A Systems Engineering Approach

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1. Introduction: The Systems Problem

Forecasting daily traffic for approximately **145,000 Wikipedia articles** is a large-scale Systems Engineering challenge characterized by:

- **Massive Scale:** Requires high computational efficiency (**Scalability**).
- **Chaos Factors:** High volatility due to viral or unpredictable events.
- **Heterogeneity:** No single model fits all series.

The architecture must be adaptive and robust to minimize the **SMAPE** metric.

2. Goal: Adaptive Forecasting Architecture

Research Question: How can a scalable and maintainable system architecture minimize SMAPE across heterogeneous time series using **Systems Engineering Principles**?

Expected Product: A **Modular Monolith** based on a **Hierarchical Ensemble** that dynamically selects the best forecasting model per article.

Performance Metric

Symmetric Mean Absolute Percentage Error (SMAPE):

$$SMAPE = \frac{100}{n} \sum_{t=1}^{n} \frac{|F_t - A_t|}{(|A_t| + |F_t|)/2}$$

3. Proposed Solution: Architecture and Patterns

A **Modular Monolith** with clear separation of concerns, anchored by two design patterns:

System A: Data Flow Integrity

- **Pattern:** Chain of Responsibility.
- **Function:** Defines a linear 9-module pipeline (*Ingestion* $\rightarrow$ *Feedback*) ensuring traceability and data consistency.

System B: Adaptive Forecasting

- **Principle:** Equifinality (multiple valid pathways to the goal).
- **Implementation:** Hierarchical Ensemble with the Strategy Pattern.

Hierarchical Ensemble Breakdown

- **Level 1 (Strategies):** Base models (**ARIMA**, **Prophet**, **LSTM**).
- **Level 2 (Meta-Model):** Analyzes metadata (*language*, *volatility*) and dynamically selects the optimal model.

Scalability: Achieved via parallel processing with `Joblib`, distributing models across multiple CPU cores.

Architectural Blueprint (Data Flow)

Insert a high-resolution diagram of the 9-module pipeline and ensemble structure here.

4. Validation and Testing Philosophy

Rigorous testing ensures robustness and maintainability:

- **Unit Tests:** Ensure deterministic behavior and prevent data leakage.
- **Integration Tests:** Validate the Chain of Responsibility pipeline.
- **Acceptance Testing:** Evaluate overall SMAPE performance.

5. Results Projected: Granular Analysis

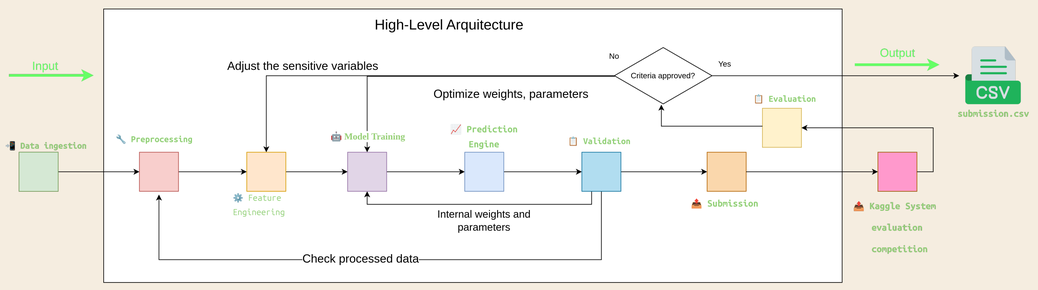
The **Evaluation Module** produces a **Stratified Post-Prediction Analysis** feeding insights back into the system.

This analysis refines feedback loops for volatile or underperforming subgroups.

6. Conclusion and Future Work

The architecture provides a robust, scalable, and adaptive solution for chaotic web traffic forecasting.

- Chain of Responsibility ensures data integrity.
- Hierarchical Ensemble ensures adaptive model selection.



Conceptual Archivtecture: Inputs, Core Processes, and Quality Loop

Future Work: Integrate advanced models (**Neural Networks**, **Random Forests**) as new strategies within the Ensemble framework to enhance modularity and predictive accuracy.

Acknowledgments and References

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1. C. E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal*, 1948.
2. Additional references to be added.