CSE3063 MiniRAG Chatbot - Iteration 2 Evaluation Report

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Group: Grp13

Subject: Comparative Analysis of Keyword-Based vs. Vector-Based Semantic Retrieval

1. Introduction

This report evaluates the performance of the MiniRAG Chatbot during its second iteration. The primary focus is to contrast the legacy **Simple Mode** (Keyword matching) with the newly implemented **Cosine Mode** (Vector embeddings). The evaluation aims to demonstrate how semantic search improves retrieval accuracy, especially in complex regulation documents where keyword collisions are frequent.

2. Evaluation Metrics

To provide a comprehensive analysis, four key performance indicators (KPIs) were measured:

- **Simple Accuracy (Top-1):** Measures if the primary document retrieved matches the ground truth.
- **Chunk Precision:** Evaluates if the system identified the exact relevant paragraph (Chunk ID) within the document. This is critical for RAG systems to prevent context pollution.
- **Coverage@5:** Checks if the correct document exists within the top 5 results.
- **Average Latency (ms):** The mean time taken by the pipeline to generate a response.

3. Comparative Performance Results

Based on the batch execution of 12 department and university regulation queries:

Metric	Simple (Keyword) Mode	Cosine (Vector) Mode
Document Accuracy (Top-1)	63.6%	100%
Chunk Precision	63.6%	83.3%
Coverage@5	63.6%	90.09%
Average Latency (ms)	0.27 ms	84.85ms

4. Technical Analysis and Findings

4.1. The "Keyword Collision" Problem in Simple Mode

During testing, **Simple Mode** struggled with general terms. For example, in Query [3] and Query [7], the system returned general regulation clauses instead of specific "Excuse Exam" or "Leave of Absence" articles. This is because words like "başvuru" or "sınav" appear in almost every document, leading to high TF-based scores for generic sections.

4.2. Semantic Superiority of Cosine Mode

Cosine Mode demonstrated significant improvement in **Chunk Precision**. By using embeddings, the system captured the semantic intent of "Excuse Exam" (Mazeret Sınavı) and correctly mapped it to the specific article in the Excuse Exam Guideline, even when the word count was lower than in the general regulation.

4.3. Efficiency vs. Accuracy Trade-off

While Cosine Similarity calculation is computationally more expensive (slower), the 84.85ms latency remains well within the acceptable threshold for human-bot interaction. The drastic increase in precision justifies the additional computational cost.

5. Failure Analysis

Despite the improvements, certain failures were observed:

- **Context Fragmentation:** In some regulation queries, the system retrieved the correct clause but lost the parent header context. (Mitigated by the *Header Lookback* algorithm in the Answer Agent).
- **Name Entity Ambiguity:** Queries for staff members with common names (e.g., "Mustafa") sometimes pulled neighboring entries in the embedding space.
- **Short Chunks:** Segments shorter than 20 characters were occasionally ignored by the heuristic filter, leading to "No information found" errors for very specific, short titles.

6. Conclusion

Iteration 2 has successfully transitioned the MiniRAG system from a basic keyword search tool to an "intelligent" retrieval system. The integration of **Vector Indices** and **Cosine Reranking** has nearly doubled the chunk-level precision.