Enhancing Semantic Search with Retrieval-Augmented Generation and Agentic AI

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MSc Thesis Defense

Presentation Structure

1. Motivation and Problem
2. Objectives
3. Architecture and Components
4. Related Work (Context)
5. Evaluation and Results
6. Conclusions and Future Work

Motivation: Enterprise Information Pain

- Public sector platforms: rich processes, poor retrieval
- Users lose time locating updated documents
- Decisions risk using superseded info
- Manual checking of dependencies = high cognitive load

Goal: Reliable answers over evolving document ecosystems.

Problem: Interdependent Information

Challenges

- Updates invalidate older assertions
- Temporal precedence matters
- Keyword search misses structure
- Naive RAG ignores relationships

Problem: Interdependent Information

Example Timeline

- Jan: Approve Vendor X (A)
- Mar: Suspend Vendor X (B)
- Apr Query: “Can we contract?”

Risk: Retrieves A, ignores B.. **Core Challenge:** Capture and reason over document dependencies.

Research Gap

- No standard tooling for dependency-aware retrieval
- GraphRAG ideas emerging; enterprise schemas underused
- Agents lack validated schema-constrained traversal tools
- Need: Hybrid semantic + structural + temporal reasoning

Objectives Overview

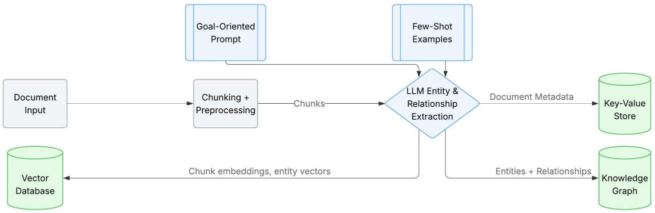
- **Represent** enterprise document structure and relations
- **Detect** updates / contradictions across documents
- **Reason** with agents over a knowledge graph
- **Standardize** access (MCP server for Weaviate)
- **Evaluate**: compare naive and baseline RAG

Objective Details

1. Schema design (workflows, entities, metadata)
2. Graph construction (entity merging, references)
3. Agent traversal (multi-hop, temporal ordering)
4. MCP tools (validated queries, follow references)
5. Evaluation (retrieval accuracy, answer quality)

Architecture Overview

1. Ingestion (OCR, chunking, embeddings)
2. Storage (Vector DB + Graph)
3. Reasoning (Agent + MCP tools)

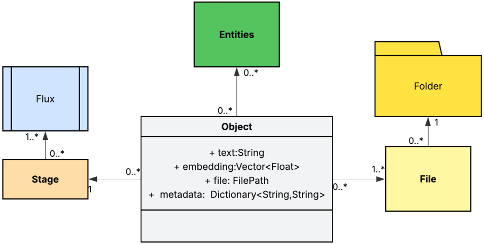


Schema Data Model

Six core classes:

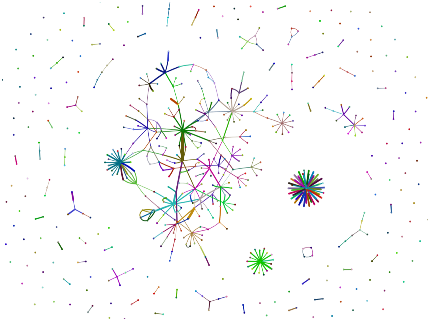
- Workflow (Fluxo), Step (Etapa)
- Entity (Entidade)
- Folder (Pasta), File (Ficheiro), Metadata (Metadados)

Cross-references enable semantic + deterministic traversal.



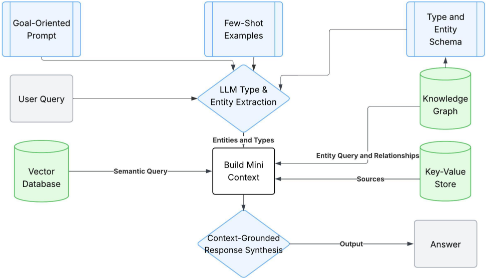
Graph Construction

- Extract entities from chunks (LLM assisted)
- Merge nodes with matching entities
- Maintain references (updates, supersedes)
- Output: lightweight knowledge graph



Agent Traversal Flow

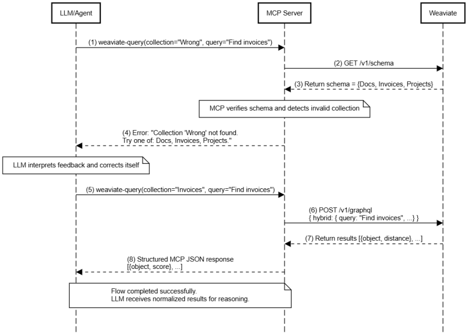
1. Parse query (entities + time)
2. Hybrid retrieval (vector + filters)
3. Follow graph refs (updates/nullifications)
4. Assemble consistent evidence set
5. Generate answer (current state)



MCP Server (Weaviate Bridge)

- Standard tool interface for agents
- Validated schema-aware queries
- Tools: weaviate-query, weaviate-follow-ref
- Enables safe multi-hop reasoning

Weaviate-Query Flow with Schema Validation and Self-Correction


LLM/Agent
MCP Server
Weaviate
(1) weaviate-query(collection="Wrong", query="Find invoices")
(2) GET /v1/schema
(3) Return schema = {Docs, Invoices, Projects}
MCP verifies schema and detects invalid collection
(4) Error: "Collection 'Wrong' not found.
Try one of: Docs, Invoices, Projects."
LLM interprets feedback and corrects itself
(5) weaviate-query(collection="Invoices", query="Find invoices")
(6) POST /v1/graphql
{ hybrid: { query: "Find invoices", ...} }
(7) Return results [{object, distance}, ...]
(8) Structured MCP JSON response
[{object, score}, ...]
Flow completed successfully.
LLM receives normalized results for reasoning.

Control Perspective (Robotics/AI)

- Retrieval = perception layer
- Graph = system state representation
- Agent traversal = planning refinement loop
- Updates = state correction (feedback)
- Ensures consistent decision inputs

Related Work: Semantic and Graph RAG

- Keyword enterprise search: lacks semantics/structure
- Classic RAG: isolated chunk retrieval
- Emerging GraphRAG: entity/relationship surfacing
- Gap: temporal nullification + standardized tooling

Comparison to Prior Approaches

- Adds temporal precedence handling
- Integrates schema-driven traversal
- Standardizes graph access (MCP server)
- Focus: enterprise interdependency reliability

Evaluation Questions

- Does graph traversal improve retrieval accuracy?
- Does dependency handling improve answer correctness?
- Does hybrid search generalize across collections?

Single-Collection Performance

Agentic RAG: 60.4% retrieval, 61% correct answers (∼2–4× over baselines)

Table: Document retrieval and answer quality metrics

Method	Avg. Retrieval Rate	Correct Answers
Agentic RAG	60.4%	61%
LexRank	33.6%	29.5%
BART	17.8%	3.0%
Naive RAG	13.8%	19.1%

Threshold via Youden optimization.

Multi-Collection Retrieval

Generalization across heterogeneous sources

- Correct collection selection
- 2–3× improvement across strategies
- Robust to format variation

Table: Multi-collection retrieval and answer quality metrics

Method	Avg. Retrieval Rate	Correct Answers
Mixed REST	46.5%	15.8%
Mixed LexRank	39.4%	24.6%
Mixed DOCX	33.0%	31.5%
Naive RAG	13.8%	19.1%

Key Result Insights

- Multi-hop reasoning reduces outdated answers
- Temporal ordering prevents contradiction leakage
- Graph adds structured context beyond embeddings

Main Contributions

1. Formalized enterprise interdependency retrieval problem
2. Schema + graph architecture for dynamic updates
3. Agentic multi-hop traversal (temporal aware)
4. MCP Weaviate server (standardized tools)
5. Empirical gains (2–4× over baselines)

Conclusions

- **Graph-aware reasoning**: prevents outdated answers
- **Temporal ordering**: resolves contradictions
- **Schema constraints**: reduce hallucination surface
- **Tool standardization** enables reproducible agent pipelines

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Limitations

- Scale constrained (compute / budget)
- No public benchmark (construction overhead)
- Residual hallucinations possible
- Need deeper privacy/ACL integration

Future Work

- Larger-scale graph + incremental updates
- Benchmark release (structure-aware retrieval)
- Multi-agent verification and consistency checks
- Integration with access control layers
- Publication submission (CONF NAME / JOURNAL TBD)

Thank You

Thank you!

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Questions?