Introduction to Large Language Models

From Foundation to Real World Applications

Pritam Prakash Shete
Scientific Officer G
Computer Division, BARC

Agenda

- Introduction
- Large Language Models
- Prompt Engineering
- In Context Learning
- Training LLMs
- LLM Applications
- Deploying LLMs
- Conclusions

Introduction

- **OpenAI**
  - GPT 3.5, GPT 4
  - GPT 4o, GPT o1
- Access – API
- Multimodal
  - Text, Image

- **Google**
  - Gemini 1
  - Gemini 1.5
- Access – API
- Multimodal
  - Text, Image

Introduction

- **Meta**
  - Llama 2, Llama 3
  - Llama 3.1, Llama 3.2
- Access – Open Source
- Multimodal
  - Text, Image

- **Google**
  - Gemma
  - Gemma 2
- Access – Open Source
- Multimodal
  - Text, Image

Large Language Models

- Next word or token prediction

I love eating ice

I love eating ice cream

I love eating ice cream with

I love eating ice cream with my

I love eating ice cream with my friends

I love eating ice cream with my friends at

I love eating ice cream with my friends at beach.

Large Language Models

- Natural Language Processing (NLP)
- Understand, Interpret, and Generate human language
- Sentiment analysis
- Text summarization
- Machine translation

Large Language Models

- Large number of parameters
  - ChatGPT–4 – ~1.8 Trillion parameters
- Trained using large amount of dataset
  - ChatGPT–4 – 570 GB or 300 Billion words

***OpenAI ChatGPT 4**

Large Language Models

• Model name	Llama 3.1 405B Instruct
• Company	Meta
• Access	Open source
• Number of parameters	405 Billion parameters
• Context size	128,000 (128K) tokens
• LLM type	Instruction fine-tuned

***Meta Llama 3.1 405B Instruct**

Sentiment Analysis

Identify sentiment of following sentence as either positive or negative.

I like “Harry Potter and the Goblet of Fire” book very much.

The sentiment of the sentence “I like ‘Harry Potter and the Goblet of Fire’ book very much” is **Positive**.

The word **“like”** and the phrase **“very much”** both indicate a **strong positive sentiment**, suggesting that the speaker has a very positive opinion of the book.

***Meta-Llama-3.1-8B-Instruct**

Summarization

Summarize the following paragraph.

A chemical reaction is a process that leads to the chemical transformation of one set of chemical substances to another. When chemical reactions occur, the atoms are rearranged and the reaction is accompanied by an energy change as new products are generated. Classically, chemical reactions encompass changes that only involve the positions of electrons in the forming and breaking of chemical bonds between atoms, with no change to the nuclei (no change to the elements present), and can often be described by a chemical equation.

A chemical reaction transforms one set of substances into another by rearranging atoms and changing energy levels. This process typically involves changes in electron positions and chemical bonds without altering the elements themselves, and is often represented by a chemical equation.

***Meta-Llama-3.1-8B-Instruct**

Machine Translation

Translate following English sentences in Hindi sentences.

Particle accelerator is a machine that uses electromagnetic fields to propel charged particles to very high speeds and energies to contain them in well defined beams.

कण त्वरक एक मशीन है जो विद्युत चुम्बकीय क्षेत्रों का उपयोग करके आँवेशित कणों को बहुत अधिक गति और ऊर्जा प्रदान करती है और उन्हें अच्छी तरह से परिभाषित किरणों में सीमित रखने के लिए।

***Meta-Llama-3.1-8B-Instruct**

Prompt Engineering

- Prompt
- Inference
- Completion

Prompt

- **Instructions to LLM**
- Context for Question
- Question

Answer following question using given context.

Context: Everyday examples of particle accelerators are cathode ray tubes found in television sets and X-ray generators. These low energy accelerators use a single pair of electrodes with a DC voltage of a few thousand volts between them.

Question: Give examples of low energy accelerators.

***Meta-Llama-3.1-8B-Instruct**

Inference

- Large Language Model
- Model prediction

Translate following English sentences in Hindi sentences.

Particle accelerator is a machine that uses electromagnetic fields to propel charged particles to very high speeds and energies to contain them in well defined beams.

कण त्वरक एक मशीन है जो विद्युत चुम्बकीय क्षेत्रों का उपयोग करके आवेशित कणों को बहुत अधिक गति और ऊर्जा प्रदान करती है और उन्हें अच्छी तरह से परिभाषित किरणों में सीमित रखने के लिए।

***Meta-Llama-3.1-8B-Instruct**

Prompt Completion

- Inference without context

कण त्वरक एक मशीन है जो विद्युत चुम्बकीय क्षेत्रों का उपयोग करके आवेशित कणों को बहुत अधिक गति और ऊर्जा प्रदान करती है और उन्हें अच्छी तरह से परिभाषित किरणों में सीमित रखने के लिए।

***Meta-Llama-3.1-8B-Instruct**

In Context Learning

- Context window
- Task example/s
- Zero shot inference
- One shot inference
- Few shot inference

Context Window

- Window size
  - ChatGPT 4 Turbo – 128K
  - Llama 3.1 405B – 128K

Answer following question using given context.

Context: The Large Hadron Collider (LHC) particle collider is the world's largest and highest-energy particle accelerator. It was built by the European Organization for Nuclear Research (CERN).

Question: What is the Large Hadron Collider?

***OpenAI ChatGPT 4 & Meta Llama 3.1 405B Instruct**

Task Examples

- One or more examples
- In context learning
- Align LLM with task

Identify sentiment of following sentence as either positive or negative.

Sentence: I like book very much.

Sentiment: Positive

Sentence: I do not like book.

Sentiment: Negative

Sentence: Harry Potter and the Goblet of Fire book is good for readers.

***Meta-Llama-3.1-8B-Instruct**

Zero Shot Inference

- No examples

Identify sentiment of following sentence as either positive or negative.

Sentence: Harry Potter and the Goblet of Fire book is good for readers.

***Meta-Llama-3.1-8B-Instruct**

One Shot Inference

- One example

Identify sentiment of following sentence as either positive or negative.

Sentence: I like book very much.

Sentiment: Positive

Sentence: Harry Potter and the Goblet of Fire book is good for readers.

***Meta-Llama-3.1-8B-Instruct**

Few Shot Inference

- Two or more examples

Identify sentiment of following sentence as either positive or negative.

Sentence: I like book very much.

Sentiment: Positive

Sentence: I do not like book.

Sentiment: Negative

...

Sentence: Harry Potter and the Goblet of Fire book is good for readers.

***Meta-Llama-3.1-8B-Instruct**

Training Large Language Models

- Model Pre-training
- Instruction Fine Tuning
- Reinforcement Learning from Human Feedback (RLHF)

Model Pre-training

- Self supervised learning
- Next word or token prediction
- Self annotations – (X – y)
  - I love ice **cream**
    - X = I love ice
    - y = **cream**
- Learn language syntax
- Master language grammar

- Large corpus of text data
- Books, articles, and websites
- Web scraping
- Vocabulary size
  - Number of tokens
  - 15.6 Trillion tokens
- Clean dataset
  - 1% – 3% original tokens

Instruction Fine Tuning

- Supervised learning
- Specific down stream task
- Instructions and Responses
  - Question and Answer
  - Text and Summary
  - English and Hindi sentences
  - Text and Sentiment

- Generate accurate responses
- Generate specific responses
- Specific domain knowledge
  - Source code
  - Medical documents
  - Legal documents
  - Financial documents

Reinforcement Learning from Human Feedback

- Align model with human values
- Reinforcement learning
- 3H – Helpful, Honest, Harmless
- Helpful answer
- Honest answer
- Harmless answer
- Responsible AI

- Agent
  - Instruct LLM model
- Environment
  - LLM context
- Objective
  - Generate aligned text
- Reward model
  - Supervised learning

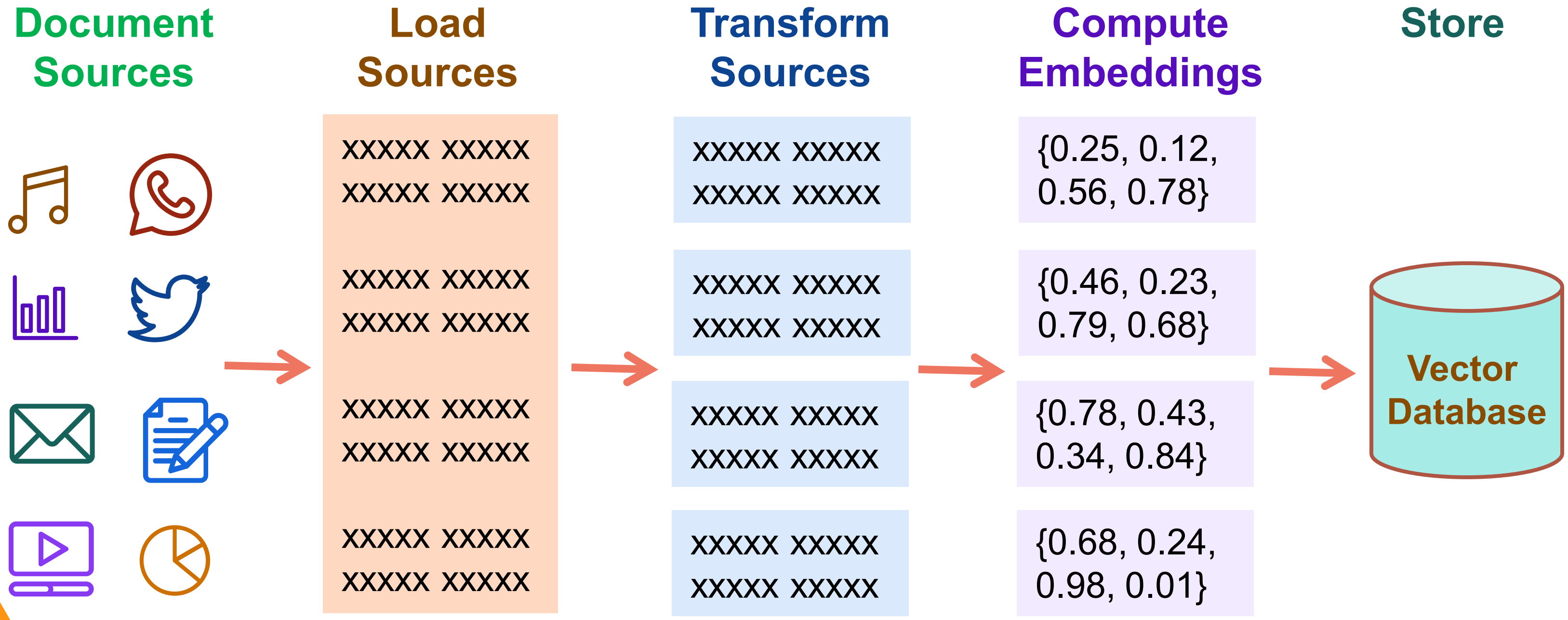
Retrieval Augmented Generation

- **Retrieval**
  - Retrieve relevant information from source documents
- **Augmented**
  - Augment input query with retrieved relevant information
- **Generation**
  - Generate response using augmented input and LLM

Retrieval Augmented Generation

- Improve accuracy
  - Closed book test v/s Open book text with Index page
- Increase transparency
  - Source references – Retrieved documents
- Reduce hallucination
  - Augmentation – Retrieval + Generation
- Up to date information
  - Ingest documents – No expensive model training

Sahaayak – Retrieval Augmented Generation



Document Sources

Load Sources

xxxxx xxxxx
xxxxx xxxxx

xxxxx xxxxx
xxxxx xxxxx

xxxxx xxxxx
xxxxx xxxxx

xxxxx xxxxx
xxxxx xxxxx

Transform Sources

xxxxx xxxxx
xxxxx xxxxx

xxxxx xxxxx
xxxxx xxxxx

xxxxx xxxxx
xxxxx xxxxx

xxxxx xxxxx
xxxxx xxxxx

Compute Embeddings

{0.25, 0.12, 0.56, 0.78}

{0.46, 0.23, 0.79, 0.68}

{0.78, 0.43, 0.34, 0.84}

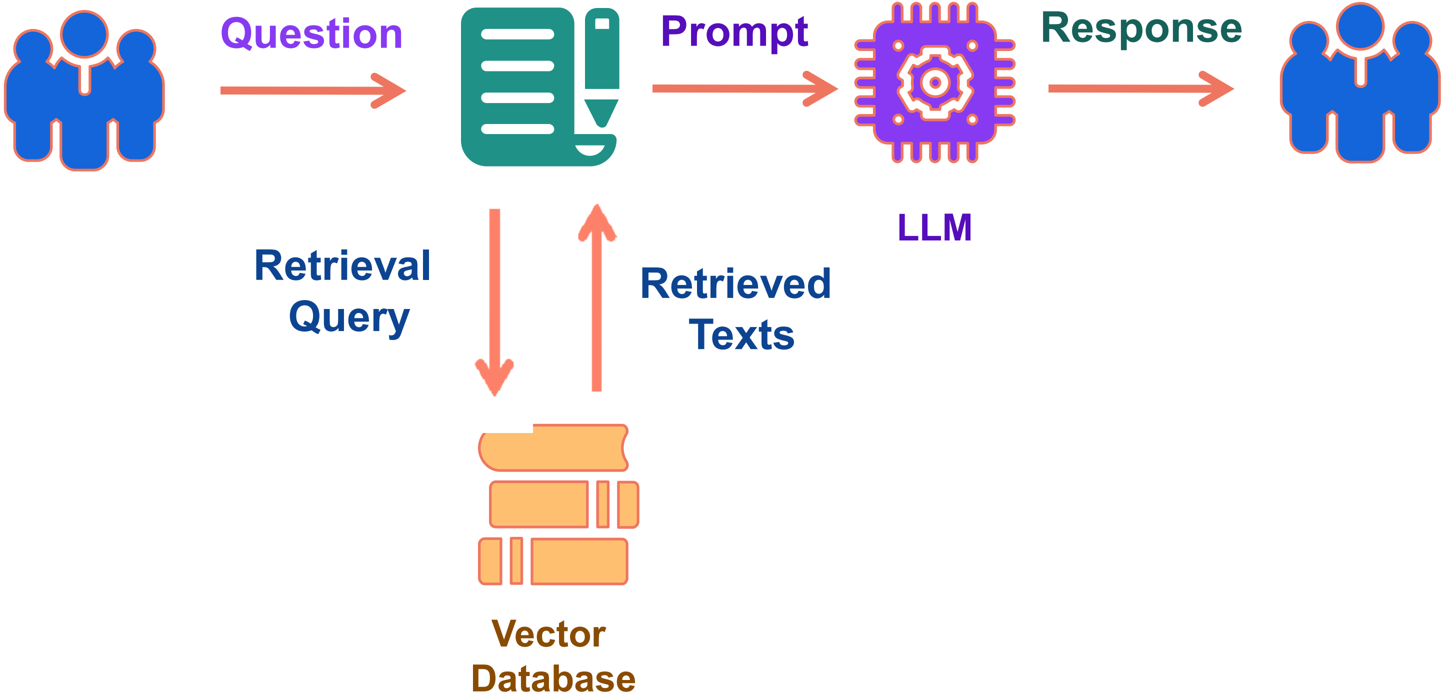
{0.68, 0.24, 0.98, 0.01}

Store

Vector Database

*** Sahaayak – Gaurika Gupta, Mohini Laghate & Pritam Shete**

Sahaayak – Retrieval Augmented Generation



Question

Prompt

Response

LLM

Retrieval Query

Retrieved Texts

Vector Database

* Sahaayak – Gaurika Gupta, Mohini Laghate & Pritam Shete

Sahaayak – BARC Documents

[INST]

<<SYS>> You are a helpful, respectful, and honest assistant. … If you don't know the answer to a question, please don't share false information. <</SYS>>

CONTEXT:

Magnesium -18's Unique Decay Process: …

provides not only new academic insights but also practical solutions …

Collaboration Identifies Rare Nuclear Decay in Long - Lived …

Question: Describe decay process of Magnesium-18.

[/INST]

Sure! Based on the provided context, Magnesium-18 undergoes a unique multi-proton decay process, where it sequentially emits two proton pairs. …

This process differs from traditional radioactive decay and highlights a complex phenomenon in the quantum world. …

The study, published in the journal Nuclear Science and Techniques, provides …

To summarize, Magnesium-18 decays through a chain of events, starting with the emission of two proton pairs, followed by the decay of Neon -16, …

*** TheBloke/Llama-2-13B-chat-GPTQ**

Sahaayak – BARC Documents

Q1. What is PWR?

Based on the context text provided, PWR stands for Pressurized Water Reactor.

Q2. What is PHWR?

Based on the context text provided, PHWR stands for Pressurized Heavy Water Reactor.

Q3. What is AHWR?

Based on the context text provided, AHWR stands for Advanced Heavy Water Reactor.

Q4. What is MSBR?

Based on the context provided, MSBR stands for Molten Salt Breeder Reactor.

*** TheBloke/Llama-2-13B-chat-GPTQ**

Pragya – Machine Learning Cluster

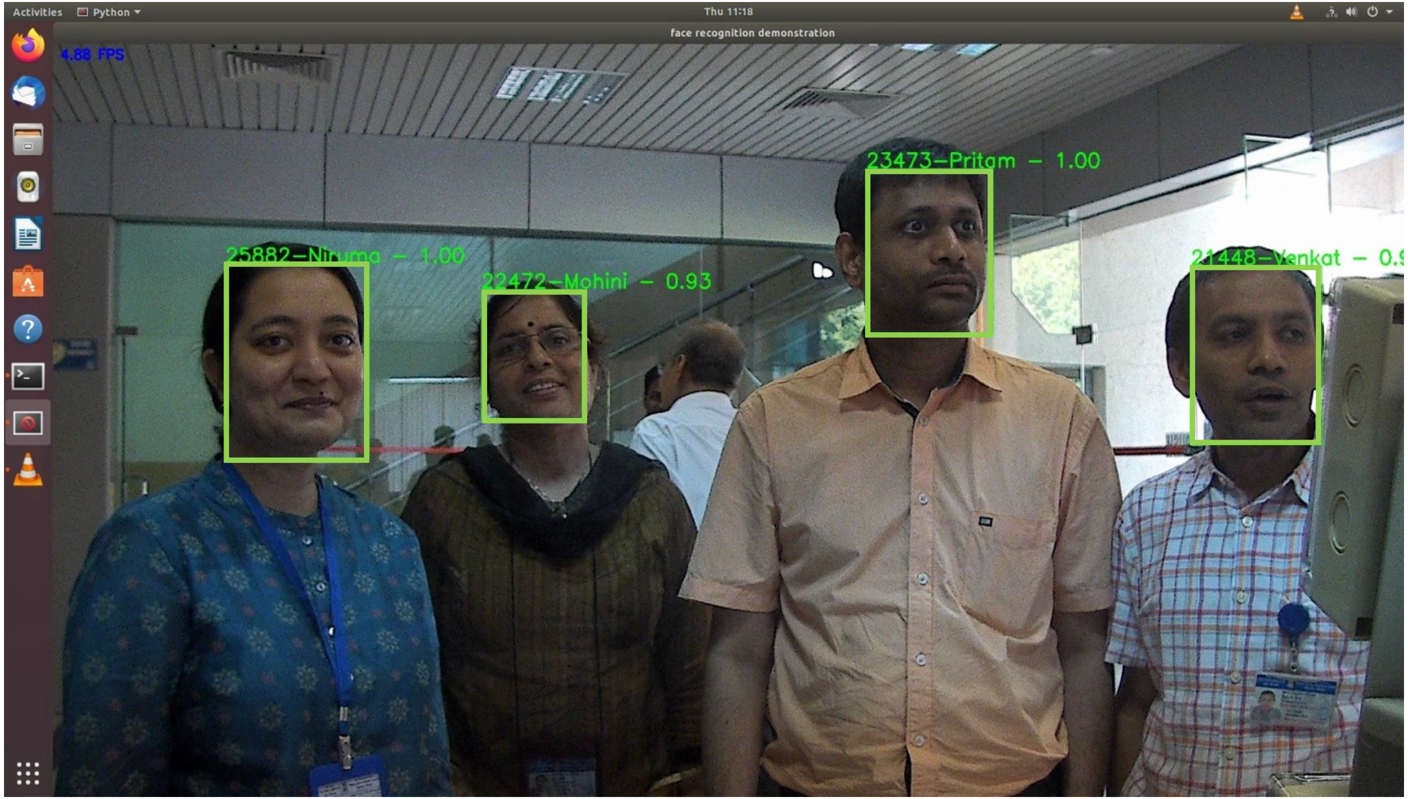
- 12 workstations
- Each workstation
  - Dual AMD EPYC Processors – 48 cores
  - 4 NVIDIA A100 GPUs
  - 6400 GB NVMe SSD storage
  - 1TB Memory
- NVIDIA A100 GPU
  - 6912 CUDA cores
  - 80 GB memory

Falcon 180B On Pragya

- Falcon 180B Chat GPTQ
  - 180 Billion parameters
  - Instruction fine-tuned model
- Model compression
  - 180B parameters – 16 bit float – 360 GB memory
  - 180B parameters – 4 bit precision – ~94 GB memory
- Model parallelization
  - Divide model among multiple GPUs
  - ~24 GB – 4 A100 GPUs – ~94 GB / 4 GPUs

*** TheBloke/Falcon-180B-Chat-GPTQ**

Pehchaan – AI based Face Recognition System



Talaash – Multimodal Query and Retrieval

- Query & retrieval system
  - Natural language
  - Input image
- Search & track users
  - User attire
  - Facial features
- Vision Language Models
  - Text & image embeddings
  - FashionVLM
- Vector database
  - Efficient storage
  - Retrieval of images

Fashion Captioning Dataset (FACAD)

- Largest dataset of fashion items
  - 130K fashion item captions
  - 993K images
  - 990 attributes
  - 78 different categories
- Rich captions
- Expressive vocabulary
- Different age groups
- Different seasons

colourful bloom and minimalist style define an everyday backpack with a convenient exterior pouch interior slip pocket and a signature logo patch at the front

flower rendered in monochromatic metallic jacquard illustrate this bateau neck dress finished with a pleat flared skirt

a notched top line accentuates the modern drama of this lofty ankle strap sandal

sparkling diamond accent a delicate pendant cast in 18 karat white gold suspended from a lovely chain necklace

*** FACAD – Xuewen Yang et. al. – ECCV 2020**

FashionVLM

- BLIP-2
  - Bootstrapping Language Image Pre–training
- Image encoder
  - Vision Transformer (ViT)
- Text encoder
  - Large Language Model (LLM)
- Connect Image and Text encoders
  - Querying Transformer (Q-Former)

*** FashionVLM (2024) – Gaurika Gupta & Pritam Shete**

FashionVLM – Evaluation on FACAD

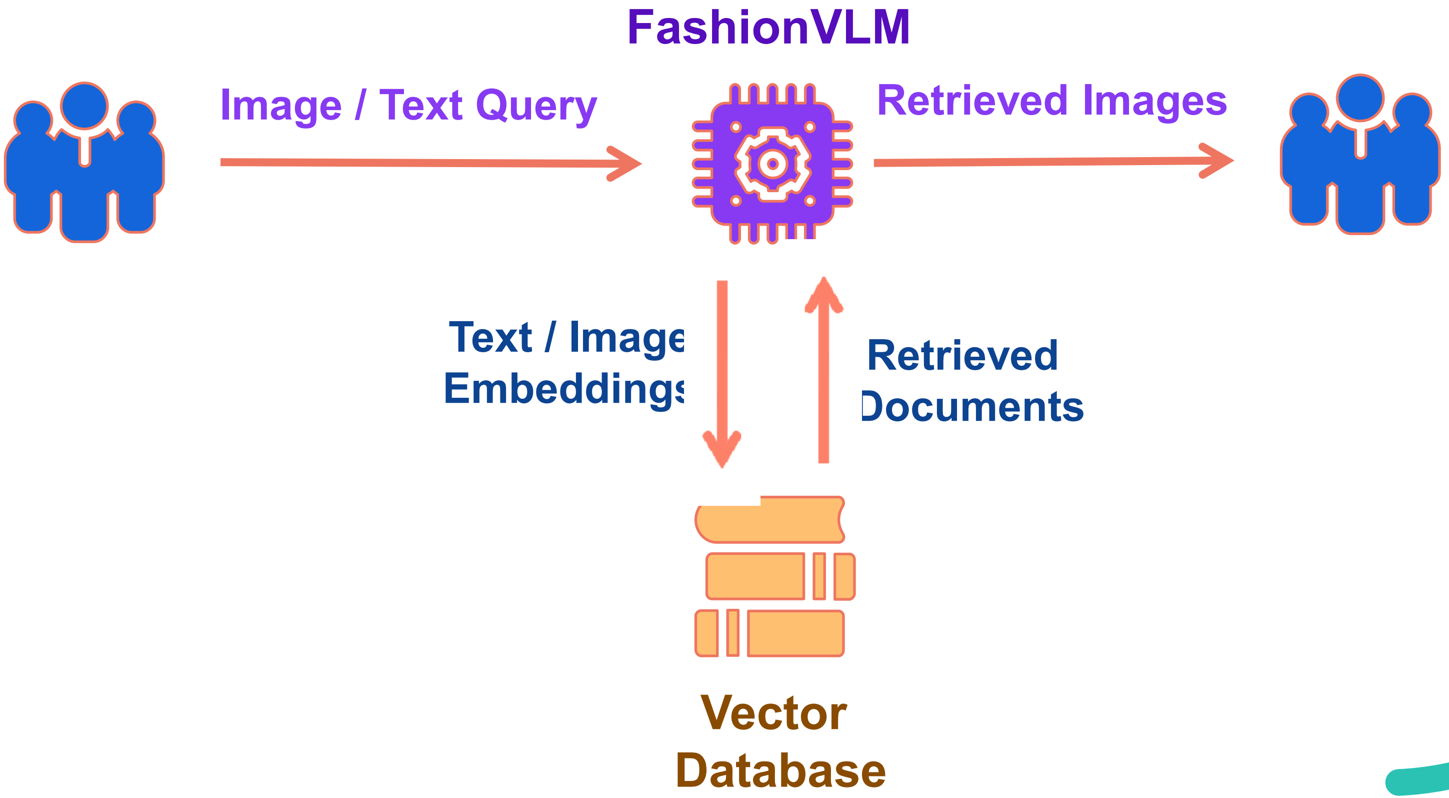
Models	Evaluation Metrics (%)			
	BLEU-4	CIDEr	ROUGE-L	METEOR
Tang (2023)	10.0	81.8	**23.0**	**11.9**
Moratelli (2023)	**10.6**	**84.5**	22.4	11.6
OPT-6.7 Stage One	12.331	101.205	26.746	14.279
OPT-6.7 Stage Two	13.409	111.396	27.756	14.946
OPT-6.7 Stage Three	**14.881**	**123.515**	**28.667**	**15.419**

*** FashionVLM (2024) – Gaurika Gupta & Pritam Shete**

Talaash – Image Registration

- Input images
- Load images
- Transform images
- Compute image embeddings
- Store embeddings in vector database

Talaash – Multimodal Search and Retrieval



FashionVLM

Image / Text Query

Retrieved Images

Text / Image Embeddings

Retrieved Documents

Vector Database

Chain-of-Thought Prompting

- Break down complex task into series of steps
- Focus on one step of task at a time
- Include responses to intermediate steps leading to final answer
- Improve accuracy of LLM's responses
- Improve relevance of LLM's responses
- Reduce hallucination

Chain-of-Thought Prompting

Let us solve this step-by-step.

What information do we need to find?

What operations might help us to solve this?

Explain your reasoning and prove the answer.

If there are 10 birds on a branch and 3 birds fly away. How many birds are remaining?

Let's break down the problem step-by-step.

What information do we need to find? We need to find the number of birds remaining on the branch after 3 birds fly away.

What operations might help us to solve this? To solve this problem, we can use a simple subtraction operation. We know the initial number of birds (10) and the number of birds that fly away (3). By subtracting the number of birds that fly away from the initial number, we can find the number of birds remaining.

Why subtraction? Subtraction is the correct operation because we are removing a certain number of birds (3) from the initial total (10). By subtracting 3 from 10, we are essentially "taking away" 3 birds from the branch, leaving us with the remaining number of birds.

Let's calculate! 10 (initial number of birds) - 3 (number of birds that fly away) = 7

Therefore, there are 7 birds remaining on the branch.

***Meta-Llama-3.1-8B-Instruct**

Code Generation

Write Python function to find a factorial of an input number.

```
def factorial(n):
    if n < 0:
        raise ValueError("Factorial is not defined for negative numbers")
    elif n == 0 or n == 1:
        return 1
    else:
        return n * factorial(n-1)
```

*Meta-Llama-3.1-8B-Instruct

Code Generation

Correct following Python code.

```
def factorial(n):
    if n == 0 or n == 1:
        return 1
    else:
        result = 1
        for i in range(2, n + 1):
            result *= i
        return result
```

```
def factorial(n):
    if n < 0:
        raise ValueError("Factorial is not defined for negative numbers")
    elif n == 0 or n == 1:
        return 1
    else:
        return n * factorial(n-1)
```

***Meta-Llama-3.1-8B-Instruct**

Virtual Assistants

- Simulate human like conversations
- Answer questions
- Provide information
- Complete simple tasks

Creative Writing

Write a story on atom for first standard student.

The Adventures of Atom

Once upon a time, in a tiny world, there was a tiny creature named Atom. Atom was so small that you needed a special tool to see him.

...

One day, Atom decided to go on an adventure. He packed a small bag and said goodbye to his family.

...

The End

This story is designed to be simple and easy to understand for a first standard student.

***Meta-Llama-3.1-8B-Instruct**

Education

In six sentences, explain proton, neutron and electron to first standard student.

Here's an explanation of protons, neutrons, and electrons that a first standard student can understand:

The Tiny Building Blocks of Atoms

You know how we're made up of tiny things called atoms? Well, atoms are made up of even smaller things called protons, neutrons, and electrons. Protons are like the strong and brave soldiers that live in the center of the atom. Neutrons are like the quiet and calm friends who live with the protons in the center. Electrons are like the fast and energetic runners who zoom around the outside of the atom. All three of them work together to make the atom strong and stable!

***Meta-Llama-3.1-8B-Instruct**

Deploying Large Language Models

GPU	CUDA Cores	Memory	FP32 FLOPS	Power	Cost
NVIDIA H100	**14,592**	**80 GB**	**67 TFLOPS**	**700W**	**$30,000**
NVIDIA A100	6,912	**80 GB**	19.5 TFLOPS	500W	$15,000
NVIDIA L40	**18,176**	48 GB	**90.5 TFLOPS**	300W	$10,000
NVIDIA RTX 4090	**16,384**	24 GB	**82.58 TFLOPS**	450W	$3,000
NVIDIA RTX 4080	10,240	16 GB	48.74 TFLOPS	320W	$1,000

Conclusions

- Large Language Models
- Prompt Engineering
- In Context Learning
- Training Large Language Models
- Large Language Model Applications
- Deploying Large Language Models

Thank you

Pritam Prakash Shete

Telephone - 022-25595212

Email - ppshete@barc.gov.in

Word v/s Token

- Token – Word or sub-word
- LLM inference cost
  - Number of tokens
  - Input tokens
    - Less cost
  - Output tokens
    - More cost

- Words with single token
  - Atomic or Primitive tokens
  - yes, no, run, red, blue, love
- Words with two tokens
  - Compound words
  - unhappy, dislike, replay, sunset
- 300 Words – 400 Tokens

LLM – Model Pre-training

- Encoder only LLM
  - Auto–encoding models
  - Masked Language Modeling
  - Reconstruct text
  - De–noising objective
  - Bidirectional context

- Applications
  - Sentiment analysis
  - Word classification
- Examples
  - BERT model
  - ROBERTA model

LLM – Model Pre-training

- Decoder only LLM
  - Autoregressive models
  - No encoder model
  - Causal Language Modeling
  - Predict next token
  - Unidirectional context
  - Statistical representation of language

- Applications
  - Text generation
  - Zero–shot inference
- Examples
  - OpenAI GPT
  - Meta Llama

LLM – Model Pre-training

- Encoder–Decoder LLM
  - Encoder and Decoder
  - Sequence-to-sequence models
  - Span corruption – T5 model
    - Mask random input tokens
    - Reconstruct masked input tokens
  - Bidirectional context

- Applications
  - Machine translation
  - Text summarization
  - Question & Answering
- Examples
  - Text-to-Text Transfer Transformer – T5 model

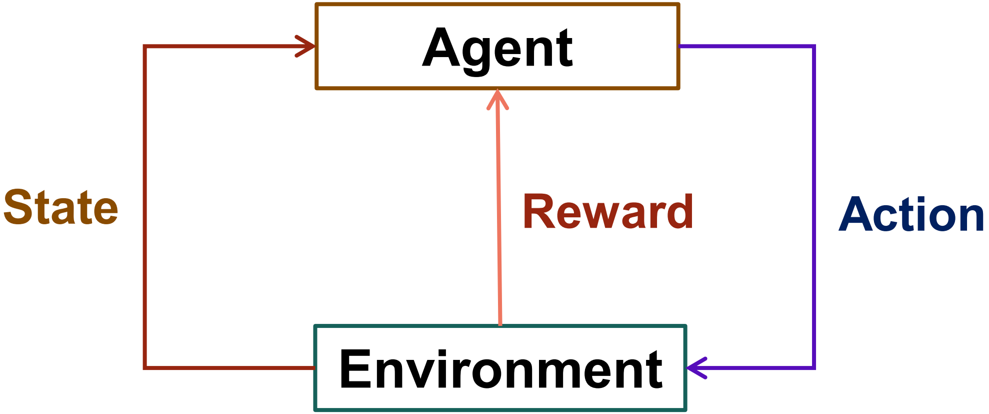
LLM – Computational Challenges

- LLM inference
  - 1 parameter – float 32 – 4 bytes
  - 1B parameters – 10^9 parameters
  - 1B parameters – 4 x 10^9 bytes
  - 1B parameters – 4 GB memory

- LLM training
  - 1 parameter – float 32 – 4 bytes
  - Model parameters – 4 bytes
  - Optimizer – 8 bytes – Two states
  - Gradients – 4 bytes
  - Activations – 4 bytes
  - Temporary variables – 4 bytes
- 20 times number of parameters

Reinforcement Learning

- Agent
- Environment
- Action
- State
- Reward or Penalty
- Maximize reward



Agent

State

Reward

Action

Environment

Reinforcement Learning

- Playout or Rollout
- Exploration
- Exploitation
- Reward hacking

Retrieval Augmented Generation – Evaluation

- Ground Truth (GT) by Human
- Character based evaluation
  - Edit distance
- Word based evaluation
  - WER, BLEU
- Embedding based evaluation
  - BERT score, Mover score

- Ground Truth (GT) by LLM
- Mathematical Framework
  - RAGAS framework
- Experimental based Framework
  - Number of tasks and datasets
  - Number of aspects
  - GPT score

Knowledge Distillation

- Knowledge transfer
- Large pre-trained model
- Set of models
- Teacher model
- Ensemble of models
- Single smaller model
- Student model
- Model compression
- Small student model
- Learn to emulate
- Large teacher model
- Leverage teacher knowledge
- Emulate thought process
- Obtain similar / higher accuracy

Models – Fashion Captioning Dataset (FACAD)

Model	Encoder	Decoder	Q-Former	Number of Parameters
CNN–LSTM	CNN (VGG)	LSTM	No	138 Million
CLIP	ResNet / ViT	Transformer	No	33 Million
BLIP	ViT	Transformer	No	583 Million
BLIP-2	ViT	OPT / FLAN T5	Yes	188 Million

Code Generation

- Mistral AI
  - Mistral 7B and Mixtral 8X7B
- Meta
  - CodeLlama, CodeLlama-Python, CodeLlama-Instruct
- Phind
  - Phind-CodeLlama-34B, Phind-CodeLlama-34B-Python
- BigCode Project
  - StarCoder, StarCoder2

Medical Diagnosis

- Symptom analysis
- Disease identification
- Treatment recommendations
- Medical literature analysis
- Medical question answering
- Medical imaging analysis

- Google Med–PaLM 2
  - Medical question answering
- Google Med-Gemini
  - Medical question answering
- BiomedGPT
  - Vision language model
  - Visual question answering