

Patent Application: Cross-Domain Governance Correlation Engine

Title of Invention

System and Method for AI-Driven Cross-Domain Correlation Analysis in Cloud Governance with Multi-Dimensional Graph-Based Relationship Modeling and Real-Time Impact Prediction

Technical Field

This invention relates to cloud computing governance analytics systems, and more particularly to systems that analyze correlations and causal relationships between multiple cloud governance domains including policy compliance, role-based access control, network security, and cost management using graph neural networks and predictive impact modeling.

Independent Claims

Claim 1 (System Claim - Broadest)

A computer-implemented system for cross-domain correlation analysis in cloud governance comprising:

a) **a multi-domain data integration engine** configured to:

- collect governance data streams from at least four distinct cloud service domains including policy compliance, role-based access control (RBAC), network security, and cost management,
- normalize heterogeneous data formats using domain-specific schema mappings,
- perform temporal alignment of asynchronous data streams using interpolation algorithms,
- maintain data lineage tracking for audit compliance;

b) **a graph-based relationship modeling engine** configured to:

- construct a hierarchical graph structure with at least three abstraction levels: resource-level (individual cloud resources), service-level (cloud service groupings), and domain-level (governance domains),
- implement dynamic graph neural networks (GNNs) with attention mechanisms for learning evolving relationships,
- perform automated entity resolution across domains using similarity metrics and confidence scoring,
- update graph edges in real-time based on detected relationship changes;

c) **a correlation analysis engine** implementing:

- multi-dimensional correlation detection using at least three distinct algorithms: statistical correlation (Pearson, Spearman), mutual information analysis, and causal inference (Granger causality),
- temporal lag analysis to identify delayed cross-domain effects with configurable lag windows,
- anomaly detection using isolation forests specifically trained on governance relationship patterns,
- confidence scoring for each identified correlation based on statistical significance;

d) **a predictive impact assessment engine** configured to:

- forecast cross-domain impacts using ensemble machine learning models combining gradient boosting, LSTM networks, and graph convolutional networks,
- perform Monte Carlo simulations with at least 1,000 iterations for uncertainty quantification,
- generate impact heatmaps showing predicted effects across all governance domains,
- calculate risk scores using multi-objective optimization algorithms;

e) **an automated optimization engine** configured to:

- identify optimization opportunities based on detected correlations and predicted impacts,
- generate Pareto-optimal solutions balancing competing objectives across domains,
- implement constraint satisfaction algorithms ensuring regulatory compliance,
- provide ranked recommendations with implementation complexity scores;

wherein the system processes at least 100,000 governance events per minute with sub-second correlation detection latency.

Claim 2 (Method Claim - Broadest)

A computer-implemented method for analyzing cross-domain correlations in cloud governance, the method comprising:

a) **collecting and integrating governance data** by:

- establishing authenticated connections to cloud service APIs for policy, RBAC, network, and cost domains,
- implementing real-time event streaming using Apache Kafka with at least once delivery guarantee,
- performing data quality validation using predefined rules and anomaly detection,
- storing integrated data in a time-series database with configurable retention policies;

b) **constructing a multi-level governance graph** by:

- identifying governance entities using natural language processing on configuration data,

- establishing relationships based on at least five relationship types: dependency, conflict, similarity, temporal, and causal,
- applying graph embedding techniques to represent entities in high-dimensional space,
- implementing incremental graph updates to maintain real-time accuracy;

c) **detecting cross-domain correlations** by:

- computing correlation matrices across all domain pairs using sliding time windows,
- applying feature engineering to extract at least 50 domain-specific features per entity,
- implementing ensemble correlation detection combining statistical and machine learning approaches,
- performing false discovery rate correction for multiple hypothesis testing;

d) **predicting governance impacts** by:

- training domain-specific prediction models on historical governance data,
- implementing transfer learning to adapt models to new governance patterns,
- generating confidence intervals using bootstrap sampling techniques,
- creating visual impact timelines showing predicted effects over configurable time horizons;

e) **generating optimization recommendations** by:

- formulating multi-objective optimization problems with domain-specific constraints,
- applying genetic algorithms for exploring solution space,
- ranking solutions based on implementation cost, risk reduction, and compliance improvement,
- providing step-by-step implementation guidance with rollback procedures.

Dependent Claims

Claim 3 (Dependent on Claim 1)

The system of claim 1, wherein the graph neural network implements:

- heterogeneous graph attention networks (HGATs) with separate attention mechanisms for each relationship type,
- dynamic node embeddings updated through message passing algorithms,
- graph pooling layers for hierarchical representation learning,
- adversarial training for robustness against noisy governance data.

Claim 4 (Dependent on Claim 1)

The system of claim 1, wherein the correlation analysis engine further comprises:

- a causal discovery module implementing PC algorithm and structural equation modeling,
- a confounding variable detection system using instrumental variable analysis,
- a correlation strength classifier categorizing relationships as strong, moderate, or weak,
- a temporal stability analyzer tracking correlation persistence over time.

Claim 5 (Dependent on Claim 1)

The system of claim 1, wherein the predictive impact assessment engine implements:

- scenario planning capabilities allowing users to model "what-if" governance changes,
- sensitivity analysis using Sobol indices to identify most influential factors,
- ensemble uncertainty quantification combining epistemic and aleatoric uncertainty,
- automated model retraining triggered by distribution shift detection.

Claim 6 (Dependent on Claim 2)

The method of claim 2, wherein constructing the governance graph further comprises:

- implementing community detection algorithms to identify governance clusters,
- calculating centrality measures to identify critical governance entities,
- performing graph compression to optimize memory usage while preserving key relationships,
- maintaining versioned graph snapshots for historical analysis.

Claim 7 (Dependent on Claim 2)

The method of claim 2, wherein detecting cross-domain correlations includes:

- implementing streaming correlation analysis for real-time detection,
- applying domain adaptation techniques to handle governance policy changes,
- using attention mechanisms to focus on most relevant correlations,
- generating natural language explanations for detected correlations.

Claim 8 (System Architecture Claim)

The system of claim 1, further comprising:

- a distributed processing architecture using Apache Spark for scalable correlation analysis,

- a GPU-accelerated computation layer for graph neural network training,
- an in-memory caching system using Redis for frequent correlation queries,
- a microservices architecture with separate services for each governance domain.

Claim 9 (Security and Compliance Claim)

The system of claim 1, wherein all cross-domain analysis operations implement:

- end-to-end encryption for governance data in transit and at rest,
- role-based access control for correlation insights with audit logging,
- data residency compliance ensuring analysis occurs in approved regions,
- differential privacy techniques to protect sensitive governance information.

Claim 10 (User Interface Claim)

The system of claim 1, further comprising an interactive visualization interface providing:

- 3D graph visualizations with zoom, pan, and filter capabilities,
- correlation heatmaps with drill-down functionality,
- timeline views showing correlation evolution,
- natural language query interface for exploring correlations.

Technical Diagrams

Figure 1: System Architecture Overview

Cross-Domain Correlation Engine

Policy Domain | RBAC Domain | Network Domain |
Data Collector | Data Collector | Data Collector |

Multi-Domain Data Integration Layer
• Schema Normalization • Temporal Alignment
• Data Quality Validation • Event Stream Processing

Hierarchical Graph Construction Engine

Resource Level | Service Level | Domain Level |
Graphs | Graphs | Graphs |

Graph Neural Network Processing

• Heterogeneous Graph Attention Networks (HGAT)
• Dynamic Node Embeddings • Message Passing

Multi-Dimensional Correlation Analysis

Statistical | Mutual | Causal | Anomaly |
Correlation | Information | Inference | Detection |

Predictive Impact Assessment Engine

• Ensemble ML Models • Monte Carlo Simulation
• Uncertainty Quantification • Risk Scoring

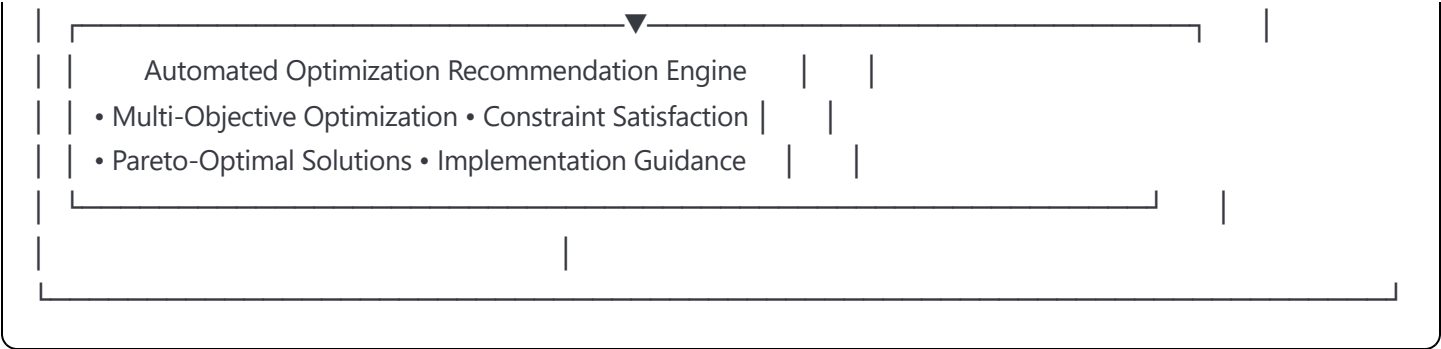


Figure 2: Graph Neural Network Architecture

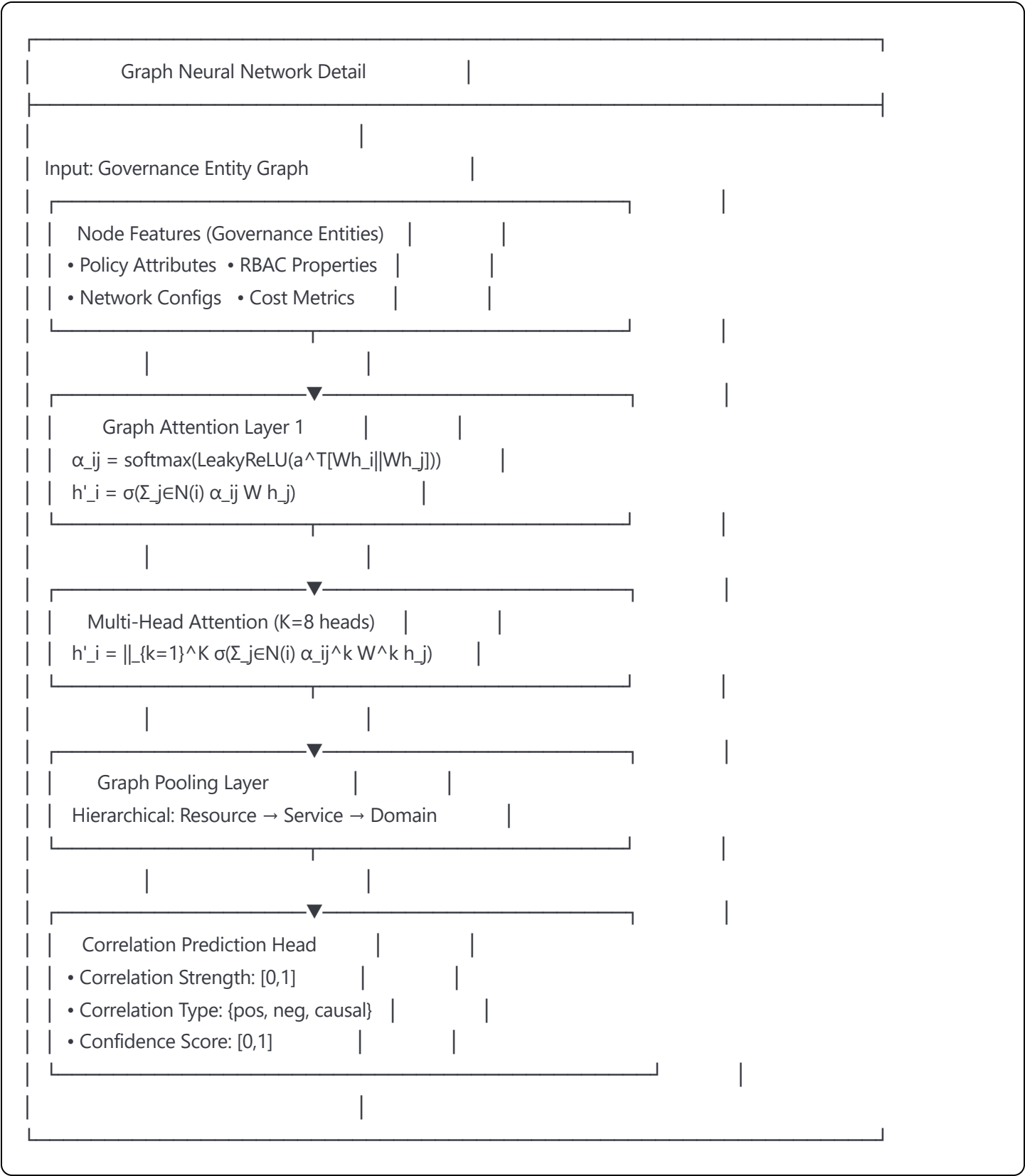


Figure 3: Correlation Detection Flow

Correlation Detection Pipeline

Policy

RBAC

Network

Events

Events

Events

Time Series Alignment Module

• Interpolation • Resampling • Synchronization

Feature Engineering Module

Temporal

Statistical

Domain

Features

Features

Features

Correlation Analysis Ensemble

Pearson/Spearman

Mutual Info

$\rho = \text{cov}(X,Y) / (\sigma_X \sigma_Y)$

$I(X;Y) = -\sum p(x,y) \log p(x,y)$

$\sigma_X \sigma_Y$

$p(x,y) \log p(x,y)$

Ensemble Aggregation Layer

Weighted voting + Confidence

Causal Inference Module

• Granger Causality Testing

• Structural Equation Modeling



Figure 4: Impact Prediction Architecture

Cross-Domain Impact Prediction System

Detected Correlation: Policy Change → Cost Impact

Input: Correlation + Context

- Correlation Strength: 0.87
- Historical Patterns: 90 days
- Domain States: Current configurations

Ensemble Prediction Models

Gradient Boosting
LSTM Networks
Graph Conv

Monte Carlo Simulation Engine

```
for i in range(1000):  
    sample = bootstrap(historical_data)  
    prediction[i] = model.predict(sample)  
confidence_interval = percentile(predictions)
```

Impact Visualization Output

Domain Impact Heatmap
Policy RBAC Network Cost
[0.2] [0.8] [0.1] [0.9]

Risk Score: 8.5/10 Confidence: 92%

A system and method for analyzing cross-domain correlations in cloud governance environments, providing real-time detection of relationships between policy compliance, role-based access control, network security, and cost management domains. The invention employs graph neural networks with attention mechanisms to model complex governance entity relationships across multiple abstraction levels. Multi-dimensional correlation analysis combines statistical methods, mutual information theory, and causal inference to identify both direct and indirect relationships with temporal lag effects. The system implements ensemble machine learning models for predictive impact assessment, utilizing Monte Carlo simulations for uncertainty quantification. An automated optimization engine generates Pareto-optimal recommendations considering multi-objective constraints across governance domains. The invention enables proactive governance management by predicting cross-domain impacts of configuration changes before implementation, significantly reducing compliance violations and operational costs while improving security posture.