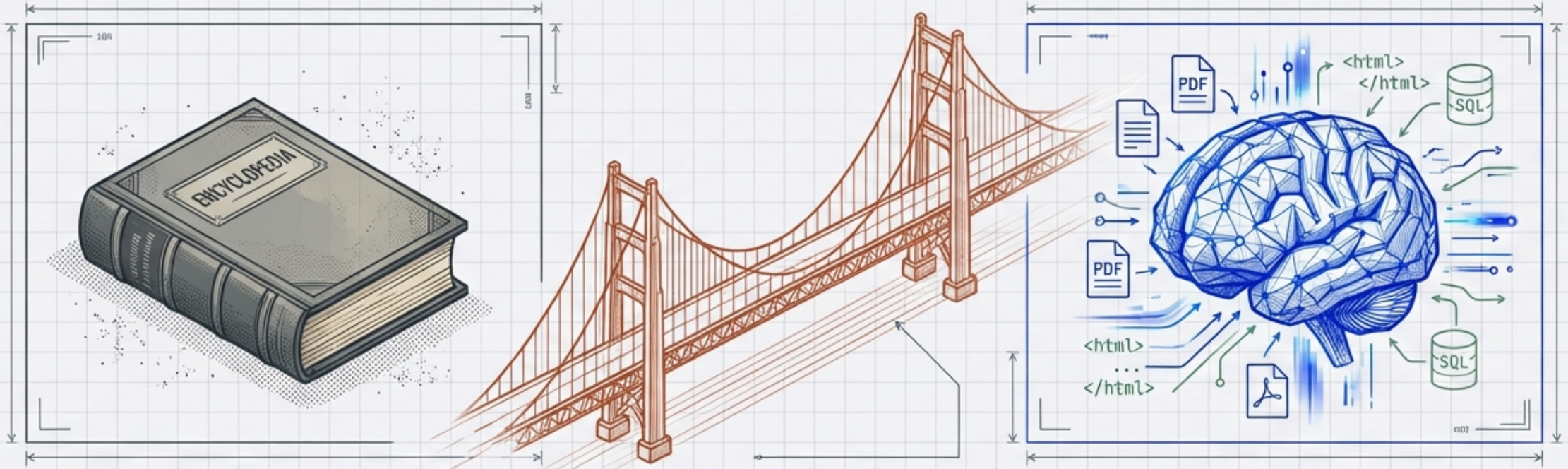
RAG: Bridging Static Knowledge and Dynamic Intelligence

A comprehensive guide to Retrieval Augmented Generation—Fundamentals, Pipelines, and Advanced Techniques



Frozen LLM Training Data

Retrieval & Augmentation Pathway

Dynamic Reality

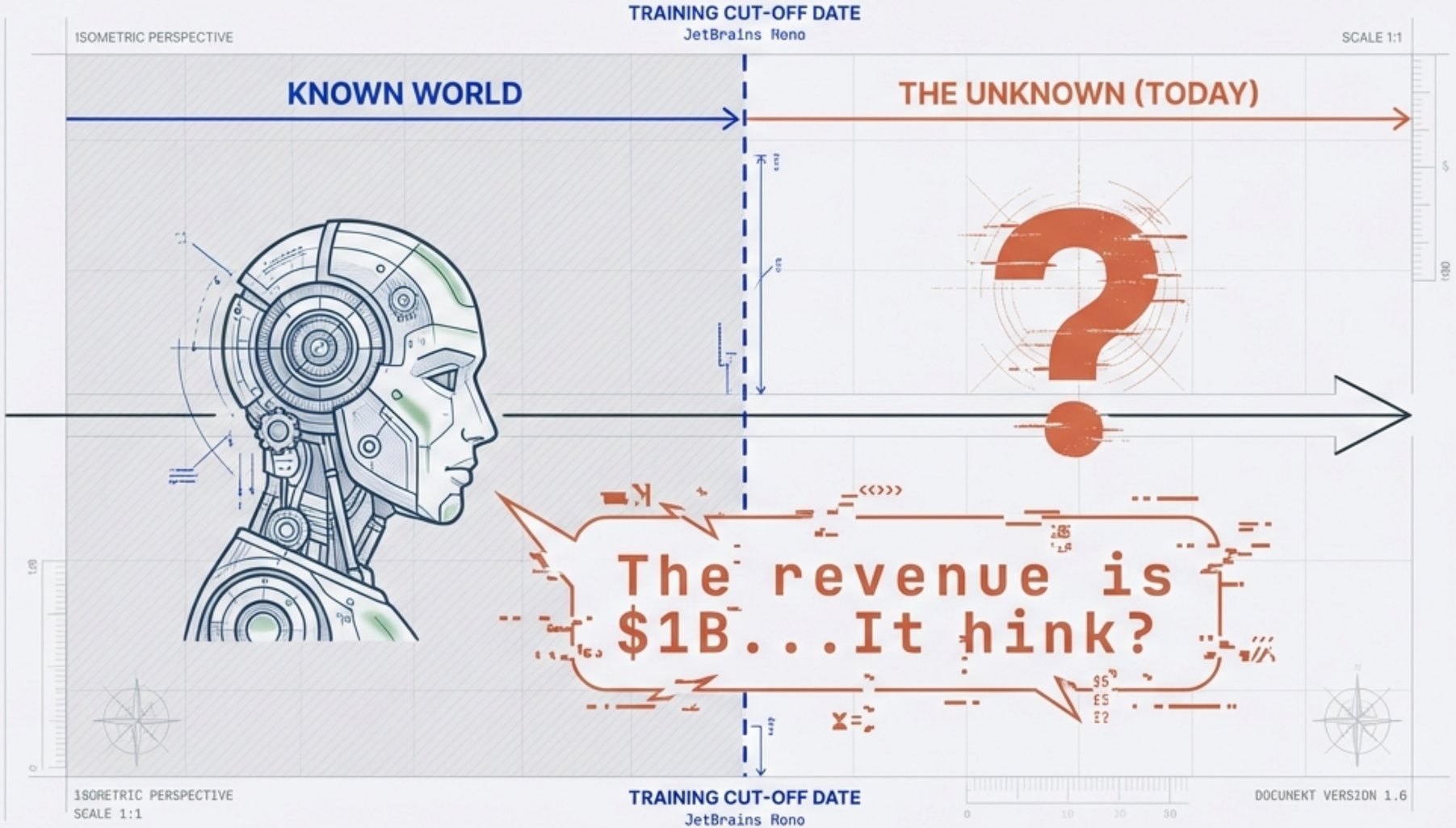
Source Material: Krish Naik, KodeKloud, freeCodeCamp

THE FROZEN BRAIN PROBLEM

WHY LLMS HALLUCINATE

LLMs are snapshots of the internet at a specific moment in time. They lack awareness of:

- Recent Events (Post-training history)
- Private Data (Company policies, financial records)
- User-Specific Context



RAG is the Open-Book Exam for AI

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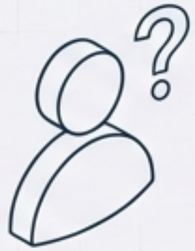
SCALE 1:1 | DOCUMENT VERSION 1.7



User Question

Retrieval
Search Knowledge Base

Context
Extract Facts

Generation
Synthesize Answer

Accurate Response

LIVE CONNECTION POINTS

Cost-Effective

No fine-tuning or retraining billions of parameters.

DATA EXTRACTION NODE

Up-to-Date

Connects to live external sources (PDF, SQL, HTML).

SOURCE TRACEABILITY

Traceable

Answers cite specific sources, eliminating the black box.

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SCALE 1:1
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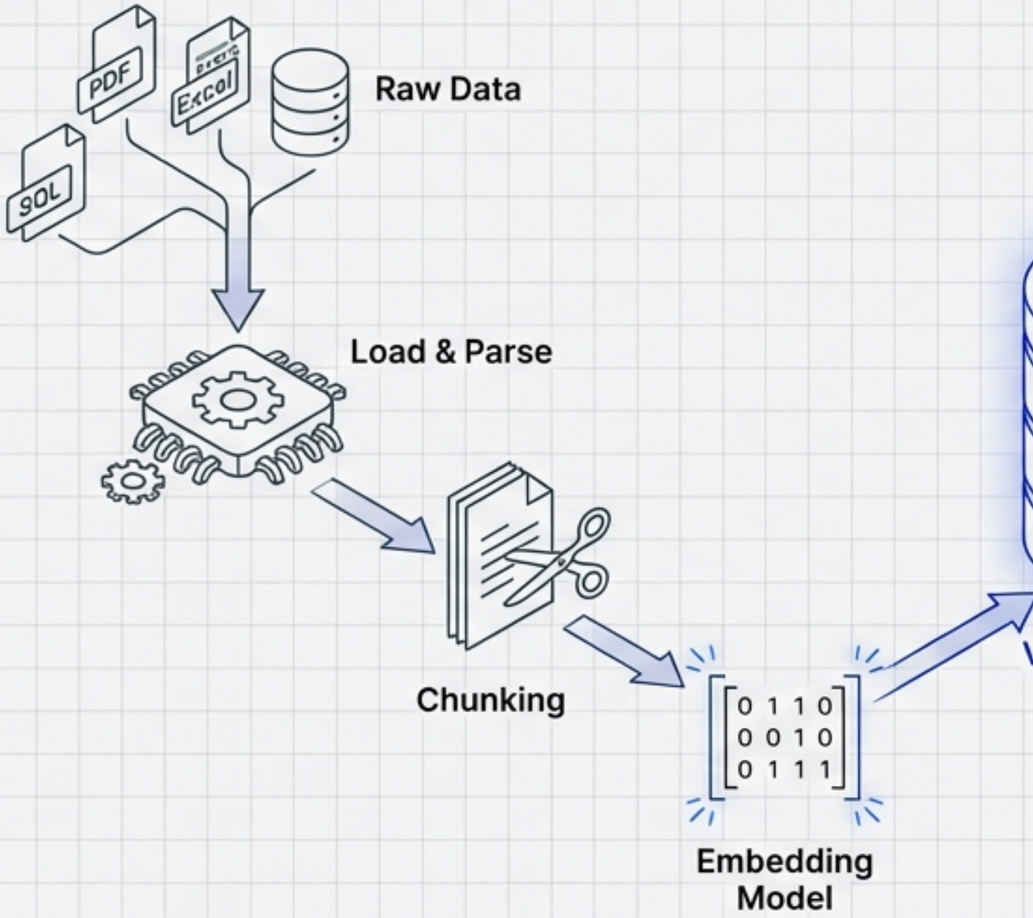
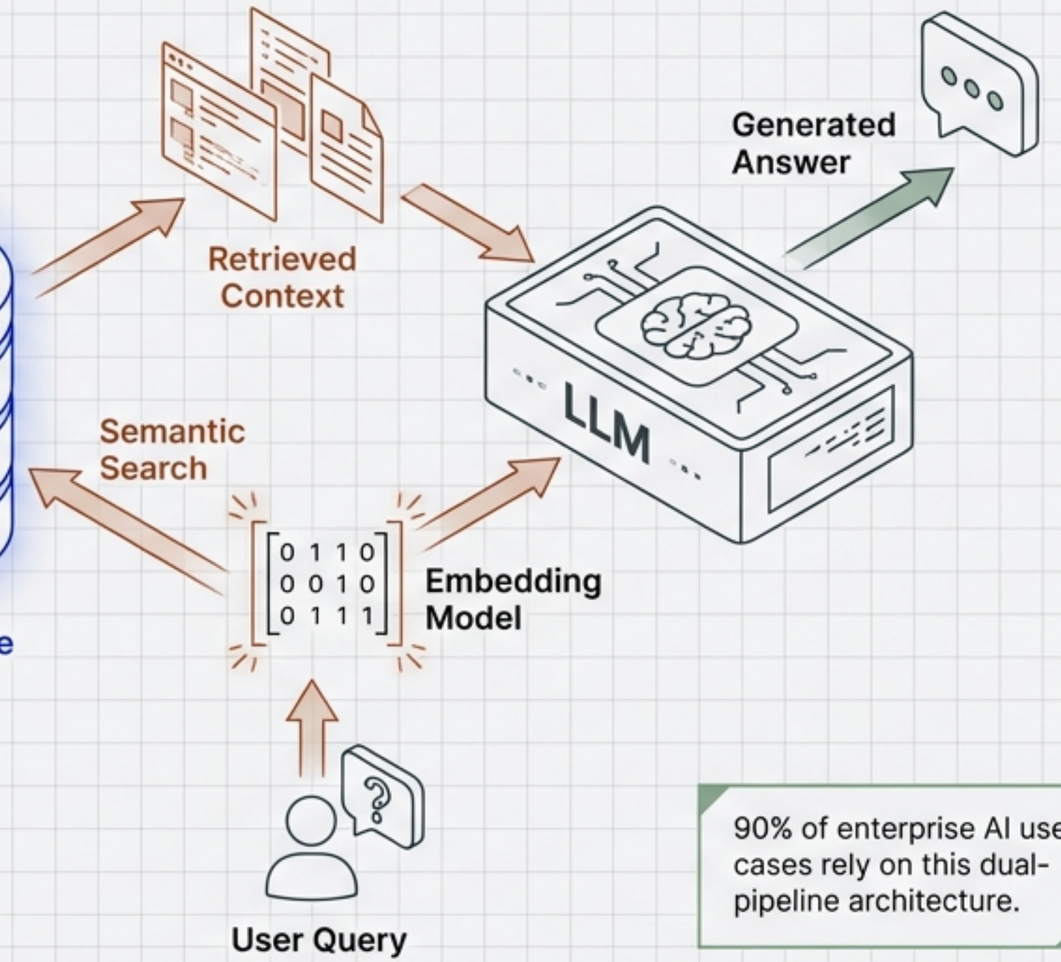
The Anatomy of a RAG System

Pipeline A: Ingestion (Offline/Async)



Pipeline B: Retrieval (Runtime)



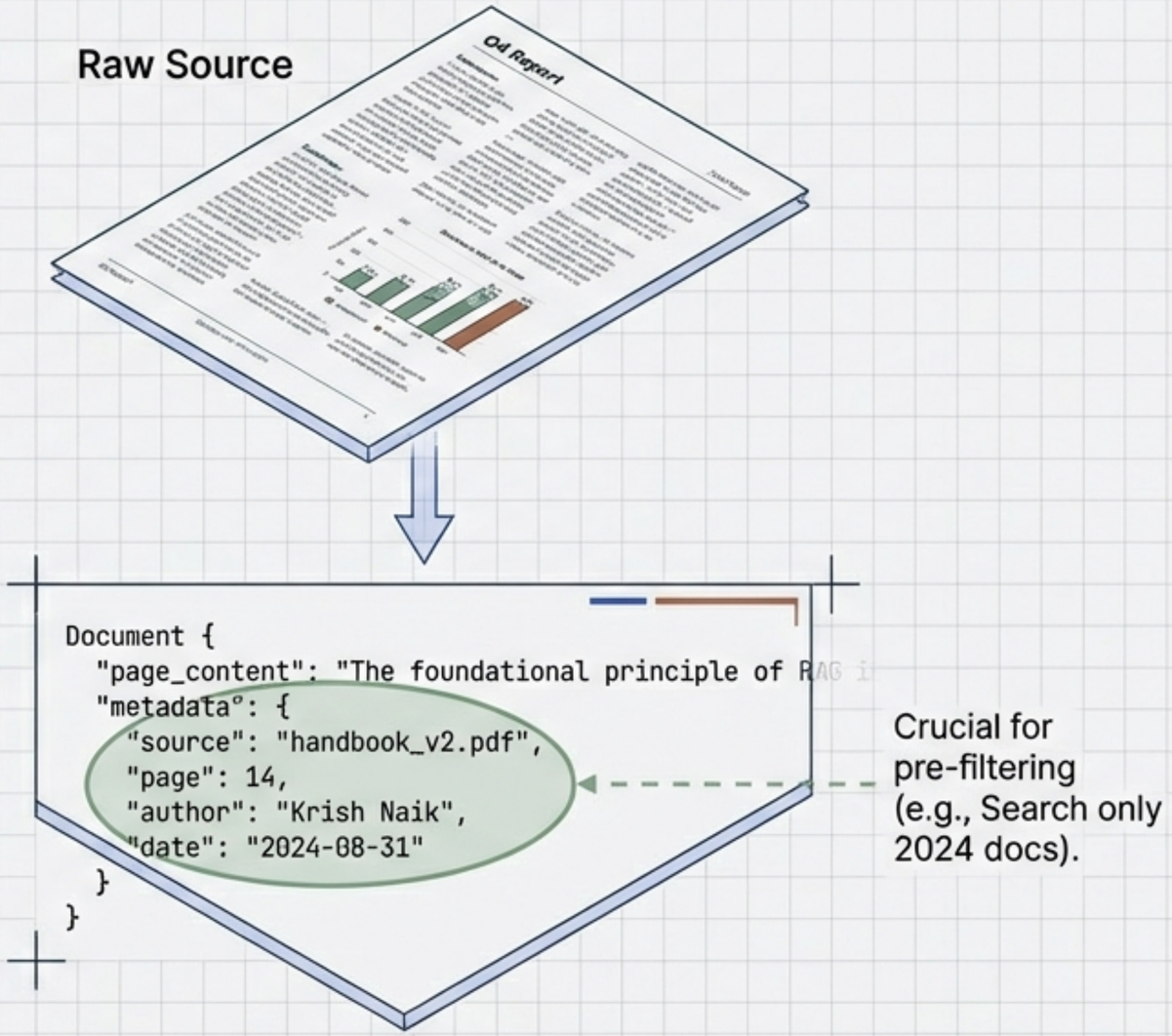
90% of enterprise AI use cases rely on this dual-pipeline architecture.

Pipeline A: Data Ingestion & Parsing

The foundation of RAG is extracting usable text from unstructured sources.

“Garbage in, garbage out.”

Tools: LangChain Document Loaders, PyPDF, PyMuPDF.



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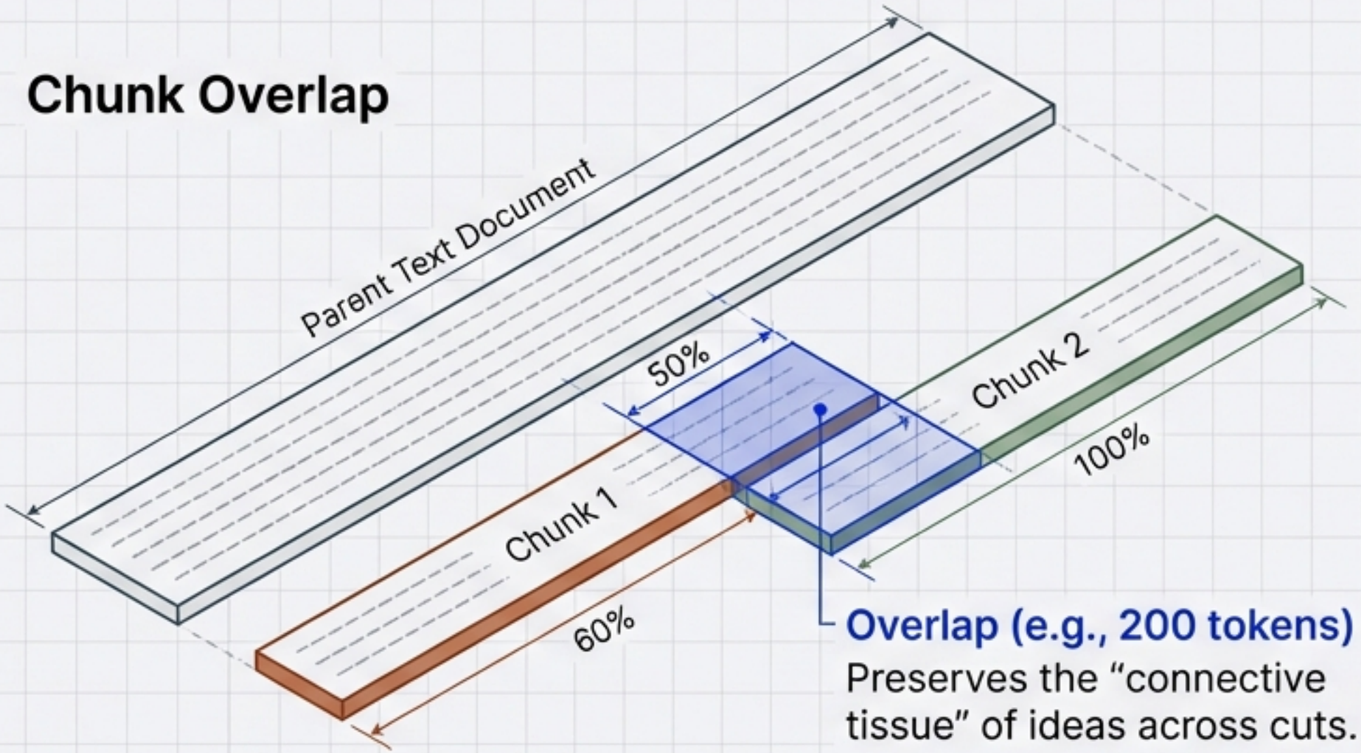
SCALE 1:1 | DOCUMENT VERSION 2.0

The Art of Chunking

Balancing Context and Precision

LLMs have a fixed “Context Window.” We split text to fit relevant information into the prompt without losing meaning.

Chunk Overlap



Overlap (e.g., 200 tokens)
Preserves the “connective tissue” of ideas across cuts.

Strategy:
RecursiveCharacterTextSplitter

```
chunk_size = 1000
chunk_overlap = 200
```

Embeddings: Converting Language to Math

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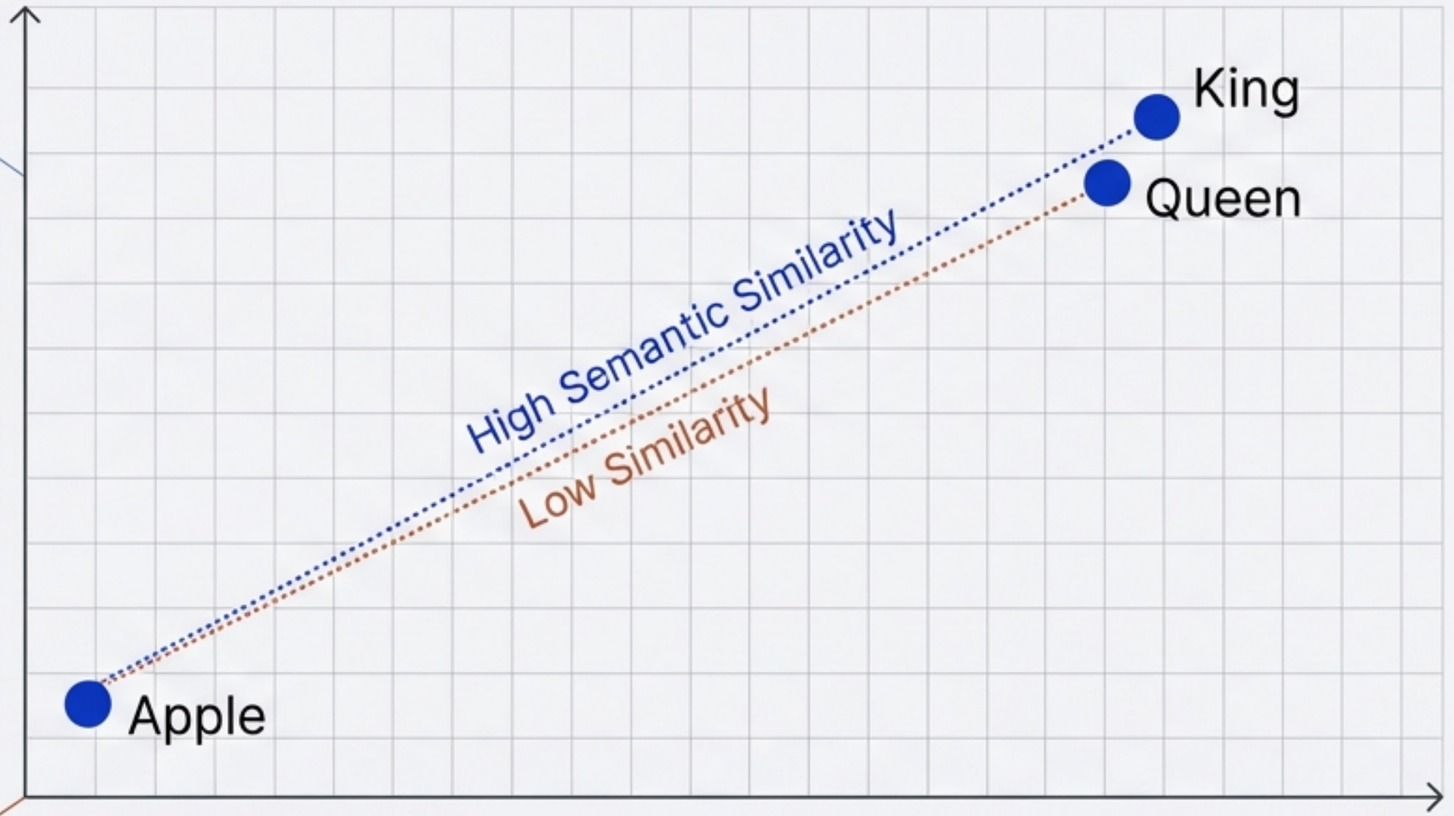
SCALE	DOCUMENT VERSION
1:1	3.0




```
Input: 'Dogs allowed'

Process: Embedding Model
         (all-MiniLM-L6-v2)

Output: Vector
       [0.002,
        -0.41,
        0.98,
        0.55,
        -0.12,
        -0.12,
        ...]
}
```

The computer doesn't read words.
It calculates distance between numbers.

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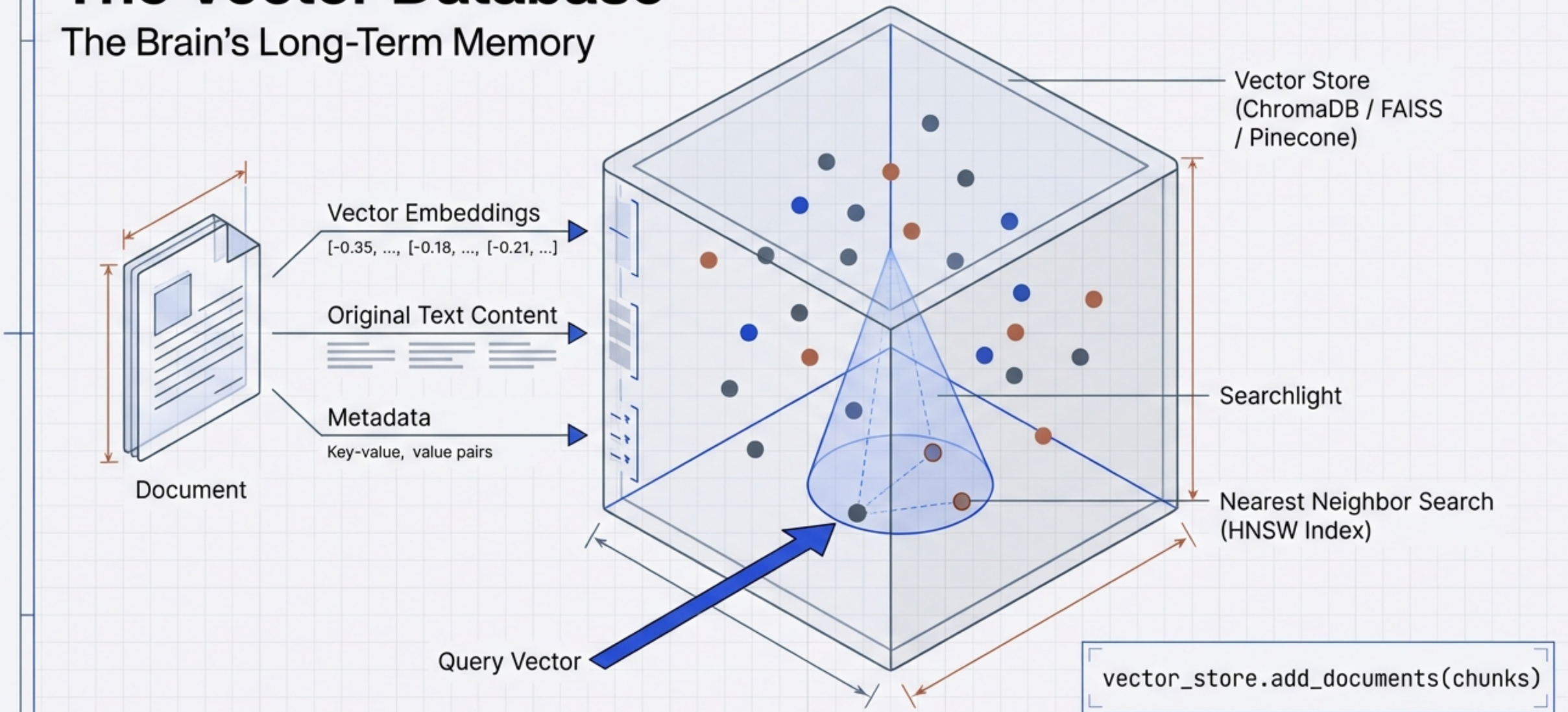
The Vector Database

The Brain's Long-Term Memory



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Pipeline B: Retrieval & Semantic Search

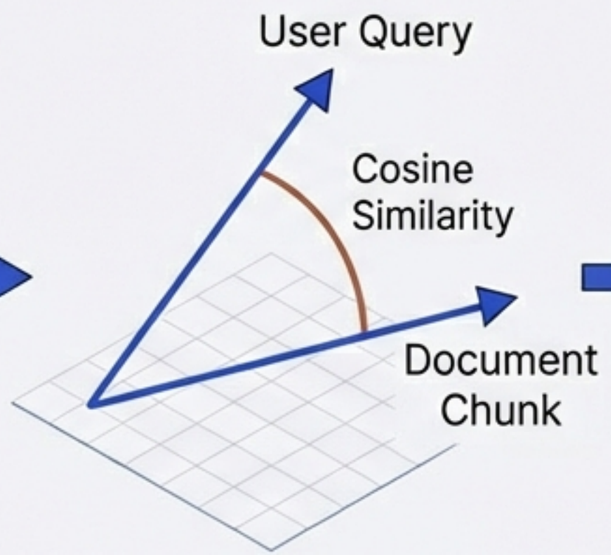
Step 1. Query Embedding

What is the pet policy?

[0.4, 0.1, ...]

Same model as document ingestion.

Step 2. Cosine Similarity



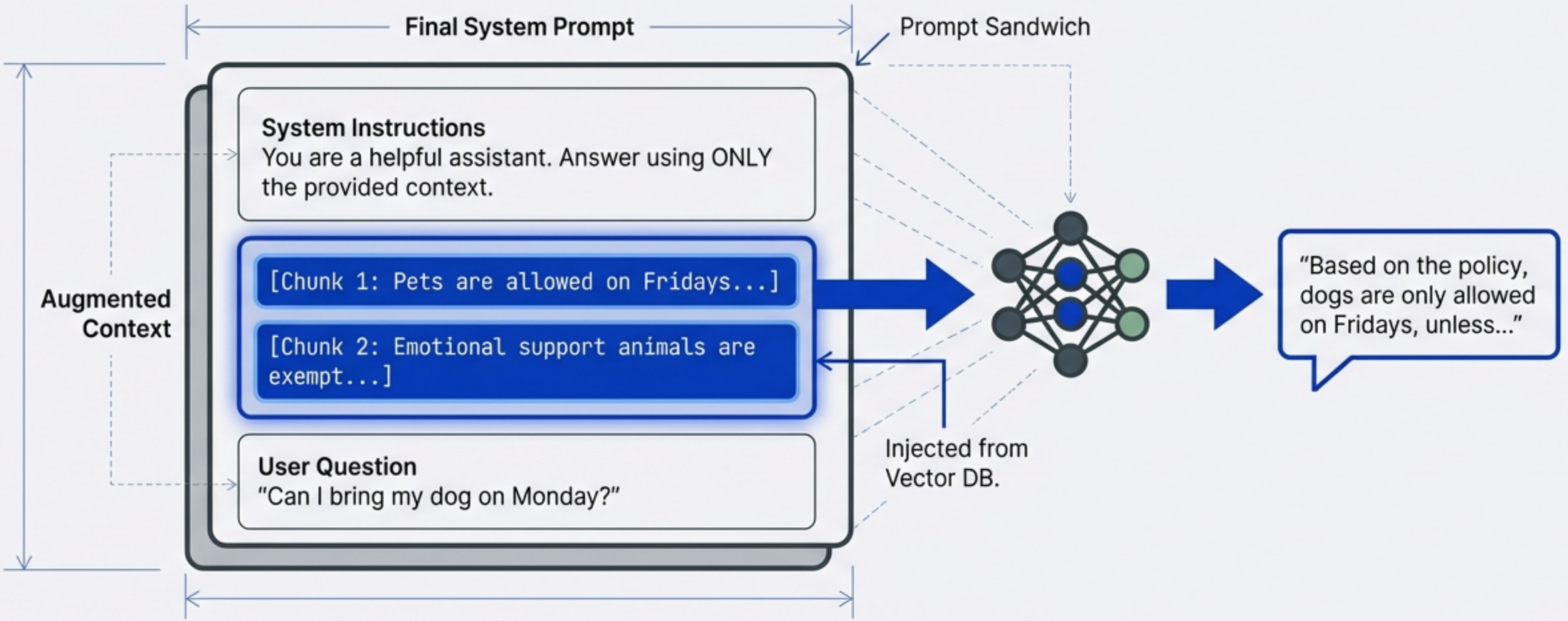
Smaller angle = Higher relevance.

Step 3. Top-K Retrieval

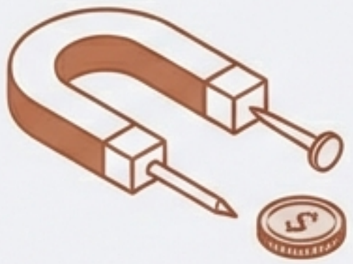
Relevant Context

Augmentation & Generation

Synthesizing the Answer



The Reality Check: Why Naive RAG Fails



Retrieval Mismatch

Semantic search finds keywords but misses intent. Queries like "Tell me about it" fail completely.

Missing Context

Documents discussing related concepts (e.g., "Climate" vs "Polar Bears") might be stored too far apart.

Lost in the Middle

LLMs tend to ignore context buried in the middle of a long retrieved list.

Integration Noise

Retrieving irrelevant chunks confuses the LLM, leading to hallucinations.

Solution: Advanced RAG Techniques.

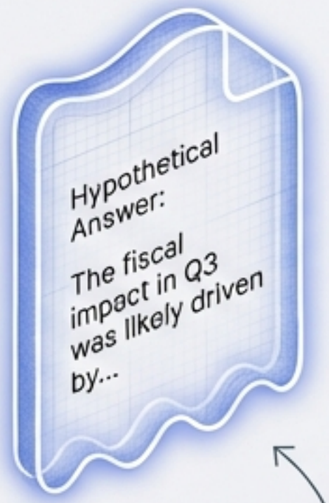
Advanced Technique: HyDE

Hypothetical Document Embeddings

User Query

`Fiscal impact of Q3?`

LLM Hallucination



System generates a fake 'perfect' answer.

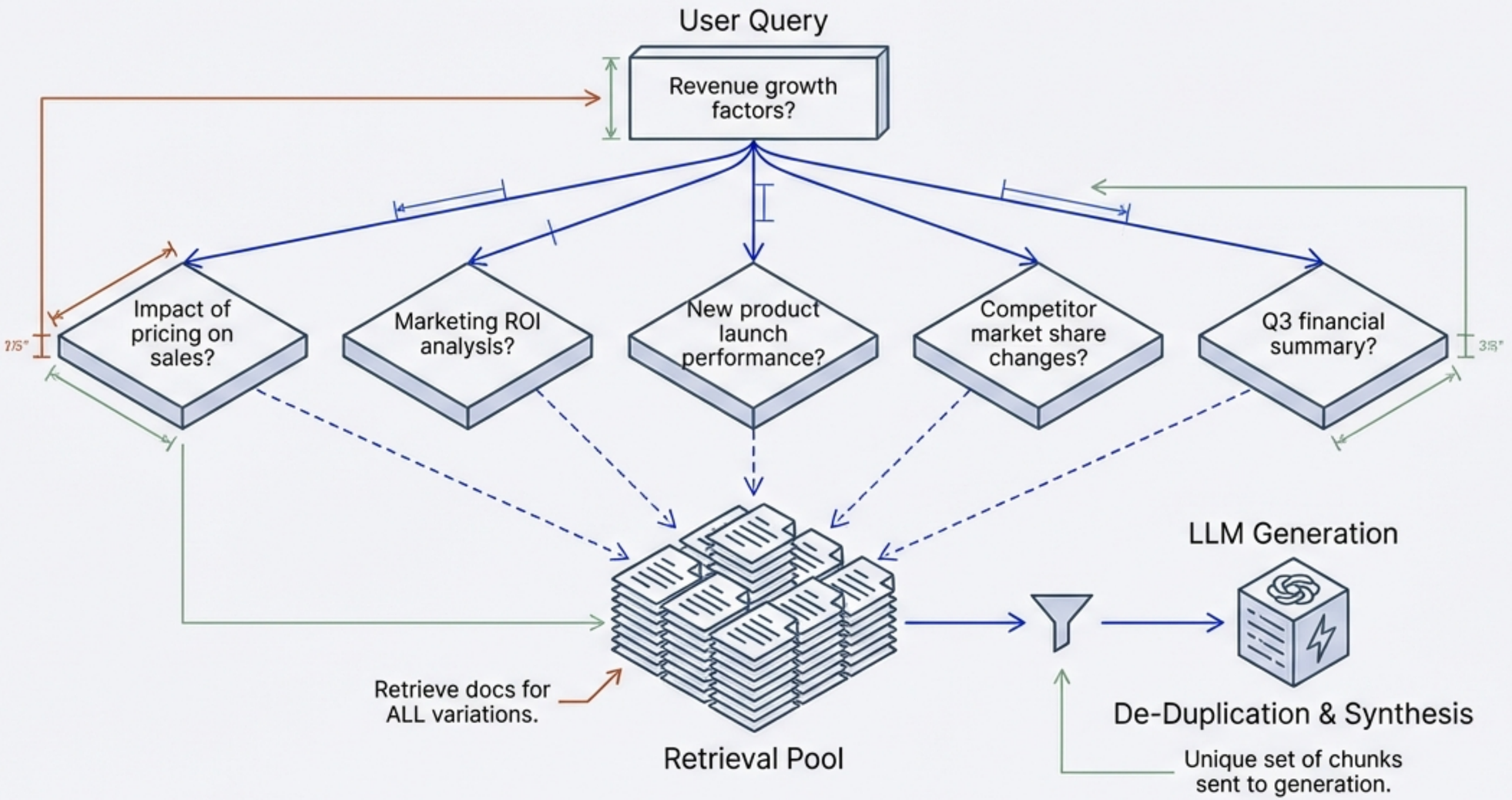
Vector Embedding

Vector Search

Search using the hypothetical answer's pattern, not the raw question.

Matches answer-to-answer patterns rather than question-to-answer.

Advanced Technique: Multi-Query Expansion



Significantly increases recall by addressing multiple potential interpretations of the user's intent.

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The RAG Technology Stack

Orchestration

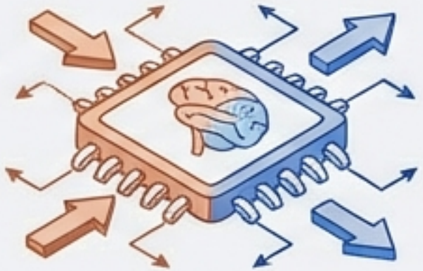
LangChain

The glue connecting the pipeline components.

LLMs (The Brain)

GPT-4 / Groq (Llama 3)

Groq for speed, GPT-4 for complex reasoning.



```
chain = (
  {"context": retriever, "question": RunnablePassthrough()}
  | prompt
  | model
  | StrOutputParser()
)
```

Vector Database (Memory)

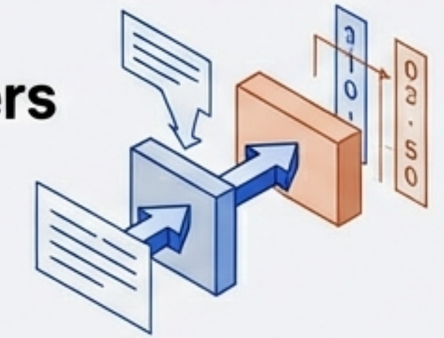
ChromaDB / FAISS

Persistent storage for embeddings.

Embeddings (The Translator)

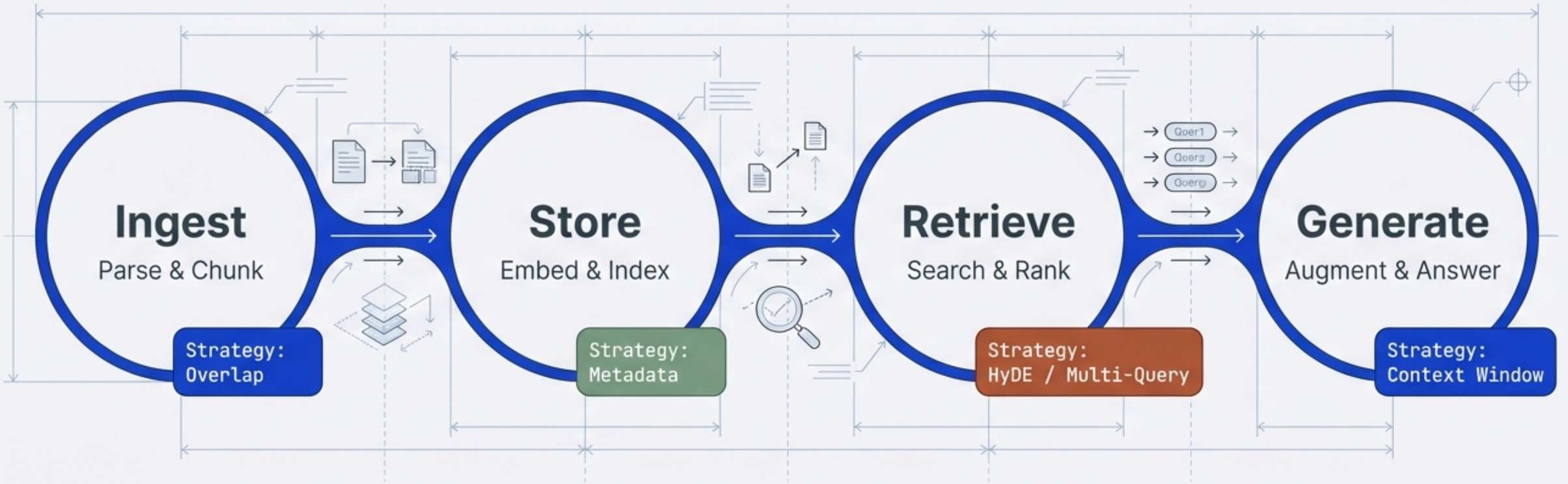
Sentence Transformers / HuggingFace

Open source models like all-MiniLM-L6-v2.



A modular and scalable architecture for building advanced Retrieval-Augmented Generation systems.

From Naive Implementation to Advanced Intelligence



RAG is not just a search engine. It is a dynamic architecture that enables AI to reason over private data without the cost of fine-tuning.