Enhancing Semantic Search with Retrieval-Augmented Generation and Agentic AI

Francisco Azeredo
Academic Advisor: Prof. Sérgio Luís Proença Duarte Guerreiro
Industrial Advisor: Eng.º Filipe Mendes Correia (Link Consulting SA)

Instituto Superior Técnico, Universidade de Lisboa

MSc Thesis Defense

Presentation Structure

TÉCNICO LISBOA

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

Enterprise Information Challenges

TÉCNICO LISBOA

Critical Business Context:

- Enterprises rely on *accurate, current* information for project approvals, compliance decisions, and operational governance
- **High-stakes work**: Incorrect or outdated information can lead to regulatory violations, project failures, or financial losses

Current Problems:

- Professionals spend significant time searching, reading, and analyzing multiple documents
- Manual verification of document dependencies creates **high cognitive load**
- Decisions risk relying on superseded or nullified information
- **Even modern semantic search systems fail** in critical situations—they cannot guarantee information currency or detect contradictions

Context: Edoclink Enterprise

Document Management Platform:

- Organizes documents with structured workflows and business rules
- Supports evolution from ad-hoc to complex workflow configurations
- Enables end-to-end process automation and digitalization
- Features: document lifecycle management, collaborative work, ERP integration
- Used in public sector and enterprises with rich, complex processes

Thesis Opportunity: Leverage this rich structure to enhance semantic search and retrieval accuracy.

Problem: Example Scenario

Example Timeline

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

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

Thesis Objectives

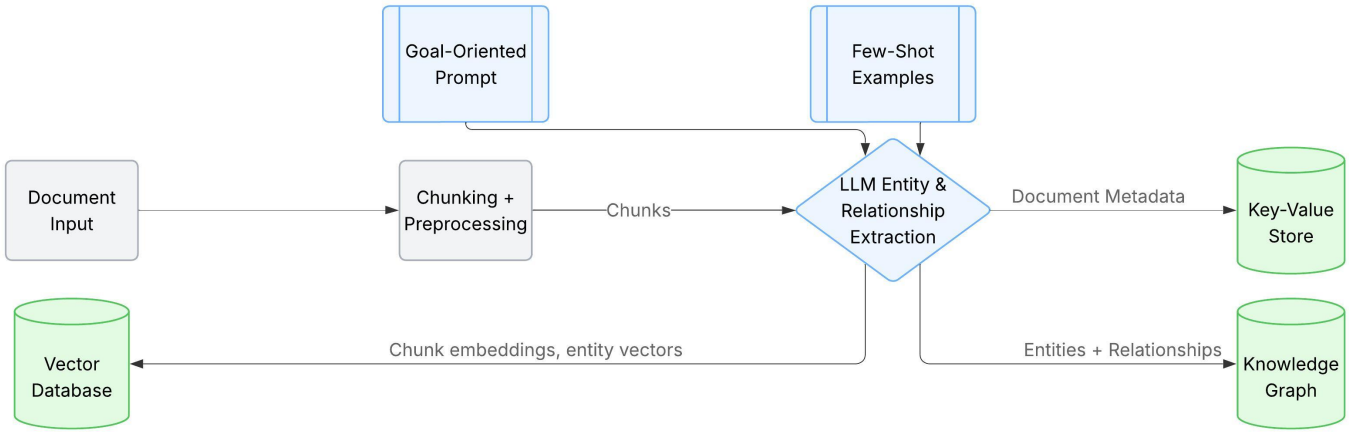
Main goal: Handle information interdependencies through graph-based agentic reasoning.

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)

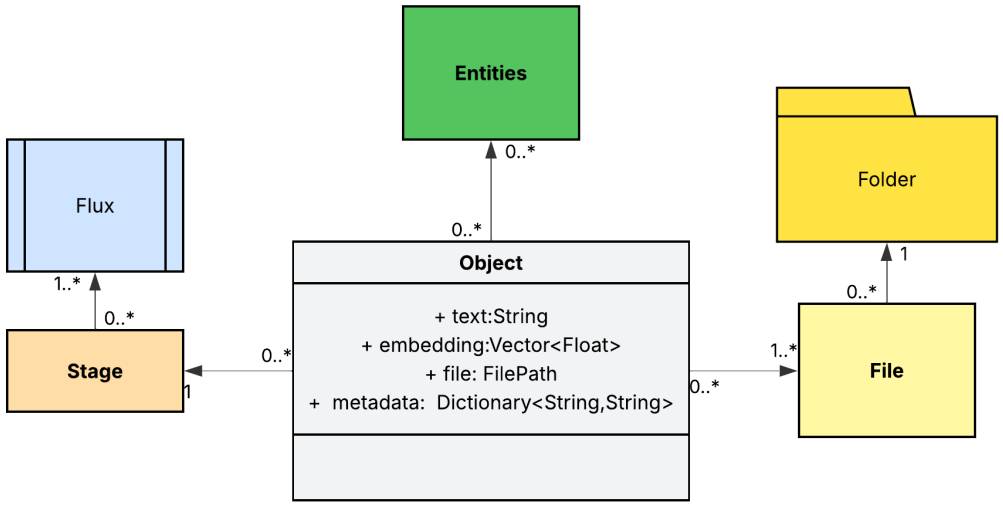


Schema Data Model

Six core classes:

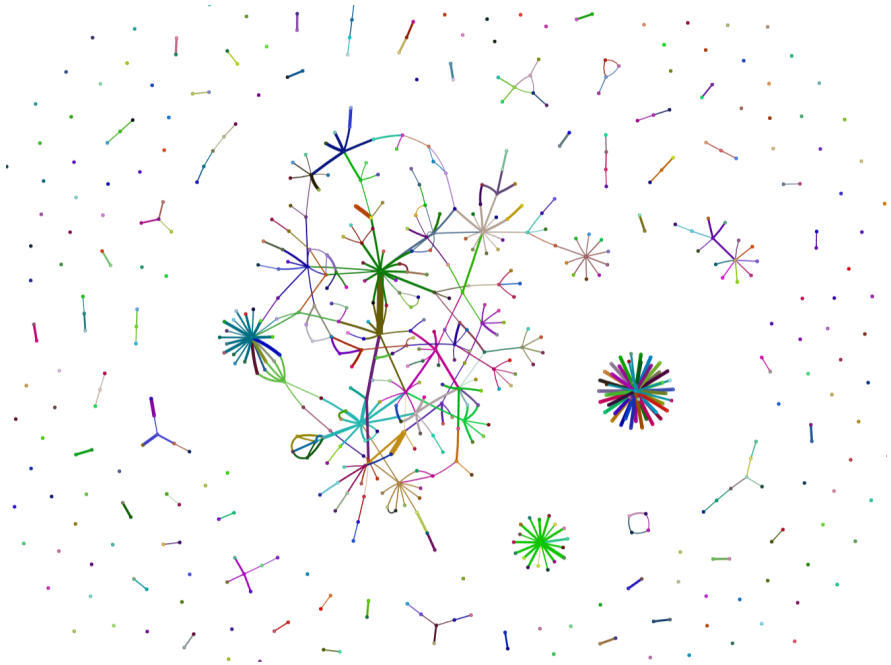
- Workflow (Fluxo), Step (Etapa)
- Entity (Entidade)
- Folder (Pasta), File (Ficheiro), Metadata (Metadados)

Cross-references enable semantic + deterministic traversal.



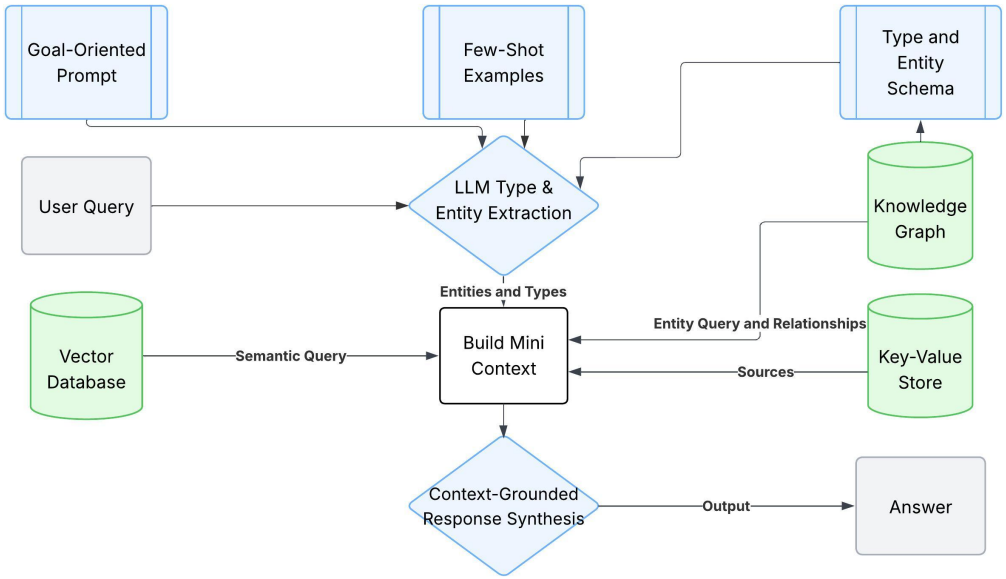
Graph Construction

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



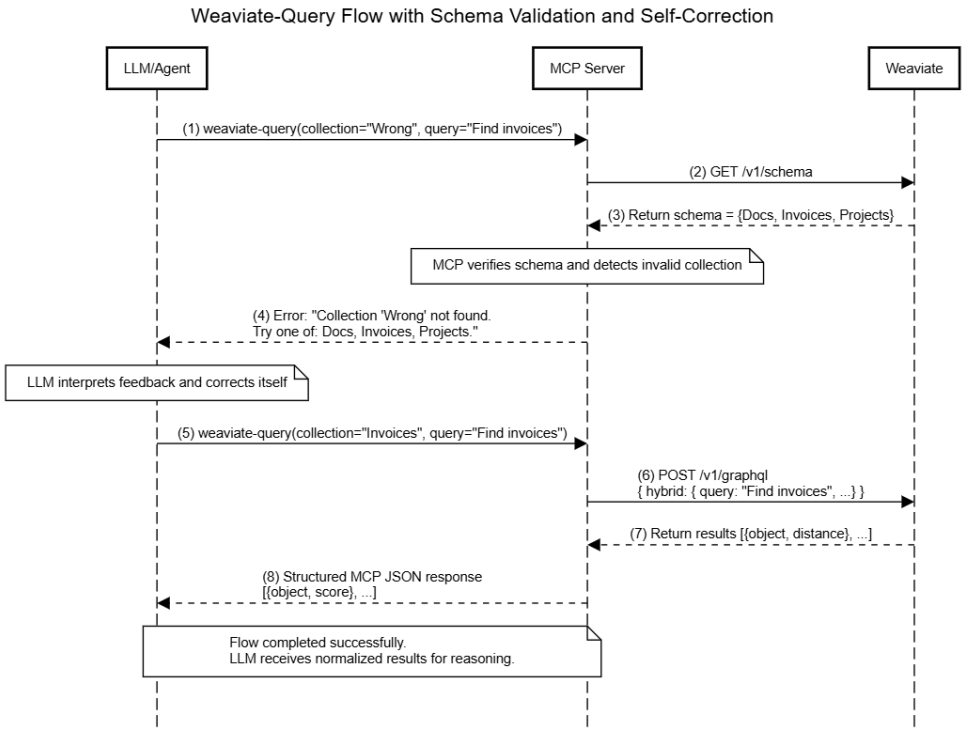
Agent Traversal Flow

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



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!

Francisco Azeredo
Instituto Superior Técnico
Questions?