Universidad Distrital Francisco José de Caldas

Systems Analysis and Design GR020-85

Workshop 3
Robust System Design and Project Management

Competition: Web Traffic Time Series Forecasting

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Chapter 1

Robust System Design and Architectural Refinement

This section refines the **Modular Monolith** architecture proposed in Workshop 2, emphasizing **robust engineering principles** to meet quality standards (e.g., ISO 9000, Six Sigma).

1.1 Refinement for Quality and Scalability

The system relies on two design patterns: the **Chain of Responsibility (CoR)** for data integrity (**NFR3: Reliability**) and the **Hierarchical Ensemble** (**Strategy Pattern**) for adaptive prediction (**NFR4: Accuracy**).

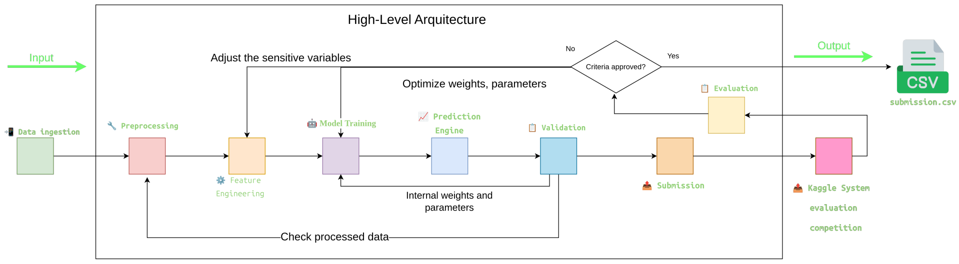

Figure 1.1: Robust System Architecture.

1.1.1 Principle 1: Modularity and Maintainability (ISO 9000)

The architecture aligns with **ISO 9000** by standardizing modules, ensuring that components can be individually maintained and tested.

- **Strategy Encapsulation:** Each forecasting strategy (**ARIMAStrategy, ProphetStrategy, Advanced ML Strategy**) is interchangeable and uses a consistent interface, allowing easy model rotation or upgrading without affecting the core prediction logic (**FR2**).
- **Decoupling:** The **Meta-Model** is decoupled from the actual forecasting implementation, focusing solely on the selection logic based on contextual metadata (language, volatility).

1.1.2 Principle 2: Fault-Tolerance and Data Integrity

Fault-tolerance is essential to combat the identified **High Sensitivity** and **Zero-Value Ambiguity** risks.

- **Chain of Responsibility (CoR) Enforcement:** The sequential nature of the CoR ensures that critical preprocessing steps (e.g., bot traffic filtering, zero-value imputation) are **mandatory** and executed sequentially, acting as a quality gate (**NFR3**).
- **Cascading Fallback:** Within the **Prediction Engine**, if a complex strategy (e.g.,

LSTM) fails to converge or times out (addressing **NFR2: Scalability** constraint), the system must immediately invoke a simpler, guaranteed strategy (e.g., Naive or Seasonal Naive) to prevent prediction failure.

Chapter 2

Quality and Risk Analysis

2.1 Risk Identification and Mitigation

We analyze three high-priority risks that threaten the system's ability to maintain a competitive **SMAPE** score and operational availability.

2.1.1 Risk 1: Model Drift (Dynamic Chaos Invalidation)

- **Description:** The underlying patterns of Wikipedia traffic shift (e.g., a major change in Google's search algorithm or a long-term global event), causing the Meta-Model's selection logic to become obsolete and predictions to fail against **Dynamic Chaos**.
- **Impact: High**. Direct degradation of the primary metric (**SMAPE**).
- **Mitigation Strategy:** Implement continuous **Drift Monitoring** via the **Stratified Post-Prediction Analysis (FR4)**. If the stratified SMAPE for a specific subgroup (e.g., 'es.wikipedia.org_mobile') exceeds a $\geq$ **15%** threshold, the system triggers an alert for mandatory re-training and recalibration of the Meta-Model's weights for that specific segment.

2.1.2 Risk 2: Resource Overload in Parallel Training

- **Description:** The parallel execution of **145,000** time series jobs using **Joblib** (**NFR2**) leads to resource contention, memory errors, or excessive runtimes when deploying memory-intensive models like **LSTM/Random Forest**.
- **Impact: Medium-High**. Can cause partial system failure or missed submission deadlines.
- **Mitigation Strategy:** Implement **Resource Throttling and Timeouts**. All training jobs must be capped by CPU and Memory limits. If a complex job exceeds a predefined time limit (e.g., 5 minutes), the process is forcefully terminated, logged, and the series prediction falls back to the simpler, pre-calculated ARIMA model (Fault-Tolerance). The usage of **Dask** over pure Joblib will be explored for better distributed resource management.

2.1.3 Risk 3: Feature Leakage during Feature Engineering

- **Description:** Information from the future (the target prediction period) inadvertently leaks into the features used for training, leading to unrealistically low SMAPE during internal validation but catastrophic failure upon external submission.
- **Impact: High**. False confidence leading to total project failure in the final Kaggle submission.
- **Mitigation Strategy:** Rigorous adherence to **Temporal Validation**. The **Feature Engineering** module (**FR3**) must be unit-tested to ensure that all lag and temporal

features are calculated using data strictly $\mathbf{t-1}$ or earlier. This requires code review and specialized integration testing to validate the **Chain of Responsibility** sequence for time-dependent data.

Chapter 3

Project Management Plan

3.1 Team Roles and Responsibilities

The team is structured to cover the full lifecycle, from architecture to testing, ensuring clear accountability.

3.1.1 Project Manager: Julián David Celis Giraldo

Definition: The Manager is responsible for planning, coordinating, and supervising all project activities, ensuring that objectives are met within the defined scope, time, cost, and quality. Their purpose within the project is to lead the team toward achieving expected results, optimizing resources, and ensuring effective communication among all involved parties.

Main Responsibilities:

- Timeline management and milestone tracking
- Resource allocation and budget management
- Risk identification, tracking, and mitigation
- External communication with stakeholders
- Define work plan, schedule, budget, and project resources
- Assign tasks, supervise progress, and control milestone completion
- Manage risks, changes, and deviations from the original plan
- Facilitate communication between technical team, clients, and stakeholders
- Promote the use of management methodologies (Scrum, Kanban, Gantt) and best practices

3.1.2 System Architect: Johan Sebastián Beltrán Merchán

Definition: The System Architect is responsible for the structural design of the system, ensuring that the architecture is modular, scalable, and complies with established non-functional requirements.

Main Responsibilities:

- Chain of Responsibility (CoR) integrity maintenance
- Design pattern adherence and implementation oversight
- NFR compliance verification (Scalability, Reliability)
- System architecture design and documentation
- Supervision of design pattern implementation
- Guarantee structural integrity of the system
- Ensure alignment with quality standards (ISO 9000, CMMI, Six Sigma)

3.1.3 Data Scientist/Model Developer: Edison David Álvarez Varela

Definition: The Developer is responsible for building and implementing the technical solution of the project, based on defined requirements. Their purpose within the project is to materialize the functional design into an operational, efficient, and maintainable system, ensuring compliance with established quality and performance standards.

Main Responsibilities:

- Implementation of Base Strategies (ARIMA, Prophet, LSTM)
- Feature Engineering logic development
- Meta-Model weights tuning and optimization
- Design, program, and integrate system or software components
- Apply best practices in coding, security, and version control
- Ensure correct functionality, performance, and system scalability
- Document code and development processes
- Collaborate with testers to validate and correct detected errors in testing

3.1.4 Quality Assurance/Tester: Yader Ibraldo Quiroga Torres

Definition: The Tester is the professional responsible for evaluating the quality, stability, and correct functioning of the system before its delivery or implementation. Their purpose within the project is to verify that the product meets defined requirements, is free of critical defects, and offers a reliable experience for the end user.

Main Responsibilities:

- Development of the Validation Module (FR4)
- SMAPE analysis and metric evaluation
- Unit/Integration testing execution
- Execution of the Post-Prediction Analysis
- Design and execute test plans (unit, integration, system, and acceptance)
- Detect, register, and track defects or deviations in the system
- Verify that implemented corrections do not introduce new errors (regression testing)
- Evaluate system performance, usability, and security
- Generate test result reports and quality metrics

3.2 Methodology and Timeline

We adopt a **Scrum/Kanban Hybrid** methodology. **Scrum** (2-week sprints) drives the model implementation (**FR2**), while **Kanban** manages the issue backlog (bugs, stratified errors).

3.2.1 Scrum Implementation

Scrum Roles:

- **Product Owner:** Yader Ibraldo Quiroga Torres
- **Scrum Master:** Edison David Álvarez Varela
- **Developers:** Johan Sebastián Beltrán Merchán / Julián David Celis Giraldo

Weekly Meetings: Every Monday, a half-hour meeting will be held via Microsoft Teams, where the week's tasks will be defined and assigned to those responsible according to the estimated effort each activity requires.

During these sessions, the team will:

- Analyze project priorities
- Discuss weekly sprint objectives
- Agree on individual commitments
- Foster transparency, collaboration, and self-management
- Resolve initial questions
- Adjust planning according to previous progress
- Ensure all members are aligned with work cycle objectives

3.2.2 Kanban Board (Trello)

For visual tracking and progress control of tasks, a Kanban board will be used in the Trello application, where the team's workflow will be represented through different states:

Workflow States:

1. **To Do:** Pending tasks to be started
2. **In Progress:** Tasks currently being executed
3. **In Review:** Verification of deliverables before completion
4. **Completed:** Finished and approved tasks

Benefits:

- Facilitates visualization of overall project status
- Allows identification of bottlenecks
- Optimizes time management
- Promotes more efficient collaborative work management
- Ensures the team maintains a constant and orderly pace of progress throughout the process

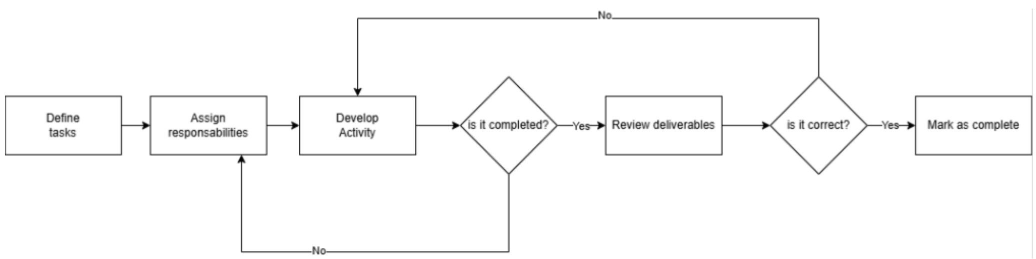

Figure 3.1: Workflow Diagrams

3.3 Key Milestones and Deliverables

Deliverables Developed	Milestone Achieved	Date
• Design of the system architecture with a modular, scalable, and fault-tolerant approach. • Specification of ISO 9001, CMMI, and Six Sigma integration in the design. • Architecture diagrams and information flows.	Milestone 1: Robust architecture designed according to quality standards and prepared for implementation.	08/11/2025
• Assignment of roles and responsibilities (Analyst, Developer, Tester, Manager). • Selection and justification of management methodologies (Scrum, Kanban, Gantt). • Internal communication plan and collaborative work scheme.	Milestone 2: Organizational and methodological structure defined, concluding the project design phase.	08/11/2025
• Set of data cleaning and validation scripts and procedures. • Initial simulation environment configuration and processing pipeline documentation.	Milestone 3: Data environment prepared and validated for simulations and computational tests.	29/11/2025
• Implementation of data-driven and event-based simulations. • Technical documentation of the simulation process (inputs, parameters, models, and metrics). • Results report with sensitivity, complexity, and chaos analysis.	Milestone 4: Experimental system validation through simulations and delivery of results report.	29/11/2025
• Academic paper with theoretical foundations, methodology, and obtained results. • Scientific poster for visual and rapid project exposition. • Final technical report with global conclusions. • Presentation (slides) for project exposition.	Milestone 5: Project completion and final delivery, consolidating all results in their different dissemination formats.	11/12/2025

Table 3.1: Project Milestones and Deliverables Timeline

Chapter 4

Incremental Improvements and Evolution

This section documents the evolution of the system in response to feedback and lessons learned.

4.1 Evolution Based on Workshop Feedback

The system's design choices were consistently validated by previous workshop findings, particularly regarding the inherent complexity of the data.

- **From W1 (Constraint):** The identification of **Massive Scale** and **Structural Complexity** led to the architectural decision to adopt parallel processing (**Joblib/Dask**) and the adaptive **Hierarchical Ensemble**, respectively.
- **From W2 (Design):** The design of the system's core feedback mechanism was refined. Instead of a simple pass/fail, the **Stratified Post-Prediction Analysis (FR4)** was formalized. This ensures that the Meta-Model learns not just from overall error, but from specific segment failures (e.g., errors isolated to 'mobile-spanish' articles), making the system's adaptation much more targeted and effective.

4.2 System Management Evolution

The management approach evolved to explicitly address quality and risk:

- **Reliability Integration:** The theoretical design of the pipeline was hardened by explicitly naming the **Chain of Responsibility** as the mechanism for **NFR3** compliance. This makes the system's reliability testable (via integration tests on the CoR).
- **Proactive Risk Management:** The identification of **Model Drift** (**Risk 1**) led to the integration of continuous monitoring thresholds (**NFR3** alignment with Six Sigma standards for deviation control) into the **Validation Module (FR4)**, transforming the module into a proactive risk-mitigation tool rather than just a final evaluation step.

4.3 Design Process Improvements

- In previous workshops, we understood that system design is a complex process that demands rigorous analysis, critical reflection, and a deep understanding of the problem to be solved. This process is not limited to defining a technical structure; it also involves understanding the environment, the factors that affect it, and the interrelationships between the various components that make up the system. Thanks to the knowledge acquired, the team has been able to identify the sensitive elements, inputs, processes, outputs, and feedback mechanisms that characterize the system. This has allowed us to develop a coherent conceptual architecture that not only synthesizes the solution but also seeks to faithfully represent the real dynamics of the problem. In this sense, the design has been oriented toward a modular, scalable, and adaptable structure, capable of responding to changing scenarios and integrating future improvements without compromising the overall stability of the system.

- The design process has evolved significantly along with its management plan, strengthening the team's collective understanding of all the elements involved in the project. This progress is reflected in the definition of a comprehensive architecture that considers as many variables as possible to ensure the system accurately and efficiently replicates reality. The management plan, in turn, establishes clearly defined roles, assigned based on each team member's strengths, as well as a work methodology aligned with the project's pace and demands. Appropriate technical and organizational tools have also been established to facilitate communication, version control, results validation, and continuous improvement. Together, these elements form a robust framework that not only guides system development but also fosters collaboration, quality, and project sustainability throughout its various stages.