CIML Summer Institute 2025
Retrieval Augmented Generation (RAG)

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Retrieval Augmented Generation (RAG)

- **Definition:**
  - Technique to improve capabilities of LLM
- **Idea:**
  - Improve quality of text generated by LLM by incorporating additional information from an external source
- **Approach:**
  - Use a *retrieval* component to extract relevant data from an external knowledge base as context to *augment* prompt to help LLM *generate* more accurate and relevant response

Why Use RAG?

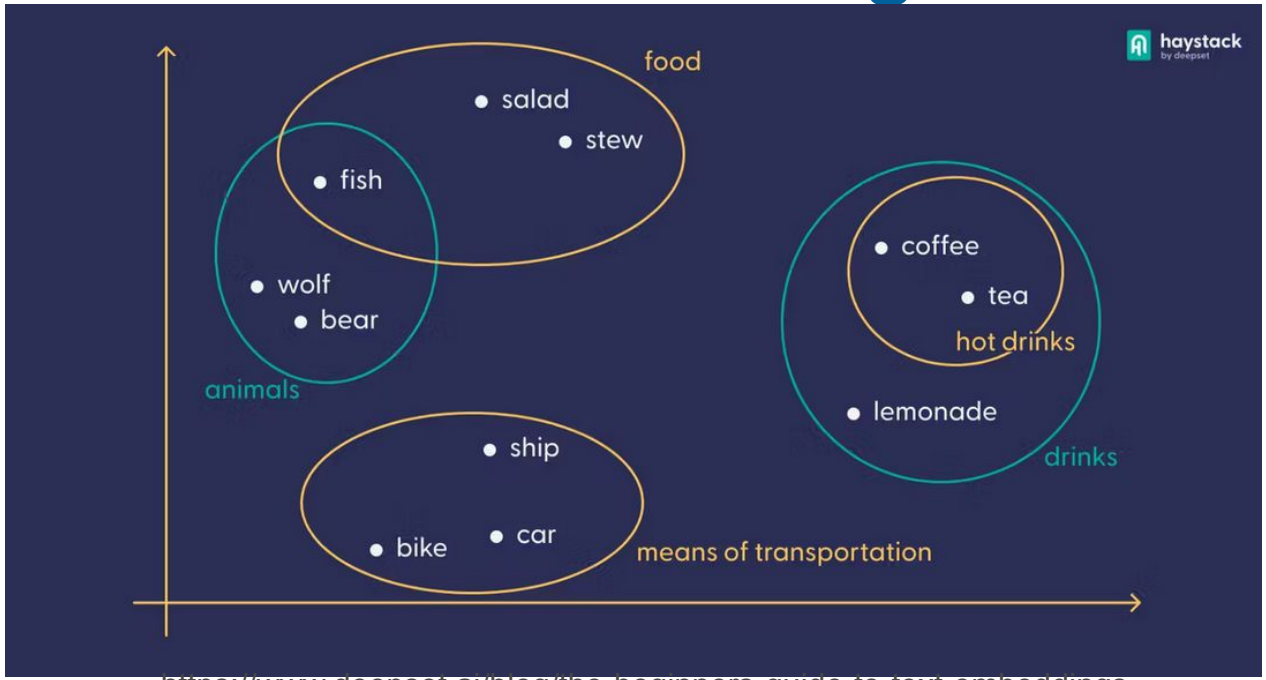
- **LLMs**
  - Responds to prompts with information from training data
- **RAG**
  - Allows LLM to access external knowledge base (e.g., company's internal database)
  - Provides most up-to-date and relevant information to LLM in generating response
  - Provides way to validate LLM's response

Embeddings

- **Text Embedding:**
  - Numeric representation of text (vector of floating point numbers)
  - Capture the semantics of the text
  - Similarity between two embeddings indicates their semantic relatedness (cosine similarity, dot product, etc)

https://cohere.com/blog/text-embeddings

Text Embeddings



https://www.deepset.ai/blog/the-beginners-guide-to-text-embeddings

Text embeddings allow for search and comparison between user queries and documents in knowledge base

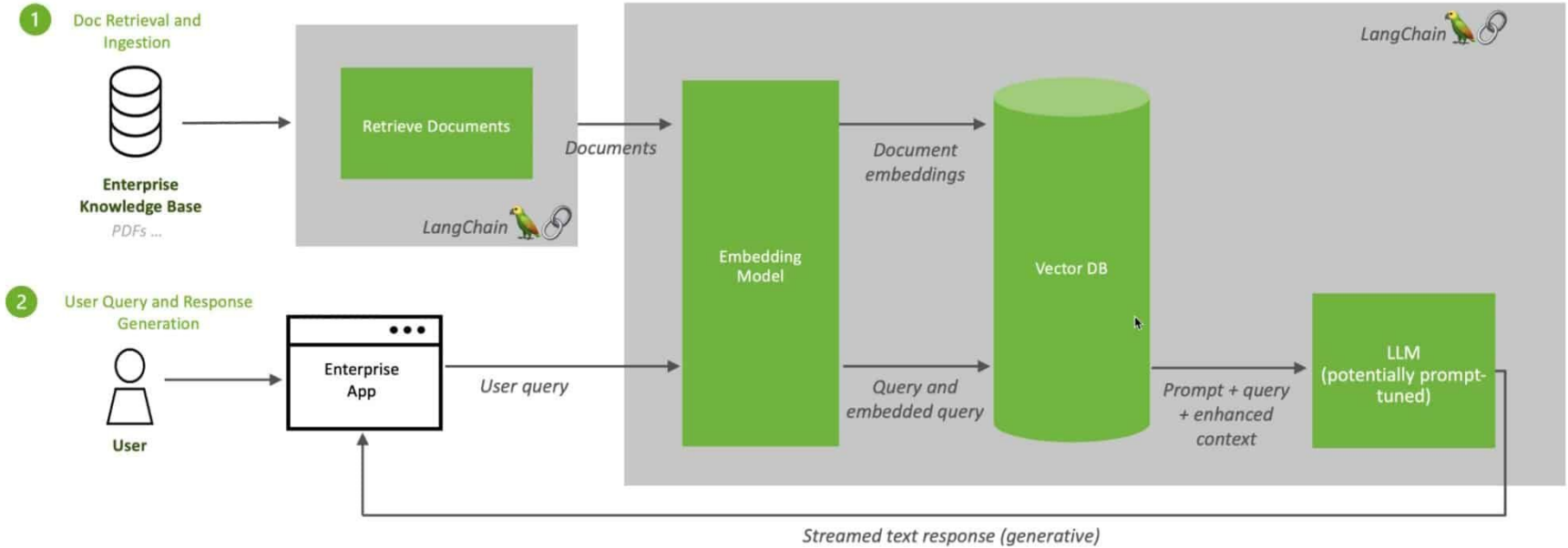
How RAG Works

- User inputs prompt
- Prompt sent to retrieval system
- Retrieval system searches knowledge base and returns top relevant document chunks
- Retrieved chunks are added as context to original prompt
- Augmented prompt sent to LLM

RAG Overview

Retrieval Augmented Generation (RAG) Sequence Diagram

https://developer.nvidia.com/blog/rag-101-demystifying-retrieval-augmented-generation-pipelines/



RAG Components

- Embedding Model
- Vector Database
- LLM

RAG Components

- **Embedding Model**
  - Document encoding
    - Generates embeddings for documents or text passages in knowledge base
  - Query encoding
    - Generates embeddings for input query
  - Some embedding models
    - HuggingFace: Universal AngIE Embedding, all-MiniLM-L6-v2
    - OpenAI: text-embedding-3-small, text-embedding-3-large (paid)

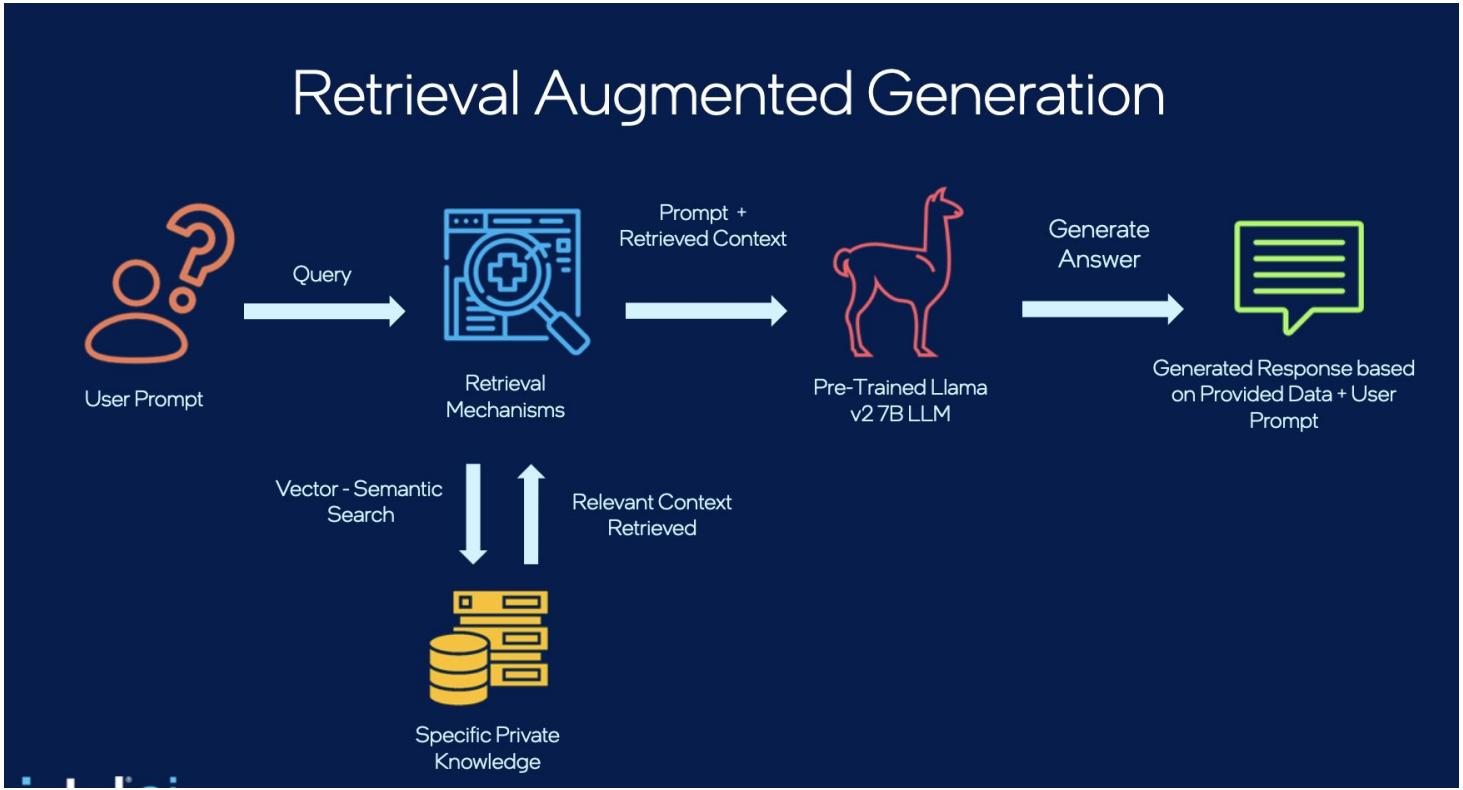
RAG Components

- **Vector Database**
  - Storage
    - Stores precomputed embeddings of documents
  - Similarity search
    - Performs similarity search between query embedding and stored document embeddings to return top-k relevant documents
      - Similarity metrics: cosine similarity, dot product, etc.
    - Optimized for fast and efficient similarity search
  - Some vector databases
    - ChromaDB
    - Pinecone
    - Milvus

RAG Components

- **LLM**
  - Content generation
    - Takes query augmented with retrieved content
    - Generates response to augmented prompt
  - Some LLMs
    - LLaMa
    - Gemma
    - GPT

RAG Overview



Intel

RAG Hands-On

- **RAG Components**
  - Embedding model: HuggingFace all-MiniLM-L6-v2
  - Vector database: ChromaDB
  - LLM: Gemma3-4B
  - LLM server: ollama

RAG Hands-On Outline

- **Retrieval Concepts**
  - Vectorization to create text embeddings
  - Similarity between embeddings
  - Vector database for storing embeddings
  - Chunking
- **Basic RAG**
- **RAG with LangChain**

RAG Hands-On - Setup

- **In terminal window**
  - jupyter-gpu-shared-llm
    - Alias for: galyleo launch --account <account> --partition gpu-shared --time-limit 4:00:00 --gpus 1 --cpus 4 --memory 32 --env-modules singularitypro --sif /cm/shared/examples/sdsc/ciml/2025/LLM/ollama-latest.sif --nv --bind /expanse,/scratch,/cm --quiet
  - Copy and paste URL to browser window

- **To check queue**
  - squeue -u $USER

RAG Setup

- **Ollama server setup**
  - Need to set up and start ollama server before Part 2
  - Follow instructions in notebook

Resources

- RAG
  - https://www.datacamp.com/blog/what-is-retrieval-augmented-generation-rag
  - Step-by-Step Tutorial on Integrating Retrieval-Augmented Generation (RAG) with Large Language Models | by Novita AI | Apr, 2024 | Medium
    ollama/examples/langchain-python-rag-document/main.py at main
- Embedding model
  - https://huggingface.co/sentence-transformers/all-MiniLM-L6-v2
- ChromaDB
  - https://docs.trychroma.com/
  - https://colab.research.google.com/drive/181Kummxd8yOyRqFu8I0aqjs2aqnOy4Fu?usp=sharing

Resources

- LangChain
  - https://python.langchain.com/v0.1/docs/use_cases/question_answering/quickstart/
  - https://api.python.langchain.com/en/latest/chains/langchain.chains.retrieval_qa.base.RetrievalQA.html
  - https://python.langchain.com/v0.2/docs/integrations/vectorstores/chroma/
  - https://python.langchain.com/v0.2/docs/integrations/text_embedding/huggingfacehub/
- Ollama:
  - https://www.ollama.com/
  - Ollama | 🦜🔗 LangChain