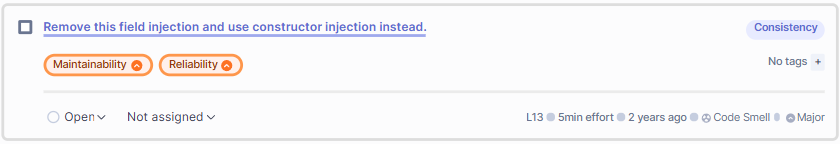
* + Overly complex logic in conditionals, making the code harder to read and maintain.

Figure 6 - Example of major maintainability issue

**Minor Issues:**

**Inconsistent Formatting**:

* + Code formatting is not standardized, leading to inconsistent indentation or spacing.
  + Example: Several files have redundant blank lines or irregular alignment of blocks.

**Redundant Code**:

* + Duplicate code snippets that could be refactored into shared methods or utility functions.
  + Example: Repeated logic for handling similar operations across different modules.

**Unused Variables and Imports**:

* + Variables and imports that are declared but never used, adding unnecessary clutter to the codebase.

Figure 7 - Example of minor maintainability issue

#### Test Coverage Analysis

The analysis of the test coverage for the project reveals an overall code coverage of **56.2%**, indicating that slightly more than half of the codebase is being executed during testing. Detailed statistics are as follows:

* **Total Lines to Cover:** 9,835
* **Uncovered Lines:** 4,056
* **Line Coverage:** 58.8%
* **Conditions to Cover:** 2,015
* **Uncovered Conditions:** 1,130
* **Condition Coverage:** 43.9%

The scatter plot below highlights the distribution of coverage against technical debt. While there are several files with high coverage, some critical areas remain under-tested, representing potential risks and opportunities for improvement.

#### Duplication Analysis

Figure 8 - Plot of test coverage distribution

The duplication analysis indicates a **duplication rate of 1.6%** across the codebase, calculated on **41,000 lines of code**. This duplication level is quite low, which is a positive indicator of code quality and adherence to software engineering best practices. However, it's essential to identify and assess duplicated blocks to ensure maintainability and reduce the risk of inconsistencies in future updates.

**Density: 1.6%**

* This indicates that 1.6% of the codebase is duplicated.
* A low duplication density like this suggests that the project is well-structured with minimal redundancy.

**Duplicated Lines: 672**

* A total of 672 lines across the project are duplicated.
* While this is not an excessive amount, reducing it further can improve maintainability and readability.

**Duplicated Blocks: 117**

* These represent blocks of code that are repeated across different files or modules.
* Duplication at the block level often results from repeated logic or functionality that could be abstracted into reusable components.

**Duplicated Files: 15**

* 15 files contain duplicated code, suggesting specific areas of the project that may benefit from refactoring.
* Focusing on these files can have a significant impact on reducing overall redundancy.

Uma imagem com texto, captura de ecrã, diagrama, Tipo de letra

Descrição gerada automaticamenteWhile the overall duplication density of 1.6% is relatively low, there are some outliers like CoursesView.vue, as we can see in the plot below, suggesting opportunities for optimization. By addressing these high-duplication files, the project can enhance maintainability, reduce technical debt, and promote cleaner code.

Figure 9 - Plot of duplication density

### Requirements Coverage

This section summarizes how the Quizzes Tutor architecture meets both original and derived functional and quality requirements established for the project.

**Functional Requirements (Original)**:

**Quiz Creation and Management**: The modular architecture allows the backend to handle quiz creation and management independently, fulfilling the original requirement to support the educational process.

**User Interaction and Experience**: The Vue.js frontend ensures that the system is accessible and responsive, meeting the original requirement to provide an intuitive experience for students and teachers.

**Quality Requirements (Original and Derived)**:

**Security (Original)**: The architecture ensures data protection and controlled access through the integration of robust authentication mechanisms, meeting the original security requirement.

**Performance (Derived)**: The separation of frontend and backend, along with the choice of PostgreSQL, guarantees fast response times, addressing the derived requirement for performance even under heavy load.

**Scalability and Flexibility (Derived)**: The system’s modularity and the ability to add backend instances support user growth without significant reengineering, meeting the derived requirements for scalability and flexibility.

### Summary of Background Changes Reflected in Current Version

This section provides an overview of the architectural changes and their rationale since the initial release of the Software Architecture Document (SAD) for the Quizzes Tutor project. These changes have been influenced by ongoing analysis, requirement adjustments, and optimization opportunities identified through testing and stakeholder feedback.

**Improved Modularity**: Based on maintainability analysis with tools like SonarQube, certain parts of the code were refactored to improve modularity. This change enhances the ease of future updates and reduces interdependencies, allowing components to be updated independently.

**Enhanced Security Measures**: In response to stakeholder concerns and security assessments, the system now incorporates additional data protection measures, particularly in user authentication and data storage. This change was driven by the need to better protect sensitive information and align with updated security standards.

**Performance Optimization**: Performance testing revealed areas where system response times could be improved. As a result, database queries were optimized, and certain backend processes were restructured. These optimizations were necessary to ensure that the system can handle increased user load during peak times, enhancing scalability and user experience.

**Scalability Adjustments**: As part of the scalability strategy, the architecture has been updated to allow easier scaling by adding backend server instances as needed. This flexibility was essential to accommodate growing usage and was informed by load testing and anticipated growth.

These updates reflect a commitment to maintaining a robust and adaptive architecture that meets evolving project needs and aligns with quality standards in performance, security, and maintainability.

## Product Line Reuse Considerations

Not applicable.

# Views

This section presents the views of the *Quizzes Tutor* architecture according to the viewpoints defined in Section 1.5. Each view offers a representation of the system from the perspective of a specific set of stakeholder concerns, as defined by [IEEE 1471]. The views illustrate architectural elements, their properties, and the relationships between them according to a specific viewpoint.

**Overview of Architectural Views**

The views are organized into three main categories, based on the nature of the elements they represent:

1. **Module Views**: These focus on the static structure of the system, dividing it into modules or implementation units. These views help answer questions such as:
   1. What is the primary functional responsibility assigned to each module?
   2. What other software elements is a module allowed to use?
   3. Which modules are related to others by generalization or specialization?

The subtypes included in this category are:

* 1. **Decomposition View**: Displays the hierarchy of modules and submodules, showing how each part of the system has a specific responsibility.
  2. **Uses View**: Highlights functional dependencies between modules, illustrating essential interactions for system functionality.
  3. **Data Model View**: Shows relationships between data entities, ensuring a clear and consistent structure for information storage.

1. **Component-and-Connector Views**: These represent the runtime components and the connectors that facilitate communication between them. This view emphasizes the system’s behavior during execution and helps answer questions such as:
   1. What are the major executing components, and how do they interact?
   2. Which parts of the system can operate in parallel, and how does data flow through the system?

The subtypes included in this category are:

* 1. **Call-Return View**: Models interactions where components receive control and data from others, execute a function, and return control to the invoker.
  2. **Repository View**: Represents large stores of persistent data managed centrally or distributed, allowing shared access to data.

1. **Allocation Views**: These show how software elements relate to the physical or virtual infrastructure, including hardware and runtime environments. These views address questions about resource distribution and allocation, such as:
   1. Where is each software element deployed in terms of physical or virtual infrastructure?
   2. How are resources assigned to development and operations teams?

The subtypes included in this category are:

* 1. **Execution View**: Maps software components to the execution infrastructure, such as physical servers or cloud environments, to support real-time operation.
  2. **Development View**: Shows the organization of development artifacts, such as source code, to facilitate team coordination and management.

**Structure of Architectural Views**

Each view documented in this SAD addresses a specific set of stakeholder concerns, using a clear separation to focus on the main areas of architectural decision-making:

* **System Code Structure** (via the **Module View**),
* **Organization of Runtime Components and Interactions** (via the **Component-and-Connector View**),
* **Allocation of Software Elements to Physical or Virtual Infrastructure** (via the **Allocation View**).

This separation allows each view to maintain its focus on a specific area of architectural interest, avoiding confusion and ensuring a clear and organized presentation of the system architecture.

The views presented in this SAD are the following:

Table 3: Views of this sad

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Name of view** | **Viewtype that defines this view** | **Types of elements and relations shown** | | **Is this a module view?** | **Is this a component-and-connector view?** | **Is this an allocation view?** |
| Decomposition View | Modules and submodules hierarchy | Modules and Submodules | “Is-part-of” | Yes | No | No |
| Uses View | Functional dependencies between modules | Modules | “Depends-on” | Yes | No | No |
| Data Model View | Data entities and relationships | Data Entities | Associations relations | Yes | No | No |
| Call-Return View | Control flow between components | Components | “Calls” relation | No | Yes | No |
| Repository View | Data storage components and access connectors | Data Repositories and Access Components | “Stores” and “Retrieves” relations | No | Yes | No |
| Execution View | Software components to execution infrastructure | Software components, infrastructure nodes | “Is-deployed-on” and “Communicates-with” | No | No | Yes |
| Development View | Development artifacts and source code organization | Development artifacts, source code modules, libraries | “Depends-on” between modules, libraries and build tools | No | No | Yes |

## Module View

### View Description

The Decomposition View presents the hierarchical structure of the system, organizing it into modules and submodules. This view highlights the responsibilities assigned to each module, providing a clear understanding of the system’s division into functional parts.

### View Packet Overview

This view has been divided into the following view packets for convenience of presentation:

Table 4: View Packets of Module View

|  |  |
| --- | --- |
| **View Packets** | **Description** |
| Frontend Module | Manages user interactions and interface elements. |
| Backend Module | Manages core business logic and data processing. |
| Database Module | Responsible for persistent data storage and management. |

### Architecture Background

The modular organization enables parallel development, easier maintenance, and scalability. It allows each module to evolve independently, provided interfaces remain consistent.

### Variability Mechanisms

This decomposition allows for flexibility in enhancing or scaling specific modules, such as expanding backend capabilities independently of the frontend.

### View Packets

#### Frontend Module (View Packet #1)

* **Primary Presentation**: Diagram showing QuizComponent, UserInterface, ResultDisplay.
* **Element Catalog**:
  + **Elements**: QuizComponent, UserInterface, ResultDisplay.
  + **Relations**: Dependency on backend APIs.
  + **Interfaces**: RESTful APIs to connect with backend.
  + **Behavior**: Provides interactive functionalities for users.
  + **Constraints**: Compatibility with multiple browsers.
* **Context Diagram**: Shows interactions between the frontend, users, and backend.
* **Variability Mechanisms**: Theme customization and language support.
* **Architecture Background**: Built with Vue.js for responsiveness and ease of use.
* **Related View Packets**: Backend Module.

#### Backend Module (View Packet #2)

* **Primary Presentation**: Diagram illustrating QuizService, UserController, and AuthService.
* **Element Catalog**:
  + **Elements**: QuizService (quiz logic), UserController (user interactions), AuthService (authentication).
  + **Relations**: Interfaces with frontend and database.
  + **Interfaces**: RESTful APIs for frontend communication.
  + **Behavior**: Manages requests, quiz processing, and data retrieval.
  + **Constraints**: Scalability and security protocols.
* **Context Diagram**: Depicts backend interactions with frontend and database.
* **Variability Mechanisms**: Scalability through load balancing.
* **Architecture Background**: Developed with Spring Boot for modularity.
* **Related View Packets**: Frontend Module, Database Module.

#### Database Module (View Packet #3)

* **Primary Presentation**: Database schema with main tables Users, Quizzes, and Results.
* **Element Catalog**:
  + **Elements**: Users, Quizzes, Results.
  + **Relations**: Foreign key constraints ensure data integrity.
  + **Interfaces**: SQL or ORM interfaces for backend communication.
  + **Behavior**: Manages data storage and ensures integrity.
  + **Constraints**: Enforces data consistency and backup routines.
* **Context Diagram**: Shows database interactions with the backend.
* **Variability Mechanisms**: Options for replication and clustering for high availability.
* **Architecture Background**: Built on PostgreSQL for transactional support.
* **Related View Packets**: Backend Module.

## Uses View

### View Description

The Uses View focuses on the functional dependencies between modules, showing how different parts of the system work together to achieve functionality. This view helps identify critical module dependencies for successful system operation.

### View Packet Overview

This view has been divided into the following view packets for convenience of presentation:

Table 5: View Packets of Uses View

|  |  |
| --- | --- |
| **View Packets** | **Description** |
| Frontend-Backend Dependency | The frontend depends on the backend for data processing and business logic. |
| Backend-Database Dependency | The backend depends on the database for data storage and retrieval. |

### Architecture Background

Understanding these dependencies is crucial for maintenance and upgrades, as changes in one module might affect the other. This view helps ensure that any critical dependencies are well-defined and managed to prevent integration issues.

### Variability Mechanisms

These dependencies allow each module to be updated or replaced independently, provided the interfaces remain consistent.

### View Packets

#### Frontend-Backend Dependency (View Packet #1)

* **Primary Presentation**: Dependency diagram illustrating how the frontend interacts with the backend to retrieve and submit data.
* **Element Catalog**:
  + **Elements**: Frontend Module and Backend Module.
  + **Relations**: "Depends-on" relationship where the frontend relies on the backend to handle data processing.
  + **Interfaces**: RESTful API endpoints for communication between frontend and backend.
  + **Behavior**: The frontend sends requests to the backend for data such as quiz content and user scores.
  + **Constraints**: Ensures frontend functionality even if backend services are updated, provided the API remains stable.
* **Context Diagram**: Illustrates the data exchange between the frontend and backend modules.
* **Variability Mechanisms**: API structure is designed to support backward compatibility, allowing for frontend upgrades with minimal impact.
* **Architecture Background**: Emphasizes clear communication channels for seamless data flow from frontend to backend.
* **Related View Packets**: Backend-Database Dependency.

#### Backend-Database Dependency (View Packet #2)

* **Primary Presentation**: Diagram showing how the backend relies on the database to persist data such as quiz results and user profiles.
* **Element Catalog**:
  + **Elements**: Backend Module and Database Module.
  + **Relations**: "Depends-on" relationship where the backend relies on the database for data persistence.
  + **Interfaces**: SQL queries or ORM for data access.
  + **Behavior**: The backend stores and retrieves data from the database as needed for application logic.
  + **Constraints**: Database integrity and transaction management to ensure reliable data storage.
* **Context Diagram**: Depicts the interaction between the backend and database, showing data flows for storage and retrieval.
* **Variability Mechanisms**: The database structure allows for replication and clustering, ensuring availability and load distribution.
* **Architecture Background**: Optimizes backend-database communication to support efficient data handling.
* **Related View Packets**: Frontend-Backend Dependency.

## Data Model View

### View Description

The Data Model View illustrates relationships between data entities within the system, ensuring a consistent approach to data storage and access.

### View Packet Overview

This view has been divided into the following view packets for convenience of presentation:

Table 6: View Packets of Data Model View

|  |  |
| --- | --- |
| **View Packets** | **Description** |
| Users Table | Contains user account information. |
| Quizzes Table | Stores quiz questions and answers. |
| Results Table | Tracks user quiz scores and responses. |

### Architecture Background

Structured for data integrity and performance, supporting complex data queries and ensuring data consistency.

### Variability Mechanisms

Adaptable schema to support future data model changes with minimal disruptions.

### View Packets

#### User Table (View Packet #1)

* **Primary Presentation**: Schema diagram showing columns for user details.
* **Element Catalog**:
  + **Elements**: User attributes such as user\_id, name, email.
  + **Relations**: Linked to Results by user\_id.
  + **Interfaces**: SQL/ORM for data manipulation.
  + **Behavior**: Stores and retrieves user information.
  + **Constraints**: Enforces unique emails for accounts.
* **Context Diagram**: Shows interaction with backend for user data requests.
* **Variability Mechanisms**: Fields can be expanded with new attributes.
* **Architecture Background**: Designed for efficient user management.
* **Related View Packets**: Quizzes Table, Results Table.

#### Quizzes Table (View Packet #2)

* **Primary Presentation**: Schema diagram showing quiz details.
* **Element Catalog**:
  + **Elements**: Quiz attributes like quiz\_id, title, questions.
  + **Relations**: Related to Results for tracking responses.
  + **Interfaces**: SQL/ORM for backend access.
  + **Behavior**: Stores quiz content for retrieval.
  + **Constraints**: Validates quiz data consistency.
* **Context Diagram**: Shows interactions with backend for quiz retrieval.
* **Variability Mechanisms**: Can add new fields as needed.
* **Architecture Background**: Supports modular quiz creation and storage.
* **Related View Packets**: Users Table, Results Table.

#### Results Table (View Packet #3)

* **Primary Presentation**: Database schema with main tables Users, Quizzes, and Results.
* **Element Catalog**:
  + **Elements**: Users, Quizzes, Results.
  + **Relations**: Foreign key constraints ensure data integrity.
  + **Interfaces**: SQL or ORM interfaces for backend communication.
  + **Behavior**: Manages data storage and ensures integrity.
  + **Constraints**: Enforces data consistency and backup routines.
* **Context Diagram**: Shows database interactions with the backend.
* **Variability Mechanisms**: Options for replication and clustering for high availability.
* **Architecture Background**: Built on PostgreSQL for transactional support.
* **Related View Packets**: Backend Module.

## Call-Return View

### View Description

The Call-Return View models the interactions between components where control and data flow from one component to another, with control being returned after task.

### View Packet Overview

This view has been divided into the following view packets for convenience of presentation:

Table 7: View Packets of Call-Return View

|  |  |
| --- | --- |
| **View Packets** | **Description** |
| Users Interaction Component | Manages communication between the frontend and backend, where the frontend calls backend services to retrieve or submit data. |
| Backend Processing Component | Handles core logic and processes requests from the frontend, returning data or processing results. |

### Architecture Background

This view supports a structured, request-response model, which is fundamental for interactive applications like *Quizzes Tutor*. By organizing components in a call-return structure, the architecture ensures that each component performs specific tasks and returns control efficiently.

### Variability Mechanisms

The backend can be scaled horizontally to support a higher number of concurrent requests. Additionally, caching mechanisms can be introduced to reduce redundant calls and improve performance.

### View Packets

#### User Interaction Component (View Packet #1)

* **Primary Presentation**: Diagram showing the frontend components, such as QuizComponent and ResultDisplay, calling backend services.
* **Element Catalog**:
  + **Elements**: QuizComponent (manages quiz display and interactions), ResultDisplay (shows quiz results).
  + **Relations**: "Calls" relationship where the frontend components make requests to backend APIs.
  + **Interfaces**: RESTful APIs between frontend and backend for data retrieval and submission.
  + **Behavior**: The frontend sends a request to the backend, waits for the response, and then updates the interface based on the data received.
  + **Constraints**: The frontend must handle response delays gracefully, and ensure compatibility with backend API versions.
* **Context Diagram**: Shows the interaction flow between frontend components and backend services for retrieving and displaying quiz data.
* **Variability Mechanisms**: Support for caching of frequently accessed data, reducing the need for repeated calls to backend services.
* **Architecture Background**: Built using a client-server model, where the frontend (client) calls the backend (server) as needed for data updates and processing.
* **Related View Packets**: Backend Processing Component.

#### Backend Processing Component (View Packet #2)

* **Primary Presentation**: Diagram showing backend components, such as AuthService and QuizService, processing requests from the frontend and returning responses.
* **Element Catalog**:
  + **Elements**: AuthService (handles user authentication), QuizService (manages quiz logic and scoring).
  + **Relations**: "Calls" relationship from frontend to backend, with backend returning control upon task completion.
  + **Interfaces**: RESTful endpoints exposed to the frontend for secure data access.
  + **Behavior**: The backend processes requests, validates inputs, retrieves or updates data as needed, and returns the result to the frontend.
  + **Constraints**: Security requirements for data access and response times for a smooth user experience.
* **Context Diagram**: Illustrates the backend components receiving requests from the frontend and interacting with the database to fulfill the requests.
* **Variability Mechanisms**: Backend load balancing and horizontal scaling to handle high traffic volumes.
* **Architecture Background**: Implemented with Spring Boot, allowing modular and efficient call-return interactions for dynamic processing.
* **Related View Packets**: User Interaction Component.

## Repository View

### View Description

The Repository View focuses on the system’s data storage and management, with a central repository for storing and retrieving persistent data. This view is essential for understanding how data is shared, accessed, and managed across multiple components.

### View Packet Overview

This view has been divided into the following view packets for convenience of presentation:

Table 7: View Packets of Repository View

|  |  |
| --- | --- |
| **View Packets** | **Description** |
| Data Storage Component | Central data repository (database) used for storing quiz data, user profile and results. |
| Data Access Component | Backend components that interact with the data repository to read and write data as needed. |

### Architecture Background

The repository structure supports data integrity, consistency, and efficient access, especially in environments where multiple users are accessing or modifying data simultaneously.

### Variability Mechanisms

The repository supports replication and clustering to improve data availability and performance, ensuring high availability and load distribution.

### View Packets

#### Data Storage Component (View Packet #1)

* **Primary Presentation**: Database schema diagram showing primary tables (e.g., Users, Quizzes, Results).
* **Element Catalog**:
  + **Elements**: Users (stores user information), Quizzes (stores quiz data), Results (stores quiz results).
  + **Relations**: "Stores" and "retrieves" relationships between backend components and the data repository.
  + **Interfaces**: SQL or ORM interfaces for backend access to the database.
  + **Behavior**: Provides persistent data storage, ensuring that data is available even after sessions end.
  + **Constraints**: Must support high read/write performance, and ensure data integrity through transaction management.
* **Context Diagram**: Shows data repository interactions with backend components for read/write operations.
* **Variability Mechanisms**: Database replication and clustering to ensure data is always available and can handle high traffic.
* **Architecture Background**: Based on PostgreSQL, chosen for its robustness and support for large-scale data management.
* **Related View Packets**: Data Access Component..

#### Backend Processing Component (View Packet #2)

* **Primary Presentation**: Diagram of backend components (AuthService, QuizService) accessing data in the repository.
* **Element Catalog**:
  + **Elements**: AuthService (retrieves user information for authentication), QuizService (reads/writes quiz data).
  + **Relations**: "Accesses" relationship between backend services and data storage.
  + **Interfaces**: SQL queries or ORM methods used by backend components to interact with the database.
  + **Behavior**: Backend services perform CRUD operations on the database to manage application data.
  + **Constraints**: Ensures secure data access and maintains consistency in concurrent operations.
* **Context Diagram**: Shows backend service interactions with the data repository for storing and retrieving data.
* **Variability Mechanisms**: Database connection pooling for efficient access, allowing multiple concurrent connections.
* **Architecture Background**: Designed to optimize data access through efficient query handling and data caching mechanisms.
* **Related View Packets**: Data Storage Component.

## Execution View

### View Description

The Execution View illustrates how software components are mapped to the physical or virtual infrastructure required to run the system. This view provides insights into the distribution of components across servers or cloud resources to support real-time operations.

### View Packet Overview

This view has been divided into the following view packets for convenience of presentation:

Table 8: View Packets of Execution View

|  |  |
| --- | --- |
| **View Packets** | **Description** |
| Frontend Deployment | Deployment of the frontend components on web servers and content delivery networks (CDNs). |
| Backend Deployment | Deployment of backend services on application servers with load balancers for scalability. |

### Architecture Background

This infrastructure design leverages cloud and load balancing to ensure reliability and scalability, supporting multiple concurrent users and handling high traffic demands.

### Variability Mechanisms

Load balancing for backend deployment to handle varying loads, and CDN configurations for optimized frontend performance.

### View Packets

#### Frontend Deployment (View Packet #1)

* **Primary Presentation**: Diagram showing the deployment of frontend components on web servers and CDNs.
* **Element Catalog**:
  + **Elements**: Web server instances hosting the frontend, CDN for static assets.
  + **Relations**: Frontend is served through a CDN to optimize delivery times and reduce server load.
  + **Interfaces**: HTTP/HTTPS for client communication.
  + **Behavior**: Manages requests from users, ensuring fast loading times by caching static assets and delivering content through the CDN.
  + **Constraints**: Requires high availability and minimal latency to maintain user experience under high load.
* **Context Diagram**: Shows the frontend's connections to the backend and interactions with end-user devices.
* **Variability Mechanisms**: CDN configuration allows content caching and load balancing for quick content delivery.
* **Architecture Background**: The frontend is distributed through a CDN, leveraging geographical proximity to reduce latency and improve user experience.
* **Related View Packets**: Backend Deployment.

#### Backend Deployment (View Packet #2)

* **Primary Presentation**: Diagram showing backend services deployed on application servers with load balancers for scalability.
* **Element Catalog**:
  + **Elements**: Backend server instances, load balancer.
  + **Relations**: Load balancer distributes requests across backend servers to manage traffic and ensure high availability.
  + **Interfaces**: HTTP/HTTPS APIs for communication with the frontend.
  + **Behavior**: Distributes incoming requests evenly across multiple servers, managing sessions and ensuring fault tolerance.
  + **Constraints**: Requires high reliability, secure API endpoints, and the ability to scale horizontally as demand increases.
* **Context Diagram**: Illustrates the backend's connections to the frontend and database, showing the load balancer and server instances.
* **Variability Mechanisms**: Load balancers allow the backend to scale horizontally, adding more server instances to handle peak loads.
* **Architecture Background**: The backend is designed to be scalable and resilient, with a load balancer to prevent any single server from becoming a bottleneck.
* **Related View Packets**: Frontend Deployment, Database Deployment.

## Development View

### View Description

The Development View presents the organization of the development artifacts, such as source code, to support team collaboration and version control. This view is essential for project management and coordination among the development team.

### View Packet Overview

This view has been divided into the following view packets for convenience of presentation:

Table 9: View Packets of Development View

|  |  |
| --- | --- |
| **View Packets** | **Description** |
| Source Code Organization | Structure of source code repositories and folders for various modules. |
| API Documentation | Documentation setup for backend APIs to ensure smooth communication between frontend and backend teams. |

### Architecture Background

A clear organization of code and documentation aids in team collaboration, facilitating version control and modular development. Using standardized tools and practices helps reduce integration issues.

### Variability Mechanisms

Modular code structure allows independent development and testing of each component, while documentation enables flexible onboarding of new team members.

### View Packets

#### Source Code Organization (View Packet #1)

* **Primary Presentation**: Directory structure diagram showing folders for frontend, backend, and database code.
* **Element Catalog**:
  + **Elements**: Repositories for frontend, backend, and database code.
  + **Relations**: Modules are organized by functionality, enabling independent development.
  + **Interfaces**: Version control (e.g., Git) for managing changes and collaboration.
  + **Behavior**: Facilitates modular development, with separate directories for each component.
  + **Constraints**: Code structure should adhere to team standards for readability and modularity.
* **Context Diagram**: Illustrates the organization of code repositories and shows the flow of updates between frontend, backend, and database modules.
* **Variability Mechanisms**: Supports branching and merging in version control to allow concurrent feature development.
* **Architecture Background**: The project uses Git for version control, supporting multiple branches and collaborative work.
* **Related View Packets**: API Documentation.

#### API Documentation (View Packet #2)

* **Primary Presentation**: Overview of API documentation setup for backend services.
* **Element Catalog**:
  + **Elements**: API endpoints documented with descriptions, usage examples, and response formats.
  + **Relations**: API documentation facilitates frontend-backend interaction by defining expected data flows.
  + **Interfaces**: Documentation tool (e.g., Swagger) for backend API endpoints.
  + **Behavior**: Allows frontend developers to interact with backend APIs based on documented guidelines.
  + **Constraints**: Documentation should be kept up-to-date with backend changes to avoid miscommunication between teams.
* **Context Diagram**: Shows the flow of information between documented API endpoints and their use by frontend developers.
* **Variability Mechanisms**: Supports versioning in API documentation to account for updates and backward compatibility.
* **Architecture Background**: API documentation is created and managed through Swagger to provide clear and accessible information for developers.
* **Related View Packets**: Source Code Organization.

# Relations Among Views

Each of the views specified in Section 3 provides a different perspective and design handle on a system, and each is valid and useful in its own right. Although the views give different system perspectives, they are not independent. Elements of one view will be related to elements of other views, and we need to reason about these relations. For example, a module in a decomposition view may be man­ifested as one, part of one, or several components in one of the component-and-connector views, reflecting its runtime alter-ego. In general, mappings between views are many to many. Section 4 describes the relations that exist among the views given in Section 3. As required by ANSI/IEEE 1471-2000, it also describes any known inconsistencies among the views.

## General Relations Among Views

In the **Quizzes Tutor** project, each view offers a unique perspective on the system's architecture. However, these views are not independent, as elements from one view often interact and correspond with elements in other views. Below are the general relationships among the key views of the system:

* **Decomposition View ↔ Uses View:** Modules defined in the Decomposition View correspond to the functional dependencies represented in the Uses View.
* **Decomposition View ↔ Data Model View:** Modules interact directly with data entities represented in the Data Model View.
* **Uses View ↔ Data Model View:** Functional dependencies between modules often involve shared access to the data entities described in the Data Model View.
* **Call-Return View ↔ Repository View:** Components described in the Call-Return View perform storage and retrieval operations on mechanisms defined in the Repository View.
* **Call-Return View ↔ Data Model View:** Components utilize data entities described in the Data Model View during runtime interactions.
* **Execution View ↔ Development View:** Development artifacts are mapped to their execution environments as defined in the Execution View.
* **Execution View ↔ Data Model View:** Data entities are stored and managed within the infrastructure mechanisms described in the Execution View.

## View-to-View Relations

Below are the specific relationships between elements of the different views, demonstrating how they interact to form a cohesive and consistent system:

**Decomposition View ↔ Uses View:**

**Relation:** Modules in the Decomposition View correspond to functional dependencies in the Uses View.

**Example:** The "Quiz Management" module depends on the "User Authentication" module to verify users.

**Decomposition View ↔ Data Model View:**

**Relation:** Modules interact with data entities described in the Data Model View.

**Example:** The "Quiz Submissions" module uses entities like "Submissions" and "Users."

**Uses View ↔ Data Model View:**

**Relation:** Functional dependencies between modules involve data entities from the Data Model View.

**Example:** The "Results Calculation" module depends on entities like "Answers" and "Grades."

**Call-Return View ↔ Repository View:**

**Relation:** Components in the Call-Return View perform operations on repositories defined in the Repository View.

**Example:** A component responsible for saving quiz results invokes repository operations to store them.

**Call-Return View ↔ Data Model View:**

**Relation:** Components utilize data entities described in the Data Model View during runtime interactions.

**Example:** A component processing quiz answers uses data entities like "Questions" and "Answers."

**Execution View ↔ Development View:**

**Relation:** Development artifacts are mapped to execution environments defined in the Execution View.

**Example:** The "Quiz API" module is implemented as a source code artifact and deployed on a specific server in the Execution View.

**Execution View ↔ Data Model View:**

**Relation:** Data entities in the Data Model View are managed within the infrastructure defined in the Execution View.

**Example:** Entities like "Users" and "Quizzes" are mapped to a cloud-based database in the Execution View.

# Referenced Materials

Table 10: Reference Materials

|  |  |
| --- | --- |
| Barbacci 2003 | Barbacci, M.; Ellison, R.; Lattanze, A.; Stafford, J.; Weinstock, C.; & Wood, W. *Quality Attribute Workshops (QAWs)*, Third Edition (CMU/SEI-2003-TR-016). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2003. <http://www.sei.cmu.edu/publications/documents/03.reports/03tr016.html>. |
| Bass 2003 | Bass, Clements, Kazman, *Software Architecture in Practice,* second edition, Addison Wesley Longman, 2003. |
| Clements 2001 | Clements, Kazman, Klein, *Evaluating Software Architectures: Methods and Case Studies,* Addison Wesley Longman, 2001. |
| Clements 2002 | Clements, Bachmann, Bass, Garlan, Ivers, Little, Nord, Stafford, *Documenting Software Architectures: Views and Beyond*, Addison Wesley Longman, 2002. |
| IEEE 1471 | ANSI/IEEE-1471-2000, *IEEE Recommended Practice for Architectural Description of Software-Intensive Systems*, 21 September 2000. |
| Main references of the project | **GitHub Repository:** Quizzes Tutor. Available at <https://github.com/socialsoftware/quizzes-tutor>  Video Domain Model: Explainer Video of the Architecture of Quizzes Tutor, available at [YouTube](https://www.youtube.com/watch?v=wEhEUCJpOpc) |
| Tools of analysis and code metrics | SonarQube Documentation: Code analysis platform used to evaluate the quality of the project's source code. Documentation available at (<https://docs.sonarqube.org/latest/>.) |
| References for Examples and Case Studies | DESOSA: Examples of software architecture projects carried out by master's students at the University of Delft:  [DESOSA 2019](https://se.ewi.tudelft.nl/desosa2019/), [DESOSA 2020](https://desosa.nl/), [DESOSA 2021](https://2021.desosa.nl/), [DESOSA 2022](https://desosa2022.netlify.app/). |

# Directory

## Glossary

Table 11: Glossary

|  |  |
| --- | --- |
| Term | Definition |
| software architecture | The structure or structures of that system, which comprise software elements, the externally visible properties of those elements, and the relationships among them [Bass 2003]. "Externally visible” properties refer to those assumptions other elements can make of an element, such as its provided services, performance characteris­tics, fault handling, shared resource usage, and so on. |
| view | A representation of a whole system from the perspective of a related set of concerns [IEEE 1471]. A representation of a particular type of software architectural elements that occur in a system, their properties, and the relations among them. A view conforms to a defining viewpoint. |
| view packet | The smallest package of architectural documentation that could usefully be given to a stakeholder. The documentation of a view is composed of one or more view packets. |
| viewpoint | A specification of the conventions for constructing and using a view; a pattern or template from which to develop individual views by establishing the purposes and audience for a view, and the techniques for its creation and analysis [IEEE 1471]. Identifies the set of concerns to be addressed, and identifies the modeling techniques, evaluation techniques, consistency checking techniques, etc., used by any conforming view. |
| maintainability | The ease with which the system can be modified to fix defects, improve performance, or adapt to a changing environment. |
| modularity | The degree to which the system is composed of separate and independent components that can be altered without affecting the rest of the system |
| reliability | Ensures the system consistently performs its core functions without errors. |
| scalability | The ability of the system to handle an increased workload or user expansion while maintaining functionality and performance. |
| Frontend | The part of the system that interacts directly with the user, usually responsible for the graphical user interface. |
| Backend | The part of the system responsible for business logic, data processing, and integration with data storage. |
| Authentication | Verifies the identity of users before granting access to the system. |
| Horizontal Scaling | Increases system capacity by adding more machines or server instances. |
| Database Connection Pooling | A mechanism to reuse database connections for efficient access and performance improvement​ |
| Data Integrity | Ensures that stored and transmitted data remains consistent and unaltered. |
| Encryption | The process of encoding information to ensure security and prevent unauthorized access. |
| Caching | Temporarily stores frequently accessed data to speed up future requests. |
| Clustering | Connects multiple servers to work as one, improving availability and fault tolerance. |
| Load Balancing | Distributes traffic across multiple servers to prevent overload and ensure reliability |
| Quality Attribute | A property or characteristic of a system that impacts its ability to meet stakeholder needs. |

## Acronym List

Table 12: Acronym List

|  |  |
| --- | --- |
| API | Application Programming Interface; Application Program Interface; Application Programmer Interface |
| ATAM | Architecture Tradeoff Analysis Method |
| COTS | Commercial-Off-The-Shelf |
| IEEE | Institute of Electrical and Electronics Engineers |
| QAW | Quality Attribute Workshop |
| RUP | Rational Unified Process |
| SAD | Software Architecture Document |
| SEI | Software Engineering Institute  Systems Engineering & Integration  Software End Item |
| UML | Unified Modeling Language |
| CI/CD | Continuous Integration/Continuous Deployment |
| ORM | Object-Relational Mapping |
| CDN | Content Delivery Network |
| SQL | Structured Query Language |
| ERD | Entity-Relationship Diagram |
| CRUD | Create, Read, Update, Delete |