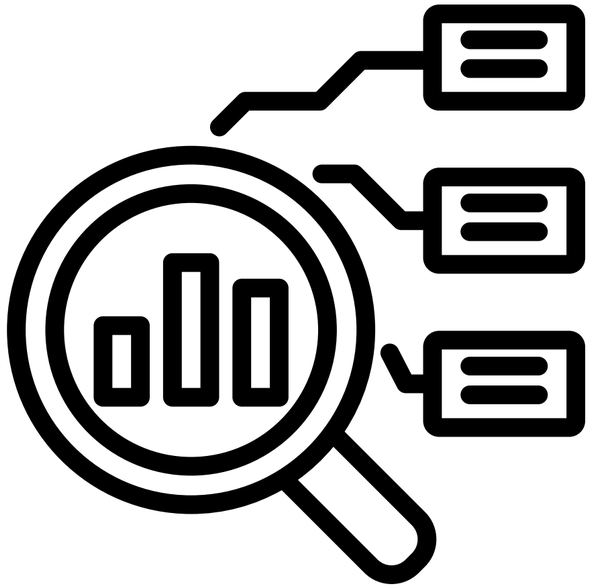
Evolution RAG Techniques 2025

By

Thanawich Juengkijthanawat (Guide)

polakorn anantapakorn (Ming)



Agenda

- **RAG-paradigm**
  - Navie RAG
  - Advanced RAG
  - Modular RAG
- **Core Retrieval Techiniques 2025**
  - **Search techniques**
    - Vector Search (Dense Retrieval)
    - Keyword Search (Sparse Retrieval)
    - Hybrid Search
  - **Retrieval-Techniques**
    - HyDE RAG
    - Apdative Retrieval
    - Long RAG
    - Graph RAG
- **Verification-Technique**
  - Corrective RAG
  - Self-Reflective RAG
- Agentic RAG
- Multimodal RAG

- **Optimization Strategies**
  - Chunking Strategies For RAG
  - Reranking and autocut
  - Retrival-Augmented + Fine-Tuning

RAG paradigm

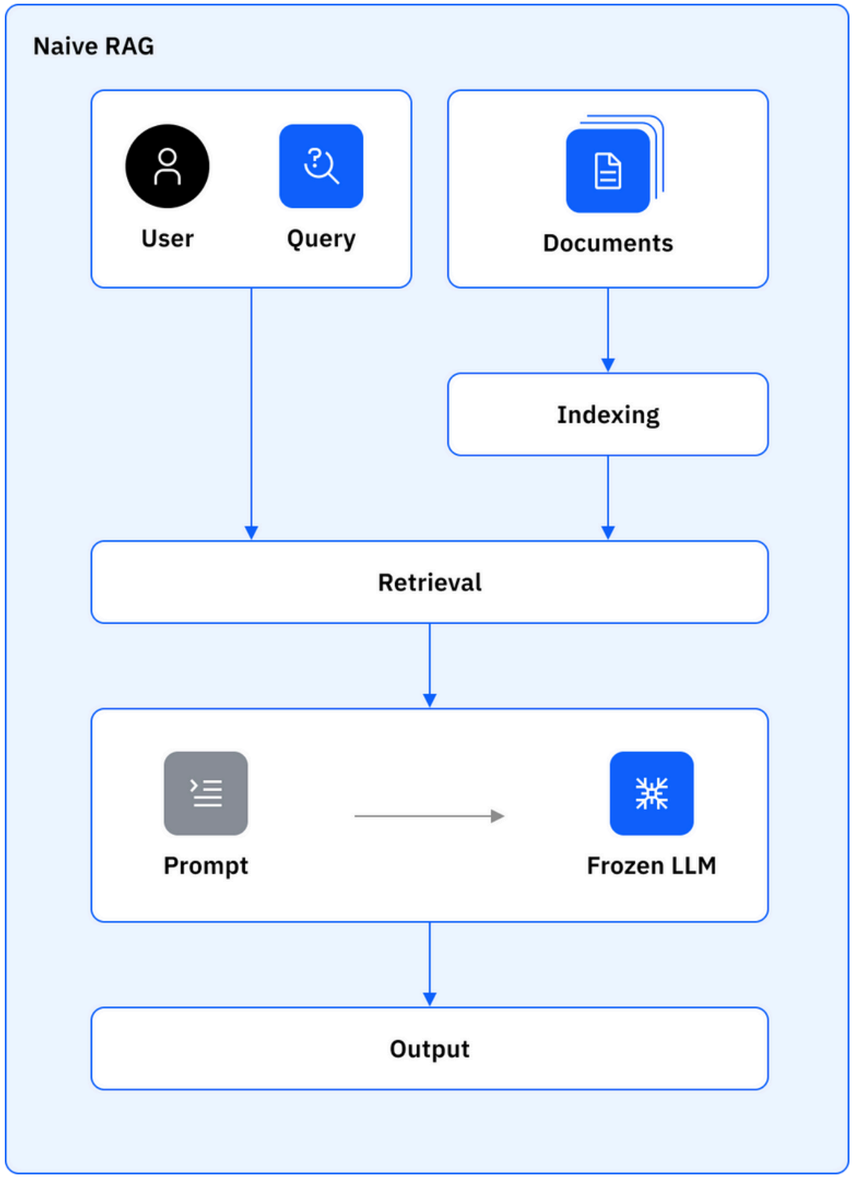
A. Naive RAG

three-step process for retrieval and content generation.

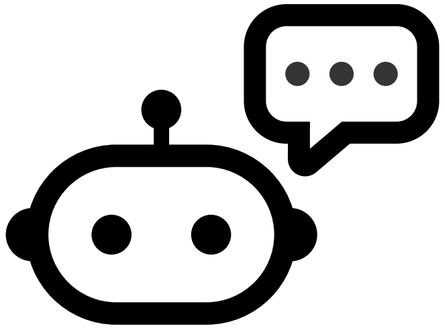
1. **Query Encoding**: **Transformed** user's query into high-Dimension **Vectors** , capturing sementic meaning of query
2. **Document Retrieval:** A similarity search is performed, though vector database retrieving N-documents
3. **Response Generation:** served context and user's query to LLM

https://www.ibm.com/think/topics/rag-techniques

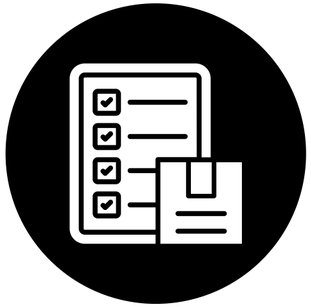
Fig illustrates the three-step process of how naive RAG works.



Applications of naive RAG



a. **Customer support chatbots**: Handling frequently asked repetitive question-answering scenarios by using LLM responses



b. **Summarization and information retrieval:** Providing a basic level of summarization by using natural language processing techniques.

c. **AI systems for enterprises**: Quickly retrieving relevant data from repositories to answer common queries.

B. Advanced RAG

the power of **better retrieval and generation by using sophisticated algorithms**

1. **Query Encoding**
2. **Document Retrieval**
3. **Reranking retrieved documents (+):** The retriever **gives a final score based on context and in relation to the query** retrieving the documents**.**
4. **Contextual fusion for generation (+):** each document is encoded differently, the decoder **fuses all encoded contexts to ensure that the generated responses** have coherence with to the encoded query.
5. **Response generation**
6. **Feedback loop (+):** various techniques like active learning, **RL** and retriever-generator cotraining to continuously enhance its performance , **explicit feedback.**

https://www.ibm.com/think/topics/rag-techniques

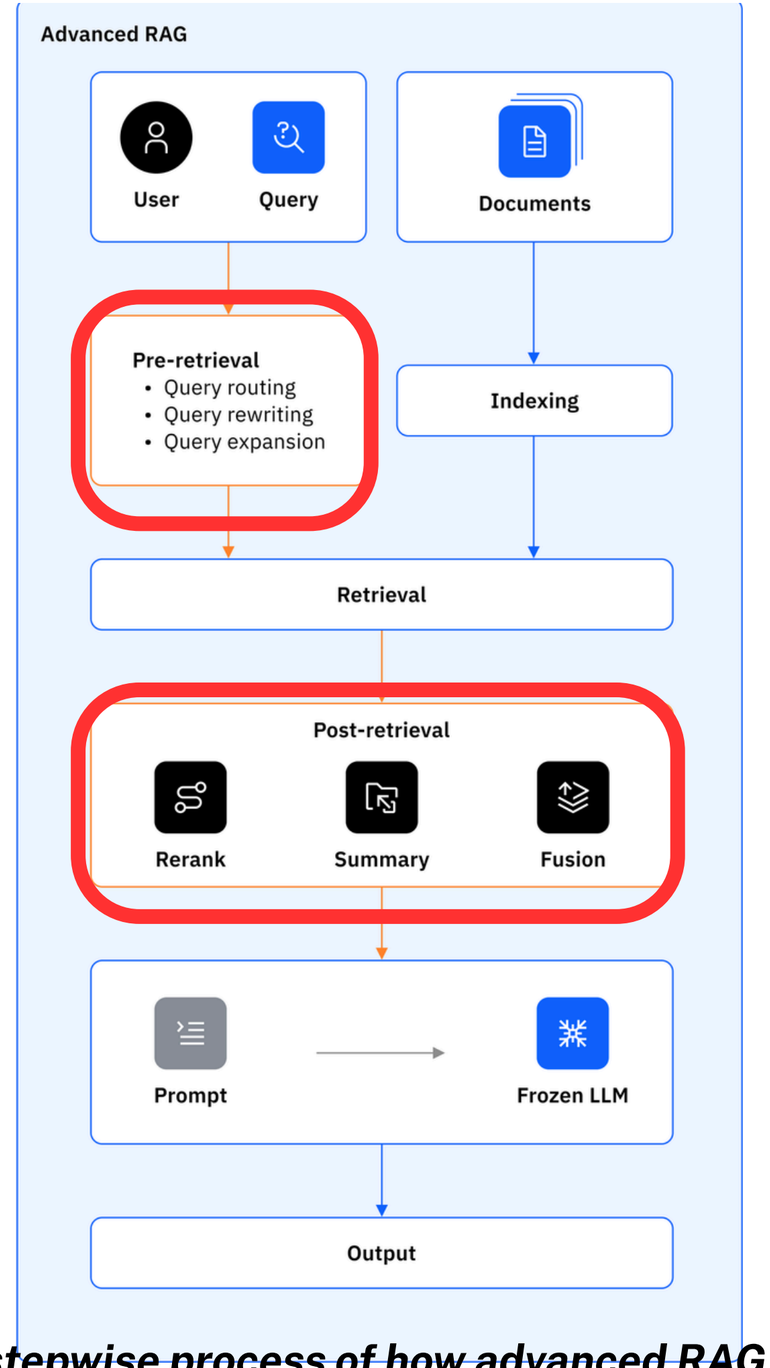
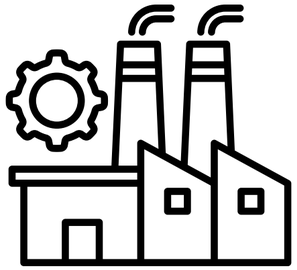


Fig illustrates the stepwise process of how advanced RAG works.

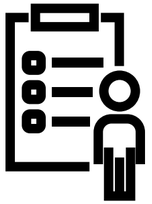
Applications of Advanced RAG



Advanced RAG is highly versatile and can be **applied across many industries**

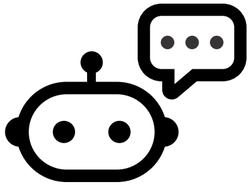
Enables real-time information retrieval with accurate, context-aware responses

Enhances personalized learning experiences



Helps **improve decision-making** by providing relevant information

Useful for customer service applications



C.Modular RAG

By **disaggregating the act of RAG into modules**, one can better adapt, debug and optimize each component independently. Now let's see how modular RAG works in real action

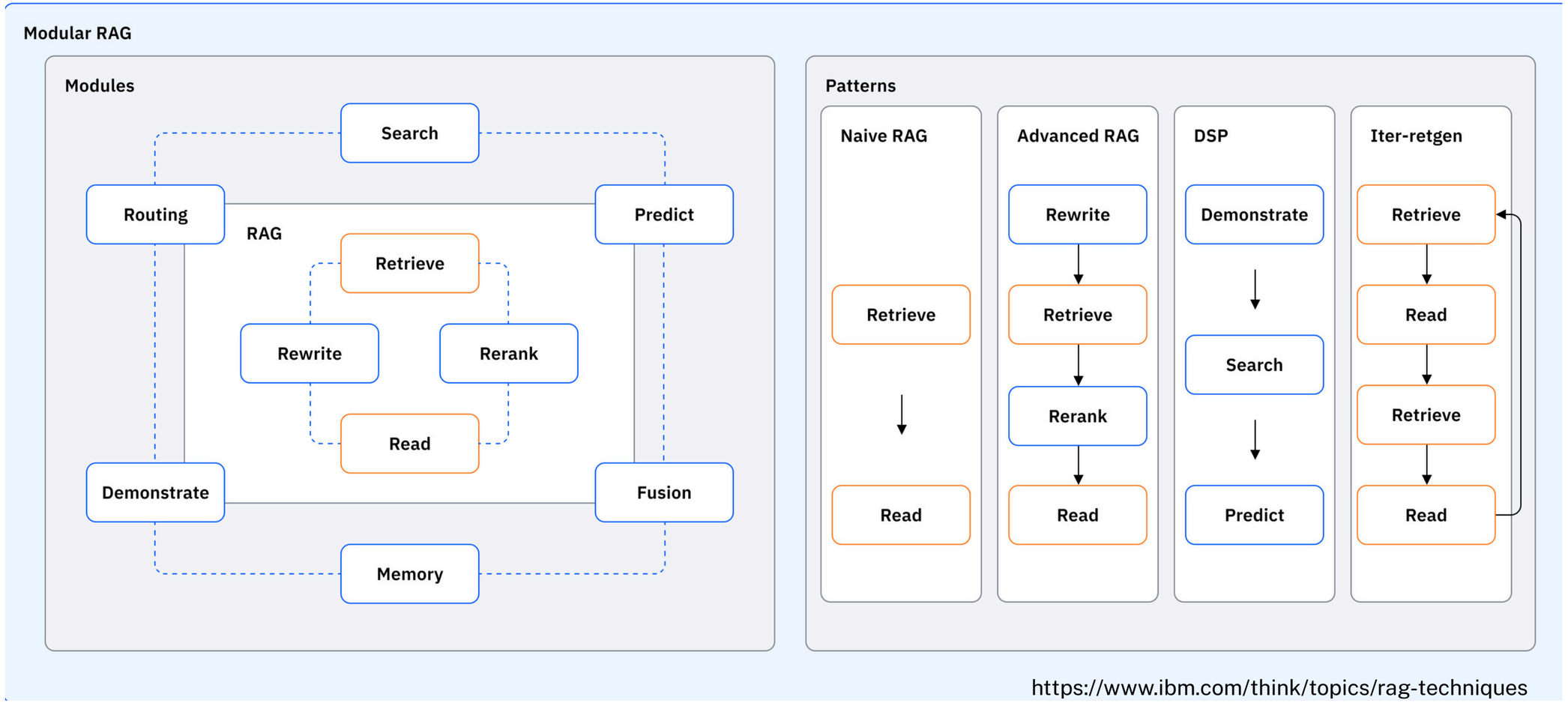


Fig illustrates the stepwise process of how modular RAG works.

Applications of Modular RAG

Modular RAG in Enterprises

1. **Customer Support Automation**: Deliver accurate, context-aware responses to customer queries.
2. **Knowledge Management**: Extract, summarize, and contextualize information from vast repositories.
3. **Content Creation:** Generate domain-specific marketing or technical content with high quality.
4. **Healthcare and Legal Industries**: Provide quick access to domain-specific knowledge, improving decision-making

https://medium.com/aingineer/a-comprehensive-guide-to-implementing-modular-rag-for-scalable-ai-systems-3fb47c46dc8e

Pros and cons of RAG paradigm

RAG Technique	Pros	Cons
Naive RAG	• **Straightforward** to implement. • Quick to set up.	• **Lacks the flexibility and scalability** required for intricate, real-world applications.
Advanced RAG	• **High Accuracy**: Uses real-time, context-specific data to minimize errors. • **Dynamic Adaptation**: Incorporates user feedback (RLHF/Active Learning). • **Domain Expertise**: Integrates specialized databases. • **Efficiency**: Optimizes context windows by fetching only pertinent data.	• **Resource Heavy**: High compute demands and significant resource needs for large knowledge bases. • **Latency**: Delays caused by both retrieval and generation steps. • **Complexity**: Hard to implement and maintain (requires fine-tuning multiple components).
Modular RAG	• **Flexibility & Customization**: Components (retrievers, rankers, generators) can be swapped or fine-tuned independently. • **Scalability**: Modules can be distributed across various resources. • **Maintainability**: Easier debugging and updates without disrupting the whole system. • **Cost-Effective**: Optimizes retrieval and minimizes LLM usage.	• **Requires framework-specific knowledge** like LangChain • **Requires careful system design** and **orchestration** • **Complexity**: Hard to implement and maintain (requires fine-tuning multiple components).

Search techniques

1. **Keyword Search (Sparse Retrieval)**
2. **Vector Search (Dense Retrieval)**
3. **Hybrid Search**

Sparse Vector Search (Keyword Search)

Keyword Search operates on the basis of **Lexical Matching** between the query and the document.

BM25 is the OG of information retrieval. It ranks documents based on term frequency, inverse document frequency (**TF-IDF**), and length normalization.

IDF (Inverse Document Frequency): How rare is this term?

- "the" appears in 99% of documents → IDF = low (not useful)
- "JWT" appears in 2% of documents → IDF = high (very useful)

TF (Term Frequency): How often does it appear in this document?

$$\text{BM25}(t,d) = \sum_{t \in q} IDF(t) \cdot \frac{f(t,d)\cdot(k_1+1)}{f(t,d)+k_1\cdot(1-b+b\cdot\frac{|d|}{\text{avgdl}})}$$

where:

- $f(t,d)$ is the frequency of t in d,
- $|d|$ is the length of document d,
- avgdl is the average document length in the collection,
- k_1 and b are hyperparameters that control the weighting.

Length Normalization : Prevent long documents from winning just by being long

Pros

- **Finds exact keywords**
- **Great for technical jargon**
- **Understands term importance**

Cons

- **Slower than dense**
- **Misses semantic relationships**
- **Struggles with synonyms**

Sparse Vector Search Use case

Best for: Specific identifiers, exact codes, or industry **jargon** where "close enough" is not good enough.

Scenario A: Law
User Query: "พ.ร.บ. คอมพิวเตอร์ มาตรา 14"

Scenario B: E-commerce / Inventory
User Query: "MBP-M3MAX-32-1TB" (Specific SKU for a MacBook)

Dense Vector Search (Semantic Understanding)

Dense Vectors **capture Meaning** excellently. They handle ambiguous or conversational queries naturally.

These vectors are stored in a Vector Database. Search is performed by calculating the distance between the query vector and document vectors using metrics like:

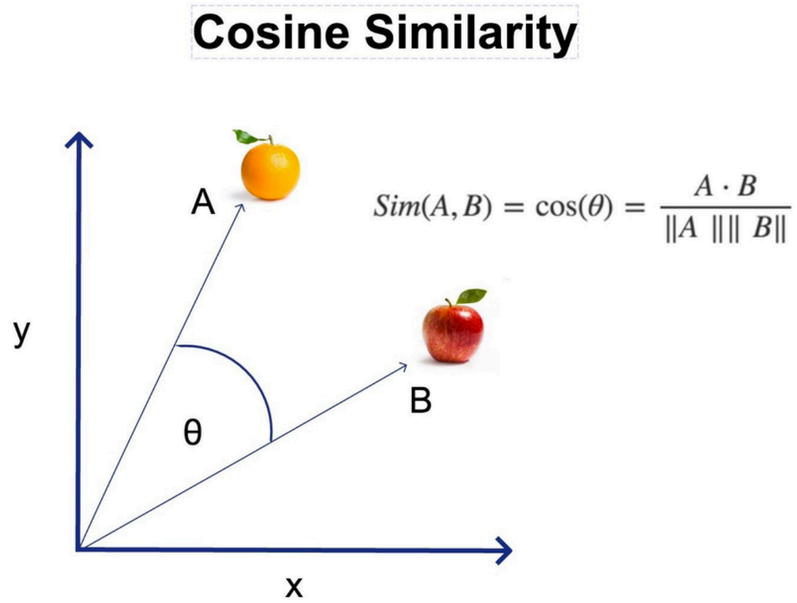
- **Cosine Similarity**: Measures the angle between vectors (most popular for semantic similarity).

Pros:

- **Fast**
- **Understands meaning**

Cons:

- **Misses exact keyword matches**
- **Struggles with technical jargon (if the embedding model wasn't trained on it)**



Dense Vector Search Use cases

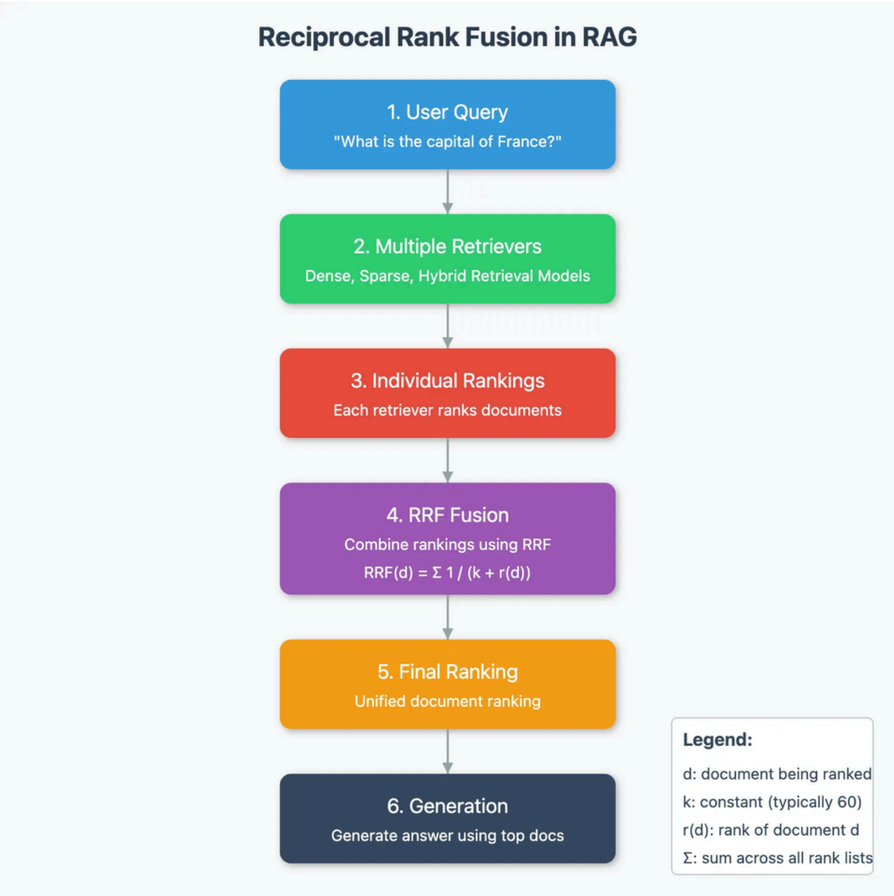
Best for: Natural language questions, describing a concept without knowing the right words, or finding synonyms.

Scenario A: Customer Service (Intent Matching)
User Query: "How do I fix my internet connection?"

Scenario B: Discovery / Exploration
User Query: "Gifts for someone who loves outdoor activity"

Hybrid Search - RRF

The combination of the two (often using **RRF - Reciprocal Rank Fusion** to merge results).



Reciprocal Rank Fusion is a rank aggregation method that combines rankings from multiple sources into a single, unified ranking.

$$RRF(d) = \Sigma(r \in R)\ 1 / (k + r(d))$$

Where:

- *d is a document*
- *R is the set of rankers (retrievers)*
- *k is a constant (typically 60)*
- *r(d) is the rank of document d in ranker r*

https://medium.com/@devalshah1619/mathematical-intuition-behind-reciprocal-rank-fusion-rrf-explained-in-2-mins-002df0cc5e2a

Hybrid Search - RRF Calculation example

Result from both Search

List A (Sparse): [Doc1, Doc2, Doc3]

List B (Dense): [Doc2, Doc4, Doc1]

Apply RRF formula

Doc1 = (1/60+1) + (1/60 + 3) = 0.016 + 0.015 = 0.031 (2nd)

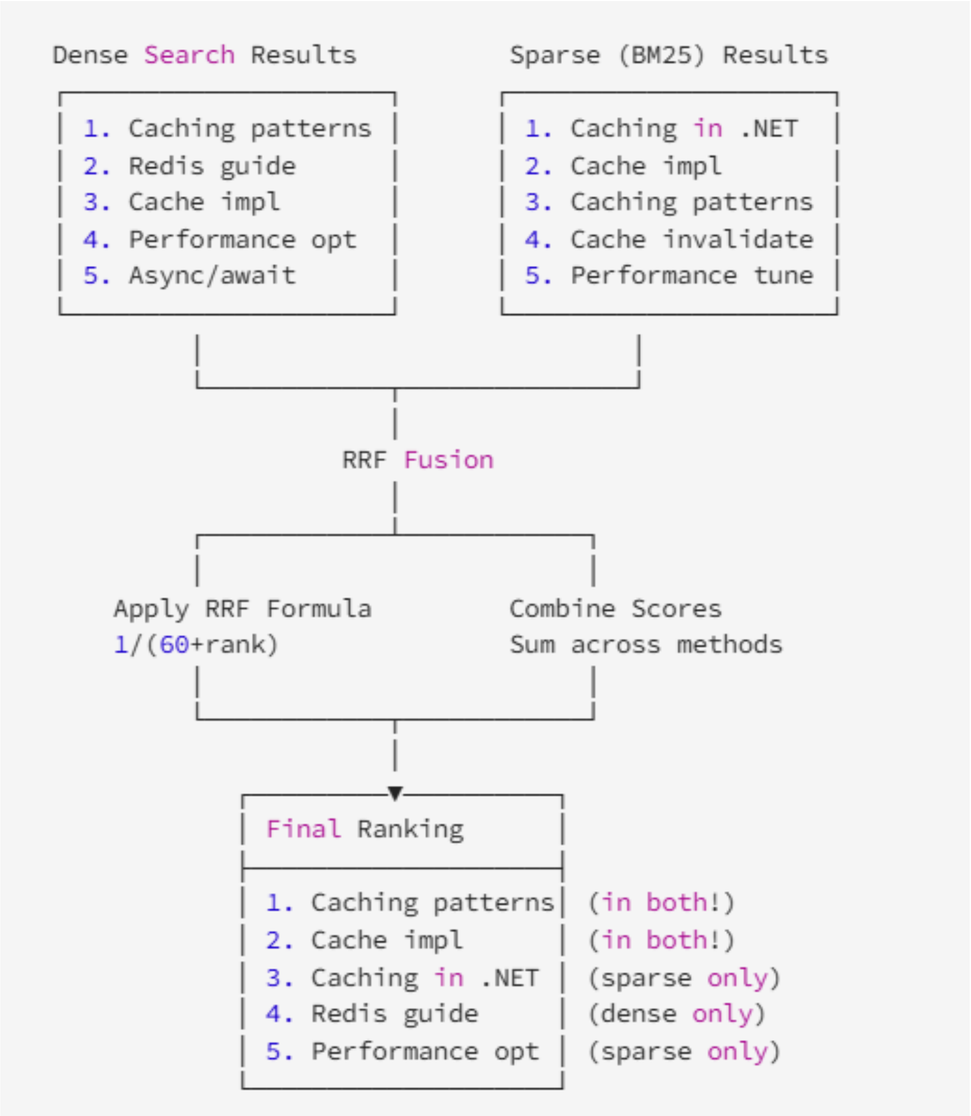
Doc2 = (1/60+2) + (1/60+1) = 0.016 + 0.016 = 0.032 (1st)

Doc3 = (1/60+3) = 0.015 (4nd)

Doc4 = (1/60+2) = 0.016 (3rd)

RRF final ranking

doc = [Doc2, Doc1, Doc4, Doc3]



https://medium.com/@devalshah1619/mathematical-intuition-behind-reciprocal-rank-fusion-rrf-explained-in-2-mins-002df0cc5e2a

Hybrid Search Use case

Best for: Complex queries that contain both specific constraints (names, places, codes) and general concepts.

Scenario A: Real Estate
User Query: "Quiet 3-bedroom home in Bangkok"

Scenario B: Shopping
User Query: "Natural fragance without aluminum"

Search Techniques Performance Comparison

Technique	Latency	NDCG@10	MRR	Precision@10	Recall@10	Improvement	Best For
Dense Only	45ms	0.72	0.68	0.72	0.65	Baseline	Semantic queries, speed critical
Sparse (BM25)	120ms	0.58	0.55	0.58	0.52	-19% vs Dense	Keyword queries, technical terms
Hybrid (RRF)	165ms	0.85	0.82	0.85	0.78	**+18% vs Dense**	Mixed queries, best balance
Hybrid + HyDE	450ms	0.91	0.87	0.89	0.84	**+26% vs Dense**	Semantic + vocab mismatch

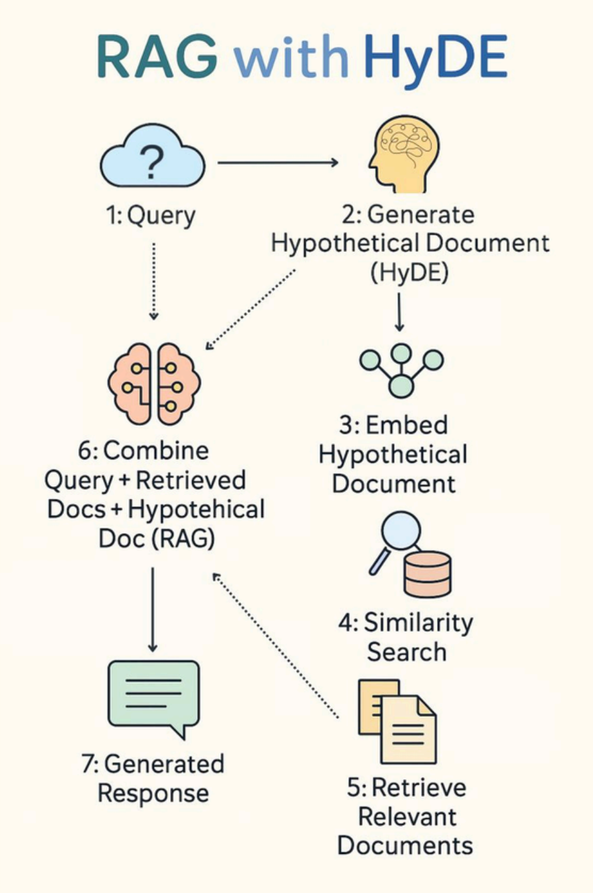
Hybrid is the answer: For 95% of use cases, hybrid RRF is the right choice

Retrieval Techniques

1. **HyDE RAG**
2. **Adaptive Retrieval**
3. **Long RAG**
4. **Graph RAG**

HyDE RAG (Hypothetical , retrieve+)

HyDE **generates synthetic documents** that hypothesize what a relevant answer might look like. This gives the system a richer context, even when the user's input is vague.



https://www.linkedin.com/posts/rohitsainice_ai-hyde-rag-activity-7314225455035793408-VOal/

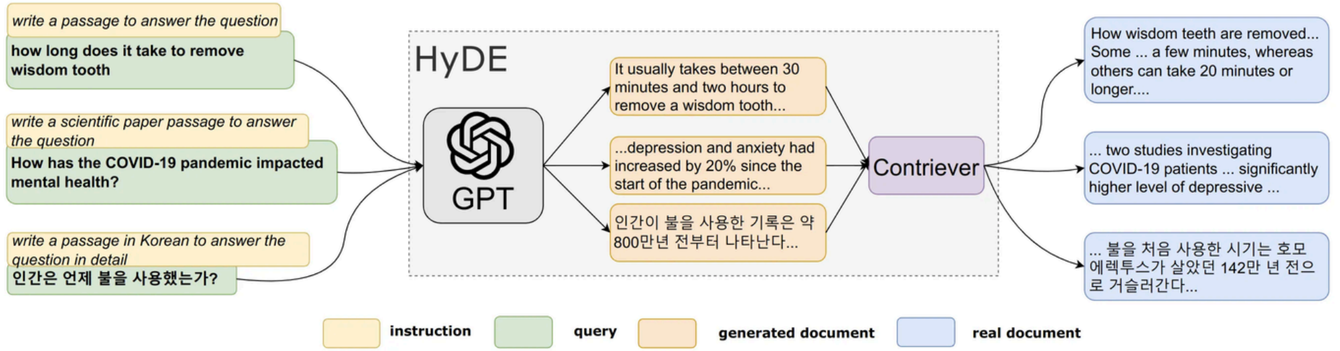


Figure 1: An illustration of the HyDE model. Documents snippets are shown. HyDE serves all types of queries without changing the underlying GPT-3 and Contriever/mContriever models.

https://medium.aiplanet.com/advanced-rag-improving-retrieval-using-hypothetical-document-embeddings-hyde-1421a8ec075a

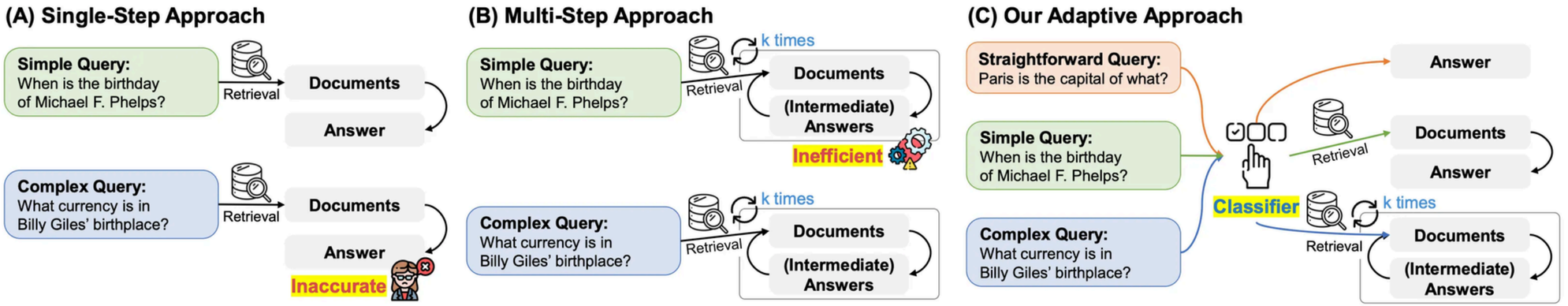
Best Use Case: HyDE is ideal for Technical Support or Research applications where accuracy is more important than speed, and where **user queries are often short or poorly phrased**.

Challenges

- **Risk of Hallucination** - from Inaccurate synthetic documents
- high-quality hypothetical documents **requires advanced models and infrastructure**

Adaptive Retrieval (routing,)

Adaptive RAG **decides when and how to retrieve based on the complexity of the question.** Unlike standard RAG, which blindly retrieves documents for every query.



Pros:

- **Cost Efficiency**
- **Optimized Latency**

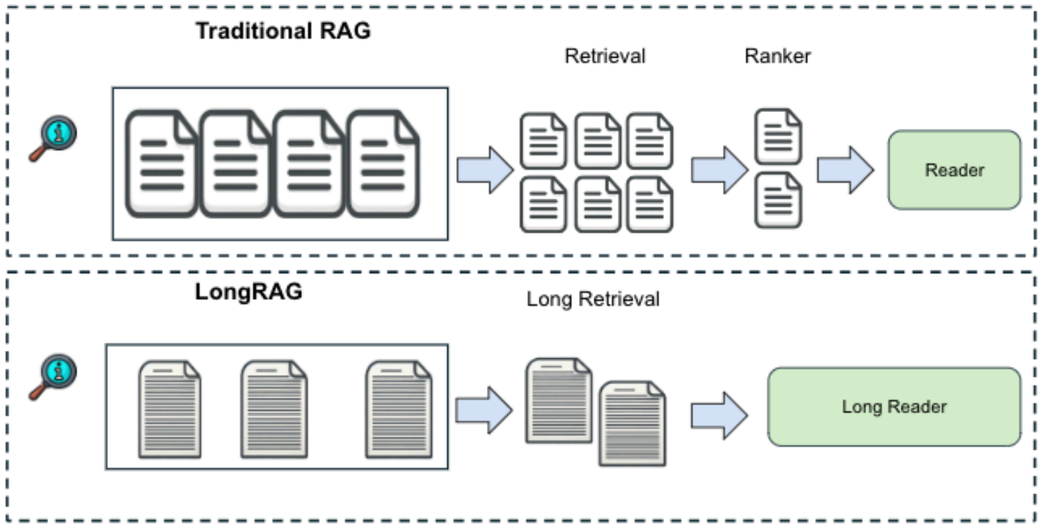
Cons:

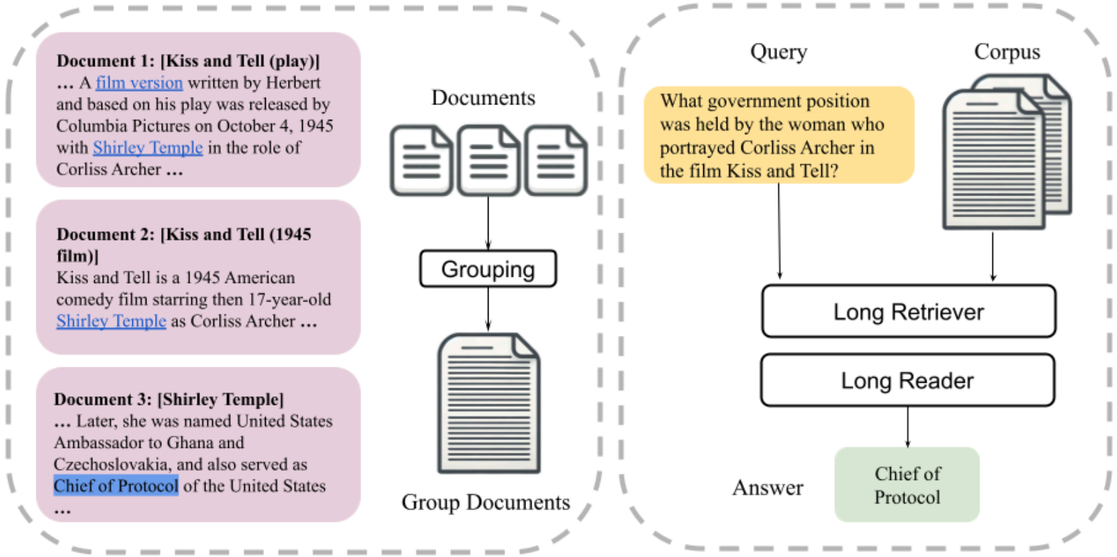
- **Classifier Bottleneck**

https://www.meilisearch.com/blog/adaptive-rag

Long RAG (context scaling)

LongRAG operates on **long retrieval units** (30x longer). **Retriever** has a much less workload, which significantly boosts the recall score. LongRAG fully exploits the ability of **long-context language models (reader)** to achieve strong performance.





Pros:

- **Improvement in Retrieval (Higher Recall)**
- **Reduced Information Fragmentation**

Cons:

- **Higher Latency (Slower Speed)**
- **LLM api Cost**

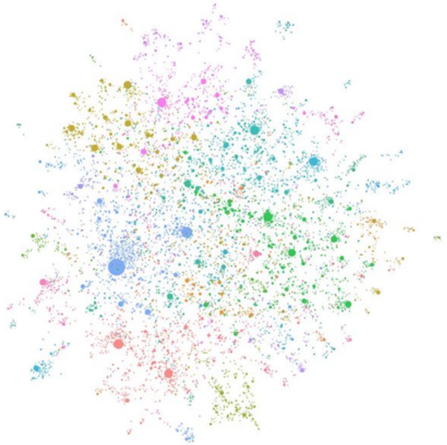
https://tiger-ai-lab.github.io/LongRAG/

Graph RAG (relation)

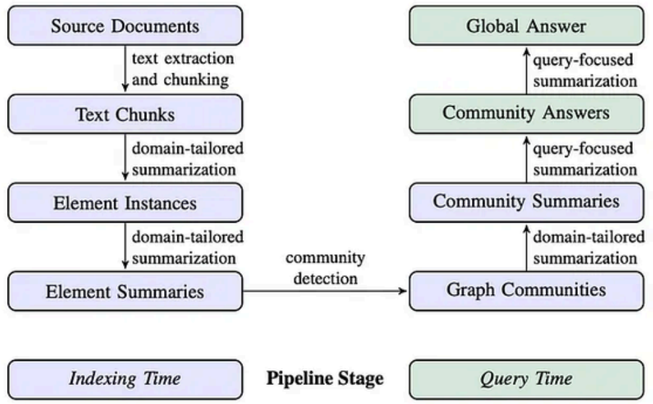
GraphRAG enhances RAG by incorporating **knowledge graphs (KGs)**. Knowledge graphs are data structures that **store and link related or unrelated data** based on their **relationships**.

Phase 1: Indexing

- **Text Unit Segmentation:** Dividing the raw input corpus into smaller, manageable pieces called **Chunks** (Text Units) to ensure detailed analysis.
- **Entity & Relationship Extraction:** Using an LLM to identify and extract **Entities** (people, places, organizations) and their Relationships from the text units to build the initial **knowledge graph**.
- **Hierarchical Clustering:** Utilizing techniques like the **Leiden Algorithm** to group related entities into "**Communities**" at different hierarchical levels.
- **Community Summary Generation:** Generating **summaries for each community** to provide a high-level overview of the information within that specific cluster.



An LLM-generated knowledge graph built using GPT-4 Turbo.



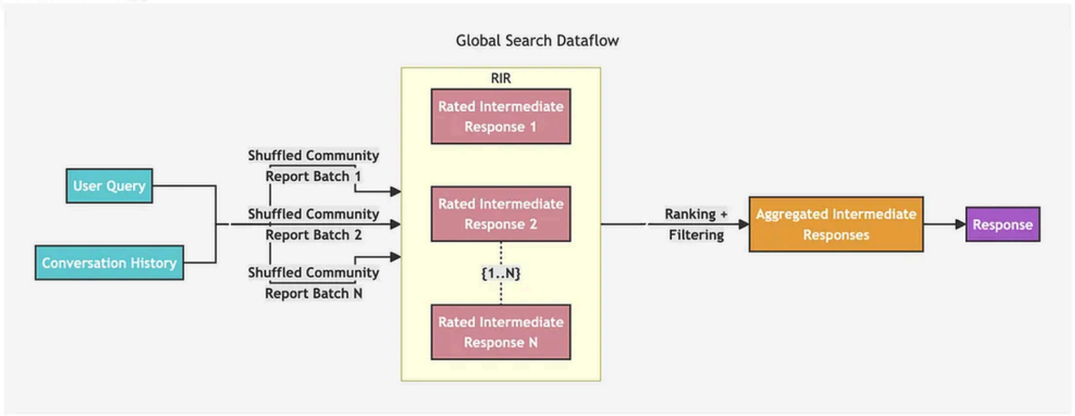
https://medium.com/@zilliz_learn/graphrag-explained-enhancing-rag-with-knowledge-graphs-3312065f99e1

Graph RAG (relation)

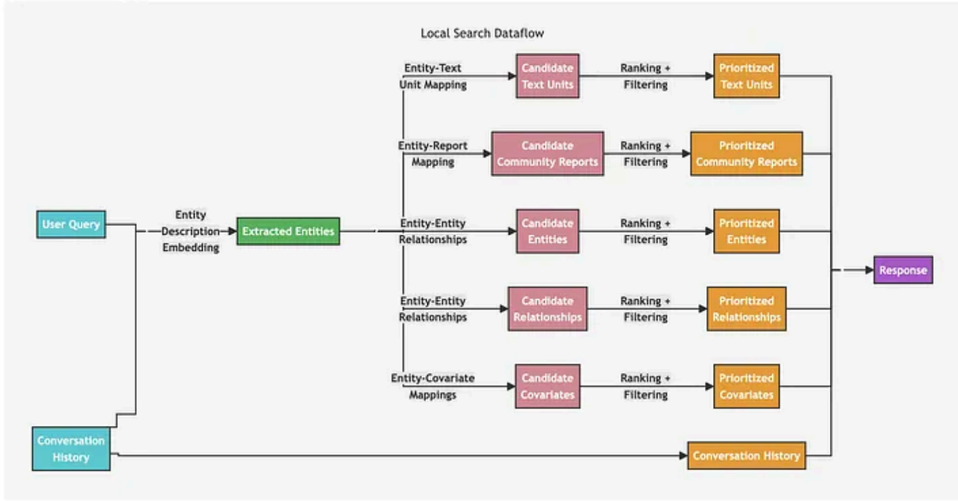
Phase 2: Querying

GraphRAG has **two** different querying workflows tailored for different queries.

Methodology



Methodology



Global Search for reasoning about holistic questions related to the whole data corpus by leveraging **the community summaries.**

Local Search for reasoning about specific **entities** by fanning out to their **neighbors** and **associated concepts.**

Pros

- **Comprehensiveness:** Provides more complete answers by **identifying hidden relationships** that standard RAG might miss.
- **Diversity:** Offers a wider range of perspectives and insights by analyzing different "**Communities**" of data.
- **Contextual Understanding:** Better at **handling complex**, multi-hop reasoning than traditional Vector-only retrieval methods.

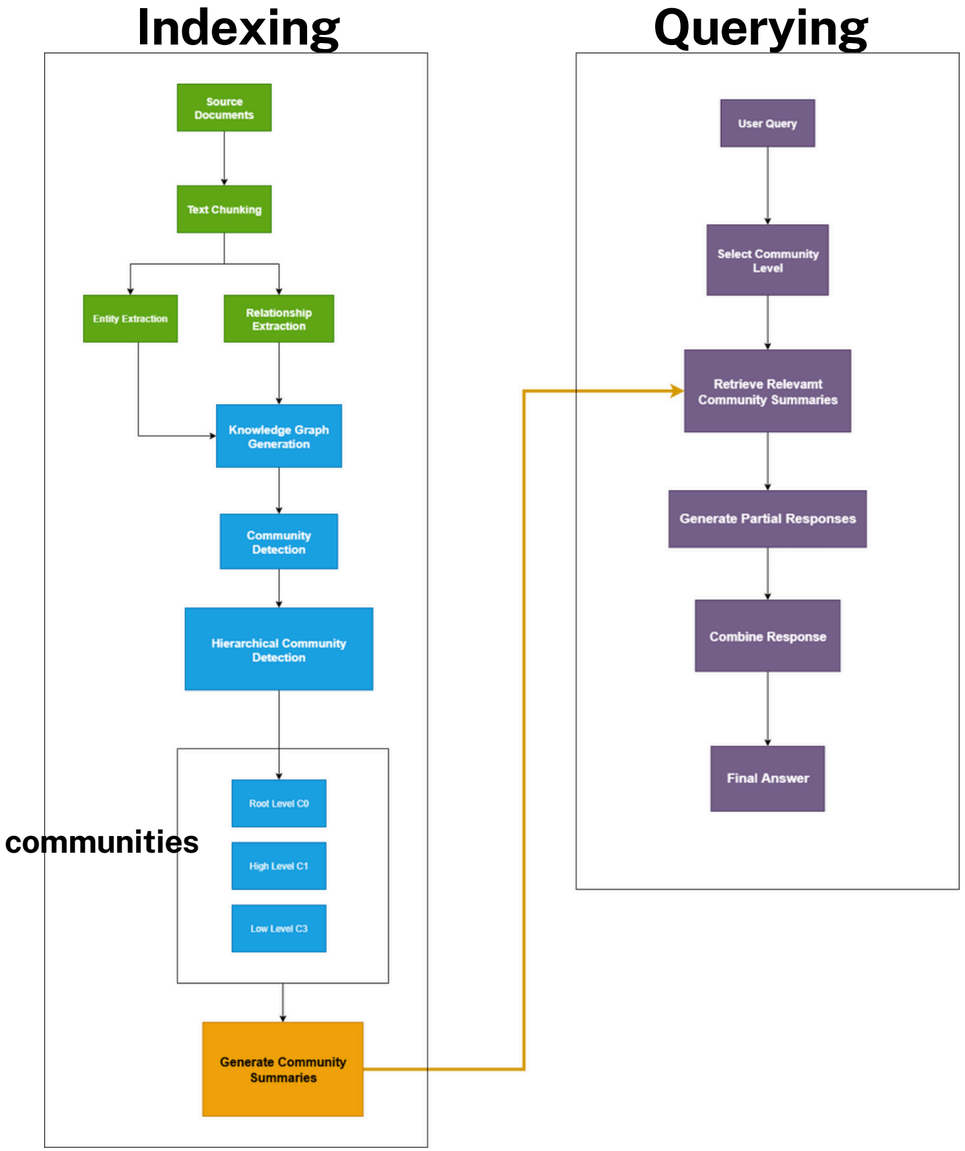
Cons

- **Cost**
- **Computational Power**

https://medium.com/@zilliz_learn/graphrag-explained-enhancing-rag-with-knowledge-graphs-3312065f99e1

Graph RAG - experiment

Experimented with example on **https://microsoft.github.io/graphrag**

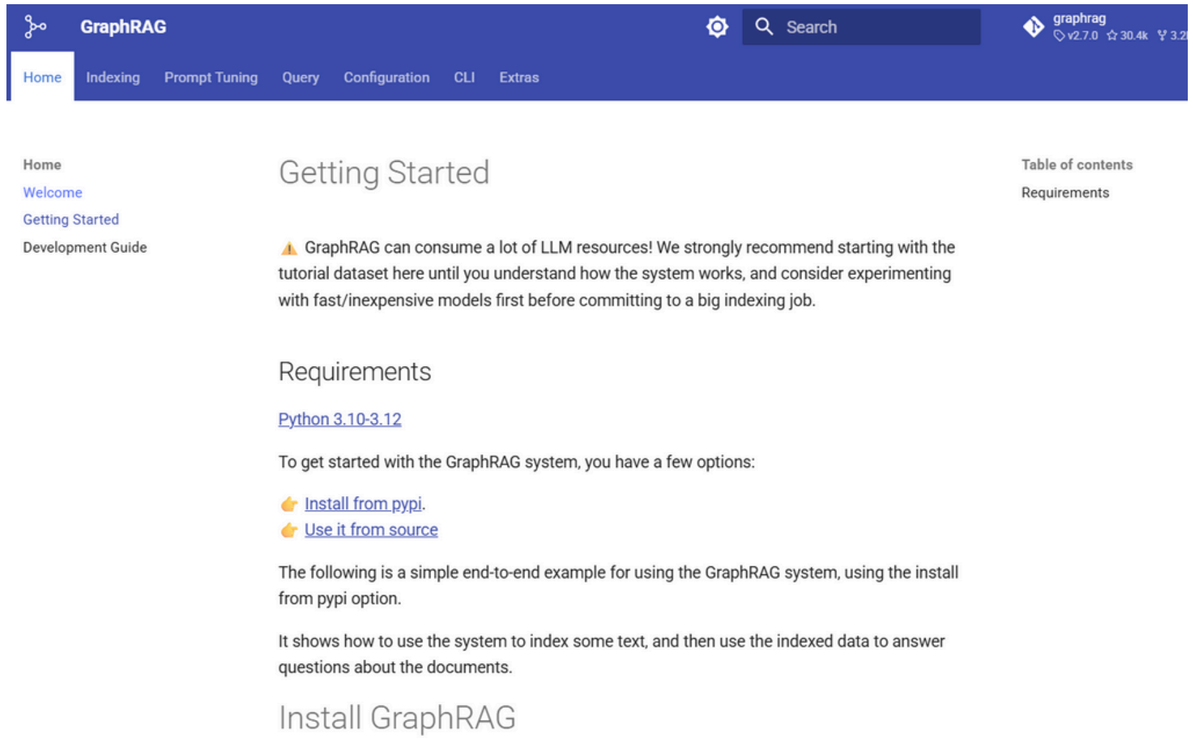


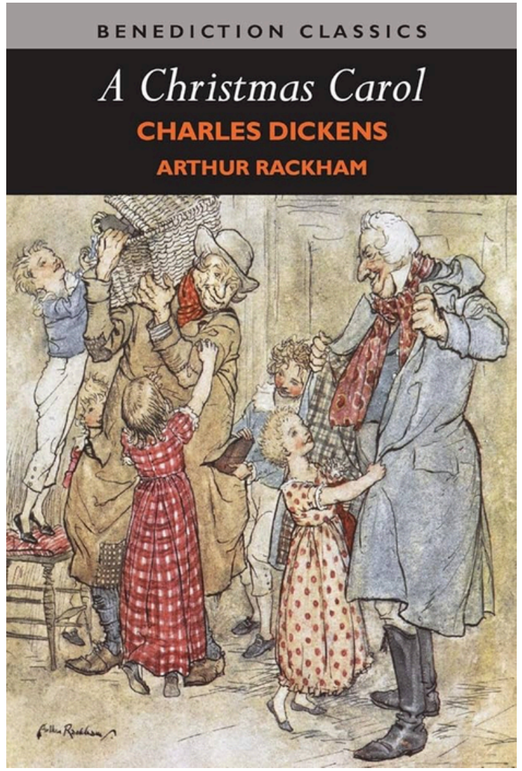
1. **Build knowledge graph and detect communities**
2. **Generate hierachical community summaries**
3. **Use summaries to answer queries**

Graph RAG - experiment

Experimented with example on **https://microsoft.github.io/graphrag**

Input (.txt): A Christmas Carol by Charles Dickens, Arthur Rackham

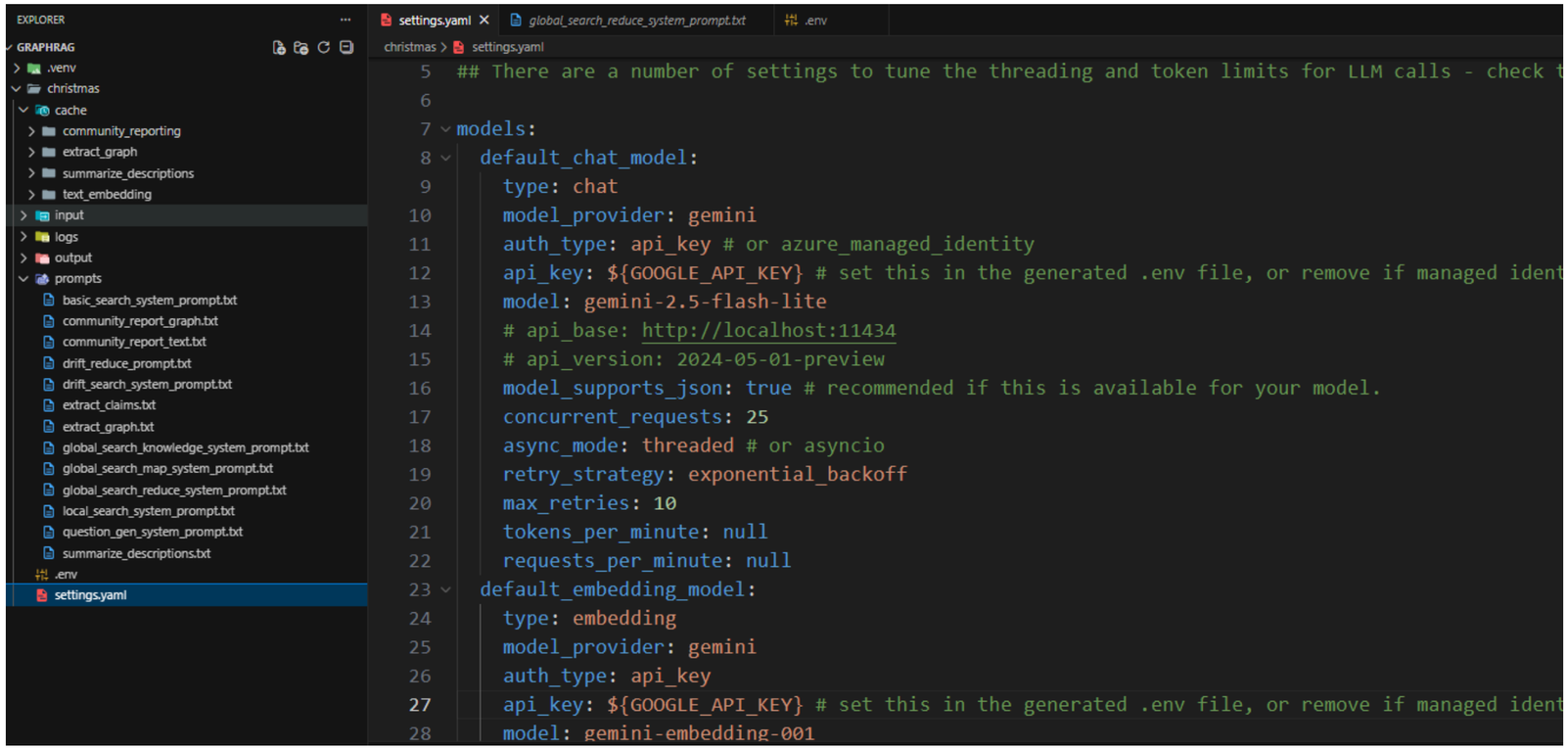




Graph RAG - experiment

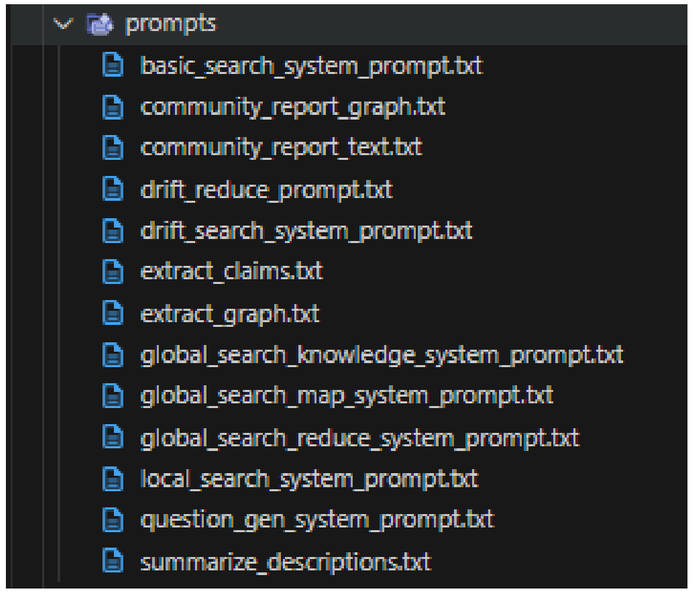
Model Configuration

1. **Chat model:** gemini-2.5-flash-lite
2. **Embedding model:** gemini-embedding-001



Graph RAG - experiment

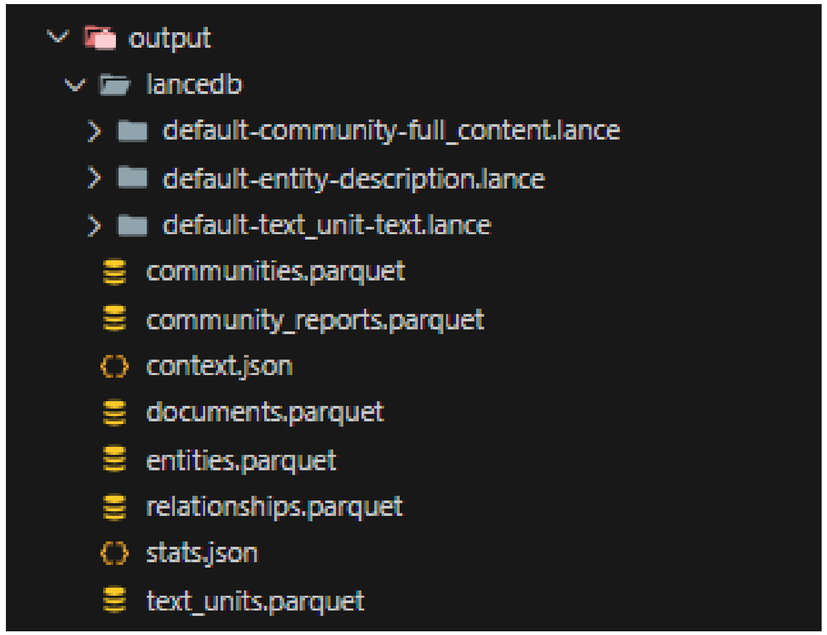
Prompts



Stage	Task	Prompt File Path
Indexing	Graph Extraction	prompts/extract_graph.txt
Indexing	Description Summarization	prompts/summarize_descriptions.txt
Indexing	Claim Extraction	prompts/extract_claims.txt
Indexing	Community Report (Graph)	prompts/community_report_graph.txt
Indexing	Community Report (Text)	prompts/community_report_text.txt
Search	Local Search System	prompts/local_search_system_prompt.txt
Search	Global Search (Map)	prompts/global_search_map_system_prompt.txt
Search	Global Search (Reduce)	prompts/global_search_reduce_system_prompt.txt
Search	Global Search (Knowledge)	prompts/global_search_knowledge_system_prompt.txt
Search	Drift Search System	prompts/drift_search_system_prompt.txt
Search	Basic Search System	prompts/basic_search_system_prompt.txt

Graph RAG - experiment

Indexing



.parquet files

	id	human_readable_id	title	type	description	text_unit_ids	frequency	degree	x	y
0	a543927c-b347-4cfa-a492-89b7fe79aa64	0	PROJECT GUTENBERG	ORGANIZATION	Project Gutenberg is a renowned initiative ded...	[336671e337e5f4539069473e8f8691b3ed696331aabe6...	4	8	0.0	0.0
1	5da89c14-9d36-4cf2-a86f-666e8973a640	1	CHARLES DICKENS	PERSON	Charles Dickens is the author of "A Christmas ...	[336671e337e5f4539069473e8f8691b3ed696331aabe6...	1	2	0.0	0.0
2	5190314f-bdde-4ba3-b2e8-b5866e398f85	2	ARTHUR RACKHAM	PERSON	Arthur Rackham is the illustrator of "A Christ...	[336671e337e5f4539069473e8f8691b3ed696331aabe6...	1	1	0.0	0.0
3	fd2d896a-9cc1-4453-8ebd-5efcb9762f8b	3	J. B. LIPPINCOTT COMPANY	ORGANIZATION	J. B. Lippincott Company is the original publi...	[336671e337e5f4539069473e8f8691b3ed696331aabe6...	1	6	0.0	0.0
4	7d999daf-f408-40ab-b31c-5a5465208277	4	SUZANNE SHELL	PERSON	Suzanne Shell was a producer of the Project Gu...	[336671e337e5f4539069473e8f8691b3ed696331aabe6...	1	1	0.0	0.0

entities.parquet

	id	human_readable_id	source	target	description	weight	combined_degree	text_unit_ids
0	069d621f-bcfa-4b38-a44b-165b45dfc017	0	PROJECT GUTENBERG	SUZANNE SHELL	Suzanne Shell produced the Project Gutenberg e...	7.0	9	[336671e337e5f4539069473e8f8691b3ed696331aabe6...
1	eab1a0f6-ab48-46a3-86f3-de2ca816126b	1	PROJECT GUTENBERG	JANET BLENKINSHIP	Janet Blenkinship produced the Project Gutenbe...	7.0	9	[336671e337e5f4539069473e8f8691b3ed696331aabe6...
2	7298b9d2-c51e-41ea-b4fa-235831d5215c	2	PROJECT GUTENBERG	ONLINE DISTRIBUTED PROOFREADING TEAM	The Online Distributed Proofreading Team assis...	7.0	9	[336671e337e5f4539069473e8f8691b3ed696331aabe6...
3	c4946d7d-b79b-4795-9719-1818eeae709b	3	PROJECT GUTENBERG	A CHRISTMAS CAROL (EBOOK #24022)	Project Gutenberg released the eBook #24022 of...	8.0	9	[336671e337e5f4539069473e8f8691b3ed696331aabe6...
4	83b010e1-a1cf-4185-b049-d7412917461b	4	PROJECT GUTENBERG	2007	The Project Gutenberg eBook #24022 of "A Chris...	8.0	9	[336671e337e5f4539069473e8f8691b3ed696331aabe6...

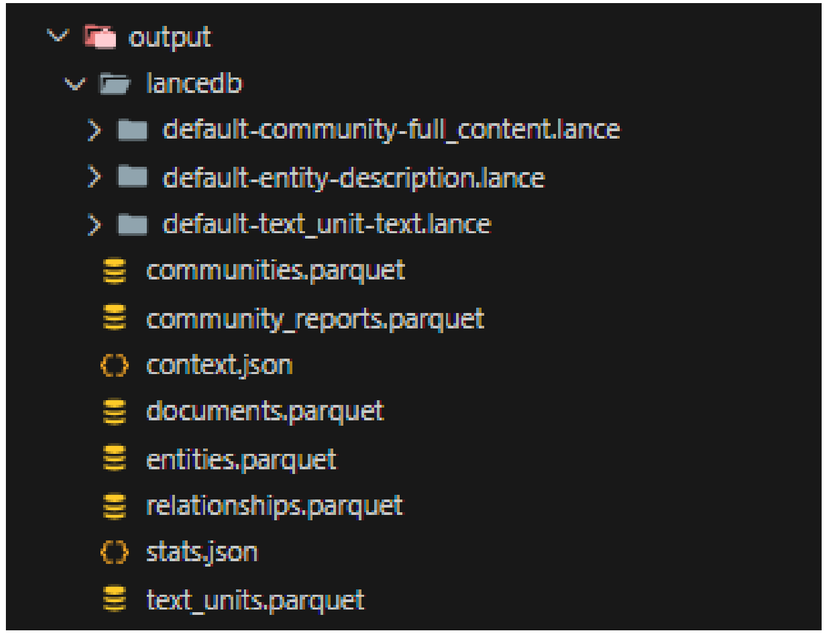
relationships.parquet

	id	human_readable_id	community	level	parent	children	title	summary	full_content	rank	rating_explanation	findings	full_content_json	period	size
0	ace58da9a9e44a5e982f357691bdab92	23	23	2	11	[]	Ebenezer Scrooge and His Transformative Christ...	This community centers around Ebenezer Scrooge...	# Ebenezer Scrooge and His Transformative Chri...	7.5	The impact severity rating is high due to the ...	[{'explanation': 'Ebenezer Scrooge is the pivo...	{\n "title": "Ebenezer Scrooge and His Tran...	2026-01-19	43
1	0ab48d33f54e481c8beca7384f7b6722	24	24	2	11	[]	Obscure Part of Town and Associated Shop	The community is centered around a specific lo...	# Obscure Part of Town and Associated Shop\n\n...	2.0	The impact severity rating is low due to the i...	[{'explanation': 'The 'Obscure Part of Town' i...	{\n "title": "Obscure Part of Town and Asso...	2026-01-19	2
2	e791a982c21d48b39a8d5c5ac2180a9e	25	25	2	20	[]	The Cratchit Family and Christmas Dinner	The community is centered around the Cratchit ...	# The Cratchit Family and Christmas Dinner\n\n...	3.0	The impact severity rating is low, reflecting ...	[{'explanation': 'Mrs. Cratchit is depicted as...	{\n "title": "The Cratchit Family and Chris...	2026-01-19	5
3	6930bed7d7734e0b94af0a6bdd944d2e	26	26	2	20	[]	Bob Cratchit and His Family on Christmas Day	This community centers around Bob Cratchit, hi...	# Bob Cratchit and His Family on Christmas Day...	6.5	The impact severity rating is moderate, reflec...	[{'explanation': 'Bob Cratchit is depicted as ...	{\n "title": "Bob Cratchit and His Family o...	2026-01-19	7
4	0e58707941394379b26dca4552ea8a7f	27	27	2	22	[]	The Cratchit Family and Tiny Tim's Fate	This community centers around the Cratchit fam...	# The Cratchit Family and Tiny Tim's Fate\n\nT...	7.5	The impact severity rating is high due to the ...	[{'explanation': 'Bob Cratchit is depicted as ...	{\n "title": "The Cratchit Family and Tiny ...	2026-01-19	4

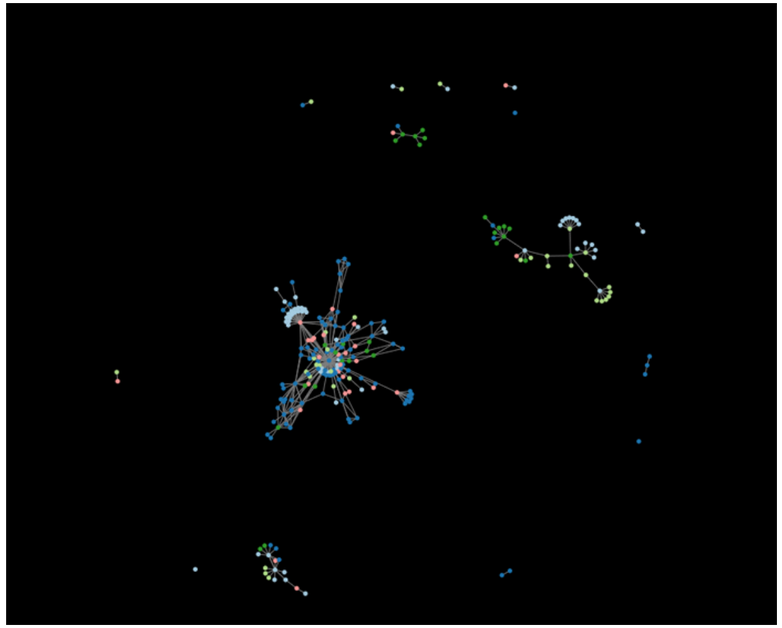
communities_reports.parquet

Graph RAG - experiment

Visualize indexing Graph on https://noworneverev.github.io/graphrag-visualizer/



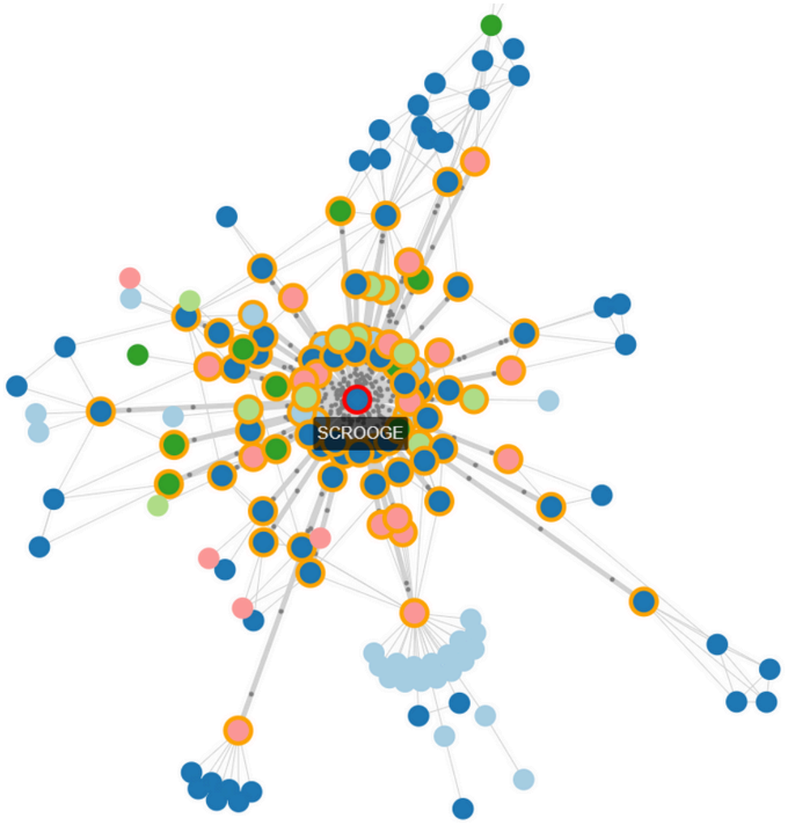
.parquet files



Graph visualization

Graph RAG - experiment

Visualize indexing Graph on https://noworneverev.github.io/graphrag-visualizer/



Node Details: SCROOGE

Node Information

ID: 4d996d08-66aa-4826-97f1-10768c3909ea
Title: SCROOGE
Type: PERSON
Community Report Title: SCROOGE
Description: Scrooge is the central protagonist of the story, a wealthy, stingy, and unfeeling businessman initially described as a "covetous old sinner," "hard and sharp as flint," and a "solitary old sinner." He operates a counting-house and is known for his ill-will and stinginess, particularly around Christmas, even icing his office in hot weather and refusing to thaw it at Christmas. Scrooge dislikes Christmas and is perceived by others as a "lunatic," "cold," and the "Ogre of the family" or "Scrooge the Baleful." He is the surviving partner of Scrooge and Marley and the uncle of Fred, who discusses him with his niece. Scrooge initially refuses to donate to the poor, believing in decreasing the surplus population and stating that it is not his business to interfere with others' affairs. However, Scrooge undergoes a profound transformation on Christmas Day. He is visited by the ghost of his deceased partner, Jacob Marley, and subsequently by three spirits: the Ghost of Christmas Past, the Ghost of Christmas Present, and the Ghost of Christmas Yet to Come. These spirits show Scrooge visions of his past Christmases, his present circumstances, and potential futures, including his own grave. Through these supernatural encounters, Scrooge is encouraged to change his ways and learns valuable lessons about life, poverty, wealth, and the emotional impact of death. He observes scenes and reflects on his life, his former self, and the choices that led him to his current state of avarice. He becomes concerned about poverty and wealth, and questions the spirits' motives. By the end of his visions, Scrooge is horrified by the potential consequences of his actions and fears his own life may end up similarly. This leads to a significant change in his demeanor; he becomes generous, kind, and a good friend, master, and man. He improves his ways, embraces Christmas, and becomes the "Founder of the Feast." He is also the employer of Bob Cratchit and shows concern for Tiny Tim's future. Scrooge is described as a man who is not easily frightened and likes darkness, but his experiences with the spirits ultimately lead him to a more compassionate and benevolent existence.
Human Readable ID: 45

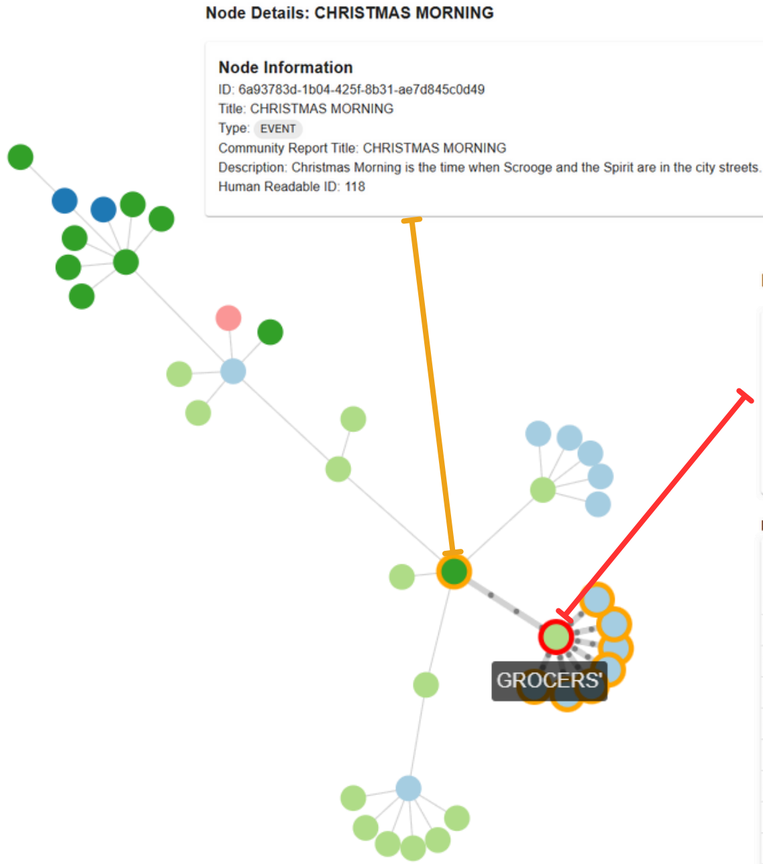
Linked Nodes

id	human_readable_id	title	type	description
aaa4e88f-ef4c-4320-aef0-f8cdb9f37231	11	FRED	PERSON	Fred is Scrooge's nephew, a familial relationship that signifies a close bond. He is known for hosting a Christmas party that Scrooge attends, and he also invite
e04a5e95-652a-4e57-8f90-c8620cd400e5	46	MARLEY	PERSON	Marley was the deceased business partner of Scrooge, who had passed away seven years before the events of the story. His name was prominently displayec
430a2ec8-84c4-4c48-bde7-f9ad4202c5b2	47	CHRISTMAS EVE	EVENT	Christmas Eve is a significant day in the narrative, characterized by starkly contrasting scenes and activities. On one hand, it is depicted as a day of harsh, unf
78e488e8-66ef-4b87-9c51-aab9d1e5fffd	48	CITY	GEO	The City is a bustling urban center where merchants actively conduct business and engage in conversations in groups. It is also a specific location within this c
901d4fd3-bef1-4262-ab14-820775b5b2ce	49	SCROOGE'S NEPHEW	PERSON	Scrooge's nephew, known as Fred, is a cheerful and good-humored individual who embodies the spirit of Christmas. He is characterized by his hearty laughter
b217ae78-1d8a-4597-8db8-51d4d58c5f18	51	COUNTING-HOUSE		
ec08f287-335f-4f83-a3c2-7241ff9e9ac5	50	CLERK	PERSON	An employee of Scrooge who works in a dismal little cell beyond Scrooge's office and is tasked with copying letters. He has a very small fire and is concerned
ecbd8ba2-a7cc-42d8-a49f-9f58039388d1	52	MR. MARLEY	PERSON	Mr. Marley was Scrooge's business partner and has been dead for seven years.
739d4757-3a2b-4c0f-a319-592c447170bb	30	SCROOGE AND MARLEY	ORGANIZATION	Scrooge and Marley was a business firm where Ebenezer Scrooge was the surviving partner. He had previously been in partnership with Mr. Marley, who was
f5760d9b-30c5-4b91-b045-cd383e02d7e6	54	CHRISTMAS		

Rows per page 10 1-10 of 83

Graph RAG - experiment

Visualize indexing Graph on https://noworneverev.github.io/graphrag-visualizer/



Node Details: CHRISTMAS MORNING

Node Information
ID: 6a93783d-1b04-425f-8b31-ae7d845c0d49
Title: CHRISTMAS MORNING
Type: EVENT
Community Report Title: CHRISTMAS MORNING
Description: Christmas Morning is the time when Scrooge and the Spirit are in the city streets.
Human Readable ID: 118

Node Details: GROCERS'

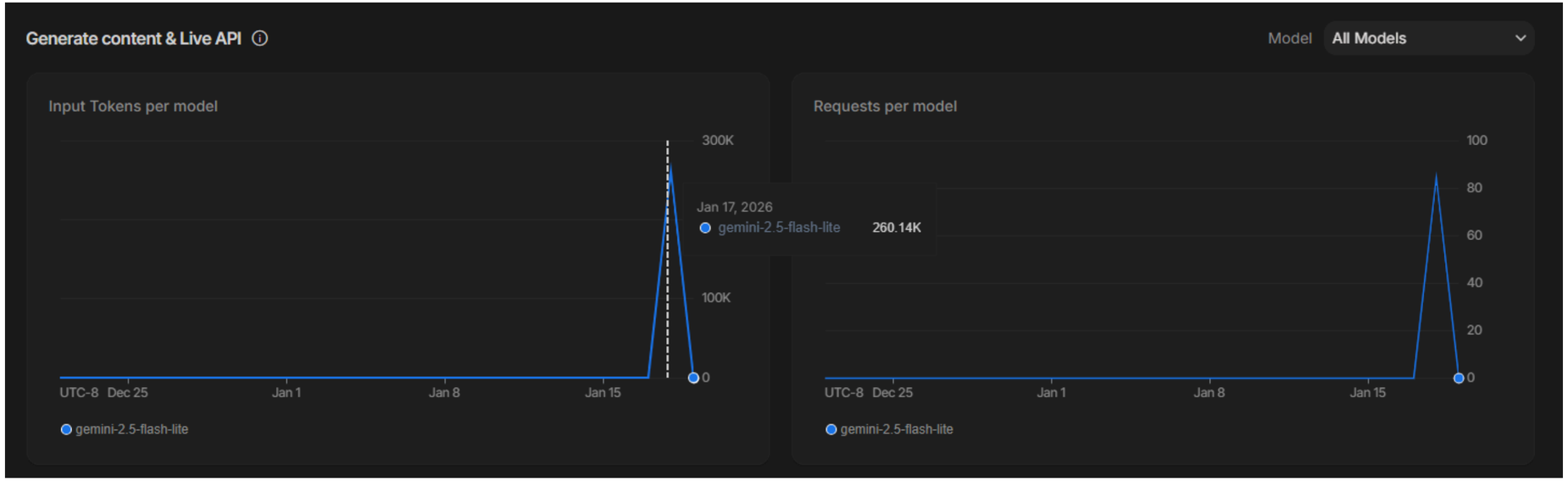
Node Information
ID: 1f0aef95-4bad-49f8-9911-33b5bed762df
Title: GROCERS'
Type: GEO
Community Report Title: GROCERS'
Description: Grocers' shops are nearly closed on Christmas morning.
Human Readable ID: 162

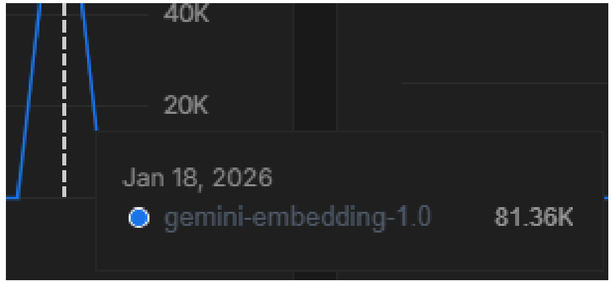
Linked Nodes

id	human_readable_id	title	type	description	text_unit_ids
6a93783d-1b04-425f-8b31-ae7d845c0d49	118	CHRISTMAS MORNING	EVENT	Christmas Morning is the time when Scrooge and the Spirit are in the city streets.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t
f6eca14b-4960-4640-9886-877dbdbe31bb	163	TEA	ORGANIZATION	Tea is a scent from the grocers' shops.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t
08bd4bb8-d9ad-4fba-842b-5c5231920e1c	164	COFFEE	ORGANIZATION	Coffee is a scent from the grocers' shops.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t
c55ec125-5c7d-437a-bcfd-099fea56666d	165	RAISINS	ORGANIZATION	Raisins are plentiful and rare in the grocers' shops.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t
be5446e6-0182-4e5f-91be-6859e8aac1fe	166	ALMONDS	ORGANIZATION	Almonds are extremely white in the grocers' shops.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t
4bdb2894-af54-48ef-be2e-3d477461eefb	167	CINNAMON	ORGANIZATION	Cinnamon sticks are long and straight in the grocers' shops.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t
b8ca744a-e66f-47aa-9820-fae793e359b9	168	SPICES	ORGANIZATION	Spices are delicious in the grocers' shops.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t
d3e5a112-a83e-4f03-9d6c-7471fb90da1f	169	CANDIED FRUITS	ORGANIZATION	Candied fruits are mentioned in the grocers' shops.	["3b2cce02868510cb86fcd63b835ab706dcf6cb84df91a6ebabe1541a1817t

Rows per page 10 1-8 of 8

Graph RAG - experiment





GraphRAG consumes a lot of LLM resources!

Input Tokens per model (chat): 260.14k

Embedding: 81.36k

Graph RAG - experiment

Global search

```
context_builder = GlobalCommunityContext(
    community_reports=reports,
    communities=communities,
    entities=entities,  # default to None if you don't want to use community weights for ranking
    tokenizer=tokenizer,
)
```

```
search_engine = GlobalSearch(
    model=model,
    context_builder=context_builder,
    tokenizer=tokenizer,
    max_data_tokens=5000,  # change this based on the token limit you have on your model (if you are using a model with 8k limit, a good setting could be 5000)
    map_llm_params=map_llm_params,
    reduce_llm_params=reduce_llm_params,
    allow_general_knowledge=False,  # set this to True will add instruction to encourage the LLM to incorporate general knowledge in the response, which may incr
    json_mode=True,  # set this to False if your LLM model does not support JSON mode.
    context_builder_params=context_builder_params,
    concurrent_coroutines=32,
    response_type="single paragraph",  # free form text describing the response type and format, can be anything, e.g. prioritized list, single paragraph, multip
)
```

Q: What are the top themes in this story?

Ans (1st paragraph)

LLM calls: 5. Prompt tokens: 29323. Output tokens: 2417.

The central theme of the narrative is the profound transformation of Ebenezer Scrooge, a miserly and unfeeling businessman, into a generous and kind individual. This significant change is primarily driven by supernatural encounters on Christmas Day with the ghosts of Jacob Marley and the Three Spirits of Christmas (Past, Present, and Yet to Come), who reveal visions of his past, present, and future, ultimately orchestrating his change of heart and understanding **[Data: Reports (11, 9, 2, 1, 13, 14)]**. Christmas itself serves as a pivotal theme, acting as the backdrop and catalyst for Scrooge's transformation and the story's events, encompassing traditions, food, decorations, and social gatherings, which starkly contrast with Scrooge's initial disdain for the holiday **[Data: Reports (2, 11)]**. The theme of redemption is central, as Scrooge's encounters with the spirits force him to confront his past actions and the consequences of his miserly life, leading to his eventual redemption and embrace of the Christmas spirit **[Data: Reports (11, 2)]**.

Graph RAG - experiment

Local search

```python
context_builder = LocalSearchMixedContext(
    community_reports=reports,
    text_units=text_units,
    entities=entities,
    relationships=relationships,
    # if you did not run covariates during indexing, set this to None
    covariates=None,
    entity_text_embeddings=description_embedding_store,
    embedding_vectorstore_key=EntityVectorStoreKey.ID,  # if the vectorstore uses entity title as ids, set this to EntityVectorStoreKey.TITLE
    text_embedder=text_embedder,
    tokenizer=tokenizer,
)
```

เพิ่ม Relationships

Q: Who is Scrooge and what are his main relationships?

Ans (single paragraph) **LLM calls: 1. Prompt tokens: 7016. Output tokens: 988.**

```
Ebenezer Scrooge, also known as Scrooge, is the central protagonist of the narrative. He is initially depicted as a wealthy, stingy, and unfeeling businessman, described as a "covetous old sinner" and "hard and sharp as

## Key Relationships

Scrooge's life is marked by several significant relationships, though many are strained by his disposition.

### Family

*   **Fred (Scrooge's Nephew):** Fred is Scrooge's nephew and a close familial relation [Data: Entities (11)]. He is known for his cheerful and good-humored nature, embodying the spirit of Christmas [Data: Entities (49)
*   **Fan (Scrooge's Sister):** Fan is Scrooge's younger sister. She is noted for coming to bring him home from school for Christmas [Data: Entities (26)].
*   **Scrooge's Niece:** Married to Fred, Scrooge's niece is described as a pretty and enthusiastic individual with a hearty laugh and strong opinions [Data: Entities (193)]. She shows interest in Scrooge's wealth and i

### Business and Associates

*   **Bob Cratchit:** Bob Cratchit is Scrooge's loyal clerk, enduring a meager salary of fifteen shillings a week [Data: Entities (7)]. Despite his low wages, Bob Cratchit is a devoted family man. Scrooge is his employe
*   **Jacob Marley (Deceased Partner):** Jacob Marley was Scrooge's business partner, who had been deceased for seven years [Data: Entities (52, 46)]. His name was prominently displayed on their warehouse door [Data: En
*   **Fezziwig:** Fezziwig was Scrooge's former employer when Scrooge was young [Data: Relationships (99)].
*   **Dutch Merchant:** The Dutch merchant built the fireplace in Scrooge's house [Data: Relationships (67)].

### Other Notable Figures

*   **Belle:** Belle is depicted as Scrooge's former fiancée and an old sweetheart. She appears to Scrooge in a vision of his past, described as a comely matron [Data: Entities (20)].
*   **Topper:** Topper is a bachelor and a friend of Scrooge's nephew and niece. He is implied to have a romantic interest in one of Scrooge's nieces' sisters and is skilled in singing and playing blind man's buff [Data

Scrooge's journey is one of profound transformation, moving from a state of isolation and avarice to one of generosity and compassion, largely influenced by his interactions with supernatural entities and his reflection
```

Graph RAG - Use for ?

GraphRAG is able to **connect information across large volumes of information and use these connections to answer questions** that are difficult or impossible to answer using keyword and vector-based search mechanisms. Building on the previous question, provide semi-technical, high-level information on how the system offers functionality for various uses.

"This lets a system using GraphRAG to answer questions where the answers span many documents as well as thematic questions such as “what are the top themes in this dataset?.”

Ref: https://github.com/microsoft/graphrag

Verification Techniques

1. **Verification-Technique**
2. **Corrective RAG**

Corrective RAG (CRAG)

Systems like CRAG **trigger web searches to correct outdated retrievals**

Pros

- Improved Performance and Real-Time Knowledge Integration
- Efficiency in Knowledge Utilization

Cons

- Detection and Correction of Wrong Knowledge
- Necessity of Fine-Tuning
- Potential Bias from Web Searches

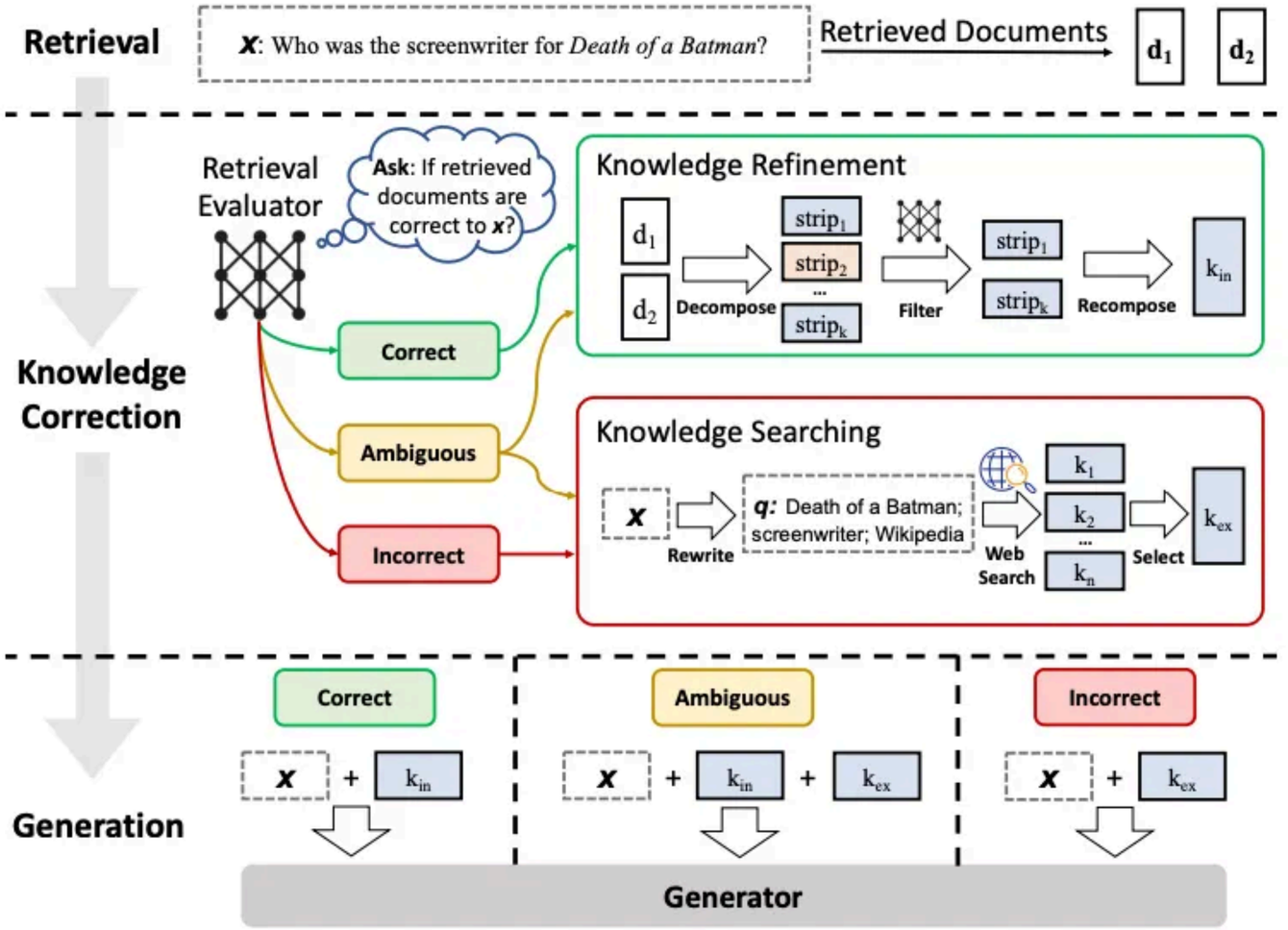
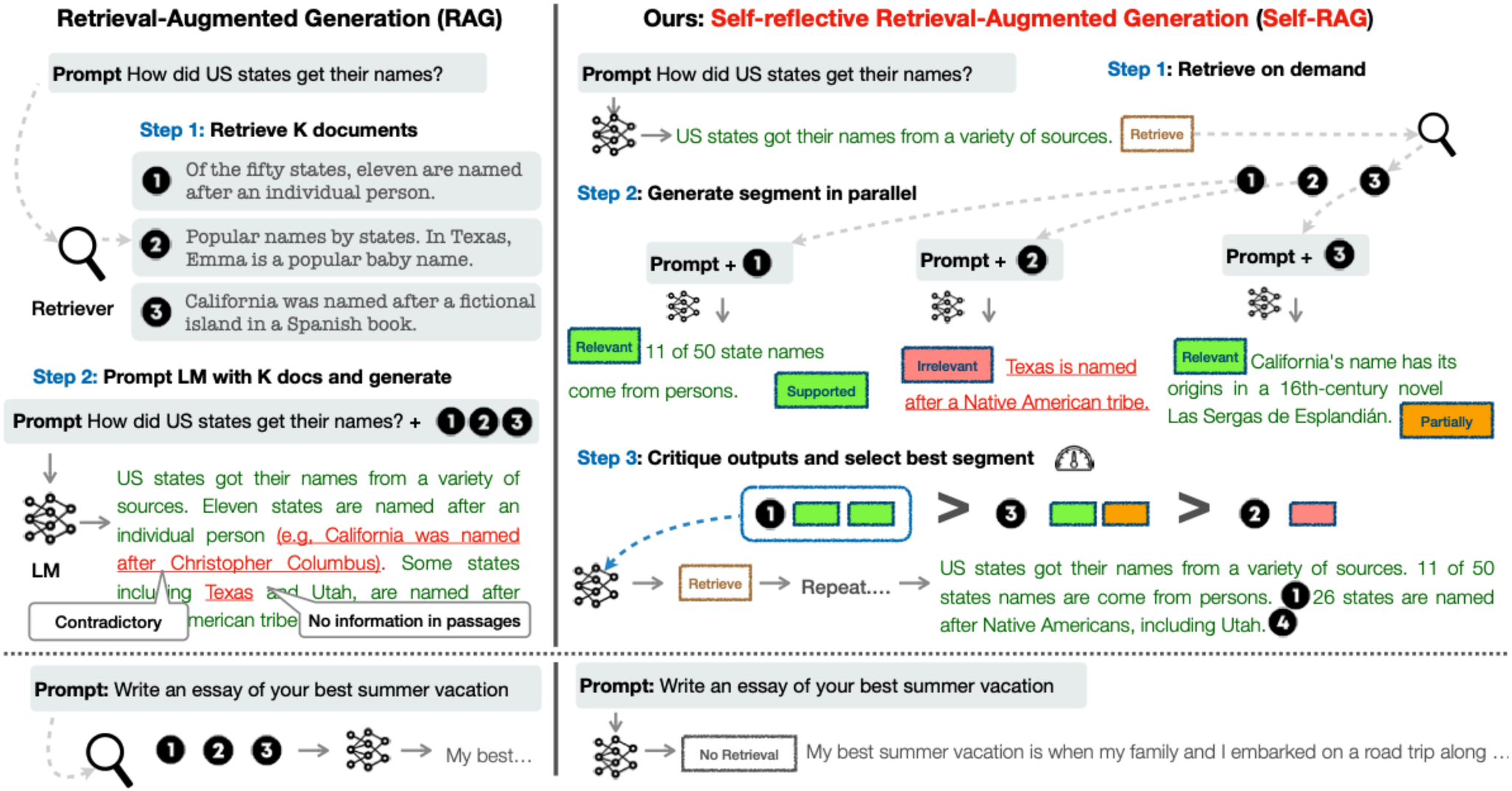


Fig illustrates Step-by-Step Process of CRAG

https://medium.com/@sahin.samia/crag-corrective-retrieval-augmented-generation-in-llm-what-it-is-and-how-it-works-ce24db3343a7

Self-RAG

Critiques its own retrievals using **reflection tokens**



https://www.linkedin.com/pulse/self-rag-learning-retrieve-generate-critique-through-vlad-bogolin-1rvge/

Self-RAG

Pros

- **Reduced hallucination**: Answers are constrained to information supported by the retrieved evidence only.
- **High accuracy**: The system selects the best information from multiple sources.
- **Transparency**: It is possible to inspect why the AI chose a particular answer through critique or evaluation scores.

Cons

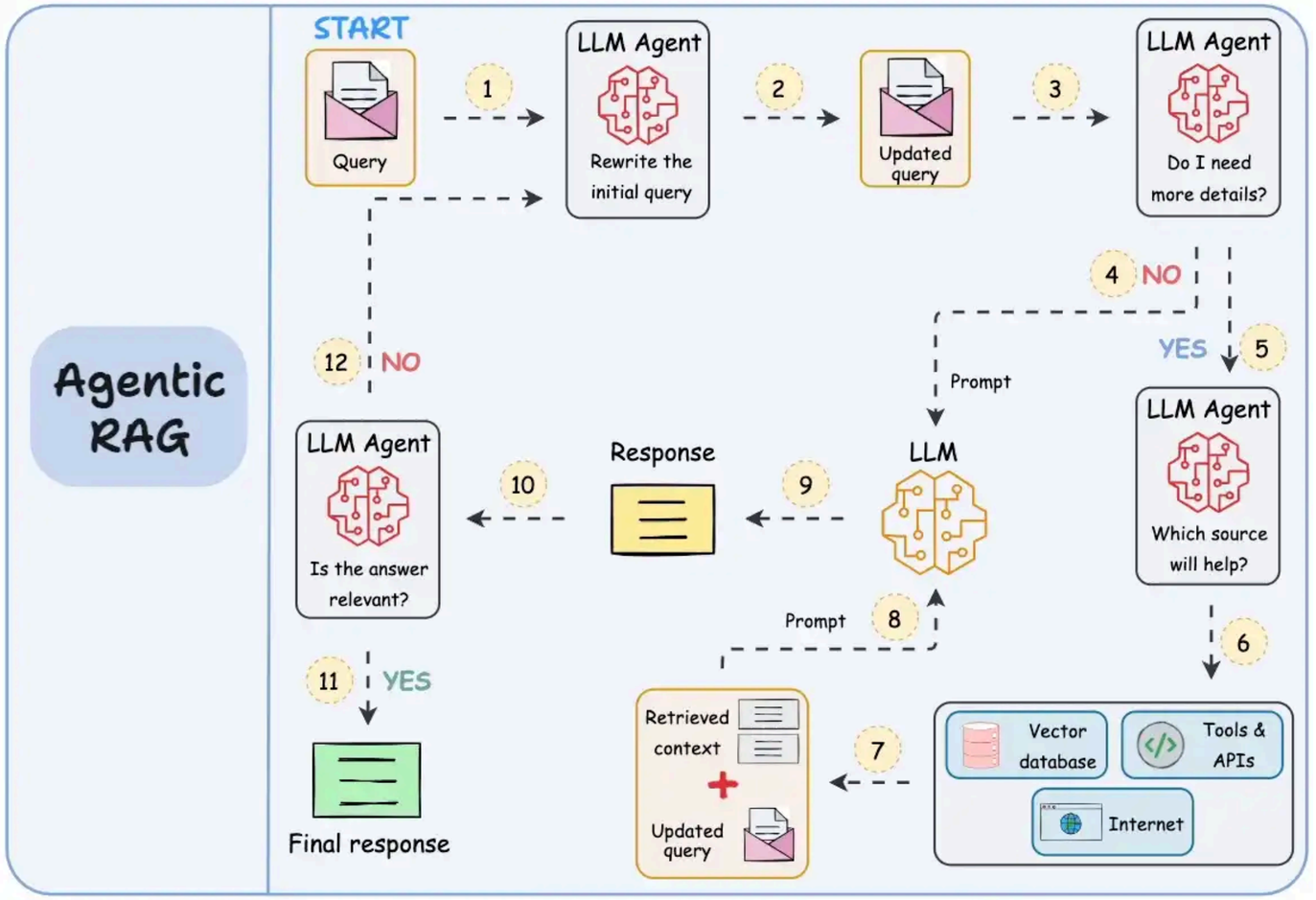
- **High resource usage**: Requires multiple rounds of generation and evaluation, increasing token consumption and response time.
- **System complexity**: Requires fine-tuning models to produce reflection tokens or the use of highly complex prompts.
- **Latency**: Slower than standard RAG due to multiple reasoning and evaluation stages.

Agentic RAG

Agentic RAG is the use of **AI agents** to facilitate **RAG**

Resoning Loop: using framework and dynamic workflow:

1. **Query Decomposition** & Planinng: Agent analyze the user's prompt. Break to sub-tasks
2. **Tool Selection**: Agent decide which tools to use
3. **Iterative Retrieval**: Agent execute a search looks at results **YES NO** If NO reformulates the query tries diff tools until YES to next step
4. **Self-Correction & Validation**



https://blog.dailydoseofds.com/p/rag-vs-agentic-rag

Agentic RAG

Pros

- **Excellent at solving complex problems**: Handles tasks requiring multiple data sources effectively (Multi-hop reasoning).
- **Intelligent data retrieval**: Smart enough to select the most appropriate method for pulling information (Similar to Adaptive RAG but more flexible).
- **Reduces Hallucinations**: Effectively minimizes false information through built-in **Verification steps.**

Cons

- **Latency (Slow)**: Slower response times because the system must think and iterate through multiple loops.
- **Cost**: Higher expense due to increased **Token** usage from the reasoning process.
- **Unpredictable**: The Agent can sometimes "lose its way" or get stuck in an Infinite Loop without finding a solution.

Usecase/ Application

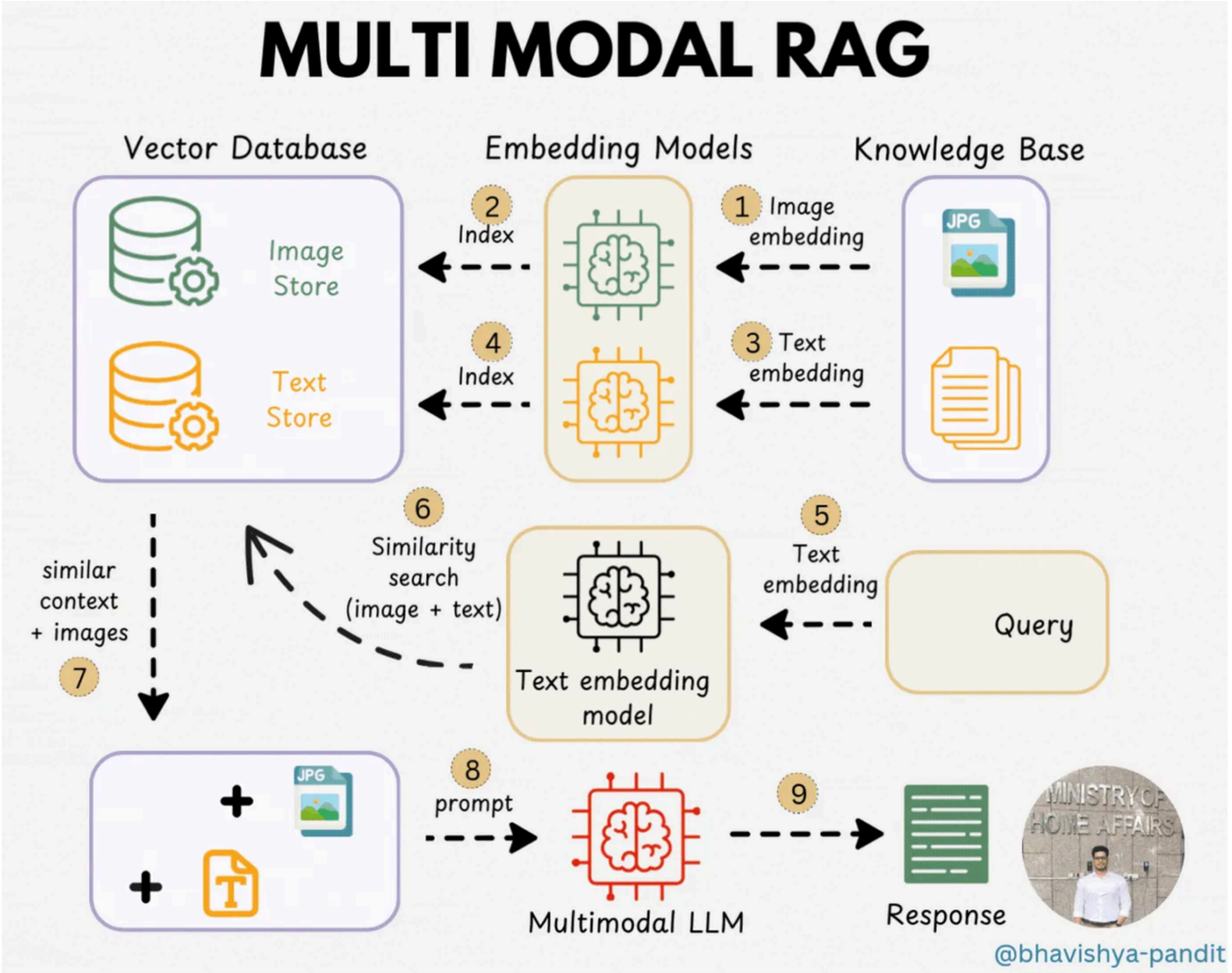
- **Real-time question-answering:** Enterprises can deploy RAG-powered chatbots and FAQs.
- **Automated support:** streamline customer support services.
- **Data management:** RAG systems make it easier to find information within proprietary data stores. Employees can quickly get the data.

Multimodal RAG

multimodal RAG can process and retrieve information from the multimodal data (text, images, tables, audio and video files) and generate contextually accurate and relevant responses.

Many Ways How multimodal RAG works:

1. **Captioning** (everything convert to text)
2. **Multimodal Embedding** (Shared Vetor Space)
3. **Multi-vector Retriever** (Summary + Object Data)



https://bhavishyapandit9.substack.com/p/multimodal-retrieval-augmented-generation

Multimodal RAG

Pros

- **Understand Context**: Understand multimodal data to answer to user's query
- **User Experience:** image to text prompt
- **Decrease Hallucination**

Cons

- **Complexity**: manage index and data for retrieval and store multimodal data
- **Cost**: High Cost / Resource to process multimodal data
- **Storage:** store emebdding of multimodal data and High usage memory

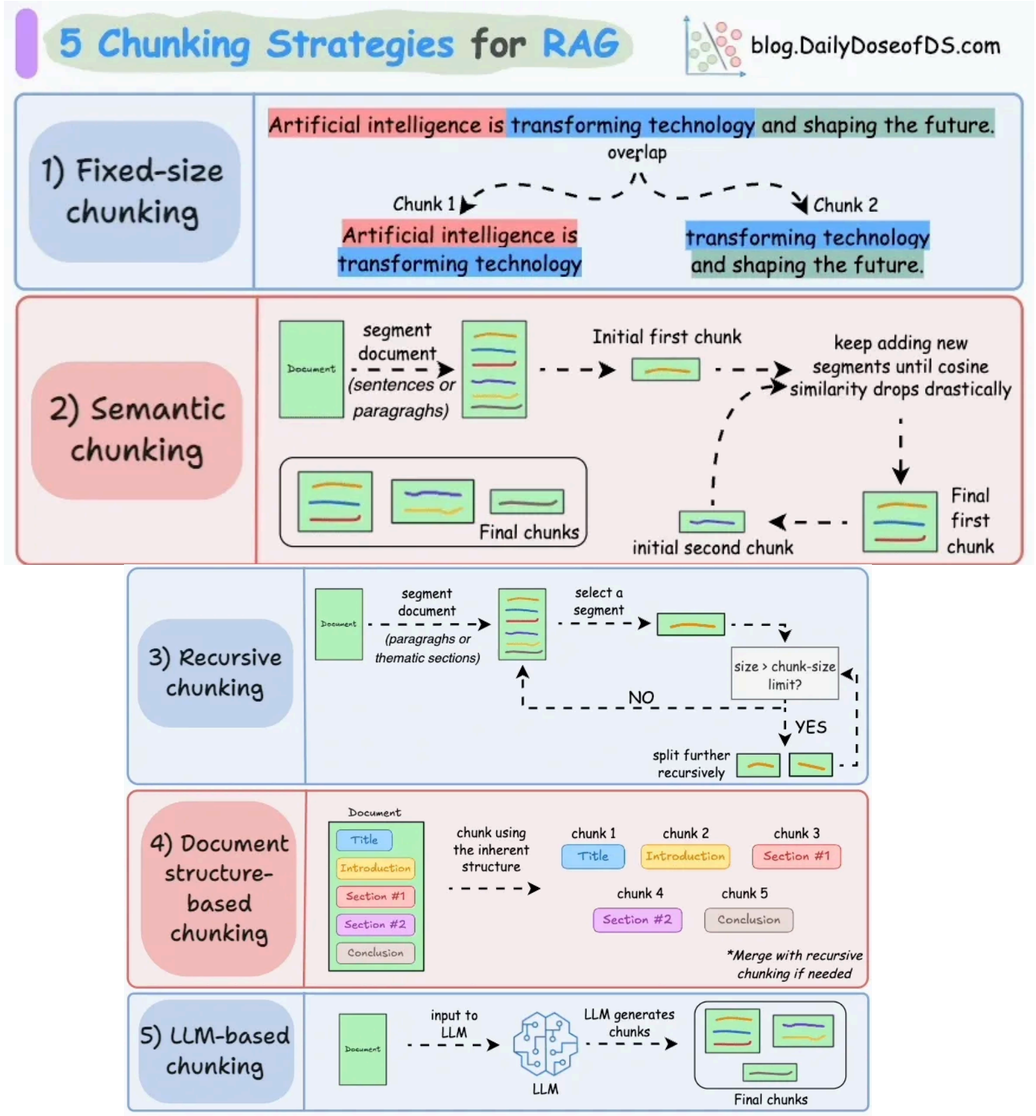
Usecase/ Application

- **Industrial Application Study: 1.)** Healthcare and Medical Diagnostics, 2) Manufacturing and Industrial Maintenance, 3) Finance and Business Intelligence, 4) E-commerce and Retail, 5) Legal & Compliance etc.
- Multimodal RAG systems combine diverse data types to improve performance o**pen-domain question answering.**

Optimization Strategies

- Chunking Strategies For RAG
- Reranking and autocut
- Retrival-Augmented + Fine-Tuning

Chunking Strategies For RAG



In **RAG systems, chunking means dividing large documents into smaller pieces (chunks)** before creating embeddings and storing them in a vector database.

This step is important because it:

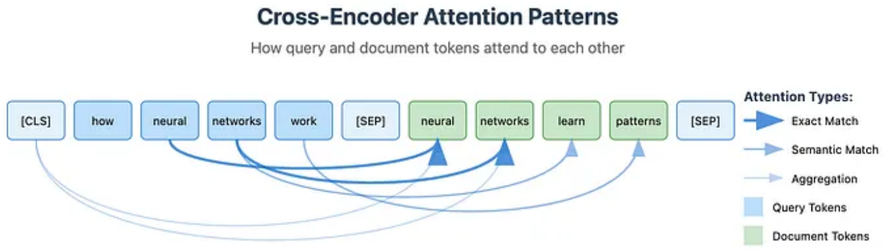
- Keeps texts within embedding token limits
- Improves retrieval accuracy
- Helps the LLM generate better answers because it gets relevant context

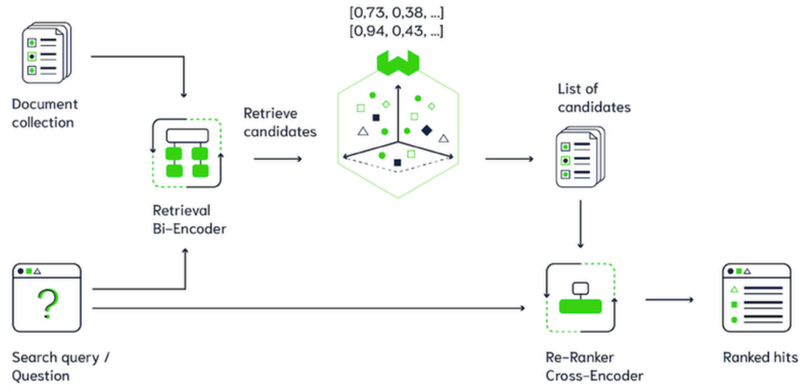
https://blog.dailydoseofds.com/p/5-chunking-strategies-for-rag

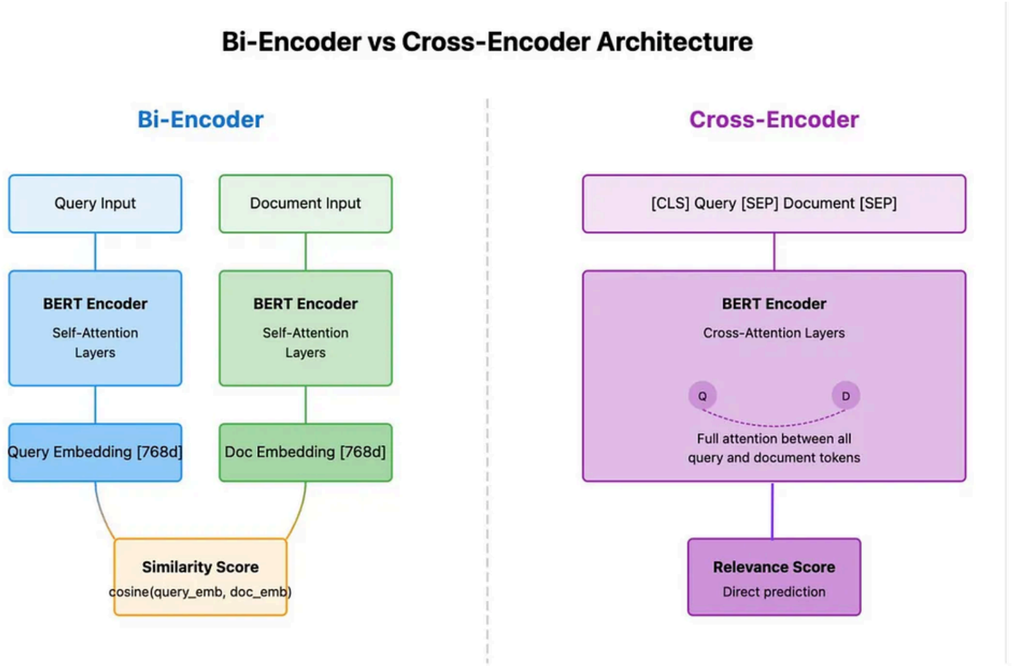
Reranker - CrossEncoder

Reranking is the process of **reordering results** so that the most relevant information rises to the top before being passed to the LLM.

Cross-encoder reranking: Feeds the user query and each candidate chunk into a transformer model (like BERT) that scores how well they match. Very accurate but slow and resource-intensive. Best when quality matters more than latency.







Key Features of Cross Encoder

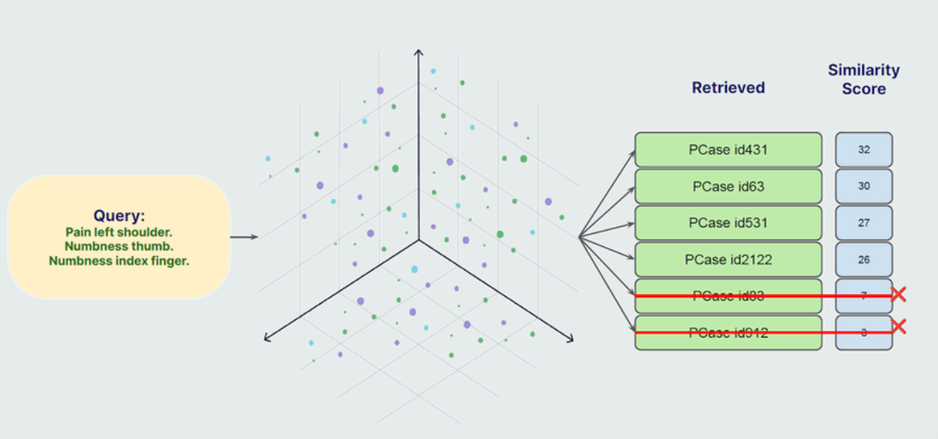
- **Deep Semantic Understanding:** Cross-encoders capture nuanced relationships between queries and documents
- **High Precision:** Superior accuracy in understanding complex relationships

Autocut

Autocut is a method to filter out irrelevant information retrieved from the database, which can otherwise mislead the LLM and cause hallucinations

Here's how it works:

1. Retrieve and Score Similarity: When a query is made, multiple objects are retrieved along with their similarity scores.
2. Identify and Cut Off: Using the similarity scores, identify a cutoff point where the scores drop significantly. Objects beyond this point are considered less relevant and are automatically excluded.



Pros

- **Reduces Latency (Faster)**
- **Cost Efficiency**

Cons

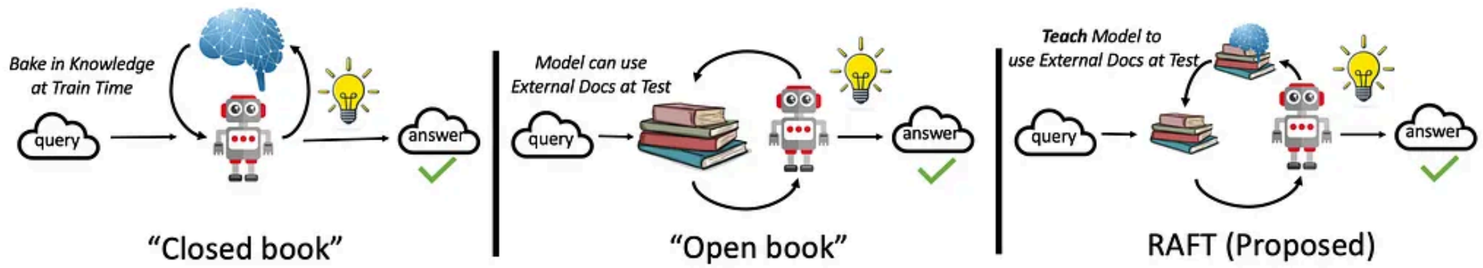
- **Computation Overhead**
- **Information Loss**

https://weaviate.io/blog/advanced-rag

RAFT (Retrival-Augmented + Fine-Tuning)

RAFT recognizes the limitations of existing approaches and aims to combine the strengths of **RAG** and **fine-tuning**. By incorporating domain-specific documents during the fine-tuning process, **RAFT enables the model to learn patterns specific to the target domain** while also enhancing its ability to understand and utilize external context effectively.

- **Training with "Distractors":** During fine-tuning, the model is given a question along with a set of documents. Some **documents contain the answer**, while others are irrelevant (**Distractor documents**).
- **Chain-of-Thought (CoT) Reasoning:** The model is trained to generate answers that include a reasoning chain, explicitly citing segments from the correct documents.
- **Learning to Ignore:** By seeing both correct and incorrect context during training, the model learns to prioritize relevant information and disregard "noise" (irrelevant retrievals) during actual use.



Pros

- **Domain Adaptation**
- **Performance**

Cons

- **High Computational & Training Costs**
- **Data Preparation**

References

NotebookLM Link: https://notebooklm.google.com/notebook/7843f990-ffd0-4f91-9f87-228cfc48010a

RAG techniques IBM: https://www.ibm.com/think/topics/rag-techniques

2025's Ultimate Guide to RAG Retrieval: How to Pick the Right Method

: https://medium.com/@mehulpratapsingh/2025s-ultimate-guide-to-rag-retrieval-how-to-pick-the-right-method-and-why-your-ai-s-success-2cedcda99f8a

The 2025 Guide to Retrieval-Augmented Generation (RAG)

: https://www.edenai.co/post/the-2025-guide-to-retrieval-augmented-generation-rag

Top 13 Advanced RAG Techniques for Your Next Project

: https://www.edenai.co/post/the-2025-guide-to-retrieval-augmented-generation-rag