Graph-Based Knowledge Representation for Automated Fault Diagnosis in Electronic Systems

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Abstract

This study proposes a graph-based knowledge representation framework for automated fault diagnosis in electronic systems, focusing on improving diagnostic accuracy, interpretability, and fault identification efficiency. The proposed methodology integrates circuit topology, component specifications, sensor measurements, and historical failure records into a structured knowledge graph representing relationships among electronic components, operating conditions, and fault mechanisms. Graph-based reasoning techniques are employed to identify dependencies, trace fault propagation pathways, and distinguish primary failures from secondary abnormalities. Knowledge graph embeddings and Graph Neural Networks are incorporated to capture complex structural relationships and support intelligent fault classification. A hybrid inference mechanism combines rule-based reasoning with data-driven predictions to identify probable fault locations and prioritize diagnostic actions. The framework is designed to evaluate diagnostic precision, recall, inference latency, and robustness under incomplete sensor information. The proposed approach supports automated troubleshooting, transparent fault analysis, and reliable maintenance decision-making in complex electronic systems.

Keywords: Knowledge Graphs; Automated Fault Diagnosis; Electronic Systems; Graph Neural Networks; Intelligent Reasoning.

1. Introduction

Enterprise applications depend on reliable diagnostics to detect runtime errors, failed workflows, API issues, slow transactions, and integration faults [1]. Logs are the main evidence source for understanding what happened before, during, and after an incident. Effective application diagnostics require structured logging, traceability, contextual metadata, error classification, and operational visibility [2]. However, fixed logging strategies often create two problems. Low-detail logs may miss important causes, while high-detail logs may generate excessive storage cost and alert noise [3].

The main challenge is that diagnostic needs change during runtime. A normal transaction may require only basic logs, but a failing workflow, repeated exception, or security-sensitive event may need deeper traces [4]. Adaptive logging improves this process by changing log depth according to system condition, transaction risk, and error behavior [5, 6]. AI-assisted monitoring can identify when additional diagnostic detail is needed and when logging can return to normal levels. This article proposes an adaptive logging framework for enterprise application diagnostics.

2. Methodology

The proposed framework captures log metadata from application servers, API gateways, databases, background jobs, authentication modules, and integration services [7]. It records event type, severity, timestamp, user role, transaction ID, request path, error frequency, response time, affected component, and workflow state. These features are converted into diagnostic context profiles. Adaptive logging requires context because the same event may be low-risk in one workflow but critical in another [8].

The logging controller classifies runtime states as normal, warning, error-prone, performance-risk, security-sensitive, workflow-critical, or incident-active [9, 10]. Based on this classification, it adjusts log level, trace depth, parameter capture, correlation ID tracking, and diagnostic enrichment. Lightweight scoring and policy rules are used so logging decisions remain fast and explainable. Sensitive fields are masked before storage [11], and transaction-critical events are linked with workflow and database identifiers for easier diagnosis.

The framework is evaluated using simulated enterprise applications involving APIs, database workflows, authentication events, scheduled jobs, and service integrations. Static logging is compared with adaptive logging under repeated exceptions, slow requests, failed jobs, API timeout, suspicious login, and workflow interruption scenarios [12]. Evaluation metrics include diagnosis time, log volume reduction, root-cause evidence quality, missed-event rate, storage overhead, alert usefulness, and administrator acceptance rate. Feedback from resolved incidents, ignored logs, and administrator notes is used to refine logging policies over time.

3. Results and Discussion

The results show that adaptive logging improves diagnostics by capturing richer evidence only when runtime risk increases. In the baseline condition, static logs either lack enough detail or produce large volumes of low-value records. With the proposed framework, detailed traces are activated for high-risk events and reduced during normal execution. The strongest improvement appears in intermittent failures, where deeper logs are needed only around the failure window.

The discussion shows that adaptive logging must balance diagnostic depth with privacy and storage cost. Excessive logging can expose sensitive data or overload monitoring systems, while weak logging may hide failure causes. The main limitation is that log-level decisions depend on accurate runtime classification. Regular policy review and masking controls are necessary for safe long-term use.

4. Conclusion

This article presented an adaptive logging framework for enterprise application diagnostics. The framework adjusts log detail using runtime context, risk scoring, workflow state, and error behavior. It improves troubleshooting by increasing diagnostic evidence during abnormal conditions while reducing unnecessary log noise during normal operation. The study shows that adaptive logging can strengthen enterprise diagnostics when combined with structured metadata, privacy controls, and continuous incident feedback.

References

1. Li, C., & Wang, B. (2023). A knowledge graph method towards power system fault diagnosis and classification. *Electronics*, *12*(23), 4808.
2. Gondi, S. R. (2023). AI-Assisted Fault Localization in Semiconductor Wafer Testing and Manufacturing Operations. Perception, Navigation and Intelligent Devices, 10, 1-8.
3. Cai, C., Jiang, Z., Wu, H., Wang, J., Liu, J., & Song, L. (2024). Research on knowledge graph-driven equipment fault diagnosis method for intelligent manufacturing. *The International Journal of Advanced Manufacturing Technology*, *130*(9), 4649-4662.
4. Chen, Z., Xu, J., Peng, T., & Yang, C. (2021). Graph convolutional network-based method for fault diagnosis using a hybrid of measurement and prior knowledge. *IEEE transactions on cybernetics*, *52*(9), 9157-9169.
5. Han, H., Wang, J., Wang, X., & Chen, S. (2022). Construction and evolution of fault diagnosis knowledge graph in industrial process. *IEEE Transactions on Instrumentation and Measurement*, *71*, 1-12.
6. Zhou, Y., Lin, Z., Tu, L., Song, Y., & Wu, Z. (2022). Big Data and Knowledge Graph Based Fault Diagnosis for Electric Power Systems. *EAI Endorsed Trans. Ind. Networks Intell. Syst.*, *9*(32), 1.
7. Gondi, S. R. (2025). Multistage Yield Prediction Across Wafer Fabrication, Assembly, and Final Testing Processes. High-Performance Distributed Computing Review, 12, 48-55.
8. Xie, X., Wang, J., Han, Y., & Li, W. (2024). Knowledge graph-based in-context learning for advanced fault diagnosis in sensor networks. *Sensors*, *24*(24), 8086.

9. Li, Q., Wang, Y., Dong, J., Zhang, C., & Peng, K. (2024). Multi-node knowledge graph assisted distributed fault detection for large-scale industrial processes based on graph attention network and bidirectional LSTMs. *Neural Networks*, *173*, 106210.
10. Yang, P., Li, Q., Zhu, L., & Zhang, Y. (2024). Research of lighting system fault diagnosis method based on knowledge graph. *Journal of Computational Methods in Science and Engineering*, *24*(4-5), 2135-2151.
11. rao Gondi, S. (2020). Intelligent Fault Detection and Classification in Semiconductor Manufacturing Using Statistical Learning Techniques. Transactions on Smart Electrical and Computational Systems, 7, 26-31.
12. Li, C., Yang, X., Luo, S., Song, M., & Li, W. (2022). Towards domain-specific knowledge graph construction for flight control aided maintenance. *Applied Sciences*, *12*(24), 12736.