Dissertation Title:

Agentic AI Framework for Building Management Systems: Towards Intelligent and Autonomous Building Operations

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Research Area: Artificial Intelligence

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Contents

Broad Area of Work

The broad area of this work lies in **Artificial Intelligence and Data Science**, with a focus on developing an Agentic AI framework for autonomous reasoning and intelligent decision making. In the evolving AI landscape, systems capable of contextual understanding, multi-agent collaboration, and proactive control is redefining what is meant by autonomy.

Among the many advancements driving this evolution, key developments include:

- **Retrieval-Augmented Generation (RAG)**: enabling context and knowledge-grounded reasoning beyond traditional pretraining and fine-tuning limitations.
- **Agentic AI Frameworks:** enabling autonomous reasoning, planning, and adaptive decision-making within any systems.

This research explores how these concepts can be applied within **Building Management Systems (BMS)** to enable self-managing, context aware, and efficient building operations.

Background

According to industry reports, the global smart building market size was around USD 117 billion in 2024 and is expected to exceed 500 billion by 2032. This rapid market growth shows a clear shift from traditional buildings to intelligent, data-driven, and "smart" infrastructure powered by **Artificial Intelligence (AI)** and the **Internet of Things (IoT)**. Modern **Building Management Systems** (**BMS**) manage key functions like HVAC, lighting, and comfort control through **networks of sensors** and controllers. These systems can increasingly monitor and automate tasks in real-time, forming the base of today's smart infrastructure.

However, as building systems become more interconnected, they also become more vulnerable to subtle or hidden faults that often remain unnoticed until they disrupt operations. Traditional rule-based BMS struggle to spot or diagnose these issues in advance, leading to reactive maintenance and unnecessary downtime. This situation has sparked more interest in creating intelligent systems that can find and explain faults autonomously. **Autonomous Fault Detection and Diagnostics (AFDD)** systems aim to reason, learn, and adapt with little human help. Advancing toward this level of autonomy represents a crucial step in the evolution of smart buildings, where systems can foresee problems and maintain stability independently.

Though recent studies have used machine learning and rule-based analytics for fault detection, these systems often stay static and fail to consider context, **needing constant human oversigh**t and retraining. They can find faults but do not reason about their causes or decide on corrective actions without assistance. Emerging Agentic AI methods address this issue by blending data-driven learning with goal-oriented reasoning and adaptive control. By integrating such agentic abilities into a Building Management System, it is possible to develop an intelligent framework that not only detects but also interprets and reacts to operational faults in real time. This dissertation builds on that idea, examining how an **Agentic AI-based framework can enhance diagnostic autonomy** in building operations and serve as a foundation for future self-governing infrastructure.

Objectives

The main goal of this dissertation is to investigate whether a hierarchical **Agentic Retrieval-Augmented Generation (RAG)** framework can improve the accuracy and independence of fault diagnosis in Building Management Systems when compared to standard single-step retrieval methods or other traditional methods. The study looks at how dynamic, reasoning-based retrieval strategies can make AI-assisted diagnostics more understandable and effective in complex HVAC settings.

To achieve this goal, the following objectives have been set:

- To identify the limitations of current rule-based and static AI methods in Building Management Systems, this highlights the need for adaptive, reasoning-based fault diagnostics.
- To **design and implement** a hierarchical Agentic RAG framework that includes multi-stage retrieval, intermediate reasoning, and confidence-driven re-prompting for fault diagnosis.
- To create a **simulation-based environment** for generating and testing realistic HVAC fault scenarios under controlled, reproducible conditions.
- To **evaluate the proposed framework** using metrics such as diagnostic accuracy, time-to-diagnosis, and provenance precision.
- To create a **lightweight visualization dashboard** that shows diagnostic insights, including detected faults, reasoning traces, and suggested maintenance actions, in a clear and evidence-based way. This will improve **transparency** and help with informed decision-making in building operations.

Scope of Work

The focus of this dissertation is on designing and developing a smart diagnostic framework for Building Management Systems (BMS). This study aims to improve automated fault management by adding reasoning abilities. It moves beyond traditional rule-based logic and static machine-learning models. Based on Agentic AI principles and hierarchical Retrieval-Augmented Generation (RAG), the research envisions systems that can reason based on context, learn over time, and produce clear fault diagnostics with minimal human input.

The research emphasizes creating a modular, end-to-end diagnostic process. This process will detect anomalies, reason through multiple stages, and generate clear, evidence-based results. The hierarchical RAG framework will operate through cycles of retrieval and refinement. This setup allows the system to reason dynamically using domain knowledge, sensor data, and maintenance records. These features will be tested in a simulated environment that replicates Air Handling Unit (AHU) fault scenarios. The AHU context provides a realistic and data-rich setting for assessing how reasoning-driven AI can analyze complex system behavior and deliver structured, verifiable diagnostic insights.

Practically, this work includes developing a reproducible simulation environment, implementing a hierarchical reasoning process, and designing a lightweight visualization dashboard that presents diagnostic results—such as detected faults, reasoning summaries, and recommended maintenance actions—in an interpretable and evidence-driven format. The dissertation centers on creating a working proof of concept that demonstrates transparency, flexibility, and autonomy in diagnostic reasoning. The ultimate goal is to advance the use of Agentic AI in building fault diagnostics and support the development of intelligent, explainable, and self-improving infrastructure systems.

This dissertation contributes to the growing field of Agentic AI by showing how reasoning-based retrieval and autonomy can improve transparency, reliability, and decision-making in modern building management systems. It also sets the foundation for future research focused on self-managing, context-aware operational intelligence.

Plan of Work

Phase	Timeline	Work to be Done
Phase 1: Problem Framing and Design	Nov 2025 – Dec 2025	Literature review on existing Fault Detection and Diagnostics (FDD) systems and Agentic AI methods. Define system architecture for hierarchical RAG-based diagnostic reasoning and finalize data flow across modules.
Phase 2: Environment Setup and Simulation Development	Dec 2025 – Jan 2026	Develop a reproducible simulation setup for Air Handling Unit (AHU) faults, including deterministic fault injection and data logging. Prepare datasets, sensor feeds, and environment metadata for integration with the diagnostic pipeline.
Phase 3: Framework Implementation	Jan 2026 – Feb 2026	Implement the hierarchical RAG framework with controller and retriever agents, integrating iterative reasoning loops for multi-stage diagnostic refinement and evidence-provenance tracking to ensure traceability of AI decisions. Develop a lightweight visualization dashboard for presenting diagnostic outcomes—such as detected faults, reasoning traces, provenance snippets, and recommended maintenance actions—to support interpretability and human decision-making.
Phase 4: System Testing and Documentation	Feb 2026	Execute end-to-end seeded scenarios to validate functionality and transparency of reasoning. Document findings, finalize the dissertation report, and prepare for the viva presentation.

Literature References

The references supporting this dissertation are drawn from both academic research and industry reports on fault detection, diagnostic reasoning, and emerging Agentic AI methods. Together, they outline the progression from traditional rule-based control to adaptive, reasoning-driven fault management frameworks in Building Management Systems.

[Research Papers]

[1] J. Zhang, Y. Li, and X. Zhao. TranDRL: A Transformer-Driven Deep Reinforcement Learning Enabled Prescriptive Maintenance Framework. arXiv preprint arXiv:2309.16935, 2023. Available: https://arxiv.org/abs/2309.16935

[2] A. Johnson, P. Huang, and M. Al-Turjman. Autonomous Industrial Control using an Agentic Framework with Large Language Models. arXiv preprint arXiv:2411.05904, 2024. Available: https://arxiv.org/abs/2411.05904

[3] T. Wang, D. Müller, and C. Petrovic. State-of-the-Art Review: The Use of Digital Twins to Support Artificial Intelligence-Guided Predictive Maintenance. arXiv preprint arXiv:2406.13117, 2024
Available: https://arxiv.org/abs/2406.13117

[Industry and Technical References]

[4] Nexus Labs. Understanding Agentic AI: The Next Leap in Building Intelligence. Nexus Labs Online, 2024. Available: Nexus Labs Report

[5] NRI North America. Predictive Maintenance with AI: How Smart Buildings Stay Ahead of Failure. NRI-NA, 2024. [Online]. Available: NRI-NA Report

Particulars of the Supervisor and Examiner

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Remarks of the Supervisor

The dissertation scope and work described is carefully studied and very effectively evaluated by the student for the current paradigm of AI in Autonomous Buildings. Given the Agentic AI framework as the next step towards autonomy and blending the cutting-edge technology with the Building Automation domain is a forthcoming idea studied by the student. Prithviraj is very meticulous, hard working and always looking forward for innovation and newness in his work. After detailed discussions on his idea and dissertation scope, I approve him to take up this dissertation project.

Information about the Supervisor:

Doctoral Degree from IISc Bangalore

24 years of work experience with 20+ years in Honeywell and 3.5 years in GE Research Centre Bangalore.

Technical Areas: AI in various domains, Numeric Data, Text, Audio, Speech, Vision Analytics

18 Patents Granted

6 Papers published in International and National Journals and Conferences.

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SECOND SEMESTER OF ACADEMIC YEAR 2021-2022

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