

# AegisNet: An Explainable Multi-Hazard Digital Twin Framework for Disaster Risk Forecasting and Emergency Resource Optimization

Suraj Indolia  
Department of Computer Science  
Agra, India

## I. RESEARCH HYPOTHESIS

This study investigates the hypothesis that integrating Digital Twin simulation with Explainable Artificial Intelligence (XAI) can improve the transparency and operational usefulness of disaster risk forecasting systems without significantly increasing computational latency.

## II. PROPOSED ARCHITECTURE

The AegisNet framework consists of five interconnected layers: Data Acquisition, Digital Twin, Forecasting, Explainability, and Resource Optimization. Data Acquisition collects heterogeneous streams from sensors and databases. The Digital Twin Layer synchronizes physical observations with virtual representations. The Forecasting Layer uses machine learning, while the Explainability Layer provides human-understandable feature attribution. Finally, Resource Optimization prioritizes emergency actions based on risk and vulnerability.

## III. MATHEMATICAL FORMULATION

The overall disaster risk score  $R_t$  is defined as:

$$R_t = \alpha E_t + \beta H_t + \gamma D_t + \delta V_t \quad (1)$$

where  $\alpha + \beta + \gamma + \delta = 1$ . The score is normalized to 0–100.

## IV. SYSTEM WORKFLOW

The workflow involves four stages: (1) Data Collection and Preprocessing, (2) Digital Twin State Synchronization, (3) Risk Forecasting and Explainability Generation, and (4) Emergency Resource Prioritization.

## V. EVALUATION METRICS

Effectiveness is assessed through:

- **Prediction:** Accuracy, Precision, Recall, F1-Score.
- **System:** Response Latency, Throughput, Scalability.
- **Explainability:** Feature Stability, Consistency, Interpretability.

## VI. DISCUSSION

AegisNet integrates explainability directly into the forecasting pipeline. The Digital Twin paradigm enables continuous state synchronization, improving situational awareness and supporting scenario analysis.

## VII. FUTURE RESEARCH

Future work includes real-time satellite integration, Edge-AI deployment, and reinforcement learning for adaptive resource allocation.

## REFERENCES

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- [3] Ribeiro, M. T. et al., Why Should I Trust You? Explaining the Predictions of Any Classifier.